TÁMOP-*4.1.1.C-12/1/KONV-2012-0004 projekt*

# FARM BUSINESS MANAGEMENT

Edited and written by:

**József HORVÁTH  Károly BODNÁR**

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Hódmezővásárhely

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MAGYARORSZÁG MEGÚJUL

A projekt az Európai Unió támogatásával, az Európai Szociális Alap társfinanszírozásával valósul meg.

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This compendium was prepared in the frame and with the support of:
**TÁMOP-4.1.1.C-12/1/KONV-2012-0004**
**AP3 Képzésfejlesztés alprojekt**

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ISBN: 978-963-306-469-6

Published by:

University of Szeged Faculty of Agriculture
Andrássy út 15.
H-6800 Hódmezővásárhely
Hungary

Hódmezővásárhely
2016

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# FOREWORD

Farming is a basic activity in most of the countries of the world for a number of different production purposes. The aim of this textbook or compendium was to give an overview about the main production, economic, management and market issues of farmers. The material was based on the results of Hungarian and foreign scientists. The textbook is designed and presented as a general volume on farm business management. It is not intended only as a book of economy or as one concerned primarily with practical production; the elements of both subjects are included.

The reader can find metric and US customary units as well in the text, for solving confusion the editors recommend the usage of a unit conversion calculator,
i.e. http://www.sciencemadesimple.com/conversions.html

Complete deatails of every subject which may be of interest to each reader could not be included, but the editors/authors hope that useful information is presented for those with diverse interests in farming.

József Horváth and Károly Bodnár

# 1. GENERAL MANAGEMENT ISSUES OF PLANT PRODUCTION

## 1.1. Mechanisation

Putting together an ideal machinery system is not easy. Equipment that works best one year may not work well the next because of changes in weather conditions or crop production practices. Improvements in design may make older equipment obsolete. And, the number of acres being farmed or the amount of labour available may change. Because many of these variables are unpredictable, the goal of the good machinery manager should be to have a system that is flexible enough to adapt to a range of weather and crop conditions while minimizing long-run costs and production risks. To meet these goals several fundamental questions must be answered.

**Machine performance**
First, each piece of machinery must perform reliably under a variety of field conditions or it is a poor investment regardless of its cost.
Tillage implements should prepare a satisfactory seedbed while conserving moisture, destroying early weed growth and minimizing erosion potential. Planters and seeders should provide consistent seed placement and population as well as properly apply pesticides and fertilizers. Harvesting equipment must harvest clean, undamaged grain while minimizing field losses.
The performance of a machine often depends on the skill of the operator, or on weather and soil conditions. Nevertheless, differences among machines can be evaluated through field trials, research reports and personal experience.

**Machinery costs**
Once a particular type of tillage, planting, weed control, or harvesting machine has been selected, the question of how to minimize machinery costs must be answered. Machinery that is too large for a particular farming situation will cause machinery ownership costs to be unnecessarily high over the long run; machinery that is too small may result in lower crop yields or reduced quality.

**Ownership costs**
Machinery ownership costs include charges for deprecation, interest on investment, property taxes, insurance and machinery housing. These costs increase in direct proportion to machinery investment and size.

**Operating costs**
Operating costs include fuel, lubricants and repairs. Operating costs per acre change very little as machinery size is increased or decreased. Using larger machinery consumes more fuel and lubricants per hour, but this is essentially offset by the fact that more acres are covered per hour.
Much the same is true of repair costs. Thus, operating costs are of minor importance when deciding what size machinery is best suited to a certain farming operation.

**Labour cost**
As machinery capacity increases, the number of hours required to complete field operations over a given area naturally declines.
If hourly or part-time hired labour operates machinery, it is appropriate to use the wage rate paid, plus the cost of any other benefits which may be provided, as the labour cost. If the farmer-owner or a hired worker who is paid a fixed wage operates machinery, then it is proper to value labour at its opportunity cost, or the estimated return it could earn if it were used elsewhere in the farm business, such as in livestock enterprises.

**Timeliness costs**
In many cases, crop yields and quality are affected by the dates of planting and harvesting. This represents a "hidden" cost associated with farm machinery, but an important one nevertheless. The value of these yield losses is commonly referred to as "timeliness costs."

**Total machinery costs**
Figure 1 illustrates the effect that changes in machinery size have on each type of cost in a typical situation. For very small machinery (relative to crop acres), a slight increase in machinery size can lower timeliness and labour costs significantly, enough to more than offset the higher fixed costs. However, as machinery size continues to increase, the timeliness cost savings diminish, and eventually total costs begin to rise. One objective of machinery selection, then, is to select machinery in the size range where total machinery costs are lowest.

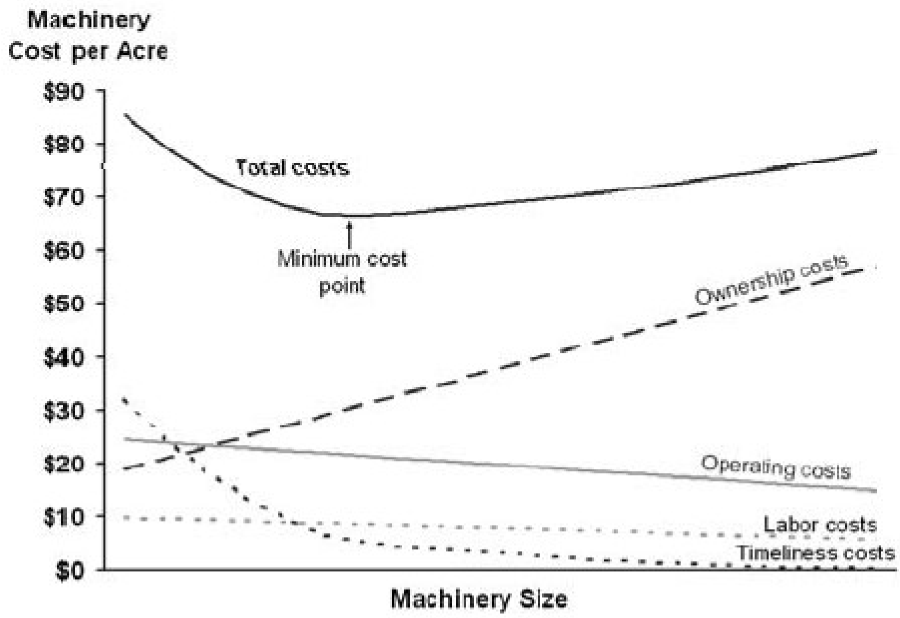



Figure 1: **Effect of increasing machinery size on machinery costs**

**Factors that affect the size of machinery needed**
Machinery recommendations must be based on the characteristics of each individual farm. The following factors influence machinery selection, and are discussed in order of importance.

**Number of crop acres**
As more crop acres are farmed, larger-scale machinery is needed to ensure that planting and harvesting are completed in a timely fashion. An alternative is to acquire a second unit of some machines, if an additional tractor and operator are available.

**Labour supply**
The number of acres that can be completed each day is the most critical measure of machinery capacity, more than machine width or acres completed per hour. Increasing the labour supply by hiring extra operators or by working longer hours during critical periods may be a relatively inexpensive way of stretching machinery capacity. In addition, the cost of additional labour only needs to be incurred in those years in which it is actually used, while the cost of investing in larger machinery becomes “locked in” as soon as the investment is made. On the other hand, extra labour may not always be available when needed, and working long hours over several days can present a safety hazard.

**Tillage practices**
The number of field days needed before planting is completed depends partly on the number of separate operations completed on each acre. Reducing the number of tillage practices performed or performing more than one practice in the same trip effectively decreases the amount of machinery capacity needed to complete field operations on time. Of course, machinery cost savings from reduced tillage must be compared to possible increased chemical costs and effects on yields.

**Crop mix**
Diversification of crops tends to spread out the periods when timely completion of field operations is critical. For example, yield reductions due to late planting begin later for soybeans than for corn. Harvesting can also be completed over a longer time period. Thus, growing more than one or two crops reduces the machinery capacity needed for a given number of crop acres. However, it may also require purchasing additional types of machinery, especially for harvesting.

**Weather**
Weather patterns determine the number of days suitable for fieldwork in a given time period each year. Although actual weather conditions cannot be predicted far enough in advance to be used as an aid to machinery selection, past weather records can be used as a guide. As a rule of thumb, weather is suitable for field work about 60% of the time in the spring and about 75% of the time in the fall. This does not take into account time off for holidays, Sundays or other occasions. Machinery selection should be based
on long-run weather patterns even though it results in excess machinery capacity in some years and insufficient capacity in other years.

**Risk management**
Fluctuations in the number and occurrence of suitable field days from year to year cause timeliness costs to vary even when the machinery set, number of crop acres and labour supply do not change. Investing in larger machinery can reduce the variability of net machinery costs by ensuring that crops are planted and harvested

on time even in years in which there are few good working days. Machinery fixed costs would be higher with larger machinery, but they would not fluctuate as long as the machinery set did not change. Farmers with high fixed cash flow needs, such as land mortgage payments, may be willing to pay more (in higher fixed machinery costs) than other operators for the “insurance” of not suffering substantial yield losses due to late planting and harvesting in certain years.

**Planting and harvesting dates**

Long-term studies indicate that corn yields typically start to decline significantly when planting occurs after May 10 to 14. The exact dates will vary from year to year. About 50% of Iowa’s corn is normally planted by this time. One reason for the decline in yield for late-planted corn is that fewer “heat units” are available during the growing season, and this influences the rate of crop development. How early to start planting requires considerable judgment. Ideal conditions would be a soil temperature of 10°C or above at planting depth and a favourable five-day weather forecast. In most of Iowa, if soil conditions and temperatures are favourable, starting to plant the last ten days of April should be advantageous. In May, the major consideration should be the condition of the seedbed. There is some risk with early planting. Replanting may occasionally be required, but the long-term benefits far outweigh this cost. An added benefit from early-planted corn is lower grain moisture levels at harvest and reduced drying costs.

Most of the same things can be said about planting soybean varieties. The ideal time for planting adapted soybean varieties is between May 1 and May 15. Yields can be expected to decline in most years if planting occurs after about May 20.

Timeliness losses at harvest are due primarily to more dropped ears, field shattering and cracked beans. These losses must be balanced against the cost of artificially drying grain harvested at a moisture level higher than that required for safe storage. Some harvesting losses occur because combining speed is too high or the machine is poorly adjusted.

**How large should machinery be?**

One way to measure the capacity of a set of machinery is by the number of work days required to complete field operations. This depends on the number of crop acres, machinery operations performed, size of the machinery in use, and availability of labour.

In research conducted recently at ISU, total machinery costs for Iowa grain farms, including the value of timeliness losses, were estimated for a number of different machinery combinations. The effects of variations in the number of crop acres and labour supply were compared. Under each set of circumstances the machinery set for which total costs were lowest, including yield losses due to poor timelines, was identified. In some cases, several machinery sets gave nearly identical minimum costs. In approximately 80% of the cases tested, the least cost machinery sets were able to complete all tillage and planting operations in about 20 to 25 field days. A good rule of thumb for farmers who wish to have sufficient machinery capacity to reduce risk, as well as maintain total costs at a low level, is to be able to complete tillage and planting in about 20 field days. Where less than one full-time person is available to operate machinery, a goal of 25 to 30 days for completing planting and tillage will most often minimize costs.

On the other hand, farms with 2 or 3 full-time machinery operators available could aim to complete this work in less than 20 days.

The machinery sets which minimized total machinery costs were most often able to complete harvesting of corn and soybeans in 25 to 30 field days. As with spring work, operators for whom risk reduction is important should use the lower end of this range as a goal, although yield losses from late harvesting are generally not as severe as from late planting.
A number of different machinery combinations may allow fieldwork to be completed in the same number of days. In putting together a machinery set, it is also important to correctly match machinery sizes and tractor power. Using tractors with horsepower in excess of that required for the implement being pulled results in excessive depreciation and interest costs, while using too little horsepower may cause faster engine wear out.
Some farms may not have enough crop acres to justify owning a full line of machinery, particularly for harvesting. Custom hiring or leasing certain machinery operations may lower total costs as well as provide more flexibility in the amount of machinery capacity.

**Field capacity**
To project the number of field days required, it is necessary to know the field capacity for each implement. Field capacity usually is measured in acres accomplished per hour, and is affected by three variables: width, speed and field efficiency. Width refers to the effective working width of the implement, excluding overlapping, and is measured in feet.

Speed, which is measured in miles per hour, refers to a safe operating speed under normal working conditions. This does not take into account slowing down to turn at the end of a field. Field efficiency is the actual field capacity that can be achieved as a percentage of the maximum theoretical capacity without overlapping, slowing for turning or stopping to adjust machinery, fill containers, empty hoppers, and make minor repairs.
The formula for estimating field capacity (in acres per hour) is:

$$\frac{\text{width (ft) x speed (mph) x field efficiency (\%)}}{8.25^{1}} = \text{field capacity (A/hr)}$$

For example, assume a 24-foot tandem disk can be pulled at 6 miles per hour with a field efficiency of 80 percent. Its estimated field capacity is:

$$\frac{\text{24 feet x 6 mph x 80\%}}{8.25} = \text{14 acres per hour}$$

To estimate the field capacity needed to complete a certain field operation in a set number of field days, use the following formula:

$$\frac{\text{acres to cover}}{\text{(days available x hours of field time per day)}} = \text{field capacity needed}$$

For example, to combine 900 acres of corn in 20 field days, harvesting 12 hours per day, would require a field capacity of:

$$\frac{900\ acres}{(20\ days \times 12\ hours/day)} = 3.75\ acres\ per\ hour$$

The minimum implement width then can be found by inverting the formula for field capacity:

$$\frac{(8.25 \times field\ capacity)}{(speed \times field\ efficiency)} = width$$

For the example, if the combine operates at 3 miles per hour with 70 percent field efficiency, the minimum width is:

$$\frac{(8.25 \times 3.75\ acres/hour)}{(3.0\ miles\ per\ hour \times 70\%)} = 14.7\ feet$$

The minimum width is about the size of a six-row, 30-inch corn head.

**Matching tractor power and implement size**

For tillage and planting implements the size of the machine that can be used is often limited by the size of the available tractor. The horsepower needed to pull a certain implement depends on the width of the implement, the ground speed, draft requirement, and soil condition. The general formula for estimating the required horsepower measured at the power take-off (PTO) is:

$$\frac{width\ (feet) \times speed\ (mph) \times draft\ (lb./ft.) \times soil\ factor}{375} = PTO\ hp$$

**Estimating the number of field days required**

The following worksheet (Table 1) can be used to estimate the number of field days required for tillage, planting and harvesting for a particular farming operation.

- *Column 1.* List all the field operations to be done before planting. Include fall and spring tillage, application of chemicals, and sowing of small grain or forages. Do not include custom hired operations.
- *Column 2.* List the total acres to be covered by each operation. Remember, if some acres have the same operation performed on them more than once, multiply the number of acres by the times over.
- *Column 3.* List the sizes of the machines used for all operations.
- *Column 4.* List the field capacity of each machine in acres per hour. Suggestions can be found by using the following formula:

$$\frac{width\ (ft) \times speed\ (mph) \times field\ efficiency\ (\%)}{8.25} = field\ capacity\ (A/hr)$$

It may be more convenient to skip directly to column 6 and enter the number of acres covered per day, if this is known.

- *Column 5.* Enter the number of labour hours available per day in the field to perform each tillage and preplant operation. Do not count time spent on repairs, transportation of machinery, livestock activities, etc. For planting and harvesting, enter the number of hours per day the planter or combine can be used.
- *Column 6.* Multiply column 4 by column 5 to estimate the number of acres covered per day for each operation. Decide if this is a reasonable figure based on experience.
- *Column 7.* Estimate the number of field days needed for each operation by dividing column 2 by column 6. Then find the total for each group of field operations.

Use extra lines to estimate how the number of field days required can be adjusted. Adjustments can be made by changing machinery size, number of field operations, number of acres covered, proportion of acres in each crop, hours available for fieldwork, or by custom hiring some operations.

This worksheet can also be used to estimate the number of field days required for harvesting forages.

Table 1: **Field days worksheet example**
**(600 acres of corn, 600 acres of soybeans)**

| (1) Type of Operation | (2) Total Acres to be covered by Implement | (3) Your Implement Size | (4) Field Capacity Acres Per Hour | (5) Labor Available for Fieldwork Hours/Day | (6) Acres Covered Per Day (Col. 4 x Col. 5) | (7) Field Days Needed (Col. 2/Col. 6) |
|---|---|---|---|---|---|---|
| | | | **All Tillage and Pre-plant Chemical Application** | | | |
| Apply nitrogen | 600 | 15 ft. | 6.5 | 12 | 78 | 7.7 |
| Chisel plow | 600 | 20 ft. | 10 | 16 | 160 | 3.8 |
| Tandem disk | 1,200 | 27 ft. | 15 | 16 | 240 | 5.0 |
| Field cultivate | 1,200 | 27 ft. | 19 | 16 | 304 | 3.9 |
| | | | | | | |
| | | | | | | |
| | | | **Planting** | | | |
| Plant corn | 600 | 12-30 | 13 | 16 | 208 | 2.9 |
| Plant soybeans | 600 | 12-30 | 13 | 16 | 208 | 2.9 |
| | | | | | | |
| | | | | | Total | 26.2 |
| | | | **Harvesting** | | | |
| Harvest soybeans | 600 | 18 ft. | 4.6 | 10 | 46 | 13.0 |
| Harvest corn | 600 | 6-30 | 3.8 | 12 | 46 | 13.0 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | Total | 26.0 |

Machinery and equipment are major cost items in farm businesses. Larger machines, new technology, higher prices for parts and new machinery, and higher energy prices have all caused machinery and power costs to rise in recent years.
However, good machinery managers can control machinery and power costs per acre. Making smart decisions about how to acquire machinery, when to trade, and how much capacity to invest in can reduce machinery costs as much as $25 per acre. All of these decisions require accurate estimates of the costs of owning and operating farm machinery.

**Machinery costs**
Farm machinery costs can be divided into two categories:

- annual **ownership** costs, which occur regardless of machine use,
- and **operating** costs, which vary directly with the amount of machine use.

The true value of these costs is not known until the machine is sold or worn out. But the costs can be **estimated** by making a few assumptions about machine life, annual use, and fuel and labor prices. This publication contains a worksheet that can be used to calculate costs for a particular machine or operation.
**Ownership** costs (also called **fixed** costs) include depreciation, interest (opportunity cost), taxes, insurance, and housing and maintenance facilities.

**Depreciation**
Depreciation is a cost resulting from wear, obsolescence, and age of a machine. The degree of mechanical wear may cause the value of a particular machine to be somewhat above or below the average value for similar machines when it is traded or sold. The introduction of new technology or a major design change may make an older machine suddenly obsolete, causing a sharp decline in its remaining value. But age and accumulated hours of use are usually the most important factors in determining the remaining value of a machine. Before an estimate of annual depreciation can be calculated, an **economic life** for the machine and a **salvage value** at the end of the economic life need to be specified.
The economic life of a machine is the number of years for which costs are to be estimated. It is often less than the machine's service life because most farmers trade a machine for a different one before it is completely worn out. A good rule of thumb is to use an economic life of 10 to 12 years for most farm machines and a 15-year life for tractors, unless you know you will trade sooner.
Salvage value is an estimate of the sale value of the machine at the end of its economic life. It is the amount you can expect to receive as a trade-in allowance, an estimate of the used market value if you expect to sell the machine outright, or zero if you plan to keep the machine until it is worn out.
Estimating of the remaining value of tractors and other classes of farm machines is made as a percent of new list price. Note that for tractors, combines and forage harvesters the number of hours of annual use is also considered when estimating the remaining value. The factors were developed from published reports of used equipment auction values, and are estimates of the average "as-is" value of a class of machines in average mechanical condition at the farm. Actual market value will vary from these values depending on the condition of the machine, the current market for new machines, and local preferences or dislikes for certain models. The appropriate values should be multiplied by the current list price of a

replacement machine of equivalent size and type, even if the actual machine was or will be purchased for less than list price.

**Interest**
If you borrow money to buy a machine, the lender will determine the interest rate to charge. But if you use your own capital, the rate to charge will depend on the opportunity cost for that capital elsewhere in your farm business. If only part of the money is borrowed, an average of the two rates should be used. For the example we will assume an average interest rate of 8 percent.
Inflation reduces the real cost of investing capital in farm machinery, however, since loans can be repaid with cheaper dollars. The interest rate should be adjusted by subtracting the expected rate of inflation. For our example we will assume a 3% inflation rate, so the adjusted or “real” interest rate is 5 percent.
The joint costs of depreciation and interest can be calculated by using a **capital recovery factor**. Capital recovery is the number of dollars that would have to be set aside each year to just repay the value lost due to depreciation, and pay interest costs.

**Taxes, insurance, and housing (TIH)**
These three costs are usually much smaller than depreciation and interest, but they need to be considered. Property taxes on farm machinery have been phased out in Iowa, except for very large inventories. For states that do have property taxes on farm machinery, a cost estimate equal to 1% of the purchase price is often used.
Insurance should be carried on farm machinery to allow for replacement in case of a disaster such as a fire or tornado. If insurance is not carried, the risk is assumed by the rest of the farm business. Current rates for farm machinery insurance in Iowa range from $4 to $6 per $1,000 of valuation, or about 0.5% of the purchase price.
There is a tremendous variation in housing provided for farm machinery. Providing shelter, tools, and maintenance equipment for machinery will result in fewer repairs in the field and less deterioration of mechanical parts and appearance from weathering. That should produce greater reliability in the field and a higher trade-in value. An estimated charge of 0.5% of the purchase price is suggested for housing costs. To simplify calculating TIH costs, they can be lumped together as 1% of the purchase price where property taxes are not significant.
The estimated costs of depreciation, interest, taxes, insurance and housing are added together to find the total ownership cost.

**Operating costs** (also called **variable** costs) include repairs and maintenance, fuel, lubrication and operator labor.

**Repairs and maintenance**
Repair costs occur because of routine maintenance, wear and tear, and accidents. Repair costs for a particular type of machine vary widely from one geographic region to another because of soil type, rocks, terrain, climate and other conditions. Within a local area, repair costs vary from farm to farm because of different management policies and operator skill.
The best data for estimating repair costs are records of your own past repair expenses. Good records indicate whether a machine has had above or below

average repair costs and when major overhauls may be needed. They will also provide information about your maintenance program and your mechanical ability. Without such data, though, repair costs must be estimated from average experience.

The total accumulated repair costs are calculated as a percent of the current list price of the machine, since repair and maintenance costs usually change at about the same rate as new list prices. Figure 2 shows how repair costs accumulate for two-wheel drive tractors. Notice the shape of the graph. The slope of the curve increases as the number of hours of use increases. This indicates that repair costs are low early in the life of a machine, but increase rapidly as the machine accumulates more hours of operation.

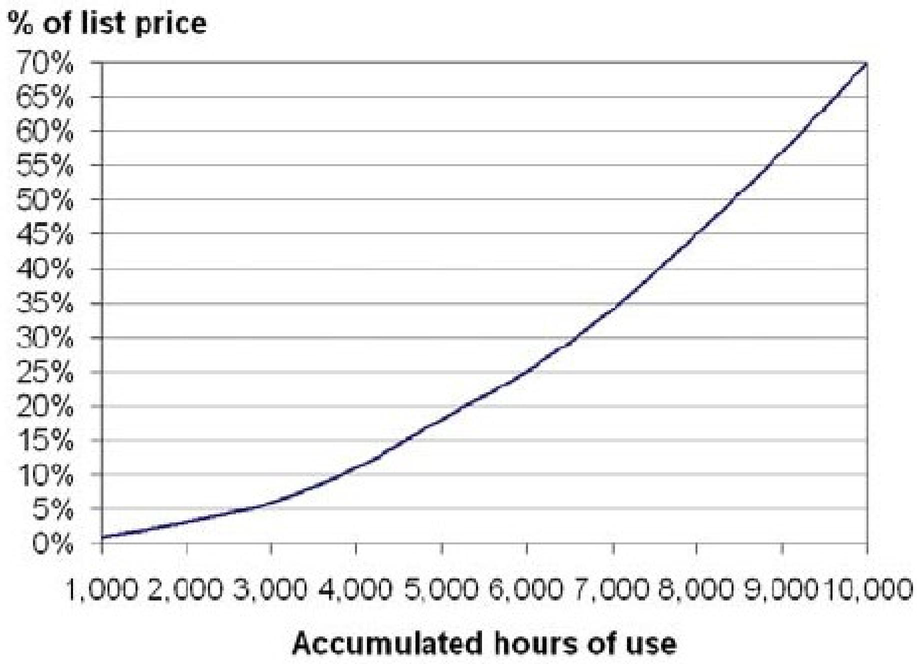



Figure 2: **Accumulated repair costs for two-wheel drive tractor.**

**Fuel**

Fuel costs can be estimated in two ways. **Fuel Required for Field Operations** lists average fuel use in gallons per acre for many field operations. Those figures can be multiplied by the fuel cost per gallon to calculate the average fuel cost per acre.

Average fuel consumption (in gallons per hour) for farm tractors on a year-round basis without reference to any specific implement can also be estimated with these equations:

*0.060 x maximum PTO horsepower for* **gasoline** *engines*

*0.044 x maximum PTO horsepower for* **diesel** *engines*

**Lubrication**
Surveys indicate that total lubrication costs on most farms average about 15 percent of fuel costs. Therefore, once the fuel cost per hour has been estimated, you can multiply it by 0.15 to estimate total lubrication costs.

**Labour**
Because different size machines require different quantities of labour to accomplish such tasks as planting or harvesting, it is important to consider labour costs in machinery analysis. Labour cost is also an important consideration in comparing ownership to custom hiring.
Actual hours of labour usually exceed field machine time by 10 to 20 percent, because of travel and the time required lubricating and servicing machines. Consequently, labour costs can be estimated by multiplying the labour wage rate times 1.1 or 1.2.

**Total cost**
After all costs have been estimated, the total ownership cost per year can be added to the operating cost per hour to calculate total cost per hour to own and operate the machine.

**Implement costs**
Costs for implements or attachments that depend on tractor power are estimated in the same way as the example tractor, except that there are no fuel, lubrication or labour costs involved.

**Used machinery**
Costs for used machinery can be estimated by using the same procedure shown for new machinery. However, the fixed costs will usually be lower because the original cost of the machine will be lower. And repair costs will usually be higher because of the greater hours of accumulated use. Therefore, the secret to successful used machinery economics is to balance higher hourly repair costs against lower hourly fixed costs. If you misjudge the condition of the machine such that your repair costs are higher than you anticipated, or if you pay too high a price for the machine so that your fi xed costs are not as low as you anticipated, the total hourly costs of a used machine may be as high or higher than those of a new machine.

**Total costs per operation**
Tractor costs must be added to the implement costs to determine the combined total cost per hour of operating the machine.
Finally, total cost per hour can be divided by the **hourly work rate** in acres per hour or tons per hour to calculate the total cost per acre or per ton. The hourly work rate or field capacity of an implement or self-propelled machine can be estimated from the effective width of the machine (in feet), its speed across the field (in miles per hour), and its field efficiency (in percent). The field efficiency is a factor that adjusts for time lost due to turning at the end of the field, overlapping, making adjustments to the machine, and filling or emptying tanks and hoppers.
Costs for operations involving self-propelled machines can be calculated by treating the self-propelled unit as a power unit, and the harvesting head or other attachment as an implement.

## *1.2. Nutrient management of soils*

Nutrient management is the process of managing the amount, source, timing, and method of nutrient application with the goal of optimizing farm productivity while minimizing nutrient losses that could create environmental problems. It includes developing nutrient budgets that consist of knowing the amounts of nutrients present in the soil, determining the amount of nutrients needed by the crop, accounting for all the potential sources of nutrients, and then applying manures, composts, irrigation water, or inorganic fertilizers to meet the nutrient need of the crop. It also uses site management practices to increase or maintain soil quality to reduce the potential for erosion and nutrient transport into surface water or nutrient leaching into groundwater. Soil quality is an important component of nutrient management because it affects nutrient retention and water movement through the soil.

Farmers need to apply nitrogen, phosphorus, potassium and other nutrients to achieve desired crop growth and yield. However, excessive nutrient application can have negative environmental impacts. Nutrients that are not efficiently used by crops or retained in the soil can leach into groundwater and move from agricultural land into surface waters (Figure 3). For example, excess nitrogen in the form of nitrate can leach through the soil into groundwater. Nitrate-nitrogen concentrations of 20 to 40 ppm or mg/l can cause health problems for horses and Ruminants.

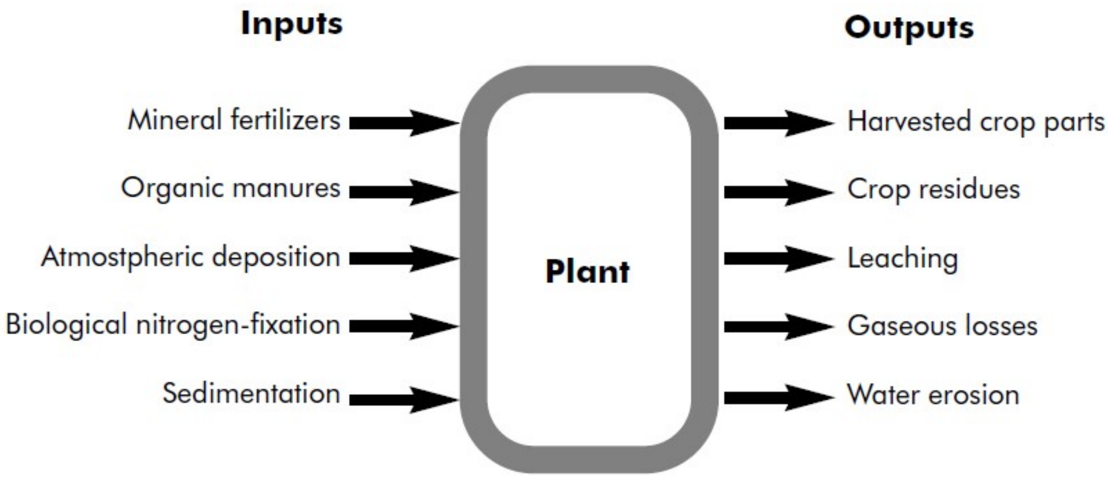



Figure 3: **The plant nutrient balance**

Excess nitrogen and phosphorus applied to crops can move into surface water with runoff during storm events causing nutrient enrichment (eutrophication) of these water bodies. Eutrophication causes excessive plant and algae growth that causes the water to turn green. When the plants and algae die, the organisms that decompose the dead material consume much of the oxygen in the water. This can cause fish kills or shifts in the types of fish species present, and can prevent recreational uses of the water. Although excess phosphorus is usually the nutrient that causes eutrophication issues in fresh water reservoirs, excess nitrogen (concentrations greater than 1 mg/l) is generally the nutrient that causes eutrophication problems in coastal waters.

Although many people do not think about the relationship between soil quality and water quality, the link between them is strong. Good soil quality is critical to protecting water quality by functioning to hold water, adsorb nutrients, and retain other contaminants. For a soil to perform these functions, its capacity to absorb nutrients cannot be exceeded. Nutrient management is critical to maintain adequate, but not excessive nutrient concentrations for crop production and maintaining soil quality.

In addition to the environmental benefits, there are economic benefits to nutrient management. Evaluating what nutrients you need for an expected crop production yield and accounting for nutrients provided by the soil, manures, composts, or legumes can reduce the supplementary amount of inorganic fertilizer needed.

Many farmers use a nutrient management plan to help them make nutrient input and economic decisions. In some areas and for some crops, the nitrogen need is based on a "realistic yield goal". This yield goal should be based on yield averages from your farm for at least three to five years. If farm yields are not available, county averages can be used.

A large part of nutrient management is record keeping. Record keeping, along with calibration of application equipment can insure proper application rates. Keeping records of all nutrients applied, cost of nutrients, crop yields, and livestock productivity will help determine what is profitable but more importantly what is not profitable for your operation. This process also helps identify what modifications should be made to improve productivity.

The key to good soil quality is soil organic matter. A sufficient amount of nutrients in the soil, particularly nitrogen, is necessary to form and maintain soil organic matter. A fertile soil has greater plant growth, which can create greater inputs of roots and other plant debris into the soil. This plant debris undergoes decomposition and adds to the soil organic matter. Applications of animal manures and composts, as well as the use of cover crops, all help increase soil organic matter. Organic matter provides a food source for soil microbes and increases microbial activity. As the microbes breakdown organic matter, nutrients are released in forms that the plants can utilize. Because nutrient management accounts for the nutrients added to the system, it promotes increasing soil quality without creating nutrient excesses.

Different soils have different capacities to adsorb and retain nutrients. This is related to the amount of soil organic matter and the soil texture (percent sand, silt, clay). Because the soil texture cannot be changed, increasing soil organic matter is the best way to increase the capacity of a soil to retain nutrients. Soils with larger amounts of soil organic matter and at a near neutral pH will have a greater capacity to retain nutrients, thus a higher soilquality than soils with low organic matter.

Soil pH also affects the availability of nutrients in the soil. A soil pH around 6.5 allows for maximum availability of the soil nutrients and microbial activity. Poultry and dairy manure have high levels of calcium and a natural liming affect on the soil, which can provide an additional benefit to acidic soils. Soil testing for nutrient management helps farmers track changes in pH so they know when additional lime is needed and can maintain optimal pH and nutrient availability.

Although soil organic matter can also retain some negatively charged nutrients such as phosphorus, the clay and carbonate content of the soil has a greater impact on nutrient retention. Aluminum and iron oxides found in clayey soils readily bind phosphorus; consequently, soils with greater percent clay can retain

higher concentrations of phosphorus than other soil types. Soils with high carbonates also tend to bind phosphorus and reduce its loss. Sandy soils have fewer iron and aluminum oxides, therefore, have a lower capacity to retain phosphorus. If phosphorus is over-applied (which can happen when manures are used to meet the nitrogen need of a crop), the capacity of the soil to bind phosphorus can be exceeded. In these cases, the soil no longer functions as a nutrient buffer, soil quality is reduced, and water quality can be impacted.
Because soil quality affects how water moves into surface and groundwater, it plays an important role in the site management practices of a nutrient management plan. Soil organic matter helps sustain microbial activity, which in turn tends to create soil aggregates by generating polysaccharides and other compounds that "glue" soil particles together. These aggregates can help prevent soil crusting and promote better soil structure, which leads to easier root penetration, as well as improved plant growth and production. Within a soil textural class, higher soil organic matter and better aggregation will allow more water to infiltrate into the soil, reducing erosion and preventing the loss of nutrients.
In areas where wind erosion is a problem, the aggregation of soil particles by soil organic matter, can also help reduce soil loss due to wind. Excessive tillage and the lack of residues or cover crops decrease soil organic matter and increase both wind and water erosion. Part of a nutrient management plan might be to change management practices to build or maintain soil organic matter to reduce erosion or establishing buffers to remove nutrients as water moves through the buffer. The management changes will be specific to the soil type, slope, and crops grown.
The best way to determine the nutrient content of the soil is by testing. Soils should be tested every 1-3 years based on the soil type and state requirements or recommendations. Soil tests usually report pH, phosphorus, potassium, calcium, magnesium, sulfur, and micronutrients. In some states, the level of soil nitrate nitrogen may also be reported. From soil analyses, nutrient recommendations can be offered based on local field trials and the experience of the land grant university. All this information helps the farmer know how much lime and fertilizer is needed for a particular crop on a particular soil.
Although soil organic matter is an important indicator for soil quality, it is often not reported in a regular soil test report. Most laboratories can analyze soil organic matter or soil carbon. Asking for this analysis is helpful to determine if soil organic matter is increasing, decreasing or staying the same.

For the best soil test results, the in-field soil sampling must be conducted properly. Individual fields should be sampled separately; areas within a field that are managed differently should also be sampled separately. In fields with different soil types each soil should be sampled separately. Cores should be taken in a zig-zag pattern across the sample area. Sampling in this way ensures a representative sample across the sample area will be collected. Soil samples should be taken from 0 to 6 inches for row crops and 0 to 4 inches in pastures and hayfields. A minimum of 15 cores should be taken from the areas that are less than 15 acres. For sample areas greater than 15 acres, a good rule of thumb is one soil core per acre. A minimum of 1 pint of soil should be collected for each sampling area.

**Local considerations**
The specifics of a nutrient management plan are dependent on soil types, cropping systems, and site conditions such as topography and hydrology. Each

state has their own specific procedures for developing a nutrient management plan based on their research and experience.

Managing nutrients with inorganic fertilizers is relatively easy because nutrients can be specifically blended in the concentrations needed for a particular crop. Nutrient management can be more difficult when organic fertilizers such as manures or composts are used. This is because the nitrogen to phosphorus (N:P) concentrations in organic fertilizers tend to be around 1:1 which does not match the N:P need of most crops which is 4-6:1. Consequently, when manures are regularly applied to meet the nitrogen needs of the crop, phosphorus is over-applied.

Composts can create similar conditions, especially when manures are used as a feedstock. Composting causes nitrogen concentrations in the organic material to decrease because some of the original nitrogen is lost as ammonia gas. Phosphorus is concentrated because the volume of the material decreases during composting and it does not have a gaseous from. Consequently, the N:P ratio in compost does not match plant requirements and phosphorus can be over-applied with regular use.

Nutrient management consists of several steps:

- Testing the soil to determine the nutrient supplying power of the soil,
- Determining the recommended amounts of nutrients needed to produce the desired yields,
- Accounting for nutrient inputs from other sources, such as legumes,
- Analyzing manures, composts, and irrigation water to determine the nutrient content,
- Applying manures or composts at recommended rates and based on the critical nutrient (usually either nitrogen or phosphorus),
- Applying the additional inorganic nutrients as needed,
- Keeping records so evaluations and adjustments can be made, and
- Being aware of your surrounding landscape so sensitive areas can be protected.

This process is an important step in building and maintaining soil quality.

**Fertilizers**

Fertilizer cost is the single biggest input cost for grain production. Fertilizers are added to supplement nutrients that are naturally occurring in the soil.

Fertilizers are available in different forms and grades. They provide either single or multiple nutrients. When choosing a fertilizer type, multiple factors need to be considered. The most important are price per unit of nutrients, availability, application equipment, timing, ease of storage, potential for nutrient losses and personal preferences. In this article we will determine the price per unit of nutrients and calculate the cost-to-value ratios.

Fertilizers as urea, triple superphosphate and muriate of potash are used to set standard costs for individual nutrients N, P and K, respectively.

The grade of a fertilizer refers to the percentage of N, $P_20_5$ and $K_20$ present on a weight basis.

**Value of nutrients in a multiple nutrient fertilizer**

Next the value of N, $P_20_5$ and $K_20$ in each multiple nutrient fertilizer is determined by multiplying the amount of each nutrient in a pound by the standard cost per pound for each nutrient and then adding together the N, P and K values. This reflects the value of nutrients that you get for your investment.

The cost-to-value ratio of each multiple nutrient fertilizer is determined by dividing the cost per pound of a multiple nutrient fertilizer by the value of its three nutrients. The lowest cost-to-value ratio is the best buy, because you get more value for what you pay, assuming that the fertilizer being evaluated supplies all the nutrients needed.

**Other considerations**
As previously mentioned, several other factors also enter into consideration when deciding on a fertilizer type. Anhydrous ammonia is the cheapest N source and despite its hazardous nature, it is used extensively to sidedress corn. Anhydrous ammonia has to be injected into soil and requires more power for application than its N counterparts. The UAN solution, which is a mixture of urea and ammonium nitrate in water, can be sprayed or dribbled on the surface of soil. When urea or UAN solutions are surface applied, there is an additional investment on urease inhibitors that may be used to prevent ammonia volatilization losses. Crop responses to liquid and dry fertilizer are similar, provided the amount and placement of nutrients are the same.
Recently the consumption of triple superphosphate has decreased because of the competitiveness and better storage properties of DAP and MAP. The DAP with its high ammonium content can cause seedling injury if placed in direct contact with seed. In contrast, MAP which has less ammonium is a better choice as a starter fertilizer. Ammonium polyphosphate (10-34-0) is popular in starter and pop-up applications because it is a liquid and therefore easier to customize lower application rates and mixing with pesticides. For fall application of P and K for build-up or maintenance, a bulk fertilizer high in P and K such as 6-24-24 would be preferred.

## *1.3. Integrated pest management*

Integrated pest management (IPM) is a pest management system that uses all suitable techniques in a total management system, to prevent pests from reaching unacceptable levels, or to reduce existing pest populations to acceptable levels.
Purpose: To manage pests with the least possible impact on people, property, and the environment.

**Integrated pest management** (**IPM**), also known as **Integrated Pest Control** (**IPC**) is a broad-based approach that integrates practices for economic control of pests. IPM aims to suppress pest populations below the economic injury level (EIL). The UN's Food and Agriculture Organisation defines IPM as "the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms." Entomologists and

ecologists have urged the adoption of IPM pest control since the 1970s. IPM allows for safer pest control. This includes managing insects, plant pathogens and weeds.
Globalization and increased mobility open allow increasing numbers of invasive species to cross national borders. IPM poses the least risks while maximizing benefits and reducing costs.

An IPM system is designed around six basic components:

- Acceptable pest levels — The emphasis is on *control*, not *eradication*. IPM holds that wiping out an entire pest population is often impossible, and the attempt can be expensive and unsafe. IPM programmes first work to establish acceptable pest levels, called action thresholds, and apply controls if those thresholds are crossed. These thresholds are pest and site specific, meaning that it may be acceptable at one site to have a weed such as white clover, but not at another site. Allowing a pest population to survive at a reasonable threshold reduces selection pressure. This lowers the rate at which a pest develops resistance to a control, because if almost all pests are killed then those that have resistance will provide the genetic basis of the future population. Retaining a significant number of unresistant specimens dilutes the prevalence of any resistant genes that appear. Similarly, the repeated use of a single class of controls will create pest populations that are more resistant to that class, whereas alternating among classes helps prevent this.
- Preventive cultural practices — Selecting varieties best for local growing conditions and maintaining healthy crops is the first line of defense. Plant quarantine and 'cultural techniques' such as crop sanitation are next, e.g., removal of diseased plants, and cleaning pruning shears to prevent spread of infections. Beneficial fungi and bacteria are added to the potting media of horticultural crops vulnerable to root diseases, greatly reducing the need for fungicides.
- Monitoring — Regular observation is critically important. Observation is broken into inspection and identification. Visual inspection, insect and spore traps, and other methods are used to monitor pest levels. Record-keeping is essential, as is a thorough knowledge target pest behavior and reproductive cycles. Since insects are cold-blooded, their physical development is dependent on area temperatures. Many insects have had their development cycles modeled in terms of degree-days. The degree days of an environment determines the optimal time for a specific insect outbreak. Plant pathogens follow similar patterns of response to weather and season.
- Mechanical controls — Should a pest reach an unacceptable level, mechanical methods are the first options. They include simple hand-picking, barriers, traps, vacuuming and tillage to disrupt breeding.
- Biological controls — Natural biological processes and materials can provide control, with acceptable environmental impact, and often at lower cost. The main approach is to promote beneficial insects that eat or parasitize target pests. Biological insecticides, derived from naturally occurring microoganisms, also fall in this category. Further 'biology-based' or 'ecological' techniques are under evaluation.
- Responsible use — Synthetic pesticides are used as required and often only at specific times in a pest's life cycle. Many newer pesticides are derived from plants or naturally occurring substances (e.g. nicotine, pyrethrum and insect

juvenile hormone analogues), but the toxophore or active component may be altered to provide increased biological activity or stability. Applications of pesticides must reach their intended targets. Matching the application technique to the crop, the pest, and the pesticide is critical. The use of low-volume spray equipment reduces overall pesticide use and labor cost.

An IPM regime can be simple or sophisticated. Historically, the main focus of IPM programmes was on agricultural insect pests. Although originally developed for agricultural pest management, IPM programmes are now developed to encompass diseases, weeds and other pests that interfere with management objectives for sites such as residential and commercial structures, lawn and turf areas, and home and community gardens.

**Process**

IPM is the selection and use of pest control actions that will ensure favourable economic, ecological and social consequences and is applicable to most agricultural, public health and amenity pest management situations. Reliance on knowledge, experience, observation and integration of multiple techniques makes IPM appropriate for organic farming (excluding synthetic pesticides). Although the pesticides and particularly insecticides used in organic farming and organic gardening are generally safer than synthetic pesticides, they are not always more safe or environmentally friendly than synthetic pesticides and can cause harm. For conventional farms IPM can reduce human and environmental exposure to hazardous chemicals, and potentially lower overall costs.

Risk assessment usually includes four issues:

1. characterization of biological control agents,
2. health risks,
3. environmental risks and,
4. efficacy.

Mistaken identification of a pest may result in ineffective actions. E.g., plant damage due to over-watering could be mistaken for fungal infection, since many fungal and viral infections arise under moist conditions.

Monitoring begins immediately, before the pest's activity becomes significant. Monitoring of agricultural pests includes tracking soil/planting media fertility and water quality. Overall plant health and resistance to pests is greatly influenced by pH, alkalinity, of dissolved mineral and Oxygen Reduction Potential. Many diseases are waterborne, spread directly by irrigation water and indirectly by splashing.

Once the pest is known, knowledge of its lifecycle provides the optimal intervention points. For example weeds reproducing from last year's seed can be prevented with mulches and pre-emergent herbicide.

Pest-tolerant crops such as soybeans may not warrant interventions unless the pests are numerous or rapidly increasing. Intervention is warranted if the expected cost of damage by the pest is more than the cost of control. Health hazards may require intervention that is not warranted by economic considerations.

Specific sites may also have varying requirements. E.g., white clover may be acceptable on the sides of a tee box on a golf course, but unacceptable in the fairway where it could confuse the field of play.

Possible interventions include mechanical/physical, cultural, biological and chemical. Mechanical/physical controls include picking pests off plants, or using netting or other material to exclude pests such as birds from grapes or rodents from structures. Cultural controls include keeping an area free of conducive conditions by removing waste or diseased plants, flooding, sanding, and the use of disease-resistant crop varieties. Biological controls are numerous. They include: conservation of natural predators or augmentation of natural predators, Sterile Insect Technique (SIT).
Augmentation, inoculative release and inundative release are different methods of biological control that affect the target pest in different ways. Augmentative control includes the periodic introduction of predators. With inundative release, predators are collected, mass-reared and periodically released in large numbers into the pest area.This is used for an immediate reduction in host populations, generally for annual crops, but is not suitable for long run use. With inoculative release a limited number of beneficial organisms are introduced at the start of the growing season. This strategy offers long term control as the organism's progeny affect pest populations throughout the season and is common in orchards. With seasonal inoculative release the beneficials are collected, mass-reared and released seasonally to maintain the beneficial population. This is commonly used in greenhouses. In America and other western countries, inundative releases are predominant, while Asia and the Eastern Europe more commonly use inoculation and occasional introductions.

The Sterile Insect Technique (SIT) is an Area-Wide IPM program that introduces sterile male pests into the pest population to trick females into (unsuccessful) breeding encounters, providing a form of birth control and reducing reproduction rates. The biological controls mentioned above only appropriate in extreme cases, because in the introduction of new species or supplementation of naturally occurring species can have detrimental ecosystem effects. Biological controls can be used to stop invasive species or pests, but they can become an introduction path for new pests.
Chemical controls include horticultural oils or the application of insecticides and herbicides. A Green Pest Management IPM program uses pesticides derived from plants, such as botanicals, or other naturally occurring materials.
Pesticides can be classified by their modes of action. Rotating among materials with different modes of action minimizes pest resistance.

**Evaluation** is the process of assessing whether the intervention was effective, whether it produced unacceptable side effects, whether to continue, revise or abandon the program.

## *1.4. Irrigation*

### Irrigation and irrigation systems

Irrigation, the addition of water to lands via artificial means, is essential to profit-able crop production in arid climates. Irrigation is also practiced in humid and sub-humid climates to protect crops during periods of drought. Irrigation is prac-ticed in all environments to maximize production and, therefore, profit by applying water when the plant needs it.

**Soil-water-plant relationships**

Effective and efficient irrigation begins with a basic understanding of the relationships among soil, water, and plants. Figure 4 illustrates the on-farm hydrologic cycle for irrigated lands. Water can be supplied to the soil through precipitation, irrigation, or from groundwater (e.g., rising water table due to drainage management). Plants take up water that is stored in the soil (soil water), and use this for growth (e.g., nutrient uptake, photosynthesis) and cooling. Transpiration is the most important component of the on-farm hydrologic cycle, with the greatest share of transpiration devoted to cooling. Water is also lost via evapo-ration from leaf surfaces and the soil. The combination of transpiration and evaporation is evapotranspiration, or ET. ET is influenced by several factors, including plant temperature, air temperature, solar radiation, wind speed, relative humidity, and soil water availability. The amount of water the plant needs, its consumptive use, is equal to the quantity of water lost through ET. Due to inefficiencies in the delivery of irrigated water (e.g., evaporation, runoff, wind drift, and deep percolation losses), the amount of water needed for irrigation is greater than the consumptive use. In arid and semi-arid regions, salinity control may be a consideration, and additional water or “leaching require-ment” may be needed.

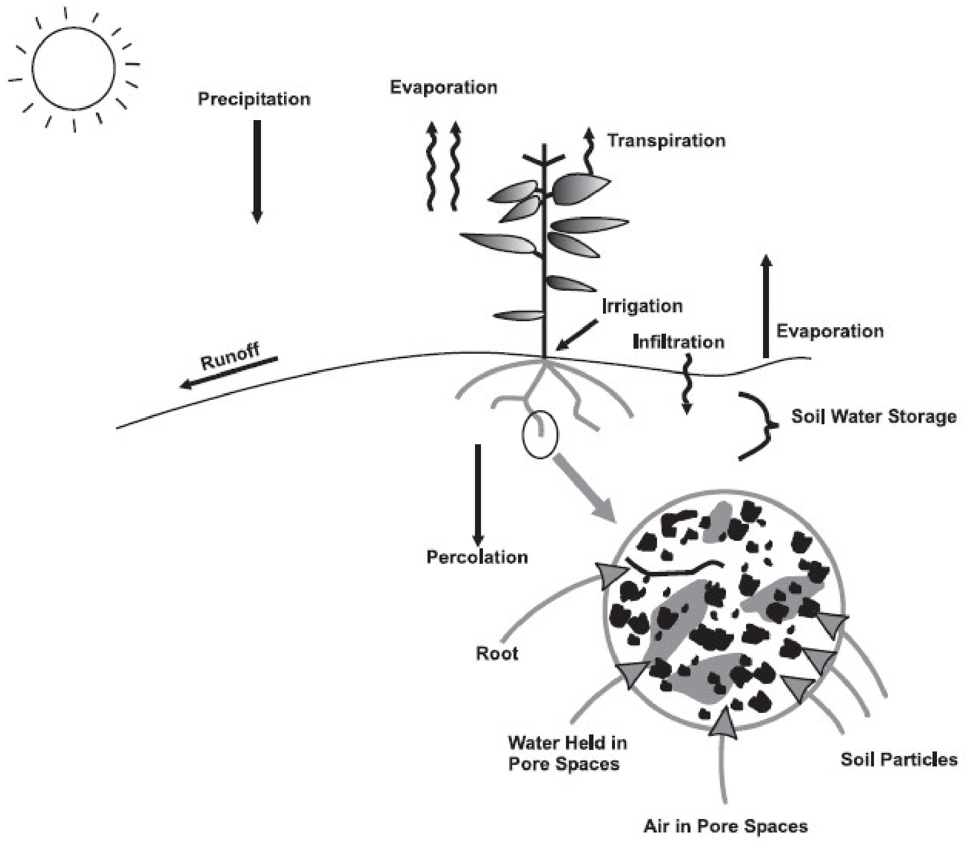



Figure 4: **On-farm hydrologic cycle for irrigated lands.**

Plant growth depends upon a renewable supply of soil water, which is governed by the movement of water in the soil, the soil-water holding capacity, the amount of soil water that is readily available to plants, and the rate at which soil water can be replenished. Efficient irrigation provides plants with this renew-able supply of soil water with a minimum of wasted time, energy, and water. Knowledge and understanding of the factors that affect water movement in the soil, storage of water in the soil, and the availability of water to plants are essential to achieving maximum irrigation efficiencies.

**Costs of irrigation**

Costs to install, operate and maintain an irrigation system will depend on the type of irrigation system used. In order to efficiently irrigate and prevent pollution of surface and ground waters, the irrigation system must be properly maintained and water measuring devices used to estimate water use.

A cost of $10 per irrigated acre is estimated to cover investments in flow meters, tensiometers, and soil moisture probes. The cost of devices to measure soil water ranges from $3 to $4,900. Gypsum blocks and tensiometers are the two most commonly used devices. A more expensive and instantaneous device is a neutron probe. It uses a radioactive source of neutrons and a probe to measure the amount of moisture in the soil. The probe is inserted into the soil through a tube and the energy, produced by neutons colliding with hydrogen and oxygen atoms that make up water, is mea-sured in the probe indicating the soil moisture content.
For quarter-section center pivot systems, backflow prevention devices cost about $416 per well. This cost (1992 dollars) is for:

1. an 8-inch, 2-foot-long unit with a check valve inside ($386); and
2. a one-way injection point valve ($30).

Assuming that each well will provide about 800-1,000 gallons per minute, approximately 130 acres will be served by each well. The cost for backflow prevention for center pivot systems then becomes approximately $3.20 per acre. In South Dakota, the cost for an 8-inch standard check valve is about $300, while an 8-inch check valve with inspection points and vacuum release costs about $800. The latter are required by law. For quarter-section center pivot systems, the cost for standard check valves ranges from about $1.88 per acre (corners irrigated, covering 160 acres) to $2.31 per acre (circular pattern, covering about 130 acres). To maintain existing equipment so that water delivery is efficient, annual maintenance costs can be figured at 1.5% of the new equipment cost.

Tailwater can be prevented in sprinkler irrigation systems through effective irrigation scheduling, but may need to be managed in furrow systems. The reuse of tailwater downslope on adjacent fields is a low-cost alternative to tailwater recovery and upslope reuse. Tailwater recovery systems require a suitable drainage water receiving facility such as a sump or a holding pond, and a pump and pipelines to return the tailwater for reapplication. The cost to install a tailwater recovery system was about $125/acre in California and $97.00/acre in the Long Pine Creek, Nebraska. Additional costs may be incurred to maintain the tailwater recovery system.

The cost associated with surface and subsurface drains is largely dependent upon the design of the drainage system. In finer textured soils, subsurface drains may need to be placed at close intervals to adequately lower the water table. To convey water to a distant outlet, land area must be taken out of production for surface drains to remove seeping ground water and for collection of subsurface drainage.

Savings associated with irrigation water management generally come from reduced water and fertilizer use.

## Questions for self-evaluation

1. What does total machinery cost contain?
2. What is soil test good for?
3. What does integrated pest control mean?
4. Why do we need irrigation?
5. What are the costs of irrigation?

# 2. MANAGEMENT OF CEREAL PRODUCTION

## *2.1. Winter wheat*

More than six million acres of Oklahoma cropland are seeded annually to winter wheat. As a result of the soil, climate, and environmental conditions, the Southern Great Plains region has a unique niche enabling the production of winter wheat for three purposes:

1. grain-only,
2. forage-only, and as a
3. dual-purpose forage and grain crop.

In the Southern Great Plains, the risk of severe Hessian fly infestations is small. This enables producers the option to plant wheat in late summer, which extends the fall vegetative growth period and increases fall forage production relative to October plantings. Extended snow cover is rare, enabling livestock to graze during the winter.

Wheat forage is of high nutritive value and gain potential of livestock is excellent. In a forage-only system, forage is available in late fall, winter, and early spring, when other forage sources are low in quantity and quality. In a dual-purpose system, wheat forage is available for grazing by livestock from mid-November until development of the first hollow stem, usually in early March. Typical rainfall patterns in April and May reduce concern about soil moisture limiting potential grain production. If livestock are removed no later than the development of first hollow stem, the wheat will mature and produce a grain crop for harvest in June.

Many lightweight calves are brought in from the Southeast, Midwest, and West to graze on wheat pasture in the Southern Plains. After wintering on wheat pasture, these calves are fed to slaughter weight in Southern Plains feedlots. The use of winter wheat as a multi-purpose crop is important in the agricultural economies of southwestern Kansas, eastern New Mexico, western Oklahoma, southeastern Colorado, and the Texas.

The United States Department of Agriculture (USDA) provides annual estimates of the wheat acres planted and harvested for grain. However, they do not differentiate among wheat uses. Hence, there are no routine data available from the USDA on the proportion of wheat acres used for each of the three purposes. Similarly, estimates of the number and class of animals stocked on wheat pasture in Oklahoma are also not provided by the USDA.

Recommended research-based wheat production practices differ across intended use. For example, the recommended planting date for wheat that is intended for forage production is two to six weeks before the recommended planting date for grain-only production. The recommended seeding rate is also greater for forage-only wheat. The optimal level of fertilizer may also differ across intended use of wheat. However, since the USDA's wheat cropping practices survey does not differentiate among the three uses, little information on actual production practices is available.

**The benefits of wheat in the crop rotation**

There are several agronomic advantages when considering adding wheat into your crop rotation. The period when winter wheat needs the most water, the flowering and early grain-fill stage, coincides with the time of year when most areas normally receive the most rain, May and June. As a result, winter wheat usually produces a crop when irrigation is limited. Most of the groundwater-irrigated land will be subject to allocations of 14 to 16 inches of water for at least the next several years. Winter wheat also can adapt to varying amounts of precipitation.

Wheat has a lot of ways to make grain and will provide at least half a crop even in the worst years. It also works well in rotation with other crops because its peak water need falls earlier than most summer crops now grown in irrigated rotations. During the growing season, winter wheat is very competitive with warm-season weeds. By the time these weeds come on, winter wheat already has developed enough of a canopy to block the sunlight from reaching the weeds.

Introducing wheat into more traditional irrigated crop rotations is advantageous with farmers' existing schedules and workloads. Winter wheat can spread the workload for producers of irrigated row crops. It is planted in September, following dry bean harvest.

Winter wheat also will fit into double-crop and relay-crop rotation systems. Under irrigated conditions, a forage crop can be planted following wheat harvest in July, enabling a farmer to produce two crops in one year.

Converting the traditional three-year crop rotation (dry beans/sugar beets/corn) into a four-year rotation by adding winter wheat also has advantages. Sugar beets are susceptible to soil-borne disease; it's good to allow an additional year between one sugar beet crop and the next.

Residue management is another advantage. Winter wheat produces a good amount of useful and resilient crop residue. Many farmers have begun harvesting with stripper headers on combines, which removes only the heads and leaves behind the remainder of the plant. This stubble has a higher silhouette factor than other crops, better protecting the soil from wind erosion. During the winter, it is effective in trapping snow, thus increasing soil moisture.

Corn in a wheat/soybean/corn rotation produced 6% higher yields. Meanwhile, soybeans in both three-crop rotations yielded 4% more than soybeans in the corn/soybean rotation.

**Wheat variety selection**

Variety selection is an important management decision. Some characteristics that may be used to select wheat varieties were listed in the survey. Respondents were asked to rank in order of importance the top three characteristics that they used to select varieties. Producers ranked grain yield and forage yield as the two most important variety characteristics in every region. Statewide, grain yield received 44% of the number one (most important) ranks, 22% of the number two ranks, and 8% of the number three ranks. Forage yield received 38%, 19%, and 8% of the one, two, and three ranks, respectively. In the Central and South Central-East regions, forage yield was ranked more important than grain yield. Producers also cited grain yield and forage yield as primary factors. Other important characteristics identified in this survey were past success, test weight, and drought tolerance. Winter hardiness was also noted as an important characteristic in both the Panhandle and South Central-East regions.

In a related question, producers were asked to rank sources of information as to their importance for variety selection. Producers rely on various sources for their information, since it is impossible for them to individually test all varieties on their farm. Statewide, 51% of the producers checked past performance as the number one source. Extension test plot results (48% checked as either first, second, or third) and results in neighboring fields (11% checked as first) were also popular sources of information. Among the other listed choices, seed availability was considered important, especially in the Central and South Central-East regions.

**Planting date**

When asked to report the target and actual fall 1999 wheat planting dates, the respondents often recorded a range of dates for each category. In those cases, the middle date of the range was used for the analysis. The reported average target planting dates show that producers consistently planted forage-only wheat earliest, then dual-purpose wheat, followed by grain-only wheat.

The state average wheat target planting dates were significantly different across intended use The average target planting date of October 2 for grain-only was significantly later than both forage-only and dual-purpose averages. The average dual-purpose target planting date of September 20 was significantly later than the average forage-only target planting date of September 13. These averages were found to be significantly different from the respective 1995-96 grain-only average of September 27, forage-only average of September 10, and dual-purpose average of September 17. Average grain-only target planting date was significantly later than forage-only and dual-purpose averages in all regions. The difference between forage-only and dual-purpose averages was significant only in the West Central, North Central, and Central regions.

The average responses to the question of actual planting date were later than the average target planting dates. Respondents on average planted wheat intended for grain-only the second week of October. Wheat intended for forage-only was planted during the fourth week of September, and dual-purpose wheat in late September or early October. Statewide, average grain-only actual planting date was significantly later than both forage-only and dual-purpose averages, and average dual-purpose actual planting date was significantly later than the forage-only average. The 1996 actual planting date state averages were October 7 for grain-only, September 23 for forage-only and October 1 for dual-purpose. Within each region, in comparison to those of target planting dates there are fewer significant differences between the average actual planting dates. The latest average actual planting date (October 16) was for grain-only wheat in the Southwest region, and the earliest one (September 21) was for forage-only wheat in the South Central-East region.

**Nitrogen fertilizer**

Soil fertility plays a major role in wheat production. Nitrogen is usually the most limiting nutrient associated with wheat forage production. Available nitrogen changes in the soil mainly as a result of the amount of nitrogen removed in forage and grain harvest relative to the amount added. Nitrogen requirements can be calculated based on expected yields. It is estimated that 1,000 pounds of dry forage requires 30 pounds of nitrogen and each bushel of grain requires two pounds of nitrogen. For an expected grain yield of 35 bushels per acre in a grain-only enterprise, an expected forage yield of 5,000 pounds of dry forage per acre in a forage-only enterprise, and 2,000 pounds of forage and 30 bushels of grain per acre in the dual-purpose enterprise, the recommended nitrogen requirements per acre will be approximately 70 pounds, 150 pounds, and 120 pounds for grain-only, forage-only, and dual-purpose wheat enterprises, respectively. These quantities are based upon the assumption that no nitrogen is available from other sources such as breakdown of organic matter, and that none of the nitrogen consumed by the livestock that is returned to the soil in the form of urine and feces is available for use by the plant.

All reported forage-only and dual-purpose nitrogen uses were lower than the recommendations by a large margin. This suggests that:

1. farmers applied an insufficient quantity of nitrogen,
2. farmers expected that the soil contained a substantial quantity of residual nitrogen, or
3. the recommendation relative to nitrogen requirements for livestock production on grazing wheat is incorrect.

It could be that the quantity of nitrogen returned to the field in the form of urine and feces is substantial and that its value is underestimated. Current nitrogen recommendations relative to forage production and use by livestock were derived from wheat plots that were clipped rather than grazed. Additional research may be needed to more precisely determine forage and livestock response to nitrogen on plots that are actually grazed.

In the state as a whole, though the grain-only average of 63 lb/acre was significantly lower than both forage-only and dual-purpose averages of 69 lb/acre, the differences were not large. The averages in 1996 were 66 for grain-only, 78 for forage-only, and 70 for dual-purpose. Only the forage-only *t* test showed the actual average nitrogen applied was significantly different from that reported in the 1996 survey. In the Panhandle, the grain-only average was significantly lower than the dual-purpose average, but other averages were not significantly different from each other. The greatest reported average actual nitrogen use was for the wheat intended for dual-purpose in the South Central-East region, and the least was for the wheat intended for grain-only in the Panhandle region.

Kansas irrigated wheat acreage has remained relatively stable since an increase in the early 1980s to between 700,000 to 800,000 acres. Irrigated wheat production represents about one-fourth of the 3 million irrigated crop base and is the second most commonly irrigated crop in the state, following corn.

Using average production figures for the past 5 years, just less than 7% of harvested wheat acres are irrigated and just over 10% of total production comes from irrigated land. Reported yield figures indicate irrigated land yields increases are 50% more than average dryland yield. The impact is even larger than this since most irrigated wheat production occurs in fallow wheat production areas. The majority of irrigated wheat production occurs in southwest Kansas.

**Water use characteristics**

Wheat can develop an extension root system with penetration to 6 feet under favorable conditions. Most of this growth occurs in the spring during the rapid growth period after breaking of dormancy. A normal root extraction pattern is to have about 70% of water extraction occur in the upper one-half of the root zone.

However, root extraction studies have shown wheat capable of extracting a substantial portion of its water need from the lower portion of the root zone. Soil water depletion levels can approach 80% of available water without serious yield potential reductions at most growth stages. However, the general recommendation would be to maintain soil water at above 50 percent depletion to maintain yield potential throughout the growth cycle.

All crops have characteristic water use curves. Summer grown crops have a bell shaped curve that indicates low daily water use needs in the spring, rises to a peak usually near the beginning of crop reproduction and then falls as the crop approaches maturity. Wheat has the same pattern, except that it begins its cycle in the fall and is interrupted by a period of winter dormancy. Figure 5 illustrates the general shape of wheat's water use curve.

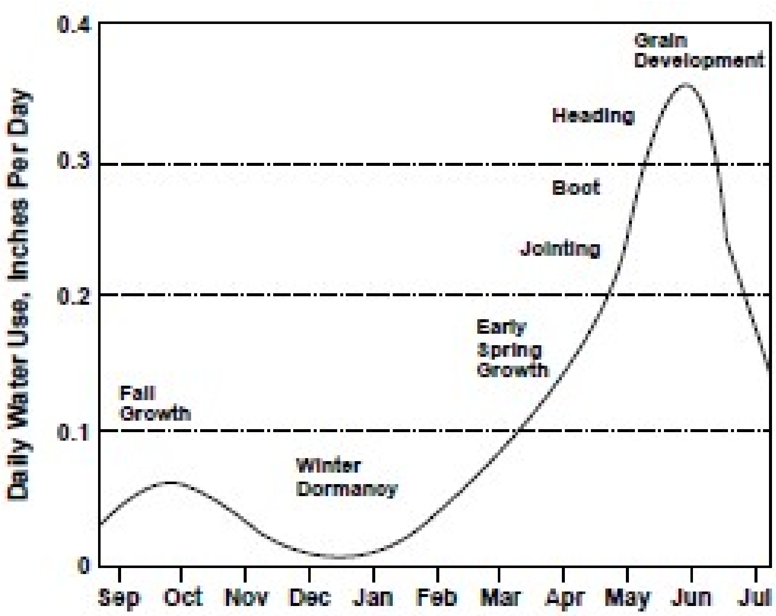



Figure 5: **Characteristic water use of winter wheat**

After planting and emergence in the fall, water use increases as wheat establishes itself until temperature forces it into dormancy. Water use begins in the spring with rapid water use increase corresponding to the rapid period of growth between breaking from dormancy until heading. Boot to heading may be the critical stage of growth for wheat, although wheat is tolerant of water stress throughout its life cycles. Peak daily water use rates of wheat can approach 0.5 inches per day but normally peak use rates will be around 0.35 inches per day during heading and grain development. Water use rates drop off rapidly after grain development.

Total seasonal water needs of wheat will vary widely depending on weather conditions but are in the range of 16 to 24 inches for a wheat crop that is not water limited.

Improvements in varieties and management practices have increased yields over time, but have not changed the water use requirements of wheat.

As already indicated, even though varieties have changed yield potential, disease resistance, etc., the water use by wheat has not changed. About 20 percent of water use will occur from emergence to the beginning of spring growth, another 20 percent will be from spring growth to jointing, 10 percent jointing to boot, 12 percent boot to flower, 15 percent flower to milk, 8 percent milk through dough stage, and the remainder until complete maturity. Net irrigation requirement as estimated in the Kansas NRCS Irrigation Guide for average rainfall range from about 12 inches in southwest Kansas to zero for eastern Kansas. Dry rainfall year estimates (80 percent chance rainfall) range from nearly 14 inches to about 3.5 inches across Kansas. The net irrigation requirement change across the state indicates why irrigated wheat production is concentrated in southwest Kansas. This is where the irrigation requirement is highest.

**Irrigation management**

Much of Kansas' irrigated wheat production occurs on surface-irrigated deep silt loam soils, most often using a single fall irrigation application. The fall application amount is generally heavy, often in excess of 6 inches. However this normally results in yields at or above the good dryland fallow yields because of good stands and full soil profile after irrigation. Normally, surface distribution in the spring after rapid growth begins is not practical for surface systems. Wheat that is being irrigated with sprinkler systems can generally make better use of applied irrigation water since a small application depth can be efficiently applied in the fall to assure good stand establishment and the remaining water applied as needed during the spring growing season. This allows better storage and utilization of both dormant and growing season precipitation.

Soil water holding capacity has a large influence on which management strategies will be successful. Heavy fall irrigation works well on deep silt and silty clay loams with available water holding capacities of 2.0 inches per feet or more, but fall irrigation would be a failure on sandy soils with holding capacities around 1.0 inch per foot or less.

Wheat irrigation is frequently used as a method of stretching the irrigation season since it has a growing season that is different from the other commonly irrigated but summer grown crops. Wheat also grows in a period when the potential demand for water is lower, and since wheat is relatively insensitive to water stress, long periods of time are available to irrigate wheat, utilizing low capacity wells, especially for individuals seeking to move to continuous production rather than a dryland fallow rotation.

Irrigation management strategies for full yield potential need to include scheduling of irrigation application to maintain soil water above 50 percent depletion. Stage of growth applications can be used to obtain maximum yield potential, but can be wasteful of water resources if water level status of soil profile is ignored.

Preplant irrigation only is sufficient to obtain a wheat yield, even in dry years although at less than full yield potential. Preplant and boot irrigation yielded essentially at the same level as did irrigation treatments scheduled by observing soil water status. One problem associated with this study is duplicating the treatment effect in surface irrigated production fields. Essentially surface production fields can only apply a fall preplant or after emergence treatment and this and other studies indicate this will be a reliable production strategy, but in dry years some yield loss will occur.

Sprinkler systems generally will require 3 to 4 applications to duplicate the effect of the single heavy application amount. This, however, is an advantage since irrigations can be withheld if no water stress developed.

In general, scheduling by soil water status or crop water use, will result in the highest yield potential with the lowest irrigation water input over the long-term since above normal rainfall years' water will be better utilized, thereby reducing irrigation demand.

**Harvest suggestions**
Today's modern, high-capacity combines are designed to do an excellent job of threshing and cleaning wheat. All too often, however, part of the crop is left in the field or the quality of the grain harvested is less than desirable. Even in good harvesting conditions, combine losses as high as 10 bushels per acre of wheat can occur in Kansas. In most cases, a few minor adjustments can drastically reduce losses or improve grain quality. Since any additional wheat saved is clear profit and clean samples are not docked, a little extra attention to combine adjustment can pay off.

**Preliminary adjustments**
As a general rule, start with the machine adjusted according to the specifications in the operator's manual. Engine speed is often taken for granted, but it is one of the most important adjustments of all. If the engine speed is too slow, separator speed will also be too low and performance will suffer. Once the combine is adjusted and ready to harvest, be prepared to fine tune it as required. To fine-tune a combine, the functions of the machine and how they relate must be considered. The combine's five basic functions are; cutting and feeding, threshing, separating, cleaning, and handling. The crop moves through the combine in this order. So if one function is not performing adequately, the areas that follow will have performance related problems. For example, if the header is too low and excess straw is entering the combine, threshing and separation will be difficult because of the excess material.
Cutting and feeding take place at the header and feeder house. Adjustments include header or cutting height, reel height and speed and reel position fore/aft.
Cutting height is controlled by the operator as conditions change. The goal should be to harvest all grain with minimal chaff and straw. The reel should be adjusted to gently move wheat into the cutterbar by positioning it slightly ahead of the cutterbar. It should turn slightly faster than ground speed and be far enough down in the wheat to lay the heads onto the platform. Make sure the sickle is sharp and in good condition. A dull sickle can limit ground speed and cause shatter loss. Crop feeding from the header should be uniform to ensure proper threshing.
Threshing occurs at the cylinder or front portion of the rotor and is affected by concave clearance and cylinder/rotor speed. Cylinder/rotor speed determines how much grain damage will occur and the amount of seeds threshed from the head. Clearance will determine how many seeds are separated and drop through the concaves. Ideally threshing removes all grain from the head without damaging grain or straw.
Cylinder adjustment is also important since it affects the performance of the rest of the machine. First, verify that the cylinder clearance indicator on the machine is accurate. The bars and concaves may be worn such that the clearance is greater than shown by the pointer. The concave and cylinder must be parallel from side-to-side and the cylinder-concave clearance must have the correct convergence from front-to-rear. The operator's manual should include detailed instructions on checking and adjusting these items.
Underthreshing, or not completely removing grain from the head, makes separation difficult. It occurs when concave spacing is too wide or cylinder speed is too slow. Overthreshing is indicated by the straw being pulverized and broken up. As a result, part of the straw may overload the shoe, thus carrying grain over

the back of the shoe. Other symptoms of overthreshing are cracked grain and excessive amounts of return. The cracked grain is more likely to be blown over the shoe, and even if retained in the grain tank, it causes problems in handling and storage. To avoid overthreshing, set the cylinder no faster and no tighter than absolutely necessary to thresh the grain from the heads. Some operators prefer to leave an occasional kernel in the head as a sign of the best balance in threshing action.

Since threshing plays an important role in grain cleaning, the cleaning shoe should not be adjusted until satisfactory threshing occurs. Shoe losses can be caused by several factors in addition to overthreshing. Narrow chaffer openings can cause grain to be carried over, as can improper fan adjustment. If the chaffer is opened too wide, it will overload the sieve and increase tailings. Chaffer and shoe openings are measured perpendicular to the louvers. An underblown condition at the shoe occurs when material is not adequately suspended in the air over the chaffer. This is caused by narrow openings or insufficient airflow. Grain should fall through the first two-thirds of the chaffer. If there is a thick mat of material on the shoe, grain cannot fall through and is carried over the rear of the shoe. If chaffer openings are too narrow, grain through them is limited, increasing losses and limiting the overall capacity of the combine. Changing chaffer openings also affects air velocity and direction; therefore they should be adjusted together. Ideally chaffer airflow and movement suspends material over the chaffer and allows kernels to drop through to the sieve. Sieve openings should be set large enough to let all grain through without allowing foreign material into the grain bin. However if they are closed to keep foreign material out, returns should be monitored to ensure there is not too much grain being recycled.

Manufacturers have greatly improved the cleaning area on newer combines by developing new fans and precleaners. Many changes in machines have focused on achieving more uniform airflow across the cleaning shoe.

These changes have improved the overall performance of the combine. Air type chaffers are popular as aftermarket equipment for combines. Some of these are adjustable and others are not, but most of them do a good job of removing large straw fragments.

**Combine capacity**

Combine capacity is the maximum rate at which a properly adjusted combine can harvest a crop while maintaining an acceptable loss level. Capacity may be limited not only by cutting and feeding or power limitations, but also by the performance of any of the functional areas of threshing, separating, or cleaning. It is important to relate capacity to an acceptable overall loss level. A common limitation on conventional combines in wheat is straw walker overload. If the combine is pushed beyond a reasonable rate, walker overloading causes the losses to increase rapidly.

With constant crop conditions, feed rate will be proportional to ground speed. At low to moderate feed rates, much of the grain is actually separated in the concave area.

About 90 percent of the separation should occur in the concave, leaving only 10 percent for straw walkers. At higher feed rates, the amount of separation in the concave area is drastically reduced so more grain is passed onto the walkers, resulting in excessive separating losses. The only way to reduce walker losses is to **slow down**. Reducing ground speed by 25 percent on an overloaded combine can easily cut harvesting losses in half.

**High quality wheat**

Combine adjustment can affect wheat quality in two fundamental ways: grain damage and cleanliness. Grain damage consists of cracked and broken kernels that make wheat harder to handle, generate dust, harbor insects, and increase mold growth. Damaged grain also can be hidden in that the operator may not see it. Some damaged grain may end up in the bin, but a high portion will probably go out the back of the machine in the form of flour and small fragments. Generally 0.5 to 2 percent grain damage is achievable, but it can be much higher.

Grain damage occurs mainly in the threshing area of the combine, but also can be caused in the clean grain conveying system. In hard threshing wheat, there is a trade-off between thorough threshing and grain damage.

An operator may not be able to completely thresh the crop without causing damage. Grain damage is usually caused by excessive cylinder/rotor speed. If slowing the cylinder/rotor speed doesn't improve the grain sample, adjustment of the concave clearance may be needed.

Foreign material also contributes to a lower quality wheat sample. Some weed seeds, especially cheat and downy brome, are difficult to separate from wheat. A good way to help is to harvest cheat infested fields last.

Drier cheat is easier to clean and the yield in 'cleaner' fields is probably higher which makes them more important. Some general adjustments for cheat infested fields are:

- Chaffer toward open end of recommended range,
- sieve toward closed end of recommended range, and
- fan toward high end.

Following these guidelines will probably cause returns to increase, so keep an eye on machine capacity to avoid plugging.

Also watch your travel patterns when dealing with cheat. The combine is a serious vector for weed seed. It typically takes more than 1 minute to fully discharge cheat from a combine. If the combine is cutting cheat along the edge of a field, it can carry it 200 yards or farther into the field before it is through.

**Estimating the losses**

Checking the machine frequently is the best way to ensure efficient harvesting. During a single afternoon, conditions can change enough to require resetting some of the machine's components. A few simple ground counts will give an indication of combine performance.

As a general rule, it takes about 20 kernels of wheat persquare foot to equal one bushel per acre when spread evenly across the field. The only item needed to check losses is a one square foot frame made out of heavy wire to carry on the combine or in the grain truck. Follow these steps to determine losses:

1. Cut through a typical area at the usual speed, then stop the combine and back up about 20 feet.
2. In the area behind the separator discharge, lay the one foot square frame down three times and take ground counts (Figure 6). Average the three counts. This is the separator count.

3. In the area between the cutterbar and the standing wheat, take three more ground counts and average them. Don't forget to look for heads. This is the header count.
4. Take a final three ground counts in the standing wheat and average them. This is the preharvest count.
5. Calculate header loss in bushels per acre. Header loss = Header count – Preharvest count
6. Calculate the separator loss in bushels per acre. Separator loss =Separator count – Header count

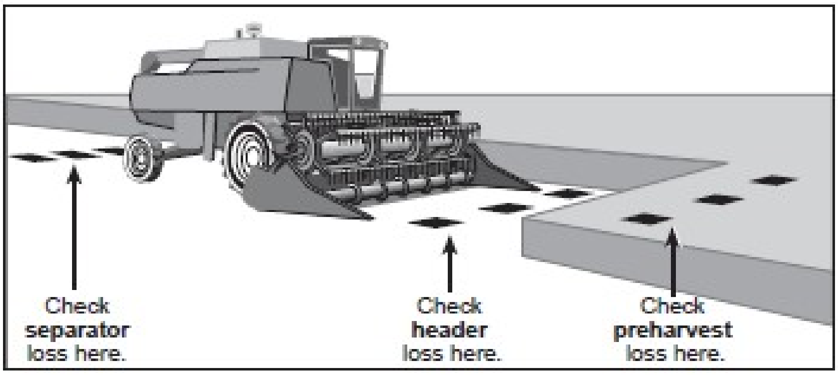



Figure 6: **Measuring wheat harvest losses**

Wheat stored on or off farm must be kept free of insects, fungi, rodents or other pests to ensure acceptance by domestic and foreign grain buyers. Low levels of insect infestations can develop into damaging populations before the grain reaches its final destination.
Integrated pest management techniques during wheat storage require proper use of sanitation, chemicals, monitoring and aeration to maintain the wheat quality.

What are acceptable losses? This depends on the condition of the crop (Photo 1) as well as the attitude of the operator. However, for standing wheat under good harvesting conditions, machine losses can usually be held to 2 percent of the total yield. Higher losses will have to be tolerated in downed or damaged wheat.
Although simple to perform, the ground counts can be time consuming. It may be more practical to have the truck or grain cart driver perform the separator ground count periodically during the day. This allows the combine to continue harvesting while the count is being made.

**Correcting the losses**
Since there are many factors that can create combine losses, an organized approach to correcting the problem is needed. Figure 7 shows one method for pinpointing the cause of the lost grain. When fine tuning a machine, try to change only one thing at a time so that the effects can be seen. Keep referring to the operator's manual; it seldom pays to deviate very far from suggested settings.

Photo 1: **Wheat damaged by storm**

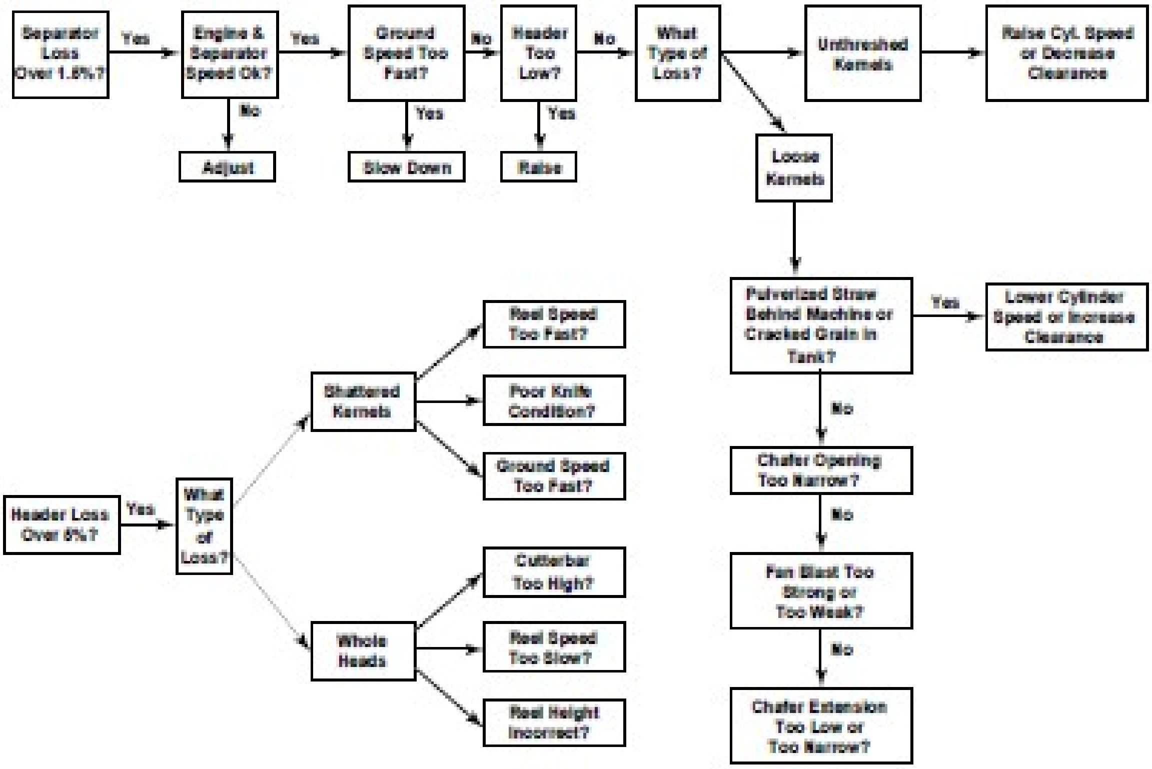



Figure 7: **Correcting wheat harvest losses**

Preventing discounts requires sanitation, monitoring, aeration, and proper use of chemicals. DKT produced by mold is the simplest damage to prevent, since it is caused by excess moisture somewhere in the grain mass. Wheat should be stored at 13 percent or less moisture content. Insect control is the most difficult part of farm wheat storage since incoming wheat must be held through the summer before cool weather arrives. Discounts related to insect presences or IDK can be minimized using integrated pest management (IPM) techniques. Moisture migration and condensation can be prevented with proper aeration.

"What is the minimum insect density at which fumigation is cost-effective?" is a common question relative to insect control. The following guidelines are based on available field research and surveys. However, they are not applicable in every situation, and one's local elevator or mill should be consulted to determine their insect thresholds. These guidelines assume that the wheat will be moved to market in the winter and that the objective is to keep insect levels below detectable levels.

- If more than two insects are found in samples, take a total of five samples from each bin.
- If lesser grain borers or weevils (internal feeders) are found in more than one sample, or if more than one of these insects is found in a single sample, fumigation may be necessary unless the entire grain mass can be cooled to below 50°F within 3 weeks.
- If only external-feeding insects (flat or rusty grain beetles, flour beetles, meal moths, sawtooth or merchant grain beetles, etc.) are found, an average of two per sample is usually acceptable if the grain can be cooled to below 50°F within 2 months.

**Structures**

The structure in which wheat is binned can help prevent loss and quality deterioration during storage. Structures used for grain storage should:

1. Hold the grain without loss from leaks or spills.
2. Prevent rain, snow, or soil moisture from reaching the grain.
3. Protect grain from rodents, birds, poultry, objectionable odors, and theft.
4. Provide safety from fire and wind damage.
5. Permit effective treatment to prevent or control insect infestation.
6. Provide headroom over the binned grain for sampling, inspecting, and ventilating.

A suitable storage for grain includes a weather-tight, rodent-proof, metal structure that is separated from hay and feed areas and animal housing. It should be easy to clean and inspect. It should have an aeration system that will allow you to cool the grain and thus limit insect development, and minimize moisture migration through the grain.

**Costs**

Kansas has long been known as the "bread basket" of the world because of its ability to produce high-quality wheat. Kansas consistently ranks number one or two in the production of wheat, with 18.7 and 13.1 percent of the total U.S. wheat crop in 1994 and 1995, respectively.

The total acres of wheat harvested in Kansas remained fairly stable during the period 1993-95 at about 11.17 million acres or about 52.5 percent of the state's harvested crop acres. In 1995, 11.0 million acres of wheat were harvested. Approximately 286.0 million bushels of wheat were produced for an average yield of 26.0 bushels per harvested acre.

Each producer must answer two questions when selecting crops and the acreage of each crop to produce are:

- Will this choice be profitable?
- Will this add more to the total net income of my farm operation than other choices? That is, is this the most profitable choice?

The fixed or overhead costs of land and machinery ownership for wheat, soybeans, corn, and grain sorghum will be basically equal for the production period under consideration. Therefore, the variable costs associated with each crop are the costs that need to be considered when selecting a given crop.

Variable costs include: labor, seed, herbicide, insecticide, fertilizer, fuel, oil, repairs, crop insurance, drying, custom work, crop consulting, and miscellaneous.

Variable costs will vary depending on the management practices used, tillage operations, labor efficiency, and type and fertility of the land. Each producer should develop the variable costs of production for wheat and any other crop alternatives. Expected yield and selling price need to be determined for each crop alternative.

The decision to plant wheat or another crop alternative can be made by comparing the expected returns above variable costs for each crop. Returns above variable costs will depend on yields and prices. Each producer should use yields that are reasonable for the land or classes of land operated.

The decision to produce wheat will depend primarily on the costs and expected returns for wheat in comparison with other crop alternatives. However, the producer should take into account other variables such as previous crop rotation, livestock operation, and the machinery and labor requirements of each crop.

The type and amount of equipment, crop rotations, and farm size all affect the cost of producing crops. The tillage practices used and their timing, also affect yields and production costs. Each producer should compute the expected returns above variable costs for the farm operation as a means of selecting the crops and acreage of each crop to produce. When computing expected returns above variable costs, consider a number of price alternatives.

## *2.2. Barley*

Barley products include malt, feed grain, food and a minor amount of hay. In the future, barley straw could become important for producing cellulosic ethanol as crops could become feedstock for energy production. The end use market determines proper agronomic management of the crop. For example, for use as malt, stringent grain quality dictates acceptability in the market. Management for malt quality factors becomes more important than management for high yield (Table 2), and generally requires more precision than management for feed. In the feed market, total barley grain yield becomes more important than plumpness and low protein.

Variety selection is most important, and varieties for malt production are not always the most economical choice for the feed grain market. This is particularly true for dryland production, although many producers, without a malt barley contract, will speculate by growing a malt variety hoping for malt quality and use the feed grain market as a safety net.

Table 2: **Typical two-row malting barley purchase specifications**

| Quality Factors | Two-Row Barley |
|---|---|
| Moisture | < 13% |
| Plump kernels (on 6/64) | > 70% |
| Thin kernels (thru 5/64) | < 10% |
| Germination | > 97% |
| Protein | 7.5 - 14 % |
| Skinned & broken kernels | < 3% |
| Wild oat | < 2% |
| DON (Vomitoxin) | < 1 ppm |

Varieties grown for malt (Photo 2) are specified by contract with individual companies. Maltsters are particular in the varieties they purchase and even narrow their choices. Most malt barley in Montana is grown under contract, and the contract will specify which variety is to be grown. If you are considering growing malt barley without a contract, you are encouraged to investigate the market prior to planting and to be aware of the potential for reduced yields, particularly on dryland, when growing a malt variety as opposed to feed barley such as Haxby. Insurance is typically not available for malting barley without a contract. Be sure to check with your insurance office prior to making the decision to plant.


Photo 2: **Two-rowed malting barley**

Variety development for feed grain production has produced some outstanding varieties capable of high yield. Variety trials are conducted annually at the Montana Agricultural Research Centers. This tool provides a way to select varieties best suited for an individual environment.

**Tillage**

Barley can be successfully produced in any tillage system. Soil management begins at harvest via residue management. It is important to distribute straw and chaff as evenly as possible during harvest of the previous crop. This is especially true if barley is to be planted no-till. Straw and chaff spreaders and choppers on combines efficiently distribute residue, simplifying the next operation.

In conventional tillage situations, as when following sugar beets, some fall tillage is required to level and smooth the field following the beet harvest. The field should be left rough to improve snow trapping and to reduce the risk of soil erosion. In the spring, one or two shallow tillage operations should be adequate to prepare the soil for planting. Excessive tillage dries the soil, making it hard to achieve good seed soil contact, resulting in poor or uneven germination.

No-till planting may be accomplished with minimum or maximum soil disturbance. Soils under no-till conditions are typically wetter and cooler than tilled soils. No-till usually results in good soil moisture at planting depth, which improves chances of an even stand and the abundant residue can protect the newly emerged crop from physical damage from wind and rain. Using planter openers such as 4-to-6 inch sweeps allows the soil to warm up quicker than using planter openers such as double discs or points.

**Planting dates and rates**

The barley types grown in Montana are spring varieties; no winter varieties are currently adapted to this region. Barley is a cool season crop, and will yield best when vegetative and early reproductive growth occurs while temperatures are cool. Spring barley will germinate at temperatures above 40°F. Optimal germination and emergence occurs when soil temperatures are between 55°F and 75°F. In the spring, plant barley as soon as possible after spraying out grassy and other weeds. Delayed planting can result in low yields and high protein, which can be cause for rejection in the malt market. In general, early seeded barley (mid-February to mid-April depending on location) avoids injury from drought, high temperatures, diseases, and insect pests that occur late in the season. As a rule-of-thumb for Montana, potential yield is reduced approximately one bushel a day for each day planting is delayed after May 1.

Planting depth should be 1-to-1½ inches. It's important that press wheels cover the entire width of the seed trough to ensure good seed-soil contact. This is especially true if you use an air seeder with wider openers. Optimum plant populations for irrigated production of malt barley range from 750,000 to 1,000,000 plants/acre, or approximately 17-23 plants/ft$^2$. If the crop is to be cultivated, this population should be increased by 10% to account for expected losses due to cultivation and burying of small plants. For dryland production, plant populations should be about half that of irrigated. Planting rates for dryland feed barley should be increased over that grown for malt by approximately 20%.

The number of seeds per pound varies by variety and within a variety each year depending on the quality of the grain. In central Montana in 2007, results from the variety performance trials showed that seed weights ranged from 8,500 to 13,000 seeds per pound. This large variation in seed size is one reason why a germination test and lab calculated values for seeds per pound should be used to determine optimum seeding rate.

**Fertility management**

Nitrogen (N): If N fertilizer is used correctly, there are no barley yield or quality differences between different nitrogen (N) fertilizer sources (e.g. 82-0-0, 46-0-0, 34-0-0, 28-0-0, 21-0-0-24 etc.). If ammonium-based fertilizers, such as urea (46-0-0) and ammonium sulfate (21-0-0-24) are used, it's best to fertilize when soil and air temperatures are cool (< 50°F) and predicted to remain cool. If N must be applied when temperatures are warm, application should occur no more than 2 days prior to an irrigation or rainfall event of at least one half inch to move the fertilizer below the soil surface. In general, ammonia volatilization rates are not high in Montana due to our cool temperatures during typical N fertilizer application periods combined with our generally fine-textured and high-lime soils. In shallow, coarse soils that are furrow irrigated, there is a higher likelihood of N leaching. In this situation, ammonium-based fertilizers may decrease losses, because it takes a few weeks for ammonium to become converted to the more mobile nitrate form of N. A slow release product may also prove valuable under furrow irrigation. In dryland situations, slow release products should be avoided or blended with conventional fertilizer N, because in Montana's cool, dry environment, the N will likely be released too late to benefit yield. If substantial amounts of N are released after flowering, grain protein levels can be too high to meet malt quality.

The lower N rate for malt barley is designed to increase the potential for obtaining good malt quality, by decreasing the risk for high grain protein (> 14%) and low plump (<70 %). Although a set N rate per bushel is simple, it is generally not the best choice economically. For example, at low yield potentials, barley obtains a higher fraction of its N from soil organic matter (OM), than at high yield potentials. Therefore, a somewhat lower amount of N per bushel should be used at low yield potentials, and a somewhat higher amount should be used at high yield potentials.

Application rates should be adjusted based on N costs and grain prices. Marginal returns to soil N +fertilizer N in barley (Figure 8) increases with grain yield to near the yield plateau. But near the peak of the response curve, input costs begin to exceed net revenue, reducing the optimum N rate from that based only on yield. This example illustrates marginal return for the initial conditions. With these initial conditions, the N rate that produced maximum barley grain yield is 105 lb N/ac, but the economic optimum N rate (EONR) is 90 lb N/ac. The difference between the two rates is higher as N prices go up and grain prices fall, and vice versa, although according to the model, over a range of prices (urea = $650 - $1000/ton, malt grain = $5 - $8/bu), the EONR varied from only 80 to 95 lb/acre for a yield potential of 80 bu/acre. Currently this model is calibrated only for barley grown on fallow, and should not be used for recrop situations. To assure that the best N rate is selected, it is critical that a representative soil sample be collected from each barley field to a depth of 2 to 3 feet and analyzed for nitrate-N, preferably in late winter/early spring.

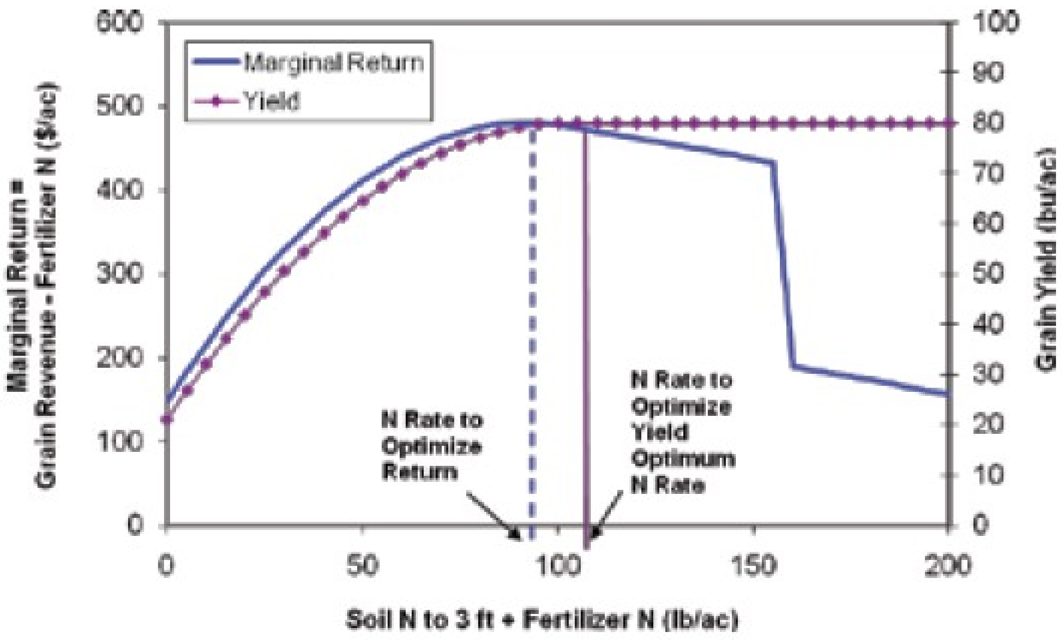



Figure 8: **Effects of available N on yield and marginal economic return**

To further optimize yields, N rates can be varied among "management zones" that are based on previous yield or soil characteristics.

Nitrogen fertilizer can be surface broadcast, surface banded or subsurface banded, with little difference in barley yields among placements; however, when soil nitrate levels are low, or volatilization potential is high, N should be subsurface banded to optimize yields. Caution must be used when placing fertilizer with the seed to prevent problems with barley germination and emergence, and problems can be worse on dry, coarse soils. How much fertilizer can be applied with the seed depends upon soil water content and soil texture, row spacing, furrow openers, etc., though a good rule of thumb is to apply no more than 30 lb N+$K_2O$/acre. Seed and fertilizer contact is reduced by using openers that spread the seed and fertilizer at least 2-to-4 inches so the fertilizer is diluted by the soil. A slow-release product could also be used, because these products generally produce fewer emergence problems.

In irrigated systems that generally broadcast and incorporate fertilizer with tillage, there should be few problems with seed-to-fertilizer contact. Liquid application of solutions on established barley is an effective means of fine-tuning N rates, yet rates should be less than 40 lb N/acre to reduce leaf burn. With center pivot and lateral move sprinkler irrigation systems, N rates can be finetuned by injecting N solutions in the irrigation water. To obtain best yields, schedule N applications so the total allocation of N is applied prior to jointing.

Applications of N fertilizer are generally most effective when they occur from late fall to early spring. Nitrogen applications made in early to mid fall have resulted in lower barley yields than spring top dressed applications, most likely due to tie-up of N by microorganisms or because of leaching losses (Jones et al., 2007). Late spring to summer N applications are generally discouraged due to increased potential for volatilization losses, stranding N in dry surface soils, or potential for excessive grain protein in malt barley.

Two granular phosphorus (P) fertilizers comprise most of the P used in Montana: monoammonium P (MAP; 11-52-0) and diammonium P (DAP; 18-46-0). MAP is used much more extensively because it provides less risk to seedling emergence due to its lower ammonium concentration. It also lowers pH near the granule which can temporarily increase P solubility, though generally yield responses are the same for the two products if total N and $P_2O_5$ rates are the same. Liquid ammonium phosphate (e.g. 10-34-0) is also available. Generally there are no yield differences among P sources as long as the actual P rate is the same. Therefore, the P source should be selected based on price per unit of P and on the equipment available for application.

Potassium (K) is generally applied as potash (KCl; 0-0-60). To determine if your field requires either P or K, soil test levels need to be compared with the "critical levels" of 16 ppm for P, and 250 ppm for K. If either soil test is below these critical levels, fertilizer should be applied.
If the soil test level is above the critical level, only starter fertilizer (approximately 10 - 20 lb nutrient/acre) is recommended to optimize yield in that year. However, to avoid depleting soil P and K, it is often recommended to apply the amount that will be removed by the crop.
Phosphorus should be placed either with the seed or up to 2 inches below the seed, so that roots will quickly contact this relatively immobile nutrient. Because P is much less soluble than N or K, there are no maximum limits for how much can be placed with the seed; however, keep in mind that a 100 lb/acre application of 11-52-0 will provide 11 lb N/acre which is more than 1/3 of the maximum recommended amount of N+$K_2O$/acre. In tilled, irrigated systems, incorporating P with tillage prior to seeding should be sufficient to optimize yield. The mobility of K is intermediate between N and P. If K requirements are small, K can be placed with the seed, but as pointed out above, rates higher than about 30 lb N + $K_2O$/acre can decrease emergence unless a wide opener is used. If higher rates are needed, K fertilizer should either be broadcast, or placed in a subsurface band at least one inch from the seed row. Because both P and K are needed in high amounts early in the growing season, and are relatively immobile, they should be applied immediately prior to, or at seeding, and should not be top dressed. Chloride ($Cl^-$) deficiencies should generally not be an issue if K fertilizer is applied annually above a rate of 10 lb $K_2O$/acre.

Research in the Golden Triangle shows sulfur (S) should not be applied to barley because it either produces no effect, or a slight negative effect on both yield and quality. If S deficiency symptoms appear (uniform yellowing starting in the upper leaves and then moving down), then a small amount of S (5 to 10 lb S/acre) should be top dressed. Low protein when N is sufficient is a potential indicator of low S, and barley leaf tissue concentrations below 0.17% indicate a S deficiency. Ammonium sulfate (21-0-0-24) is a soluble, relatively available S source, and is effective when broadcast. Elemental S takes months to become available, so should not be used to correct a deficiency, but can be used to build soil S over time in chronically S-deficient soils. Elemental S is also useful in lowering the pH of calcareous soils (pH>7.5), thereby increasing availability of P and metal micronutrients. But elemental S should be used cautiously on acidic and neutral soils to prevent too large a drop in soil pH.

Micronutrient deficiencies are rare for barley grown in Montana. Plants should still be inspected for deficiency symptoms, and a liquid micronutrient blend can be foliar-applied if deficiencies are observed or suspected. A granular micronutrient blend can also be applied with the seed to prevent deficiencies. The highest likelihood for micronutrient deficiencies are on eroded, low OM soils.

**Weed management**

Although barley is a vigorous and competitive crop, weeds have the potential of reducing yields. Not only do weeds compete with barley for light, nutrients and water, they can also make crop harvest difficult, increase dockage, and encourage insect infestation or mold growth in stored grain.

Weeds can reduce crop quality as barley contaminated with weeds may not achieve malting grades or may have reduced palatability when used as animal feed.

In Montana, grassy weeds including wild oat, cheatgrass, green foxtail, and Persian darnel are among the most serious weed problems to many barley growers. Broadleaf weeds including kochia, Russian thistle, prickly lettuce, and field pennycress also pose a threat to barley growers. To reduce the chances of developing herbicide resistant weeds, weed scientists recommend that you periodically rotate herbicide type.

By knowing what chemical you applied on a particular field one year, you can choose an herbicide with a different mode of action for next year's crop. Herbicides with multiple chemicals may have more than one mode of action. Although chemical options to manage weeds in barley exist, they can damage crops if not correctly applied. Mistakes usually occur when herbicide applications are not correctly timed, when weather conditions enhance barley susceptibility to herbicides, when non-recommended applications are applied, or when uncalibrated or contaminated equipment is used. Further, there are herbicides labeled for use on wheat that have plant back restrictions for barley as well as for most broadleaf crops.

Simple steps can help you reduce the risk of herbicide injury in barley. Make sure that you read and understand the herbicide label. Do not use complex, non-recommended tank mixes. Non-recommended herbicide mixes can also lead to a chemical reaction in the spray-tank which could damage your equipment, affect your safety, or compromise the environment. Make sure that your equipment is properly calibrated and that the spray-tank, lines, boom and nozzles are carefully cleaned at the end of each application. If crop injury to barley does occur, immediately contact the dealer who provided the herbicide or made the application. That way an assessment of the injury can be made as soon as possible and remedies can be identified and implemented to minimize potential yield impacts.

Barley growers should be aware that the selection of herbicide resistant weed biotypes threatens the long-term sustainability of this approach for weed control. Developing an *integrated weed management* program is essential to successfully control weeds in barley. To do so, barley growers must start by preventing the introduction and spread of weeds in their fields. This preventive practice must be complemented with cultural practices to enhance crop competitiveness, rotation of crops, and chemical treatment when necessary. For example, field experiments conducted in Canada indicated that barley competitive ability against wild oat declined with delayed crop emergence in spring and increased with seeding rate. Low barley seeding rates also allowed greater weed-seed production, increasing the chances of infestations in future years.

**Cropping systems**
Most crops respond positively to crop rotation. Barley is no different. Because of efficiencies in water use, nutrient use (primarily nitrogen), and the presence of crop pests, growing barley following any crop other than a cereal crop typically provides a yield boost, and perhaps a protein boost.
For comparison, barley yield in canola stubble was intermediate compared to that of pea and wheat stubble (Figure 9). The yield difference in pea versus canola stubble was attributed to differences in pest pressure, while the yield differences in pea versus wheat stubble, especially at low levels of nitrogen were more clearly due to nitrogen rate.

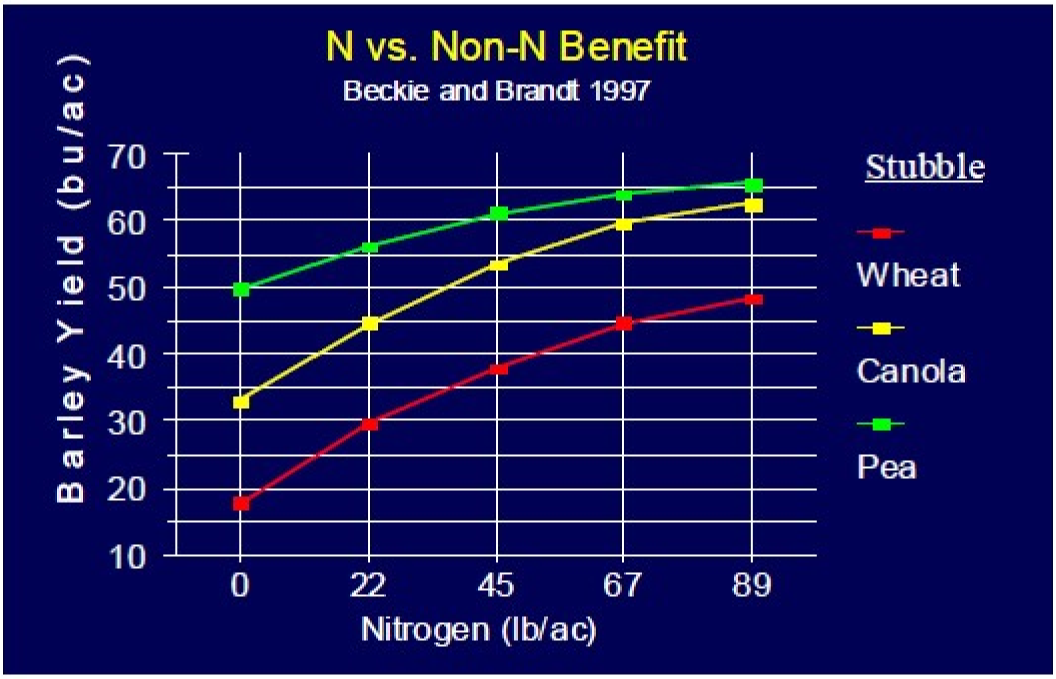



Figure 9: **Effect of nitrogen and previous crop on barley yield**

For dryland production systems, in addition to the nitrogen benefits and reduced pest pressure that can be realized when placing barley in a proper rotation, water management by crop choice can play an important role. Peas and lentils are short season pulse crops that root fairly shallow. They use soil water only from the top couple of feet. By growing a deeper rooting barley or wheat crop in rotation after a pulse crop, soil water stored at greater depths can be accessed. This improves water use efficiency when calculated over the course of two years.

**Managing plant diseases**
Plant diseases can severely impact barley yields. Management to prevent occurrence is preferred to treatment. In most cases (but not all) crop rotation to reduce the amount of disease organisms (inoculum) present and to alter the environment so that the disease is not expressed is the best management practice for successful barley production. When diseases do occur, prompt identification is

needed so that management of the condition can be used to salvage the current crop. The following descriptions may help to determine the cause of various plant disease and physiological problems.

**Field diagnostics**

Fields should be scouted regularly during the growing season for signs of trouble. Early diagnosis is important to correct a deficiency or to determine an alternate management plan. Determining cause and effect is an art which improves with practice.

Plant damage from natural events will follow a different pattern than that caused by human error, such as herbicide overlap. Look at the ends of fields where double applications of fertilizer or agricultural chemicals may have occurred. Compare plants in these areas to those away from the field ends, or to those plants displaying damage symptoms.

When inspecting damaged plants, look for signs of mechanical abrasion, or signs of insect feeding such as ragged edges of leaves, or evidence of feeding on roots or stems.

Compare plant color against those plants you deem to be normal. Use a sharpshooter, or shovel to excavate plants and compare root growth habit.

Frost injury is caused by freezing temperatures after plant emergence. The worst damage occurs when barley is damaged before the 2-leaf stage or at heading or soft dough stage. If injury occurs during heading or pollination, symptoms will include white heads, sterility, white awns and watersoaking and shriveling at the base of the head. Hail injury is most damaging from heading through harvest. The number of days between heading and the time of hail damage is more indicative of yield loss than the number of stems left standing. Hail kinks and severs plant parts randomly. Other symptoms include drying and bleaching of damaged tissues, white heads, stem lesions, and spike bruising.

Nutrient deficiency symptoms include stunted or uneven growth, yellowing, poor vigor, reduced tillering, and low yield and seed quality. Most symptoms occur between tillering and heading when there is high demand for nutrients. Diagnosis can be obtained from plant or soil analyses.

**Harvesting and handling grain**

For malting barley, grain quality is of utmost concern. Premiums are paid for malting barley that is in good condition and has been stored properly. Because the malting process requires complete and uniform germination, grain handling to minimize physical damage is very important. A high percentage of skinned and broken kernels results in inferior quality malt.

No pre-harvest desiccants are labeled for malting barley, so none should be used. Barley is considered to be physiologically mature at approximately 35% moisture. It can be cut anytime after this, but the grain can be easily damaged by harvesting equipment at moisture levels above 18%. If facilities are available to properly dry the grain, barley can be direct cut at 18% moisture. Otherwise grain is stable for storage when moisture is below 13%.

All modern combines can be adjusted to thresh barley and specific settings by the manufacturer should be followed. While threshing, regular checks should be made for skinned and broken kernels. Minor adjustments may be necessary during the day to compensate for changes in humidity and moisture content. In general, slower cylinder speeds and close concave adjustments usually result in cleaner harvested grain.

Grain handling after harvest by on-farm elevators and augers can also lead to damaged kernels. Bent or dented auger housings and ragged edges can cause damage to grain. Pneumatic elevators can be used to move grain. Do not run this type of equipment above the recommended speed, as grain can be damaged by sharp angles, high velocities, and by moving grain long distances.
If malting barley is harvested at moisture levels above 13%, it must be dried before being stored. Natural air/low temperature drying is generally preferred as high temperatures can cause cracking and reduced germination and test weight of grain. Air movement to remove heat from stored grain is a good practice.

## *2.3. Maize (Corn)*

Corn seeds, growing under the right conditions, will eventually grow into small factories with the ability to produce ample amounts of food. Understanding the conditions under which a seed may properly germinate, develop into a plant, and produce grain should help us prepare and manage the crop to achieve expected yields.

The yield of a corn plant depends on the genetic potential of a given hybrid, in addition to a number of environmental conditions and in-season management. Although there is little a corn grower can do about mother nature and the genetics of a plant (other than selecting the hybrid best adapted to a given location, and properly supplementing the site’s inherent fertility and availability of water), in many instances yield losses may be due to poor planning and management, factors that are under the control of a grower.

The seed is obviously the starting point. It consists of three major parts: the pericarp, the endosperm and the embryo. The pericarp is the outer part of the seed, and is made up of several cell layers, which act as barriers to diseases and moisture loss. The endosperm is the seed’s food storage compartment, which contains starches, minerals, proteins and other compounds. The embryo is in reality a miniature plant consisting of several parts: the plumule (leaves) at one end, the radicle (roots) at the other end, and the sculletum which absorbs nutrients stored in the endosperm.
When a seed is placed in moist soil, it absorbs water which in turn dissolves the nutrients stored in the endosperm. These nutrients are then absorbed by the embryo through the sculletum. The radicle will emerge from the seed and will eventually become the plant’s root system. Leaves (plumule) also start to grow at this time. Under Arkansas conditions it may take between 5 and 21 days for a seedling to emerge, with depth of planting, soil moisture and soil temperature all significantly affecting the time required for seedling emergence.
A system to identify crop growth stages was developed by researchers from Iowa State University. This system classifies growth stages into vegetative (V) and reproductive (R) stages, with each stage designated numerically as V1, V2, V3 and so on. Each number represents the uppermost leaf with a visible collar, with

the leaf collar being a visible light-colored narrow band at the base of the leaf (Figure 10). The last vegetative stage is named VT, to denote tasseling. The last branch of the tassel is visible at this time, while the silks are not.
This classification system allows for a relatively easy way to identify growth stages when plants are young but, as they grow, it requires more detailed examination since plants will eventually slough off their first three to four leaves. Also, early-maturing hybrids may develop fewer leaves or progress through different stages at a faster rate than late-maturing hybrids. Consideration should also be given to the fact that plants in a given field may show different growth stages; for that reason a stage should be assigned only when 50 percent or more of the plants are in or beyond that stage.

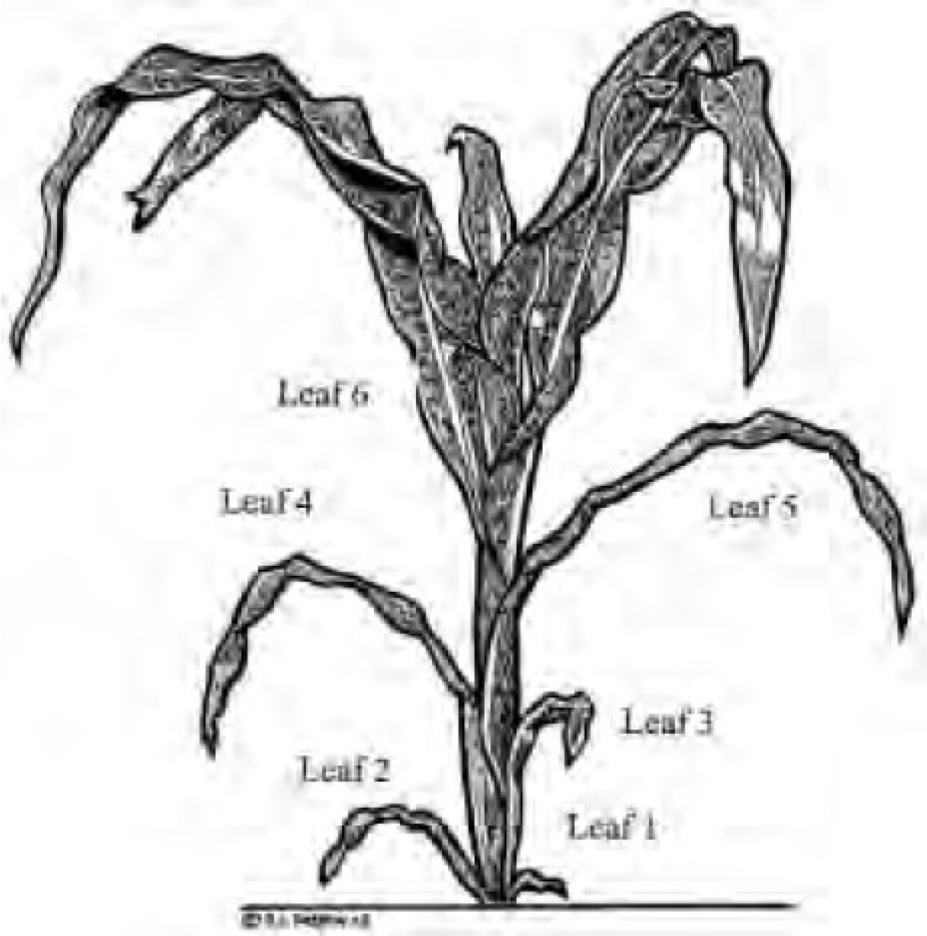



Figure 10: **Corn plant at the V5 growth stage.**
**Leaf collar of 6th leaf is not visible.**

As stated before, it may take 4 to 5 days for a seedling to emerge if conditions are appropriate, but up to 21 days if they are not favorable. The radicle is the first part of the seed to begin elongation, with VE (emergence) observed when the growing coleoptile reaches the soil surface. The nodal root system is established around VE and eventually becomes the supplier for water and nutrients.
During the next two to three weeks following seedling emergence the plant is fairly resistant to hail and other stresses, since the growing point is still below ground.
By the V3 stage, although still very young, the plant has already finished deciding how many leaves and ear shoots is going to produce.

By the time the plant reaches the V6 stage (plants are normally “knee high”), the growing point and tassel are above the ground and the plant becomes much more susceptible to stresses. At the V6 to V8 stage, the plant will experience a rapid rate of growth, with proper and sufficient fertilization and irrigation, which are critical at these stages. The number of rows per ear is established around this time, and the lowest two leaves are no longer present.
The tassel develops rapidly (inside the stalk) and the stalk continues elongating during the V9 to V10 stages. Soil nutrients and water are in greater demand at this time, and upon dissecting a corn plant at the V9 stage, ear shoots become visible.
The period between V12 and V17 is particularly important since the number of ovules (kernels) per ear and the size of the ear are being determined.
Moisture and nutrient deficiencies during this time may result in unfilled kernels and light ears. The tip of the tassel as well as the tip of the ears may be visible by the time the plant reaches the V17 stage, and silks have started to appear at this time. Stress during the V18 stage will delay silking until after the pollen sheds, with ovules that silk after completion of pollen shed not filling and consequently not contributing to final grain yield.
Tasseling (VT), the last vegetative stage, begins a few days before silk emergence. At this time the plant has reached full height, with pollen shed occurring primarily during late mornings. Silks that have not emerged by this time will not be pollinated, and consequently will not be developed.

The reproductive stages (R) relate to the development of the kernels, with the R1 stage being characterized by the silks being visible outside the husks. It is defined when even a single silk strand is visible from the tip of the husk. Every potential ovule (kernel) on an ear develops its own silk, with environmental stresses and especially the lack of water resulting in poor pollination and in some cases a bald ear tip. Pollination occurs when the pollen grains are captured by moist silks, with this process moving progressively from kernels near the base of the ear to the tip ear kernels. Kernels reach the R2 (blister) stage about two weeks after silking; at this time they physically resemble tiny blisters.

Starch has begun to accumulate in the endosperm, with moisture being around 85 percent. The milk stage (R3) is generally observed a week after blister. Fluid inside the kernels is milky white due to the accumulation of starch, and the silks turn brown and dry. The milk line can easily be seen by breaking a cob in half. Starch continues accumulating in the endosperm at the R4 (dough) stage. The milky fluid thickens and attains a doughy consistency, with moisture content being around 70 percent. The R5 (dent) stage is normally reached a week after the R4 stage, and is recognized by the appearance of the starch layer. This layer appears as a line across the kernel that separates the liquid (milky) and solid (starchy) areas of the kernels. As the kernel matures, this line progressively moves toward the cob. Kernel moisture has decreased to 55 percent, and any stress at this stage will affect kernel weight only, since kernel number has already been decided.

Kernels reach physiological maturity (R6) two to three weeks after R5 (dent), and no further increases in dry weight will be observed. The starch layer has reached the cob, and a black layer is formed. Black layer formation occurs gradually, with kernels near the tip of the ear developing this layer earlier than kernels near the base of the ear. Grain moisture at this time ranges between 25 and 35 percent.

It is obvious now that being able to identify the growth stage of a particular field can help in making replanting decisions, and in scheduling fertilization, irrigation, pest management and harvesting operations in a timely fashion to achieve maximum yields.

**Land selection**
Corn performs best on deep, well-drained, medium to coarse textured soils, but producers have successfully produced corn on a wide range of soil types. High rainfall amounts are common in the spring and early summer when the root system of corn is developing. Perhaps the most important consideration for land selection is drainage. Corn production will be limited if drainage is inadequate. No-tillage can be a high-yield method of planting corn if the land is well-drained. Drainage should be corrected or improved prior to planting to increase corn yield potential. In most years, drainage and timely irrigation are the primary factors determining the yield potential of well-managed corn in Arkansas.

**Seedbed preparation**
Preparing raised beds and planting into a freshly-tilled seedbed is currently the most common practice in Arkansas, but planting “flat” is practiced. Planting no-till into beds from the previous crop may be cost-effective. Most farmers are satisfied with beds that are formed from fall to early in the spring, where rainfall has settled and “firmed” the bed.
The advantages of planting on a bed versus flat include:

- beds normally warm more quickly in the early spring, thus allowing for earlier planting;
- beds provide drainage following heavy rainfall; and
- in a dry spring, the top of the bed can be knocked down in order to plant into moisture.

Planting no-till corn can be successful if the seedbed is not rutted from the previous harvest operation or washed out from heavy rainfall. A burndown herbicide to kill existing weeds is necessary, but little else is required to get a stand. Timing may be more vital with no-tillage; otherwise, the management of no-tillage varies little from conventional planting. Shredding stalks or a light disking complicate no-tillage planting. An undisturbed seedbed provides a firm surface for cutting through residue and obtaining a more uniform seeding depth.

Subsoiling compacted soils is needed to raise corn yield potential. Where shallow hardpans exist, a ripper-hipper, may penetrate through the root- and moisture-restricting layer. A high-residue ripperhipper can be used to subsoil under the future row as the beds are formed in the fall. The ripper-hipper has a heavy draft, high horsepower requirement. A good approach is to use a 4- or 6-row ripper-hipper and examine several field locations to assure that the shanks are penetrating the hard soil layer. To be compatible with the number of rows on his planter and combine header, a grower follows by bedding on these rows again with an 8- or l2-row bedder. Several GPS-guided controls (for example, the John Deere AutoTrac™ assisted steering system) may provide a sufficiently accurate row spacing to make a second bedding pass unnecessary.

Some growers use high-residue subsoilers in the fall at an angle to the anticipated rows to eliminate deeper compaction. The advantages of a highresidue subsoiler is that preparatory tillage after the last season's crop is unnecessary because coulters cut the residue, and less tillage is required to prepare the beds after subsoiling.

**Planting precision**

Uneven plant spacing and emergence may reduce corn yield potential. Seed should be spaced as uniformly as possible within the row to ensure maximum yields, regardless of plant population and planting date.

Vacuum seed selection planters typically achieve the most uniform plant densities followed by plateless or finger pickup seed selection. With all other factors equal, maximum yields occur when corn is placed uniformly deep into the soil with uniform spacing between seeds. Producers should follow the manufacturer's recommended planting speeds.

**Planting date**

Corn growth and development responds primarily to temperature and is not controlled by day length. Thus, the calendar date is not as important as soil temperature and air temperature when considering when to plant corn. Good germination and emergence are expected when the soil temperature at a 2-inch depth is 55˚F by 9:00 a.m. for three consecutive days. This normally occurs in late March in south Arkansas and early April in north Arkansas. Frost may occur after these planting dates in some years, but corn typically withstands frost with little economic injury. Early frosts may remove a single emerged leaf, but a leaf will emerge from the seed. Severe frosts later in corn development can be destructive, but these conditions are very rare in Arkansas.

Seed should be planted 1.5-2 inches deep into moist soil. If moisture is deeper than 3 inches, it is advisable to wait until after a rain before planting. If center pivot irrigation is available, it may be used prior to planting to obtain the soil moisture desired.

**Seeding rate and plant populations**

The desired final plant population depends on the hybrid, whether the field is irrigated and reasonable yield expectations. The recommended plant populations range from 16,000 to 32,000 plants per acre. Recommended population for dryland production ranges from 16,000 to 24,000 plants per acre whereas irrigated corn has greater yield potential from 26,000 to 32,000 plants per acre. Most seed companies recommend a specific planting range for each hybrid. They suggest the lower end of the range if the field is not irrigated and the yield potential is less than 160 bushels per acre. Where higher yield potential exists and corn is well-irrigated, the higher end of the range is recommended. Most seeding densities are based on "ear flex."

Full ear flex hybrids can compensate for fewer plants per acre because the ear grows both in length and girth. These hybrids usually produce only one ear per stalk. Individual semi-flex hybrid ears will not compensate to the extent that full flex hybrids will, but with low stand density and excellent growing conditions they may set two or more ears. Few of the modern corn hybrids released today are “fixed” ear. Fixed ear hybrids must obtain the desired population for maximum yields.

To check planting rates, count the number of seed placed in 10 row feet. Tractor speed, seed size, and several other factors can affect the seeding rate. Furrow counts should be done several times during planting, especially where a planter is prone to bounce. Initially it is advisable that each row be checked, since row units may fail to plant at the same rate. If each row has a separate seed box, monitoring the fill levels will help to detect planter unit skips. However, a good seed monitor is highly recommended to detect seeding failures immediately.

**Hybrid selection**
Hybrid selection (Photo 3) is one of the important decisions a producer will make. Yield is an important factor but maturity, stay green, lodging, shuck cover, ear placement, disease and insect resistance play a role in hybrid selection. In Arkansas, 112 to 120 day maturity hybrids usually produce the highest yields.

Photo 3: **Demonstration of corn hybrids**

Most corn hybrids will grow taller as day length increases due to increased day and night temperatures. Rapid growth results in more space between nodes, thus ear placement can be substantially different within the same hybrid planted at different times.
Usually, the higher the ear placement, the greater the lodging potential. If possible, select late-planted hybrids that have lower ear placement. Biotechnology advances have resulted in corn hybrids that are resistant to insects due to toxins produced in the plant tissue. There are also some hybrids that are herbicide resistant. A few hybrids contain both of these traits and are referred to as “stacked” trait hybrids. Selecting hybrids and managing them to utilize genetic strengths are addressed in the weed and insect control sections.

**Drainage**
Adequate drainage is necessary for maximum corn production. It is highly recommended that corn be planted on raised rows or beds, especially on fields that are relatively flat. Corn is typically planted early when low temperatures and significant rainfall are likely. Raised rows or beds reduce the effect that cold, wet soil conditions have on planting and early crop development. Rolling fields that have significant slopes may not need raised rows or beds for drainage, but may still benefit from the beds warming up faster than flat seed beds. Poor drainage hampers field operations from field preparation through harvest and limits the effectiveness of irrigation. Eliminating poorly drained areas preserves natural soil productivity by reducing field rutting that requires additional tillage. Poorly drained areas reduce yields and often require the most tillage. Water infiltration is also reduced if soilis tilled when it is too wet. Good field drainage complements all crop production practices and makes it possible to consider reduced or no-till corn production. The goal for drainage is to have minimal standing water on a field 24 hours after a rainfall or irrigation.

**Irrigation**
Corn production in Arkansas is only recommended with irrigation. All five locations for the Arkansas Corn Hybrid Performance Tests are irrigated, even though there is still a small percentage (estimated 20% or less) of corn in Arkansas that is not irrigated. Reasonable corn yields may be obtained without irrigation in some years that have good rainfall patterns and growing conditions. However, if adequate rainfall does not occur, yields can be a disaster and the drought stress can contribute to charcoal rot and aflatoxin, which can result in crop failure. These potential risks are the basis for the strong recommendation to irrigate corn in Arkansas.

**Water needs**
The total amount of water that a corn crop needs during the growing season may vary from 20 to 30 inches depending on factors such as weather conditions, plant density, fertility, soil type and days to maturity. In most seasons, the amount of water needed will be about 20-24 inches. The inches of irrigation water required will vary depending on the beginning soil moisture and the rainfall received during the growing season. The irrigation system needs to be capable of providing 12 to 16 inches of irrigation water to assure a good yield potential.
Moisture stress anytime after planting can affect plant development and reduce yield potential. The amount of yield loss is dependent on the growth stage of the corn when moisture stress occurs.

**Soil**
Soil testing is the foundation of a sound fertility program, with the goal of a soil testing program being to provide guidelines for the efficient use of lime and fertilizers. University of Arkansas fertilizer and lime recommendations are based on field research conducted under varying soil conditions, crop rotations, crop nutrient requirements and yield goals.

**Nitrogen**
Nitrogen is an important component of amino acids and proteins, which are the basic building blocks of all living matter – both plant and animal. Nitrogen-deficient

plants normally show a pale-yellowish color (Chlorosis), which results from a shortage of Chlorophyll in the plant's "solar collection cells." A rough rule of thumb is that, based on the yield level, 1 to 1.5 pounds of actual nitrogen (N) are required for each bushel of corn produced. More N is normally required per bushel on the silty clays and clays than on the sandy loams and silt loam soils.
In Arkansas, this is due to the tendency of clay soils to fix ammonium ions between the clay particles in an unavailable form. If high carryover N is suspected, a soil nitrate-nitrogen test may be used to refine recommended N rates. For a reliable indication of N carryover, the grower should submit at least one subsoil sample along with a topsoil sample about a month ahead of planting. The topsoil and subsoil samples should each represent at least 12 inches of soil depth. Total soil profile N in excess of 40 pounds per acre should be subtracted from the preplant rate in order to achieve a particular yield goal.

Figure 11 shows a typical nutrient uptake pattern for a corn plant. No more than half of the total amount of the recommended N should be applied preplant, since the root system is not yet fully developed and salt damage to the young seedlings is a possibility. Also, in the event of poor stands, there remains the option of saving the fertilizer that would have been sidedressed. The remainder of the N should be sidedressed or topdressed after a stand is obtained but before the corn gets "knee high" (six leaves). At this point the corn plant will experience a period of rapid growth, the growing point is above the soil surface and the plant is "deciding" what type of yield load it can support. Thus, it is critical that the plant has an ample supply of nutrients, and water, at this time.

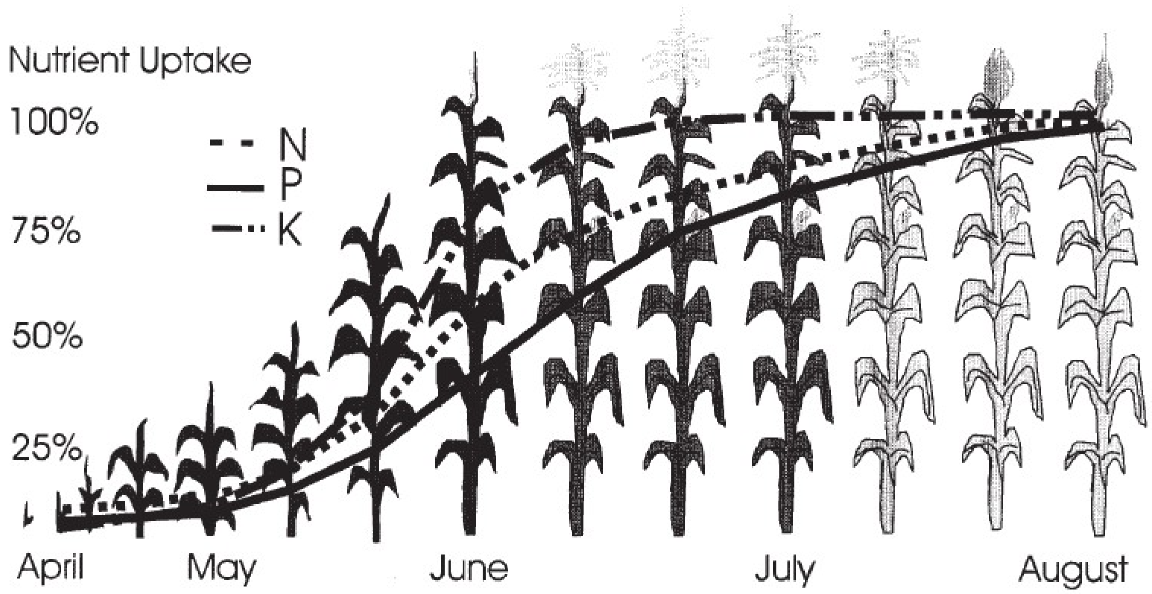



Figure 11: **Typical nutrient uptake pattern of a corn plant.**

Preliminary results of on-going research in Arkansas have shown the potential for significant yield increases when a portion of the fertilizer is applied just before the tassel emerges. Common N-fertilizer sources include ammonium, nitrate and urea. These are sold in dry or in liquid formulations (with urea ammonium nitrate having a N content of 28 to 32 percent, for example). Ammonium has a positive charge that is attracted to the negatively charged surface of clay and humus and, as a

result, is not as mobile as the nitrate ion. However, under alkaline conditions N, in the ammonia form, may be lost through volatilization.
Nitrate is the form used in the largest proportion by most plants. Nitrates are repelled by the negative charges of soil since nitrates possess a negative charge as well. Nitrate thus tends to remain in solution, subject to leaching and denitrification.

**Animal manures**
Animal manures and particularly poultry litter may be used as supplements to commercial fertilizers. Rates should be based on soil test results and the nutrient content of the manure, keeping in mind that only 50 to 60 percent of the nitrogen in manure becomes plant-available the first year, and that applying manure based solely on crop N requirements may supply P in excess of plant needs.
Where higher rates of animal manures are used, plant analysis should be used to monitor N needs in order to make possible adjustments during the growing season.

**Phosphate and potash**
Phosphates have been called the "key of life" because they play an important role in the storage and transfer of energy within plant cells. Phosphates react rapidly with soil constituents that reduce the availability of this nutrient to plant roots. Phosphates interact positively with nitrogen and potassium, while high soil phosphate levels may also reduce plant uptake of zinc and copper. In soils of pH 7.0 or higher, phosphorus also binds with calcium, forming insoluble compounds that are largely unavailable to plant roots. Starter fertilizers may be beneficial for high pH soils and/or with rice in the rotation, with a typical starter rate being 5 gallons per acre of 10-37-0 material.
Apply all recommended P and K at or before planting, along with at least 30 pounds of N per acre. Early planted corn, and corn under no-till, may exhibit phosphorus deficiency symptoms even on soils that have high levels of soil-test P. Where this occurs, as little as 15 pounds per acre of $P_2O_5$ sidedressed near the row has proved effective in overcoming these temporary P deficiency symptoms. However, a warming period will usually allow the corn to recover, and seldom are yields permanently reduced by the temporary phosphorus deficiency.

Phosphorus is recommended unless soil-test P is higher than 100 pounds per acre. Recommended rates range from 50 to 100 pounds of $P_2O_5$ per acre, depending on the soil test level, the soil type and the yield goal.

Potash also plays a critical role in the nutritional balance of a plant. Potash deficiency in corn results in reduced growth, delayed maturity, lodging caused by weak straw and low bushel weight, with visual symptoms including leaf burning. Potash is recommended at soil test levels below 275 pounds per acre. Recommended rates range from 50 to 200 pounds of $K_2O$ per acre, based on needs. Potash applications greater than 90 pounds per acre should be split to avoid salt injury.

**Calcium, magnesium and sulfur**
The secondary elements calcium, magnesium and sulfur are generally considered adequate in most soils. Calcium is generally adequate for corn as long as crop

lime needs (pH) are being met, but magnesium and/or sulfur deficiencies are possible on sandy soils low in organic matter. The University of Arkansas Soil Testing Laboratory routinely determines both magnesium and sulfate-sulfur.
A low level of available magnesium or sulfur in the topsoil is difficult to interpret unless a subsoil test is also obtained. Both elements tend to leach downward and accumulate with the subsoil clays.
However, medium to high soil-test levels of these elements in the topsoil should indicate adequate levels for the corn crop. A good rule of thumb is that soil-test sulfur levels below 20 pounds per acre and magnesium levels below 75 pounds per acre may be an indication of a deficiency. It is not uncommon for well waters to contain 1 to 2 pounds of magnesium and 2 to 6 pounds of sulfate-S per acre-inch. Secondary element needs are best assessed by foliar analysis of corn leaves during the growing season. When a soil test indicates very low levels of magnesium (generally on very sandy soils of low CEC), 20 to 40 pounds per acre of additional magnesium are needed.

Dolomitic lime is the most economical source of magnesium where lime is needed. Potassium magnesium sulfate, commercially known as K-Mag or Sul-Po-Mag, typically contains 23% potash, 23% sulfur and 11% magnesium. It has relatively high water solubility compared to dolomitic lime. There is also a granular 36% magnesium product that contains both magnesium sulfate and magnesium oxide.

**Corn harvesting**

A combine equipped for corn is the starting point for successful harvesting. In the midsouth, combine components vary, requiring you to confirm that your combine has proper options to obtain full capacity and efficient cleaning in corn. Plan to harvest the bulk of your corn between 15 and 18 percent moisture content, for an economical choice based on recent grain terminal moisture discounts and long-term Arkansas weather patterns.
Other considerations, such as scheduling rice harvest, are briefly noted in the section “Corn Harvest Moisture.” Fine tune the combine in the field. Have a bit more handling and drying capacity than shelling capacity to prevent field delays.

**Corn equipment**

A corn head and rasp-bar cylinder or rotor modifications are needed for corn. Check your combine before purchasing a corn head. New costs for conversion to corn vary from $25,000 to $50,000. The cost is lower if you already have some of the corn options and if good used equipment can be found. Due to differences between combine models, your dealer can help identify corn features appropriate for your combine. Certain models require a corn head drive and feed elevator. A variable speed header drive allows faster synchronized (with the stalk roll speed) forward speed. If your combine has a feed elevator compatible with corn, conversion cost is less.

**Corn head**

Row spacing should match the planter. Research indicates gathering loss can increase 2.5 bushels per acre if the gathering opening is 4 or 5 inches off the row. If damage from windstorms or corn borers causes ears in misaligned rows to drop off, field losses often exceed 10 bushels per acre. Corn heads aligned with combine wheels and matched with planters and row bedders improve combine performance.

**Estimating field loss**

Everyone wants to do an expert job of harvesting. One way to gain expertise is to check field losses and compare them to top growers. Field loss can be estimated quickly. Losses are determined by counting shelled corn and ears left in the field. Corn normally dries at the rate of 1/2 to 1 percent moisture content per day in the field. Approximately two weeks before harvest is a good time to begin measuring corn moisture and counting field ear loss.

Counting ears on the ground prior to harvest as well as behind the combine provides facts to optimize harvest profit. If loss is high, the kind of loss is a clue to making adjustments. Keeping losses low doesn't cost; it pays (Figure 12)!

**Procedure**

To count field loss, choose a representative field portion at least 100 yards from the end. Disconnect the straw spreader or straw chopper to aid in diagnosing the source of loss. Otherwise, kernels thrown into adjacent rows will add confusion about where the loss really occurred.

**Ear loss**

Ear loss is sampled in 436 square foot areas (1/100 acre) and kernel loss in 10 square foot areas. Sample the field ear loss first and then determine what portion occurred at the corn head.

Then measure preharvest ear loss. In fact, making early preharvest loss samples prior to entering the field with the combine helps to identify which field to harvest first and, possibly, when to start.

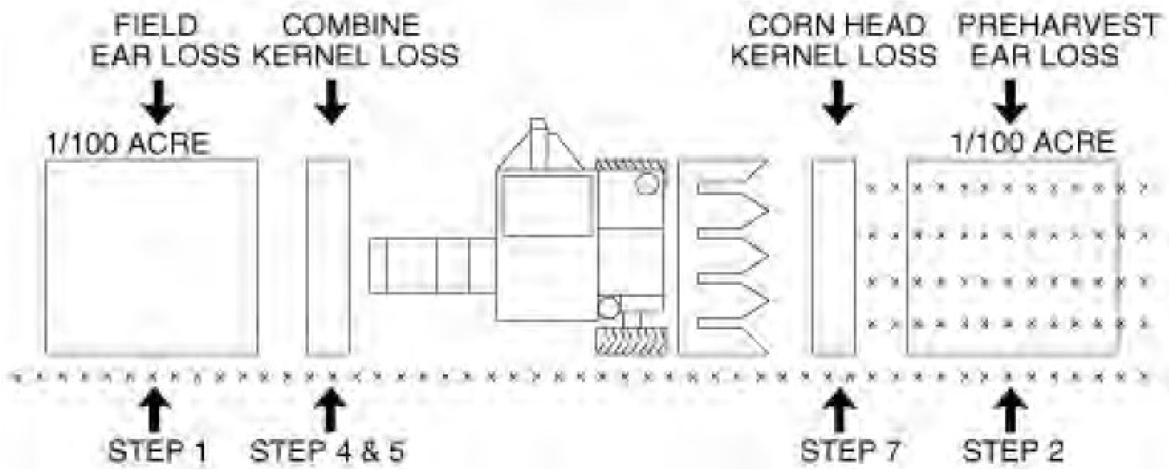



Figure 12: **Where to measure corn harvest losses.**

**On farm storage and drying**

A good deal of Arkansas corn will be dried and stored on the farm each year. Corn has the highest quality it will ever have at harvest. Grain has a limited storage life. The way that corn is handled during the drying and storage process will determine how much of this quality is retained. Proper management practices may also prolong the storage life of grain.

Corn should be quickly dried down to a moisture level of about 12 percent for storage – particularly if it is going to be stored for several months. Corn is typically dried to 15.5 percent when it is expected to be marketed right away. The reduction of grain moisture is done by passing relatively large quantities of dry air over the corn after it is placed in the bin. The quality of this air determines the final moisture content of the corn kernel. This “air quality” is typically referred to as the equilibrium moisture content (EMC). If the air has an EMC of 12 percent and is moved over the grain long enough, then the grain moisture will eventually reach 12 percent.
A given volume of air has the capability of holding a given amount of moisture. The amount of moisture that air can hold will depend on the quality.

One way to increase drying potential or cause the grain to reach equilibrium with the air sooner is to pass larger amounts of air over the grain. Doubling the air flow will typically cut the drying time in about half.
Pass or continuous flow dryers are often utilized to speed up the drying process. These high flow driers pass very large amounts of high temperature air over the corn. Three to six moisture points may be taken from the grain in a single pass. This helps to prepare grain for shipment if the desire is to market the grain quickly. Quickly drying the grain down to values of 16 percent or less will lessen potential spread of toxins if that is a concern. In-bin drying is more gradual and may cause less stress and potential damage on the kernels.
As grain bins are filled and the grain depth increases, it becomes more difficult to pass air up through the grain. As the grain depth increases, there is also less air available for each bushel of grain in the bin. High volumes of air are needed to carry the moisture away in a timely fashion when the grain is at high moisture levels. Most on-farm bins have a limited amount of available air capacity.
These criteria dictate that bins should not initially be filled too full if the grain is at a high moisture content.
Once grain moistures reach 15 percent or less throughout the bin, the bin filling process may be completed.
In most on-the-farm storage, the grain is subjected to modest temperatures for long periods of time. There must always be sufficient air flow to cool the upper portions of the bin to eliminate the possibility of mold development in that area. The top layers are the last segment of the bin to reach a safe moisture level.
Grain may be dried without adding any heat if the EMC is low enough. Careful monitoring of the EMC and managing drying times to optimize low values will provide the most economical drying. Many times Mother Nature simply will not provide dry enough air, particularly at night, and the addition of heat is needed to condition the air to the correct EMC.

**Estimating production costs for corn in Arkansas**

Enterprise budgets represent a type of information that can be used by a wide variety of individuals in making decisions in the agricultural industry. They are used:

- by farmers for planning,
- by Extension personnel in providing educational programs to farmers,
- by lenders as a basis for credit,
- to provide basic data for research and
- to inform non-farmers of the costs incurred by farmers in the production of food and fiber crops.

The purpose of these publications is to provide a systematic procedure for estimating the cost of producing corn.

However, since these estimates are intended to be a planning guide, drying costs are included which allows the user the opportunity to make adjustments.

Each budget estimates the direct and fixed expenses associated with producing corn. Input price data used in estimating direct costs are updated annually by obtaining prices from farm input suppliers throughout the crop's production area.

Fixed expenses include depreciation, interest, taxes and insurance and represent an average cost allocated over the entire useful life of the machinery. Various financing arrangements and tax depreciation methods can produce costs that vary significantly from these estimates in a given year.

The ability to estimate the actual cost is a complex economic procedure whereby cash accounting and economic costs may vary greatly.

Each budget also includes a sequential listing of all operations used in the estimation procedure. This information can be used to determine the cost of a specific tillage operation, pesticide application or irrigation practice. The user can also compare the number of tillage operations or irrigations with their own expectations.

## Questions for self-evaluation

1. What kinds of factors have influence on wheat yield?
2. What are the uses of the barley?
3. Why is the level of N fertilazition of the barley so important?
4. List the main development phases of the corn plant!
5. What kind of losses might occur at corn harvesting?

# 3. MANAGEMENT OF PLANTS FOR INDUSTRIAL USE

## *3.1. Sunflower*

Sunflower is a crop (Photo 4) which, compared to other crops, performs well under drought conditions; this is probably the main reason for the crop's popularity in the marginal areas of South Africa. Unfortunately, the crop is particularly sensitive to high soil temperatures during emergence and it is especially in the sandy soil of the Western Free State and the North West Province where this problem often leads to poor or erratic plant density.
In large parts of the sunflower producing areas, the soil has acidified dramatically during the last decade. Consequently, molybdenum shortages often occur and are possibly one of the greatest yield-limiting factors. The crop is very susceptible to bird damage and for this reason, it cannot be cultivated at all in some areas. On the positive side, however, the drought tolerance and low input cost of the crop are major advantages. The short growth season of the crop, which has the consequence that it can be planted over a period of at least three months, renders it extremely suitable for producers who make use of adaptable crop rotation and/or fallow systems. In any case, sunflower is a crop which only belongs in a crop rotation system.

Photo 4: Sunflower at blooming

**Soil requirements**
Sunflower adapts relatively well to a wide variety of soil types. Traditionally, sunflower cultivation has been limited to soils where the clay percentage varies between 15 and 55 %, In other words sandy loam to clay soil types. At present, the major planting areas are in soils with a clay percentage of less than 20 %.

In South Africa, a shortage of water is the main factor limiting crop production. It is important that the available water is used to the best advantage. Especially in the more arid western areas, it is essential that as much water as possible be stored in the soil profile before planting, to limit the chance of failure.
The sunflower plant has a deep and finely branched tap-root system which can utilize water from deep soil layers, even deeper than 2 m. Consequently, the crop often performs well even during a dry season, especially in deeper soils or in soils with a water-table. Because of its unique water-use pattern and root system the shallow soils which are found mainly in the eastern areas, such as shallow Westleigh, Estcourt, Kroonstad and other duplex soils, are suitable for the cultivation of sunflower as well. Sunflower is capable of utilizing water from the clay horizons of these soils. The potential for high yields on these soils is, however, limited.
The following characteristics of soils will limit successful sunflower production and should be avoided:

- Sunflower is very sensitive to wind damage in the seedling stage and for this reason, cultivation on light-textured soils susceptible to wind erosion, should be avoided unless wind erosion is being combated successfully.
- Sunflower is very sensitive to water-logging.
- Sunflower is very sensitive to high aluminium levels and should not be planted in soils with a pH lower than 4.6 (KCl).

**Yield potential**
From a management point of view, it is essential to make a reliable assessment of the yield potential, with effective planning in mind. Plant density, cultivar and especially the fertilisation programme cannot be planned unless yield potential has been accurately determined.

**Choice of cultivars**
Choice of cultivar is an important facet in the production process and its effect is often underrated. Choosing the right cultivars is one way of ensuring higher profits at no extra cost. Sunflower is not very subject to diseases and from a production point of view, disease resistance and quality do not play a major role yet. For this reason, yield and yield reliability are by far the most important criteria when cultivars are evaluated. The yield reliability of a cultivar at a certain yield potential is the minimum yield which will be achieved by that cultivar in nine out of ten cases. Yield reliability therefore takes the yield disposition, average yield and the riskiness of a cultivar into account, It is a very reliable criterion which can be used for cultivar recommendations.

**Soil cultivation**
Production stability can be enhanced by the application of cultivation practices which limit moisture stress as far as possible. The point of departure in soil preparation should be to utilise rainfall and soil moisture to a maximum, Soil preparation should be focused on decreasing runoff losses, especially in the case of soils with a low infiltration rate. These losses can be limited to a great extent by applying the correct soil cultivation practices.

Primary cultivations, such as ploughing with a mouldboard plough or chisel plough, are suitable. The aim of the cultivation is to break up limiting layers, destroy weeds, provide a suitable seedbed and to break the soil surface at the same time to ensure maximum rainfall infiltration as well as to prevent wind and water erosion.

Sunflower is usually cultivated in rotation with maize or sorghum and benefits from the dense mulches of these crops. Mulches protect the soil against the impact of raindrops, which seals the surface and reduces the infiltration rate but may enhance some other pests. Soil compaction can be a serious problem, especially in sandy soils. If the compaction is not broken, the crop cannot utilise the full water capacity of the soil profile, because roots cannot penetrate the compacted layer. The root development of the previous crop should be examined through profile pits. In dry years, the root development of the sunflower plant will be seriously hampered where compaction exits.

**Planting date**
Normally sunflower can be planted from the beginning of November until the end of December in the eastern areas and until mid-January in the western areas, when choosing the best planting date, a number of factors should be taken into consideration. These include the onset and lost dates of frost, the soil temperature, moisture requirements of the crop, rainfall pattern, other crops being cultivated and the risk of bird damage.
High soil temperatures during planting time lead to poor emergence. In the warmer western areas with sandy soils, this is a major factor, which often leads to a poor stand. At Viljoenskoorn in the northwestern Free State, soil temperatures as high as 45 °C have been measured in a sandy soil at plant depth during December. In these parts planting should rather be done before mid-November when soil temperatures are not as high yet or when a period of two to three days' cooler weather is expected.

**Row width**
The influence of row width on sunflower yield is quite small. Row widths of 90 to 100 cm are mostly used, but wider rows can also be used. Where other crops such as maize are planted in rows of 1.5 m or even 2.1 m, sunflower can also be planted successfully in these row widths, in order to fit farm implements. Wide row spacing is only suitable for yield potentials lower than 1500 kg/ha.

**Plant density**
A correct and uniform plant density with sunflower is the basis of a good yield. Although the plant is able to compensate by head size and number of seeds per head, a very low plant density (eg. less than 20,000 plants/ha) often limits yield. At a low plant density, heads are forming which are too large, dry out unevenly and eventually impair the harvesting process. Large heads also have serious seed setting problems, For instance, a sunflower head of 30 cm produced only 19 g of seed (20 % seed setting), compared to the 54 g of seed of a 16 cm head (80 % seed setting). High densities of 55,000 plants/ha and more cause a higher occurrence of lodging, which should be avoided. Plant densities higher than 30 000 plants/ha should be avoided at yield potentials below 1200 kg/ha as the high rate of water use often causes water stress, leading to poor yield or even crop failure.

It is essential that sunflower be spaced evenly. The accuracy of the planter determines whether an even plant density will be achieved.

**Planting depth and planting techniques**

Sunflower seeds are planted at relatively shallow depths. In soil with a high clay content, seeds are planted at a depth of 25 mm. In sandy soils, seeds can be planted at a depth of up to 50 mm. For the planting process, the importance of a good planter cannot be over-emphasised. To plant sunflower, a planter should be able to space seeds evenly, it should have a good depth control mechanism and should be equipped with press wheels. Good contact between the seed and the soil is essential. For this purpose, the use of press wheels is necessary. During germination, however, sunflower plants are particularly sensitive to compacted soil, which means that press wheels should only exercise light pressure on the soil to avoid compaction.

**Fertilisation**

Compared to grain crops, sunflower utilises soil nutrients exceptionally well. The main reason for this is the finely branched and extensive root system. The roots come into contact with nutrients which cannot be utilised by other crops.

**Macro nutrients**

Sunflower normally reacts well to nitrogen and phosphorus fertilisation where there is a shortage of these elements in the soil. It is therefore essential that any fertilisation programme for sunflower should be based on soil analyses. Soil analyses will not only lead to more appropriate fertilisation levels, but can also significantly limit unnecessary fertilisation costs.

**Nitrogen**

When there is a shortage, growth rate decreases dramatically, leaves turn to pale green and the lower leaves die off.

**Phosphorus**

A shortage of phosphorus is characterised by retarded growth. In serious cases, necrosis can be detected on the tips of the lower leaves. Factors which should be taken into account when planning a phosphorus fertilisation programme, are the following:

- Attempts should be made to build up the phosphorus content of the soil over time.
- The optimum soil phosphorus level for sunflower is about10 mg/kg.

This means that phosphorus fertilisation is essential when the level of phosphorus in the soil is below 10 mg/kg. However at a higher level the crop will probably not respond to phosphorus fertilisation.

**Potassium**

Although sunflower draws large quantities of potassium from the soil, potassium fertilisation is usually unnecessary as South African soils generally have adequate quantities of this nutrient.

**Molybdenum and boron**
Shortages of boron and molybdenum often limit the growth and yield of sunflower in the eastern parts of the country. To avoid problems concerning these two elements care should be taken to apply fertiliser containing boron and to ensure that seeds are treated with molybdenum. Local seed companies usually treat their seed with molybdenum.
If no soil analysis is available 50 to 100 kg/ha of a 3:2:1 (25) fertiliser mixture applied at planting is adequate for a yield potential of 1000 to 1500 kg/ha.

**Weed control**
Efficient weed control is a prerequisite for high sunflower yields. It is achieved by a combination of mechanical and chemical practices.
Young plants are very sensitive to strong weed competition and cannot develop fast enough to form a full shade covering which can suppress weed seedlings. Therefore, the first six weeks after planting are a critical period for the mechanical weed control.
Mechanical weed control can be very effective provided it is done in time and with care not to damage the crop. Chemical weed control can be applied successfully together with mechanical methods and cultivation practices to bring about better weed control. The following tips are given for mechanical control:

- Cultivate before the sunflower is too high for equipment, otherwise the plants will be damaged easily.
- To prevent damaging the sunflower roots, cultivation should be shallow (less than 75 mm).
- Throw loose soil onto the row-this will help to suffocate weeds which sprout in the row.
- Smaller weeds die off easily when dry soil is hoed.
- Hoe during the hottest part of day when the sunflower is wilted - this reduces stem breakage.

**Chemical weed control**
The use of herbicides has many advantages, of which the most important is that effective weed control can be applied during wet periods when mechanical weed control is impossible. If sunflower is cultivated in crop rotation with maize, weeds can be controlled more effectively in both crops as grass and broadleaf herbicides can be used to succeed each other continuously.

**Insects and diseases**
Although a number of insects and diseases may attack sunflower, it is often not serious enough to have a negative effect on yield. Soil insects such as cutworms, dusty surface beetle and ground weevils may cause damage to emerging seedlings.

**Crop rotation**
Sunflower should be grown in rotation with other crops as:

- The risk of diseases and weeds increase with monocropping.
- A yield and quality advantage is often measured in a follow-up maize or sorghum crop.
- Weed and pest problems lessen with crop rotation.

However, take note that some herbicides do have a long residual period and may damage the follow-up crop in a rotation system. It is therefore important to strictly follow instructions on herbicide labels.

**Harvesting**
Harvesting should commence as soon as 80 % of the sunflower heads are brown in order to minimize losses caused by birds, lodging and shattering.

**Development stages**
The development stages and associated crop management inputs of sunflower are shown in Figure 13.

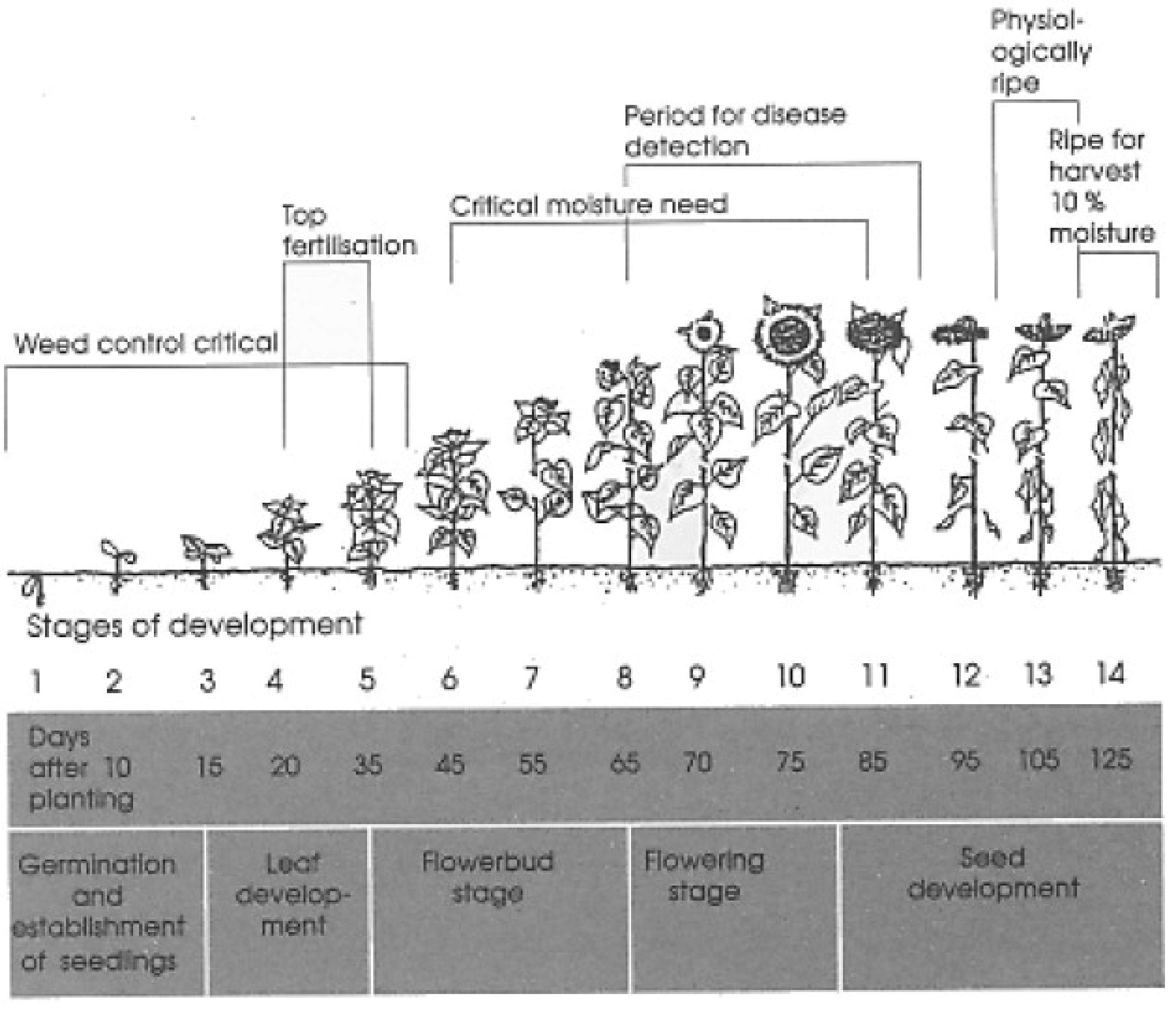



Figure 13: **A schematic representation of sunflower's stages of development**

**Marketing**
Sunflower seed producers have two marketing options:

- cash sales and
- contracts.

The former is primarily used for on the spot market sales or to elevators. The latter includes mainly forward cash contracts that have a number of requirements from the producers but also provide safety nets. In Kentucky, most sunflowers are sold to the birdseed market, either to local retailers or birdseed packagers.

**Market outlook**
The primary demand for sunflower seed comes from three markets:

- birdseed,
- snack and baking products, and
- oil and livestock meal. In the U.S.

25 percent of sunflower production is directed to birdseed, 10 to 20 percent to snack and baking products, and the remaining to oil and livestock meal products. Increased world competition in conjunction with the end of support programs has led to a decline in U.S. sunflower seed exports. However, exports of confectionary sunflower seed remain steady primarily due to the higher quality and desirable properties of U.S. produce. Moreover, the increased demand has led to higher prices. National price outlook is about 28 to 30 cents per pound.

**Economic considerations**
Initial investments include land preparation and purchase of seed. Kentucky sunflowers will generally not have worthwhile returns above operating and ownership costs (returns to land and management). Currently, this crop will not generate positive returns to land, overhead labor, and management in Kentucky due to the distance of transporting sunflower to market. The nearest known markets are located in Ohio and Missouri. With closer birdseed markets, returns could approach $50 to $100 above operating and ownership costs and may generate positive returns to land and management.

## *3.2. Rapeseed (Canola)*

Canola (*Brassica napus*) is a genetically altered and improved version of rapeseed that was developed for its superior edible oil and high value meal. The term “canola” can only be applied to those varieties that produce less than 2 percent erucic acid. Canola oil is lower in saturated fats than any other vegetable oil, making it a popular choice among health-conscious consumers. The portion of the seed left after the oil is extracted (canola meal) is of value as feed for livestock and poultry. Canola may also be used as an annual forage. In addition, canola is being considered as a source of biodiesel fuel (Figure 14).

**Marketing**
The nearest canola markets for producers in the Kentucky region are currently (2011) in Windsor, Ontario (ADM) and Courtland, Alabama (Farmers Cooperative). Regional producers incur a significant freight cost (as much as one-third of the price per pound) to ship canola there. However, with good weather and proper management, these freight costs might be covered. Canola can produce returns similar to wheat.

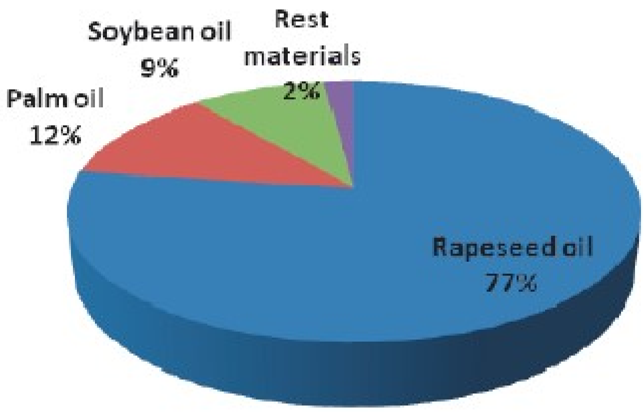



Figure 14: **Structureof input materialsused for biodiesel production int he EU**

Canola production has extended south from the Upper Plains since 2005. Producers in Oklahoma and Kansas, where canola can be substituted for wheat in crop rotations, grew about 60,000 acres of canola in 2006.
There is a very small niche for canola production for birdseed. While this market is more profitable for producers, it is already being captured by Missouri growers. However, Kentucky producers with the ability to store canola after harvest may be able to take advantage of other windows in this niche market.

**Market outlook**
The world-wide demand for canola oil continues to increase (Figure 15). Canola markets trend with other oilseed markets, and prices for oilseeds increased globally in the early 2010s. U.S. consumption of canola oil has steadily risen in recent years as its benefits have become more widely known. The food industry is also utilizing the oil in a growing number of food products. Domestic production of canola, however, is not keeping up with this increased demand. Because canola is well adapted to our climate and fits into our cropping systems, Kentucky seems well positioned to take advantage of these expanding production opportunities.

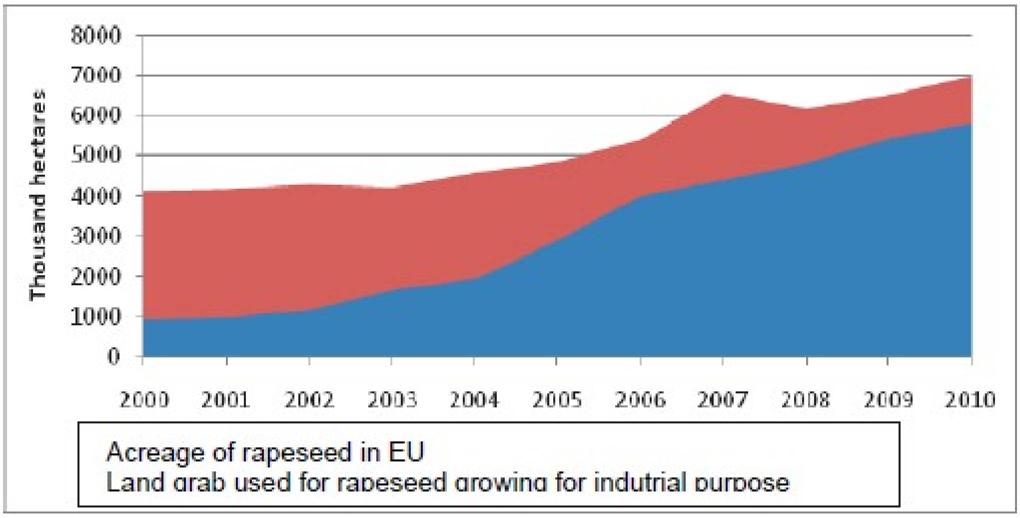



Figure 15: **Development of acreage of land used for rapeseed growing in the EU**

## Production considerations

*Cultivar selection*

Only winter-type canola varieties should be grown in Kentucky. Cultivars differ in days to maturity, seed yield, seed size, oil content, disease resistance/tolerance, lodging resistance, and several other agronomic characteristics. Choose varieties for high yield potential and winter hardiness. Growers should select only adapted varieties that have the qualities in demand for the intended market.

*Site selection and planting*

Canola is an annual that is grown as a fall-seeded winter crop in Kentucky. Production practices, including machinery and equipment, are similar to those used for winter wheat. A medium textured, well-drained soil is best for canola, although it will grow over a wide range of soil textures. Since canola does not tolerate waterlogged conditions, it should not be planted on fields prone to standing water, flooding, or poor drainage. Avoid fields where winter legumes, canola, and other Brassica crops have been grown for the past 2 to 3 years.

Canola should be planted in September in Kentucky, with planting dates of September 1 through September 25 providing the best yields. Seed can either be broadcast or drilled; however, drilling is the most reliable and preferred method. Although more difficult, the no-till method of seeding can be used with canola. Recommended seeding rates are 4 to 6 pounds per acre for drilling and 6½ to 8 pounds per acre for broadcast seeding. Plant seeds at a relatively shallow depth since they are very small. The ideal seeding depth is 1/2 inch in a firm, moist seedbed. Row spacing between 7 and 14 inches are acceptable for winter canola production.

Seedlings go dormant during the winter and although much of the leaf tissue freezes, the plant remains alive as long as the crown does not die. Growth resumes in late winter and early spring when temperatures increase. Plants produce bright yellow flowers (Photo 5), which later develop into pods containing 15 to 30 small round seeds. Bees are believed to aid in pollination and increase yields.

*Pest management*

Canola, as a member of the crucifer family, can support a very large and diverse group of insects. However, the insects of most concern are the striped flea beetle, aphids, and the cabbage seed pod weevil. Diseases that have greatest potential for causing serious losses include Sclerotinia stem rot, blackleg, and Alternaria black spot. Currently, few pesticides have a national label for use on canola.

Weed control strategies (whether mechanical, chemical, or a combination) should primarily be directed toward reducing weed competition during the first 4 to 8 weeks after seeding. Otherwise, canola seedlings, which tend to grow slowly, can be overcome by certain weed species. Wild radish can cause significant problems and will require aggressive control measures prior to planting canola.

Photo 5: Canola field

*Harvest and storage*
Canola ripens quickly, making timely harvest extremely critical for maximum yield. To determine when the crop is ready to harvest, the number of undesirable green seeds in the field, the moisture content of the canola seed, and the presence of dew or surface moisture on the plant must be monitored. In general, seed is harvested when most pods have turned tan in color and contain seeds that are black, with few to no green seeds. Harvesting too early will result in too many green seeds and a lower test weight, while late harvest can result in excessive shattering.
This crop can be harvested by swathing, if the proper equipment is available, or by direct combining. Canola stores well if it is kept dry, cool, and clean in weather-tight, rodent-proof structures. Because of the small seed size, precautions should be taken with equipment (harvesting, transporting, handling, and drying) and storage facilities to prevent seed loss.

*Labor requirements*
The labor needs of canola are virtually identical to those of wheat, with 3 hours per acre for production and 1/2 hour per acre for harvest.

**Economic considerations**
Initial investments include land preparation and purchase of seed. Canola production requires no new investment of equipment for a farm already producing small grains. Production costs (conventional tillage, drilled) are similar to wheat and may be estimated at $210 to $240 per acre, with harvest and marketing costs at $45 to $75 per acre. Total expenses per acre, including both variable and fixed, would come to approximately $285. Presuming a yield of 2,000 pounds per acre

and a market price of $0.21 per pound, returns to land, capital, and management would be approximately $175 per acre.

Oilseed and other commodity prices have experienced high degrees of variability in recent years. Expected yields and production costs for Kentucky indicate that growers will need to obtain a price of at least $14 per hundredweight (cwt) to economically justify canola production. Canola offers returns competitive with wheat and double cropping canola with soybeans is competitive with wheat/soybeans, corn, and full season soybeans. The price of canola is strongly affected by the price of soybeans, by prices of other competing vegetable oils, and by U.S. farm programs.

## *3.3. Soya bean (Soybean)*

Soybean varieties have a maximum yield potential that is genetically determined. This genetic yield potential is obtained only when environmental conditions are perfect, however such conditions rarely exist. The actual yield potential for soybean varies considerably according to environment and management decisions. The highest recorded soybean yield is 155 bu./acre.
After genetic yield potential, environmental conditions and agronomic decisions have the most influence on soybean growth, development and yield. The goal of every management decision should be to increase yield by providing optimum conditions during specific growth periods that impact yield.
Checkoff-funded research was conducted from 2004 through 2006 to determine the maximum yield potential of soybeans grown in Iowa. The research was designed to challenge our current recommendations on growing soybeans. The research was executed at three locations representing diverse environmental conditions and soil types.
The highest soybean yield was obtained in western Iowa near Whiting, where yields near 100 bu./acre were achieved every year. In eastern Iowa, 80 bu./acre was consistently achieved. However, in central Iowa, in the Des Moines Lobe soil region, 65 to 70 bu./acre seems to be the maximum yield potential with our current commercial varieties and agronomic practices. This research clearly showed that obtaining high yield is possible in Iowa but it is greatly dependent on environment, soil type, variety selection and agronomic decisions.

Soybean yield is determined much earlier than most people think; a good August rain is not enough to achieve high yields. To achieve maximum yield, row closure must be achieved by beginning pod set (R3) to maximize light interception during the critical pod and seed filling period. This is achieved by reducing stress from weeds, insects and pathogens and then planting early and in narrow rows. Early row closure is also critical to achieving higher yield because it reduces soil moisture loss. Understanding how a soybean plant develops throughout the growing season will provide insight into the selection of best management practices that lead to maximum yield. Simply putting more inputs into an inferior management system will not improve yield.

**Achieving high soybean yield**

There are no magic bullets, or "quick fixes" that can be applied to increase soybean yield. Producing high yielding soybeans is achieved through a combination of optimizing all manageable variables and making the right agronomic decisions to reduce stress. Seven steps (Figure 16) are needed to maximize your yield in Iowa no matter where your farm is located:

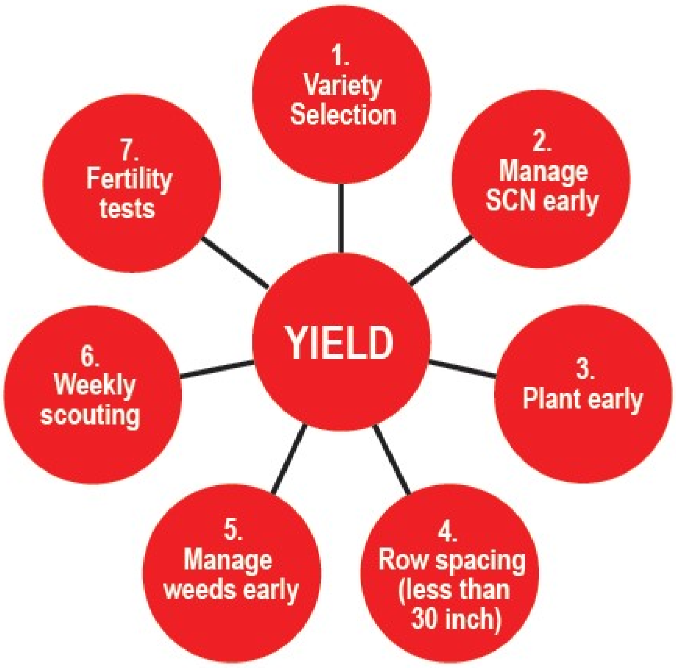



Figure 16: **High yielding soybeans has nothing to do with a "silver bullet." (It is a combination of many agronomic and cultural variables that are manageable)**

1. Variety selection is the most important decision a producer makes to achieve high soybean yield. Producers must select high-yielding varieties with agronomic traits that match the ever-changing stresses in each field. Today's monoculture production system of soybean/corn rotation has resulted in additional stress from diseases.
2. Soil test and manage soybean cyst nematodes (SCN). SCN appeared to be the greatest limiting factor of soybean yield in our research. The best management practice for fields with SCN is to rotate high-yielding SCN resistant varieties with a non-host crop such as corn. Soybean cyst nematode resistant varieties can also help minimize the impact of many pathogens such as sudden death syndrome, brown stem rot, iron deficiency chlorosis and *Pythium*.
3. Plant early. The optimum time to plant soybeans in Iowa is April 25 for the southern two thirds of the state and May 1 for the northern one third if the seedbed is satisfactory.
4. Plant soybeans in rows less than 30-inch rows. Soybean rows need to close quickly to improve light interception. Increased light interception is essential to promote rapid growth beginning at flowering.
5. Manage weeds early to promote early canopy development. Soybeans are sensitive to early-season competition from weeds, which reduce canopy

development. Use of a pre-emergence herbicide can minimize the risk of early-season weed competition.

6. Remove plant stresses from yield robbing insects. Weekly scouting is a must to help minimize the impact of any in-season stresses that can rob “easy bushels.” By scouting weekly, population densities of particular insects can be monitored carefully so they can be managed at economic thresholds using integrated pest management strategies. Bean leaf beetles and soybean aphids are insects that should be monitored frequently. Scouting can also be used to plan for next year’s crop since it is often much easier to see what the yield limiting factors are in the field during the growing season than just looking at the yield monitor.
7. Soil fertility tests should be conducted at least every other year to verify that appropriate fertility levels are maintained. The best time to sample soil is in the fall. Consider taking soil samples to assess SCN population densities at the same time.

Matching soybean varieties to a specific field is the foundation of maximizing soybean yields. Unfortunately, a soybean variety’s genetic yield potential is only achieved when environmental conditions are perfect and such conditions rarely exist. Agronomic decisions, however, have much greater impact on yield than most people think. The soybean crop has to be raised as a “biomass” generator without any stress and optimum light interception early in the growing season since lack of biomass and vegetative nodes prior to flowering hold down the yield potential. Understanding how a soybean plant develops through the season will provide insight into selection of management practices that should lead to maintaining the yield potential and revenues (Figure 17). Simply putting more inputs into a management system will not improve yield if the crop does not get the right start.

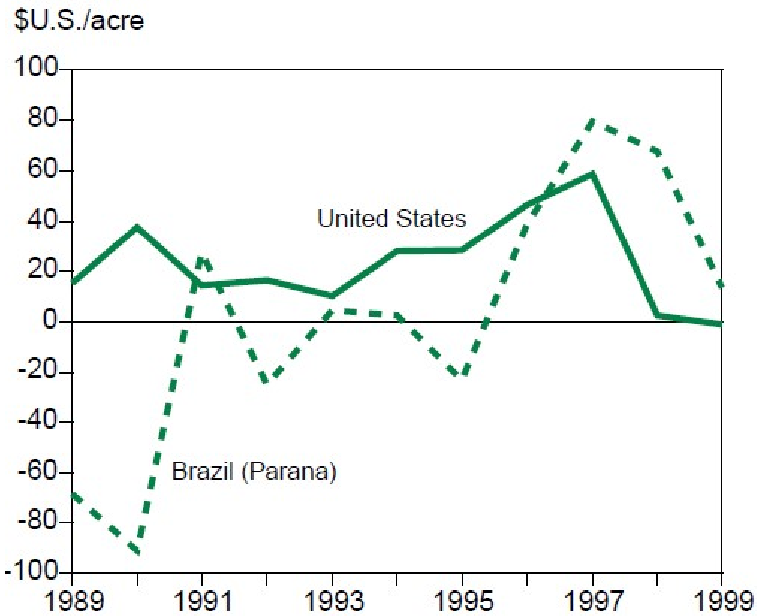



Figure 17: **Net farm revenues per acre of soybean production: United States and Brazil, 1989-99**

## 3.4. Peas

Field pea is a cool-season legume crop that is grown on over 25 million acres worldwide. Field pea or "dry pea" is marketed as a dry, shelled product for either human or livestock food. Field pea differs from fresh or succulent pea, which is marketed as a fresh or canned vegetable.
The major producing countries of field pea are Russia and China, followed by Canada, Europe, Australia and the United States. Europe, Australia, Canada and the United States raise over 4.5 million acres and are major exporters of peas. In 2002, there were approximately 300,000 acres of field peas grown in the United States.
Historically, field pea was primarily grown in the Palouse region of Washington and Idaho. In the 1990s, North Dakota, South Dakota, Montana and Minnesota began producing dry peas. In 1991, approximately 1,600 acres of dry peas were planted in North Dakota; in 2002 157,000 acres were planted. The majority (over 70 percent) of the dry pea produced in the United States is exported.

**Uses**
Field pea is primarily used for human consumption oras a livestock feed. Field pea is a grain legume commonly used throughout the world in human cereal grain diets. Field pea has high levels of amino acids, lysine and tryptophan, which are relatively low in cereal grains.
Field pea contains approximately 21-25% protein. Peas contain high levels of carbohydrates, are low in fiber and contain 86-87% total digestible nutrients, which makes them an excellent livestock feed. Field pea contains 5-20% less of the trypsin inhibitors than soybean. This allows it to be directly fed to livestock without having to go through the extrusion heating process. Field pea is often cracked or ground and added to cereal grain rations.

Research has shown that field pea is an excellent protein supplement in swine, cow, feeder calf, dairy and poultry rations. Field pea is often used in forage crop mixtures with small grain. Field pea forage is approximately 18-20% protein. Pea interseeded at 60 to 100 pounds per acre with a small grain such as oat can increase the protein concentration of the mixed forage by two to four percentage points and increase the relative feed value by 20 points over oat seeded alone.

Field pea also may be grown as a green manure or green fallow crop. With either option, soil and future crop productivity will be maintained or improved. Use of field pea for green fallow instead of black fallow protects the soil from erosion, improves soil quality, substitutes water loss by evaporation or leaching from black fallow with transpiration through plant growth and exploits rotational benefits. Costs of tillage and idled land in black fallow are substituted with costs of field pea establishment and termination (at early flowering) in green fallow. Field pea in a green fallow system yielded 3,425 pounds per acre of biomass and 103 pounds per acre of accumulated nitrogen in above-ground biomass at the Carrington Research Extension Center during 1990-1992. Spring wheat averaged 39 bushels per acre over a two-year period at Carrington when grown without additional N fertilizer following green fallow as field pea or following black fallow. This demonstrates that wheat following pea green fallow can be as productive as wheat grown on black fallow, plus the numerous rotational benefits of the legume can be utilized.

**Adaptation**

Field pea is an annual cool-season grain legume (pulse) crop. There are two main types of field pea. One type has normal leaves and vine lengths of three to six feet; the second type is the semi-leafless type that has modified leaflets reduced to tendrils, resulting in shorter vine lengths of two to four feet. Pea normally has a single stem but can branch from nodes below the first flower.

Most varieties of pea produce white to reddish-purple flowers, which are self-pollinated. Each flower will produce a pod containing four to nine seeds. Pea varieties either have indeterminate or determinate flowering habit.
Indeterminate flowering varieties will flower for long periods and ripening can be prolonged under cool, wet conditions. Indeterminate varieties are later in maturity ranging from 90 to 100 days. Determinate varieties will flower for a set period and ripen with earlier maturity of 80 to 90 days. Field pea is sensitive to heat stress at flowering, which can reduce pod and seed set.

Indeterminate varieties are more likely to compensate for periods of hot, dry weather and are more adapted to arid regions. Determinate, semi-leafless varieties that have good harvestability are more adapted to the wetter regions.

Pea roots can grow to a depth of three to four feet; however, over 75 percent of the root biomass is within two feet of the soil surface. A relatively shallow root system and high water use efficiency make field pea an excellent rotational crop with small grains, especially in arid areas where soil moisture conservation is critical.
Field pea is well adapted to cool, semi-arid climates. Field pea seed will germinate at a soil temperature of 40 degrees F. Emergence normally takes 10 to 14 days. Field pea has hypogeal emergence in which the cotyledons remain below the soil surface. Seedlings are tolerant to spring frosts in the low 20s and if injured by frost, a new shoot will emerge from below the soil surface.
Flowering usually begins 40 to 50 days after planting. Flowering is normally two to four weeks, depending on the flowering habit and weather during flowering. Field pea has shown to be well adapted to most regions of the Northern Great Plains. Field pea yields are similar to or exceed spring wheat on a pound or bushel basis within a specific region. A six-year average (1993-1998) of 'Profi' field pea yield on re-crop at the North Central Research Extension Center at Minot was 2,784 pounds per acre or 46 bushels per acre, compared to spring wheat on re-crop at 2,148 pounds per acre or 36 bushels per acre.

**Varieties, types and performance**

Selecting the appropriate field pea variety should be based on review of the many differences that exist among varieties. Factors to consider should include market class, yield potential, harvest ease, vine length, maturity, seed size and disease tolerance.
The first criterion for selecting a variety should be market class. The green and yellow cotyledon types are the primary classes. All field pea varieties may be

considered feed peas, but only selected varieties are acceptable for either the green or yellow human edible market.
After market type is determined, growers should review the field pea performance test information from trials conducted across the state with particular attention paid to those trials reflective of their farming area.
Crop harvestability is a very important factor in variety selection and is often noted by harvest ease scores in trial results. Most growers prefer a variety that will stand upright at harvest since it allows a faster harvest, minimal equipment modification and higher quality seed. The newer varieties that have shorter vines and are semi-leafless will be easier to harvest. It is important to review harvest ease data since varieties within this plant type differ greatly in standability.
Another factor to consider in variety selection is the producer's location. The indeterminate nature of the long-vined normal leaf type varieties may make them a preferred type in western North Dakota where moisture stress is more prevalent. Indeterminate varieties tend to express more stable seed yields when moisture and heat stress impact crop development. This type of variety will normally be heavily lodged at harvest and require special harvest procedures. Most growers will select among the semi-leafless varieties that are more determinate in development. Selection within these semi-leafless types should consider the impact of vine length. In areas with higher rainfall and cool summers, the shortest-vined varieties may be best, while in the drier regions, a grower should choose a semi-leafless type with longer vines. A wide selection of field pea varieties exists for producers across the region.

**Field selection**
Field pea can be grown on a wide range of soil types, from light sandy to heavy clay. Field pea has moisture requirements similar to those of cereal grains. However, peas have lower tolerance to saline and water-logged soil conditions than cereal grains. Peas most often will die after 24 to 48 hours in a water-logged condition. Poorly drained and saline soils should be avoided when growing peas.

Field peas are most often grown on re-crop following small grain. Being a legume, field pea will fix the majority of required nitrogen if the seed is properly inoculated. Residual nitrogen will also be present for the succeeding crop.
Fields that have a history of perennial weed problems such as quackgrass, Canada thistle, perennial sowthistle and field bindweed should be avoided. Check field records for prior use of herbicides with soil residual.

**Seeding**
Field pea can be grown in a no-till or conventional-till cropping system. Avoid excessive tillage in the spring to avoid drying out the seedbed. Pea seed requires considerably higher amounts of moisture for germination than cereal grains. Field peas are typically seeded in narrow row spacings of 6 to 12 inches. A conventional grain drill or air seeder that is capable of handling large seed without cracking is essential.
Field pea should be seeded early, April to mid-May, so flowering will occur during potentially cooler weather in June and early July. Seeding date studies conducted in North Dakota indicate that field pea yields decrease significantly when seeding is delayed beyond mid-May.

Seeding peas beyond mid-May will result in the crop beginning flowering in mid-July, which increases the risk of heat stress and disease problems, such as powdery mildew, reducing yields.
Maintaining firm seed-to-soil moisture contact is critical. Seeding pea well into moisture is critical and seeding peas into dry soil should be avoided. Seeding depth of one to three inches is recommended, with a rule of thumb that pea should be seeded at least a half inch into moisture and never seeded onto the interface where soil moisture meets dry soil.

**Seeding rate**
The seeding rate will depend on the size of the seed. Field pea varieties will range from 1,600 to 5,000 seeds per pound. A plant population of 300,000 plants per acre or seven to eight plants per square foot is recommended. Always select high-quality, disease-free seed. When seeding pea, always adjust for germination. Planting equipment should be calibrated or modified to allow for seed and inoculant to flow properly without cracking the seed or plugging the opener.

**Seed treatments**
Seed treatments are not commonly used with field pea; however, there are seed-borne and soil-borne diseases such as Fusarium, Rhizoctonia, Alternaria and Pythium that can cause significant stand reduction. Field pea is often seeded early into cool or cold soil conditions.
Preventing seed rot or seed decay with the use of fungicide seed treatments in pea is recommended when field pea is planted into cold soils and is seeded close in rotation with other broadleaf crops. Large-seed field pea varieties appear to be more susceptible to Pythium; therefore, seed treatments such as Apron or Allegiance that control Pythium should be considered.
It is very important to consult the seed treatment label for its effect on rhizobial inoculants. Most seed treatments have little or no effect on rhizobial inoculants and nodulation; however, there are seed treatments that are very toxic to all formulations of inoculants. Allowing the seed treatment to fully dry and adding inoculants just prior to planting is always recommended.

**Inoculation**
Field pea is a legume crop and has the inherent ability to obtain much of its nitrogen requirement from the atmosphere by forming a symbiotic relationship with Rhizobium bacteria in the soil.
Grain legumes vary widely in the proportion of the crop's total nitrogen requirement that may be met through nitrogen fixation. The total amount of nitrogen fixed by the crop also depends on favorable growing conditions. Hot temperatures and dry soils during the later vegetative and early reproductive stages are especially detrimental for N-fixation. Field peas are among the most highly efficient nitrogen fixing crops and may obtain as much as 80% of their total nitrogen requirement under good growing conditions. However, for this relationship to occur, the seed must be properly inoculated with the appropriate strain of Rhizobium bacteria. Producers must be certain that the inoculum product they obtain is specific for field pea.
Use of an inoculum labeled for soybean, clover or other legume will not allow the nitrogen fixation process to occur. Inoculants are available in various forms including dry peat, liquid and granular.

Application of inoculant to the seed is an extremely important procedure. Many failures with nitrogen fixation have been associated with improper application technique. Thorough coverage of the seed is critical since seeds not exposed to the bacteria will result in plants unable to fix nitrogen. Inoculants are living organisms, so proper storage and handling is important.
Granular inoculant, a relatively new form of inoculant, has alleviated many of the concerns with inoculant applications. This inoculant is metered through the planter and delivered directly into the seed furrow. Producers should refer to the manufacturer's package labels to review proper inoculum rate and handling procedure.
Growers should check their fields to determine if inoculation was successful. Normally, nodules will form on the roots two to four weeks after emergence. To check for nodulation, carefully dig up a number of plants and gently clear the soil from the root mass. Nodules will be present both on the primary root and on the lateral roots. Effective nodules will have a pink to red coloration on their interior. If nodulation does not occur and soil nitrogen levels are low, an application of nitrogen fertilizer over the top may be required to optimize seed yields. Nitrogen fixation will take place from about four weeks after emergence through seed formation.

**Fertilization**
Under most conditions, the use of inoculants will satisfy the nitrogen requirement of a field pea crop. A soil test should be conducted to determine the status of the primary nutrients.
Addition of a nitrogen fertilizer may be required when field pea is planted on land with less than 30 pounds of available nitrate N in the top two feet of the soil profile. Under these conditions, the addition of 20-30 pounds of nitrogen with commercial fertilizer is recommended to meet the needs of the developing field pea plant until nodulation becomes fully effective.
Producers should avoid planting field pea on fields that have a high level of nitrogen. Excess nitrogen will promote vegetative development over reproductive seed production. Higher nitrogen levels will also reduce the potential of nitrogen fixation and increase the potential for lodging. A rule of thumb is that 1.25 pounds of residual nitrogen per acre is available for every bushel of peas (field pea has a standard bushel weight of 60 pounds) produced per acre.

Beyond nitrogen nutrition, phosphorus fertilization is likely the primary concern for field pea growers. Research has indicated the importance of adequate phosphorus fertility for optimizing seed yield. Proper fertilizer source, rate and placement are necessary to avoid reductions in plant stand while at the same time meeting the P needs of the field pea plant. Avoid placing fertilizer directly with the seed. North Dakota research has indicated stand loss is likely while yields are not increased.

**Weed control**
Field pea is a poor competitor with weeds, especially during the first month after planting. Relatively slow early-season growth and lack of complete ground cover by the crop canopy allow weeds to be competitive. Field pea is most competitive with even, rapid emergence. A well-established stand of seven to eight plants per square foot is critical for field pea to be competitive with weeds.

Perennial weeds and annual weeds that emerge early in the season, including common lambsquarters, kochia, volunteer grain, wild mustard and wild oat, are very competitive with pea. For example, a Canadian trial indicated that two wild mustard plants per square foot reduced pea yield as much as 35%. Good weed control is also very important in raising high-quality human edible pea.
Weeds such as kochia, Russian thistle, nightshade and wild buckwheat can cause harvest problems with fields that are intended to be straight combined. Nightshade berries can stain the pea seed, causing a reduction in quality.
Cultural methods that should be used as part of an integrated weed management system include crop rotation, field selection, rapid crop establishment at an adequate density and use of clean seed. Pre-emergence or early post-emergence tillage with a rotary hoe or harrow can reduce populations of shallow-emerging weeds such as common lambsquarters, foxtail, kochia and pigweed.
Post-emergence tillage with a rotary hoe or light spring-tooth harrow needs to be timed to control emerging weeds on small (half- to two-inch tall) field pea. Pea stand reduction probably will occur with post-emergence tillage. There are several soil-applied and post-emergence herbicides labeled for weed control in field pea. Generally, post-emergence herbicides should be applied to small weeds and pea (two- to four-inch height) to maximize weed control and minimize crop injury. Pre-harvest desiccants also are labeled to dry weeds for a more efficient harvest.

**Diseases**
Controlling disease in field pea begins with crop rotation. A preferred crop rotation would have field pea planted with at least two cropping years between plantings.
Long-term crop rotational research in Canada indicates that a rotation of small grain/canola, or flax or lentil/small grain/field pea has been successful without any major buildup of disease.

**Insects**
There are a few insects that are of economic importance in field pea. Aphids that infest peas are small, about ½ inch long, and light green in color. Aphids do not overwinter in North Dakota and are often blown in from southern states in early summer. Populations usually increase as the summer progresses. Aphids usually don't reach economic importance in field pea. Aphids will pierce the plant tissue and suck plant juices, causing the plant to weaken, especially under drought stress. There are no threshold populations developed for aphids in field pea. Aphid populations are usually kept low by heavy rains or by beneficial insects such as lace wings or the lady bird beetle.
The lygus bug or "tarnished plant bug" has the potential of being the most serious insect pest in field pea. Lygus bugs feed preferentially on meristematic tissue or developing reproductive tissue. The effect of Lygus feeding is shriveled seed. "Chalk spot" is a damage consideration in field pea. Chalk spot is a chalky white spot which may appear on the cotyledons of some legumes. It is considered as damage mainly because it severely affects the appearance of the seed, lowering the grade and marketability.

**Harvest and storage**
Harvest management is especially important if field pea is to be marketed as human food (Photo 6) or as seed. Growers should have a goal of producing high-quality peas to receive a premium price for their crop in the human food or seed

markets. If quality problems exist, including bleached, split, cracked or earth-tagged (dirt attached to seed that cannot be removed) seed, the livestock feed market will likely be the only option. The following suggestions will help growers maintain a high-quality crop during harvest and storage.


Photo 6: **Harvester for green peas**

Field pea may be swathed before combining or straight (direct) combined. Peas are normally swathed to preserve quality if there is uneven crop maturity or heavy weed pressure present. If green-cotyledon pea harvest is delayed, bleaching may occur. Bleaching is caused by rainfall at maturity, high humidity, bright sunshine and warm temperatures. If green peas are swathed, timely harvest is essential, for green pea will be more susceptible to bleaching in the swath than if left standing.
When swathing peas, the seed needs to be at physiological maturity. At this stage of growth, the majority of pods should have turned from green to a yellow color. The crop matures from the bottom pods upward. Swathing will normally result in increased harvest losses, but swather modifications make the procedure easier and will reduce harvest loss. Vine-lifters enable producers to get under the pea vines and lift them over the cutting knife.
Many growers use a pickup reel as well. Peas should be swathed in the early morning or late afternoon when the pods are tough to reduce shattering losses. Combining should not be delayed after swathing, because pea swaths are susceptible to movement by wind.
Straight combining is possible, depending on pea cultivar and harvest equipment. Many short- to medium-vine and semi-leafless pea cultivars have characteristics that allow straight harvesting compared to cultivars with indeterminate and prostrate-vine growth. For example, semi-leafless pea have a more open canopy, remain erect longer and dry down more rapidly after a rain or heavy dew than indeterminate long-vine type.

The first choice for direct harvest of short- to medium-vine and semi-leafless pea varieties is a combine header with a floating cutter bar or flex head. Also, attachments such as lifter guards and pickup reels reduce losses and improve harvest efficiency. Direct harvesting of weakand prostrate-vine cultivars is most efficient with an aggressive pickup attachment and a lead coulter on a standard combine.

Field peas should be combined with seed moisture of 14 to 20% (Table 3). At this moisture range, the seeds are firm and no longer penetrable with a thumbnail.

Harvest should occur during humid conditions to minimize seed shatter. However, pea vines must be dry or harvest will be extremely slow and difficult. Seed that is too dry will be susceptible to seedcoat breakage or peeling.

Table 3: **Number of weeks for safe storage of peas at the specified grain moisture content and storage temperature**

| Storage Temp. (° C) | Moisture content (%) | | | | |
|---|---|---|---|---|---|
| | 12 | 14 | 16 | 18 | 21 |
| 26 | 31 | 16 | 7 | 4 | 2 |
| 20 | 55 | 28 | 13 | 7 | 4 |
| 16 | 100 | 50 | 20 | 12 | 6 |
| 10 | 200 | 95 | 38 | 20 | 21 |
| 6 | 370 | 175 | 70 | 39 | 20 |

Correct combine settings and operation are important to maintain seed quality. Reel speed should be slow to minimize seed shatter. Low cylinder speeds, normally 350 to 600 rpm, should be used to minimize seed cracking or splitting. Initial concave settings of 0.6 inch clearance at the front and 0.2 inch at the rear are suggested. Adjust combine settings as crop and weather conditions change.

Combine and portable augers should be operated at full capacity and low speeds to reduce pea seed damage.

Alternative seed handling equipment such as belt conveyors should be considered for handling seed intended for seed or the human food market. Minimize the number of times seed is handled. Also, don't handle peas during cold temperatures as potential for seed damage dramatically increases.

Green weed seeds or foreign material should be cleaned from the crop before storage to avoid spoilage and fewer market opportunities. Seed should be stored at 14 to 16% moisture. Seed that is marketed in the human edible market often requires moisture below 14%. Pea seed at 18% moisture can be stored for 20 weeks at 68°F, but only for four weeks at 77°F. An aeration system should be present in the storage facility. The recommended airflow volume for bins is about one to two cubic feet of air per bushel per minute. Warm seed should be immediately cooled after binning, even if seed moisture is low.

**Markets**

Primary field pea market opportunities are for livestock feed, seed and human food. Markets are readily available with minimal quality restrictions for peas sold as livestock feed. Prices received for feed peas should be considered base prices. Opportunities exist to enhance the value of feed peas by using the commodity as an on-farm livestock feed source.

*Feeding peas to livestock*

Premium prices are associated with the human food and seed markets. Selling peas in the premium markets is a greater challenge than marketing a traditional small grain crop. Premium pea markets are normally limited and require a more aggressive approach by the grower.

Pea markets should be identified before peas are produced to optimize the ability to harvest a crop that will meet market standards. For example, when marketing food-grade peas, numerous factors that affect market grade include market class (e.g. green or yellow cotyledon, specialty types), seed size and shape, splitting potential, harvest moisture, seed handling techniques during harvest and storage and seed damage factors (e.g. bleach, cracked seed coats, splits, shriveled seed, earth tag, chalk spot, etc.).

After harvest, the crop needs to be graded to determine what markets are options for the grower.

It is important to keep abreast of current markets by using sources such as written or electronic agricultural publications. Due to limited market opportunities for human food grade peas, make sure local, state or regional buyers are aware of the quality and quantity of crop you have available for sale. An additional market option for human food grade peas is the PL-480 program, a U.S. government program designed to distribute surplus commodities to aid developing nations.

## *3.5. Potato*

The potato is a cool season crop and in Oklahoma it is grown through the spring months and harvested in early summer. Fall potato production usually results in poor plant stands and low production, due to high soil temperatures at planting and during early crop development. Potatoes grow best in fertile, well-drained, sandy loam soils. Planting on poorly drained soils usually results in a poor plant stand, due to seed piece decay and poor quality potatoes at harvest. Soils which blow or have poor water holding capacity should be avoided. A good potato yield in Oklahoma is 200 to 250 cwt/acre. High temperatures or insufficient moisture in the late spring and early summer, while the potato tubers are forming reduces yield. Under good management and weather conditions, yields of 300 cwt/acre are possible.

**Varieties**

Select the potato variety (Table 4) (Photo 7) best suited to your conditions and market. Buyers contracting potato production for chipping will designate the variety to be grown.

Table 4: **Potato varieties by skin colour**

| Red skinned | Yellow skinned |
|---|---|
| Aladin | Agria |
| Amorosa | Burren |
| Bellefleur | Electra |
| Desiree | Frieslander |
| Esmee | Impala |
| Kondor | Riviera |
| Red Sun | Sissi |


Phot 7: **Red Sun potato variety**

**Soil pH and fertilizer**

Potatoes grow well on a wide variety of soils and soil pH can be as low as 5.0 with satisfactory production. Potatoes are less susceptible to scab when soil pH is between 5.0 and 5.5. If pH is too low apply dolomitic limestone. Based on soil test results the quantities of $P_2O_5$ and $K_2O$ are recommended.

**Nitrogen**

Apply 75 Ibs/A N along with recommended $P_2O_5$ and $K_2O$ by either broadcast preplant incorporated or one half broadcast and one half with the planter in bands placed 3 to 4 inches to each side and 1 to 2 inches below the seed piece. Top dress or irrigate on additional N when tubers begin to form. Two or three N top dress applications of 30 to 40 Ibs/acre each may be needed. Too much N can be detrimental and decrease tuber quality, grade, and yield. Soils having a high amount of nitrate-N from previous fertilization, green mature crops, or from livestock manure will require less N fertilizer. Potassium sulfate is preferred to potassium chloride as the potassium source, since skin color and specific gravity may be adversely affected by potassium chloride.

**Soil preparation**
Good water penetration and aeration are musts for proper growth and tuber formation. Excessive tillage and land preparation causes compaction and should be avoided. To be effective the soil should be plowed below any compacted layer within the normal root zone and then disk harrowed before planting. Spike-tooth harrowing to break clods and level the soil may be needed just prior to planting.

**Seed and planting**
Use only certified seed tubers. Potato production costs are too great to risk using noncertified seed. Certified seed of good quality grown in the northern states normally produces the largest yields, the highest quality tubers, and the fewest disease problems. Pieces of large seed tubers are used for planting. Small whole tubers can be used with equal results. Seed pieces should be 11/2 to 2 ounces in size. Using smaller seed pieces usually results in lower yields. Cut seed pieces can be suberized (healed over) before planting, but planting fresh cut seed is a normal practice since growers usually lack the time and space to store large quantities of cut seed before planting. Treatment of seed pieces with fungicides may not always be necessary as OSU researchers have shown that such applications are likely to increase yield only when the cut seed pieces must be stored three or more days prior to planting. Seed required to plant an acre depends upon seed piece size and seed spacing. Distance between rows is commonly 36 inches.

Planting should begin in early March in central Oklahoma to promote early crop development and avoid extreme summer temperatures. There are several types of planters available that place the seed pieces in the soil and apply fertilizer and systemic insecticides in one operation. Seed depth should be about 4 inches below the top of the planted bed. Soil is ridged over the row by throwing soil to the plants during early cultivation, so that about 6 inches of soil cover the seed piece when tuber formation occurs. Depth for hilling differs between varieties.

**Cultivation**
Potatoes develop larger and more extensive root systems in response to proper cultivation. Loose, friable soil improves tuber set and development of smooth, well-shaped and even-colored potatoes. Cultivation may be necessary to control weeds, keep soil hilled-up, and aid water penetration and soil aeration. Cultivate only when needed. Deep cultivation should be avoided since many roots are destroyed. Extra cultivations are expensive, increase soil compaction, and reduce yield. By the time plants reach full bloom cultivation should cease.

**Weed control**
Weeds should be controlled in potato fields, since they cause many problems besides being hosts for insects and diseases. An effective weed control program takes into account the weed problem, cultivation, and herbicides. Fields containing perennial weeds should be avoided. When herbicides are used, the choice of which one or ones to use should be tailored to the specific weed problems and when these weeds germinate. Methods of application vary from preplant incorporation, post-plant and preemergence, to post-emergence applications. Various herbicides can be applied by ground rig, airplane, or through the sprinkler irrigation system.

**Irrigation**
Soil moisture is probably the most important factor determining potato yield and quality. About 20 inches of water are needed to produce a potato crop in central Oklahoma. When irrigation is practiced to supplement rainfall it should be applied in frequent light amounts. Secondary growth and growth cracks occur when irrigation or rainfall occurs after moisture stress. The soil should be kept uniformly moist until tubers have reached full size. For irrigation management decisions:

1. the effective rooting depth of potatoes is two feet,
2. the soil should not be allowed to dry below 65% of field capacity, and
3. moisture levels above field capacity will seriously

**Harvesting, handling, and marketing**
Digging potatoes begins in late June and continues to the end of July. For best quality table stock potatoes, the tubers should be fully matured before digging. Vines may need to be killed by vine beaters or chemicals to promote good skin set. However, since potatoes are edible at any time, the question of when to dig must be decided by the grower. Considerations include price, demand, market conditions, and expected yields. Early potatoes are sometimes dug before optimum maturity to take advantage of certain limited market demands and high prices. Processors may require that a test for reducing sugars be made to determine if tubers are in the acceptable range for chipping into light colored chips. Potato harvesting is almost fully mechanized. The harvester digs and loads the potatoes on trucks for transport to a shed where tubers are washed, graded, and sized for bulk marketing or packed in bags or boxes. Due to high temperature conditions during harvest, speed is very important in handling the potato crop from digging to loading for shipment. Tubers bruise easily during harvest at temperature above 85°F and below 50°F. Soil condition, tuber condition, and harvester operation are important factors that influence bruising. Besides bruising, other common market defects are rots, cracks, skinning, enlarged lenticels, heat sprouts, greening, and numerous diseases. Summer harvested potatoes are not stored or held any longer than necessary before marketing. The best temperature for holding potatoes is 40 to 42°F. Oklahoma potatoes are usually sold on the open market at prevailing prices. Chipping potatoes are normally sold at contract prices and may be graded or ungraded. B size and creamer potatoes are usually sold to processors for canning.

**Economic and social impact of the potato**
Most the production of potatoes comes from Europe, Eastern Europe and the Russian Federation. Recently, developing countries have increased their participation. This situation has evolved rapidly indicating that a sustained trend will result in most of the world production of tubers coming from Asia, Africa and Latin America. In fact, the high productivity level in developed countries in Europe, North America, Australia and others have left few possibilities to augment potato production by convention methods.
A majority of the world potato production is dedicated to the direct human consumption (50-60%). Around 25% are used to feed animals. Approximately 10% are dedicated for seed. The difference, in large part, is its use as raw material for industrial products. A smaller measure of tubers is counted as losses.

In Europe and North America, the potato varieties currently in consumption have barely altered for many years. For example, the variety of more consumption in United States (Russet Burbank) had appeared in 1872. In a similar way, new varieties have hardly been introduced in Europe. The efficient certified seed programs, easy access to pesticides, the sterilizing effect of the hard winters plus the expansion of the processing industry has all influenced the consolidation of tubers.
In the last 20 years, the developing countries have been more willing to accept the introduction of new varieties. Genetic improvement together with more efficient production programs and seed distribution offers positive base to improve productivity levels.
The integrated practices of pest control have demonstrated outstanding success in the Andes of South America and in North Africa. The sustained expansion of these techniques, often combined with cultural production practices (improved seed) and post-harvest (rustic storage) will result in larger quantities of produced and marketed potatoes.

**World trade**
Over the years, potato supply and demand has followed divergent paths. The cultivated area and production in Europe has experienced reductions, with some exceptions like the Netherlands and Portugal. Most of the production of the developed countries (84%) is concentrated on Europe and the countries that were part of the Soviet Union. Mainly North America, Australia, New Zealand, Japan, South Africa and Israel produce the remaining crop.
The potato crop productivity average in Africa, Asia and Latin America has increased 44%, 25% and 71%, respectively, within a 30 year-old period. Potato production and yield vary considerably among countries in Latin America. Generally, there has been a slight reduction of the cultivation area offset by a productivity increase. The tendency to reduce the growing area in Latin America has led to concentration in more productive areas. High yields have been obtained comparable to those of Asia and Africa. Colombia and Mexico have the highest growth rates.
Mainly small and medium farmers in the developing countries cultivate potato. This situation is reflected in most of the region except Argentina where large farmers prevail.

## *3.6. Sugar beet*

The sugar beet needs a peculiar soil and a unique climate for its successful cultivation. The most important requirement is the soil must contain a large supply of plant food, be rich in humus, and have the property of retaining a great deal of moisture. A certain amount of alkali is not necessarily detrimental, as sugar beets are not especially susceptible to injury by some alkali. The ground should be fairly level and well-drained, especially where irrigation is practiced.
While the physical character is of secondary importance, as generous crops are grown in sandy soil as well as in heavy loams, still the ideal soil is a sandy loam, i.e., a mixture of organic matter, clay and sand. A subsoil of gravel, or the

presence of hard-pan, is not desirable, as cultivation to a depth of from 12 to 15 inches (30.5 to 38.1 cm) is necessary to produce the best results.
Climatic conditions, temperature, sunshine, rainfall and winds have an important bearing upon the success of sugar beet agriculture. A temperature ranging from 15 to 21 °C (59.0 to 69.8 °F) during the growing months is most favorable. In the absence of adequate irrigation, 460 mm (18.1 inches) of rainfall are necessary to raise an average crop. High winds are harmful, as they generally crust the land and prevent the young beets from coming through the ground. The best results are obtained along the coast of southern California, where warm, sunny days succeeded by cool, foggy nights seem to meet sugar beet's favored growth conditions. Sunshine of long duration but not of great intensity is the most important factor in the successful cultivation of sugar beets. Near the equator, the shorter days and the greater heat of the sun sharply reduce the sugar content in the beet.

**Fertilizing sugarbeet**
Sugarbeet quality is dependent on the sucrose content in the roots and the level of impuritiesthat must be removed during sugar refining. Production of high quality sugar is especially important to growers who are paid based on extractable sugar delivered to the factories Proper nitrogen fertilizer use increases both root and sugar yield. However, excessive nitrogen increases impurities and decreases sugar content. More precise nitrogen management within each crop in a sugarbeet rotation will help prevent over-application and buildup of nitrogen in the subsoil.
Choose grid soil sampling if field history is unknown, if fertility is high, when the field has a history of manure applications, when two or more fields have been merged together, or if phosphate levels are particularly important.
Choose zone soil sampling if yield monitor or remote imagery reveals pattern relationship with landscape, if there is no history or manure use, if the field has a history of relatively low P rates, or if mobile nutrient levels, particularly nitrate, are required.
Sugarbeet is a crop that is especially responsive to banded P placement. It is also a crop that is especially sensitive to fertilizer salts, so any banded starter fertilizer with the seed must be used at low rates.
It is rare for sugarbeet to respond to the use of micronutrients. Before using micronutrients on an entire field, try a test strip to determine a possible need.

**Row widths and plant populations**
Row width of 22 inches is recommended. Irrigated beet growing areas indicates 400-600 pounds of sugar per acre are lost as row widths increase to 28 or 30 inches. Higher, more uniform plant populations are easier to establish on narrow rows. Growers interested in row widths greater than 22 inches must consider the anticipated advantages against lower yields per acre.
A good sugarbeet plant population at harvest shouldbe about 175 to 200 uniformly spaced plants per 100 ft. of row. This population should produce very good yields of high quality sugarbeet.

**Seeds and seeding**
Many varieties of seeds are available commercially. Trial provides an excellent comparison of the performance.

Sugarbeet should be planted as early as weather, soil moisture and temperature conditions permit. The potential for very high yields from early plantings is usually considered worth the risk of frost damage.

1. Plant seed 1.00 to 1.25 inches deep for maximum germination and emergence. Use shallow depths for earlier planting.
2. Plant sugarbeetseeds 3 to 4 inches apart in 22-inch rows if they are to be thinned.
3. Plant sugarbeetseeds 4.5 to 5 inches apart in 22-inch rows if planting to stand.
4. A planting speed of 4 miles per hour is recommended.
5. Performneeded maintenance on planter prior to planting.
6. Please attend test stand clinic.

**The volume of the sugar beet production in Hungary and its concentration**

Despite of that the conditions are less favourable for the sugar beet production in Hungary, the yields cover the domestic consumption. According to the specific yields, the Hungarian figures belong to the last third of the European countries.

Yields above 60-70 tons per hectare are frequent in the European Union, due to the favourable soil conditions, the high potential breeds, the high level of machinery, pest control and fertilisation and the more favourable ecological conditions. In Hungary, the sugar beet production is 5.0 to 5.5 per cent and the sugar production is 1.5 to 3.0 per cent of those of the European Union.

In Hungary, several companies are producing sugar beet. The average yield is higher than 40 tons per hectare on hardly more than half of the producing land. The yield is especially low in the small farms of Middle Hungary and the Middle Transdanubian region.

**The situation of the sugar sector and market in Hungary**

The sugar producer companies belonged to three groups with foreign interest:

1. Argana is Austrian (factories were in Petőháza, Ács, Ercsi, Sárvár and still exist in Kaposvár),
2. Béghin Say (Photo 8) is French (factories were in Hatvan, Szerencs, Selyp és Szolnok),
3. Eastern Sugar, English-French (factory was in Kaba)

The sugar factories in Mezőhegyes and Sarkad had been owned by Argana and in 1997 these were bought by Eastern Sugar, which in the end closed them down.

A more and more important actor of the Hungarian sugar market is Hungrana Ltd, which produces sweetener, isoglucose from corn. The isoglucose is the biggest competitor product of the conventional sugar, its capacity is one fifth of the whole Hungarian sugar producing capacity. In the EU, there is a quota for the iso-sugar production in 2 to 5 percentage of the whole sugar production. The Hungrana is owned by foreign concerns, too; Agrana and Amylum own it in 50-50%.

The French Béghin-Say group sold its factories in 2003. The factories in Szolnok, Szerencs and Hatvan were bought by Nordzucker AG, Braunschweig. The Nordzucker wants to extend its interest in Eastern Europe; it has already got factories in the Czech Republic and Slovakia. These three factories produce 130 thousand tons of sugar annually.


Photo 8: **Sugar factory in Nantes (France)**

Thus, at the moment, there is only one actor on the Hungarian sugar market: Kaposvár.
In 2002, the regulation based on production quotas was introduced and applied on the Hungarian sugar factories and sugar beet producers. The effect of the new system has already being seen at the seeding, as the sugar factories have their partners produced only that amount of sugar beet, which is enough to fill the quota given (Table 5). It is considered as EU-conform process.

Table 5: **The land contracted for sugar beet production**

| | 2000 | 2001 | 2002 | 2002, in % of 2001 |
|---|---|---|---|---|
| production land, ha | 54573 | 67559 | 55703 | 82,45 |
| yield, tons | 2010469 | 3094878 | 2555097 | 82,55 |
| average yield, t/ha | 36,84 | 45,81 | 45,87 | 100,13 |

In 2002, 530 thousand tons of quotas were allocated by the agricultural minister. The white (beet) sugar was given 400 thousand tons and 130 thousand tons for the isoglucose. The total quota for sugar beet production was divided among the producers of beet sugar based on their production in last year.
The factories ~~has~~have made their contracts with their farmers and producers according to these quotas. The net price for the sugar beet with 16 per cent of sugar content is contracted at 8,131 HUF per ton; and with optional surcharge the average purchase price can reach 9,000 HUF per ton.
The regulation of the sugar production, which was implemented in 2002 made the co-operation more calculatable between the producers and the factories.
Despite of that, some fields of the regulation need further refinements and complementation. Also the subsidies are paid for the farmers by the integrators.

**Regulation of the sugar production in the EU**

The common market of the sugar sector started to be organised by six countries establishing the European Union, in 1967. The different areas of the Community had so great differences in their effectiveness and production that a quota system had to be introduced in the sugar sector in the beginnings. The role of the production quotas was intended for a transitional period, only till the equalisation of the differences. Though, after the structural changes the quotas could have been eliminated, they became an important element of the system and remained. Likely, due to the combination of the quotas, the self-financing system and thus the detachedness of the sugar sector, the reforms of the CAP did almost not affect the sugar industry.

The price of the sugar was stabilised with intervention guarantees, and the domestic sugar was defended with import duties and export subsidies. The intervention covered the sugar, while the price of the sugar beet was guaranteed by the regulators included in the contract between the farmers and the factories.

By 1981, the sugar regulation became self-financing due to the different duties on sugar and raw materials.

The common market organizations of the sugar sector were introduced in 1968 in the European Union. Basically, it has not changed since and is organised on the basic theory of the beginnings.

The first regulation covered only the sugar, and in 1980, the isoglucose and in 1994, the inulin beet syrup were included. The current sugar regulation covers the production of beet and cane sugar, sugar beet, sugar cane, inulin syrup, isoglucose, molasses and other sugars.

The several-decade-old sugar regulation covering almost all small details is built on five main factors that determine its strategy:

1. production quotas,
2. prices and guarantied prices,
3. self-financing,
4. import duties and export subsidies,
5. intervention.

The quotas for sugar production is being reviewed and modified along with the EU enlargement. During the last negotiations with the candidate countries, the Committee took the production of five years before the application into account. Leaving out the years with the highest and lowest production, the rest three years and consumption and trade data were the basis for determining the quotas .A. and B. for the new member countries. There are quotas A. and B. and production C. for sugar, isoglucose and inulin allocated. The quota for inulin is given individually for each company. Though, both the quota system and the production duties are applied on the production of isoglucose and inulin, institutional prices are not valid for these product.

Quota A. is provided for satisfying the domestic consumption, quota B. is a safety amount to balance the variation of the yields and the quota for export subsidies. Generally, the share of sugar quota B. is around 20 to 25%, but in case of the lately joined countries it was about 10%. In general, quota B. can not be less than 10% of quota A., in case of isoglucose and inulin this level is at least 23.55%.

The member countries are not allowed to give quotas to each other, though 10 per cent of the quotas can be allocated within the countries among the factories; and to this extent, also the authorities can limit the quotas of the companies.

Production C. means the (sugar and beet) production above the quotas A. and B.

For the producers, the minimum price of the sugar beet is a guaranteed price, which in any conditions has to be paid by the factories for the sugar beet produced within quota. As production duty is paid by the farmers, too; the basic price of the sugar beet reduced by the production duty gives the minimum price.

## Questions for self-evaluation

1. Which plants are used for biodiesel production?
2. What are the main purposes of the sunflower seed?
3. What kind of factors has major influence on soybean yield?
4. Which are the main potato producer countries in the World?
5. Please, tell the quota system of EU in the sugar beet production!

# 4. MANAGEMENT OF FORAGE PLANTS

It appears, that livestock feed are relatively high-priced. Ruminant animals have the advantage of using some feedstuffs, like forages, that are not used in human diets and not in high demand for bio-fuels either. The logical thing would be to utilize as much forage as possible while still maintaining a productive level acceptable to the producer. Within forage sources - alfalfa, grass, corn silage, small grains or straw - it is an advantage to have higher quality forage to feed.

With regard to animal requirements, whether the animal is growing or producing milk, it has a set of requirements for that activity. These are in amounts per day of energy, protein, minerals, vitamins and fiber. But more specifically, there are amounts of metabolizable energy (ME), metabolizable protein (MP) and NDF. Metabolizable energy and protein is what reaches the small intestine with the potential to be digested and absorbed. Metabolizable protein is ~60% MP from the rumen microbes and 40% dietary proteins not digested in the rumen. There are further constraints with NDF - there is a minimum amount needed each day as forage NDF to provide an amount of effective fiber and a maximum amount so it does not limit dry matter intake (DMI). Sources of ME are starch, digestible NDF and fats.

Protein content of forage is influenced by species and relative maturity. Because protein is expensive to provide in feed, immature forage is often preferred, usually alfalfa, to provide a source of crude protein (CP). Unfortunately, alfalfa can be too high in soluble protein and end up wasting protein when it is converted to non-protein nitrogen in the rumen and not utilized by rumen microbes. Alfalfa, even immature alfalfa, is higher in lignin and thus lower in NDF digestibility or NDFD, than other forage species like grass or corn.

In recent years, grasses, especially high quality grasses, are once again being considered as forage for dairy animals. Grasses typically are lower in CP than alfalfa at similar maturities. However, they have a role in balancing the amount of soluble protein in alfalfa and the amount of starch in corn silage while providing NDF and greater NDFD. Lignin content of grasses is typically about half that of legumes which allows increased digestibility of the NDF. Grasses have been criticized in the past as poor forage for dairy animals because they were higher in NDF than legumes and were unjustly discounted in the RFV formula. With the advent of Relative Forage Quality index (RFQ), grasses are valued because of their higher NDFD.

Grasses are slower to digest, which provides a more effective fiber mat. However, they are more completely digested than legumes. This eliminates the need for addition of straw to diets of lactating cows.

Corn silage provides less CP per unit of forage but excels in energy content due to starch content and digestible DM and NDFD. The forage portion can be higher in NDFD than alfalfa as well as the grain and cob portion, which is highly digestible. Corn silage also brings consistency and yield potential to a forage system. Within corn hybrids, corn breeders are identifying certain varieties that are referred to as silage specific. These varieties are above average in NDFD in forage portion, have high DM yields and may have a softer endosperm in the corn. An extreme example for NDFD is the BMR hybrids. Although often lower in total DM yield, yield of digestible NDF may be greater than other hybrids.

In the future, producers will likely need to increase the amount of forage in diets fed to dairy animals and other ruminants in order to save money while maintaining productivity. This can be done by combining different species of high quality forages. Mathematical models will be used to better understand the combinations which will accomplish that goal. Evaluations may need to be shifted to yields of digestible NDF and CP that will yield the greatest ME and MP in the animal. This will be in addition to the many other management practices already used while still relying on adequate rainfall and good weather at harvest to maximize yields and minimize losses.

## *4.1. Alfalfa*

Alfalfa (*Medicago sativa*) has the highest yield potential and highest feeding values of all adapted perennial forage legumes. It is a versatile crop that may be used for pasture, hay, silage, green-chop, pellets, cubes, soil improvement, and soil conservation.

**Variety selection**

Selecting the best alfalfa varieties is one of the most important decisions producers make in developing a good forage-production system. Selecting alfalfa varieties is a 5- to 10-year investment. It is important to buy quality seed of certified varieties with high germination percentages. Planting highyielding, adapted varieties not only ensures good yields but also healthy and vigorous stands 1 to 2 years longer than poorly adapted varieties.

When selecting alfalfa varieties, producers not only need to be aware of yield potential but also of disease and insect resistance, fall dormancy, and winter hardiness. These varietal characteristics determine stand persistence and productivity. It is important to select varieties that are highly resistant to bacterial wilt, leaf and stem diseases, and crown rots, such as phytophthora root rot. Resistance to insect pests, including the spotted alfalfa aphid and pea aphid, has been incorporated into some varieties, and they are recommended. Varietal resistance to the alfalfa weevil has not been achieved; however, a few varieties are tolerant to low levels of weevil infestations. Increased insect resistance will likely be conferred by the use of glandular hairs in new cultivars.

Some modern varieties have incorporated specialty traits that may be important for certain growers. Producers that sell hay on a protein-quality basis may realize greater income from varieties bred for higher protein content or quality, although harvest management is usually the greatest factor affecting hay quality. Multifoliate cultivars, those with more than three leaflets per leaf, can have a higher leaf-to-stem ratio, which improves forage quality; however, multifoliate types do not necessarily have higher quality or yield. Many genetic and environmental factors affect both yield and quality.

Basing variety selection on any single trait, such as multifoliate habit, would be a mistake. Growers interested in grazing alfalfa should examine some of the new varieties developed specifically for grazing tolerance. Several varieties withstand grazing quite well and also are useful for hay production.

Fall dormancy is a varietal characteristic that helps plants prepare for winter. Varieties differ in fall dormancy and, thus, in their ability to remain productive late in the season. If varieties have too high a fall dormancy level, they go dormant too early, reducing late-August and September yields.

**Time of planting**

Alfalfa can be planted either in the spring or late summer. Spring plantings can be made after danger of frost. April to mid-May plantings allow establishment without danger of freezing. In southern and eastern areas, earlier plantings occur, especially when seeded with spring oats as a nurse crop.

With irrigation, plantings should be made in April through May but can be made through early June. There is an increased chance of weed competition with spring plantings, and use of preplant-incorporated herbicides may reduce weeds.

Establishment-year yields of spring-planted alfalfa are considerably lower than those of late-summer plantings.

Late-summer plantings usually have fewer weeds, but available soil moisture for germination and establishment prior to the killing frost may be limiting. A late-summer planting should be done in mid-August, as moisture and temperature conditions permit. These plantings begin in northwestern areas and should be completed by early or mid-September in southeastern Kansas. This provides adequate time for seedlings to become well established before entering winter dormancy. Plants should have at least three to five trifoliate leaves before dormancy.

**Planting methods**

A perfect alfalfa seedbed should be firm to reduce air pockets, fine to obtain an even covering of seed, level with no places where water stands, and free from weeds that compete with seedlings for moisture and plant nutrients. Seedbed preparation is costly, time-consuming, and promotes the loss of valuable soil moisture. It is important to prepare a seedbed in the most efficient manner to reduce establishment costs and moisture loss.

There is increased interest in planting no-till alfalfa into row-crop stubble in the spring and after small grain cereals or in forage sorghum and silage stubble in late summer. Late summer seedings are often after winter wheat or spring oats. Alfalfa can be planted no-till into these residues. Most no-till drills can be used effectively to penetrate the standing stubble to obtain good seed-soil contact.

Planting no-till alfalfa after row crops also can be effective, especially if the crop is harvested for silage and if conditions were dry during harvest so there are no tire tracks. Often, farmers choose to perform some tillage to knock down the ridges and level the field. When considering no-till planting, planning is important for success. Fields that have had residual herbicides applied for the previous crops should be avoided to reduce the chances of carry-over herbicide damage to alfalfa seedlings. A fertility program for alfalfa will have to be implemented prior to planting the no-till alfalfa.

Good seed-soil contact is critical in alfalfa establishment to ensure quick germination. A cultipacker-type seeder or grain drill with press wheels firms the soil, resulting in good contact with the seed.

Some producers reduce the seeding rate by half in conjunction with cross drilling. Planting in one direction is followed by planting at a right angle to the initial seeding. Broadcast seedings followed with a soil packer may result in adequate stands, but this is the least-desirable method. Seeding rates should be increased by one-third when using this method.

Other producers have broadcast the seed with large fertilizer applicators at the same time liquid fertilizer is being applied. The success rate with this practice, as with any broadcast seeding, depends on available surface moisture.

Some producers overseed alfalfa by drilling or broadcasting into winter wheat in early spring. This method is more successful when wheat stands are thin or in late-planted wheat, which has little spring growth. If the wheat is too tall or has thick stands, the seedling alfalfa is unable to compete, resulting in a poor stand.

**Planting rates**

Planting rates vary across the state and with differing conditions. In western Kansas, 8 to 12 pounds per acre is recommended for nonirrigated seeding rates. On medium- and fine-textured irrigated fields, a planting rate of 10 to 15 pounds per acre is adequate. On irrigated sandy soils, 15 to 20 pounds per acre is recommended. In central and eastern Kansas, the planting rate varies from 8 to 15 pounds per acre, depending on soil types and moisture conditions.

The recommended seeding rates may seem exaggerated when considering there are about 225,000 seeds per pound. A 1-pound-per-acre seeding rate would be equivalent to about five seeds per square foot. Not all seeds germinate and emerge, though, and the recommended rates ensure adequate stands.

**Planting depth**

Planting depth is important in determining stand establishment. Small-seeded legumes, like alfalfa, cannot emerge from deep plantings. Planting depths may vary with soil types. On sandy soils, the seed should not be placed deeper than 0.5 to 0.75 inch, whereas on medium- or fine-textured soils, 0.25 to 0.5 inch is adequate. A guideline for alfalfa is the planting depth should be no more than 10 times the diameter of the seed.

**Stand renovation**

Overseeding to thicken an old stand is generally unsuccessful because alfalfa plants produce a toxic compound that kills alfalfa seedlings. The exception would be newly seeded stands with large unestablished areas in which the seedbed can be prepared before planting. Cultivating with a disc, harrow, or other tillage implement to thicken old stands is not recommended. Damage to the crown often results in further stand deterioration.

**Producing alfalfa seed**

Seed production is of secondary importance to Kansas alfalfa growers. Alfalfa is grown primarily for hay and left for seed production only if weather conditions are appropriate.

Production practices are the same for hay and seed, but in seed production, row widths of 20 to 40 inches are used. Adequate phosphorus is important for satisfactory seed production. Phosphate fertilizer should be applied according to soil-test recommendations.

The seed crop should receive only enough water to promote moderate top growth until blooming. Moisture conditions that promote slowgrowing, vigorous plants provide root reserves for seed production. At blooming, additional water will lengthen the blooming period, but excessive water will promote vegetative growth and lower seed yields. Avoid sprinkle irrigation while the alfalfa is in bloom because it damages the flowers and interferes with pollination.

In most years, the second cutting is best suited for seed production. The first cutting is usually light in bloom due to cooler weather and shorter day length. Pollinating insects are not as active earlier in the season, and as a result, seed yields are lower. The third and fourth cuttings are often too late for good seed set and maturation. The ideal time to have alfalfa come into bloom for high seed yield is July. The first cutting should be delayed to one-half or three-fourths bloom to increase root reserves and allow the second cutting to bloom and mature during the warm conditions of July and August. It takes about 30 days from the time a flower is pollinated and fertilized until the seed is mature.

Blooming will continue for about 3 weeks, which stretches seed maturity over several weeks. Higher yields will be obtained if the whole seed crop is allowed to mature before harvest. This is seldom achieved in Kansas due to the weather. Therefore, producers harvest when three-fourths of the pods are black or brown.

The alfalfa flower must be tripped to set seed. This is done best by pollinating insects, primarily wild bees and honeybees. No practical mechanical means of pollinating alfalfa have been developed.

**Lime and fertilizer needs**

Alfalfa responds well to liming and fertilization with phosphorus and potassium. Because alfalfa is a forage crop normally harvested three to five times a growing season with the above-ground portion of the plant harvested, nutrient removal is high. Table 6. shows the nutrient removal for alfalfa. A soil test prior to alfalfa establishment is essential to determine lime and fertilizer needs. Soil tests should be taken well before seeding to allow time for incorporation of lime and fertilizer into the soil. Once alfalfa is established, there is no opportunity to incorporate lime.

Table 6: **Nutrient removal by alfalfa (Pounds of nutrient per ton of alfalfa)**

| | |
|---|---|
| N * | 55.0 |
| $P_2O_5$ | 10.0 |
| $K_2O$ | 60.0 |
| Ca | 30.0 |
| Mg | 4.6 |
| S | 8.0 |
| Zn | 0.06 |
| Cu | 0.14 |
| Mn | 1.8 |
| Fe | 1.8 |
| B | 0.02 |

* Properly inoculated and nodulated alfalfa gets nitrogen from the air.

**Irrigating alfalfa**

Alfalfa is a deep-rooted, drought-tolerant perennial with a long growing season. As a consequence, it also is a large water user with seasonal water use (Figure 18) in excess of 40 inches. In deep, well-aerated soil, roots may extend 8 to 12 feet deep. Alfalfa grows from early spring until late fall or early winter. Growth begins when the average temperature reaches 50°F and continues until a killing freeze occurs. When soil water is sufficient, alfalfa grows in direct relation to the temperature and sunlight available.

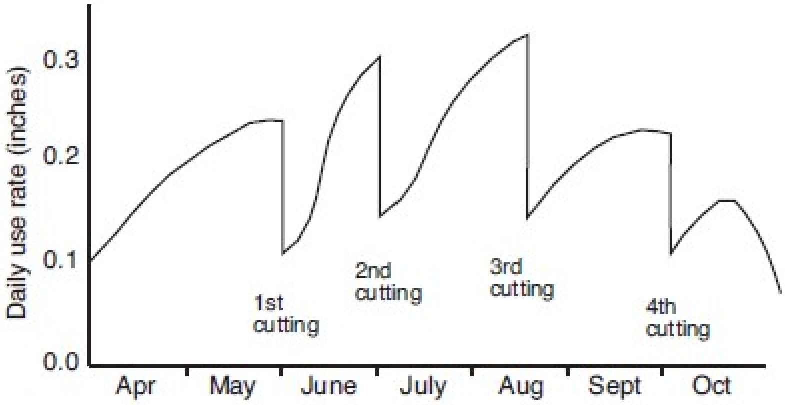



Figure 18: **Normal water-use pattern of alfalfa**

Alfalfa is sensitive to excess soil water or the lack of good aeration. Surface water should not be allowed to stand more than 24 hours during hot weather or 48 hours during lower temperatures.

A deep, medium- to coarse-textured soil with adequate water is ideal. Fine-textured soils are usually difficult to manage. Excess moisture is conducive to development of root and crown diseases. Shallow water tables limit root growth.

Alfalfa does not have a critical stage of growth, as do many other crops. The seedling stage is sensitive to soil water because seeds are small and the reserves of energy and moisture also are small. The period of regrowth after cutting is sensitive, but that is due to encouraging weed competition from surface water if it is applied immediately after cutting. Irrigation is therefore not advised. A dry surface with adequate water below the top 12 to 18 inches gives alfalfa an advantage over shallow-rooted grasses and weeds.

**Cutting management and forage quality**

Stage of maturity at harvest affects alfalfa forage yield, quality, and stand persistence. Alfalfa has the potential to produce substantial tonnage of quality forage, high in protein and carotene and low in fiber.

Obtaining the highest season-long forage yields, however, requires cutting at late-maturity stages. Cutting at early-maturity stages maximizes quality. In either case, stand persistence can be adversely affected, thus shortening stand life.

A balance between forage yield and quality is necessary in order to preserve the stand. The exception is the dairy producer who demands high-quality forage with less concern for quantity and stand longevity.

In this case, the characteristic high-percentage crude protein, protein digestibility, and carotene content of alfalfa harvested at the pre-bud and bud stages are the priority.

With established stands, three indicators determine when alfalfa should be cut: crown regrowth, one-tenth bloom, or prior to extreme leaf loss. In the spring, alfalfa flowering is delayed because of the shorter photoperiod. With accumulated aboveground growth, however, nutrients are translocated to roots to replenish carbohydrate reserves. Crown regrowth is initiated in response to replenished root reserves. This regrowth will be the second cutting. If first cutting is delayed to one-tenth bloom or later, the advanced regrowth will be removed with the first cutting, delaying the next hay crop. First cutting should be based on crown regrowth and subsequent cuttings on one-tenth bloom (Photo 9) which generally coincides with crown regrowth. This growth stage is the compromise for optimizing both forage yield and quality, yet maintaining stand longevity. One goal of alfalfa producers is to make two cuttings before wheat harvest, if weather permits.

Photo 9: **Alfalfa matured for cutting**

Situations may arise that cause premature leaf loss and require cutting before crown regrowth or one-tenth bloom. These include lodging, insect and disease damage, and drought. Green leaves contain the majority of nutrients compared to stems, thus leaf retention is essential to produce high-quality forage.

If cutting is required before the recommended stage, root reserves may not be fully recovered to permit rapid regrowth; yet left uncut, the hay crop will deteriorate, and stand vigor may decline.

Cutting at an increased stubble height will aid in conserving root reserves. Although yields may be affected slightly, this practice will enhance axillary-bud regrowth along with crown regrowth, which will reduce demands on weakened plants. After salvaging this cutting, the next cutting must be delayed slightly to ensure replenishment of carbohydrate reserves.

Cutting management of newly established stands is slightly different compared to older stands. The first cutting on new stands should be delayed from one-tenth to one-half bloom to ensure replenishment of root reserves for rapid regrowth.

Typically, the regrowth under this delayed initial cutting is not significant enough in height to be removed with the first harvest. Subsequent cuts can be made at one-tenth bloom or when crown regrowth appears.

The last fall cutting may influence the alfalfa stand’s performance the following year. If root reserves are not replenished before the fall killing freeze (20 to 25 degrees Fahrenheit) or initiation of dormancy, the stand is more susceptible to winter damage, resulting in slower initial spring growth. Final fall cuttings should be based on crown regrowth rather than one-tenth bloom because of the decreasing photoperiod. The last cutting, prior to fall dormancy, should be made so there are 8 to 12 inches of foliage or 4 to 6 weeks of growth time before the average killing freeze date. This allows adequate time for replenishment of root reserves. For northern areas of the state, the third week of September should be the target date for the last cutting before dormancy.

Alfalfa forage quality is based on two components: protein and fiber. The protein is calculated as percent crude protein. The fiber is divided into two groups: acid detergent fiber (ADF) and neutral detergent fiber (NDF). An estimate of the energy value of the feedstuff, which includes both ADF and NDF in its calculation, is the relative feed-value (RFV) index. The crude-protein estimate includes both the true protein and the nonprotein nitrogen fractions. It is calculated by first measuring the total nitrogen, then multiplying by 6.25. A percent-crude-protein figure is then used to determine the capacity of the forage to meet the animal's protein requirement.
Typically, alfalfa harvested at early maturity stages or with a high percentage of leaves will result in a relatively high crude-protein forage (Table 7).

Table 7: **Height, percent crude protein, and percent relative feed value of alfalfa at different first-cutting stages**

| Maturity stage | Height (inches) | Crude protein (percent) | RFV (percent) |
|---|---|---|---|
| Vegetative | 16 | 26 | 153 |
| Early-bud | 20 | 23 | 134 |
| Late-bud | 22 | 21 | 132 |
| First-regrowth | 25 | 20 | 117 |
| 25%-bloom | 27 | 17 | 111 |
| 50%-bloom | 30 | 15 | 107 |
| Full-bloom | 31 | 14 | 103 |
| Green-seedpod | 31 | 14 | 98 |

K-State, 1992

Acid detergent fiber is the percentage of highly indigestible and slowly digestible components of forage. These include cellulose, lignin, pectin, and ash. This fraction is indicative of forage digestibility with lower values—such as 30 percent ADF—being more desirable.
Considering the quality components, cutting time becomes a method of controlling alfalfa forage quality. Alfalfa cut at the late-bud to one-tenthbloom stages can have 20 to 25 percent crude-protein levels. Delaying harvest until full bloom to increase dry-matter yields results in hay crude-protein levels of 10 to 15 percent, with lower relative feed values and carotene content. Research has shown alfalfa cut at one-tenth bloom for more than 6 years yielded a significantly greater tonnage of both dry matter and crude protein compared with forage alternately cut at the bud and full-bloom stages.

Leaves, compared with stems, are essential to obtain high-quality alfalfa forage. Approximately two-thirds of the crude protein and more than half of the carotene in alfalfa hay is in the leaves. It is critical to limit leaf damage in unharvested alfalfa and leaf loss during harvest to preserve the highquality potential of alfalfa forage.

**Harvest equipment and storage**

When selecting a hay harvesting-storage-feeding system, the following questions must be considered:

- What are the costs associated with the system?
- What are quality considerations?
- Is the harvesting system compatible with present and future equipment, facilities, and operations?

Labor has been a major factor in the adoption of various hay-harvesting systems. More labor is needed for small square bales when they are handled manually than for any other system. Bale accumulators and automatic bale wagons reduce labor requirements.

Increased labor requirements increase production costs, but the cost of the entire system should be considered when making a decision.

Other harvesting costs to consider are associated with owning and operating equipment. The side-pull mower-conditioner has the least cost if less than 200 acres are harvested annually. The pull-type swather is the most economical choice when more than 200 acres are harvested annually. The self-propelled-swather costs approach those of the pull-type swather but are never lower. One explanation for this is that both machines are assumed to have the same field efficiencies, which is probably not true. Increasing the field efficiency of the self-propelled swather would reduce the costs associated with this machine.

A similar comparison of baling equipment is shown in Figure 19. The costs presented include baler, tractor, labor, and twine for each system. The small square baler appears to be the best choice if less than 200 acres are harvested annually. At this point, the large round baler becomes more economical. The extremely high costs associated with the large square baler on low acreage are due to the higher purchase price of the tractor and baler. The large square baler becomes more economical than the small square baler at 1,500 annual acres and approaches the large round baler at about 3,000 annual acres.

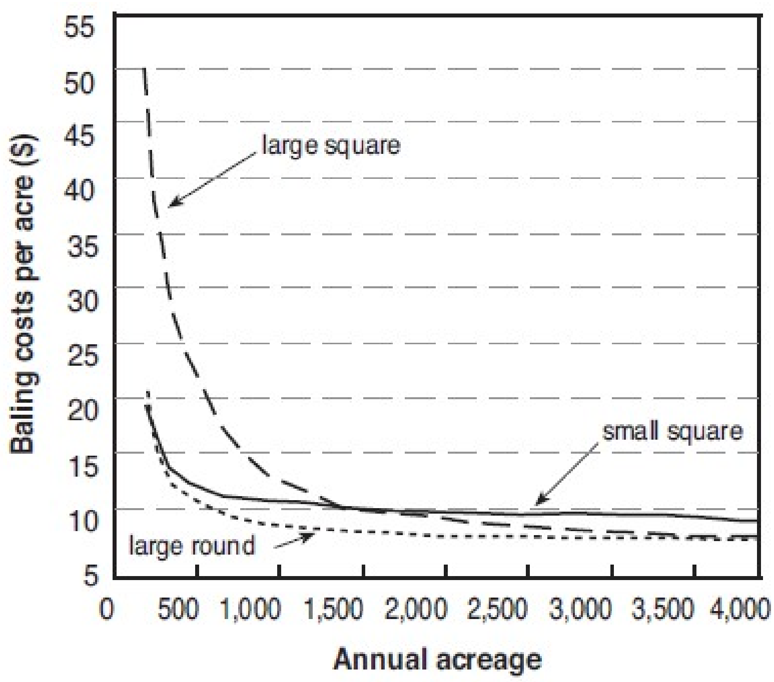



Figure 19: **Cost comparison of baling systems**

## Storage

Storage losses occur even under barn conditions and cannot be eliminated. Losses are greatest during unprotected, outside storage of large round bales. Storage losses can be divided into two categories: dry-matter loss and reductions in palatability and digestibility. Dry-matter loss is simply a reduction in bale weight. It does not include any reduction in moisture content due to additional drying. It includes hay lost from the bale during handling and any hay lost to rodents.

Reduced palatability and digestibility usually are caused by weather but can be caused by high-moisture content at baling. Weathered hay may not be as appealing to livestock as unweathered hay. Feeding losses will increase due to the undesired hay being wasted. Even if livestock consume the weathered hay, they mat not be getting any feed value from it. If digestibility is lower, rate of gain also may be lower.

Storage method has a tremendous effect on weathering losses. Barn-stored hay suffers significantly less weathering loss than unprotected hay stored outside. Dry-matter losses for barn-stored hay are generally in the 2 to 8% range. Because of their shape, large round bales are not well suited for barn storage. A hay barn simply will not hold as much hay in large round bales as in square bales.

### Storing bales outside

Large round bale storage losses can exceed 25% when bales are stored outside without protection in Kansas, but losses can be minimized through good management. Due to lower annual rainfall, western and north central Kansas are better suited for outside storage than south central and eastern Kansas. If outside storage is chosen, close attention should be paid to selecting a storage site and stacking method.

### Choosing a storage site

A well-drained site minimizes deterioration on the bottom of the bales. Bales stored on damp soil will absorb moisture and deteriorate. Bales should be elevated by stacking them on old tires, shipping pallets, or railroad ties. Adding a base layer of 3 to 4 inches of crushed rock to the storage site will help minimize losses on bale bottoms. Weeds or tall grass at the storage site will increase deterioration of bale bottoms. Round bales stored outside need air circulation and sunlight to help dry the outer layer after rain.

Storing the bales under trees blocks wind circulation and sunlight, which help dry the bales. Any protection the trees might offer is more than offset by the damage due to the shading they cause.

### Choosing a stacking method

Tightly stacking bales end-to-end minimizes storage area and protects the ends of bales from weathering. If bales are not stacked tightly against each other, rain can penetrate the ends, which increases damage. If bales cannot be stacked tightly end-to-end, an 18-inch space should be left between bales for air circulation. Stacking bales with the rounded sides touching is not recommended. This creates a trap for rain and snow.

Aligning rows north to south allows an equal amount of sunlight on both sides of the bale row, which results in uniform drying. Leaving at least 3 feet between rows allows air to circulate and sunlight to reach the bales. The distance between rows reduces the chance of snow accumulation on the bales. If snow accumulation is a

possibility, stack the rows farther apart. The greater distance allows sunlight to melt the snow sooner and reduces weathering losses from the snow.
Stacking bales in pyramids is a good way to make the most of limited storage space, but weathering losses can be extremely high if bales are not covered.

**Bale wrapping**
Net or mesh wrapping is a popular alternative to twine for tying large round bales, and one of the perceived advantages is improved protection from weather. K-State studies found net-wrapped bales did not retain quality better than twine-wrapped bales.
Solid plastic wrapping also is available for large round bales. It can be applied with the baler or as a separate operation. While the plastic will shed rain, it also traps moisture in the bale. Bales wrapped with plastic should be stored individually if the moisture content at baling exceeds 18 percent.

**Covering bales**
Covering bales (Photo 10) offers some promise for reducing weather-related losses for outside storage. Covering bales does have drawbacks. First, if a low-quality cover is used, it may be difficult to keep it on the bale. Wind damage can be devastating for plastic tarps. Any tears must be repaired immediately if the cover is to remain in place. Covers also need to be anchored to the ground or stacked to keep them in place. Reinforced plastic sheeting is more expensive but will probably require less maintenance and last longer.


Photo 10: **Covering different bales**

Covering bales with plastic will trap moisture the same as wrapping them in plastic. If high-moisture hay —more than 18%— is sealed under plastic, quality losses can result from excessive heating and mold. Condensation at the top of the stack could cause spoilage in high-moisture hay. Stacking covered bales in pyramids minimizes covering costs.

**Barn storage**

Barn storage is the best method for preserving hay quality but can be expensive if building a structure is necessary. A typical pole barn with 16 feet of clearance requires about 13 square feet of floor space for each ton of hay stored. With an initial construction cost of $4 per square foot, the cost of building a structure is slightly more than $50 per ton of storage capacity. Depreciation, interest, taxes, insurance, and maintenance can be estimated to have an annual cost of 20 percent of the original cost. This results in an annual ownership cost of about $10 per ton of storage capacity.

If the value of hay lost is typically greater than storage costs, a barn should be considered.

**Feeding**

The possibility of hay waste appears to be greater when feeding large hay packages than when feeding small bales, primarily because big packages are more commonly fed without racks. One study showed 13 percent of hay was wasted when fed without racks, while less than 5 percent was lost when feeding with racks. The hay saved with a feed rack will likely pay for the rack in its first or second year of use.

**Profit prospects**

Each producer must answer two questions when selecting crops and the acreage of each crop to produce:

1. Will this choice be profitable?
2. Will this add more to the total net income of my farm operation than other choices? That is, is this the most profitable choice?

The fixed, or overhead, costs of land and machinery ownership for alfalfa, wheat, soybeans, corn, and grain sorghum will be basically equal for the production period considered. The variable costs associated with each are the costs that need to be considered when selecting a given crop. Variable costs include labor, seed, herbicide, insecticide, fertilizer, fuel, oil, repairs, crop insurance, drying, custom work, crop consulting, and miscellaneous.

Variable costs will depend on the management practices used, tillage operations, labor efficiency, and type and fertility of the land. Each producer should develop the variable costs of production for alfalfa and any other crop alternatives. Expected yield and selling price need to be determined for each crop alternative.

The decision to plant alfalfa or another crop alternative can be made by comparing the expected returns above variable costs for each crop. Returns above variable costs will depend on yields and prices.

Each producer should use yields that are reasonable for the land or classes of land operated.

The producer also should take into account other variables such as previous crop rotation, livestock operation, and the machinery and labor requirements of each crop. Labor requirements for alfalfa hay are significantly higher than for other crops, unless the harvest is custom-hired. The market and associated marketing

costs for alfalfa hay also need to be considered if the hay is not fed to livestock in the farm operation.
The type and amount of equipment, crop rotations, and farm size all affect the cost of production.
The tillage practices used and their timing also affect yields and production costs. Each producer should compute the expected returns above variable costs for the farm operation as a means of selecting the crops and acreage of each crop to produce. When computing expected returns above variable costs, consider a number of price alternatives.

## *4.2. Grassland*

Well-managed grass provides a cost-effective, high quality feed for sheep and cattle. With farms under increasing pressure to reduce costs and maximise outputs, good grassland management can play a vital role in helping to maximise feed quality and to improve growth rates of your livestock. Good grassland management starts at the soil and its impact is felt right through to the eating quality of the final product by the consumer.

**Establishing new swards**
New swards are usually established on lowland farms in the spring or late summer, whereas July to early August is the most suitable time on many upland farms. Spring sowings provide herbage for grazing later in the same season while late summer sowings allow up to two cuts of silage to be taken from the previous sward. Spring barley is a useful nurse crop for establishing spring-sown swards. Mixtures that include clover should be sown before mid-August.

**Before reseeding check the soil status**
Test the soil to identify any deficiencies in phosphate (P), potash (K), magnesium (Mg), acidity (pH) and organic matter. Target minimum soil indices are 2 for both P and K. Further testing may be needed if there is a risk of trace element deficiency.
Sample grass fields to a depth of 7.5 cm with a corer (15 cm in arable fields). Take 25 samples by walking the field in a 'W' pattern to provide one bulk sample for analysis.
Check the physical condition of the soil and ensure that future production will not be adversely affected by any soil compaction (i.e. soil pan) or water logging.

**Field operations**
Ploughing will remove soil compaction caused under less favourable ground conditions by cattle treading or the impact of machinery during silage making. Deeper subsoiling may be required for deeper pans. Sow seed at the recommended rates – inadequate seed rates will reduce productivity and encourage open swards that are vulnerable to weed invasion. Sow seed in the top 15 mm of a fine tilth when the soil is warm and has adequate moisture. Roll the seedbed to ensure good consolidation. Encourage plants to tiller by lightly grazing with young cattle or sheep when the ley is 7.5-10 cm.

**Seed mixtures**
Before purchasing seed mixtures decide on the future utilisation of the sward (longer-term ley for grazing, shortterm ley for silage) and the type of stock that will be grazing the swards (sheep, cattle, sheep + cattle). Will fertiliser-N (conventional) or white clover (organic, low input) be the main source of nitrogen?

- Swards for cutting should include varieties with similar cutting dates to ensure they can be cut when optimum yield and quality is reached.
- Swards for grazing should include species and varieties that maintain productivity during the grazing season, provide good ground cover and persistency.

Many mixtures include both intermediate and late heading perennial ryegrass varieties. Establishing a dense, welltillered sward will reduce the risk of poaching.

Some seed mixtures used for establishing longer-term swards also include other species including Timothy (highly palatable), meadow fescue (tolerates wetter conditions), cocksfoot (deep rooting and suited for dry soils), alsike clover (tolerates lower pH and soil fertility than red clover) or herbs such as chicory and plantain (deeper rooting, high mineral content).

**Maintaining existing swards**
Maintaining good production depends on:

- maintaining soil nutrient status - test the soil every:
    - 4-5 years in fields cut for silage,
    - 7-8 years in grazed fields,
    - 2-3 years on sandy soils or in high rainfall areas,
- always sample at the same time each year and at least 2 months after the last slurry or fertiliser application,
- good management of the grazing and cutting swards,
- the survival of the most productive species (grass, white clover).

**Renovating existing swards**
A useful way to improve the composition and yield of a low yielding sward is to introduce seed of more productive species, including high-yielding ryegrass varieties, or white clover when fertiliser-N inputs are to be reduced.
Renovation can be carried out in both reseeded swards and permanent pastures grown on lowland and upland farms.
Renovating a sward:

- is cheaper and faster than reseeding,
- is only beneficial if the poor productivity of the existing sward is due to poor botanical composition or an open sward prone to weed invasion, rather than a management problem that has NOT been addressed including soil nutrient deficiency, soil compaction, over grazing or cutting swards too low during silage making,
- hybrid ryegrasses and tetraploid perennial ryegrasses have larger seeds, tend to germinate faster and are more aggressive than diploid varieties,
- is a useful technique on shallow soils or stony ground,
- seed establishment rate is less reliable compared with reseeding.

Renovating options:

- **over seeding or surface seeding:**
    - seed rate of 8-10 kg/acre for ryegrass + white clover mixtures,

    - seed rate of 1.5-2.0 kg/acre for white clover.
- **slot seeding or direct drilling:**
    - this ensures good contact between seed and soil,
    - higher germination rates than oversowing technique,
    - slugs eating the germinating plants can be a problem during wetter periods.

Guidelines for oversowing:

- only oversow into swards grazed down to a sward height of 3-4 cm,
- harrow or rake the area in two directions until the sward is open and most of the weed grasses and trash in the bottom of the sward has been removed – normally between 2 and 6 passes,
- aim to achieve at least 25% bare soil surface,
- spread seed immediately after harrowing,
- apply P and K fertiliser if required but NO nitrogen,
- either use stock to trample in seed or a flat roller,
- continue to graze until seedlings start to emerge, then rest the area for 4-5 weeks,
- sowing time:
    - spring – plenty of moisture available, but lower soil temperatures can delay germination and increase competition from the established grass plants,
    - after a silage cut – swards are open and require less harrowing, less risk of prolonged drier conditions after later silage cuts.

**Fertiliser use, farm manures and weed control**

Maximising output from grassland systems, while minimising the environmental impact, depends on the efficient use of on-farm manures and slurry, the use of legumes to provide nitrogen via fixation and the application of purchased fertilisers. Minimising the effect of weed populations in grass systems is also essential to avoid reducing the quality of swards grown for grazing and ensiling and, in the case of bracken and ragwort, the risk of toxicity to stock.

*Nutrients for grass crops grown for grazing and silage*

Whether grass and grass+clover swards are to be grazed or cut, the availability of adequate nutrients will ensure that good yields are achieved. However, applying excess nutrients from either fertilisers or on-farm manures increases the risk of environmental losses, feed energyprotein imbalance and unnecessary costs.

The main sources of nitrogen (N), phosphate (P), potash (K) and calcium (Ca) on grassland farms are from:

- nutrients in the soil, including residual nitrogen from previous clover crops,
- purchased fertiliser applications that supply straight N, N-P-K, lime, trace elements or sulphur,
- farm yard manure (FYM) and slurry – a valuable source of nutrients that should not be regarded as just a ‘waste product’,
- nitrogen fixation by clovers and other legumes – the main N-source on organic farms and many conventional farms,
- excreta from grazing stock.

Cutting and ensiling rather than grazing swards increases the off take of nutrients. Always apply fertilisers at the appropriate time and in favourable weather conditions.

Weed control
The major weeds influencing the production of grass and grass+clover swards are docks and thistles. Chickweed is a problem in some newly sown swards and bracken, ragwort or rushes can be a specific problem on some grassland farms. Herbicide use is an option for many conventional farmers while organic farms and farms in some agri-environmental schemes rely on good management and mechanical practices to achieve effective control.

**Grazing management and livestock performance**
Well managed grass provides a cheap, high quality feed for livestock (Photo 11). Good grassland management aims to maximise grass quality whilst maintaining sward structure to maximise forage intakes and can lead to faster growth rates in livestock.

Photo 11: **Well managed planted grassland**

Grazing Quality
There are 3 main factors that determine the nutritional quality of grassland:

1. Dry Matter Content (DM)
2. Digestibility (D Value) and Energy
3. Protein level

One of the best ways to control sward quality is to measure sward heights. Knowing the amount and the quality of the forage available can allow for a greater

use of grazed grass and aid management decisions. The simplest way to measure sward height is to use a ruler or tape measure with a large scale.
Some farmers take measurements as often as twice weekly during the peak growing season. To maintain sward tiller density, graze fields to the recommended 'post-grazing' height in tables 3.1 and 3.2.
Silage aftermath swards will respond differently to grazing pressure and should be encouraged to tiller before applying sward height guidelines.

**Silage**

Silage making is the efficient conservation and preservation of fresh forage to preserve a high proportion of the nutritional value of the green forage. The fermentation process occurs under anaerobic (no oxygen) conditions and has a significant influence on the quality of the silage produced. The aim is to ferment the ensiled crop as quickly as possible to maximise the production of lactic acid, achieve a rapid decline in the pH and prevent protein breakdown.
Ensure that your silage making practices meet both the Cross Compliance requirements and the 'Codes of Good Agricultural Practice'.

Grass silage from fertilised ryegrass-dominant swards is the main forage conserved for feeding during the winter on conventional farms with organic farms relying on grass+clover silage or red clover silage. Permanent pastures also make an important contribution on many farms. Other crops which are ensiled include whole-crop cereal silage and forage maize.
Good quality silage is palatable and leads to high intakes, good growth rates and an opportunity to minimise concentrate inputs. However, there are often large variations in silage quality and pontential losses (Table 8) both between farms and different clamps on the same farm. Poorly made, low quality silage not only reduces animal performance but also costs as much to produce per tonne as good quality silage.

Table 8: **Potential losses when silage is made**

| Stages in the conservation and feeding of silage | potential losses (%) |
| --- | --- |
| Field losses during harvesting | 2-12 |
| In-silo losses from respiration and fermentation | 5-18 |
| Losses in silage effluent | 0-8 |
| Feed-out losses due to aerobic deterioration | 1-10 |

**Haylage**

Haylage is a high dry matter and palatable feed. Haylage is a fermented, less acidic forage with a pH of 5.5 or above. Good quality haylage depends on fast fermentation andan inoculant can be applied during baling.
Grass for haylage is cut at a more mature stage (50-60% DM) than for silage, but at a more digestible and less mature stage compared with hay crops.

Grass is spread for drying and raked to aid wilting. Field losses may be lower when compared with hay crops.
Chopping prior to baling will aid fermentation. Compared with big bale silage, haylage bales can be more prone to aerobic spoilage due to their reduced compaction and a higher DM content.

**Hay**
Well made hay is a palatable, non-acidic feed that can increase the intake of stock grazing low DM herbage or feeding on silage-based diets with both a low pH and DM content.
Delaying the cutting of swards with a high diversity of species to make hay, rather than silage, has environmental benefits. Removing stock early during the grazing season allows the plants to grow, flower and set seed before the crop is cut. Refer to your agri environment scheme officer for advice on the role of hay in the management of environmentally sensitive pastures.
The main disadvantage of making hay rather than silage making is the dependency on a longer period of good weather to ensure the cut crop is dried to a DM content of >82%. There is also the potential for higher field losses and a loss of feed value due to an extended drying period and a need for extra mechanical operations and handling of the crop.

**Grassland and product quality**
Improving the quality of animal products is important to meet the rapidly changing requirements of consumers who require food which is safe, healthy, traceable, of consistent eating quality, diverse and convenient. It is also important as a route for achieving product differentiation, improving competitiveness and adding-value.
Grass (fresh and conserved as silage) is very high in linolenic acid. Other major fatty acids include linoleic acid (C18:2n-6) and palmitic acid (C16:0). When compared to feeding animals on high concentrate diets, grass feeding results in higher concentrations of the omega-3 fatty acids in the meat. Feeding grass for longer periods results in higher levels of omega-3 fatty acids in the meat.
Colour and shelf-life of the meat are important aspects of the quality for the consumer. Diet not only affects fat composition but also has an important influence on colour and shelf-life. Grass feeding, in comparison to concentrate feeding, enhances not only the polyunsaturated fat content in the meat, but reduces the oxidative changes that occur during retail display, slowing colour deterioration. This is related to the delivery of beneficial vitamin E from the grass diet through to the meat. Grass fed beef has been shown to have up to 4.5 days extra shelf life compared to traditional highconcentrate diet beef. There is also some evidence, in particular for lamb, that the taste of the meat is different with grass and more preferred by consumers used to eating grass-fed lamb.
To achieve maximum benefit in terms of omega-3 fatty acids and good colour shelf life from grass feeding it is important to maintain leafy grass swards. Conserving grass as silage will retain some of these benefits of fresh grass. Wilting is a crucial factor in this: if the grass is overwilted, for example, 48 hours, it is overexposed to sunlight and will lose the beneficial fats and vitamin E through oxidation. A short, rapid wilt of 5-6 hours, followed by quick ensiling and good clamp management will help to preserve good fatty acids and vitamin E.

## *4.3. Other plants for ensilaging*

**Maize**

In milk and beef production, besides green low crop fodder, an essential feed component is maize. It is most frequently utilized as silage made from whole plants, mainly for use during the winter season; sometimes it is also used to compensate energetic requirements due to pasture feeding. It is often observed that high yield milk cows can achieve proper results only when from the energetic and feeding point of view, silage is utilized in a feeding dose.

The development of hybrid ensilage varieties can be characterized by the growth of share of corn cobs in total yield, which affects the growth of energetic and caloric value of the feed. It is important for the share of corn cob dry matter in total plant mass (about 50%) and dry matter content of whole plants to be in the range of 28–35%, which allows to achieve the highest quality of ensilaging plant material and high feed digestibility. Energetic value is growing together with growing maize maturity, but because of high sugar content and low protein content, maize is known as a very good plant for ensilaging.

The whole utilization of components present in a feed is possible due to the application of proper harvesting and ensilaging methods (Photo 12). Corn crops for ensilaging will be rational if proper machinery is applied for harvesting to guarantee proper split of plants and grain.

Photo 12: **Maize silage in plastic tube**

Maize is a plant which allows very good ensilaging in all conditions because of its low buffer capacity, which is connected with low protein content, but high content of soluble sugars. However, because of the fact, that in addition to the necessary milk acid, ensilage mass contains also bacteria of butter acid, putrefactive bacteria, moulds and leaven, conditions should be created to stop the development of all such organisms. In spite of this, it is also very important to prepare non oxygen conditions, which can be achieved by the proper compaction of maize chaff and the use of hermetic cover to avoid air access.

**Legumes**

Of perennial legumes used for the production of the bulk feed are: alfalfa, red and white clover, bird's-foot trefoil and lupine. Of annual legumes the most important are vetch and forage pea, and less significant are soy, lupine, forage fava beans, etc.

High nutritious value of voluminous mass of legumes is underused. The lesser part of total amount of legumes is used as the green mass, while the most part is conserved using different techniques. Conserving of the legumes, as well as other feed, is the inevitable need, primarily because of providing of food during the annual period of vegetation hibernation.

Livestock feed with legumes, in relation to grass feed, provides better utilization of production potential of livestock. Factors that contribute to the superiority of legumes in relation to the grass are: the animals consume larger quantities; decomposition of consumed food and the exploitation of the nutritional substances are more efficient and it contains more specific biological elements. One of the most important characteristic of legumes is the ability to use of nitrogen from the atmosphere and the preservation of ecosystems.

Red clover is one of the important forage culture of the group of perennial legumes. Behind it is white clover, bird’s foot trefoil, lupine and others. Quality, as well as in alfalfa, depends on the phase of plant development.

In terms of the content of nutrient substances for livestock feed, biomass of white clover is one of the highest forage quality. It has the high content of protein and minerals and low content of crude cellulose.

It is the one of the forage plants with the most uniform nutritional substances content during the vegetation period, meaning there is the least quality oscillations.

Forage pea and vetch are used for the production of the bulk animal feed, and rarely or very rarely soy, fava bean and lupine. Annual legumes are very important group of forage crops, because they provide high yield of green mass (30-50 t ha-1 green mass) of the excellent quality.

In the pure crop, protein content was 18-22%, 22-26% of cellulose and 33-40% NFE in the dry matter. They can be cultivated in winter, spring or summer sowing, both as a single crop or combined with grain cultures. They, also, fixate nitrogen as the other legumes.

Annual legumes, due to the tendency to lie down, are cultivated the combination with grain crops (oats, rye, wheat, etc.). The quality of biomass, in this case, depends on the proportion of legumes and grain crops. However, in some studies, annual legumes are cultivated incombination with grasses and perennial legumes. Biomass conservation, especially the biomass of perennial legumes, is followed by certain losses in dry matter. Due to that, the best is to use the green biomass (pasture). But there is no vegetation in the course of the year, and some legumes have anti-nutritive properties, and can cause certain problems in animal nutrition (bloating, etc.). So, it is necessary to conserve biomass. Hay and silage are the main forms of conserved bulk feed. The hay quality is influenced by weather conditions, so hay is less prepared and used. Its place is taken by silage. Hay is, above all, expensive feed, but the minimum amounts are necessary for normal functioning of the complex digestive system of ruminants. In many countries, there is trend to prepare and use of large amounts of silage compared to hay.

Ensilaging is the process of conservation of plant biomass and plant by-products by lactic acid. Lactic acid is the product of the natural microflora or added (inoculated) selected lactic acid bacteria strains. Suitability of plants for ensilaging can be precisely determined based on the sugar (s) content and on the buffer capacity (BC).
High buffer capacity of legumes (a consequence of the high percentage of protein and minerals - calcium) and small amounts of fermentable carbohydrates are the main limiting factors for the application of silage technology for legumes on the large scale. Therefore, since the thirties of the twentieth century, many experiments were performed around the world. The task is to find ways for the successful alfalfa red clover, pea, vetch, soybean, and etc. conservation by ensilaging. During the development of technology of silage the results of numerous experiments have been successfully used in practice (chemical preservatives based on organic acids, carbohydrate additives, wilting and biological products). Today, in Europe and worldwide, biological products and organic acids are mostly used. The main goal of the modern technologies is the making of silage with higher quality, with the smaller losses of dry matter, the maximum aerobic stability and nutritive value.
The amount of dry matter in silo mass is one of the most important factors for the level of losses of dry matter and directing the fermentation process in silo mass, especially when it comes to silo mass that is rich in protein and minerals. Wilting, or short-term drying, is certainly the least expensive solution for a successful ensilaging of legumes and mixtures of legumes and grain crops. Effective conservation of wilted crops is explained by ability of lactic acid bacteria to be active in the area withincreased osmotic pressure, while most other anaerobic microorganisms can not compete with them.
However, the possibility of wilting depends on weather conditions, and can not be always done. Also, wilting requires further engagement of mechanization and manpower for the collection of forage mass from the ground, which can easily lead to the contamination with dirt, sand and other substances. Only the biomasses of annual legumes + grain crops in the phase of the beginning of pod formation, with dry matter content about 300 g kg-1 can be successfully ensilaged without wilting, or with the direct ensilaging.

*Mixing with the easily ensilaged crops and the addition of carbohydrate feed*
The mixing with the crops that are easy for the ensilaging is usually done in the early fall, at the time of the last alfalfa cut, as well as silage maize or sorghum from the main or additional sowing. In addition, it is possible to combine alfalfa with grain crops, but in this cases is used mainly the second alfalfa cut. In such combinations, the grain crops provide the required amount of carbohydrates, and legumes enrich ensilaged mass with protein. In the studies by our authors, it is found that the maximum share of alfalfa in the combined silages with maize is 50: 50%. On the practical side, the ratio of maize and alfalfa in the mixture for ensilaging depends first of the available amount of alfalfa.

In order to provide the necessary amount of carbohydrates for lactic fermentation it is practiced to add carbohydrate feed such as ground maize (5-10%), molasses (1%), dry chopped beet (5-10%) and others.

*The use of chemical preserving agents*

The chemical conservation of crops is based on the inhibition of the plant enzymes by reducing the pH values below 4.5. Today, a small number of chemical preserving agents, mostly organic acids (formic and propionic) and their salts, are being used worldwide. One of the main reasons for this is the aspiration to produce food, both for human and livestock nutrition, as natural as possible, and to obtain the healthier products. In the last decades, in our country, numerous experiments with the use of formic acid were conducted. The effects of formic acid were compared with chemical preservative agents of mineral acids and their salts, carbohydrate additives or bacterial inoculates.

Despite very good results, these kinds of additives are not used in every country because of high prices.

*The use of biological additives*

The advantage of biological additives in relation to the chemical preserving agents is primarily in that they do not leave residua and do not negatively affect the health of livestock and on the quality of their products. Due to this, they increasingly push out the chemical preserving agents, regardless of their lower efficiency. The experiments conducted in our country confirmed the positive influence of the biological preparations, which are now applied in practice in our large farms.

The greatest effects of bacterial inoculation are expressed in the feed which are difficult to ensilage, especially legumes.

By using the homofermentative bacteria cultures the present soluble carbohydrates, which are at the border sugar minimum, are being exploited. The original products based on lactic acid bacteria contained the homofermentative microorganisms in monoculture or in the combination of several species. The majority of the experiments proved that the combination of different bacteria is more flexible in regard tothe choice of the nutritional substances, temperature intervals and other conditions, meaning they complete various aspects of their activities, in relation to the monoculture. Modern biological preparations contain Lactobacillus plantarum and other Lactobacillus species, in combination with Enterococcus, Lactococcus and Pediococcus species. In the next phase of development of this technology there is a trend of combining the lactic fermentation bacteria with celulolitic enzymes. By using these products, the intensification achieved of lactic acid fermentation of homofermentative type is achieved. Also, the decomposition of the different fractions of fibers, and at the same time increasing of the content of fermentable carbohydrates, is achieved.

Recently, a great attention is paid to the increasing of aerobic stability of silages, especially of maize silages, but, also, of other forage species, due to lactic acid being the main product of fermentation of sugar in the ensilaged mass. The lactic acid has very strong bactericide but weak fungicide properties. In contrast, acetic, byteric and propionic acid have expressed fungicide effects, so the lesser amount of these acids is even desirable in maize silages, as in the other forage species silages.

**Forage sorghum**

Forage sorghum is a large, warm-season annual grass that is adapted to Pennsylvania and can be grown as a silage crop. Forage sorghum can be a profitable alternative crop, provided that it is managed well and used in the right situations. For instance, forage sorghum is cheaper to produce and has comparable yields, but has slightly lower forage quality when compared to corn for silage. The objective of this fact sheet is to describe some attributes of forage sorghum, provide some management recommendations, and describe the potential role of forage sorghum in the forage/livestock systems used on many Pennsylvania farms.

Forage sorghum is a member of the sorghum family and is closely related to grain sorghum, broomcorn, sorghum-sudangrass, and sudangrass. Forage sorghum is best adapted to warm regions and is particularly noted for its drought tolerance compared to corn. Forage sorghum has higher temperature requirements than corn. For example, the minimum temperature for sorghum growth is about 60°F, and highest yields occur when the mean temperatures during the growing season are between 75°F and 80°F. Forage sorghums have even been grown successfully in short-season areas of Pennsylvania where 95-day corn is considered full season. Forage sorghum growth can range from 5 to 15 feet tall, depending on the hybrid. Hybrids can be fertile and produce grain yields comparable to grain sorghum, or they can be sterile and produce no grain.

Forage sorghum usually does not regrow following harvest, unlike sorghum-sudangrass or sudangrass, so forage sorghum is best adapted to a single-cut harvest for silage.

Forage sorghum silage is usually slightly lower in energy than corn silage and is similar in protein. Yields of forage sorghums are comparable to corn and can range from 15 to 30 tons per acre depending on the soil, weather, and the hybrid. Both grain sorghum and especially forage sorghum have more resistance to deer damage than does corn. Consequently, they are also adapted to fields where deer damage makes corn production unprofitable.

*Cultural practices*

Forage sorghum is most often planted in rows with a corn planter to facilitate harvest, reduce lodging, and permit cultivation for weed control. Most corn planters need special sorghum plates or feed cups to handle sorghum seed. Air planters may require a special drum or plate. Like corn, forage sorghum yields increase with narrower rows.

Planting should be delayed until soil temperatures reach 65°F at the 2 to 4 inch depth. Planters should be set to place seed at a depth of ¾ to 1¼ inches. Planting too early or too deep are two of the main causes of sorghum stand problems. It is important to pay attention to these details to ensure consistent success with forage sorghum. Forage sorghum yields also can be reduced with late planting, although not to the extent yields would be reduced with late planted corn. In most areas, yields will be maximized with a mid-May to early June planting date. Forage sorghum has performed well in no-till systems when conditions are favorable in the seed zone. It has less tolerance than corn to cool soil conditions under heavy residue or to soils that may be wet where furrow closure is a problem.

Optimum planting rates for forage sorghum are about 8 to 12 pounds of seed per acre. Seed lots often contain about 14,000 to 17,000 seeds per pound, and sorghum emergence is often about 75 percent, so these planting rates will result in plant populations of 85,000 to 150,000 plants per acre.

Many growers have found that once they develop some experience planting the crop, seeding rates in the low end of this range are adequate. Excessive seeding rates can increase the risk of lodging problems.

Forage sorghum should be fertilized similar to corn for silage. Soil pH should be maintained above 6.0 with target pH of 6.5. A forage sorghum silage crop removes large amounts of nutrients, so soil testing is essential with this crop.

Forage sorghum hybrids can vary considerably in yield potential, height, forage quality, grain content, and maturity. It is important to match the traits of the hybrid to the production situation and the desired use of the crop.

Maturity is an important consideration for the medium-season and short-season areas of Pennsylvania. Full-season forage sorghums will not mature in these areas and the crop will have to be killed by frost before harvest can begin. This causes harvest delays because of prussic acid concerns, and may result in forage quality reductions. Sorghum maturity is rated either as full, medium, and early or by the days needed to flower. Adapted forage sorghums range from full season in southeastern counties to early maturity in the short-season areas of the state. Seed suppliers can provide hybrid maturity recommendations for specific areas.

Smaller seed size and higher temperature requirements for sorghum result in slower emergence and lower seedling vigor compared to corn. Since forage sorghum is adapted to warm conditions, early season growth is also slow compared to corn. However, forage sorghum grows rapidly when temperatures rise in July and August. Sorghum will continue to grow when adjacent corn fields are exhibiting leaf rolling due to water stress. If moisture stress becomes severe, sorghum will become dormant until the stress is relieved. Severe drought stress or cool, late season temperatures may delay the maturity of the crop. Generally, this delayed maturity will not be a major problem if the crop is harvested for silage.

Forage sorghum is best utilized as a silage crop, although it can be grazed or cut for hay if managed appropriately. Like most crops, forage sorghum responds well to good silage management practices—harvest at the right moisture content for the silo, chop uniformly, fill the silo as quickly as possible, and pack the silage well. Sorghum yield and forage quality are maximized at levels between 60 and 72 percent moisture content. This usually occurs between the medium-dough and hard-dough stages. Harvesting at moisture contents higher than 72 percent may cause problems during the ensiling process and will decrease intake by cattle. Harvesting drier sorghum can reduce the energy and protein value. Forage sorghum typically dries down slowly.

For sealed silos or large upright silos, consider planting an earlier maturing hybrid or adding a dry feedstuff such as ground ear corn to reach the desired moisture level. The recommended chop length is ⅜ to ½ inch. Consider using a recutter screen if the crop is dry and the grains are hard.

This will crack more kernels and reduce the potential for kernel passage through the animals.

Forage sorghums typically have slightly lower energy values than corn silage but are similar in protein. When compared to sorghum-sudangrass, forage sorghum silage is higher in energy and lower in protein.

Because of the lower quality of forage sorghum crops compared to corn, they are best used in situations where forage sorghum yields are higher than corn or where livestock energy requirements are less than what is supplied by corn silage.

## Questions for self-evaluation

1. Which stage is the best for cutting to produce high quality hay?
2. Compare natural and planted grasslands by value and yield!
3. What effect maize silage could have on cattle nutrition?
4. What are the methods to help the fermentation of legumes?
5. When can sorghum substitute maize for ensilaging?

# 5. MANAGEMENT OF VEGETABLE PRODUCTION

New varieties and strains of particular varieties of vegetables are constantly being developed throughout the world. Since it is impossible to list and describe all of them, only some of the better performing commercial types are listed in the specific crop section, either alphabetically or in order of relative maturity from early to late. These varieties are believed to be suitable for commercial production under most conditions.
The ultimate value of a variety for a particular purpose is determined by the grower, the variety's performance under his or her management, and environmental conditions. Strains of a particular variety may perform better than the standard variety under certain conditions. Several years of small trial plantings are suggested for any variety or strain not previously grown. For a true comparison, always include a standard in the same field or planting.

## *5.1. Paprika*

**Origin and distribution**
Sweet peppers (*Capsicum annuum* L.) originate from central and South America where numerous species were used centuries before Columbus landed on the continent. The cultivation of peppers spread throughout Europe and Asia after the 1500s. Although perennials, they grow as annuals in temperate climates. They are sensitive to low temperatures and are relatively slow to establish. Greenhouse production provides most of the local source of this product.

**Production requirements**
Most sweet peppers are bell-shaped, therefore the name bell pepper is common. However, sweet peppers come in a range of shapes from round to oblong, to taper. The skin is smooth and shiny and can be a range of colours. Most peppers are green when immature, and red if allowed to ripen. However, new cultivars offer both mature and immature peppers in red, yellow, orange, purple, or brown. These are tender annuals or perennials from South America. They are green at first and change to red, yellow or purple. They contain many flat, kidney-shaped, white seeds, which are very hot tasting. When the fruit is ripe it is red or yellow, but it is used as a vegetable in the green stage.
Although these plants are technically perennials, they are not worth keeping after fruiting once. It is better to start new plants every year.

Greenhouse production of peppers is based on indeterminate cultivars in which the plants continually develop and grow from new meristems that produce new stems, leaves, flowers and fruit. In comparison, field pepper cultivars are determinate; the plant grows to a certain size, produces fruit and stops growing and eventually dies off.
Indeterminate cultivars require constant pruning to manage their growth. In order to optimise yield, a balance between vegetal (leaves and stems) and generative (flowers and fruit) growth must be established and maintained.

Kinds that are frequently grown are varieties of *C. frutescens*, which are the peppers grown in the vegetable garden and include those from which red pepper, cayenne pepper, tabasco and paprika are made.

There are many varieties of garden peppers. They are divided into two groups; the sweet peppers or mild-flavoured varieties, which are used for stuffing, salads and garnishing; and the hot peppers, which are mainly used in sauces and flavouring. The Spanish word “Chili” describes peppers of all kinds, but in English, the name is usually only applied to the pungent varieties used for flavouring. *C. frutescens grossum*, the sweet or bell pepper, is a popular vegetable.

Certain types of peppers are very pretty when grown as potted plants, especially in the fall and early winter. The best are *C. frutescens cerasiforme*, the cherry pepper and *C. frutescens conoides*, the cone pepper. The varieties of these kinds have red, purple or cream-coloured fruit displayed above the rich green foliage.

**Cultivar selection**

Bell pepper cultivars differ in such horticultural traits as fruit size, shape (e.g. blocky *versus* elongated), number of lobes, flavour, and disease resistance. Standard green bell cultivars typically ripen to red; however, specialty bell peppers include cultivars that ripen to a colour other than red. These specialty bells may be yellow, orange, brown, white, and even purple at maturity. Compared to green bell peppers, coloured bells are often more difficult and expensive to produce because a longer time to reach maturity is required.

Growers should only select adapted varieties that have the qualities in demand for the intended market. Owing to the prevalence of bacterial leaf spot in Kentucky, only hybrid varieties with leaf spot resistance are recommended for commercial production. While resistance to bacterial leaf spot has helped reduce losses because of this devastating disease, new races of the pathogen have been isolated to which there is currently no resistance.

**Climatic requirements**

*Temperature*

Pepper is a warm-season crop, which performs well under an extended frost-free season, with the potential of producing high yields of outstanding quality. It is very vulnerable to frost and grows poorly at temperatures between 5 and 15°C. The optimum temperature range for sweet pepper growth is 20 to 25°C.

The germination of pepper seed is slow if sown too early when soil temperatures are still too low, but seedling emergence accelerates as temperatures increase to between 24 and 30°C.

The optimum soil temperature for germination is 29°C. Low temperatures also slow down seedling growth, which leads to prolonged seedling exposure to insects, diseases, salt or soil crusting, any of which can severely damage or kill off the seedlings.

High temperatures adversely affect the productivity of many plant species including green pepper. Sweet pepper requires optimum day/night temperatures of 25/21°C during flowering. The exposure of flowers to temperatures as high as 33°C for longer than 120 hours leads to flower abscission and reduced yields. Pollen exposed to high temperatures (>33°C) normally becomes non-viable and

appears to be deformed, empty and clumped. Temperatures lower than 16°C can lead to fruitless plants. Higher yields are obtained when daily air temperature ranges between 18 and 32°C during fruit set (Photo 13). Persistent high relative humidity and temperatures above 35°C reduce fruit set. Fruit that is formed during high-temperature conditions is normally deformed. Sweet peppers are also very sensitive to sunscald.
Fruit colour development is hastened by temperatures above 21°C.


Photo 13:

**Notice on climate control panel in a Hungarian greenhouse for the workers:**
**"ALWAYS the plants demands are the first in the greenhouse!"**

**Soil requirements**
Bell peppers prefer deep, fertile, well-drained soils. Avoid planting in lowlying fields next to streams and rivers because these sites are subject to high humidity and moisture conditions and, therefore, especially prone to bacterial spot epidemics. Producers should also avoid fields where longresidual corn or soya bean herbicides have been used, because herbicide carry-over can cause serious damage to peppers.
Pepper fields should be located as far away from tobacco plantings as possible owing to potential spread of aphid-vectored viruses from tobacco to peppers. It is also advisable not to grow peppers after other solanaceous crops (such as tobacco, tomatoes and potatoes) or vine crops for a period of three years because all of these crops are susceptible to some of the same diseases. Peppers do extremely well following fescue sod.
Use a soil test to determine fertiliser and liming requirements. Peppers grow best at soil pH between 6.0 and 7.0. Adjust the soil pH to near neutral (7.0) for maximum yields.
To reduce the risk of Verticillium wilt and other diseases, avoid using fields in your rotation plans in which eggplant, tomato, pepper, potato and strawberry or caneberry have been planted.

**Propagation**
Pepper seed may be sown directly in the field, but most commercial farmers prefer to transplant seedlings bought from vegetable seedling growers. With direct sowing, laborious and costly activities must be carried out to ensure a good plant stand.
Emergence of directly sown peppers is hampered by soil crusts caused by raindrops, which results in poor plant stands. Frequent irrigation prior to emergence solves this problem, but it results in an unnecessary increase in water use and production cost.
Direct (*in situ*) sowing of peppers requires seed of about 2 kg/ha-1. Seedlings are produced by sowing seed in seed trays under greenhouse or shade-cloth conditions. Pepper seedlings are ready to be transplanted after 6 to 8 weeks when the seedlings are 150 to 200 mm tall.
Stands established using seedlings are more even and uniform and can achieve earlier maturity than direct-seeded plants. The use of seedlings also reduces thinning cost and can tolerate or avoid early unfavourable plant growth conditions. The quantity of seed required to produce enough seedlings for one hectare is 400 to 800 g.
Many hectares of plant beds in the open field are used to grow pepper plants for selling to farmers. However, pepper plants are somewhat more difficult to grow. They have to be transported over long distances and delivered to the field in good condition for transplanting.
Pepper plants are harmed more than tomato plants by unfavourable conditions in the plant bed, in transit, or upon delivery. Transported plants therefore, are used for a smaller percentage of the total number of hectares under peppers than under tomatoes.

**Soil preparation**
More important than fallowing in particular rotation over many years is the precaution to avoid growing peppers on the same soil more often than once in 3 or 4 years. As tomatoes and peppers are subject to some of the same diseases, neither should follow the other in successive seasons in the same soil. Soil used for plant beds should have had no peppers grown in it for 4 or 5 years, preferably never before.

**Planting**
Greenhouse peppers are sown in October through February for harvest of red fruit approximately five months later, March through July.

*Days to maturity*
The exact time to maturity varies depending on the exact variety of bell pepper. Most sweet peppers mature in 60 to 90 days after planting; hot peppers can take up to 150 days. Keep in mind, however, that the number of days to maturity stated on the seed packet refers to the days after transplanting until the plant produces a full-sized fruit.

*Spacing*
Although much of the greater part of the total area of all kinds of peppers is grown from transplants, seed is also sown directly in place in the open field, principally in some of the warmest parts of the country. Ten to 12 seeds can be planted 45 cm

apart on rows that are 75 cm apart and later thinned when 8 to 10 cm tall to 2 plants per stand. The costs of production by sowing in place are nearly the same as by transplanting, because of the costs for much more seed, thinning and additional cultivation to control weeds. Sowing in place is not generally recommended, even in places where the season is long enough to permit its use. The seedbed for raising seedlings is made 120 to 150 cm wide and as long as necessary. The soil is pulverised by forking and breaking up the clods and removing stones and straw.
One hectare requires 100 to 200 g of seeds.

**Fertilisation**
Recommendations for supplemental organic matter, fertiliser, lime and manure should be based on a soil test and a nutrient management plan. Nutrient management plans balance the crop requirements and nutrient availability, with the aim to optimise crop yield and minimise ground-water contamination, while improving soil productivity.

A soil test is the most accurate guide to fertiliser requirements. The following recommendations are general guidelines for loamy soils or when organic matter exceeds 2.5%.
The fertiliser programme for sweet pepper production depends on the type of soil, the nutrient status and the pH of the soil. It is therefore important to analyse the soil before planting to determine any nutrient deficiency or imbalances. The withdrawal quantities for sweet pepper are 1.5 to 3.5 kg N, 0.2 to 0.4 kg P and 2 to 4 kg K of fruit harvested.
Nitrogen is important for sweet pepper plant growth and reproduction. The element is mobile in the soil and leaches out easily. Split applications of nitrogen are therefore necessary to minimise leaching. On sandy soils, topdressing with lower and more frequent split applications is necessary to reduce the risk of leaching. Excess application of nitrogen promotes too much vegetal growth which leads to large plants with few early fruit. Under high rainfall and humidity conditions, too much nitrogen delays maturity, resulting in succulent late-maturing fruit.
Phosphorus plays a role in photosynthesis, growth, respiration and reproduction. It is in particular associated with cell division, root growth, flowering and ripening. Potassium is associated with resistance to drought and cold, and fruit quality. It promotes the formation of proteins, carbohydrates and oils. Phosphorus is applied before planting while potassium fertilisers are usually applied at planting time. Sweet pepper is sensitive to calcium deficiency, which normally results in blossom-end rot. The crop is also sensitive to deficiency of micronutrients such as zinc, manganese, iron, boron and molybdenum.

**Irrigation**
Many growers of fresh-market peppers, plant under black plastic mulch with trickle irrigation laid under the plastic. This provides uniform moisture and fertilisation during the growing season.
Dry conditions result in premature small-sized fruit set, which leads to reduced yields. Sweet pepper has a total water requirement of about 600 mm and a weekly water requirement of 25 mm during the first five weeks and 35 mm thereafter.
Excessive rainfall or water supply can negatively affect flower and fruit formation and eventually lead to fruit rot. Unrestricted water supply to the crop can be as

harmful as not enough water. Root rot diseases can be caused by waterlogged conditions that last for more than 12 hours; therefore drainage of the field is very important. If plant growth is slowed by water stress during flowering, blossoms and immature fruit are likely to drop off.

Irrigation is essential in arid and semiarid regions to provide enough water for pepper production (Bosland & Votava, 1999). Furrow irrigation is well known as a major factor favouring conditions leading to the development of diseases like bacterial wilt.
Drip irrigation is one method of water application that optimises water supply for pepper production and conserves water in arid regions. Drip irrigation with cultural practices like mulching generally leads to additional yield increase. Drip irrigation allows for frequent application of low levels of soluble nutrients to the root zone (fertigation). The control over the root environment with drip irrigation is a major advantage over other irrigation systems. Sprinkler irrigation requires very good quality water. However, the type of irrigation is likely to make bacterial diseases more of a problem through splashing.

**Harvesting**
Yields of 6 to 10 t/ha of bell peppers may be obtained for processing. Fresh market yields may range from 500 to 1 000 12 kg cartons per hectare. When using appropriate plasticulture techniques, yields of 1 428 12 kg cartons per hectare have been reported. Pimiento and dried chilli pepper yields range from 1 to 2 t/ha. Pepper yields are greatly influenced by the number of harvests and season. As peppers mature, their walls thicken.
Pick peppers when the fruit is firm and well coloured. In some areas, bell peppers are generally hand harvested as green mature fruit. For the fresh market, or when the fruit is to be stored, peppers should be cut cleanly from the plant, using a hand clipper or sharp knife, leaving about a 2 cm section of the pedicel (stem) attached to the fruit. A clean cut is important as such cut surfaces heal more quickly. This reduces incidence of decay in storage and during transport to the market. Care should also be exercised to ensure that the stems do not cause puncture wounds in harvested fruit. Maturity is determined when the fruit is smooth and firm to the touch (it is a function of wall thickness). Bell peppers for the fresh market must also be 8 cm in diameter and not less than 9 cm long. They can also be harvested red, which are considerably sweeter and more flavourful. Mature yellow, orange and purple bell peppers, together with red bell peppers represent a generally higher-value product in fresh market channels.
Cherry peppers are machine harvested, most successfully. Cherry types are harvested as both green and red fruit and the banana types are generally harvested as yellow, mature peppers. Jalapeño and some cherry peppers have been machine harvested successfully in other areas. Machine harvesting may be successful with other types, especially where the peppers are intended for processing.

*Harvesting methods*
Peppers are generally broken off from the plants with the stems left attached to the fruit. For sweet peppers strong cloth picking bags, which are suspended from the shoulders of the pickers, are preferable to baskets or boxes. This frees both hands for rapid and careful removal of the fruit from the plants. Hard picking containers

may become rough and sandy, and as a result cause damage to the peppers. Pepper fruit is later carried to a central point where it is graded and packed into standard baskets or put into containers for delivery to the market or processing plant. The red-ripe peppers are sometimes sun dried and stored in bags.
Care should be taken when breaking the peppers from the plants, as the branches are often brittle. Hand clippers or pruners can be used to cut peppers from the plant to avoid excessive stem breakage. The number of peppers per plant varies with the variety. Bell pepper plants may produce six to eight or more fruit per plant.

Bell peppers are harvested when they are immature and green, but when they have reached full size and maximum wall thickness. Each field is harvested multiple times by hand. Some are picked after they have ripened to red or other colours. Peppers destined for wholesale shipment are usually washed, sorted and graded on a packing line.

**Preparation for market**
Green bell peppers are hand harvested for the fresh market when they are at the mature green stage. Coloured or specialty bell peppers are allowed to ripen fully on the plant. Coloured peppers generally weigh more than green fruit.
The fruit must be handled carefully to prevent skin breakage and puncturing that could lead to decay. Cooling peppers, as soon as possible, after harvest, will extend their shelf life. Once the fruit is cooled, it can be stored for two to three weeks under the proper conditions.

**Packaging**
Nearly all bell peppers are harvested by hand, usually into bulk bins (Photo 14) or trailers for transit to a packing facility. A limited number of growers pack peppers in the field from mobile packing platforms. The fruit is graded by size and condition.


Photo 14: **Peppers in plastic bin**

The standard unit of sale is a carton holding approximately 12 to 14 kg of fruit. Some growers of specialty bell peppers pack the fruit into smaller cartons. Chilli peppers and yellow types are packaged in 7 into 11 kg lugs or 4 to 9 kg cartons. Peppers are usually packed according to the preference of the particular market/buyer.

**Storage**
Store sweet peppers at 7 to 12°C and 90 to 95% relative humidity. Sweet or bell peppers are subject to cold damage at temperatures below 7°C, and temperatures above 12°C encourage ripening and spread of bacterial soft rot. Bell peppers should not be stored longer than 2 to 3 weeks even under the most favourable conditions. At 0 to 2°C peppers usually develop pitting in a few days. Peppers held below 7°C long enough to cause severe cold damage also develop numerous lesions of Alternaria rot, which causes mould and decay of the calyx at 4°C and below and predisposes peppers to Botrytis rot.
Rapid precooling of harvested sweet peppers is essential in reducing marketing losses, and this can be done by forced-air cooling, hydrocooling or vacuum cooling. Properly vented cartons are recommended to facilitate forced-air cooling. If hydrocooling is used, care should be taken to prevent the development of rot. Sweet peppers prepackaged in moisture-retentive films, such as perforated polyethylene, have a storage life (at 7 to 10°C) up to a week longer than non-packaged peppers. The use of film crate liners can help in reducing moisture loss from the fruit.
It is commercial practice to wax fresh-market peppers. Only a thin coating should be applied. Waxing provides some surface lubrication, which not only reduces abrasions in transit but also reduces shrinkage; the result is longer storage and shelf life. Senescence of sweet peppers is hastened by ethylene.
Therefore, it is not a good practice to store peppers with apples, pears, tomatoes, or other ethylene-producing fruit types in the same room. Lowoxygen (3 to 5%) atmospheres retard ripening and respiration during transit and storage. High concentrations of carbon dioxide delay the loss of green colour. However, high carbon dioxide also causes calyx dis colouration.

### *5.2. Tomato*

The tomato (*Lycopersicon esculentum* Mill.) is the most widely grown vegetable in the United States. Almost everyone who has a garden has at least one tomato plant. They can even be produced in window box gardens or in single pots. Commercially, it is of equally great importance. From processing to fresh market, and from beefsteak to grape tomatoes, the variety and usefulness of the fruit is virtually boundless.

**Soil requirements**
Tomatoes can be produced on a variety of soil types. They grow optimally in deep, medium textured sandy loam or loamy, fertile, well-drained soils. Avoid sites that tend to stay wet. Also, rotate away from fields that have had solanaceous crops within the past 3-4 years. Select sites that have good air movement (to reduce disease) and that are free from problem weeds.

In field production, plants depend on the soil for physical support and anchorage, nutrients and water. The degree to which the soil adequately provides these three factors depends upon topography, soil type, soil structure and soil management.
For tomato production, proper tillage is crucial for adequate soil management and optimal yields. Land preparation should involve enough tillage operations to make the soil suitable for seedling or transplant establishment and to provide the best soil structure for root growth and development.
The extent to which the root systems of tomato plants develop is influenced by the soil profile. Root growth will be restricted if there is a hard pan, compacted layer or heavy clay zone. Tomatoes are considered to be deep rooted and, under favorable conditions, some roots will grow to a depth of as much as 10 feet. The majority of roots, however, will be in the upper 12 to 24 inches of soil. Since root development is severely limited by compacted soil, proper land preparation should eliminate or significantly reduce soil compaction and hard pans.
Tillage systems using the moldboard (“bottom” or “turning”) plow prepare the greatest soil volume conducive to vigorous root growth. This allows the development of more extensive root systems, which can more efficiently access nutrients and water in the soil. Discing after moldboard plowing tends to recompact the soil and should be avoided.

**Transplanting**
Seeding tomatoes directly into the field is not recommended due to the high cost of hybrid seed and the specific conditions required for adequate germination. Most tomatoes are transplanted to the field from greenhouse-grown plants. Direct seeding has other disadvantages:

1. Weed control is usually much more difficult with direct seeded than with transplanted tomatoes;
2. direct seeding requires especially well made seedbeds and specialized planting equipment to adequately control depth of planting and in-row spacing;
3. because of the shallow planting depth required for tomato seed, the field must be nearly level to prevent seeds from being washed away or covered too deeply with water-transported soil; and
4. spring harvest dates will be at least 2 to 3 weeks later for direct seeded tomatoes.

At 59, 68 and 77°F soil temperature, tomato seed require 14, 8 and 6 days, respectively, for emergence when planted ½ inch deep.
Typically, 5- to 6-week old tomato seedlings are transplanted into the field. As with most similar vegetable crops, container-grown transplants are preferred over bare root plants. Container grown transplants retain transplant growing medium (soil-substitute) attached to their roots after removal from the container (flat, tray). Many growers prefer this type transplant because:

1. they are less subject to transplant shock,
2. usually require little if any replanting,
3. resume growth more quickly after transplanting, and
4. grow and produce more uniformly.

Tomato plants produced in a 1-inch cell size tray are commonly used for transplanting. Many growers will use a 1.5-inch cell tray for transplant production in the fall when transplant stress is greater.

Tomato transplants should be hardened off before transplanting to the field. Hardening off is a technique used to slow plant growth prior to field setting so the plant can more successfully transition to the less favorable conditions in the field. This process involves decreasing water for a short period prior to taking the plants to the field. Research shows that reducing temperatures too drastically to harden tomato transplants can induce catfacing in the fruit.
For maximum production, transplants should never have fruits, flowers or flower buds before transplanting. An ideal transplant is young (6 inches to 8 inches tall with a stem approximately ¼ inch to ⅜ inch in diameter), does not exhibit rapid vegetative growth, and is slightly hardened at transplanting time. Rapid growth following transplanting helps assure a well established plant before fruit development. In most cases, it is more economically feasible to have transplants produced by a commercial transplant grower than to grow them on the farm. When purchasing transplants, be sure the plants have the variety name, have been inspected and approved by a plant inspector, and they are of the size and quality specified in the order.
Set transplants as soon as possible after removing from containers or after pulling. If it is necessary to hold tomato plants for several days before transplanting them, keep them cool (around 55-65°F if possible) and do not allow the roots to dry out prior to transplanting. When setting plants, place them upright and place the roots 3 to 4 inches deep. Setting plants at least as deep as the cotyledons has been shown to enhance plant growth and early fruit production and maturity. Completely cover the root ball with soil to prevent wicking moisture from the soil. Tomatoes growbest if nighttime soil temperatures average higher than 60°F.
At transplanting, apply an appropriate fertilizer starter solution. After transplanting (especially within the first 2 weeks) it is very important that soil moisture be maintained so that plant roots can become well established.

**Varieties**
Select varieties on the basis of marketable yield potential, quality, market acceptability, adaptability and disease resistance or tolerance. The selection of a variety(ies) should be made with input from the buyer of the crop several months in advance of planting. Other characteristics to consider include maturity, size, shape, colour, firmness, shipping quality and plant habit.

**Irrigation**
Irrigation is essential to produce consistent yields of high quality tomatoes in Georgia. Rainfall amounts are often erratic during the growing season, and tomatoes are often grown in sandy soils with low water holding capacity. This combination of factors makes supplemental irrigation necessary for commercial tomato production.
Irrigation studies in the southeast show that irrigation increases annual tomato yields by an average of at least 60 percent over dryland production. Quality of irrigated tomatoes is also much better. Irrigation eliminates disastrous crop losses resulting from severe drought.

**L**ime and fertilizer management should be tailored to apply optimal amounts of lime and nutrients at the most appropriate time(s) and by the most effective application method(s). Fertilizer management is impacted by cultural methods, tillage practices and cropping sequences. A proper nutrient management program takes into account native soil fertility and residual fertilizer. Therefore, the first step in an appropriate fertilizer management program is to properly take a soil test 3 to 5 months before the crop is to be planted.

**Harvesting**

Fresh market tomatoes are harvested by hand in Georgia. The harvesting operation varies somewhat among growers. Mature-green harvested tomatoes are placed into polyethylene picking buckets that are carried to a flat-bed trailer where the fruit is dumped into plastic bulk bins. Each bin holds between 800 and 1,200 pounds of fresh fruit, and the trailer is positioned in the field so pickers only have to walk a minimal distance to reach a bin. Once all bins are loaded, they are transported to a centralized packinghouse where the fruit is washed, sized and packed out. Some growers avoid use of bulk bins because of potential damage to the fruit and field pack tomatoes into boxes. Some growers also combine the two approaches, with field packing of “pinks” (tomatoes that have begun changing color) and bulk harvesting of mature green tomatoes.

Good harvesting management is needed to pick high quality tomatoes. Care must be taken when harvesting “breaker” stage fruit because the riper the tomato, the more susceptible it is to bruising. Harvest crews should carefully place fruits into picking containers instead of dropping them. Research has demonstrated that a drop of more than 6 inches onto a hard surface can cause internal bruising that is not evident until after the tomato is cut open.

Bruising is characterized by water-soaked cellular breakdown of the cross-wall and locular (seed cavity) area. External bruising will be caused if pickers hurl or dump tomatoes too vigorously from the picking bucket into unpadded bulk bins. Bins should never be over-loaded because excessive tomato weight will cause bruise damage due to compression. Harvested tomatoes must be shaded to minimize heat-up while waiting for pallet bin dumping at the packinghouse. Research hasshown that bulk bin tomatoes held in the hot sun for just one hour can be as much as 25°F warmer than fruit held in the shade. Field heat can speed up breakdown after packing.

Pickers should do preliminary grading to remove decayed fruit from the plants as they harvest the field. This will prevent cross-over disease contamination to otherwise healthy, sound fruit. Wet tomatoes should never be harvested, because surface moisture increases field heat accumulations in the load and enhances disease development.

All picking buckets should be cleaned and sanitized at the end of each harvest day to prevent the potential accumulation of disease organisms from infecting sound fruit picked the next production day. Rinse buckets with water to remove soil and field debris, then wash them in a sanitizing solution consisting of 5 oz. of household bleach (5.25 percent sodium hypochlorite) mixed in 5 gallons of water.

**Postharvest handling**

The importance of care in handling tomatoes between the time of harvest and shipping to market cannot be overemphasized, since about half of the cost of tomato production is in the grading, cooling and packing of the product. Bulk bins of harvested tomatoes are taken from the field to the packing house, where they are mechanically unloaded in a water dump tank or concrete pit. Water jets convey the fruit by flume onto an inclined dewatering roller belt with soft bristle brushes that remove field debris. The fruit is then dried, pre-graded, color sorted and sized before being jumble-packed into 25-pound fiberboard cartons.

Mechanical damage (i.e., cuts, punctures, bruises, scars, scuff marks and discolored areas) accounts for more defects at the shipping point and in the market than all other defects combined. Of these, bruises are the most common and serious, comprising about half of all mechanical damage. Bruised tomatoes may be flattened or indented and soft; the locules either are dry or, if gelatinous tissue is present, it may be thick and stringy from continuous pressure or watery from severe impacts.

When tomatoes are physically injured during handling, disease organisms can easily invade the flesh, setting up decay. Bruising was the greatest contributor to tomato loss in marketing channels.

Tomatoes are scuffed and scarred when they rub against rough surfaces, such as bin boxes, pack-out cartons, dirty sorting belts, or even against each other, particularly when dirty. Tomatoes below about 60°F scuff more easily than warm fruit. Scuffing and scarring are followed by pitting and browning, because the injured tissue dries out.

Tomatoes may be bruised any time between field and kitchen by being:

1. thrown into picking box or bin;
2. pressed out of shape in a bin loaded too deeply;
3. dumped too vigorously from box or bin onto sorting belt, or dropped too far from sorting belt to shipping container;
4. squashed during stacking, loading or in transit;
5. handled roughly during sorting in the ripening room or during prepacking;
6. dumped into bulk retail display; or
7. squeezed in the hand of the customer or between harder items in the grocery bag.

External bruising mainly occurs before the fruit is packed, which allows the removal of most of the damaged fruit at origin. Internal bruising, however, occurs mainly during or after packing. The riper the fruit, the more readily it bruises. Degree of bruising under given conditions is not related to size, weight or mass of fruit in any one cultivar, however, although the latter do differ in their susceptibility to bruising.

Mechanical injury can be prevented, or at least reduced, only by careful analysis of each step during handling and by devising ways to minimize throwing, dropping or squeezing the fruit. Where drops are unavoidable, padding with 1-inch thick foam rubber substantially reduces injury. Avoid drops of 6 inches or more, whether the fruits hit a solid object or each other. Dumping fruit into water instead of directly onto a belt can help reduce bruising.

Scuffing and scarring can be minimized by keeping boxes, bins and belts clean and by packing fruit firmly but not too tightly. A loose pack allows fruits to rotate and rub against each other in transit, which leads to scuffing injury.

**Grading and packing**

Most buyers will accept only the equivalent of US No. 1 grade or higher. Tolerances for US No. 1 grade state that tomatoes should have no more than 15 percent total defects (maturity, color, shape), including 10% serious damage (scarring, bruising, sunburn, discoloration) and 5% decay (blossom-end rot) in any lot of tomatoes examined. Some buyers expect higher quality than these limits.

Georgia tomatoes are graded and packed at the breaker stage of maturity, based on size. Federal color classification requirements define “breakers” as when there is a definite break in color from green to tannish-yellow, pink or red on not more than 10% of the external tomato surface.
Tomatoes must be graded to achieve uniform shape, color and size (Photo 15). Tomatoes are sized by passing them over a series of perforated belts with holes corresponding to the maximum allowable diameter for the particular size (Table 9). Georgia growers typically pack only 5x6, 6x6, and 6x7 numeric sizes into jumble-packed fiberboard cartons to a net weight of 25 pounds.

Photo 15: **Uniform tomato in plastic bin**

Table 9: **USDA size classifications for field harvested tomatoes**

| Classification | Minimum Diameter[1] | Maximum Diameter[2] | Carton Size/Arrangement[3] |
|---|---|---|---|
| Small | 2-4/32 in. (5.4 cm) | 2-9/32 in. (5.79 cm) | 7 x 7 |
| Medium | 2-8/32 in. (5.72 cm) | 2-17/32 in. (6.43 cm) | 6 x 7 |
| Large | 2-16/32 in. (6.35 cm) | 2-25/32 in. (7.06 cm) | 6 x 6 |
| Extra Large | 2-24/32 in. (7.00 cm) | ——— | 5 x 6 |

[1] Will not pass through a round opening of the designated diameter when tomato is placed with the greatest transverse diameter across the opening.
[2] Will pass through a round opening of the designated diameter in any position.
[3] Designates number of rows of tomatoes in top layer.

### Cooling and shipping

Since the tomato is a tropical fruit, it is adversely affected by exposure to refrigeration temperatures (less than 50°F) during storage. While several cooling methods can be used, “forced air” cooling is recommended. Tomato cartons and RPCs are placed in parallel rows in front of exhaust fans in specially designed refrigerated rooms. When the exhaust fans are turned on, a negative air pressure is produced, which in turn pulls the cold air through the containers and is then lifted up toward the refrigerated units for recooling. This circular process allows

faster cooling of the product. Once tomatoes are cooled to the appropriate storage temperature, a solenoid switch turns the fans off and the room becomes a storage cooler. Forced air cooling is more advantageous than room cooling because field heat is removed more rapidly, permitting longer shelf-life of the product.
Forced-air coolers are slightly more expensive to build than conventional room coolers because of the fans and extra refrigeration capacity needed. However, proper utilization of forced-air coolers significantly enhances quality and shelf life. Once pre-cooled, colored and ripe tomatoes must be held between 50-55°F and 95% relative humidity for a 7-10 day shelf life. Pre-cooling tomatoes before loading into transit trailers is critical. Truck coolers are not designed to remove field heat from tomatoes. They have only enough refrigeration capacity to maintain temperature once tomatoes are cooled. Tomatoes loaded in a transit trailer at 90°F will likely arrive at the market at 90°F. Tomatoes will be soft and overripe and buyers will not accept them.
Tomatoes are subject to *chilling injury* when held at temperatures below 50°F if held longer than 2 weeks, or at 45°F if held longer than 6-8 days. The consequences of chilling injury are failure to develop full color and flavor, blotchy, irregular color development, surface pitting, increased decay (especially black mold caused by *Alternaria* spp.), and browning of seeds (internal).Tomatoes are also susceptible to water loss through the stem scar. Shriveling becomes evident with as little as three percent loss in weight if held at less than 85% relative humidity.
Tomatoes are moderate to heavy ethylene producers. Ethylene is a natural ripening gas produced by certain fruits and vegetables that can cause physiological and pathological disorders in ethylene-sensitive commodities. Shipping “mixed loads” of tomatoes with other sensitive commodities such as cucumbers, peppers, lettuce, and other leafy greens can cause quality problems (i.e., loss of chlorophyll, accelerated decay) in these commodities and should be avoided.

Marketing tomatoes or any horticultural product is more than just selling. Marketing includes planning, production, harvesting, packaging, transportation, distribution, warehousing and pricing. To be successful, marketing must be responsive to consumers’ demands. Simplistically, it must be customer oriented.
To add to the multifaceted problems, marketing skills are required and prior determination or knowledge of one’s targeted market is a necessary condition. Is it direct marketing, marketing to retail outlets, specialty food stores or wholesalers? Do you need any promotion? Is any specific harvest time required? All these and more questions need to be addressed. Do consumers demand quality, freshness, “reasonable” prices or all of the above?
Marketing tomatoes, or any product, is more than selling. Marketing includes production, distribution, and pricing. To be successful, marketing must be responsive to consumers’ demands. Consumers demand quality, freshness and “reasonable” prices.

**Production Costs**
Tomato growers can use enterprise budgets to estimate production and break-even costs. Budgets include cost estimates for those inputs necessary to achieve the specified yields over a period of years. Since production practices vary among

growers, each grower needs to adapt budget estimates to reflect his or her individual situation.

**Types of Costs**

Total costs of producing any crop include both variable and fixed costs. The variable or operating costs vary with the adopted cultural practices. Common variable cost components include seed, fertilizer, chemicals, fuel, and labor.

Variable costs are further broken down into pre-harvest and harvesting and marketing operations in the hypothetical budget. This provides you an opportunity to analyze the costs at different stages of the production process.

Fixed costs include items such as equipment ownership (depreciation, interest, insurance, and taxes), management, and general overhead costs. Most of these costs are incurred even if little production takes place and these costs should be considered when planning production costs.

Land cost may either be a variable or a fixed cost. Because it varies significantly from county to county, from region to region, and whether it is irrigated or non-irrigated, it is not included in this hypothetical budget. Even if you own the land, there is a cost. Land is a fixed cost in this budget even though no cost has been recorded. A fixed cost per hour of use shows ownership costs for tractors and equipment (depreciation, interest, taxes, insurance and shelter). Overhead and management are 15% of all pre-harvest variable expenses. This amount pays for management and farm costs that cannot be allocated to any one specific enterprise. Overhead items include utilities, pick-up trucks, farm shop and equipment, and fees.

**Cost/unit of production**

The cost categories are broken down in cost per unit. The pre-harvest variable costs and the fixed costs decline with increasing yields.

**Budget uses**

In addition to estimating the total costs and break- even costs for producing tomatoes, there are other uses of the budget. Estimates of the cash costs (out-of-pocket expenses) provide information on how much money needs to be borrowed. The cash cost estimates are helpful in preparing cash flow statements. In the instance of share leases, the cost estimates by item can be used to more accurately determine a fair share arrangement by the landlord and tenant.

## *5.3. Cucumber*

The cucumber (*Cucumus sativus*) is a warm-season vining crop in the Cucurbit family. Cucumbers suitable for immediate consumption are referred to as “slicers,” while those for processing are “picklers.” Although there once was a large pickling cucumber industry in Kentucky, nearly all cucumbers grown commercially in the state are now for fresh market consumption.

**Greenhouse cucumber types**

The most popular types grown in greenhouses are the long, seedless hybrid F1 varieties often referred to as English cucumbers (Photo 16). These seedless varieties are gynoecious in flowering habit (produce only female flowers), and produce parthenocarpic fruit (not needing pollination for fruit development). The fruit have thin, edible, smooth green skin, which can have slight longitudinal ridges/ribs. Varieties with shorter fruit, known as midi cucumbers are also grown for some markets.

Photo 16:

**Cucumber hybrid in greenhouse**

**Traditional seeded/field cucumber types**

The traditional seeded varieties produce both male and female flowers and require pollination to form healthy fruit, which have seeds and white spines. These are more suited to open field production, and are commonly called Field Cucumbers. In order for pollination to take place pollen must be transferred from the male flowers to female flowers. Outdoors, bees normally do the pollination under good weather conditions, but in greenhouses it is the grower's responsibility to transfer pollen. When cucumbers are not properly pollinated, the fruit will be misshapen and poorly developed, especially on the blossom end of the fruit. The fruit should be harvested when they have reached full diameter but while the seeds are still small and soft. If the fruit are light green or yellow or have hard mature seeds, the fruit are considered over-mature.

**Germination and transplanting**

The optimum germination temperature for cucumber seed is 25°C to 28°C. Daytime temperatures should be maintained between 23°C to 25°C and night temperature not lower than 18°C. Seedling must be kept moist but not water soaked. Seedlings in seeding trays could be transplanted to bags three to four weeks after germination, or the seed can be planted directly into the planting bags. Begin fertilising three days after transplanting or when true leaves have begun to emerge.

Plants should be watered frequently with the fertilizer solution. A minimum of 14 hours of strong direct light is required for developing seedlings.

**Planting spacing**
The light availability, production system and trellising method will affect the exact spacing required. Generally, under good light conditions, 2.2 to 2.5 plants per square meter should be sufficient. This should ensure good air circulation and adequate light for fruit production. A well-ventilated tunnel will have lower disease pressure and will have easier access for spraying of pest and diseases.

**Fertilization and irrigation**
In order to prevent over/under fertilizing, it is of utmost importance to have an analysis of the soil and water used for cucumber growing. This should be taken into account when calculating the fertigation program. The ECW (electrical conductivity of the water) must be taken into account when determining what the total EC should be. EC and pH should be checked when the fertigation mix flows out of the tank, again where it flows into the growing media or soil, and once more when it flows out of the growing media or soil.
Generally, to lower the pH either nitric, sulfuric or phosphoric acid may be recommended. Potassium hydroxide is usually used when it is needed to raise the pH. If the source water is alkaline as a result of high bicarbonate concentrations, the pH should be amended before the fertilizer salts are added to prevent precipitation.

**Production considerations**
Vines should be trained to run lengthwise in the row soon after vining starts. This training makes hand harvesting easier and quicker with less damage to the plants. Cucumbers can also be trellised to improve fruit quality; trellising has been most beneficial in mid-summer plantings for fall harvest.
Providing one strong hive of bees for each acre of cucumbers will help to ensure good pollination in commercial plantings.

**Pest management**
Cucumber beetle, the major insect problem of cucumbers in Kentucky, is also the carrier (vector) of one of the most serious cucumber diseases, bacterial wilt. The use of an imidacloprid insecticide at transplanting provides good protection for about 4 weeks and may be followed by regular foliar insecticide applications. Other troublesome pests include mites and squash vine borer. In addition to bacterial wilt, powdery mildew, downy mildew, gummy stem blight, belly rot, and viruses can result in crop losses. Multiple control strategies are needed to prevent or reduce disease losses. As with all vegetables, weeds can be a serious problem for growers. Black plastic mulch usually works well to remove weed pressure from within rows while areas between rows are typically cultivated and a pre-emergent herbicide applied shortly after planting.

**Harvesting**
Cucumbers are harvested as immature fruit when full length has been reached. At suitable harvest maturity, a jellylike material has started to form in the seed cavity. Cucumber production will be reduced if the fruit are left on the plant for too long. Cucumbers are hand harvested, normally 3 times per week, depending on the weather and growth stage of the plant.
Harvest at the coolest time of day and avoid any heating of the harvested product. To reduce damage and disease a sharp clean tool should be used to cut the fruit

from the plant. The harvested fruit should be placed in clean harvesting containers, kept in the shade, and taken to the pack house as soon after harvest as possible. Cucumbers should be handled carefully and care taken not to damage the thin skin.

**Postharvest handling**

Cucumbers lose moisture quickly and have the tendency to soften during storage. Marketable cucumbers should be sorted according to size and quality and individually wrapped in clear plastic.

The optimum storage temperature for cucumbers is 10-12.5ºC, at relative humidity of 95% RH.

Storage or transit temperatures below this range should be avoided as this will result in chilling injury after 2-3 days.

**Marketing**

Cucumbers are grown in Kentucky primarily for fresh market (slicing types) rather than for processing (pickling types). Some pickling types are sold at auctions and farmers markets. Fresh market options include wholesale markets, auctions, cooperatives, community supported agriculture (CSA) subscription shares, farmers markets, and roadside stands. Sales to local retail markets, such as supermarkets and restaurants, are also an option.

**Market outlook**

U.S. per capita consumption of fresh cucumbers rose about 15% (one pound per capita) from 1995 to 2005. This indicates a normal increase for quantity demanded. Consumption of cucumbers was steady from 2005 to 2009, with fresh cucumber use forecast at 6.6 pounds per capita in 2009. Prices can fluctuate, with lower prices occurring when production peaks in June. Adding value to fresh cut processing (slicing) could increase wholesale profits. A noticeable trend in the early 2010s was that restaurants showed more interest in purchasing larger lots of cucumbers for pickling at the restaurant. Kentucky’s location provides access to good wholesale markets for both spring and fall slicing cucumbers. Some Kentucky growers try to capitalize on the narrow marketing window that occurs in mid-September after slicing cucumbers from northern sources have moved from the market.

**Labor requirements**

Labor needs for irrigated cucumbers are approximately 20 hours per acre for production, plus 50 hours per acre if plants are trellised. Plasticulture will add 8 to 10 hours more per acre for the post-harvest removal and disposal of the plastic. Harvesting, washing, and packing will require about 348 hours per acre.

**Economic considerations**

Initial investments include land preparation and the purchase of seed or transplants. Additional start-up costs can include the installation of an irrigation system and black plastic mulch.

Production costs for cucumbers grown on black plastic with trickle irrigation are estimated at $1,303 per acre, with harvest and marketing costs at $2,751 per acre. Total costs (including fixed costs) are approximately $4,500 per acre.

Production costs for irrigated late summer plantings with a single strand trellis are approximately $2,003, with harvesting and marketing costs of $3,528. Total costs are approximately $6,000.
Since returns vary depending on actual yields and market prices, the following per acre returns to land and management estimates are based on three different scenarios. Conservative estimates represent the University of Kentucky's statewide average cost and return estimates for 2009.

## Questions for self-evaluation

1. What kind of harvest methods are used in different peppers?
2. What kind of storage is needed for peppers?
3. What kind of costs are in tomato production?
4. What post-harvest handling is usual in tomato?
5. What is the labour requirement of cucumber in plasticulture?

# 6. MANAGEMENT OF ORCHARDS

## *6.1. Apple*

Over the past 40 years Kentucky growers have produced apples (*Malus domestica*) using free-standing trees in low- to medium-density plantings. Today's high-density orchards have closely planted trees on dwarfing rootstocks requiring permanent support structures. Earlier production, quicker returns on the investment, and improved fruit quality are just a few of the many benefits of the new high-density systems.

Growers, however, who do not have an excellent site or a source of water for drip irrigation should not consider high density plantings. Additionally, because high density systems require a significantly greater level of grower expertise and cultural management, semi-dwarf plantings may be more suitable for producers who are new and inexperienced.

**Marketing and market outlook**

Kentucky's fresh apple market is almost exclusively retail, with very few growers selling on the wholesale market. For wholesale apple production to be profitable in Kentucky, the grower would usually need to receive a fresh price of more than \$0.25 per pound. The national average for grower prices exceeded \$0.25 per pound only twice from 1990 to 2005. The national average fresh wholesale apple prices then increased, ranging from \$0.30 to \$0.40 since 2006; even at these price levels, extensive wholesaling is not recommended for Kentucky growers.

There is a strong demand for locally grown, full-flavored, quality apples, especially varieties not commonly available in supermarkets. Direct marketing, value-added processing (cider), and entertainment farming are the primary reasons that Kentucky apple orchards can be profitable. Farmers markets, U-Pick, and roadside stands are all good outlets for selling apples. Restaurants are interested in local apples, and value-added apple products (fried apple pies, preserves, etc.) are very popular with Kentucky consumers. Apple producers may maximize profitability by developing multiple market channels based on their production volume, location, and marketing preferences. Diversifying sales between different market channels helps guard against product oversupply to any one channel.

**Cultivar selection**

Selecting cultivars that produce quality fruit in our area, perform reliably, and meet the market demand is a critical step in establishing an apple orchard. Cultivars differ in such horticultural traits as fruit characteristics (e.g. size, color, flavor, and intended use), earliness (early, mid, and late season), as well as disease and insect resistance. Tree size, which is determined by the rootstock, may be dwarf, semi-dwarf, or standard.

**Site selection and planting**

Select an orchard site that is considerably higher than surrounding areas and has excellent air drainage. Apples perform best on deep, friable, fertile soils with good internal drainage. Avoid heavy, poorly drained soils, as well as those with impervious hardpans close to the surface. Irrigation is essential for high-density plantings, so the orchard should be located near a ready source of water.

Apple planting stock may need to be ordered as much as 24 months in advance of planting to obtain commercial quantities (275 to 350 trees per acre) of the desired cultivars and rootstocks. While more costly per tree than conventional unbranched whips, planting well-branched or feathered trees can be well worth the investment by bringing the orchard into full production one year earlier. Trees are best planted in fall or early spring in rows running north and south.

**Orchard maintenance**
Pruning and training methods employed in high- density plantings are considerably different from those in conventional orchards. The goal in high- density orchards is to promote early fruiting and to discourage excessive vegetative growth. Efforts are initially focused on training limbs, rather than pruning. A permanent tree support system is essential because dwarf trees have brittle graft unions that can break; they should be in place as soon after planting as possible.

**Pest management**
There are a large number of insects and diseases to control on apples. These include the San Jose scale, codling moth, oriental fruit moth, plum curculio, stink bug, aphid, and leafhopper insects and scab, cedar apple rust, fire blight, sooty blotch, flyspeck and fruit rot diseases. The Integrated Pest Management (IPM) approach helps growers determine exactly when pesticide applications are needed. Using IPM in Kentucky can reduce the number of pesticide applications by about one third when compared with a calendar-based program. IPM involves collecting detailed data regarding the crop, pests, and weather conditions to make sound pest management decisions. Deer browsing and rubbing causes considerable damage to trees and will need to be managed through electric fencing or hunting. Voles will need to be controlled during the winter to prevent root and trunk feeding.

**Harvest and storage**
The optimum maturity level for harvest will depend on the cultivar, intended market, and whether the fruit will be stored. Color, starch level, sugar content, and firmness are important harvest indicators. Fruit is hand-picked and handled carefully to avoid bruising. Cold storage will be needed to extend the marketing season.

**Labor requirements**
A medium density system will require nearly 300 hours of operator labor per acre per year. Trees take 4 to 6 years to reach full bearing. A high- density system can require more than 2,000 hours per acre over 4 years.
An experienced apple picker can harvest about 12½ bushels of apples per hour. At a yield of 450 bushels per acre, this will require about 36 hours of harvest labor. On-farm packing and grading will require additional labor (15 to 25 hours), depending on packaging used. Packing labor can be minimized by field sorting and having customers select their own apples from retail bins.

**Economic considerations**
The cost of establishing a high-density orchard is greater than that of a lower-density orchard. Total (variable and fixed) costs for establishing an apple orchard can range from $7,500 per acre for medium-density plantings of 300 trees to more

than $14,000 for high-density plantings of 600 trees per acre. Initial investments include land preparation, purchase of trees, tree establishment, installation of an irrigation system, and construction of a tree support system (Photo 17). Pest control equipment and pesticides, including tree guards, fencing for deer control, plus an air blast sprayer for insect and disease control and a boom sprayer for weed control, will also be needed.
Annual pre-harvest production costs for each production system can come to approximately $1,500 per acre. Harvest costs will vary depending on the wage rate paid to labor and the availability of harvest equipment, but can be estimated between $1.50 and $2 per bushel. At a retail price of $20 to $40 per bushel, returns to land, labor and management from the central leader (medium-density) and high-density systems can range from $2,250, to $7,500 per acre in a full production year. Wholesale production on well-managed plantings can result in returns to land, labor and management in the $1,500 range.

Photo 17: **Apple orchard with irrigation system and net cover against hail**

## *6.2. Peach*

The peach (*Prunus persica*), which originated in China, is a member of the Rose family. In the past, commercial peach production in Kentucky has been profitable only in western counties, in southern counties, and in areas along the Ohio River. However, over the past 15 years as winters have become warmer, peach growers are also doing well in areas west of the mountains, as long as good sites that avoid late spring frosts are selected.

**Marketing**
Growers need to determine their market in advance of planting. At this time, Kentucky peaches are grown for the following fresh market outlets: farmers

markets, roadside markets, local retail outlets, U-Pick orchards, and shipping to terminal markets. Most peach sales are currently through retail markets. Produce auctions have reported a strong wholesale market for local peaches. Producers can also investigate wholesaling to restaurants. Peaches are popular in value-added products, such as ice cream, baked goods, and preserves.

**Market outlook**

Per capita peach consumption (processed and fresh) is down about 20% from levels exceeding 10 pounds per person in the 1980s and 1990s. Fresh peach consumption fluctuated between 4 and 5 pounds per capita during the 2000s. Nationally, total fresh peach consumption is dependent on production levels in California and Georgia; when production in these states declines (such as in California in 2009), grower peach prices typically strengthen. Fresh, local peaches remain very popular as a summer fruit choice.

Kentucky consumes more peaches than it produces, thus providing opportunities for additional peach production within the state. Peach acreage in Kentucky declined from 800 acres in 1992 to about 590 acres in 1997; however, state peach plantings increased to 749 acres in 2010. The continued demand for high quality locally produced commercial peaches offers promise for producers willing to invest the time and capital into further developing Kentucky's peach market.

**Cultivar selection**

Selecting hardy bacterial spot resistant cultivars that produce quality fruit, perform reliably, and meet the market demands is a critical step in establishing a peach planting. Peaches are grouped as either freestone (the flesh easily separates from the pit) or clingstone (the flesh clings to the pit). Cultivars differ in such horticultural traits as fruit (e.g. size, color, flavor, and skin texture), disease resistance, days to harvest, and required chilling hours. Many consumers prefer a high quality, flavorful freestone peach that is relatively fuzz-free. Peach planting stock is produced commercially by budding or grafting a desired cultivar onto a seedling rootstock.

**Site selection, planting and maintenance**

Selection of the orchard site is probably the most important single factor in peach production. Even in areas of the state generally recommended for peach production, the site must be chosen very carefully. The orchard should be considerably higher than surrounding areas, with good slopes suitable for air drainage. A gentle slope is ideal; however, if the site is terraced, a steeper slope can be used. Slopes should preferably face east, southeast, or northeast. Avoid protected areas, such as near wood lots, since these obstruct air flow and allow frost pockets to form. Peaches do well on a wide variety of soil types; however, they will not tolerate heavy, poorly drained soils. Planting trees on raised beds or ridges substantially increases performance because of improved soil drainage. It is generally thought that sandy soils and other lighter soil types are best.

Commercial quantities of peach planting stock need to be ordered four to 24 months in advance of planting, specifying the desired delivery date. Peaches are best planted in the early spring. Equipment size and ultimate desired tree size are factors to consider in tree spacing.

Annual pruning should be done in late spring, preferably during or after bloom, depending on the number of trees that have to be pruned. Pruning is used to develop and maintain tree size and shape. Pruning also opens the canopy for more effective pesticide coverage. Because trees set more fruit than can be matured to a desirable size, peaches are thinned. Thinning is generally done by hand.

**Pest management**
Peach tree short life and cold injury can cause serious losses in Kentucky. Following sound management practices is essential to minimizing these problems. Brown rot, bacterial spot, peach leaf curl, peach scab, and perennial canker can also cause losses. Insect pests include oriental fruit moth, plum curculio, spotted wing drosophila, and borers. An extensive regular preventative spray schedule must be followed to control insect and disease problems and to ensure high quality fruit. Mice and other rodents can also damage peach trees. Peach growers use cultivation, herbicides, and cover crops in their orchard weed management program.

**Harvest and storage**
Each tree is hand-harvested from three to five times over the course of the harvest period. The fruit needs to be cooled as soon after harvest as possible to extend fruit shelf life (Photo 18).

Photo 18: **Peach storage in wooden boxes**

**Labor requirements**
Peach production requires considerable hand labor for pruning, thinning, and harvesting fruit. Labor needs are approximately 40 hours per acre during the year of land preparation (year 0) and 32 hours per acre during planting and

establishment (year 1). Fourteen hours per acre plus an additional one hour of pruning per tree are required for general production in years 2 and 3. During the fruit bearing years (year 3+), labor needs for production and harvest total 100 hours per acre plus 1½ hours per tree for pruning.

**Economic considerations**

There is a significant start up cost, demanding management, and a time lapse of at least three years after planting before the first harvest is realized. Full production generally will not occur until the sixth to seventh year. While the initial investment may be large, well-tended trees should last 12 to a maximum of 17 years, depending on the amount of winter injury to the wood.

Initial investments include land preparation, purchase of plants, and tree establishment. A good sprayer for insect and disease control is one of the most expensive equipment items needed. Other significant startup costs can include pest control costs for young trees and purchase of cold storage facilities for direct retailing.

Total costs from land preparation to bearing age (years 0 through 2), including costs of equipment and operator labor, are estimated at $5,700 per acre. Production and harvest costs for bearing trees (3+ years) are estimated at $2,700 per acre. Based on the Kentucky average grower price reported by the USDA Economic Research Service of $0.815 per pound of peaches in 2008, expected returns above total costs for full-bearing peach trees are in the $2,000 per acre range. Prices of $1.00 per pound can produce returns over total costs of more than $3,000 per acre. U-Pick operations have the potential to reduce harvest costs and increase returns above total costs by as much as 30% to 60% per acre.

## *6.3. Strawberry*

Strawberries are adapted to many growing regions in Idaho, and commercial production is potentially profitable. Strawberries require a fairly long-term commitment, since they are normally harvested during their second, third, and fourth seasons after planting. Day-neutral (everbearing) cultivars can be lightly cropped and harvested during the year of planting in some areas. Commercial plantings are normally replaced at least every 3 or 4 years. Strawberries are very labor-intensive, and establishment and operating costs can be high.

Commercial success depends first of all on selecting and preparing an excellent site. Strawberries require well-drained soil at least 8 inches deep, preferably more. Raised beds are used for sites with shallow soil. An optimum site has a slope of about 2 to 4 percent to provide for water and cold air drainage. High organic matter concentrations are highly desirable. Optimum soil pH is between 5.0 and 7.0 (pH 7.0 is neutral). Strawberries are less sensitive to soil pH and salts than are raspberries or blueberries, and production is possible on slightly alkaline soils. Strawberries cannot tolerate drought and require irrigation.

Matching suitable strawberry cultivars to your site is also critical. There are hundreds of strawberry cultivars available, many of which are suitable for commercial production in Idaho. Strawberry cultivars vary for all cultivars in cold climate, short growing season areas are normally obtained during the year after planting and decrease during subsequent seasons due to buildups of pests and diseases.

Since strawberries are delicate and perishable, for fresh use they must be picked at least every other day during the harvest, be handled as little as possible, and be cooled immediately after picking. Under ideal conditions, strawberries have a shelf life of 8 to 10 days. Strawberries can be picked by machine, but are then only suitable for processing. Rainy weather during harvest increases the incidence of fruit rots, decreasing yields.

**Management**

Strawberry production is complex, and intensive management is needed to produce a successful commercial crop. Growers must know the physiological needs of the crop, proper cultural practices (Photo 19), and identification and control of insects, diseases, weeds, and pests. Cultural practices vary tremendously, according to growing region, production system, and cultivar.

Prospective growers must understand financing, cash flow, business management, and marketing; attention to detail and meticulous record keeping are essential. Prospective growers should also find out if local and state permits are required for producing and marketing their crop. Insurance may also be needed before food products are sold.

Photo 19: **Strawberry with straw mulch**

**Costs and returns**

Establishing and maintaining a commercial strawberry enterprise is expensive, and you should not expect a positive cash flow until the second growing season. Before purchasing land, equipment, or plants, you should develop a budget to

ensure you have idely in their cold hardiness, from 25°F to -50°F. The most popular commercial cultivars for northern climates are June-bearing types, which produce a single crop of berries during the spring or early summer beginning 1 year after planting.
Day-neutral cultivars are also available, which flower and bear fruit throughout the growing season and bear a light crop the year of planting. Double-cropping or traditional everbearing cultivars begin bearing 1 year after planting, but most are more suitable for home gardens than for commercial production. Peak yields adequate capital not only to establish and maintain a berry operation, but also to survive a poor crop or marketing year. Advance budgeting is also necessary before expanding an existing operation.

Strawberries can tolerate a wide range of soil conditions, require no trellises, and can be irrigated effectively with simple overhead or furrow systems. Thus, site preparation and equipment costs are generally lower than for raspberries. However, labor needs are generally higher, making the overall cost of establishment about the same as for raspberries. Refrigerated storage facilities will be needed for all but strictly U-pick or local direct-market operations, and deer fences are necessary in many parts of Idaho. For harvesting you will need about 8 experienced pickers per acre per day.

Strawberry prices are generally lower than those for other small fruits. From 1979 to 1990, growers in the Pacific Northwest received average wholesale prices of $0.34 per pound for processing berries and about $0.54 per pound for fresh berries. Wholesale price fluctuations of $0.10 to $0.15 per pound occurred between consecutive years during the same period.
At the present time, wholesale profits are marginal for fresh berries, and processing berries have actually sold for less than the cost of production. Profits for small-scale growers selling to direct local markets will depend upon individual production costs and selling prices.
Strawberry yields in Idaho typically range from 3,000 to 10,000 pounds per acre, depending upon cultivar, planting system, climate, and age of the planting. To put this in a national perspective, average yields in California are 47,500 pounds, and the highest-yield growers may obtain 100,000 pounds per acre each year.

**Marketing**
You need to determine your market before planting, since the type of market largely controls the selection of cultivars, storage facilities, and transportation. Whatever market you select, remember that strawberries are extremely perishable, and fresh berries must reach consumers within 2 days of harvest.

**Direct marketing**
Selling berries directly to consumers through roadside stands, farmers' markets, or U-pick operations simplifies marketing and transportation activities. Local rural markets are easily flooded, however. Market potential is better near large population centers. Most successful U-pick operations require a population of about 2,500 people within a 20-mile radius for each acre of strawberries.
In some areas, tourists represent an additional market for prepicked berries. Whatever your market is, don't grow more berries than you can sell.

**Wholesale marketing**
Selling berries in fresh or processing wholesale markets is more demanding than direct local marketing, and is normally only suitable for large producers or grower cooperatives.
Grading, packaging, storage, and transportation must meet certain standards. Transportation across state or national borders often requires special permits and tariffs. Successful wholesale marketing requires expertise in postharvest physiology, refrigeration, and transportation. In the United States, wholesale export markets for strawberries are dominated by California, Florida, Oregon, and Washington. Strawberry producers in Idaho are unlikely to have much success in exporting wholesale berries. Locally owned grocery stores and restaurants are potential wholesale outlets.

**Value-added products**
Strawberries lend themselves to purees, jams, concentrates, pastries, yogurt, and other processed commodities. Local specialty products offer potential for niche marketing, especially where there is access to tourists or a large population center.

## Questions for self-evaluation

1. What is the cost of establishing a high-density apple orchard?
2. How much labour is needed in an apple orchard?
3. What kind of maintenance is needed in a peach orchard?
4. How much time is needed for peach production after planting?
5. What does strawberry direct marketing mean?

# 7. MANAGEMENT OF VITICULTURE

## *7.1. Grape production*

Grapes (*Vitis* spp.) are suitable for either large-scale or small-scale commercial production. Typically three types of grapes are grown in Kentucky: Native American, hybrid, and European grapes. The climate in Kentucky is the limiting factor to grape production. Although American and hybrid cultivars are better suited for production in Kentucky, European (vinifera) cultivars are more desirable and potentially have the highest economic gain for grape growers and wine makers. However, vinifera cultivars are more susceptible to winter injury and diseases resulting in a lower yield, reduced fruit quality, and often vine death. Growing grapes in Kentucky can be highly successful and rewarding if the cultivars are matched to a specific site and proper production techniques are implemented.

**Marketing and market outlook**

It is critical that growers determine their marketing strategy before planting, since this is an essential consideration in selecting appropriate cultivars.

A marketing system for Kentucky's table grapes does not exist. The volume of grapes that can be marketed in Kentucky through fresh market outlets is limited and currently concentrated at the farmers market and fine dining levels. There may also be some potential for producers wishing to explore and expand markets in more populated sections of the state, especially in the Louisville and Northern Kentucky areas.

Wine grapes do offer the opportunity to market larger volumes. Several wineries operating in the state are interested in purchasing certain cultivars of high-quality, Kentucky-grown grapes. Demand does differ by variety and close communication on variety selection with wineries is a critical part of long-term planning. More wineries are utilizing production contracts, and UK has conducted specific research into this issue. Growers should also estimate their breakeven price per ton and compare their cost of production to recent prices paid by wineries.

Marketing and policy guidelines are dynamic for wine grapes and wineries. Careful attention should be paid to local and state laws governing the production and sale of wine. While wine grape production certainly can be profitable, there remains substantial policy uncertainty. That said, many new wineries are emerging onto the market in and around Kentucky, creating additional market opportunities for quality wine grapes.

**Plant and cultivar selection**

There are many grape cultivars from which to choose. Each type of grape has its own characteristic and each cultivar within these types has its own advantages and disadvantages. While all species of grapes can be used to make wine, the quality of the finished product is influenced by cultivar, fruit quality, and vine management practices. Cultivar selection will be based on site suitability, target market, and salability of both the harvest yield and final product. Well-adapted cultivars that are cold tolerant and have increased disease and pest resistance for their locale are essential components of selection.

Purchase true-to-name nursery stock that is certified virus-free.

**Site selection and planting**
Sites for grapes should have full sun exposure, good air circulation, and well-drained soil. The best sites are above the level of adjoining land, so that cold air drains away from the planting. Gently rolling hillsides with well-stabilized soil are fine; however, cultural operations are easier on level or gently sloping sites. Vines are normally planted in the spring after the risk of freezing temperatures has passed.

**Trellis construction**
Grapevines require a trellis for vine support and the production of a high quality crop. The trellis system should be chosen prior to planting and in place by the start of the second growing season. However, installing the trellis prior to planting is advantageous. The training system should be strong, long-lived, and appropriate for grape cultivar and vineyard site. This is a major vineyard investment that should last 20 years or more.

**Maintenance**
Grapevines require regular maintenance
including training, pruning, and canopy management. Weed control under trellises, maintaining row middles, and post-planting fertilization will also be required.
Training begins with young vines at the end of the first season and continues on mature vines. In Kentucky, many grape producers prefer to develop a vine that has two trunks of different ages to reduce losses in case of winter injury to one trunk.
Vineyards require regular pruning to aid in the production of large crops of high quality fruit and to keep the vines healthy. Vines are normally pruned from late winter to early spring after severe weather is past.
Canopy management commonly includes shoot thinning, shoot positioning, shoot hedging, cluster thinning, and if needed, leaf-pulling. The purpose of canopy management is to increase sunlight exposure to the grapevine canopy, provide better spray coverage, and to balance vegetative and fruiting growth that will maximize grape production each year. Balanced vines will improve fruit quality, cold hardiness, and longevity of the vineyard.

**Pest management**
Black rot is one of the most important diseases of grapes in Kentucky. Other common diseases include anthracnose, botrytis gray mold, crown gall, downy mildew, phomopsis cane and leaf spot, and powdery mildew. Fungicide applications, along with good cultural practices, are critical for the management of these diseases. Insect pests such as grape flea beetle, grape berry moth, grape cane gall maker, green June beetle, Japanese beetle, leafhopper, spotted wing drosophila, brown marmorated stink bug, and phylloxera can all attack grapes. Regular scouting is necessary to monitor diseases and insect populations. Grapes usually require 12 to 15 pesticide sprays per season.
Weeds are managed with herbicides and/or mechanical cultivation. Most grape varieties are easily damaged by the vapor or drift of either 2,4-D or Dicamba.
Birds can cause serious crop losses during some years, often depending on the availability of other wild food sources and water. Netting is the best method of

control; however, sonic bird repellents have been proved to help in some circumstances.

**Harvest and storage**

Harvest is dependent upon grape maturity in a given year and is determined by Brix, pH, and tartaric acid (TA) levels, as well as taste. Proper, calibrated equipment is needed to obtain accurate Brix, pH, and TA levels in the grape sample. Ideally, whole clusters would be sampled; however, it is common to take a 200-500 berry sample to test. Due to yearly seasonal changes in Kentucky, harvest dates for a specific cultivar may vary year-to-year. Often, the exact harvest date will be dictated by seasonal rains near full grape maturity.

Grapes should be harvested as early as possible to avoid deterioration during the heat of the day. Storage of and delivery of wine grapes is usually agreed upon between the grower and the winemaker. Table grapes are often immediately packed into 1-, 2-, or 4-quart containers or vented plastic bags for market sales.

**Labor requirements**

Labor needs per acre during the first and second years include planting (30 hours), training (30 hours), and maintenance (24 hours). A fruiting vineyard will require vine and trellis maintenance (80 hours) along with spraying and mowing operations (48 hours). Harvest will require approximately 48 hours per acre. The above numbers are generalized numbers. It is advantageous to have one full-time vineyard manager to scout for diseases, provide canopy management, and spray the vineyard. Grapevines need daily attention.

**Economic Considerations**

Producers should carefully examine their own costs and production situation before beginning production. Kentucky's climate and developing grape market can lend considerable risk for producers who do not pay the utmost attention to marketing and management. Initial investments include land preparation, purchase of planting material, and trellis installation.

*Table grapes*

Establishment costs for table grapes are estimated at about $9,000 per acre over a four- to five-year period. These establishment costs are recouped through year six. Most vines should produce a fair crop the third year and reach full bearing potential in four years.

Returns vary depending on actual yields and market prices.

*Wine grapes*

Wine grapes will be economically feasible only in areas of the state where climatic risk for production is minimized and market prices approaching $1,000 per ton are assured. Returns per acre vary considerably depending on the varieties grown and the price paid per ton. A mature planting of European-American hybrids with a yield of 6 tons per acre and gross returns of $5,700, could return $1,750 per acre to land and management.

## 7.2. Winemaking

Winemaking is the production of wine, starting with selection of the grapes or other produce and ending with bottling the finished wine. Although most wine is made from grapes, it may also be made from other fruits or plants.
Winemaking can be divided into two general categories: still wine production (without carbonation) and sparkling wine production (with carbonation — natural or injected).

The Washington wine industry has experienced rapid and diversified growth. Washington State now maintains the second largest premium table wine industry in the United States. Growth in the Washington wine industry is expected to continue due to the growing recognition of Washington wines as a high end, premium product. The number of wine grape acres planted across Washington State reflects the growth of the industry, along with the increase in number of wineries and wine sales. Wine grape acreage increased from 4,440 prior to 1992 to an estimated 27,000 in 2004. The number of wineries increased from 19 in 1982 to 368 in 2004.

Buildings
The winery buildings were considered primarily production facilities, with two-thirds of the square footage dedicated to production and storage. The remainder of the facility served as retail and office space. The structure was built for operating/production efficiency rather than aesthetics.
Each building had cat walks, windows, and bay doors and were equipped with standard lighting, electrical, and plumbing facilities. Control of the temperature throughout the winery was accomplished through commercial glycol air handlers.

Equipment
All grape presses were assumed to be membrane presses with sizes ranging from one to four tons press capacity per hour. Crush capacity on average yielded 62.5 cases (150 gallons) or 750 bottles of wine per ton of grapes crushed.
General practices in the Washington wine industry include the minimal filtration of wines, especially red wines. Many of the wineries that do filter use a plate and frame filter, rather than multiple filters such as membrane, leaf, or lees filters.
The wineries were assumed to use jacketed stainless steel tanks for fermentation and for storage (Photo 20).
Another method for fermentation and storage that has gained increasing popularity in recent years is the use of fermentation bins. Fermentation bins are stainless steel, square, open top fermenters that hold up to 350 gallons of must. Fermentation tanks range from 450 gallons to 2,500 gallons, while storage tanks range from 250 gallons to 1,000 gallons. Each winery used fermentation bins; however, the bins were utilized more by the smallest wineries. Assumptions regarding tanks included the use of glycol to control the temperature of the tanks during fermentation. Fermentation was 7 days for red wines and 21 days for white wines.

Product mix
Product mix assumptions were gathered from current Washington winery trends and from surveying the typical boutique wineries in Washington. Current trends

include the shift from white to red wine varieties. Significant white wine production is dominant in larger wineries (>50,000 cases annually) with the capabilities of producing more types of wines. Smaller wineries tend to predominantly produce red wines.

Photo 20: Stainless steel tanks for fermentation

Total investment costs
Total investment cost for all of the wineries ranged from $560,894 to $2,339,108. As the winery size increases, so does the investment cost. However, the investment costs increase at a decreasing rate.
Plant and office equipment represent the majority of a winery's investment costs.
Investment costs for plant and office equipment range from 49 to 56% of total investment.
The reason the plant and office investment cost is much higher than any other costs is because it includes building and land costs.

The second most significant investment cost is cooperage (wooden wine barrels). Cooperage initial investment costs range from 9 to over 22 percent of investment cost for some wineries.
Another relatively significant investment cost includes receiving equipment, which ranges from 6 to over 11% of a winery's total investment cost.

Operating and fixed costs
Variable operating costs were separated into the following eight categories:
1. Grapes
2. Cooperage
3. Packaging
4. Bottling
5. Taxes and fees (federal excise tax, Washington state excise tax, business and occupations tax, and Washington Wine Commission dues)
6. Full- and part-time labor
7. Marketing

8. Utilities, office supplies, and miscellaneous

Fixed operating costs were separated into the following six categories:

1. Insurance
2. Property tax
3. Maintenance
4. Depreciation
5. Loan interest expense
6. Cost of equity

Each category is discussed below.

Grape prices

Grape prices were calculated using a three-year average by variety to reflect recent price levels in the industry. The varietal average was also used to help represent the significant price differences reflected in prices for the different varieties. For the years 2002-2004, the average price per ton in Washington of Chardonnay, Riesling, Merlot, Cabernet Sauvignon, and Syrah was \$788, \$685, \$1,011, \$1,174, and \$1,201, respectively.

Cooperage

The percentage of new barrels purchased each year varies by winery and individual wine making practices. It is assumed that each winery would purchase 75% of their barrels new each year, except for the first three years, when the wineries will purchase all new oak barrels. Therefore, initially, barrels were considered an investment cost. After the third year, barrels were considered a fixed cost. With the cost of new French Oak barrels upwards of \$800, many wineries, especially smaller wineries, use alternative methods. American Oak is commonly considered an alternative to the classic French Oak. For the purpose of this study we assumed that half of the barrel requirements are met with French Oak and half are American Oak.

Packaging costs

Packaging costs, including bottles, labels, corks, capsules, and case box materials, were gathered by surveying several suppliers. The lowest quote for the packaging products was used to determine total packaging costs.

Bottling

Mobile bottling services consist of a mobile semi-truck equipped with all the necessary bottling equipment. Mobile bottling outfitters are available for all wineries to reserve during bottling. The service provides one experienced operator while the winery provides the rest of the labor. In year one, bottling occurs only for the White Riesling that is not barrel aged. In the following years, all of the wine is bottled.

Taxes and fees

Information regarding taxes was gathered from a variety of sources, primarily the Washington Department of Licensing, the Washington State Liquor Control Board, and the Bureau of Alcohol, Tobacco, Firearms, and Explosives. Licensing fees include the master license application fee and, for the Washington State Liquor Control Board, a one-time \$100 application fee, an annual fee of \$100, and a state excise tax of \$0.87 per gallon produced. Federal taxes include a \$1,000 annual tax

for proprietors of bonded wine cellars and a federal excise tax of $1.07 per gallon produced at wineries that produce less than 250,000 gallons.
In addition, there is a business and occupation tax of 0.484 percent of gross receipts. The Washington Wine Commission also charges a fee of $5.25 per ton of grapes crushed at the winery facility.

Labor
Labor information was gathered from two sources. Information regarding staffing and winery positions was collected directly from wineries in Washington State. Labor requirements were divided into full and part-time employment and increased or decreased to reflect the needs of the individual winery. The part-time wage rate was based on the average paid within the industry.
Salaries include all benefits, and taxes paid by the employer.

Marketing
Wineries spend an average of $4.15 per case for marketing wholesale wine. Estimate was adjusted using national inflation rates to be $4.86 per case in 2004 dollars.

Insurance and maintenance
Insurance and maintenance costs were calculated similarly to costs for utilities, office supplies, and miscellaneous items.

Property tax
Property tax rates were found on the Washington State Department of Revenue website. Using Benton County as the location for the winery, property tax rates are approximately $14.33 per $1,000 of assessed value. Assessed value includes the value of the land, building, and equipment investment for each size winery.

Depreciation
To calculate depreciation, the Internal Revenue Service's Modified Accelerated Cost Recovery System (MACRS) was used. Standard depreciation was calculated by the Alternative Depreciation System (ADS). This system is widely accepted for depreciating equipment and buildings for corporations. The straight-line method was used because of its advantages for cash flow.

Interest expense
Each winery has two different loans, one for equipment and one for land and buildings. The loan for the equipment is amortized over five years at an interest rate of 7.5%. The equity requirement for the equipment loan is 15% (the remaining 85% is financed). A fee of one percent was applied to each loan to cover closing costs in the first year.
The land loan is amortized over 20 years at a 6.5% interest rate. The land loan has an equity requirement of 25%, with the rest financed by debt. The closing costs for the land loan were estimated at two percent for all wineries. Closing costs includes all appraisal and title fees.

Cost of equity
Foregone returns for choosing one investment over another are considered the cost of equity or opportunity cost (the difference between one choice and the next

best alternative). The cost of equity was 11.3%, which is the historical rate of return on common stock.

## Questions for self-evaluation

1. What is the difference between table grapes and wine grapes?
2. How much labour force is needed in grape production?
3. What is covered by packaging cost?
4. What kind of investments is needed for wine production?
5. What are the fixed costs of wine making?

# 8. MANAGEMENT OF DAIRY FARMING

The importance of critical decisions that must be made is increasing, and progressive producers must continually analyze the costs and benefits of business decisions. Dairy replacement heifers are often viewed as simply another cost-of-doing business on a dairy. While replacement heifer programs following feed costs usually rank as the second largest cost of producing milk. Much like any other investment, money is spent today for a return that will not be realized until the heifer calves and enters lactation. Within the dairy heifer growing period, the highest daily expense is before the weaning and is a consequence of the liquid diet and the high labour costs associated with liquid feeding. with conventional rearing systems, typical age at first calving is usually between twenty-five and twenty-eight months and the impact is a large delay in positive cash flow (milk production) and requires a greater number of young stock to fill the gaps created by culling poor producing animals.

At the end of each year, producers need to evaluate and benchmark their dairy operations. After identifying strengths and weaknesses, summarizing and benchmarking cost of production, as well as identifying production opportunities, the producer is ready to plan a cash flow for the coming year that reflects the business climate that is expected that year. The cash flow provides a guide for both the owners and managers to understand what it takes for the farm to achieve profitable income levels and to experience adequate cash flow. But developing the cash flow plan is only the first step and, since business conditions constantly change, the producer must review the plan against actual performance on a regular basis in order to make the adjustments needed to achieve or improve on planned outcomes. The process is repeated each year as another business cycle begins.

## Table 10: Annual Cash Flow Model for Dairy Enterprise

| Dairy Annual Cash Flow | | | |
|---|---|---|---|
| **GENERAL DATA** | | **Related Operating Expenses (Overhead):** | |
| Milk Price | | Fuel and oil | |
| Total Cows | | Repairs | |
| Cows Milking | | Hired labour, Insurance | |
| Milk/Cow/Day | | Land rent | |
| Projected Milk Sales | | Machinery leases | |
| **CASH INFLOWS** | | Building leases | |
| Beginning cash balance | | Real estate taxes | |
| Milk sales (gross) | | Farm insurance | |
| Cull cow sales | | Utilities | |
| Bull calf sales | | Dues and professional fees | |
| Miscellaneous dairy sales/income | | Miscellaneous | |
| Governmental dairy payments | | **Total Related Operating Expenses** | |
| Other subsidies | | Family Living/Owner Draw | |
| Crop sales | | Income Taxes | |
| Other farm income | | Minimum ending balance | |
| **TOTAL INFLOW** | | **TOTAL OUTFLOW** | |
| **CASH OUTFLOWS** | | **Operating Surplus** | |
| Milking Cow Feed and Whole Farm Crop Expenses | | Capital Sales | |
| Seed | | Capital Purchases | |
| Fertilizer | | New Borrowing | |
| Chemical | | Loan Payments (Principal + Interest) | |
| Purchased Milking Cow Feed | | **Cash Surplus or Deficit** | |
| **Total Milking Cow Feed and Crop Expenses** | | **Change in Cash Balance (Ending - Beginning)** | |
| **GROSS MARGIN PER KILOGRAM MILK** | | **Total Outflow per Kilogram** | |
| Purchased Dry Cow & Heifer Feed | | Net Margin Needed per Year | |
| **Direct Expenses:** | | Net Margin Needed per Month | |
| Breeding & Registration | | Income Over Feed Cost (IOFC) Breakeven | |
| Veterinary & Medicine | | Total Outflow (Excl. Cap. Sales & Purch. New Borrowing) | |
| Supplies | | Minus Non-Milk Income | |
| Milk Hauling | | Total Outflow Covered by Milk Sales | |
| Milk Marketing | | Kilogram Milk Sold | |
| Bedding | | **GROSS MILK PRICE - FARM BREAKEVEN** | |
| **Total Direct Expenses** | | Basis to Use | |
| | | **Breakeven Price** | |
| | | **Beginning Annual Operating Balance** | |
| | | Annual operating borrowing | |
| | | Annual operating interest payment % | |
| | | Annual operating principal payment | |
| | | **Ending Annual Operating Balance** | |

The Statement of Cash Flows examines how cash has entered and left the financial life of farm during the year. Farmers need cash to flow into their lives so it is available to cover the family living, pay taxes, service the debt they are committed to, and to make investments in their business and personal lives.

Feed costs have typically represented 40 to 60% of the total cost of producing milk. The current volatility of milk and feed prices may increase this to 70%. The same market volatility affecting milk and feed prices is also affecting fertilizer, seed, and fuel costs, to name a few. To remain profitable, producers should be monitoring and making decisions based on their herd's "income over feed costs" (IOFC). This enables producers to make more informed decisions about feed purchases, know when to lock in milk price, or adjust the ration program to accommodate price volatility.

The one constant right now is the daily volatility of the grain market. Add to that the increasing expenses across the board because of high fuel costs and it is no surprise the increased challenges dairy producers face to maintain profitability. Now more than ever is the time to focus on the details of nutrition, feed management and forage quality. Changes in forage quality have a dramatic impact on expenses, income and forage inventories. Effective managers should do everything in their power to facilitate the harvest and storage of high quality forages to improve farm profit. Additionally, producers should plan to harvest sufficient forage tonnage to accommodate years when quality is high and monitor forage inventory at least monthly to assure that there is sufficient forage to account for differences in quality.

There are some basic steps producers can take to help manage price volatility. It does require extra time and commitment, but the payback can be substantial. The following are a few areas to evaluate.

*1. Monitor income over feed costs (IOFC).* This simple calculation can help answer some very important questions: Is the feed cost per cow appropriate for the current level of milk production? Does my IOFC fall within the recommended range? Where does my IOFC need to be to maintain profitability? The table below lists the recommended range for IOFC per cow based on gross milk price/kilogram over $0.41.

Table 11: Recommended Goals of Income Over Feed Costs

| Gross Milk Price ($/kg) | Goal - IOFC Range ($/per cow) | |
|---|---|---|
| 0.41 | 8.33 | 9.62 |
| 0.42 | 8.55 | 9.88 |
| 0.43 | 8.78 | 10.14 |
| 0.44 | 9.00 | 10.40 |
| 0.45 | 9.23 | 10.66 |
| 0.46 | 9.45 | 10.92 |

Monitoring income over feed costs is a proven way to evaluate the profitability of a dairy enterprise. When IOFC is monitored on a monthly basis, it can be a good barometer to estimate when the herd is profitable, when it is not, and when changes need to be made. There are several strategic decision-making levels related to calculating IOFC. In order to make this process user friendly, a web-based tool is available that will allow the user to determine actual feed cost per cow, their IOFC, and compare it to industry benchmarks.

Income over feed costs is a gross margin concept. Simply take the cow, value her daily output, and then subtract off the highest variable cost, which in this case is feed. What is left is gross income, which can be used to pay for other material costs, labour, machinery, interest expenses and veterinary bills and to provide the owner funds for withdrawals and loan payments.

Income over feed costs is measured in dollars per cow per day. The following equation can be used:

$$\text{IOFC (\$/cow/day)} = \text{Pmilk} \times (\text{DAMP}/100) - \text{DFC}$$

Pmilk is the all-milk price ($/kg), DAMP is “daily average milk production” (kg/cow/day), and DFC is “daily feed costs” ($/cow/day). DFC is the daily cost of feedstuffs required to produce the amount of milk reflected in DAMP.

The first approach is to compare a herd’s IOFC to a benchmark based on the value of milk output (milk production and price). The second approach is to calculate the herd’s cash flow to determine the breakeven IOFC value. The latter has more meaning as this reflects what the dairy operation needs to make in IOFC to pay bills and remain profitable. The IOFC tool will allow the producer to compare against both market conditions and their cash flow requirements.

Dairy rations consist of two basic components: home-grown and purchased feeds. These can be further divided into forages (hay and corn silage), concentrates (cereal grains, protein sources, minerals, and vitamins), and by-products (distiller’s grains, extracted sunflower and soy, bakery products). Many combinations of feedstuffs can be used to develop balanced rations.

*2. Maximize forage inclusion levels.* If forage quality is good, then now may be the time to incorporate higher levels of forage into the lactating cow ration. There are many farms successfully feeding 60 to 65% forage rations. However, to do this, forage quality needs to be highly digestible and properly fermented.

*3. Critically evaluate feed additives in the ration.* There are a lot of extras that go into concentrate mixtures. The question is: Are they working for me? It is never a good idea to remove several additives at one time, but if there are one or two that are difficult to justify why they are being fed, then maybe they can be removed. Monitor animal performance to document any positive or negative responses.

*4. Monitor dry matter intake.* This can tell you if intakes are appropriate for the level of milk production. If cows are consuming more dry matter than what is being produced, this is not good. Dry matter intake efficiency is a tool to monitor how efficient cows are using nutrients to make milk. This can be calculated by taking energy corrected milk (ECM) divided by dry matter intake. The equation for ECM =

(12.82 x fat (kg)) + (7.13 x protein (kg) + (0.323 x milk (kg). The recommended range for intake efficiency is 1.40 to 1.60. Example: a herd producing 3825 kilograms of milk, 3.6% fat and 3.1% protein and consuming 2610 kilograms of dry matter would have an intake efficiency of 1.47.

*5. Don't overlook feed costs on dry cows and heifers.* These groups of animals are not currently contributing to farm income however, they could be "eating" into your profits. The same basic feed management practices that apply to lactating cows should apply to these animals as well. Know what and how much these animals are consuming. Evaluate the benefits of the extras being fed.

Dairy cattle can be fed by different kinds of crop residues and by-products from food industry. For instance livestock industry, including dairy, can benefit from ethanol production through the consumption of the ethanol co-product distillers grain. A dairy cow typically can consume two or more kilograms of dry distiller grain per day. Distiller grain is a very cost-effective feed ingredient for lactating dairy cattle, and access to this co-product continues to grow.

According to a general approach a normal reproduction of dairy cow results less than 420 days calving interval, has no mastitis and high somatic cell count, at least 25 kilograms daily milk production which does not drop under 16 kilograms 90 days before the expected calving. In the continental climate cows are usually housed in free stall barns. At the day or some days before of calving, cows go to the calving stable. During lactation, cows are milked twice (morning and late-afternoon) or three times (early morning, early afternoon and in the evening) daily. The drying-off protocol for cows with the thirty- and sixty-days dry period consisted of a transition to the far-off ration at day seven before drying off, and milking once daily at day four before drying off cows.

Photo 21: A typical middle-sized dairy farm in Hungary

On the basis of the latest investigations shortening or cancelling the dry period has been proposed as a management strategy to improve energy balance of dairy cows in early lactation. Shortening (30 days) or omitting the dry period (0 day) results, however, also in lower milk production in the next lactation. In a meta-analysis including 22 studies, cows with a short dry period produced 1.4 kg/day less milk than cows with a conventional dry period, with an average milk loss of 4.5% in the next lactation. When the dry period was omitted, cows produced 5.9 kg/d less milk than cows with a conventional dry period, with an average milk loss of 19.1%. Some cows have less milk production loss than other cows after applying no dry period or a short one. Especially the effect of parity on milk production after a short or omitted dry period, compared with a conventional one, is mentioned in several studies. The reduction in milk production after a short dry period is larger for primiparous cows compared with multiparous cows. Other researchers reported a reduction in milk yield for primiparous cows with a short or no dry period but not for multiparous cows.

The reported parity effect would imply that selecting specifically multiparous cows for no or a short dry period will result in limited or no milk production losses. Moreover, besides parity, probably also other cow characteristics can be related to the production response of dairy cows to a short or no dry period. It could be expected that knowledge on cow characteristics that determine the production response of dairy cows to shorter dry period could be applied to optimize dairy cow management and result in economic benefits for applying an individual-cow approach with different pre-planned dry period lengths. Preferably, these cow characteristics would be available at the moment a farmer needs to decide about the dry period length of the cow (e.g., 8-12 weeks before the expected calving date).

Ideally, a decision-support model will support the decision on the economic optimal dry period length based on production and health characteristics (e.g., udder health) of the cow. Some researchers found that farms which switched completely to a no dry period management strategy had a reduced replacement rate compared with a conventional dry period strategy. Based on these results, it could be concluded that switching to no dry period for all cows in the herd could have a positive economic effect. It has, however, not yet been investigated whether opting for no dry period for an individual cow or applying an individual cow approach with different pre-planned dry period lengths within the same herd would be economically profitable.

Photo 22: A typical heifer-rearing farm in Iowa State, USA

Reduced milk quality increases costs while decreasing revenues and efficiency. Every dairy farm produces a quantity of milk which is not suitable for sale. With the rising cost of milk replacers, many producers are looking towards utilization of waste milk as a source of nutrition for their calves. Before making this management decision, several important factors should be considered:

- Waste milk frequently has a high bacteria count and may contain disease organisms not favourable to calf health.
- Both quality and quantity of waste milk varies considerably.
- Milk needed for the pre-weaned calf enterprise varies by the intensity of feeding program.
- Producers should seriously consider the effectiveness of their herd health program if there is this much “waste” milk available on a daily basis.
- There are a number of very effective pasteurizers well suited for heating waste milk to a sufficient temperature to destroy known disease organisms. However, field studies of on farm pasteurizers reveals that failure to reach sufficient temperature and time of heating is not uncommon. According to several recommendations routine testing of pasteurizers is advised. Operation and maintenance of a pasteurizer system requires additional skilled labour.

Using saleable milk rapidly escalates calf feeding costs. Strongly consider all costs in using waste milk in comparison to use of a high quality milk replacer which can supply nutrients more consistently as well as valuable additives to enhance nutrition and animal health.

Dairy producers on many small to moderate size operations often assume dual roles of management and labourer, milking worker or feeder and manager. Getting consumed by daily tasks can be an obstacle to effective farm management on dairies of any size. Dairy producers should invest time in managing the key profit centre on the farm. Management time should be devoted to identifying and addressing obstacles to production. Here are some questions to help refocus a manager when sitting down with their records.

1. Is nutrition or cow comfort limiting production? What are the production trends? Did yield change with a diet change? How many cows are lying for at least 12-14 hours per day? Does production decline significantly during hot weather?
2. Is fresh cow management limiting production? How are peak yields trending? Are greater than 5% of cows leaving the herd in the first 30 days, or greater than 10% in the first 90 days? What are the rates of fresh cow problems, retained placenta, metritis, and milk fever?
3. Is mastitis limiting production? What are current and past somatic cell count scores? Are new infections and chronic cases each <10% of the herd?
4. Is heifer development limiting production? Are 1st lactation cows peaking at 80% of 2nd lactation cows or 75% of 3rd and later lactation cows?
5. Is reproduction limiting production? Is the 21 day pregnancy rate 20% or better during most of the year?

Once a deficiency is identified, more detailed information can be attained and action steps taken to address it.

Regardless of one's perspective, finding the right dairy information system is critically important to the profitability of a dairy operation. Having accurate, current information to make operational and financial decisions is the key. Dairy information systems have changed much in recent years, largely due to advances in computer technology. While handwritten notes are simple and cheap, they don't allow for the summarization and data sorting needed to effectively monitor herd status and trends, particularly as herd size increases.

Information needs vary from herd to herd due to differences in herd size, milking facilities, feeding programs, labour, etc. Several things should be considered when putting together the right information system. First, the system should have a positive impact on profitability; it should be within the operation's means when considering the cost, and it should give the producer tools to make better decisions that affect the bottom line. The system should also be flexible, easy to use, and must provide the necessary information to manage the operation.

As we could see there are many things that make dairy farms successful today. There is one thing, however, that encompasses all of the things and actually makes all of them more effective. Keeping detailed records may be one of the most important things farmers can do to improve the profitability of their dairy enterprise. It is important that someone else knows where and how farmer keeps the records, in case of an emergency. Record keeping should be part of farmer's plan for continuous improvement.

It is worth to keep records of crops: what was planted, where, and when. Record crop harvest dates and yields. With nowadays focus on environmental awareness, farmers should have a nutrient management plan that includes how much fertilizer and chemicals are applied to each field, and when they are applied.

Photo 23: Automated record keeping

Cow records can tell farmers where they came from, where they are now, and help shape where they will be. There are three main aspects of cow record keeping. The first is the cow herself. Some may think this means registered versus non-registered cattle, but in fact it is important to keep records and identify all dairy cattle regardless of registry status. Properly identifying cows, their offspring are very important for making mating decisions. These records can help reduce inbreeding and increase the profitability of farmers' dairy enterprise. They can also be used to evaluate past breeding decisions.

Second, farmers are recommended to keep detailed health records. Health records can be very useful in identifying when animals are getting sick and how quickly they recover. These records also should include treatments with withdrawal times for any antibiotics used. This can prevent antibiotic residue violations. Producers may also be able to use these records to evaluate performance later.

Third – and maybe the most important – are production records. It would be suggested using a system that can keep the cow records up to date at least weekly, this is particularly important for looking at pregnancy rates. Production information records are important for evaluating many things on a whole herd scale or an individual cow. Whole herd information can be used to determine changes in management or changes in forages. Individual cow information can be used to make culling or breeding decisions.

Farmers rely on the manure to fertilize the fields and crops to feed their cows. However, treatment of manure needs thorough attention because poorly ventilated facilities pose health problems for cattle. Toxic gases from manure can lead to respiratory problems in cows, which can ultimately affect milk production and reproduction. Sick cows eat less which in turn reduces milk production and creates an unstable energy balance leading to reproductive problems.

Photo24: Wellbeing of the animals is one of the bases of proper production

The most important equipment on a dairy farm is in the parlour. This equipment is critical for the proper realization and storage of the dairy farm main yield and will function best if provided routine maintenance. It is expensive to service and maintain equipment; however, the costs of not doing routine maintenance are far higher. Weighing the investments already made against the replacement costs of the equipment on hand highlights that maintenance truly pays dividends in the long run.


Photo 25: Milking parlour

Progressive dairy managers often find themselves managing people as much or more than they manage animals and equipment. The primary objective of a job description is to help employees and supervisors reach a mutual understanding about important details of a job in order to avoid future problems. Job descriptions should never be considered final; they should be open to changes and should be reviewed at least once per year by both employee and supervisor. Below, you can find a possible sample of job description at a dairy farm.

***Job Title***
Milking Parlour Operator

***Summary***
The parlour operator prepares the milking equipment and bulk tank, milks cows, and cleans equipment and facilities. He/she is responsible for basic maintenance of parlour equipment and some record keeping. Follow-up animal care as prescribed by the herdsperson is also required.

***Qualifications***

- Stand and walk for up to 6 hours
- Lift up to 30 kilograms
- Accurately follow directions
- Gently and patiently handle cows

***Duties***

- Prepare milking equipment
- Prepare and milk cows
- Clean and sanitize milking equipment
- Clean milking parlour and milking house
- Detect mastitis or abnormal milk
- Perform follow-up treatment as directed by herdsperson
- Other duties as assigned

***Relationships***
The work is supervised by the parlour manager. Works closely and maintains communication with parlour manager, other parlour operators, and the herdsperson.

***Hours***
Full-time parlour operators work 45 to 55 hours per week. Milking shifts typically last 6 hours. The parlour manager maintains the milking schedule.

***Compensation***
Parlour operators start at EUR__.__ per hour for a probationary/training period of 90 calendar days. After the 90-day probationary/training period, qualified parlour operators base pay increases to EUR__.__ per hour. The parlour manager will determine if a milker is qualified based on established work quality and efficiency standards found in the incentive program. Qualified parlour operators who receive

cross training to become qualified to work in other parts of the business are eligible for pay increases.

**Questions for self-evaluation**

1. Which is the most significant cost of milk production? What is the economic impact of that on the profitability?
2. How does the annual dairy cash flow model build up?
3. How can farmers manage price volatility?
4. What are the most important reproduction and technological conditions of successful milk production?
5. What is the role of job description and what does it contain?

# 9. MANAGEMENT OF BEEF CATTLE FARMING

Cattle meat production is divided into two production sectors: cow-calf operations and beef cattle fattening. The cattle cycle refers to cyclical increases and decreases in the cattle herd over time that arises because biological constraints prevent producers from instantly responding to price. In general, the cattle cycle is determined by the combined effects of cattle prices; the time needed to breed, birth, and raise cattle to market weight; and climatic conditions. If prices are expected to be high, producers slowly build up their herd sizes; if prices are expected to be low, producers reduce their herds. The cattle cycle averages 8-12 years in duration, the longest of all meat animals, but the effects of persistent dry conditions on pastures and harvested forage supplies can shorten or extend cycles.
Eventually, farmers intend to maximize the net cash farm income and net farm income. Net cash farm income is gross cash income less cash expenses. This indicates the cash earnings realized within a calendar year from the sales of farm production and the conversion of assets, both inventories and capital consumption, into cash. Net cash income is a solvency measure representing the funds that are available to farm operators to meet family living expenses and make debt payments.

Photo 26: Beef cattle keeping in pasture

Net farm income is net cash farm income less charges for depreciation and the value of noncash benefits for hired labour, plus the value of commodity inventory changes and nonmonetary income. Net farm income is a value of production measure, indicating the farm operators’ share of the net value added to the national economy within a calendar year, independent of whether it is received in cash or a noncash form such as increases or decreases in inventories and imputed rental for the farm operator’s dwelling Cow-calf operations are located throughout the world, typically on land not suited or needed for crop production.

These operations depend on range and pasture forage conditions, which in turn depend on variations in the average rainfall and temperature for the area. Beef cows harvest forage from grasslands to maintain themselves and raise a calf with very little, if any, grain input. The cow is maintained on pasture year round, as is the calf until it is weaned. If additional forage is available at weaning, some calves may be retained for additional grazing and growth until the following spring when they are sold.

Photo 27: Water supply and electric fence in the pasture

The importance of having an animal identification system was highlighted during 1986-88 when bovine spongiform encephalopathy (BSE), or mad cow disease – a fatal neurological disease – was identified in cattle herds of the United Kingdom. Subsequent testing found BSE to be widespread among the UK cattle population, resulting in the slaughter of 3.7 million head. In May 2003, several United States Government agencies announced that Bovine Spongiform Encephalopathy (BSE – also known as Mad Cow disease) had been found in a cow in Alberta, Canada. All beef and cattle exports from Canada immediately stopped, devastating the Canadian beef industry, where approximately half of annual production is exported. The following December, agencies reported that BSE had been found in a cow in Washington State. Both of these sets of announcements had the potential to influence consumers’ food choices and retail food markets. Consumers and food suppliers might both gain if consumers do not avoid foods that are safe. When consumers make informed risk decisions, they create incentives for food suppliers to take cost-effective safety precautions. During the past 20 years, however, protecting consumer confidence in beef products has emerged as an additional motive. The identification of the animals by ear tags is one of the most important elements of traceability.

Photo 28: Cow and calf both have ear tag

On one hand several beef cow-calf production occurs on large farms, but cow-calf production is not the primary enterprise on many of these farms. Most farms with beef cows do not specialize in beef cow-calf production. Actually, beef cow-calf farms operate in a sector characterized by large numbers of small farms. Many of these farms specialize in beef cattle production, but farm households on these operations tend to generate more income from off-farm sources, such as wages and salaries or retirement income, than from the farm businesses themselves. These findings suggest that operators of beef cow-calf farms, large and small, have varying goals for their cattle enterprises, of which farming as a lifestyle choice is not uncommon.

The majority of beef cow-calf farms produce calves that are sold at or shortly after weaning. These are usually small farms. Many of the farm households on these operations generate most of their income from off-farm sources. Certain beef cow-calf farms retain ownership of calves after weaning and continue grazing the calves from 30 to 90 days before selling. These farms are generally larger, have more beef cows.

Economies of scale in beef cow-calf production suggest that farms have an incentive to become larger. However, the significant land area required for large-scale beef cow-calf production inhibits many producers from expanding. In most areas, beef cow-calf production is the residual user of land. As the opportunity cost of pasture increases for uses such as crop production or recreational activities, the size of beef cow-calf operations may be limited or fragmented into smaller units. In the United States, specialization in cattle production increases with farm size and peaks at 60 percent of farm product value for operations with 250-499 beef cows. Among the largest operations, those with 500 or more cows, less than 50 percent of farm product value is from cattle.

Beef cow-calf operations are located typically on land not suited or needed for crop production. These operations depend on range and pasture forage conditions, which are in turn dependent upon variations in the average level of rainfall and temperature for an area. Beef cows harvest forage from grass and range lands to maintain themselves and raise a calf with little grain fed. Forage availability determines the stocking capacity of pasture land and can determine whether calves are sold at weaning or retained for additional grazing and growth.

Feeder cattle prices and supplemental feed costs are important factors affecting the profitability of beef cow-calf production. Feeder cattle prices are affected by prices paid for slaughter cattle, which in turn, are affected by consumer demand for beef as reflected in retail beef prices. Cow-calf producers respond to high (low) feeder cattle prices by increasing (decreasing) production, but biological constraints of cattle prevent producers from instantly responding to price. This gives rise to the cattle cycle – cyclical increases and decreases in the cattle herd over time, determined by the combined effects of cattle prices; the time needed to breed, calve, and raise cattle to market weight; and climatic conditions.

Beef cow-calf production costs are sensitive to the amount of supplemental feed, in addition to grazing, that is required to over-winter, feed during drought, or otherwise maintain beef cows during the year. There is a cost advantage for producers in areas with a longer grazing season and milder winter, thus requiring less supplemental feed. Other factors shown to influence beef cow-calf production costs are investments in machinery and equipment, calving percentage, calf death loss, and length of the breeding season.

Commercial beef cattle production can be classified into three phases:

1. cow-calf: cow maintenance during breeding, gestation, and calving to when calves are weaned from between six and nine months of age, weighing 180-300 kilograms;
2. stocker: addition of 100-200 kilograms of extra weight to weaned calves over three-eight months; and
3. feedlot: finishing of calves, usually on a combination of forage and grain, to a slaughter weight of 450-700 kilograms.

Photo 28: Timing of the calving is crucial condition of competitiveness

In most of the cases, beef cows are bred during the summer in order to calve nine months later in late winter or early spring. This system takes advantage of abundant summer pasture for cattle grazing at a time when lactating cows have their greatest nutritional requirements. In midwinter, most cows are not lactating and thus have lower nutritional requirements. Late winter calving also fits into a slack labour period on most farms.

Autumn calving is used on some operations. In this system, calves are born in mid to late autumn and marketed anywhere from late spring to early summer. An advantage of this system is that calves are old and large enough by spring and early summer to utilize grass pastures. Autumn calves are typically heavier at weaning than spring calves, but the greater cost of feeding a lactating cow through the winter may offset any additional value from the heavier calf. Autumn calving may also interfere with harvesting field crops on some farms.

The ideal time of year for calving on a beef cow-calf operation depends on the forage and/or feed supply, available labour, and the intended marketing dates. Also important is a controlled, scheduled calving season (sixty-ninety days), as opposed to year-round calving. A defined calving season also means that the calves are more uniform in size at marketing.

With a controlled, scheduled calving season, such as spring or autumn calving,

1. most herd management practices can be performed at the same time,
2. use of time and labour can be concentrated and efficient,
3. non-breeding cows can be more easily identified, and
4. a more uniform calf crop can be produced.

Calves are weaned at 180-300 kilograms, at six-nine months of age. Calves are either sold directly after weaning or kept on the operation in a preconditioning program, often referred to as backgrounding, before being sold. It is common for beef cow-calf producers to retain calves after weaning and conduct the stocker phase on the same operation, often referred to as backgrounding calves.

Backgrounding is an intermediate stage sometimes used in beef cattle production that begins after weaning calves and ends when calves are placed in a feedlot to be fed to a slaughter weight. Feeding during the backgrounding phase relies more heavily on forages (e.g., pasture, hay, crop residues) in combination with grains to increase a calf's weight by several hundred pounds before it enters a feedlot (see stocker calves). Backgrounding is often conducted on farms where calves are born, but some farms specialize in backgrounding cattle.

Some cow-calf producers also purchase calves for backgrounding, and weaned calves may be backgrounded on specialized stocker operations. The decision to sell calves at weaning or to retain ownership or purchase calves for backgrounding is made each year based on cattle prices and forage availability. Cow-calf/stocker producers, acting as speculators, distribute the seasonal inventory of calves on the market across the year.

Relatively few cow-calf operations finish calves in farm feedlots. Instead, most calves are finished in large commercial feedlots that purchase most or all feed ingredients, employ nutritionists and veterinarians, and buy and sell cattle regularly. About half of all beef cow-calf operations hold calves zero days after weaning. Selling calves at weaning is the most common among small operations. Cow-calf/feedlot farms were most often located in areas where corn and other crops are readily available for finishing cattle, while cow-calf only farms were located more often in areas with abundant pasture.

The technologies and practices used on beef cow-calf farms vary substantially. Cow-calf only producers are less likely than other cow-calf producers to use many beef cow-calf production practices, including a defined calving season, artificial insemination and veterinary and nutritional services. Information management technologies, including on-farm computer recordkeeping systems and the Internet, are also used less often on cow-calf only operations than on cow-calf/stocker and cow-calf/feedlot operations. Information management technologies are systems or processes that provide the information necessary to manage operations more effectively. Examples used on beef cow-calf farms include individual cow records, on-farm computer records, and beef cattle information accessed from the Internet. Differences in the use of management technologies may be due to time available for cow-calf production given that more operators of cow-calf only farms worked primarily in other agricultural branches and off-farm as well.

Although beef cows are kept on pasture land throughout the year in some areas, few producers can depend on grazing alone to furnish a year-round supply of forage. In parts of the world, snow cover occasionally prevents grazing during the winter. In the northern regions, farms may be required to purchase supplemental forage to sustain beef cows during the winter. In other parts, growth and nutritive content of pasture plants limit grazing during part of the year. Thus, most producers feed cows some harvested forage almost every year. These harvested forages are a substantial production cost for producers in some areas.

Cow-calf herds are grazed not only on range and pasture lands but also on land primarily used for other purposes. In some areas of the world, wheat can be grazed for a period during the autumn and winter before being harvested for grain later in the year. Crop residues are also grazed in some areas for limited periods following the harvest of corn, grain sorghum, and other crops. Feed costs, including purchased feed, harvested forages, and grazing, frequently account for about two-thirds of the total operating costs of beef cow-calf production. Regional variation in climate and grazing conditions affects the calving and weaning practices of beef cow-calf producers. Climatic differences among the regions affect beef cow-calf feed costs.

The emergence of large dairy and hog farms and the continued shift in production to such farms is well documented, but less is known about the economics of large-scale beef cow-calf production. Langemeier et al. (2004) found evidence of economies of scale (decreasing costs as size of operation increases) in beef cow-calf production using the National Cattlemen's Association-Integrated Resource Management-Standardized Performance Analysis (NCA-IRM-SPA) database. The findings indicate that average economic costs per cow for operations declined with farm size up to 500-999 beef cows, but average economic costs per cow were 10 percent higher on operations with 1,000 or more cows than for those with 500-999 cows. The study used data from 206 herds in 20 States that were part of the NCA-IRM-SPA database. Short (2001) also reported finding economies of scale in beef cow-calf production using a larger database, but the largest size group included in the analysis was 250 or more cows. Economies of scale in beef cow-calf production have also been documented in other studies.

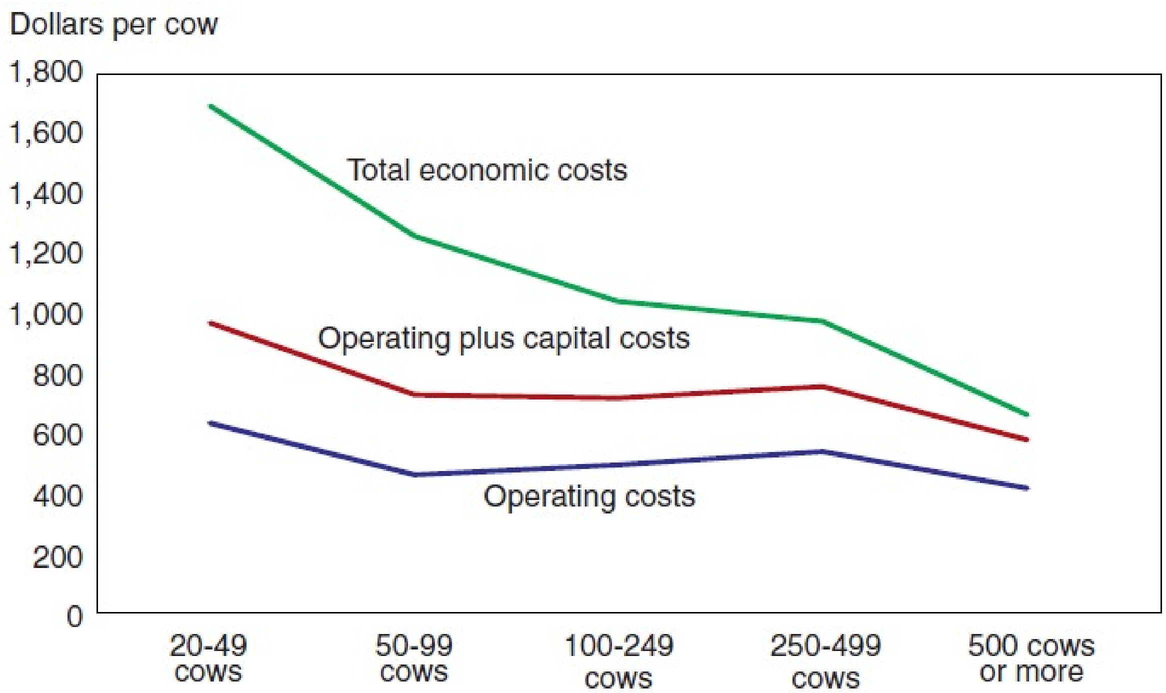



Figure 20: **Beef cow-calf cost of production per cow by size in the US**

*Notes: Production cost estimates for operations with less than 20 beef cows are not available because the sample is limited to operations with 20 or more beef cows. The number of cows refers to the peak number on the operation at any time.*
Source: McBride – Mathews (2011)

Figure 20 illustrates the relationship between costs of production and size of operation for beef cow-calf operations. Operating, operating plus capital, and total economic costs (see glossary) per cow are highest among the smallest (20-49 cows) producers and lowest among the largest (500 or more cows). Significant economies of scale are achieved by moving from the 20-49 cow herd size to the 50-99 cow herd size. Between the 50-99 and 200-499 herd sizes, operating and operating plus capital costs per cow are much the same for the three size groups. With significant economies of size achieved by operations with 50 or more cows, one would expect operations with 1-19 cows to have much higher costs, especially capital and labour costs, than other operations.

Operating costs of beef cow-calf production are the costs for purchased input items that are consumed during one production period. These are feed; cattle purchased for backgrounding; veterinary services; marketing; custom services and supplies; fuel, lubrication, and electricity; repairs; hired labour; and operating capital.

Total economic costs of beef cow-calf production are the full costs of all resources engaged in the beef cow-calf enterprise. These include operating plus ownership costs, opportunity costs for unpaid labour and land, and general farm overhead costs.

Total economic costs, primarily due to charges for unpaid labour, reveal economies of scale across all size groups, and the largest farms (500 cows or more) have significantly lower costs per cow than all other farms. Capital and labour costs are much lower on larger operations because they are able to spread fixed units of these resources over greater production. For example, farms with 20-49 cows reported using 31 hours of labour per cow (29 unpaid hours), compared with 6 hours per cow (2.5 unpaid hours) on farms with 500 or more cows. Even if charges for unpaid labour are omitted from production costs, significant economies of scale remain.

Calving and weaning practices used on beef cow-calf operations varied significantly by size of operation. The largest beef cow-calf operations were more likely to follow a defined calving season than smaller operations. The smallest operations were more likely to sell calves at weaning, whereas the largest were more likely to add value to the calves after weaning by backgrounding.

Unlike farms in other livestock industries, most farms with beef cows do not specialize in beef cow-calf production. For example, on hog and dairy farms, the average share of farm product value from hog and milk production is more than 70 and 80 percent, respectively. On farms with beef cows, less than 40 percent of farm product value stems from cattle production in several cases. Part of the farm product value is from the production of harvested forages that are fed to cattle. The value of these forages is not counted as part of the value of beef cow-calf production. The degree of specialization in beef cow-calf production varies significantly by region. Size of operation as measured by the number of beef cows did not necessarily indicate specialization in beef cow-calf production.

## Questions for self-evaluation

1. What does cattle cycle mean?
2. How can beef cattle farms be characterised in the sense of size and specialization?
3. What is the economic role of the timing of calving?
4. How can you take into account the economies of scale in beef cattle farming?
5. How do the costs vary with the change of the beef cattle farm size?

# 10. MANAGEMENT OF FATTENING CATTLE PRODUCTION

Cattle producers often say that to make money in this industry you must buy low and sell high, but the beef industry is more than just the buying and selling cattle. Beef producers add value to their products at each stage in the marketing channel. Cow-calf producers sell a product called a calf. What they are really selling is not the calf but output from the cow and bull and the grass, grain, labour, management and capital used to produce this product called a calf.

Stocker cattle can be defined as weaned calves that are placed on small grain pastures or placed in barns and backgrounded. Stocker operators buy 130 to 230 kilogram calves from the cow-calf segment of the industry and put an additional 130 to 200 kilograms on them, hence, increasing their value to the market place. Stocker operators provide an interim step in the production process--taking these lightweight calves, growing them on cheap feed correcting for any problems that happen at or before weaning.

Feedlots buy the stocker cattle, feed grain to fatten and then sell them at about 500 to 700 kilograms to the packer. Feedlot is a type of animal-feeding operation used for finishing cattle prior to slaughter. Cattle are finished, usually on a combination of forage and predominantly grain. The packer slaughters the animal and breaks the carcass into wholesale cuts for the retailer who in turn sells the beef cuts to the final consumer.

Each production level buys or invests in additional production inputs adding value to the animal. The animal is then sold to the next level in the production system or ownership is retained, where more value is added. This process is repeated until products are finally sold to the consumer at the retail level. It takes time to learn the beef production system and how the product moves through the various levels. Production inputs include physical items like cows, bulls, stockers, feeders, slaughter cattle, carcasses, etc.

An understanding of the relative impact of profit determinants can help producers identify which variables of production and financial risk to focus on managing. A large amount of research has evaluated the difference in cattle feeding profit variability based on profit determinants in calf-fed and yearling finishing systems. However, less research has been done to consider the impact of the backgrounding phases on the yearling system's total profitability and profit variation, driven by determinants unique to each particular backgrounding phase.

For the calf-fed system, the variables to explain the variation in profits included fed cattle sales price, feeder cattle purchase price, corn price, interest rate, etc. The model analysing this correlations was constructed in the United States. Fed cattle sales price was used in the model to represent revenue, while feeder cattle sales price was included as one of the main cost variables in the calf-fed system. Another main cost variable for this system was feed, measured here by corn price. Interest, or opportunity cost of money, was charged on variable costs associated with feeding cattle. All cattle prices and corn prices were market prices reported by USDA's Agricultural Marketing Service, and interest rates were reported by the Kansas City Federal Reserve Bank's Survey of Agricultural Credit Conditions.

Standardized beta coefficients were used to rank the relative influence of profit determinants on profit risk. This method of analysis involved normalizing profit and the explanatory variables, resulting in a unit-less measure that allowed comparison of the influence of the explanatory variables on profits regardless of differing units of measure used to define each variable. Standardized beta coefficients have a special interpretation. Suppose that the explanatory variable fed cattle sales price has a standardized beta coefficient of 1.25. This means that for a one standard deviation change in fed cattle sales price, profit changes from its mean by 1.25 standard deviations. Thus, the greater the standardized beta coefficient for a given variable, the greater the influence that variable has on profit variation.

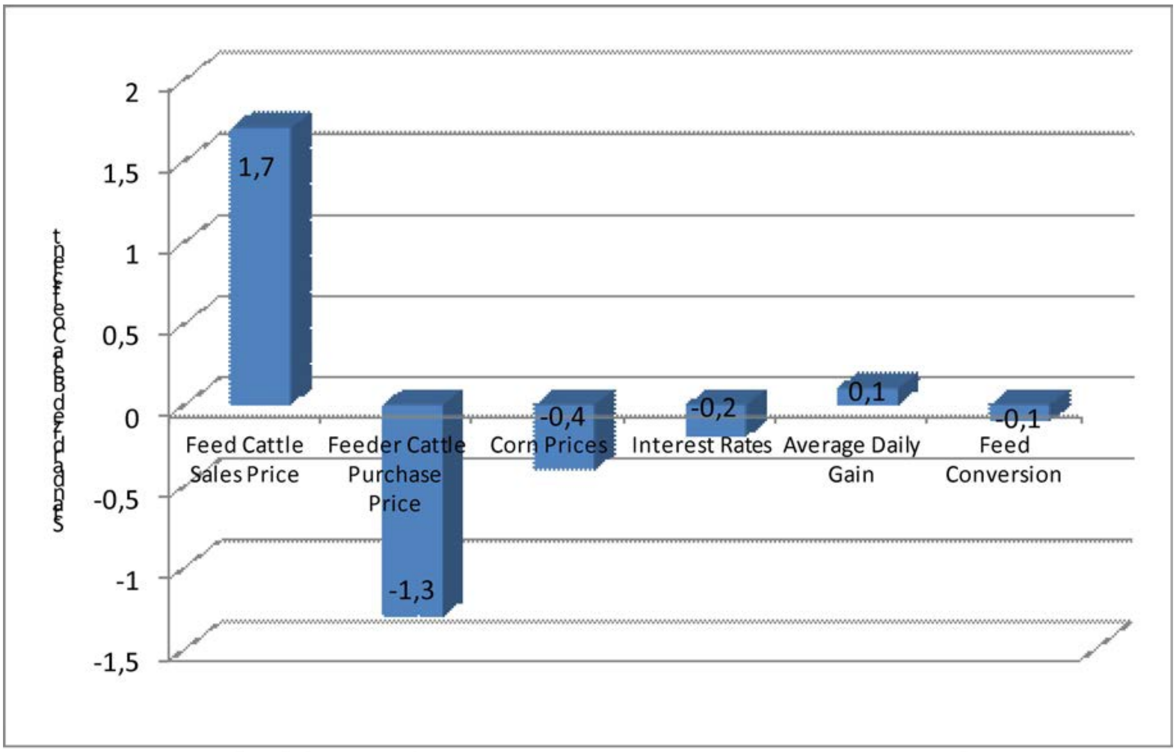



Figure 21: **Calf-fed profit variation caused by price and performance**

Figure 21 indicates the magnitude of the standardized beta coefficients of the variables that affected profits in calf-fed systems. The variables represented by bars on the right side of the graph have a positive relationship with profits (i.e., profits increase with increases in the given variable). The variables represented by bars on the left side of zero have a negative relationship with profits. As shown in Figure 21: fed cattle sales price had the largest impact on profit variation, followed by feeder cattle purchase price. Corn price, interest rates, feed conversion, and average daily gain were the next most influential profit determinants.

Even though animal performance is important in determining whether or not a profit resulted, average daily gain and feed conversion are not tend to explain a large proportion of the variation in profits across years. In a relative sense, the variability of cattle performance is much smaller than the variability of cattle and corn prices, leading to the result that the more variable determinants like cattle and corn prices cause the most profit variability.

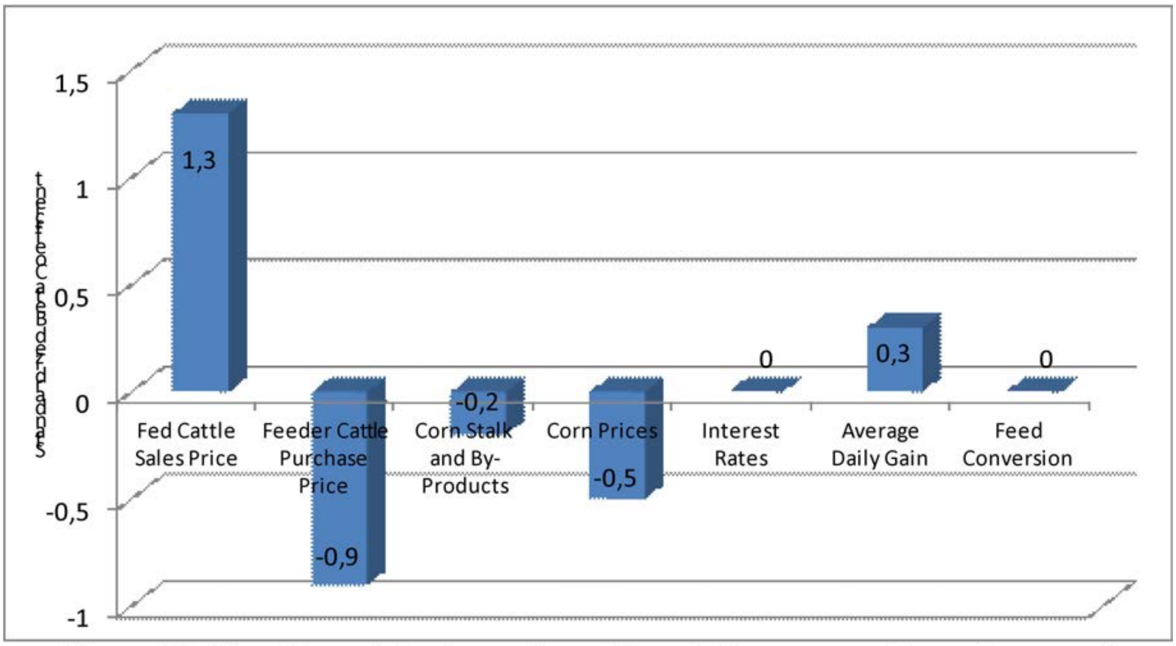



Figure 22: **Yearlings (all phases) profit variation caused by prices and performance**

The magnitude and signs of the standardized beta coefficients for the entire yearling system are illustrated in Figure 22. Comparison of the bars in Figure 22 with those in Figure 23 demonstrates that the relative rank of a variable's importance in determining profits is somewhat different for yearlings (all phases) than for calf-feds. Similar to the profit determinants evaluated in the calf-fed system, fed cattle sale price, feeder cattle purchase price, and corn price have the largest influence on profits. Conversely, average daily gain is the next most important variable explaining profit variation for the yearling system, followed by the average cornstalk and other by-products. Also note that the standardized beta coefficients for the sales price and purchase price are smaller in terms of absolute values for yearlings than for calf-feds.

It would be expected that the standardized beta coefficient associated with the feeder cattle purchase price for calf-feds would be greater than that of the yearling system. It might also be assumed that corn prices for a yearling system would have a smaller impact on profit variation relative to a calf-fed system, since yearlings consume corn for less time than calf-feds. However, yearlings are less efficient with the corn consumed, which may be the cause of the larger standardized beta coefficient for corn in the yearling model than in the calf-fed model.

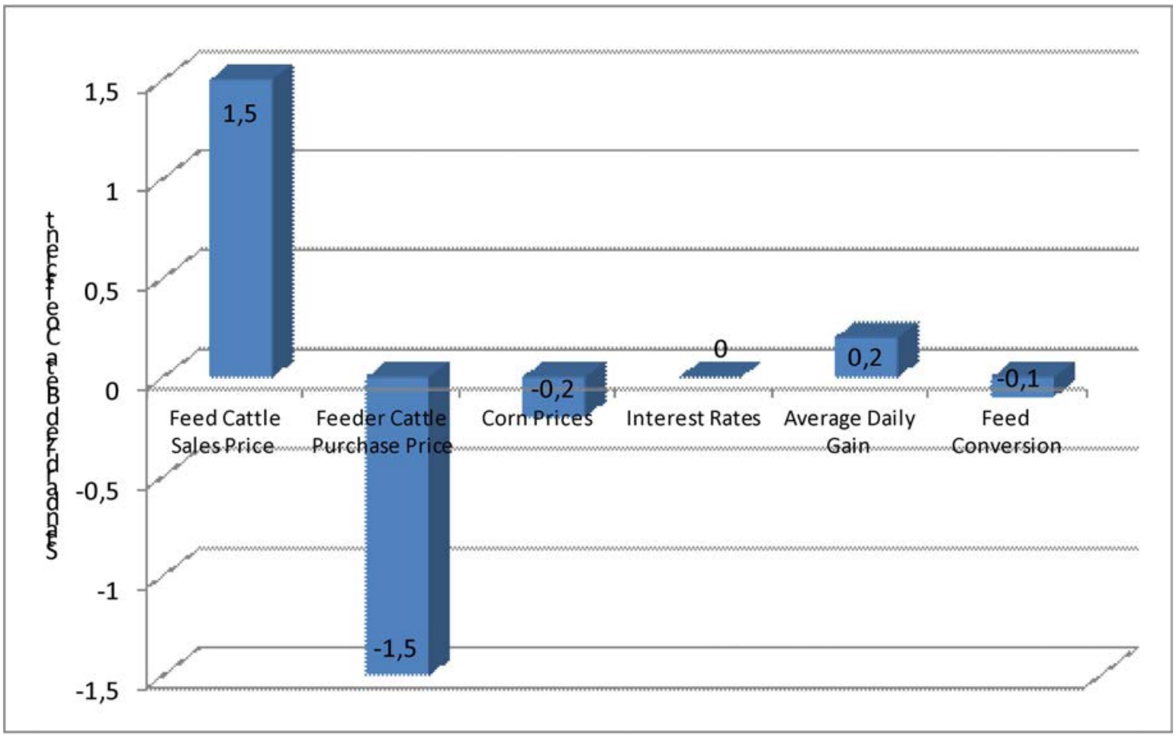



Figure 23: **Yearlings (feedlot phase) profit variation caused by prices and performance**

In the feedlot phase model of yearling, purchase price of the feeder cattle entering the feedlot is the most influential profit determinant (see Figure 23). Figure 23 also shows that fed cattle sales price is the next most important variable in influencing profit variation. Although they do not have as large an impact on profit variation, corn price, feedlot average daily gain, and feed conversion are important profit determinants as well. All of the results showed that fed cattle sales price, feeder cattle price margins, feeder cattle purchase price, and corn price had the largest impact on profit variation for calf-feds and yearlings.

When we take into consideration the resources of beef cattle production it can be concluded that the most important baseline is the genetics, which helps us talk about what cattle are coming at what time, what we should expect in terms of quality. Handling facility can also significantly contribute to both the saving and making of money. The bottom line is that beef cattle handling facilities can improve the profitability of an operation. Handling facilities offer the opportunity for added value by carrying out practices that are economically important.

Another important item to consider is that a good cattle handling facility can reduce the probability of injury to the animals and producer as well as stress. Cattle that are stressed will experience reduced performance and immunity to disease, efficacy of vaccines and other physiological items. It is widely accepted that storing farm equipment under a shelter is better than storing it outside and that hay stored in a barn is better than hay stored in the field. But how can we determine just how much a farm storage building is worth? The answer is different for every individual operation, but there are some guidelines that will help you make an intelligent decision about whether or not you can afford a building (or afford not to have one). As with any practice, constructing and using cattle handling facilities should be evaluated for effect on weaning or market weight, calf crop percentage weaned, cost of production, and market price.

Photo 29: **Slatted floor for better animal welfare and production**

As businesses grow, owners may find it necessary to hire individuals to assist with a variety of responsibilities. Hiring workers leads to more managerial responsibilities and questions about how to best recruit, train, and manage employees. Taking into account that fattening cattle market is quite changeable human resource has to be an outstanding significance among the physical resources.

Beef cows are culled from the herd for a variety of reasons including reproductive failure, age, and unsatisfactory performance, among others. A significant portion of income for beef cattle enterprises comes from culled animals. By being able to improve the weight and value of cull animals at low input cost, producers will be able to increase revenue by selling them. Feeding out cull cattle has many opportunities, but it also has some challenges. Mature cows do not add weight as efficient as growing cattle, so the producer will have to use more feedstuffs in order to make the cow gain.

To achieve the best gains possible, producers need to provide a low cost feed source like corn stalks or other kinds of by-products. If producers want to add value to their culled animals, they need to make sure the animals are healthy and sound. Unhealthy cows should also be avoided. Keep in mind, if a treatment is required, it will likely come with a slaughter withdrawal, which could delay marketing. It is also recommended to work with a veterinarian to plan a vaccination strategy. It is best to use cattle that are at a body condition score between three and five because fat cows do not gain more fat. However, cows are often sold at the time of culling without regard for opportunities to add value and capture additional revenue.

As a side note, it may be worth to check for pregnancies a second time, possibly via ultrasound. The producers that sold the cows lost out on a substantial price differential between an open cow and a bred cow. Cull cows are usually mature, non-gestating, and non-lactating so their requirements are quite low.

The decision on how long to feed cows should be based upon the condition of the cows, expected feedlot performance, feed cost, and market timing. Cows that are over fed can be subject to price discounts. To avoid discounts cows that begin the feeding period in moderate (body condition score of five) or better body condition should be fed for shorter durations. Cows that are thinner can be fed for longer periods of time; however, it is important to remember that as the duration of the feeding period increases, it is possible that feed efficiency may decrease.

Cull cows can gain tremendous amounts of weight in relatively short times on grain-intense diets. Cow fed for shorter durations will likely experience more rapid gains. In economic point of view it must be added that compared to non-ruminants, beef cattle are inherently inefficient in converting feed to gain. Feed conversion may also depend on the age of the cattle: it decreases linearly with age. With the high average daily gains and relatively poor feed conversion it is not unreasonable for a cow to consume dry matter at between 2.25% and 2.6% of her body weight. This level of intake can result in high feed costs. Therefore, any management factors that can be used to improve animal performance will help improve the profitability of feeding cattle.

Photo 30: **Culled dairy cows usually go for slaughter**

Several factors determine the potential for adding value to cull cows. While the increase in price and associated increase in revenue is certainly appealing, feeding cull cows does not result in an automatic profit. It is important to carefully consider all of the costs (feed, supply, labour, facilities, others) involved in feeding cull cows. Cull cows are not efficient in a feedlot and need to have every possible management strategy implemented to maximize feed conversion. When well planned and carefully managed, feeding cull cows can improve revenue and potentially profit on a beef cattle operation.

Actually, economics is the study of human behaviour. Economists try to relate how people will react to changes in supply and demand, to higher or lower interest rates or to increases in the cost of production. Marketing of beef cattle is also a study of human behaviour. Cattle prices are determined by how much beef people choose to buy and sell in the market place. If people want to buy more beef than is available in the marketing channel, then the price of beef is bid up rationing the beef among buyers. If producers need to sell more beef than people are willing to buy, then the price of beef will be forced downward to move the excess supply. Thus demand is made up of various components, including quantity and time. Other factors that may affect price are consumer income levels, number of consumers in the market, and prices of related products such as poultry and pork.

So how are prices really determined? Prices are determined by negotiation. These negotiations take place simultaneously at every level of the marketing channel. Consumers have money to spend and they want to purchase beef. But, consumers only have a limited amount of money to spend and they like other goods and services as well as beef. They decide what amount of beef they buy based upon the amount of money they have to spend, the price of beef and their desire to eat beef compared to other food items available to them.

Marketing is the cattleman's way of obtaining money for the value he adds to the product he produces. The fact remains that both record keeping and marketing provide a viable means to increase producer profits. It is often the difficult things in business that make the most money. In beef cattle production, survival depends on a producer being above average in production, marketing, and financial management. A producer must know what marketing alternatives are available to him, how to use each alternative, and how to interpret market signals.

Every stage of the production marketing channel wants to provide the consumer with a safe, quality product that adds value to the consumer's decision to buy beef. Each segment of the channel adds value to the calf produced to satisfy this consumer need, but each segment also must make a profit. The poultry industry solved this problem with vertical integration.

If the industry is profitable cattle producers retain heifers, breed them and in time expand the size of the herd. When the supply of beef exceeds demand, prices fall and the cattle producer diminishes the size of his herd by culling cows and by selling heifers. This process continues through time as the industry tries to adjust the size of the herd to reflect the signals it receives from the forces of supply and demand at work in the market. As it was explained before, the term used to explain this process is "the cattle cycle". The cycle is frequently defined as the time between the lowest stand in a cattle numbers to the next time that cattle numbers reach a low point.

Another relationship may also help us understand why prices react as they do to market forces. This is the relationship between cow slaughter numbers and calf prices. As cow slaughter levels increase, calf prices decline. That's right. Low levels of slaughter indicate a healthy cow-calf segment within the beef industry. Cattle producers are making a profit; consequently, they will retain cows and heifers in an attempt to build the herd and have more animals to sell. Marketing, therefore, is a systematic approach toward achieving a reasonable return for the producer's money, labour, management ability and other resources he/she has invested in the production of his/her animals. Marketing requires detailed planning and the estimation of costs and prices.

The first step in the development of an individual cattle producer's marketing plan is to estimate his cost of producing the calf. This estimate is the focal point of the marketing plan it is the market target price. The objective of any plan is to receive a market price that will meet or exceed this cost of production. The producer must keep this market price target in mind when he/she develops or implements and evaluates his/her marketing efforts. First and foremost there is not a single magical alternative that cures all of the producer's marketing problems. There are alternatives that if used wisely under reasonable conditions have served producers will for many years. Farmer should choose the proper way of marketing of the proper kind of animal.

The marketing plan does not need to be elaborated or complex but, it does need to be well thought out and adapted to meet the needs of farmer's cattle operation. There are many ways to classify a market plan but, here is a simple approach. This focuses on six steps:

1. Know what you have to market,
2. Develop your cost of production and market target price,
3. Analyze the market environment,
4. Review available market alternatives,
5. Compare market alternatives against your operation's goals; and,
6. Make your decision and market your cattle.

These steps allow cattle producer to inventory his herd and review it is strengths and weaknesses. Reviewing the market environment also provides information about basic supply and demand factors that influence prices. Comparison of market alternatives allow the opportunity to match the strengths of the operation against what the market is offering this year. Finally, a marketing decision must be made. This step wise procedure allows the cattleman to make an informed decision.

## Questions for self-evaluation

1. What are the typical phases of beef cattle fattening and what are their main characteristics?
2. Which factors affect the production cost of calf-fed?
3. Which factors affect the production cost of yearlings in the feedlot phase?
4. What are the preconditions of profitable fattening of cull cows?
5. How should farmers make a plan for fattening cattle marketing?

# 11. MANAGEMENT OF PIG FARMING

Almost all part of the world over the past two decades, pig producers have adjusted the size, organizational structure, and technological base of their operations; some have ceased pig production. The economic environment for pork producers changed as new uses for corn, the primary ingredient of pig feed, have increased feed prices. A slowdown in productivity growth suggests that the era of dramatic growth in pig production is likely over, absent new technological innovation.

Modern pig farming is mostly done in enclosed buildings to protect animals from the weather, from predators and from the spread of diseases. While larger operations enabled farmers to significantly increase the efficiency of production using less labour, it resulted in environmental challenges with larger amounts of manure concentrated in a small area.

Market pigs are produced on either farrow-to-finish or feeder pig-to-finish operations. Farrow-to-finish operations are those on which pigs are farrowed (birthed) and raised to slaughter weight (100-130 kilograms). On feeder pig-to-finish operations, feeder pigs (15-40 kilograms) are obtained from outside the operation, either purchased or placed under contract, and then raised to slaughter weight.

The phases of pig farming that take place on the farm to produce hogs ready for market are called: breeding-gestation, farrowing, nursery and grow-finish. Pig production can be logically separated into a number of phases, beginning with the sow being bred. Sows in enclosed shelters come into oestrum, three until five days after their pigs are weaned. The oestrum period, or standing heat, is the period when the sow can be bred. Oestrum only lasts a short time, so it is critical that the sow is bred at this time. During oestrum, the sow shows outward signs of being willing to accept the boar, such as standing still when the producer applies downward pressure on her back or holding her ears erect. If the sow is not bred during this period, she normally returns to oestrum about 21 days later. These two periods are known as "first heat breeding" and "second heat breeding". The non-pregnant sow is considered unproductive during this three-week period, since she still must be fed and housed. Most modern operations have sows bred only on first heat. Sows that fail to breed during this oestrum are often sent to market and replaced in the sow herd by gilts, or young females that are removed from the grow-finish group of pigs. After breeding, the sow gestates her embryos for 113 to 116 days before the pigs are born or farrowed. A good way to remember gestation length for sow is that it is approximately "3 months, 3 weeks and 3 days".

Photo 31: **Breeding animals are usually kept in confinement pen**

Just before giving birth, called farrowing, sows are normally moved into a farrowing room. Sows typically farrow from eight to twelve piglets, which as a group are called a litter. Most confinement operations place the sow in a temperature-controlled environment and usually in a farrowing pen which restricts her movement to protect her sucking pigs. The baby pigs spend most of their time in a creep area on one or both sides of the pen where they have ready access to their mother, but are protected from crushing when she lies down. A few farrowing operations use larger pens and provide deep straw bedding on solid floors. While this is a more natural process for the sow, it involves more labour and often results in higher crushing losses.

Photo 32: **The creep area protect piglets against crushing**

An average sow will raise three to five litters of pigs in her lifetime. Sows may be culled and sent to market, because of age, health problems, failure to conceive, or if they are able to raise only a low number of pigs per litter. Pigs are born with eight sharp teeth and curly tails. When the tips of the teeth injure to the sow's utter and other piglets and other piglets they are clipped and the tail is shortened to prevent serious tail biting. Piglets weigh about 1-1.5 kilograms at birth and are weaned from the sow from three to seven weeks, with most operations weaning pigs at four weeks.

After weaning, pigs are normally placed in a nursery where they are kept in a temperature-controlled environment, usually on slotted floors. The floors in a nursery are usually constructed from plastic or plastic covered steel instead of concrete to provide additional comfort for the small pigs. Pigs are normally given around 0.3 square meter of space each and provided with ready access to water and feed. Nursery pens are sometimes elevated, with their slotted floor above the room floor level twenty to thirty centimetres. This is done to minimize the possibility of cold floor drafts chilling the young pigs. Immediately after weaning, the temperature in the nursery may be as much as 29 Celsius degrees, and then dropped gradually to about 21 Celsius degrees as the pigs grow. Pigs are normally removed from the nursery at about six to ten weeks of age and placed in a grow-finishing building. Nursery rooms are almost always heated with furnaces and ventilated with mechanical fans, controlled by a thermostat, in order to keep the pigs warm and dry throughout the year.

This phase is where pigs are fed as much as they wish to eat until they reach market weight of 100 to 130 kilograms and provided around 0.75 square metre of space per pig. Marketing normally occurs at five to six months of age, depending on genetics and any disease problems encountered. Some gilts are returned from the grow-finish phase to the sow herd for breeding purposes, to replace older sows that are culled.

Animals in a grow-finish operation are larger and produce a great deal of body heat. Ventilation to keep the animals cool is usually more of a concern than providing heat in winter. Animals at this age grow best at around 16-21°C. In winter, they are protected from winter winds in a moderately well insulated building. Enough ventilation must be provided to remove moisture and to provide fresh air for the animals. In summer, large sidewall vents are opened or large ventilation fans are operated to keep the animals comfortable. This is referred to, respectively, naturally ventilated (air change due to the wind) mechanically ventilated (where air is drawn into the buildings through vents due to a negative pressure created with wall fans that exhaust inside air.

With the development of slotted floors and liquid manure handling equipment, it became possible for producers to more easily care for larger numbers of animals, and to shelter from the weather. It also made it practical to give birth sows twice a year (or statistically more than twice a year), rather than once. This was the beginning of intensive production schedules on relatively small areas as found throughout the world today.


Photo 33: **Automated feeding and technology control**

In a continuous flow barn, animals of many different stages of development may be housed in close proximity to one another and the facilities are never empty. Advantages are that space is efficiently used, because pigs can be moved to larger pens as they grow, and new arrivals replace them in the smaller pens. Continuous systems are also simple to plan. If the producer wants to wean two litters each week, two sows must be bred each week. Disadvantages are that different ages of animals (with different degrees of disease resistance) are housed together, facilitating disease spread, stress levels can be heightened with changing social groups, adequate cleaning and disinfecting are not easily feasible, and higher levels of antibiotics and other medications are normally required to control disease.

All-in–all-out (AIAO) pig production is a system that keeps animals together in groups. Animals from different groups are not mixed during their stay on the farm. The groups are closely matched by age, weight, production stage and condition. The group is moved into a phase of production together, such as into an empty nursery, and is moved out of that phase as a group according to a production schedule. Most swine today are raised AIAO systems, where each room or building is completely emptied and sanitized between groups of pigs. Each new group of pigs enters a freshly disinfected environment, and stays there for this phase of their life. The facility has a separate room or building for each group of pigs weaned, with extra space if needed to allow workers time to clean the room before the next group of pigs. AIAO animals in each room are of a uniform age and size and are isolated to the extent possible to decrease the possibility of diseases spreading from older animal groups to younger ones.

AIAO can also be by barn, room, “air space” or pen. In an AIAO system, sows are bred as groups to farrow during a five- to ten-day period. By comparison, sows in a continuous flow system are bred continuously and farrow also continuously. In a continuous flow system, pigs move as individuals, not as closely matched age groups, and a facility is never totally emptied because pigs are always moving through it.

The primary advantages are that disease spread can be better contained while animals are less stressed because they remain with the same age and social group throughout their development, and complete cleaning and disinfecting between groups is possible. The disadvantage is that space is less efficiently allocated, and that more space may be needed to allow rooms to be empty for cleaning between groups.

Changing from a continuous flow system to AIAO, or from AIAO by pen to room or barn, can improve production and reduce costs. It is recommended to compare the advantages in each stage of production in order to decide if AIAO will benefit the farm. AIAO production:

- Reduces disease transmission,
- Improves management,
- Allows better environmental control,
- Improves record keeping,
- Improves pig performance.

Photo 34: **All-in-all-out system ensures balanced animal group**

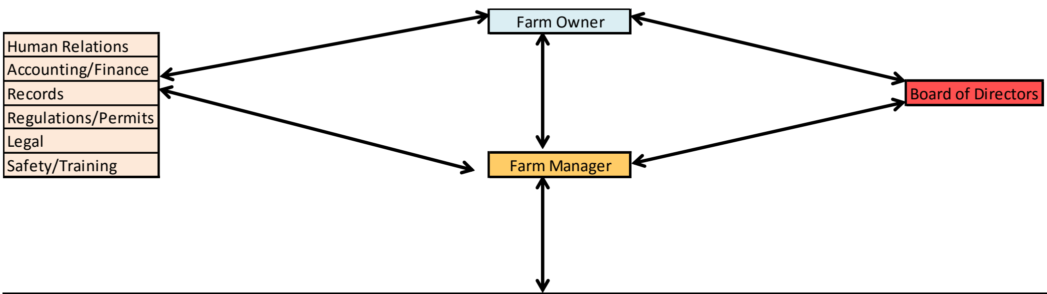
AIAO breaks the chain of infection and prevents disease build-up. Infectious organisms have two main sources: (1) other pigs and (2) the environment. Infection from other pigs is reduced or eliminated in an AIAO system because once a group is established no pigs are added to it. Pigs that have similar ages, immunities, and disease histories are kept together.

AIAO enhances the producer’s ability to manage. Management is enhanced because the pigs within each group have similar nutritional and environmental requirements. The confinement facilities can be better adapted to meet pigs’ environmental requirements for temperature and ventilation, because pigs that are closely grouped by age have the same requirements. AIAO also makes keeping records easier. Keeping records of feed consumption, pig performance, and disease occurrence is an easier task when the pigs are run as a group.

In all stages of production AIAO has a great potential for improved pig performance. In the grow-finish stage, AIAO can increase feed efficiency and daily gain. Increased average daily gain from AIAO translates to decreased days to market; improved feed efficiency from AIAO translates to lower feed costs.

Until the eighties pig production systems were usually housed on a single site, because of labour savings and convenience. Health concerns have since caused many pig operations to house the various production phases at different sites to further minimize contact between pigs of different ages. This is either a two-site or a three-site system. A two-site system has breeding and gestation at one site while farrowing-nursery and growing finish pigs at a separate site. A three site also places the nursery at a separate site. In the latest decades, some producers have constructed “wean to finish” barns where pigs go immediately after weaning, and stay until market. This combines the nursery and grow-finish phases of production. These barns provide substantially more space per pig than is needed initially, but provide the advantage of only moving pigs once during their lifetime. This reduces stress on the animals and saves labour since buildings are not cleaned until the pigs are marketed.

Governance structure of a farm should be a very detailed and highly dynamic blueprint to the operations of farm business. As the legal structure of the farm outlines how the assets and profits are shared among the farms owners, a governance structure outlines the activities and responsibly of every member of the farm. In its simplest form, a governance structure may be organizational chart of a farm.




| Crop Supervisor | Equipment Supervisor | Maintenance Supervisor | Livestock Supervisor | Nutrition Supervisor | Health Supervisor | Marketing Supervisor | Security Supervisor |
|---|---|---|---|---|---|---|---|
| Fields | Tractors | Barns | Breeding | Rations | Desease | Buying | Biosecurity |
| Tillage | Trucks | Grounds | Gestation | Feeds | Prevention | Selling | Watchmen |
| Harvest | Field Equipment | Facilities | Farrowing | Feeding | Genetics | Transport | Guards |
| Hauling | Cars | Equipment | Growing | Additives | Wash in | Ordering | Records |
| Storage | Trailers | Irrigation | Market Pigs | Antibiotics | Wash out | Contracts | |
| Rotations | Wells | Roads | Boars | Feed Mill | Sewage | Advertising | |
| Planting | Records | Signs | Sows | Records | Worker Safe | Promotion | |
| Health | | Records | Processing | | Death | Records | |
| Irrigation | | | Records | | Records | | |
| Fertilization | | | | | | | |
| Records | | | | | | | |

Figure 24: **Organisation chart of a pig operation**

This chart might outline job responsibilities and reporting structure. However, a true governance structure takes on a more complicated form when it adds those members of the farm who are not a part of the day-to-day operations and outlines their roles and responsibilities as well. As each operation is different, so should the governance structure; this is not something can be downloaded and used. As the operation changes over time, so should the governance structure.

Who decides who will clean the barns this afternoon? Who decides when the rations are switched? Who decides if the farm will buy the operation on the other side of the county? These are all decisions the operations may one day face. At some point, all these decisions might have been made by the same person, the farmer. But as an operation grows and become more complex, the list of people who makes the decisions will become increasingly difficult to sort out if some kind of structure is not in place. For an operation to successfully grow the roles and responsibilities of everyone involved need to be outlined and understood by everyone.

Maybe one of the family members or employees makes the decision on which corn hybrids will the planted this year, but the farmer, as the general manager, must approve all expenditures over $10,000. Or maybe as the general manager farmer decides a new manure spreader is needed, but he needs to approval of the farm's board of directors for major capital purchases.

A governance structure helps the current operations in three ways. First, it empowers. Whether it is the employee hired last week or the retired farmer, the governance structure is a way every person on the farm knows how the farm is counting on them. When everyone knows what corners of the operations they are responsible for and in charge of, they can focus on how to make that place a more successful one.

Secondly, a governance structure will make everyone's life easier. Without a governances structure, the general manager of the farm might become overwhelmed with decisions. If the employees do not know what they are able to decide on their own, they will have to get approval from someone.

Finally, a governance structure will reduce surprises. Surprise can come in many forms, but outlining a structure and sticking to it is critical to keep all the member of the farm one the same page. Let us imagine if the general manager bought a new tractor. The farmer's son, who works with the tractor, might be surprised to find a machine in the shed that is not what he would have wanted to buy and the largest owners of the farm might also be surprised that the farmer spends all of the profit of the year when they were hoping for a big dividend.

Establishing a governance structure for the operation can also create value in managing the performance expectations and goals for the farm. This can happen at both the individual and business level. With a governance structure in place, the reporting structure is clearly identified. The reporting and evaluation structure is important for employees to understand. To increase employee satisfaction and help with their growth and develop, employee evaluations are often critical. Evaluating employee performance is much easier once a clear structure is in place. Additionally, when the ownership of the company sets goals for the farm, the governance structure creates an opportunity for clear objectives to be set so that each area of the farm knows what they contribute to the overall operation.

Time management is an important skill to develop and consciously allocating time to various activities can make farmer more efficient, effective, and ensure that he/she is spending his/her time on the activities that are moving him/her in the direction he/she wants to go. Creating an inventory of farmer's time is an insightful way to learn how time is spent. In several cases time is not spent exactly how farmer would like to think it is.

A couple things to consider:

1. Inventory the time in a horizon appropriate for the situation being analyzed. Annually, quarterly, monthly, and weekly could all be appropriate for evaluating different situations.
2. There are a limited number of hours in a day, so time is a scare resource. Additionally, farmer will not spend his/her time absolutely efficiently. It is worth to be realistic with how much time farmer really have to allocate to tasks within the workday.

Economic competition and the incentive to maximize profits drive structural change and technological innovation in the pig industry. If larger operations are more profitable than smaller ones, competitive pressures may be expected to result in a larger average farm size in the long run. Similarly, operations that are first to adopt a cost-saving technology are more likely to survive and grow. Technological innovation in pig production includes such advances as improved genetics, nutrition, housing and handling equipment, veterinary and medical services, and management that improves the performance of hogs and the efficiency of the operation and/or reduces production risk.

Declining pig farm numbers in latest decades suggest that many small, likely high-cost operations ceased production, adding to the average size of pig operations. Increases in the scale of production have resulted in greater animal density, creating possible environmental risks. On the other hand, increased feed efficiency accompanying structural change offset some of these risks as the waste per animal fell. In addition, concentrating manure sources in fewer locations potentially affects fewer people and may also make some manure treatment technologies (e.g., energy from bio-waste, or processing into concentrated fertilizer) feasible.

The gains from exploiting scale economies are nearly exhausted, as most pig production now takes place at a size where returns to scale are nearly constant. The measurable technological and organizational innovations contributing to productivity growth (e.g., confinement housing, production contracts, artificial insemination, AIAO management) are now widely diffused.

The technologies and practices used by the different types of pig producers varied widely. Age of facilities is an indicator of the technology employed. Where pig operations specialise in individual production phases they tend to have newer pig production facilities. Specialized farrowing, weanling, and finished pig producers are more likely to use improved technologies such as artificial insemination, terminal crossbreeding, commercial seed-stock, and AIAO management. Because large, specialized hog operations can spread fixed costs over more production and more easily take advantage of resulting productivity gains, they are better able to invest in current pig-production technologies.

Pig farms are becoming more consolidated, thus larger operations are producing a greater volume of manure on smaller fodder-production areas. A higher manure-to-cropland ratio has magnified the risk that manure nutrients (nitrogen, phosphorous, and potassium) as well as pathogens might flow into ground and surface water due to overuse of manure on crops or leakage from manure storage facilities.

**Questions for self-evaluation**

1. How could the pig production process be divided into different phases?
2. What does AIAO keeping system mean?
3. Which technological elements can serve the welfare of pigs in modern barns?
4. How can the organization chart of a pig operation be outlined? What is its role?
5. How could any reasonable time management help the pig farmer’s work?

# 12. MANAGEMENT OF EGG PRODUCTION

Over three-fourth of egg production is for human consumption (the table-egg market). The remainder of production is for the hatching market. These eggs are hatched to provide replacement hens for the egg-laying flocks and to produce broiler chicks for grow-out operations. Egg products and eggs for use in processed and prepared food items are expected to experience continued growth worldwide.

There are a number of ways to rear laying hens. It would be very unlikely that any two enterprises rear layers exactly the same way. Management differences for rearing layers may be accounted for by economics (breed selected, vaccination package and decision when to molt). Egg producers usually purchase their layer stock (i.e., day old leghorn chick) from an egg-type hatchery. Hatcheries deliver chicks to the producer within one to two days of hatching. At the hatchery, chicks are vaccinated according to the producer's specifications. At arrival, chicks are either placed in typical layer pens or reared in a pullet house. A single layer cage may occupy as many as fifty chicks, but as they mature, cage density is lessened. Chicks placed in pullet houses are reared on a floor covered with absorbent materials, such as straw or pine shavings.

Pullets started on the floor remain there for approximately ten to fifteen weeks and then move to a layer facility. In either case, from chick placement through approximately sixteen weeks of life, the pullets are fed according to body weight gain and/or age. The goal is to raise a strong and healthy pullet that can support egg production.

Daily light exposure (photoperiod) begins to increase at week sixteen. This increase in light exposure triggers hens to begin laying eggs. If the laying hen has not reached proper body weight (usually 1.3-1.4 kilograms) by week eighteen, egg production will likely cease very quickly, following the starting of the laying period. Hence, it is important for the young laying hen (pullet) to reach the proper body weight that will support egg production. In tandem with light manipulation, the diet is also altered in order to support egg production.

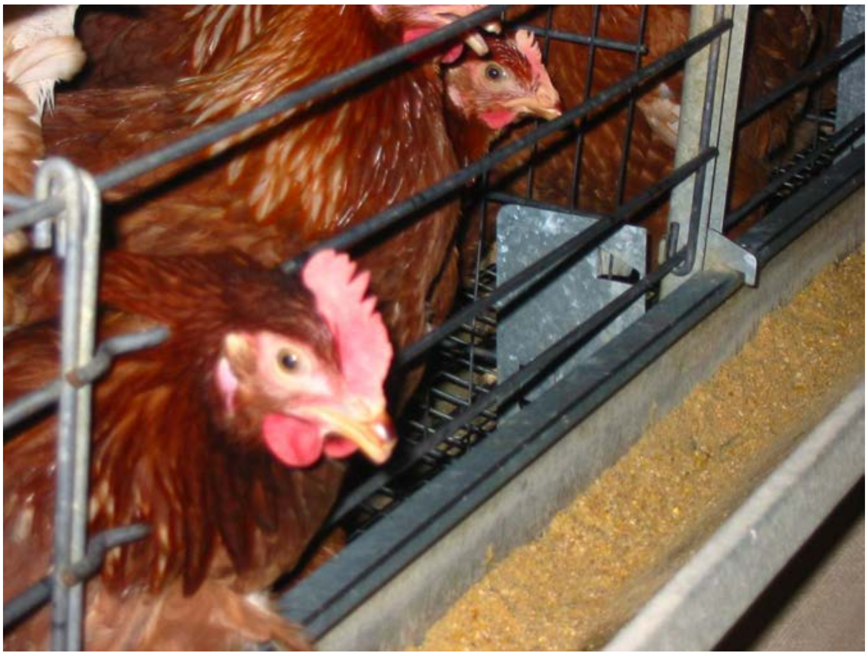


Photo 35: **Laying hens in cages**

It is assumed that layers, unlike birds raised specifically for meat, regulate their feed intake. Layers are generally reared on full feed (ad libitum). The feed is offered to birds via the chain system. The chain system transports feed into the metal feeder at precise times during the day. In general, 5-6 centimetres of feeder space is allotted per pullet and 6-7 centimetres or more for each adult laying hen.

Young birds are fed a high protein diet (twenty percent) during the first few weeks of life. This level continuously decreases until it reaches approximately twelve to fifteen percent proteins during egg production. In addition to monitoring dietary protein, producers must closely examine other ingredients. During the laying phase, lysine, methionine, calcium, and phosphorus are precisely monitored to support maximum egg production.

Producers begin to photo-stimulate and manipulate the diet around eighteen weeks of age in order to support egg production. Minor nutrients have also been manipulated such that calcium levels in the diet are approximately five to seven times greater than phosphorus levels. When a flock (group of hens) first enters egg production, the rate of egg lay will be around ten to twenty percent. This means that ten to twenty percent of the hens are laying eggs at eighteen to twenty-two weeks of age. The flock quickly reaches peak egg production (over ninety percent) around thirty to thirty-two weeks of age.

Post-peak egg production (after thirty to thirty-two weeks of age) continually decreases to approximately fifty percent around sixty to seventy weeks of age. At this point an economic decision must be made by the producer; fifty percent production is near the break-even point for egg producers (e.g., feed cost = market price of eggs). When the flock reaches fifty percent production, producers commonly decide to molt the flock in order to achieve a higher level of egg production. It takes approximately ten weeks from the beginning of a molting program to be back at fifty percent production following the molt.

Post-molt egg production will increase such that peak egg production reaches about eighty percent. Peak production following a molt is short-lived and the flock generally returns to fifty percent production by one hundred to one hundred and ten weeks of age. Many producers (one-third to one-half) will induce a second molt this is the same process that occurred at sixty to seventy weeks of age. The second molt is commonly dictated by the current egg prices and the availability of replacement pullets.

As previously stated, once flock egg production falls below fifty percent, an economic decision is made whether to molt the hens to a spent-hen processing facility. The majority of hens are between one hundred and one hundred and thirty weeks of age when they reach the end of their egg production cycle. The time span between one hundred and one hundred and thirty weeks of age can be accounted for by management decisions. Thus hens may be molted a second time and then sent to a spent hen facility (one hundred and twenty to one hundred and thirty weeks of age) or sent directly to a spent hen facility following the first molt (one hundred to one hundred and ten weeks of age).

Culling hens refers to the identification and removal of the non-laying or low producing hens from a laying flock. Unless the birds are diseased, they are suitable for marketing or home cooking. Removing the inferior hens reduces the cost of producing eggs, reduces the incidence of disease, and increases the available space for more productive animals. Hens eat feed whether or not they are laying. Removing the cull birds will make more feed and space for more productive ones.

Two types of culling are usually used to remove the inferior hens:

- sight culling at the time of housing and
- culling by individual inspection, which evaluates the hen's ability to lay or her past productive performance.

Sight culling of pullets when being placed in the laying house removes the obviously undersized, underdeveloped, weak or diseased birds which have very little chance of becoming good laying hens. The number of pullets culled partly depends on space available in the laying house. Depending on the current legal regulations it has to be allowed at least 700-1000 square centimetres of floor space for each hen from light breeds and 1000-1500 square centimetres for each hen from heavy breeds of chickens.

Farmer is worth not be too critical when evaluating the pullet's size and development, since some good laying hens mature late. It is recommended to give the pullets a chance to mature if they show characteristics that they may develop into good layers. Grower should remove any pullet which has a permanent genetic or injury-produced deformity such as crossed beak, slipped wing, one or both eyes blind, or any leg deformity that can interfere with the bird's ability to mate or to reach feed, water, or the laying nest. It is most economical to remove these pullets from the flock as soon as grower notices them. This will eliminate feeding birds with little or no chance of becoming good laying hens.

After the laying flock has reached peak egg production and production begins to decrease, farmer should occasionally check the flock for poor producing hens.

As it was described earlier each year chickens molt, lose the older feathers, and grow new ones. Most hens stop producing eggs until after the molt is completed. The rate of lay for some hens may not be affected, but their molting time is longer. Early molters drop only a few feathers at a time and may take as long as four to six months to complete the molt. Early molters are usually poor producers in a flock. Late molting hens will produce longer before molting and will shed the feathers quicker (two to three months). The advantage of late molters is that the loss of feathers and their replacement takes place at the same time. This enables the hen to return to full production sooner. The length and incidence of a molt are influenced considerably by the hen's body weight, physical condition and environmental conditions such as nutrition and management.

In layer facilities, there are two primary methods of egg collection, in-line facilities, and off-line facilities.
In either case, hens lay eggs onto an angled wire floor which rolls the egg toward the front of the cage (floor angle is generally eight to ten degrees) onto a nylon belt. The belt transports eggs out of the house either to the egg processing facility or to a store-house cooler. Since the processing facility and cooler remove eggs from the house, based on hourly demand, eggs may reside on the belt for as long as twelve to fourteen hours, but most are collected within a few hours post-lay.

Photo 36: Transportation belt rolls the eggs from cages

The first type of layer facility is the in-line facility. In this facility, eggs move directly from the layer house to the egg processing facility. Once the eggs enter the egg processing centre, within minutes to twelve to fourteen hours post-lay, they are washed (detergent solution near 38°C, pH 11.0 that removes contaminations), visual inspected (checked for eggshell problems, cracks, and blood spots), and then graded for packaging. Following packaging, eggs are moved to a cooler room (5-7°C), where they await shipment to retail outlets. Egg producers commonly deliver eggs to retail outlets within one week of lay.

The second type of layer facility is the off-line facility. This facility functions nearly identical to the in-line facility except that the eggs are transported out of the barn directly to an egg cooling room. In this method, the eggs remain in the cool room for approximately two to three days, and then they are transported to an egg processing facility via a refrigerated truck. These eggs are treated identically as those from the in-line operations.

Table 12: **Temperature control during the layer cycle**

| Week | Temperature (˚C) |
|---|---|
| 1 | 32 |
| 2 | 29 |
| 3 | 27 |
| 4 | 24 |
| 5 | 21 |
| 6 throughout layer cycle | 21 |

The laying cycle of a hen flock usually covers a span of about twelve months. Egg production begins when the pullets reach about eighteen to twenty-two weeks of age, depending on the breed and season. Flock production rises sharply and reaches a peak of about ninety percent, six-eight weeks later. Production then gradually declines to about sixty-five percent after twelve months of lay. Egg production can be affected by such factors as feed consumption (quality and quantity), water intake, intensity and duration of light got, parasite infestation, disease, and numerous management and environmental factors.

Photo 36: **Selection, classification and packaging of eggs**

Hens can live for many years and continue to lay eggs for many of these years. However, after two or three years many hens significantly decline in productivity. This varies greatly from hen to hen. Laying hens require a completely balanced diet to sustain maximum egg production over time. Inadequate nutrition can cause hens to stop laying. Wrong levels of energy, protein or calcium can cause a drop in egg production. This is why it is so important to supply laying hens with a constant supply of nutritionally balanced layer feed.

Although the salt requirement of hens is relatively low, adequate levels are essential, and excessive amounts are highly toxic and reduce egg production. Birds require a sensitive balance between necessary and toxic levels of salt. The nutritional role of phosphorus is closely related to that of calcium. Both are constituents of bone. The ratio of dietary calcium to phosphorus affects the absorption of both these elements; an excess of either one impedes absorption and can reduce egg production, shell quality and/or hatchability.

The major mycotoxin of concern with corn is aflatoxin, produced by the mold Aspergillus flavus. The mold infects corn both in the field and in storage. Botulism is an acute intoxication caused by consumption of a neurotoxin produced by the bacteria Clostridium botulinum. It commonly occurs when birds consume decomposing carcasses, spoiled feed or other decaying organic materials. Ponds and other stagnant water sources are often areas of decaying materials that may contain this toxin. Numerous plants are toxic to varying degrees if plant parts or seeds are consumed by the chicken. Production, hatchability, growth, and viability may be reduced. Anticoccidials (to prevent coccidiosis) are commonly used in diets for replacement pullets, meat chickens and young breeding stock that are reared on litter floors. Anticoccidials are not given to commercial laying hens.

If hens are out of feed for several hours, a decline in egg production will probably occur. The amount of decline will be related to the time without feed. Farmer must be sure that all the hens have access to an adequate supply of a complete feed which meets all their nutritional requirements. Water is often considered natural, and it is probably the most essential nutrient. Water is by far the single greatest constituent of the body, and, in general, represents about seventy percent of total body weight. Access to water is very important, and a lack of water for several hours will probably cause a decline in egg production. Hens are more sensitive to a lack of water than a lack of feed. The amount of water needed depends on environmental temperature and relative humidity, diet composition, and rate of egg production. It has been generally assumed that hens drink approximately twice much water as the amount of feed consumed on a weight basis, but water intake varies greatly, especially in hot weather.

Hens need about fourteen hours of day length to maintain egg production. The intensity of light should be sufficient to allow a person to read newsprint at bird level. The decreasing day length during the autumn and shorter day lengths in the winter would be expected to cause a severe decline, or even cessation, in egg production unless supplemental light is provided. When production ceases, the hens may also undergo a feather molt. Hens exposed to only natural light would be expected to continue egg production in the spring.

Many hens slow or stop egg production during the winter. Their bodies rest because of reduced daylight and cooler temperatures. If the farmers want their hens to keep laying, it is recommended to follow these tips:

- Producer should provide supplemental daylight. The flock needs approximately twelve-fourteen hours of day length to stimulate laying. Up to sixteen hours is the maximum day length to encourage production.
- Farmer should make sure the light is constant. It is suggested to set a timer for about fourteen hours of light to start. If egg production slows down, farmer should add an additional half-hour gradually until the hens respond. The additional daylight makes them think spring is coming.
- He/she also must make sure the diet of the flock is balanced for calcium and protein. Producer may have to alter rations to provide the hens with extra energy for maintaining body heat and egg production.
- It is worth to use an infrared heat lamp for a couple of hours each day for additional warmth. If it is really cold, hens conserve energy and stop laying for a couple of days. Farmer will see more eggs when they warm up again.

High environmental temperatures pose severe problems for all types of poultry. Feed consumption, egg production, egg size, and hatchability are all adversely affected under conditions of severe heat stress. Shade, ventilation, and a plentiful supply of cool water help reduce the adverse effects of heat stress.

There are many species of endoparasites such as roundworms, which tending to infect a specific area of the gastrointestinal tract. Although tapeworms do not produce extensive lesions or damage to the intestines, they are nutritional competitors. Coccidiosis is a protozoan disease characterized by enteritis and diarrhoea in poultry. Unlike the organisms which cause many other poultry diseases, coccidia are almost universally found wherever chickens are raised. Coccidiosis outbreaks vary from very mild to severe infections. It is common to add a coccidiostate in the feed of broilers. In addition, live vaccines are currently available.

Infectious bronchitis is a highly contagious respiratory disease. The disease is caused by a virus which is moderately resistant, but can be destroyed by many common disinfectants. Infectious bronchitis occurs only in chickens. All ages of chickens are susceptible to infectious bronchitis. In laying hens it is characterized by respiratory signs and a marked decrease in egg production. Egg quality is also adversely affected. Low egg quality and shell irregularities (soft-shelled or misshapen) may persist long after an outbreak. Chickens that have had infectious bronchitis, especially during the first week of life, may never be good layers. There is no effective treatment for infectious bronchitis, although broad spectrum antibiotics for three to five days may aid in controlling secondary bacterial infections. Vaccines can be used for prevention, but they are only effective if they contain the right serotypes of virus for a given area.

Avian encephalomyelitis (epidemic tremors) is a viral disease usually affecting young poultry. There is no effective treatment. All replacement breeder and layer pullets should be immunized.

Most antibiotics are given in feed or water, preferably in water. Injecting antibiotics may be more effective if the disease is advanced and if the flock is small enough to be treated individually. Live and inactivated vaccines also are commonly used to reduce the adverse effects of the disease.

Fowl cholera is an infectious bacterial disease of poultry. With an acute outbreak, sudden unexpected deaths occur in the flock. Laying hens may be found dead on the nest. Antibiotics can be used, but require higher levels and longer medication to stop the outbreak. Where fowl cholera is endemic, live and/or inactivated vaccines are recommended. At the same time it is suggested not to start vaccinating for fowl cholera until it becomes a problem on the farm and a diagnosis is confirmed.

There are a variety of other problems which can cause an apparent drop in egg production especially of hens kept in backyards. They include:

- Predators and snakes consuming the eggs.
- Egg-eating by hens in the flock.
- Excessive egg breakage.
- Hens which are able to run free hiding the eggs instead of laying in nests.

Photo 37: **Alternative (cage-free) keeping technology**

Hen housing and keeping technology play a major role in the improved longevity and health of hens compared to previous decades. Nowadays, much of the manure from laying hens is utilized to nourish crops, which provides nutrients to the soil and reduces the use of fertilizers.

Eggs are a popular and inexpensive source of protein in our diets. With the ever-significant statistic of nine billion people in the world by 2050, this affordable food will be in high demand. Egg farmers are now in a position to help fulfil the growing need for an affordable and nutritious source of protein in an environmentally responsible manner.

**Questions for self-evaluation**

1. What economic aspects should be considered before rearing of pullets?
2. How can the profitable production of laying hens be ensured? Which technological requirements are essential?
3. How can the molting period be managed successfully?
4. How do nutritional factors affect egg production?
5. How do animal health factors affect egg production?

# 13. MANAGEMENT OF BROILER PRODUCTION

The processes of broiler industry are usually controlled by firms called integrators, who operate processing plants, feed mills, and hatcheries, and who contract with farmers to grow broiler chicks to market weight. Most broiler production is under contract with a broiler processor. The grower normally supplies the grow-out house with all the necessary heating, cooling, feeding, and watering systems. The grower also supplies the labour needed in growing the birds. The broiler processor supplies the chicks, feed, and veterinary medicines. The processor schedules transportation of the birds from the farm to the processing plant. In many cases, the processor also supplies the crews who place broilers into cages for transportation to the slaughter plant.

Because broiler housing is specialized and long-lived, the decision to produce broilers is a long-term commitment, and most producers have worked with their integrator for at least ten years. Actual contracts often specify very short durations but durations also range widely. Integrators usually own hatcheries, feed mills, slaughter plants, and further processing plants - that is, they may be vertically integrated into all stages except for broiler production, where they rely on networks of growers assembled through production contracts. Integrators also contract with, or own, primary breeder companies that develop poultry breeding stock, and they contract with other farm operations to produce broiler eggs for hatcheries.

Production contracts in all commodities pay farmers for their growing services, not for the commodity. But the broiler industry uses a distinctive compensation arrangement. Farmers are most often paid on the basis of their relative performance, compared with other producers who deliver broilers to the integrator within a specified time period, usually a week. Under a relative performance standard, all producers receive a base fee, but those who deliver more poultry meat for the number of chicks placed receive higher payments; differences in relative performance, therefore, are driven by differences in chick mortality and feed efficiency.

Contract fees are usually determined in the following way. The integrator measures the average cost of the inputs that the integrator provided to growers for chickens delivered to the processing plant in a week—the total value of feed, chicks, and veterinary services provided to growers divided by the total weight of chickens delivered that week. The company develops this calculation for each grower. Each grower is then paid a base fee, and those growers whose costs are lower than the average for all growers receive a premium over the base fee; those whose costs exceed the average for all growers receive a deduction from the base. The amount of the premium or deduction reflects the size of the cost difference.

In other cases the grower's compensation is calculated in the following way. The method is the same in that sense that integrator pay for all input expenditures in advance. The difference in the system is that the total revenue of marketed chickens is calculated then value of the already financed inputs is subtracted from that and the remaining net income is paid for the grower.

Photo 38: **Provision of best possible barn climate is the base of good performance**

Growers' relative costs differ, reflecting differences in chicken mortality and feed conversion across growers. Growers with higher mortality in their flocks will deliver fewer live-weight kilograms to the processing plant, and hence, they will have higher costs per kilogram. Growers whose flocks put on less weight for a given amount of feed provided will also deliver fewer live-weight kilograms and have higher costs per kilogram delivered.

A typical operation produces about 400 thousand chickens per year. Geographic concentration is driven by economies of scale in broiler production and slaughter, which encourage the growth of large facilities, and from the reductions in transportation costs for chicks, feed, and birds that can be achieved by locating processing plants, hatcheries, feed mills, and grow-out farms near one another.

But the industry now faces several challenges. Slowing productivity growth will press profits and lead to searches for different organizational designs. While the geographic concentration of the industry enables integrators to realize scale economies in production and processing, it also creates several risks and public policy challenges. Governments should also be involved in planning for and reacting to any serious outbreaks, and they need a deeper understanding of the organization of the industry in order to carry out their responsibilities.

Because production occurs in localized networks, growers in most areas have very few integrators from which to choose. Many growers have only a single integrator in their area and most have no more than three. Integrators will not necessarily be able to exercise market power, even if there were only one or two in an area, because the competition for growers depends on more than just the number of integrators in a market. Integrators must recruit growers away from other activities, such as producing other commodities on the farm or working off the farm. In addition, high geographic concentrations of broiler litter can create increased risks of water and air pollution from excessive applications of the nitrogen and phosphorous in litter.

Farms specialize according to the size of the bird produced; smaller broilers are used in the food service and restaurant trade, while the largest are cut into parts in processing plants. Over time, production has shifted to larger birds, reflecting the growth of de-boned and further processed products. Large birds are grown in larger houses equipped with more modern climate controls. They also spend more time on the farm, and hence consume more labour, feed, utilities, and housing services, so producers of larger birds receive higher revenue per bird.

Broiler houses are a major investment for growers. A single large house of nearly 3000 square metres can cost about 200-250 thousand EUR, depending its construction type. Most of the growers have multiple houses. Housing also plays an important role in the industry's productivity growth, as improvements in housing design and climate control systems can lead to improved feed efficiency, lower bird mortality, and reduced costs of feeding, litter management, and bird removal.

The slowdown in new barn construction mirrors the slowdown in the growth of the industry. It can be added that newer broiler barns can produce more birds from a given capacity than older houses because they have better temperature controls. Broiler barns have become steadily larger over time.

Photo 39: **Large-sized broiler barn**

Two important types of climate control equipment are tunnel ventilation and evaporative cooling cells. Tunnel ventilation systems consist of large fans at one end of a broiler barn and air inlets at the other end. The fans pull air through the house, removing heat from the building and creating a wind chill that provides further cooling. Evaporative cooling systems can be activated when tunnel ventilation alone fails to provide sufficient cooling. The systems are located on the outside of the house near air inlets. The cooling pads then lower the temperature of the air as it is pulled through the pads and the barn. Additional control equipment can be used to automatically monitor the temperature and humidity, adjusting the climate accordingly.

Slowing industry growth means fewer recent entrants to broiler production. Once a contract has expired, growers may have to retrofit their houses with new capital equipment in order to gain a contract extension. These expenditures can be substantial. Retrofitting is related to the age of the facilities of the operations, and those with the oldest houses were much less likely to make significant investments in new equipment.

All-in-all-out production limits the spread of disease and also allows operations to tailor feed mixes to birds of a specific age. Approximately half of the operations require that barns to be fully cleaned out, washed, sanitized, and dried after removal of each flock. The alternative, removing some or no litter after a flock is removed, with full clean-out occurring only after several flock removals, is less costly for the grower. Both approaches seem to be widely used.

The size of the operation affects the form of broiler enterprise expenses. For example, large and small operations provide labour in different ways. In the smallest enterprises (1-2 barns), the primary operator provides the broiler enterprise with twenty-five hours per week, on average. For those with 1-2 barns, a broiler enterprise provides additional income, but it is unlikely to be the primary source of employment. In contrast, larger enterprises rely on considerable amounts of hired labour, which allows for greatly expanded production for a given time commitment by the operators.

Gross farm income combines gross cash farm income with noncash income. In turn, noncash income includes the net change in inventories and accounts receivable, as well as the imputed rental value of the operator’s home if it is part of the farming operation. Net farm income subtracts cash and noncash operating expenses from gross farm income, and net cash farm income subtracts cash operating expenses from gross cash farm income. Cash operating expenses typically amount to two-third of gross cash farm income and average depreciation expenses, which account for almost all noncash operating expenses, amount to one-third of cash operating expenses. Net farm income is the difference between gross farm income and operating expenses, and it amounts to 25-30 percent of gross farm income.

Poor productive performance may be one source of negative net income. Depreciation is a more important factor explaining differences in net income. Farms with recent major capital expenditures will usually record substantial depreciation expenses, often large enough to generate negative net farm incomes. Correspondingly, older operations with fully depreciated assets rarely report negative net incomes.

The vertical integration has resulted in improved production efficiencies in the poultry industry. It also has benefited from consumer’s interest in lower fat sources of protein and has responded to the demand for more convenient products. The industry has continually provided increased brand name, processed products. The availability of value-added products and the other industry changes have resulted in large supplies of poultry products that were relatively low-priced meat sources.

Additionally, convenience is an important factor when consumers make food purchases. The trend to eat more prepared and processed foods and the trend to eat more meals away from home is a trend to monitor in the food industry. Value-added poultry products that cater to the ready-to-cook, heat-and-serve or ready-to-eat markets are expected to see continued growth.

At the same time the new animal health welfare guidelines for poultry and egg producers cause some uncertainty in the poultry sector. Production capacity will be an issue that will be affected, as will other factors related to the flock certification process. Environmental and political concerns have had an impact on the poultry industry. Restrictions on the placement of livestock production facilities and limitations surrounding the disposal or usage of poultry litter have also been issues of concern for poultry producers. Ensuring the minimal place especially for laying hens as well as the prioritisation of alternative keeping methods instead of cages also induce additional investment cost for farmers.

There are many things to consider when selecting the most suitable type of broiler housing and related equipment. Housing should be cost effective, durable and provide a controllable environment. When planning the construction of a broiler barn, one should first select a well-drained site that has plenty of natural air movement. The barn should be oriented on an east-west axis to reduce the effect of direct sunlight on the sidewalls during the hottest part of the day. The main objective is to reduce the temperature fluctuation during any 24-hour period. Good temperature control always enhances feed conversion and growth rate.

Correct stocking density is essential to the success of a broiler production system by ensuring adequate place for optimal performance. To accurately assess stocking density, factors such as climate, housing types, ventilation systems, processing weight and welfare regulations must be taken into account.

Thinning a portion of the flock is one approach to maintaining optimum chicken density. In some countries, a higher number of birds are placed in a house and reared to two different weight targets. At the lower weight target, 20-50% of the chickens are removed to satisfy sales in this market segment. The remaining birds then have more space and are reared to a heavier weight. Many different stocking densities are employed around the world. In warmer climates a stocking density of 30 $kg/m^2$ is closer to ideal.

Key to maximizing chicken performance is the provision of a consistent barn environment. Large fluctuations in barn temperature will cause stress on the chicken and affect feed consumption. Furthermore, these fluctuations will result in additional energy expenditure to maintain body temperature. This will help to conserve heating costs, reduce solar energy penetration and prevent moisture condensation. The most important insulation requirements are in the roof. A well insulated roof will reduce solar heat penetrating the barn on warm days, thus decreasing the heat load on the chickens.

Providing clean, cool water with adequate flow rate is fundamental to good poultry production. Without adequate water intake, feed consumption will decline and chicken performance will be compromised. Both closed and open watering systems are commonly used. Water purity with open systems is difficult to maintain as chickens will introduce contaminants into the reservoirs resulting in the need for daily cleaning. This is not only labour intensive, but also wastes water. Litter conditions are an excellent means of accessing the effectiveness of water pressure settings. If litter under the drinkers is excessively dry, it may indicate water pressure is too low.

Some recommendations for the open drinkers:

- Bell drinkers should provide at least 0.6 centimetres per chicken of drinking space.
- All bell drinkers should have a ballast to reduce spillage.
- Bell and cup drinkers should be suspended to ensure that the level of the lip of the drinker is equal to the height of the birds' back when standing normally.
- Height should be adjusted as the birds grow in order to minimize contamination.

For optimal broiler performance, it is recommended to use a closed drinker system. Water contamination in a closed drinker system is not as likely as with open drinker systems. Wasting water is also less of a problem. In addition, closed systems offer the advantage of not requiring the daily cleaning necessary with open drinking systems. However, it is essential to regularly monitor and test flow rates as more than a visual assessment is required.

Water meters should be sized the same as the incoming water supply line to ensure adequate flow rate. Water consumption should be evaluated at the same time each day to best determine general performance trends and chicken well-being. Any substantial change in water usage should be investigated as this may indicate a water leak, health challenge or feed issue. A drop in water consumption is often the first indicator of a flock problem.

Water consumption should equal approximately 1.6-2 times that of feed by mass, but will vary depending on environmental temperature, feed quality and chicken health.

- Water consumption increases by 6% for every increase in 1 degree in temperature between 20-32 °C.
- Water consumption increases by 5% for every increase in 1 degree in temperature between 32-38 °C.
- Feed consumption decreases by 1.23% for every increase in 1 degree in temperature above 20 °C.

Photo 40: **Closed drinking system has several advantages but needs regular checking**

Adequate water storage should be provided on the farm in the event that the main system fails. A farm supply of water equal to the maximum two-day demand is ideal. The storage capacity is based on the number of chickens plus the volume required for the evaporative cooling system. In hot climates tanks, should be shaded because elevated water temperatures will decrease consumption. The ideal water temperature to maintain adequate water consumption is between 10 - 14 °C.

Regardless of which type of feeding system is used, feeding space is absolutely critical. If feeder space is insufficient, growth rates will be reduced and uniformity severely compromised. All feeder systems should be calibrated to allow for sufficient feed volume with minimal waste.

Table 13: **Recommended number of feed lines on the basis of barn width**

| Barn Width | Number of Feed Lines |
|---|---|
| up to 13 metres | 2 lines |
| 13-15 metres | 3 lines |
| 16-20 metres | 4 lines |
| 21-25 metres | 5 lines |

When automated feeder is applied 50-70 chickens per 33 centimetre diameter pan are recommended. In case of automated chain feeder it should allow for a minimum of 2.5 centimetre feeder space per bird - when determining feeder space, both sides of the chain must be included. Lip of feeder track must be level with the chickens' back. Attraction lights are best used during the first five days following placement. At day five, background lights should be gradually increased, reaching normal whole house lighting by day ten.

Photo 41: **Automated broiler feeder**

The main purpose of minimum ventilation is to provide good air quality. It is important that the chickens always have adequate oxygen, optimum relative humidity and minimum amounts of carbon dioxide ($CO_2$), carbon monoxide (CO), ammonia ($NH_3$) and dust. Correct litter management is fundamental to chicken health, performance and final carcass quality which subsequently impacts the profit of both growers and integrators. The litter is the main residue of the broiler barn. Re-use of litter is practiced in a number of countries with a degree of success. Health and economic aspects beyond the environmental legislation must be taken into account before deciding to re-use the litter.

The following are some key points to consider when re-using the litter:

- Down time between flocks should be at least 12 days to maintain good litter quality.
- All wet caked litter to be removed during down time.
- In the case of a disease challenge, it is never recommended to re-use the litter.
- The availability and cost to replace old litter.

The manure contains nutrients, including nitrogen, phosphorous, potassium, and calcium that can be used to fertilize cropland. Excessive applications of nutrients, however, can create environmental risks to water and air resources. Litter management, therefore, becomes an important issue. Farms may apply used litter to cropland or they can remove it to other farms or other uses. For an operation that removed 400 thousand chickens in a year, and aimed to field-apply all litter, one hundred acres would be required, on average.

## Questions for self-evaluation

1. What are the most important elements of a contract between integrator and broiler grower?
2. What are the main size features of broiler farms?
3. How net farm income can be calculated in case of broiler production?
4. Which are the major technological conditions of adequate chicken performance?
5. Which circumstances must be taken into account when thinking about litter utilization?

# 14. MANAGEMENT OF SHEEP FARMING

In most agricultural enterprises, profit margins are slim and profitability varies from year to year, as supply and demand vacillate, and input costs rise (and rarely fall). Sheep production is no different than any other agricultural enterprise. It is not a "get rich quick" scheme. It requires good animal husbandry and business management skills to be successful and generate a return to land, labour, and management. Sheep can be raised for meat, milk and wool. As wool revenues have declined, producers have turned their attention especially to meat and secondly to milk production and the possibility of other by-products such as sheep leather. Most meat is sold as lamb and comes from animals under fourteen months old.

Sheep producers range in size from those with small flocks to large operations. Two types of enterprises exist: stock-sheep production and lamb feeding. Stock-sheep producers manage grazing flocks on pasture and range forage, often on arid lands with few alternative uses. Stock-sheep producers sell lambs that are either slaughtered or placed in feedlots. Feeder lambs are raised on forage until they are around 20-35 kilograms, then placed in feedlots to be fattened and finished for slaughter. Hair sheep have high parasite resistance and low heat stress and are known to provide multiple lambing possibilities.

Financial success usually begins with business planning. A business plan is a road map. It allows farmers to plan their business before spending any money. It increases their chances of success and helps avoid costly mistakes. Business planning is considered essential to the success for both new and established enterprises. While the formats and components of business plans vary, most plans include an executive summary, business description, production plan, marketing plan, and financial plan. Not all plans include all of the same components. Business planning will be more complicated for value-added enterprises versus production-only enterprises.

The key factors that determine profit in a sheep enterprise are feed costs, lamb production, and market prices. Feed costs represent nearly sixty percent of the cost per kilogram of lamb produced, and escalating feed grain prices during the first decade of the millennium have further increased the cost of lamb production. According to serious surveys, worldwide lamb and goat meat demand is expected to increase by one-third until 2030, and much of the additional demand can be met by increasing productivity and efficiency, rather than animal numbers.

Regardless of the purpose of the enterprise, most sheep producers want to know how they can reduce their feed costs. Everything they feed to their animals is more expensive than it was a few years ago, and it is likely to stay this way for the foreseeable future. However, there are some steps producers can take to reduce feed costs. Many of the steps are common sense and do not cost money (or much) to implement. Other strategies require a financial investment that should pay for itself in the long run. Some strategies may require some economies of scale.

Photo 42: **Sheep housing in modern but cost-effective way**

Photo 43: **Shearing of ewes every spring is essential regardless the price of the wool**

The first step towards reducing feed costs is fine-tuning the feeding program to make sure farmers are meeting, but not exceeding their animals' nutritional requirement. Nutrition requirements of sheep are based on its size (weight), age, and stage and level of production. Environmental conditions also affect nutrient requirements. Animals that have to walk further for the feed have higher nutritional needs, as well as animals below their critical temperature.

Efficiency of conversion of nutrients into gain in sheep is under some genetic control. Improvement in efficiency depends on increasing output and/or reducing input, but direct selection for improved efficiency requires measurement of feed intake, which has not been feasible on a large scale. Systematic use of breed diversity in terminal crossbreeding systems can improve the efficiency of commercial lamb production. However, lamb mortality can increase with terminal sire crossing for many reasons, such as increased lambing difficulty associated with excessive size and weight of lambs at birth. However, breed of ram should not affect fertility or litter size of the ewes, and it should not affect lamb survival from birth to weaning.

It is difficult to know how much to feed a sheep, if farmers do not know how much it weighs. Ideally, farmers should weigh the animals at least once per year. Prior to breeding is usually the best time. If farmers never weigh their livestock, their feeding program will be rooted in guesswork. Very few people, if any, can accurately estimate the weight of livestock. It is worth to consider purchasing a scale or sharing a scale with other producers.

Sheep should be divided into production groups and fed according to their nutritional requirements. If you keep pregnant and lactating females in the same feeding group, some females will be overfed or some will be underfed. If you keep females nursing triplets in the same feeding group as females nursing twins or those nursing singles, the same thing will happen. Feeding growing animals in the same group as mature animals is also problematic.

The feeding program can be made easier if the flock is uniform in size and productivity. Mixing breeds that vary significantly in size and productivity makes feeding properly more challenging. Farmers also enhance their marketing opportunities if they are able to market lambs of similar size and quality.

Dairy ewes should be separated into production groups and fed according to their stage of lactation, genetic potential for milk production, and desired level of production (maximum production is not always the most profitable). It may not be necessary to physically separate dairy ewes if different amounts of concentrate can be fed at the time of milking. Producers with small numbers of animals may also be able individually feed animals that have higher nutritional requirements.

Over or underfeeding sheep is costly, in many ways. Overfed sheep are obviously more expensive to feed. They tend to experience more reproductive problems. Fat animals are less heat tolerant. It may cost less to underfeed an animal, but farmers probably lose more money in the long run, as a result of poorer performance and health. If they financial resources inhibit them from feeding properly, they should reduce their animal numbers, not reduce how much (or what) they feed to the whole flock.

You can balance rations by hand (using simple math) or using a personal computer. Forages are usually the most variable part of any feeding program for sheep. Forage quality varies by plant species, stage of plant maturity, and various other production factors. Because of this, forages should be tested to determine their nutritive content. If hay is not tested, producer may be over or underfeeding certain nutrients. Farmers may be feeding more grain than is necessary or they may not be feeding enough grain to meet the nutritional requirements of their high-producing animals.

Photo 44: **Hay is the most frequent and important forage for sheep**

Because forages vary in cost and nutritive value, it is important to feed the right forage at the right time to the right group of animals. Alfalfa and other legume hays tend to cost more than grass hays. It is a waste of money to feed alfalfa or other high quality forages to sheep and goats that do not have high nutritional requirements. Alfalfa hay should be saved for lactating females or growing animals. Alfalfa hay tends to provide more protein and calcium than is needed by females in late gestation. Mature males and dry females do not have very high nutritional requirements. Grass hay (or pasture) almost always meets their nutritional needs. A high quality hay or grain supplementation is not usually necessary. Lambs that are being fed a high quality concentrate diet also do fine with grass hay.

A ewe in late gestation often cannot consume enough forage (dry or fresh) to meet her nutritional requirements, especially if she is carrying multiple births. Ewes nursing twins and triplets can usually not eat enough forage (dry or fresh) to meet their nutritional needs to produce enough milk for their offspring. Large-framed lambs often have a difficult time finishing on pasture and may require grain supplementation.

One of the best tools for evaluating the feeding program is body condition scoring. Body condition scores can be an indication of whether farmers are over or underfeeding their animals. They should aim for body condition scores of 3 to 3.5/5 at the time of breeding and lambing. When a ewe weans her offspring, her body condition score may slip to 2 or 2.5. This is right, so long as she is able to improve her body condition score in time for the next breeding season.

If body condition scores are still below 3 at the time of breeding, producer should flush the flock. Flushing is when farmer increase the nutrient intake of ewes prior to and during the early part of the breeding season. Flushing causes the ewes to gain weight. It is usually achieved by feeding 0.2 to 0.5 kilogram of corn or barley or moving the flock to a superior pasture. Flushing increases ovulation rates.

If ewes' body condition scores are 3 or above, it generally does not pay to flush them (with grain), though it is always a good idea to move the flock to a better pasture for breeding. A ram's body condition score may fall below 3 during the breeding season. It may be advisable to supplement him with grain during the breeding season.

In previous decades lambs started to be marketed at lighter weights, before they start to put on excessive fat. Perhaps, there will be an emphasis in the industry to produce more heavily muscled lambs, as opposed to bigger lambs. In lambs, optimal slaughter weight is determined by amount of fat covering the twelfth rib of the carcass. While the optimal fat thickness varies by market segment and consumer preference, 0.4 to 0.6 centimetres is generally accepted. The weight at which a lamb is slaughtered varies by breed, genetics, and management. Farmers can increase the optimal slaughter weight of a lamb by growing it slower on a higher-fibre diet. Lambs that are full-fed concentrate diets will tend to finish at lighter weights than those that are allowed to put on frame before fat.

Grinding and mixing of feed is an added cost that many sheep producers could avoid. Of all farm animals, sheep are best able to do their own grinding. With few exceptions they should be fed whole grain. Once the lamb has a functioning rumen, it can be fed whole grains. Whole grain feeding of lambs increases feed efficiency, increases average daily gain, and lowers overall cost of gain. It is not necessary to feed roughage (hay) when a whole grain diet is fed to lambs. Sheep can also be fed whole (raw) soybeans. Raw soybeans can safely replace soybean meal in a diet, though slightly slower rates of gain may be expected in a corn-based diet. Feeding raw soybeans to lactating ewes does not have any effect on lamb weaning weights or average daily gain. Due to their high oil content, whole soybeans are lower in protein than soybean meal.

In a self-feeding situation, livestock have feed in front of them at all times. With hand (or limit) feeding, a set amount of hay or grain is fed twice per day at approximately the same time each day. There are pros and cons to each feeding system. Lambs that are self-fed will consume more feed and gain faster. Those that are hand-fed tend to make more efficient gains. It is easier to monitor animal health when livestock are hand-fed. Hand feeding requires more feeder space per animal. Hand-feeding requires more labour, so it is less common with larger operations, though hand-feeding can be automated.

If square bales are being fed, shepherd can feed hay according to the animals' nutritional requirements. If round bales are fed, shepherd may want to limit access to the feeders. Some sheep get too fat on pasture and producer may want to limit grazing time. If labour is an issue, it is possible to self-feed a total mixed ration (TMR) to mature ewes. However, the ration must be composed predominantly of high-fibre feeds, such as hay or soy hulls. Less feeder space is required for self-feeding. High-producing dairy ewes or ewes nursing triplets are often given free access to feed, due to their high nutritional demands.

Photo 45: **Sheep grazing in good pasture conditions**

Because sheep do not require specific feedstuffs, it is possible to use many different feedstuffs to meet their nutritional requirements. To formulate a least cost ration, shepherd needs to be able to compare the cost of one feedstuff to another. The only way to compare the cost of one feedstuff to another is to compare it on the basis of how much it costs to provide a certain nutrient (energy or protein). The dry matter conversions are more important when we are comparing feedstuffs that vary in dry matter (e.g. silage vs. hay). The final calculation is to convert the price of dry matter to the price per kilogram of energy.

Hay stored outside lost twenty to fifty percent in dry matter. Storing hay in an open-sided building can reduce losses by seventy percent. The best way to store hay is inside a closed barn. Storage requirements vary with the type and density of bale, but normally range from five to six cubic metres per ton of dry hay. A sheep consumes its body weight in dry feed each month. When hay values are high, it is easier to justify investment in hay storage.

Hay and grain should generally not be fed on the ground. There is considerably more feed wastage when feed is fed on the ground. Feeding on the ground can also spread diseases. In larger operations where stock is wintered on pasture, it is right to feed supplements on frozen ground.  All feed should be fed in feeders. Shepherd should favour feeders which minimize wastage and keep the feed clean and free from manure or other foreign matter. There are many different designs for feeders. Not all feeder designs work equally well for all classes of sheep.

If feed is limit-fed, there needs to be enough feeder space for all sheep in the feeding group to eat at one time. It is generally recommended that each female have forty to fifty centimetres of feeder space. Lambs should have twenty to thirty centimetres of feeder space. It may be wise to cull animals that are too aggressive at the feeders or who do not stay out of the feeders.

Sheep do not require specific feedstuffs. They require specific nutrients: energy, protein, vitamins, and minerals. Though it varies by geographic region, year, and farm, grain is often a more economical source of nutrients than hay. 1 kilogram of corn is equivalent to 1.4 to 1.9 kilograms of hay. At the same time, it is important to remember that sheep are ruminant livestock that require a certain amount of roughage in their diet to maintain a healthy ruminant digestive system.

Soy hulls are a by-product of soybean processing. They are the seed coat of the bean. Soy hulls can replace a portion of either the forage or grain in the diet. Because of their unique physical characteristics, soy hulls can replace up to fifty percent of the forage in a diet. One kilogram of soy hulls is equivalent to approximately 1.4 kilograms of forage. Soy hulls can substitute kilogram for kilogram with corn or barley.

Producers who live near an ethanol plant may be able to feed dried distiller's grains (DDG) to their sheep. DDG are an excellent source of energy and protein, including rumen by-pass protein (up to fifty percent). But, they are also high in potassium, phosphorus, and sulphur, which can be problematic. Up to thirty percent of the corn in lamb finishing rations could be replaced with DDG. In ewe diets, DDG has been used to replace soybean meal as a protein supplement or up to two-thirds of the grain (corn), equating to twenty-five percent of the diet, without any ill effects.

Silage can be an economical source of nutrients for sheep, especially on large farms where feeding can be mechanized. Corn silage is composed of the entire corn plant. Silage can also be made from forage and small grain crops. The biggest risk factor associated with feeding silage to sheep is the risk of listeriosis. Listeriosis or “circling disease” is caused by the bacterium *Listeriosis monocytogenes*. Listeria are naturally present in the soil and also thrive in cool, moist conditions. The bacteria grow in spoiled fermented feeds and wet hays. To grow in silage, the bacteria require oxygen and a pH above 5.5. Listeria grows in silages where there is an infiltration of oxygen, such as the end of the bunker or near a hole in the silage bag. In sheep, listeria can cause late-term abortions, generalized infection, inflammation of the brain (encephalitis), and death in newborns. There is no known cure for listeriosis. Aggressive antibiotic treatment is usually employed.

Pastures should be subdivided into smaller areas for grazing. Smaller paddocks and shorter rotation periods result in less feed wastage and give the plants more time to recover. Shepherds can usually achieve higher stocking rates with intensive, rotational grazing systems. Rotational grazing may or may not aid in internal parasite (worm) control. The length of pasture rest is more important than the frequency of rotation.

There are several ways to extend the grazing season and reduce the amount of purchased feed inputs. Planting annual crops is one of the ways to extend the grazing season. Brassicas are high in digestible nutrients and protein. Winter cereal crops (wheat, rye, oats, and triticale) can provide autumn and winter grazing. Warm season annuals and perennials (native grasses) can be planted to improve summer grazing.

When feed costs are high, culling standards should be equally high. Shepherd cannot afford to take a chance on marginally productive animals when feed costs are high. Why feed a ewe that raises only one offspring when there are plenty of other females that will raise twins or triplets. On-average, a ewe's most productive years are from three to six. The most efficient ewes in the flock are the ones that wean a greater proportion of their body weight. It is a good idea to weigh and condition score the ewes at the start of breeding season and to weigh their offspring at the time of weaning. This will enable the shepherd to determine which ewes in your flock are the most efficient and which one's offspring shepherd should retain for breeding.

Photo 46: **Twin lambs can increase the income by spreading the fix costs**

Replacements should be selected from the most productive ewes in the flock. These are not necessarily the prettiest ones. They are the ones that utilize expensive feed resources to produce lambs that grow well. Productivity can be increased by breeding ewe lambs. Well-grown ewe lambs can be bred to produce offspring by the time they are one year old. Size is more important than age when decided if/when to breed lambs. The recommendation is that ewes achieve approximately two-thirds of their mature weight before being bred. Ewe lambs should be managed and fed separately from mature females, ideally up until the time they wean their first set of offspring. If ewe lambs are not big enough and shepherd cannot manage them separately, they should not be bred until the second year of life. Every extra lamb that farmers produce will reduce their feed costs, because it will spread out the fixed costs (overhead). Feed costs tend to comprise fifty to seventy-five percent of the production costs on a sheep farm.

## Questions for self-evaluation

1. Which primary sheep products can be produced and what is their economic significance?
2. Why does feed cost have outstanding importance in sheep farming?
3. What are the bases of ewes’ profitable nutrition?
4. How should farmers provide the best possible feeding technology of sheep?
5. What are the principles of breeding selection and culling in sheep husbandry?

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ISBN: 978-963-306-469-6