5-1982

An Approach to Selection of Variety and Planting Date in Corn Silage Production

Carlos A. Luna-Gonzalez

Recommended Citation

Luna-Gonzalez, Carlos A., "An Approach to Selection of Variety and Planting Date in Corn Silage Production" (1982). *All Graduate Plan B and other Reports*. 1058.
https://digitalcommons.usu.edu/gradreports/1058

AN APPROACH TO SELECTION OF
VARIETY AND PLANTING DATE
IN CORN SILAGE PRODUCTION

by

Carlos A. Luna-Gonzalez

A report submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Agricultural Economics

(Plan B)

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1982

ACKNOWLEDGEMENTS

Special appreciation is expressed to Dr. Jay C. Andersen, who, through his direction, helped me to write and develop this program.

Most of all, I would thank my parents, Carlos and Esperanza, for their support and encouragement throughout my graduate program.

Carlos A. Luna-Gonzalez

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES--(Continued)

ABSTRACT

An Approach to Selection of Variety and Planting Date in Corn Silage Production

by

Carlos A. Luna-Gonzalez, Master of Science
Utah State University, 1982

Major Professor: Dr. Jay C. Andersen
Department: Agricultural Economics

The major purpose of this study is to make additional information available to the farm manager to improve the decision-making process relating to corn silage production. This study is primarily concerned with factors that influence planting date and variety selection. Within the framework of decision theory analysis, a Bayesian approach is employed to calculate the best time to plant and the best variety to plant. The approach is used both with and without the possible occurrence of harmful spring frosts. The "seventy growing degree day" method is employed as a criterion for planting date selection. The planting dates are matched with four different season length corn varieties to formulate the courses of action available to the farm manager. The states of nature that may confront a grower are the degrees of damage associated with various frost intensities.

The decision theory approach of this study identifies the short to medium season variety as the optimal corn crop for Cache Valley. This study indicates that planting a shorter season variety than some Cache Valley farmers have been using in the past would be profitable.

The problem of a short water supply adds a constraint as to what varieties can be planted where the time required to reach the third stage of growth is most critical in obtaining potential yields.

(67 pages)

INTRODUCTION

This study is an update and refinement of a previous study on this topic by James L. Anderson (1976). Risk and uncertainty are conditions that are encountered frequently as part of agricultural life. The farm manager may improve his success by using a systematic scientific approach when dealing with weather conditions. The systematic approach employed in this study is that of Bayesion decision theory. Corn silage production in short-season areas is a process that could benefit by the use of this systematic approach.

The growing season for corn silage in Northern Utah is hampered by late spring and early fall frosts. Because corn silage is well adapted as a livestock feed, however, the farmer is willing to take some risk. This study is mainly concerned with Cache County because of data availability and because the frost constraints that are present there are a significant factor to be reckoned with in the decision process.

There are several decision points faced in corn silage production. Among them are: (1) selecting an optimal planting date, (2) choosing the best variety of corn to be used, and (3) deciding on a harvest date.

STATEMENT OF THE PROBLEM

Justification

Decision theory as a method takes advantages of the most up-to-the-minute information as the time for each decision approaches. Since there is some uncertainty involved, special methods must be employed to handle the process.

A purpose of this paper is to show if a systematic approach will yield better results than relying merely on past experience or intuitive feelings as to what the best decision might be.

Objectives

The objectives of this study are:

1. To determine the best variety of corn to be used, given the information that is available at the time the decision must be made,
2. To determine an optimum planting date,
3. To determine the optimal time of harvest,
4. To provide for the changes that might be necessary in any of these decisions due to changes in the states of nature.

Methods of Procedure

The following are the steps in the decision theory method as outlined in the work by Anderson (1976):

1. Determine the available actions that can be taken.

2. List the various states of nature which can occur.
3. Consider the consequences (gain, losses) of each combination of action and state of nature (state-act pair).
4. Design a procedure for obtaining knowledge about the state of nature. The procedure consists of:
    a. Possible observations that may forecast the true state of nature and which are observable at the time a decision is made.
    b. Estimation of a relationship that shows the dependence of the observations upon the states of nature in probablistic terms.
5. Evaluate the available strategies or recipes telling the decision maker which action to take in the event of a particular observation from the experiment.
6. Study the consequences of each strategy for each state of nature, as determined by the action probabilities.
7. Establish a choice criterion by which the decision maker solves the final problem.

This approach is designed to solve for the most economically efficient operation. This point is by no means fixed; as the states of nature continue to vary, the choices will also vary.

There are several available actions that must be given consideration. One of the most important variables is the variety of corn to be planted. The available varieties can be categorized according to length of season required for maturity such as: long, medium, short, and very short. Another action that is open to the farm manager is to vary the planting dates.

The states of nature are almost as complex as the available actions open to the farm manager. The length of season is to be considered with a relative heat factor added, measured in growing degree days. Frosts at the beginning and end of the season are significant factors in Northern Utah. The next general state of nature to consider is the amount of water available excluding irrigation. This includes the spring water storage in the soil and the rainfall, both quantity and timing.

The remaining steps three to seven are those where the actual work of the decision process takes place. A major portion of the input for this model will be drawn from information, experimentation, and data gathered in other projects. With minor adjustments, such a management system could also be applied to other areas and crops.

APPLICATION

For a description of the area under discussion and a review of literature, please see the work by James L. Anderson (1976).

Feeding Value of Corn Silage

Although the world literature on corn culture is voluminous, most of the published information pertains to warmer climates with longer growing seasons than those of Northern Utah. In order to make rational management decisions pertaining to practices followed within a corn silage enterprise, it is advantageous for farmers to know the factors associated with success in the production of corn.

As with any crop, attention must be given to all management practices. However, in the production of silage corn in short-season areas, two things seem obvious: first, there is need for more precise management information, and second, due to the short season, there is less room for error in the management of the crop relative to more favorable environments.

Corn silage is an important crop in states with large dairy industries. In some areas, the season is too short for grain production, in others grain can be produced but silage is preferred because of its higher nutrient yield. In areas where both grain and silage production are possible, many growers use later hybrids for silage than for grain because late hybrids will produce more tons of fresh silage than early ones. Much of the extra fresh weight of late hybrids is due to higher moisture content. However, many growers believe, and data from some works confirm, that the late hybrids also produce more dry matter per unit of land.

Growth is restricted in the short-season areas by a number of factors. Low spring temperatures in all regions, and rain, result in cool, wet soils delaying early working of the land, as well as reducing percent germination, emergence, and early growth. Lower accumulated corn heat units (or growing degree days) delay maturation of the crop during the season. Early fall frost reduces the effective growing season by severely restricting or halting growth prior to physiological maturity, and harvesting is often difficult due to inclement fall weather.

Early planting would be expected to improve maturity through a longer growth period, but extremely slow germination reduced the expected advantages of early planting. Because of the short, low-heat-unit season, it is difficult to consistently obtain whole plant dry matter (DM) levels above 25 percent at the time frost normally kills the corn crop (White, 1978).

Early frost does not always kill the growing point protected below the soil even though it may kill most leaves. Often partially-frosted corn will outperform later planted corn (Aldrich & Leng, 1965). Planting dates are basically governed by soil temperatures.

Early planting should effectively lengthen the growing season, but does so only if the early seedings germinate and emerge as rapidly as do later plantings, and if early growth is not restricted. White (1978) reported that the longer germination periods of the mid- to late-May plantings reduced the actual number of days from emergence to frost from those expected by early planting.

The strong correlation between emergence and soil temperature demonstrate the problem of determining the optimum time to plant corn. One finds little published data on the effect of planting dates on silage corn production in the northern states. Data from Charlottetown (Canada) over a four-year period (White, 1977) indicated significant yield differences each year due to planting dates, with the latest planting always giving the lowest yield. A maturity advantage for earlier plantings is clearly indicated for whole-plant silage. A progressive decline in whole-plant dry matter (DM) content occurred each year as planting is delayed. Such a decline is very detrimental to silage quality.

If one considers the amount and maturity of the grain in silage important, early planting is also advantageous, as indicated by the relative grain component yields. Later plantings greatly reduced grain yields, and the maturity of the grain component also declined rapidly with delayed planting each year. Overall, a definite maturity advantage to early planting occurred even when yields were not increased.

In a work conducted by White (1977), the earliest plantings gave a distinct maturity advantage as indicated by greater whole plant and grain DM contents, but there was no significant yield advantage. Greater maturity would be expected, since the actual days from emergence to harvest increased with earlier planting. One might, however, have expected a greater maturity advantage from the early plantings considering the differences in total days between planting and harvest resulting from different planting dates; but, the considerable longer germination periods reduced the overall advantage of early planting.

In 1973, 12 days' earlier planting added only 5 extra days between emergence and harvest; in 1974, a 15-day planting advance resulted in only a 7-day growth period advantage. Even though the earliest plantings were not made until the soil temperature had reached or exceeded 10° C., these low temperatures, coupled with rain, produced cold, wet soil conditions unfavorable to germination and early growth (Beauchamp & Lathwell, 1966; Gubbels, 1974; Free et al., 1966). Bunting (1968) reported as many as 40 days required for emergence from March plantings in England, with decreasing emergence periods for later plantings. Marley and Ayres (1972) also reported an increasing number of days to emergence with earlier plantings in Iowa.

But, once the plants emerged, only slight differences occurred in the time required to reach silking. Under farm conditions, germination problems might affect yields if plant stands are not adequate. Osafo and Milbourn (1975) suggested that early planting leads to higher grain yields because the production of the peak vegetative weight occurring near the time of silking allowed DM produced after that stage to be moved directly into the ears rather than into the stalks and leaves as occurred with later plantings. Since whole plants are harvested in silage production, whether the photosynthate has been transferred into stored grain or remains in the stalk may not be as important as it is in grain production (Daynard & Hunter, 1975). Early planting may also be related to maximum DM production in that a greater portion of the vegetative period occurs during longer day lengths. More DM was produced under long-day conditions than under short-day conditions in a study by Hunter et al. (1974). However, sufficient time after planting is required to allow the plants to reach their maximum DM production before frost, and this requires as much of the available season as possible with the hybrids currently grown. Germination is the most serious problem on the earliest plantings. Since obtaining sufficient maturity to produce a silage with a high DM content is a major problem, the maturity advantage of the early plantings becomes very important for silage quality. However, due to slow germination and growth of mid-May plantings, the benefits were not as great as expected. Early plantings took much longer to emerge and gave evidence of poorer germination.

Obviously, spring weather controls how early land can be tilled. Fall plowing with a single working in the spring, spring plowing with minimum tillage, no-till planting, or spring discing of corn stubble may permit earlier planting than the traditional multiple working of the land in the spring.

Because emergence and early growth are strongly linked to soil temperatures, increasing spring soil temperatures should improve yield and maturity. In Michigan, Lucus et al. (1976) reported that conventional plowing resulted in a 1° - 2° C. higher soil temperature (15 cm.) up to 14 days after plowing than did chisel plowing or no-tillage. At another location the increase was from 0° to 1° C.

Depth of planting for optimum performance varies with conditions (Aldrich & Leng, 1965). Since temperature decreases with soil depth, early plantings should be relatively shallow (4-6 cm.) whereas with later plantings, especially where the potential for a drying seedebed exists, deeper plantings (7-13 cm.) may be required to maintain moist conditions for germination. Stubble mulching, used to prevent wind erosion in the drier regions, may reduce soil temperatures.

However, some foreign workers have improved soil conditions with different mulching techniques. In France, Ballif and Dutil (1974) obtained earlier emergence, lower grain moisture, and higher grain yields by covering the soil with a plastic film directly after planting. Other French workers reported that a black plastic mulch increased growth, yield, and the N, P, K, and S contents of corn (Simon-Sylvestre & Chabannes, 1976). Jurgens et al. (1978) showed that during dry conditions, photosynthesis is more inhibited than translocation of photosynthate within the plant. Thus, translocation of photosynthate to the grain continues even when total accumulation of photosynthate is restricted as a result of soil water stress.

In short-season areas, growth is usually arrested by frost at some point prior to physiological maturity. However, prediction of the exact date that this will occur is difficult. To obtain as much maturity as possible, growers are reluctant to harvest prior to frost, and some wait until long after frost so the plant will be much drier. The effect of delayed harvesting on silage corn yields in a two-year harvest date study (White et al., 1976) showed that average DM yields increased rapidly during September until the harvest on 25 September. In both years, a frost that killed the leaves occurred on the day before this late September harvest.

A progressive decrease in DM yield of up to 2 t/ha occurred after frost as harvest was delayed. Daynard and Hunter (1975) report that the in vitro digestibility of corn is constant over a wide range of maturity. Harvesting in late September, just prior to frost, when the highest DM yield occurred would give a good quality feed as long as there is sufficient DM content.

In addition to DM yield losses, considerable tissue nutrient losses were also measured with delayed harvests. The K content decreased from 2.4 percent in early September to 1.85 percent at frost and then to about 1.45 percent in November. The percent N also decreased, but at a much slower rate. Calcium and Mg levels also decreased (White et al., 1976), with Mg dropping to below 0.2 percent in the tissue shortly after frost. Such low levels are very important from an animal feed standpoint.

Feeders using frosted corn with reduced levels of Mg and Ca should alter rations accordingly. Phosphorus levels were not seriously affected by harvest date. Depressed tissue nutrient levels coupled with decreasing DM yields represent substantial losses from the nutrients available in silage corn harvested prior to frost or just after being frozen. Thus corn should be harvested as soon as possible after being frozen.

Daynard and Hunter (1975) noted that maximum dry matter (DM) yield in Ontario occurred at 66-70 percent whole plant moisture. They suggested that neither seepage from the silo nor the ability of animals to consume sufficient feed were serious enough reasons to delay harvesting after whole plant moisture content was below 70 percent. They also reported that the in vitro DM digestibility (IVD), that is, actual value as a livestock feed, of the whole plant was essentially constant for corn over a wide range of maturity, as reflected in harvest dates, and thus would not influence choice of harvest date. Thus, the digestibility was constant as maturity and TDNs increased. In a two-year study in Indiana, Cadwell and Perry (1971) reported that DM yield of corn decreased after the middle of October, but there was no observed decrease in percent crude protein content. Maximum DM yield occurred at a whole plant content of 33 percent. In Ohio, Jurgens et al. (1978) observed maximum DM yields early in September when corn was between the dent and glaze stage. Total yield as well as leaf and stalk yields declined thereafter, apparently due to losses of crude protein and soluble carbohydrates from the plants. In Georgia, Cummings (1970) observed maximum corn DM yields in mid-September at 35-37 percent DM content with lower yields occurring at later harvests. Whole plant IVD values declined with late harvest in one of the three years studied.

The feeding value of corn silage prepared at various stages of plant maturity has been evaluated in numerous studies (Bryant et al., 1965; Johnson & McClure, 1968). Although differences in feeding value were reported, a major problem with early cut silage was the low DM intake due to the excessive amount of water consumed by animals eating the high moisture silage (Bryant et al., 1965). Huber (1975) suggested that the high acid content of silage made from immature corn rather than the low DM content restricts animal intake.

The declining whole plant yields which occurred after frost is apparently the result of a number of factors. Direct losses of plant parts such as leaves and tops of plants would account for part of the yield decrease, especially at the later dates when the plants are dry and brittle.

Deterioration of the plant through tissue breakdown and rotting of the stalks increased with time. At later harvests the pith of the stalks is jelly-like, an indication of decomposition. Loss of leaves and decomposition within the stalk could account for some nutrient loss and the relative increase in the percent cellulose at later harvest.

It is also possible that the first frost which killed the leaves, but not necessarily the whole plant, permitted continued respiration with little or no photosynthesis, thus utilizing plant reserves and reducing DM yields. This may also have allowed continued carbohydrate transfer to and filling of the grain component, which might explain the higher grain yields recorded after frost in 1974 (White et al., 1976). The IVD declined with time after frost in 1973, yet in 1974 this trend did not occur. The 1973 data do, however, suggest that loss in feed quality may be of concern in late harvested silage. In considering the IVDDM (in vitro digestibility dry matter) data, it is obvious that the quantity of digestible material harvested was greatest at the time of frost and declined thereafter. Daynard and Hunter (1975) reported changes in the relative IVD of different parts of the corn plant with time, but the overall IVD remained constant. However, their corn was not frozen. It is possible that freezing, and possible decomposition in parts of the plant after frost, could account for the decreasing IVD levels.

Decreasing N, P, and K contents in the plant tissue are a normal situation in maturing corn, since growth is increasing more rapidly at this time than is nutrient uptake. This is the situation observed prior to frost in various years. However, after frost, uptake of these nutrients apparently ceased since both yields and total nutrient content on a per hectare basis declined. It is not clear whether the nutrient losses are due to losses in plant parts or whether there are losses of nutrients directly from the plants themselves.

The work by White et al. (1976) found that in 1973 the loss in total DM yield between frost and the latest harvest amounted to about 25 percent, while the losses in N, P, and K amounted to 26, 26 and 39 percent respecitvely, of the amounts at frost. In 1974 the DM yield loss was about 12 percent, yet the N, P, and K losses were 22, 21, and 39 percent respectively. This suggested that the nutrient losses were not only directly related to the physical loss of plant parts, but were due as well to decomposition and/or leaching of soluble portions from the plants. The high K loss is understandable since this nutrient exists in a water-soluble form in the plant. Once frost killed the living cells, the K would be easily leached from the plants by rain. Johnson and McClure (1968) also reported lower contents of K, Ca, and Mg in late harvested, frozen silage corn compared with earlier harvests.

Nitrogen losses after frost, as indicated by a decrease in plant N content, are in agreement with the crude protein losses reported by Bryant et al. (1965), but disagree with the results of Cadwell and Perry (1971) and Johnson and McClure (1968), who found no decline in crude protein content with time of harvest. Various plant parts contain different concentrations of nutrients. Leaf nutrients accounted for 15, 10, and 20 percent of the whole plant N, P, and K nutrient contents respectively. Thus, leaf loss should be prevented if possible. The stalk below the ear is very rich in N and K whereas the ear contains most of the plant's P. Decomposition and loss of the interior of the lower stalk could thus release both N and K, accounting for some of the nutrient losses observed.

Growing Degree Days

Growing degree days takes into consideration the heat factor since growth is dependent upon heat over a restricted temperature range. The growing degree days calculation used in this model is that referred to as the U.S. Weather Bureau 50-86 method suggested by Gilmore and Rogers in 1958 and expressed as:

$$GDD = (TH/2 + TL/2) - 50$$

where

GDD = growing degree days for a given day in degrees Fahrenheit.

TH = maximum daily temperature in °F. (If $TH \geq 86°$, then $TH = 86°$.)

TL = minimum daily temperature in °F. (If $TH \leq 50°$, then $TL = 50°$.)

Since the corn plant begins growth at about 50° Fahrenheit, this temperature is used as the lower limit in the equation. Growth of the corn plant tapers off above an upper limit set at 86° F. Growing degree days are cumulative from the date of planting through maturity.

Total Digestible Nutrients

It is not sufficient when considering feasibility and profit to look only at tons per acre yields since the value of a ton of corn silage can vary significantly. Two of the more important factors are percent dry weight and degree of maturity. In this study, these factors will be taken into account by use of a term called Total Digestible Nutrients (TDN). As silage corn becomes more mature, it increases in percent dry weight and in TDN, thus becoming more nutritious and yielding more feed value to animals.

An index of the maturity values for field trials on corn is recorded in Appendix, Table 24.

For purposes of this study, TDN rather than total tons of silage per acre is considered in order that benefits may be more properly assigned.

THEORETICAL FRAMEWORK

Decision Model

This section contains an outline of the general decision theory process. This will follow the same seven general steps described earlier. The text and notation closely follow the works of Anderson (1976), Halter and Dean (1971), and Chernoff and Moses (1959).

The first step includes the list of available actions open to the farm manager:

$$a_1, a_2, \ldots a_i$$

Some actions as well as possible states of nature are excluded for simplicity as the model can become too complicated.

Step two is the listing of the states of nature:

$$\eta_1, \eta_2, \ldots \eta_i$$

In the third step, a gain-loss table (Table 1) is generated to show the consequences of each combination of action and state of nature. In this table, the values of U = Utility are listed. These are the gains or losses relative to each combination of available action and state of nature.

Step four separates what is known as the "data" problem from the "no data" problem. An experiment or other device is organized to gain information about the states of nature. Observations are made in the experiment that are related to the states of nature. It is then possible

TABLE 1

GAIN-LOSS RELATIONSHIP FOR EACH COMBINATION OF ACTION AND STATE OF NATURE

	Available Actions				
States of Nature	a_1	a_2	.	.	a_i
η_1	$U(\eta_1, a_1)$	$U(\eta_1, a_2)$	.	.	$U(\eta_1, a_i)$
η_2	$U(\eta_2, a_1)$	$U(\eta_2, a_2)$	.	.	$U(\eta_2, a_i)$
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
η_j	$U(\eta_j, a_1)$	$U(\eta_j, a_2)$	.	.	$U(\eta_j, a_i)$

to make those same observations just prior to the actual decision. An actual relationship in probablistic terms between the observations and the states of nature is made, thus making is possible to draw some conclusions about what the state of nature will be depending on the observation. If it is not possible to conduct such an experiment or make observations just prior to the decision, then the only choice is to deal with the situation as a "no data" decision problem.

As the experiment is conducted and the observations are made, the probabilities given in Table 2 are generated.

TABLE 2

PROBABILITY OF MAKING OBSERVATION o_k WHEN ${}_j$ IS THE STATE OF NATURE

States of Nature	Observations				
	o_1	o_2	.	.	o_k
η_1	$P(\eta_1, o_1)$	$P(\eta_1, o_2)$	.	.	$P(\eta_1, o_k)$
η_2	$P(\eta_2, o_1)$	$P(\eta_2, o_2)$	.	.	$P(\eta_2, o_k)$
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
η_j	$P(\eta_j, o_1)$	$P(\eta_j, o_2)$	.	.	$P(\eta_j, o_k)$

These probabilities are then used to calculate the optimal strategy in the steps to follow. This table can be updated as more information becomes available.

The "No Data" Decision Problem. Even in the case where it is not possible to make an observation that yields an updated prediction on the state of nature, decision-making ability may be improved by using *a priori* probabilities. This is called the "no data" problem. In other words, the probability of a state of nature may be formulated by using the data of all past periods. An example of this in weather data is the *a priori* probability of frost occurring on a certain spring day calculated by the Weather Bureau from the data of past years. Probabilities of η_j states of nature may be stated as in Table 3.

TABLE 3

A PRIORI PROBABILITIES ($\overline{\omega}_j$)

$\overline{\omega}_j = P(\eta_j)$
$P(\eta_1)$
$P(\eta_2)$
.
.
.
$P(\eta_j)$

With the use of the gain-loss table and the a priori probabilities, it is now possible to arrive at the best option under available actions or the best decision of an available action. See Table 4.

After conducting the operations in these tables, it is possible to pick the optimal action. If it is a loss table, the optimal action will be the minimum of the sums from a_1 to a_i,

$$B(\overline{\omega}, a_i) = \text{Min} \sum_{\eta=1}^{j} \omega_j \, U(\eta_j, a_i)$$

If it is a gain table, the optimal action will be the maximum value in the sums. In any case, the optimal action is indicated.

TABLE 4

CALCULATION OF THE "NO DATA" PROBLEM

	Loss-Gain Table Available Actions				Probability Table A Priori Probabilities
States of Nature	a_1	a_2	. .	a_i	$P(\eta_j)$
η_1	$U(\eta_1, a_1)$	$U(\eta_1, a_2)$	. .	$U(\eta_1, a_i)$	$P(\eta_1)$
η_2	$U(\eta_2, a_1)$	$U(\eta_2, a_2)$	. .	$U(\eta_2, a_i)$	$P(\eta_2)$
.	.	.	. .	.	.
.	.	.	. .	.	.
.	.	.	. .	.	.
η_j	$U(\eta_j, a_1)$	$U(\eta_j, a_2)$	. .	$U(\eta_j, a_i)$	$P(\eta_j)$

Loss-Gain Table with Probabilities Considered

Available Actions

a_1	a_2	. .	a_3
$[P(\eta_1)][U(\eta_1, a_1)]$	$[P(\eta_1)][U(\eta_1, a_2)]$	. .	$[P(\eta_1)][U(\eta_1, a_i)]$
.	.	. .	.
.	.	. .	.
.	.	. .	.
.	.	. .	.
.	.	. .	.
$[P(\eta_j)][U(\eta_j, a_1)]$	$[P(\eta_j)][U(\eta_j, a_2)]$	. .	$[P(\eta_j)][U(\eta_j, a_i)]$
$\sum_{a=1}^{i} \sum_{\eta=1}^{j} [P(\eta_j)][U(\eta_j, a_1)]$	$\sum_{a=1}^{i} \sum_{\eta=1}^{j} [P(\eta_j)][U(\eta_j, a_2)]$		$\sum_{a=1}^{i} \sum_{\eta=1}^{j} [P(\eta_j)][U(\eta_j, a_i)]$

The "Data" Decision Problem. Now that the "no data" situation has been discussed, the "data" problem will be considered with the commencement of step five. The available strategies are tabulated, including all possible combinations of actions which the decision maker might have, given the observations o_1 through o_k (see Table 5).

TABLE 5

LIST OF POSSIBLE STRATEGIES

	Actions Taken with Given Observations				
Strategies	o_1	o_2	.	.	o_k
s_1	a_1	a_1	.	.	a_i
s_2	a_1	a_2	.	.	a_i
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
s_m	a_2	a_3	.	.	a_i

The sixth step determines the consequences of each strategy for each state of nature as determined by the probabilities in Table 2. This computation gives the expected gain or loss for each strategy and the possible states of nature (see Table 6).

The last step includes multiplying the expected gains or losses of each state of nature in the preceding step by its respective *a priori* probability and totaling the results to yield one gain or loss figure for each strategy. This approach has the advantage of including all possible solution strategies. It may be a disadvantage to calculate all strategies if only the optimal one is wanted. In this case, there is a short-cut using what is called the a posteriori probabilities. No new information is needed to calculate the a posteriori probabilities. The letters ω_1 to ω_j will represent these a posteriori probabilities.

TABLE 6

EXPECTED UTILITY FOR EACH STRATEGY AND RESPECTIVE STATE OF NATURE

States of Nature	Strategies	
	s_1	$....s_m$
η_1	$P(\eta_1,o_1)\cdot U(\eta_1,a_i)+P(\eta_1,o_2)\cdot U(\eta_1,a_i)+...+P(\eta_1,o_k)\cdot U(\eta_1,a_i)$	....
η_2	$P(\eta_2,o_1)\cdot U(\eta_2,a_i)+P(\eta_2,o_2)\cdot U(\eta_2,a_i)+...+P(\eta_2,o_k)\cdot U(\eta_2,a_i)$	....
.	.	
.	.	
.	.	
η_j	$P(\eta_j,o_1)\cdot U(\eta_j,a_i)+P(\eta_j,o_2)\cdot U(\eta_j,a_i)+...+P(\eta_j,o_k)\cdot U(\eta_j,a_i)$	....

The first step in calculating the a posteriori probabilities is to multiply the probability of states of nature with respect to the observations by the corresponding a priori probabilities (Table 7). The resulting sums of the products relative to each observations are then totaled. The sums corresponding to o_k are divided into the

TABLE 7

COMPUTATION OF THE A POSTERIORI PROBABILITIES

States of Nature	Observations $Pr(\eta_j,o_k)$					A Priori Probabilities
	o_1	o_2	.	.	o_k	$P(\eta_j)$
η_1	$P(\eta_1,o_1)$	$P(\eta_1,o_2)$	.	.	$P(\eta_1,o_k)$	$P(\eta_1)$
η_2	$P(\eta_2,o_1)$	$P(\eta_2,o_2)$	.	.	$P(\eta_2,o_k)$	$P(\eta_2)$
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
η_j	$P(\eta_j,o_1)$	$P(\eta_j,o_2)$	.	.	$P(\eta_j,o_k)$	$P(\eta_j)$

Joint Probabilities
$P(\eta_j)\ P(\eta_j,o_k)$

o_1	o_2	.	.	o_k
$P(\eta_1)\ P(\eta_1,o_1)$	$P(\eta_1)\ P(\eta_1,o_2)$	.	.	$P(\eta_1)\ P(\eta_1,o_k)$
$P(\eta_2)\ P(\eta_2,o_1)$	$P(\eta_2)\ P(\eta_2,o_2)$	.	.	$P(\eta_2)\ P(\eta_2,o_k)$
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
$P(\eta_j)\ P(\eta_j,o_1)$	$P(\eta_j)\ P(\eta_j,o_2)$	.	.	$P(\eta_j)\ P(\eta_j,o_k)$
$\sum_{\eta=1}^{j} P(\eta_j)\ P(\eta_j,o_1)$	$\sum_{\eta=1}^{j} P(\eta_j)\ P(\eta_j,o_2)$	.	.	$\sum_{\eta=1}^{j} P(\eta_j)\ P(\eta_j,o_k)$

relative members of the joint probabilities matrix as performed in Table 8. The a posteriori probabilities are then multiplied by the corresponding figures in the loss-gain table (Table 1). These values are then totaled for each available action as shown in Table 9.

If a loss table is used, the object is to find the minimum $B(\overline{\omega}, a)$, or Bayes strategy for the observations. If a gain table is used, then the maximum should be found. The above procedure may be followed to find the optimal course of action for each observation o_1 through o_k. These optimal available actions for each observation become the Bayes strategy.

TABLE 8

A POSTERIORI PROBABILITIES

A Posteriori Probabilities	Observations				
	o_1	o_2	.	.	o_k
ω_1	$\frac{P(\eta_1)\ P(\eta_1,o_1)}{\sum_{\eta=1}^{j} P(\eta_j)\ P(\eta_j,o_1)}$	$\frac{P(\eta_1)\ P(\eta_1,o_2)}{\sum_{\eta=1}^{j} P(\eta_j)\ P(\eta_j,o_2)}$	.	.	$\frac{P(\eta_1)\ P(\eta_1,o_k)}{\sum_{\eta=1}^{j} P(\eta_j)\ P(\eta_j,o_k)}$
ω_2	$\frac{P(\eta_2)\ P(\eta_2,o_1)}{\sum_{\eta=1}^{j} P(\eta_j)\ P(\eta_j,o_1)}$	$\frac{P(\eta_2)\ P(\eta_2,o_2)}{\sum_{\eta=1}^{j} P(\eta_j)\ P(\eta_j,o_2)}$	.	.	$\frac{P(\eta_2)\ P(\eta_2,o_k)}{\sum_{\eta=1}^{j} P(\eta_j)\ P(\eta_j,o_k)}$
.	.	.	.	.	.
.	.	.	.	.	.
ω_j	$\frac{P(\eta_j)\ P(\eta_j,o_1)}{\sum_{\eta=1}^{j} P(\eta_j)\ P(\eta_j,o_1)}$	$\frac{P(\eta_j)\ P(\eta_j,o_2)}{\sum_{\eta=1}^{j} P(\eta_j)\ P(\eta_j,o_2)}$	.	.	$\frac{P(\eta_j)\ P(\eta_j,o_k)}{\sum_{\eta=1}^{j} P(\eta_j)\ P(\eta_j,o_k)}$

TABLE 9

BAYES STRATEGY

	Observation o_1				
	a_1	a_2	.	.	a_i
$B(\bar{\omega}, a)$	$\sum_{\eta=1}^{j} \omega_j U(\eta_j, a_1)$	$\sum_{\eta=1}^{j} \omega_j U(\eta_j, a_2)$	.	.	$\sum_{\eta=1}^{j} \omega_j U(\eta_j, a_i)$

USE OF THE DECISION MODEL

Planting Date Criteria

The decision model described is applied to the date of planting and best variety of corn. A method of determining an optimal planting date consists of determining the first seven consecutive spring days for which the growing degree days (GDD) as computed according to the formula on page 15 total 70. The earliest planting date would be the day on which the cumulative GDD for the previous 7 days reaches this total. Optimal planting dates determined according to this method for the years 1959-1966 are presented in Table 18 of the Appendix. These years are selected because they are the ones for which the yield data of Nielson (Corn Trials published for the years between 1953 and 1966) and the climate data are available.

Some indication of the relative success of this method of planting date selection can be gained by examining the records of spring frost activity for the eight years in question. Table 20 of the Appendix gives the dates and intensities of late spring frosts for those eight years. Using the figure of about seven days to emergence, the degree of frost damage that the crops received can be noted.

Another method of planting date selection is the use of mean soil temperature. This method recommends planting when the mean soil temperature reached 50° F. Although the data for this method are relatively recent, some conclusions can be drawn. Table 18 (Appendix) gives those dates for the years 1969-1975 when the spring mean soil temperature for Cache Valley first reached 50° F. According to the data of Table 18, this method would have the farmer in Cache Valley plant earlier, on or about May third. A direct comparison cannot be made, however, since data are not available for those years. Applying this criterion for planting to the years 1969-1975, it can be noted from the data of Table 19 (Appendix) that 1970 crops would have received some frost damage and those for 1975 would have had major frost damage.

It is not immediately apparent which is the better of these two methods; however, it appears that the GDD method provides a safer margin for avoidance of frost damage. Comparing the two methods for the years 1969 to 1975, one sees that the 70 GDD method is a little more conservative.

An examination of the growing degree day method is of some interest. By applying the criterion of 70 GDD in seven consecutive days and calculating the corresponding date of emergence, the severity of frosts affecting corn silage crop planting could be more closely quantified. From the information on maturity and the formulation of growth stages in Appendix, Table 24, it is possible to predict the time of emergence once the planting date has been selected. The corn plant will emerge 80 GDD after planting. Suppose that the various planting dates or courses of action are labeled a_1 through a_i, where

a_1 = May 2-7
a_2 = May 8-13
a_3 = May 14-19
a_4 = May 20-25

a_5 = May 26-31

These courses of action are applied in the data of Table 10. Conclusions can be drawn as to the relative success of this criterion for determining the course of action for planting dates relative to past experiences.

The states of nature $\eta_1 \ldots \eta_j$ in Table 10 reflect the state of nature with respect to frost, where:

η_1 = no frost
η_2 = mild frost (32° - 29° F.)
η_3 = hard frost (28° F. and below)

It is evident from Table 10 that the GDD method is successful in the avoidance of frost in seventeen out of twenty-three years from 1952, the first full year when data were recorded at the Utah State University Experimental Farm, until 1974. A record of 83 percent success in avoiding major frost damage but with early planting would be desirable. As a general rule, then, the GDD method is more reliable in selection of the optimum planting date to avoid these frosts. There is, of course, the constraint of field conditions due to wet or adverse weather to be considered. Some information relative to how wet the soil generally will be is in the precipitation data presented in Table 25 (Appendix).

Planting Decisions

In addition to planting date, variety is an important decision. Hybrid corn offers a wide range of growing season varieties by which farm managers may optimally match growth to climate conditions for

TABLE 10

70 GDD PLANTING DATES AND POTENTIAL DATES OF EMERGENCE

Year	70 GDD Reached	Planting Date Action a_i	Emerge 80 GDD After Plant	Days to Emerge	States of Nature η_j
1974	May 5	a_1	May 11	6	η_1
1973	May 12	a_2	May 18	6	η_1
1972	May 7	a_1	May 16	9	η_1
1971	May 5	a_1	May 14	9	η_1
1970	May 7	a_1	May 19	12	η_1
1969	May 6	a_1	May 12	6	η_1
1968	May 7	a_1	May 18	11	η_1
1967	May 20	a_4	May 25	5	η_1
1966	May 3	a_1	May 8	5	η_3
1965	May 16	a_3	May 24	8	η_1
1964	May 15	a_3	May 21	6	η_1
1963	May 6	a_1	May 14	8	η_1
1962	May 6	a_1	May 12	6	η_2
1961	May 22	a_4	May 27	5	η_1
1960	May 10	a_2	May 16	6	η_3
1959	May 14	a_3	May 30	16	η_1
1958	May 6	a_1	May 16	10	η_1
1957	May 5	a_1	May 15	10	η_1
1956	May 8	a_2	May 19	11	η_1
1955	May 10	a_2	May 19	9	η_2
1954	May 8	a_2	May 14	6	η_3
1953	May 31	a_5	June 9	9	η_1
1952	May 4	a_1	May 12	8	η_3

their areas. Most regions presently enjoy the options of long, medium, short, and very short season varieties.

Four such hybrids were selected for purposes of this study and applied to growing conditions for Cache Valley. These varieties are: Utah Hybrid 680 (long season, 2550 GDD), Utah Hybrid 544 (medium season, 2450 GDD), Utah Hybrid 330 (short season, 2250 GDD), and Utah Hybrid 216 (very short season, 2150 GDD). These designations are of one particular company. Others have similar selections. In the decision model, these four varieties will be labeled v_ℓ, where: $\ell = 1, 2, 3, 4$.

v_1 = Utah Hybrid 680
v_2 = Utah Hybrid 540
v_3 = Utah Hybrid 330
v_4 = Utah Hybrid 216

In the following analysis, potential green weight yields (based on Table 24, Appendix) were assumed to be twenty-six tons per acre for Utah Hybrid 680, twenty-five tons per acre for Utah Hybrid 544, twenty-three tons per acre for Utah Hybrid 330, and sixteen tons per acre for Utah Hybrid 216. The prices used in figuring the profit or loss are taken from Table 22 in the Appendix. The budget cost information comes from budgets worked out at Utah State University (Table 27, Appendix). Both prices and budget information are for the year 1981.

Allowing for all possible combinations of planting dates and varieties, there are twenty courses of action open to the farm manager. Using the growth data in Table 24, Appendix, the GDDs to maturity for each variety, and the above assumptions, values of TDN per acre may be calculated for each combination of course of action and state of nature

(Table 11). This table is the profit or gain table as referred to in the decision model. The growing degree days in Table 11 are figured from Utah State University Experiment Station data recorded during the years 1959-1966.

In the first planting period, a_1, if there is no frost, Utah Hybrid 544 yields the highest profit, but by the next planting period, a_2, Utah Hybrid 330 has a higher profit yield. Hard frosts that affect the first planting period would also give the advantage to Utah Hybrid 330 over 544. It can be concluded from the foregoing that it is best to use the corn hybrid with the longest possible growing season and still come close to the potential of the crop. Thus, it can be seen that the grain development during the final growth stage is quite important.

The data of Table 12 have been prepared to show the possibility of each state of nature occurring in combination with the possibility of potential observation (for calculation procedure, see Table 20 in the Appendix). These are frequency of potential observation for various states of nature given any one planting date a_1 to a_i, figured on the basis of the thirty-year period 1931-1960. (Note: Planting dates $(a_1 \ldots a_5)$ are implicit in o_k's.)

Where there are no experimental means of predicting with any degree of accuracy the state of nature that will affect the decision in the immediate future, the situation becomes a "no data" problem to be solved by use of the *a priori* probabilities and the profit or gain table. Table 13 gives the results of this process as calculated from the data in Tables 11 and 12.

TABLE 11

PROFIT TABLE WITH ALL POSSIBLE COMBINATIONS OF PLANTING DATES, VARIETIES, AND STATES OF NATURE (BASED ON 1981 PRICES AND COSTS)

	States of Nature								
	No Frost			Mild Frost			Hard Frost		
	1			2			3		
Courses of Action	GDD	TDN*	Profit in $/acre	GDD	TDN*	Profit in $/acre	GDD	TDN*	Profit in $/acre
a_1v_1	2318	5.67	199.66	2278	5.56	192.71	2220	5.41	183.23
a_1v_2	2318	5.70	201.56	2278	5.60	195.24	2220	5.44	185.13
a_1v_3	2318	5.59	194.61	2278	5.59	194.61	2220	5.51	189.56
a_1v_4	2318	3.89	87.19	2278	3.89	87.19	2220	3.89	87.19
a_2v_1	2259	5.51	189.56	2219	5.40	182.61	2158	5.24	172.49
a_2v_2	2259	5.55	192.08	2219	5.43	184.50	2158	5.26	173.76
a_2v_3	2259	5.59	194.61	2219	5.51	189.56	2158	5.33	178.18
a_2v_4	2259	3.89	87.19	2219	3.89	87.19	2158	3.89	87.19
a_3v_1	2199	5.35	179.45	2159	5.24	172.49	2091	5.07	161.75
a_3v_2	2199	5.39	181.97	2159	5.26	173.76	2091	5.08	162.38
a_3v_3	2199	5.46	186.40	2159	5.33	178.18	2091	5.15	166.81
a_3v_4	2199	3.89	87.19	2159	3.89	87.19	2091	3.77	79.62
a_4v_1	2137	5.18	168.71	2097	5.07	161.75	2015	4.87	149.12
a_4v_2	2137	5.21	170.59	2097	5.10	166.94	2015	4.88	149.75
a_4v_3	2137	5.27	174.39	2097	5.16	167.44	2015	4.93	152.90
a_4v_4	2137	3.86	85.29	2097	3.78	80.24	2015	3.61	69.50
a_5v_1	2065	4.99	156.69	2025	4.89	150.38	1935	4.66	135.85
a_5v_2	2065	5.02	158.59	2025	4.92	152.28	1935	4.68	137.11
a_5v_3	2065	5.07	161.75	2025	4.96	154.80	1935	4.72	139.64
a_5v_4	2065	3.71	75.82	2025	3.63	70.77	1935	3.45	59.39

SOURCE: GDD taken from Appendix Table; prices taken from Appendix Table 22; costs from L. H. Davis, *Crop Enterprises Budgets For Farm and Ranch Planning in Utah*, Appendix, Table 27.

*TDNs in tons/acre.

TABLE 12

FREQUENCY OF POTENTIAL OBSERVATION FOR VARIOUS STATES OF NATURE IN RELATION TO POSSIBLE COURSE OF ACTION (BASED ON 1941-1971 NORMALS)

	$\Pr(o_k/\eta_j)$				
	Potential Observation on Planting Date				
States of Nature	$o_1^{\eta*}$	$o_2^{\eta*}$	$o_3^{\eta*}$	$o_4^{\eta*}$	$o_5^{\eta*}$
η_1	.30	.45	.60	.70	.85
η_2	.05	.05	.05	.05	.025
η_3	.65	.50	.35	.25	.125

$*\eta$ = 1, 2, 3, 4 corresponding to each corn variety (v_1, v_2, v_3, v_4).

From Table 13, the optimal time to plant would be the first period in May, a_1. It would be unwise to plant prior to May in Cache Valley as the probabilities of a killing frost are too high and the GDD or heat units decrease rapidly.

Now, turning to a discussion of the "data" problem, observations are taken and <u>a posteriori</u> probabilities are calculated. The first is to obtain the probability of success of the observation over an experimental period. From 1952-1974, there were seventeen years in which the frost damage was successfully avoided (η_1), two years with minor frost damage (η_2), and four years with major frost damage (η_3). (See Table 10.) The probability of each state of nature

TABLE 13

"NO DATA" PROFIT TABLE

States of Nature	Available Actions			
	a_1v_1	a_1v_2	a_1v_3	a_1v_4
η_1	199.66	201.56	194.61	87.19
η_2	192.71	195.24	194.61	87.19
η_3	183.23	185.13	189.56	87.19
	a_2v_1	a_2v_2	a_2v_3	a_2v_4
η_1	189.56	192.08	194.61	87.19
η_2	182.61	184.50	189.56	87.19
η_3	172.49	173.76	178.18	87.19
	a_3v_1	a_3v_2	a_3v_3	a_3v_4
η_1	179.45	181.97	186.40	87.19
η_2	172.49	173.76	178.18	87.19
η_3	161.75	162.38	166.81	79.62
	a_4v_1	a_4v_2	a_4v_3	a_4v_4
η_1	168.71	170.59	174.39	85.29
η_2	161.75	166.94	167.44	80.24
η_3	149.12	149.75	152.90	69.50
	a_5v_1	a_5v_2	a_5v_3	a_5v_4
η_1	156.69	158.59	161.75	75.82
η_2	150.38	152.28	154.80	70.77
η_3	135.85	137.11	139.64	59.39

occurring after the observation of 70 growing degree days for the first time in seven consecutive days would be:

A Priori Probability $\bar{\omega}$	η_1	.739	[17 years that η_1 occurred out of 23 years]
	η_2	.087	[2 years that η_2 occurred out of 23 years]
	η_3	.174	[4 years that η_3 occurred out of 23 years]

These observation probabilities are multiplied by the corresponding probabilities (frequency of potential observation) of Table 12 to derive the joint probabilities shown in Table 14. The columns have also been summed. Each a_i, η_j value in the matrix of Table 14 is divided by its corresponding sum at the bottom of each column to generate the values for the a posteriori probabilities (Table 15).

TABLE 14

JOINT PROBABILITIES

States of Nature	$Pr(\eta_j) \cdot Pr(O_k/\eta_j)$				
	a_1	a_2	a_3	a_4	a_5
η_1	.2218	.3326	.4435	.5174	.6283
η_2	.0043	.0043	.0043	.0043	.0022
η_3	.1130	.0869	.0608	.0391	.0217
Total Pr(0)	.3391	.4238	.5086	.5608	.6522

TABLE 15

A POSTERIORI PROBABILITIES

States of Nature	Available Actions a_1	a_2	a_3	a_4	a_5	A Posteriori Probabilities
η_1	.6541	.7848	.8720	.9226	.9633	W_1^k
η_2	.0127	.0101	.0085	.0077	.0066	W_2^k
η_3	.3332	.2051	.1195	.0697	.0301	W_3^k
Total	1.0000	1.0000	1.0000	1.0000	1.0000	

It now becomes a simple operation to replace the a priori probability column from above with the a posteriori probability values from Table 15. A linear transformation would generate our base table. Through this process the smallest value of all possible actions given the states of nature, (a_v/η_j), are selected as a base. Then, all other entries in Table 16 given the relative states of nature will be transformed downward accordingly (Table 16). (Note: In Table 13 (a_5v_4/η_1), (a_5v_4/η_2), and (a_5v_4/η_3) are our respective bases.)

At this stage, we multiply those values (Table 16) by the corresponding a posteriori probabilities from Table 15 to generate our adjusted pay-off table (Table 17).

From the entries in Table 17 denoted by (*), the action which maximizes the value of $B(\overline{\omega},a_1)$ is as follows:

TABLE 16

BASE TABLE, GIVEN THE POSSIBLE PLANTING DATES AND VARIETIES

States of Nature	Available Actions				A Posteriori Prob.	Appropriate Planting Date
	a_1v_1	a_1v_2	a_1v_3	a_1v_4	ω_j^k	
η_1	123.84	125.74	118.79	11.37	.6541	a_1v_ℓ
η_2	121.94	124.47	123.84	16.42	.0127	
η_3	123.84	125.74	130.17	27.80	.3332	
	a_2v_1	a_2v_2	a_2v_3	a_2v_4		
η_1	113.74	116.26	118.79	11.37	.7848	a_2v_ℓ
η_2	111.84	113.73	118.79	16.42	.0101	
η_3	113.10	114.37	118.79	27.80	.2051	
	a_3v_1	a_3v_2	a_3v_3	a_3v_4		
η_1	103.63	106.15	110.58	11.37	.8720	a_3v_ℓ
η_2	101.72	102.99	107.41	16.42	.0085	
η_3	102.36	102.99	107.42	20.23	.1195	
	a_4v_1	a_4v_2	a_4v_3	a_4v_4		
η_1	92.89	94.77	98.57	9.47	.9226	a_4v_ℓ
η_2	90.98	96.17	96.67	9.47	.0077	
η_3	89.73	90.36	93.51	10.11	.0697	
	a_5v_1	a_5v_2	a_5v_3	a_5v_4		
η_1	80.87	82.77	85.93	0.0	.9633	a_4v_ℓ
η_2	79.61	81.51	84.03	0.0	.0066	
η_3	76.46	77.72	80.25	0.0	.0301	

$$B(\overline{\omega}) = \text{Max } B(\overline{\omega},a_1),\ B(\overline{\omega},a_2),\ B(\overline{\omega},a_3),\ B(\overline{\omega},a_4),\ B(\overline{\omega},a_5)$$

where

$$B(\overline{\omega},a_1) = a_1v_2$$

$$B(\overline{\omega},a_2) = B(\overline{\omega},a_3) = B(\overline{\omega},a_4) = B(\overline{\omega},a_5) = a_1v_3$$

TABLE 17

ADJUSTED PAY-OFF TABLE:
*MAXIMIZING ACTION CRITERION

Time of Attaining GDD 70 Criterion	Available Actions			
	a_iv_1	a_iv_2	a_iv_3	a_iv_4
a_1	123.81	125.72*	122.64	18.91
a_2	113.59	115.85	118.78*	14.78
a_3	103.45	105.74	110.21*	12.47
a_4	92.65	94.47	98.20*	9.51
a_5	80.72	82.61	85.73*	0.00

If the seven consecutive days GDD total reaches seventy in the first planting period, then Utah Hybrid 544 would be the recommended crop for planting. If the seventy growing degree days are reached in the later periods in May, then Utah Hybrid 330 would be the recommended variety to plant.

Harvest Considerations

There has been much discussion about the best time for harvesting corn. Some of the key areas for consideration are: precipitation, fall frosts, maturity, and silage moisture content.

Precipitation. Snow and rain are possible constraints on the growing season. Although it could be a problem, snow does not generally stay on the ground long enough to interfere with the harvest. Snow in Cache Valley does not begin to accumulate until late November or early December, and frosts would have stopped the growth of the plant long before that time.

Rain is more of a problem than snow. The rain itself does not damage the corn, but if the soil gets too wet, the heavy equipment used for harvesting is unable to function properly. Table 25 (Appendix) gives moisture accumulations in the fall months near an expected normal harvest time. From these data, it is evident that there are not too many times when the farm manager can harvest and avoid the heavy moisture. Harvesting early would minimize the risk of wet weather but would also shorten the growing season. The farm manager takes more of a risk by waiting until the last week of September to harvest. If harvest is delayed past the first few days of October, the risk factor is greatly increased. After the first ten days of the month, precipitation begins to accumulate more rapidly (Table 25, Appendix).

Fall Frosts. Cool nights can be expected in the fall months in the valleys of Northern Utah. By the last week in September, the probability of a 32° F. frost is 50 percent, and by October 11, the probability of a 28° F. frost is 50 percent. In selecting a harvest date, DeVere R. McAllister, Extension Agronomist at Utah State University, suggests three procedures that will help:

> 1. If the corn was in the early glaze stage when frosted, harvest as soon as possible as further drying will make packing more difficult.
>
> 2. If the corn is immature (milk, early dough--partially dented), let it be, if the frost nips only the tops above the ears. Periodically check for the early glaze stage and harvest when ready. More growth will occur.
>
> 3. If corn is immature (milk or early dough--partially dented), and is frosted to below the ears or to the ground, let it dry several days in the field under bright, clear weather or a week in damp, cloudy weather. There will be no further growth during this delay, but the moisture level in the stalks and ears will decrease allowing better storage and diminished leakage from the silage mass. The leaves on a mature, unfrosted corn plant make up only 15 percent of the total weight. Should they frost and blow off, you still have from 85 to 90 percent of the total left (McAllister, 1974, p. 3).

One of the real danger of frost is that too much drying can take place. Most sources have stated that the ideal moisture level is between 60 and 70 percent for compacting and storage.

Maturity. Determining the proper degree of maturity is an important factor in optimizing crop yield. There have been several methods suggested for testing maturity. The Northrup King Company, for example, suggests:

> One good way to determine whether or not your crop has matured is to split a kernel from tip to top. It has completed its growth cycle when a tough black layer has formed just above the tip, which seals off the embryo and

> starchy endosperm. Once it reaches this state, corn will start to dry out naturally. No further grain development occurs.

McAllister makes the following suggestion on how to tell the corn is mature:

> The ideal time to harvest for safe storage and maximum milk or meat per acre is when the kernels begin to glaze, which is well past the time when kernels are just dented. It is later than you think by just looking at the plant and the outside of the ears. You can afford to let some of the lower leaves die and fall off rather than rush harvesting the crop with the grain still growing. In late August or early September, go into the field at least once a week and break the upper half off of several ears from scattered locations leaving the butt of the ear on the plant. Now examine the kernels around the ring of the broken upper half of each ear. Using your fingernail, a pencil, a nail, or other pointed object, pierce the lower part of each kernel around the ring. If juice comes out, you are too early as starch is still being deposited in the kernels and maximum starch accumulation has not occurred. When the kernels have reached the hard-dough or early glaze stage, no juice will be evident and growth will have ceased--go ahead and harvest (McAllister, 1974, p. 1).

Another method that has proven accurate and that is easy to use is the accumulation of growing degree days. This measure gives the farm manager up-to-date information as to how his crop is maturing. Through the accumulation of heat units, it can be noted whether or not the season has been as hot or as long as normal. From Table 24 in the Appendix, it is possible to predict the time of maturity by accumulating heat units.

SUMMARY AND CONCLUSIONS

This paper has been performed for the purpose of helping the farm manager in making better decisions with regard to the choices of action that will yield the best results in corn silage production, when some constraints of variable nature are imposed. A foreknowledge of the states of nature that can occur is an exigency for improving the decision process.

The farm manager does not know when or how nature is going to move to frustrate or to aid him, but by studying the alternatives and planning a strategy for each, he stands a much better chance of making the correct move when a given constraint is imposed at random.

Specifically, this work has considered the various states of nature that are likely to occur in any given year that will condition corn silage production in the Cache Valley area.

An excellent water supply reading, from the observation of snowpack and water storage, such as is normal in Cache Valley, has no effect at all upon the action to be taken.

The seventy growing degree days accumulated in seven days method as a criterion for planting date selection is reliable and can be applied with little training. Only one piece of equipment is needed for collecting data, a minimum-maximum thermometer.

The farmer can improve the safety margin of the method by allowing a few days between when the 70 GDD are reached and the planting date if the 70 GDD date is unusually early, as in 1952 and 1966 (see Table 10).

Along with the planting date, it is important to select an appropriate variety of silage corn to plant. Within the limits imposed, the best variety would be Utah Hybrid 330 or Utah Hybrid 544. Modern technology applied to the breeding of the corn silage plant has made significant improvement in productivity, offering a wide range of varieties which may optimally be matched to climate conditions.

This study recommends the use of the accumulated growing degree days (GDD) to maturity for determining the approximate date of maturity. GDD are measurable and can provide up-to-date prospects at decision time.

By applying the right data to the decision theory model, more efficient decisions should be applied to the production of corn silage in Northern Utah. With minor adjustments, this farm management system could be applied to other areas and to other crops.

BIBLIOGRAPHY

Aldrich, S. R., and Leng, E. R. "Modern Corn Production." The Farm Quarterly (Winter 1965):77, 215-216.

Anderson, J. L. "A Decision Theory Approach to a Resource Management System in Corn Production." (Unpublished M.S. thesis, Utah State University, 1976).

Ashcroft, G. L., and Derksen, W. J. Freezing Temperature Probabilities in Utah. Logan, Utah: Agricultural Experiment Station, Utah State University Bulletin 439, 1963.

Ballif, J. L., and Dutil, P. "The Use of Photodegradable Plastic Film in the Cultivation of Maize in the Chalk Area of Champagne." C.R. Seances Acad. Agric. Fr. 60 (1974):389-401. (Field Crop Abstracts 1975, 28:340, #3409).

Beauchamp, E. G., and Lathwell, D. J. "Effect of Root Zone Temperatures on Corn Leaf Morphology." Can. J. Plant Sci. 46 (1966): 593-601.

Bryant, H. T.; Huber, J. T.: and Blaser, R. E. "Comparison of Corn Silage Harvested at Milk and Medium Dough Stages of Maturity for Dry Matter Intake, Digestibility, and Milk Production of Lactating Cows." J. Dairy Sci. 48 (1965):838.

Bunting, E. S. "The Influence of Date of Sowing on Development and Yield of Maize in England." J. Agric. Sci. Camb. 71 (1968): 117-125.

Cadwell, D. M., and Perry, T. W. "Relationship Between Stage of Maturity of the Corn Plant at Time of Harvest for Corn Silage and Chemical Composition." J. Dariy Sci. 54 (1971):533-536.

Chernoff, H., and Moses, L. E. Elementary Decision Theory. New York: John Wiley and Sons, Inc., 1959.

Cummings, D. G. "Quality and Yield of Corn Plants and Component Parts When Harvested for Silage at Different Maturity Stages." Agron. J. 62 (1970):781-784.

Davis, L. H., and Wheeler, R. "Crop Enterprises Budgets for Farm and Ranch Planning in Utah." Logan, Utah, 1981.

Daynard, T. B., and Hunter, R. B. "Relationship Among Whole-Plant Moisture, Grain Moisture, Dry Matter Yield, and Quality of Whole-Plant Corn Silage." Can. J. Plant Sci. 55 (1975):77-84.

Free, G. R.; Wilkelbelch, G. S.; Wilson, H. M.; and Bay, G. E. "Time of Planting in Comparison of Plow-Plant and Conventional Seedbed Preparation for Corn." Agron. J. 58 (1966):333-336.

Gubbels, G. H. "Growth of Corn Seedling Under Low Temperatures as Affected by Genotype, Seed Size, Total Oil, and Fatty Acid Content of the Seed." Can. J. Plant Sci. 54 (1974):425-426.

Halter, A. N., and Dean, G. W. Decisions Under Uncertainty. Cincinnati, Ohio: South-Western Publishing Co., 1971.

Hill, R. W.; Hanks, R. J.; Keller, J.; and Rasmussen, P. V. Predicting Corn Growth as Affected by Water Management: An Example. Logan, Utah: Department of Agricultural and Irrigation Engineering, Utah State University, Report No. 211(d)-6, September 1974.

Huber, J. T. "How to Make the Most of Immature Corn Silage." Hoard's Dairyman 120 (1975):543.

Hunter, R. B.; Hunt, L. A.; and Kannenberg, L. W. "Photoperiod and Temperature Effects on Corn." Can. J. Plant Sci. 54 (1974): 71-78.

Johnson, R. R., and McClure, K. E. "Corn Plant Maturity and Effects on Digestibility of Corn Silage in Sheep." J. Anim. Sci. 27 (1968):535-540.

Jurgens, S. K.; Johnson, R. R.; and Boyer, J. S. "Dry Matter Production and Translocation in Maize Subjected to Drought During Grain-Fill." Agron. J. 70 (1978):678-682.

Kwon, I. Statistical Decision Theory with Business and Economic Applications. New York: Mason/Charter Publishers, Inc. 1978.

Lucus, R.; Vitosh, M.; Chase, R.; and Hyde, D. No Till Corn Studies. Res. Rep. MSU Soils Farm, East Lansing, Michigan State Univ., Agric. Exp. Sta., 1976, pp. 9-12.

Marley, S. J., and Ayres, G. E. "Influence of Planting and Harvesting Dates on Corn Yield." Trans. Amer. Soc. Agric. Eng. 15 (1972): 228-229.

McAllister, D. R. More and Better Corn Silage Through Timely Harvest, "It's the Grain that Counts." Logan, Utah: Plant Scient Department, Utah State University, August 1974.

Nielson, Rex F. Testing Corn Hybrids for Yield; Project Completion File, Project No. 371. Logan, Utah: Utah Agricultural Experiment Station, Utah State University, March 1967.

Osafo, D. M., and Milbourn, G. M. "The Growth of Maize and the Effect of Date of Sowing and Bitumen Mulch on Dry Matter Yields." J. Agric. Sci. 85 (1975):271-279.

Raiffa, Howard, and Schlaifer, Robert. Applied Statistical Decision Theory. Boston, Mass.: Division of Research Graduate School of Business Administration, Harvard, University, 1961.

Richardson, E. A., and Ashcroft, G. L. "Freeze-Free Seasons of State of Utah"--Map and Table (Published jointly by Utah Agricultural Experiment Station, Utah State University, Logan, Utah, and Department of Commerce, ESSA, Environmental Data Services).

Simon-Sylvestre, G., and Chabannes, J. "The Effects of Some Cultural Techniques on Certain Soil Properties: Effect on a Maize Crop." Field Crob Abstracts 1976, 29:323, #3659.

Statistical Reporting Service, U.S. Department of Agriculture. Utah Agricultural Statistics--1981. Salt Lake City, Utah.

U.S. Department of Commerce, Weather Bureau. Climatological Data, Utah--1952-1975.

U.S. Department of Commerce, Weather Bureau. Climatological Summary, Climatography of the United States No. 20-42. Logan, Utah: Utah State University, 1941-1970.

U.S. Department of Commerce, Weather Bureau. Climatological Summary, Climatography of the United States No. 20-42. Richfield, Utah: 1925-1954.

White, D. J. Fundamentals of Decision Theory. New York: American Elsevier Publishing Company, Inc., 1976.

White, R. P. "Cultural Practices Affecting Maturity and Yield of Corn (Zea Mays) for Whole-Plant Silage in Short-Season Areas." Can. J. Plant Sci. 58 (1978):629-642.

White, R. P. "Effects of Planting Dates on Forage Corn Yields and Maturity on Prince Edwards Island." Can. J. Plant Sci. 57 (1977): 563-569.

White, R. P.; Winter, K. A.; and Kunelius, H. T. "Yield and Quality of Silage Corn as Affected by Frost and Harvest Date." Can. J. Plant Sci. 56 (1976):481-486.

APPENDIX

TABLE 18

DATES WHEN THE SUM OF GDD FOR SEVEN CONSECUTIVE SPRING DAYS FIRST REACHED 70 AS RECORDED AT U.S.U. AGRICULTURAL EXPERIMENT STATION, 1959-1966

Year	Date
1959	May 14
1960	May 10
1961	May 22
1962	May 6
1963	May 6
1964	May 15
1965	May 16
1966	May 3
Daily mean 1959-1966 reached on May 16	

DATES WHEN THE SPRING MEAN SOIL TEMPERATURES EQUAL 50° F. AT U.S.U. AGRICULTURAL EXPERIMENT FARM, 1969-1975 (DEPTH = 4 IN.)

Year	Date
1969	May 1
1970	May 4
1971	May 2
1972	May 3
1973	May 6
1974	May 2
1975	May 3

SOURCE: U.S. Department of Commerce, Weather Bureau, Climatological Data (Utah, 1952-1975).

TABLE 19

YIELDS COMPARED WITH FROST DATES AND THEIR INTENSITIES FOR THE YEARS 1959-1966

Frost Dates	Temp. (°F)	GDD Between Last Spring and 1st Fall Frosts	Planting Date	Emergence	Harvest Date	GDD Between Planting & Harvest Dates	Yield (Tons/Acre) Variety							
							680		544		330		216	
							DW	TDN	DW	TDN	DW	TDN	DW	TDN
1966 May 23	27	2177.5	May 3	May 8	Sep 21	2412.0	6.4	4.2	-	-	-	-	3.8	2.7
1966 May 23	27	2177.5	May 24	May 29	Sep 21	2177.5	6.7	4.4	-	-	-	-	4.4	3.0
1965 May 3	30	1962.5	May 3	May 16	Sep 21	1985.0	8.3	5.5	6.9	4.5	7.0	4.9	4.6	3.2
1964 May 2	30	1771.0	May 11	May 17	Sep 14	1992.5	6.5	3.8	5.9	3.8	6.2	4.3	5.5	3.9
1963 Oct 24	29*	2381.0	May 8	May 17	Oct 2	2381.0	9.4	6.5	7.2	5.0	7.1	5.0	5.7	4.0
1962 May 1	30*	1769.0	May 4	May 10	Sep 10	1990.5	7.1	4.0	6.6	4.3	6.6	4.4	4.9	3.4
1961 May 3	31*	2222.0	May 4	May 16	Sep 24	2288.0	7.9	5.5	8.3	5.8	9.1	6.4	7.9	5.5
1960 May 18	32	1735.5	Jun 21	Jun 26	Sep 23	1735.5	-	-	5.3	2.8	5.6	3.2	4.7	3.1
1959 May 3	28*	2019.0	May 8	May 16	Sep 17	2125.5	5.8	3.7	6.0	4.1	6.2	4.3	4.8	3.4

SOURCE: Data compiled from: Rex F. Nielson, Corn Trials 1953--1966, (Logan, Utah: Department of Soil Science and Biometeorology, Utah State University); U.S. Department of Commerce, Weather Bureau, Climatological Data, Utah--1952-1975; E. Arlo Richardson, Utah State Climatologist, Dept. of Soil Sciences and Biometeorology, Utah State University.

*Locally heavy frosts.

TABLE 20

PROBABILITY OF LOWER AND UPPER BOUND (TEMP. F°) FOR 130 DAYS FROST-FREE SEASON FOR EARLY SPRING FROST

Average* a'	Date of Emergence	$Pr(\eta_2 \& \eta_3)$ Pr 32° $\leq$	$Pr(\eta_3)$ Pr 28° $\leq$
a'_1	May 12	0.7	.65
a'_2	May 18	.55	.50
a'_3	May 24	.40	.35
a'_4	May 30	.283	.225
a'_5	June 5	.15	.125

*Average a'_1 is calculated as follows; a'_i is the emergence where $i = 1, \ldots, 5$.

a_1 = May 2-7, average required number of days for emergence is equal to 8 days (Table 14). So, the emergence interval will be 10-15 May and the average May 12 is chosen as a base.

Using the following formulas:

$$Pr(\eta_2/a_i) = P(\eta_2/a_i \; \& \; \eta_3/a_i) - Pr(\eta_3/a_i)$$

$$Pr(\eta_1/a_i) = 1 - P(\eta_2/a_i \; \& \; \eta_3/a_i)$$

where η_1, η_2, η_3 are the states of nature, a_i planting date and p's represent the respective probabilities.

TABLE 20--Continued

A 130 DAY FROST-FREE GROWING SEASON FROST PROBABILITY TABLE

May	Prob. of 32°	Prob. of 28°	June	Prob. of 32°	Prob. of 28°	Sept	Prob. of 32°	Prob. of 28°	Oct	Prob. of 32°	Prob. of 28°
1		.55	1			1			1		
2			2	.20		2			2	.65	.25
3		.50	3			3			3		
4	.85		4	.15		4			4	.70	.30
5		.45	5			5			5		
6			6			6	.05		6	.75	.35
7	.80	.40	7			7			7		
8			8			8			8	.80	.40
9	.75	.35	9	.10		9			9		
10			10			10			10	.85	.45
11		.30	11			11	.10		11		.50
12	.70		12			12			12		.55
13			13			13			13	.90	
14	.65	.25	14			14	.15		14		.60
15			15	.05		15			15		
16	.60	.20	16			16	.20		16		.65
17			17			17			17		
18	.55		18			18	.25		18	.95	.70
19		.15	19			19			19		
20	.50		20			20	.30	.05	20		.75
21			21			21			21		
22	.45		22			22	.35		22		.80
23		.10	23			23			23		
24	.40		24			24	.40		24		.85
25			25			25		.10	25		
26	.35		26			26	.45		26		
27			27			27	.50		27		.90
28	.30		28			28	.55	.15	28		
29		.05	29			29			29		
30			30			30	.60	.20	30		
31	.25								31		

SOURCE: E. Arlo Richardson and Gaylen L. Ashcroft, Freeze-Free Seasons of State of Utah--Map and Table, published jointly by Utah Agricultural Experiment Station, Utah State University, Logan, Utah, and Department of Commerce, ESSA, Environmental Data Services.

TABLE 21

MEAN GROWING DEGREE DAYS USING THE 50°-86° F. METHOD, FOR VARIOUS TIME PERIODS AND STATIONS IN UTAH

Growing Degree Days - Base 50° F.									
					Mean GDD 1959-1966 USU Experiment Station				
Week Begins	Lewiston Mean	Logan USU Mean	Rich-field Mean	Day of Month	May	Jun	Jul	Aug	Sep
Apr 5	26	25		1	9.4	13.3	19.1		
Apr 12	41	40		2	8.9	13.6	19.3		
Apr 19	44	44		3	7.5	12.7	20.3		
Apr 26	45	45		4	8.4	10.9	18.4		
May 3	58	59	74	5	8.3	11.8	18.2		
May 10	66	64	77	6	8.3	13.6	19.6		
May 17	69	67	84	7	9.6	13.9	20.3		
May 24	82	84	97	8	8.8	12.0	18.3		
May 31	77	80	97	9	10.1	14.1	20.4		
Jun 7	91	94	109	10	9.6	13.8	19.7		
Jun 14	101	107	116	11	9.7	14.8	19.4		
Jun 21	110	119	121	12	9.6	14.6	20.9		
Jun 28	118	128	128	13	11.0	16.2	20.4		
Jul 5	126	144	132	14	10.1	15.8	20.4		
Jul 12	130	152	134	15	9.4	14.1	18.9		
Jul 19	132	158	135	16	10.3	14.0	19.5		
Jul 26	136	159	138	17	9.8	14.3	20.8		
Aug 2	131	152	135	18	9.3	15.4	21.3		
Aug 9	129	148	132	19	10.8		20.3		
Aug 16	126	149	129	20	11.8		20.3		
Aug 23	119	134	125	21	10.9		21.2		
Aug 30	114	125	121	22	10.0		21.5		
Sep 6	107	114	115	23	8.9		21.2		
Sep 13	95	97	111	24	10.4		20.8		
Sep 20	81	79	97	25	10.9		20.6		
Sep 27	75	75	91	26	11.4		19.8		
Oct 4	65	60	80	27	10.7		21.1		
Oct 11	53	49	67	28	10.9		20.9		
Oct 18	40	36	62	29	12.4		20.5		
Oct 25	29	28	53	30	13.1		21.9		
				31	13.2		23.1		
				Monthly Totals	314	454	626	575	409

SOURCE: Drawn from U.S. Department of Commerce, Weather Bureau, Climatological Data, Utah--1952, 1975.

TABLE 21--Continued

Growing Degree Days, 50° F. Base, 86° F. Maximum			
County	Community	Elevation	Silage Corn May 3 - Sep 13 22 Weeks 133 Days
Cache	Lewiston	4480	2059
	Logan	4785	2275
Sevier	Richfield	5270	2236

SOURCE: E. Arlo Richardson, Utah State Climatologist, Department of Soil Science and Biometeorology, Utah State University.

TABLE 22

PRICES FOR CORN SILAGE IN UTAH FROM 1953 THROUGH 1980

Year	$ Value/Ton	Year	$Value/Ton
1953	7.00	1967	8.60
1954	7.50	1968	8.10
1955	7.50	1969	8.30
1956	7.00	1970	9.80
1957	6.50	1971	10.00
1958	6.50	1972	11.50
1959	7.00	1973	14.50
1960	8.00	1974	17.20
1961	8.00	1975	15.90
1962	7.40	1976	17.30
1963	7.60	1977	17.20
1964	8.20	1978	15.80
1965	8.40	1979	18.30
1966	9.80	1980	21.10

SOURCE: Statistical Reporting Service, U.S. Department of Agriculture, Utah Agricultural Statistics--1981. Salt Lake City, Utah.

TABLE 23

GROWTH STAGES OF CORN IN GROWING DEGREE DAYS

	Varieties				
		Utah Hybrids			
Stages	Basic Model*	216	330	544	680
	Growing Degree Days				
Plant					
Emerge	80	80	80	80	80
Tassel	850	800	838	916	955
Silk	370	348	365	398	415
Milk	140	132	138	151	157
Mature	840	790	829	905	943
Totals	2280	2150	2250	2450	2550

*Model and Program developed by Dr. R. J. Hanks, and P. V. Rasmussen, Utah State University.

TABLE 24

SILAGE YIELD DATA FOR UTAH HYBRID CORN TRIALS IN THE YEARS 1953 THROUGH 1966

Variety	Yield in Tons Per Acre Dry Weight	Maturity*	Percent Dry Weight	Year
Utahybrid 680	7.8			1953
544	8.4			
330	6.8			
Utahybrid 680	9.1	1.3		1954
544	7.3	2.0		
330	7.0	1.0		
Utahybrid 680	7.4	1.3		1955
544	7.9	2.0		
330	7.6	1.3		
216	6.1	1.0		
Utahybrid 680	8.6	1.9		1956
544	7.8	1.8		
330	6.7	1.1		
216	5.7	1.0		
Utahybrid 680	7.8	1.6		1957
544	7.7	2.1		
330	6.8	1.1		
216	5.1	1.0		
Utahybrid 680	9.6	1.0		1958
544	8.2	1.0		
330	7.9	1.0		
216	4.8	1.0		
Utahybrid 680	5.8	2.8		1959
544	6.0	1.5		
330	6.2	1.0		
216	4.8	1.0		
Utahybrid 544	5.3	4.4	20	1960
330	5.6	3.9	22	
216	4.7	2.4	23	

TABLE 24--Continued

Variety	Yield in Tons Per Acre Dry Weight	Maturity*	Percent Dry Weight	Year
Utahybrid 680	7.9	1.0	30	1961
544	8.3	1.0	30	
330	9.1	1.0	38	
216	7.9	1.0	41	
Utahybrid 680	7.09	3.9	27	1962
544	6.57	2.9	30	
330	6.58	2.1	34	
216	4.85	1.0	38	
Utahybrid 680	9.40	1.2	29.4	1963
544	7.20	1.0	31.4	
330	7.10	1.0	37.6	
216	5.72	1.0	39.1	
Utahybrid 680	6.5	3.7	22.9	1964
544	5.9	3.0	22.5	
330	6.2	1.2	29.0	
216	5.5	1.0	32.0	
Utahybrid 680	8.3	2.1	29	1965
544	6.9	2.4	27	
330	7.0	1.0	36	
216	4.6	1.0	46	
Utahybrid 680	6.4	2.0	27	1966
544	5.5	1.0	29	
216	3.8	1.0	36	
216	4.4	1.4	26	
544	5.8	1.6	28	
680	6.7	2.0	25	

SOURCE: Rex F. Nielson, <u>Corn Trials, 1953-1966</u>, (Logan, Utah: Department of Soil Science and Biometerology, Utah State University).

*Key: 1.0 Dent
2.0 Hard Dough
3.0 Soft Dough
4.0 Milk
5.0 Kernels Not Formed

TABLE 25

PRECIPITATION ACCUMULATED OVER THE 14-DAY PERIOD ENDING WITH THE DATES LISTED, (IN INCHES), AT UTAH STATE UNIVERSITY EXPERIMENT STATION

	Precipitation in Inches							
	Years							
Dates	1959	1960	1961	1962	1963	1964	1965	1966
May 1	1.81	1.30	.41	1.63	2.10	1.26	.29	.82
2	1.03	1.30	.31	1.63	2.06	1.82	.21	.22
3	.73	1.07	.31	1.63	1.86	1.69	.21	.13
4	.71	1.28	.35	1.54	1.39	1.57	.21	.13
5	.71	1.28	.35	.82	.89	2.28	.51	.13
6	.71	1.28	.08	.82	.89	2.28	.41	.08
7	.71	1.01	.18	.82	.89	2.28	.41	.08
8	.71	.84	.18	.82	.92	1.97	.68	.08
9	.71	.84	.18	.82	.97	1.97	.81	.30
10	.21	.84	.18	.69	.68	1.77	.81	1.02
11	.00	.84	.18	.69	.26	1.98	.81	1.12
12	.00	.56	.18	.01	.30	1.98	.81	1.12
13	.00	.42	.18	.15	.30	1.98	.81	1.12
14	.00	.42	.21	.27	.30	1.98	1.07	1.12
15	.00	.42	.41	.44	.23	1.76	1.07	1.12
16	.26	.42	.53	.53	.23	1.15	1.07	1.12
17	.26	.22	.53	.53	.23	1.10	1.07	1.12
18	.30	.06	.52	.53	.23	1.10	1.07	1.12
19	.30	.06	.52	.53	.23	.21	.77	1.12
20	.30	.06	.52	.56	.23	.21	.88	1.12
21	.30	.06	.38	1.26	.23	.21	.88	1.12
22	.50	.05	.38	1.35	.20	.21	.55	1.17
23	.54	.05	.38	1.35	.15	.21	.42	.95
24	.54	.05	.38	1.42	.15	.21	.99	.15
25	.61	.05	.38	1.45	.14	.00	.99	.05
26	1.05	.05	.38	1.51	.10	.00	1.00	.05
27	1.78	.19	.38	2.04	.00	.30	1.00	.05
28	1.78	.19	.35	1.97	.00	.37	.74	.05
29	1.78	.19	.15	1.92	.00	.94	.74	.05
30	1.54	.19	.13	1.92	.00	.97	.74	.05
31	1.54	.19	.13	2.22	.00	.97	.74	.05

TABLE 25--Continued

	Precipitation in Inches							
	Years							
Dates	1959	1960	1961	1962	1963	1964	1965	1966
Sep 14	.00	.44	.04	.00	.47	.04	1.62	.79
15	.51	.09	.04	.00	.47	.08	1.62	.64
16	.56	.07	.06	.00	.47	.04	2.35	.59
17	.56	.16	.18	.00	1.86	.04	2.35	.59
18	.61	.16	1.08	.00	1.86	.10	2.35	.59
19	.67	.12	1.75	.00	2.18	.10	2.27	.59
20	.93	.12	1.80	.00	2.19	.10	1.01	.59
21	1.07	.12	1.80	.02	2.30	.10	.98	.59
22	1.07	.22	1.80	.02	2.34	.10	.80	.59
23	1.07	.22	1.85	.02	2.34	.10	.73	.59
24	1.09	.22	1.85	.02	2.34	.10	.73	.59
25	1.45	.22	1.85	.02	2.34	.10	.73	.54
26	1.62	.22	1.85	.02	2.34	.10	.73	.55
27	1.74	.20	1.85	.08	2.04	.10	.73	.65
28	2.02	.20	1.85	.25	2.04	.10	.73	.32
29	1.59	.20	1.85	.31	2.04	.06	.86	.21
30	1.54	.20	1.79	.31	.65	.06	.13	.21
Oct 1	1.54	.10	1.67	.31	.65	.06	.13	.21
2	1.49	.10	.77	.31	.33	.00	.13	.21
3	1.43	.10	.10	.31	.32	.00	.13	.21
4	1.17	.10	.05	.31	.15	.00	.13	.21
5	1.03	.10	.05	.68	.00	.00	.13	.21
6	1.03	.00	.05	.76	.00	.00	.13	.21
7	1.19	.06	.14	.84	.00	.00	.13	.21
8	.17	.58	.15	.84	.00	.00	.13	.21
9	.95	1.07	.21	.84	.00	.00	.13	.19
10	.78	1.14	.46	.78	.00	.00	.13	.10
11	.66	1.26	.46	.61	.00	.00	.13	.00
12	.38	1.28	.46	.55	.19	.00	.17	.00
13	.30	1.64	.46	.55	.83	.00	.04	.41
14	.30	1.64	.46	1.03	.83	.00	.04	.41
15	.30	1.64	.46	1.04	.83	.00	.04	.41
16	.30	1.64	.46	1.04	.83	.00	.04	.41
17	.30	1.64	.46	1.04	.83	.00	.04	.41
18	.30	1.64	.46	.65	.83	.00	.04	.41
19	.30	1.64	.46	.57	.83	.00	.04	.41
20	.30	1.64	.46	.49	.83	.00	.04	.41
21	.14	1.58	.32	.49	.83	.00	.04	.41

TABLE 25--Continued

Dates	Precipitation in Inches						
	Years						
	1952	1953	1954	1955	1956	1957	1958
Sep 14	.15	.00	.26	.00	.06	.00	.50
15	.15	.00	.26	.00	.06	.00	.50
16	.15	.00	.14	.00	.06	.00	.50
17	.15	.02	.14	.03	.06	.00	.50
18	.15	.02	.14	.03	.06	.05	.50
19	.15	.02	.14	.36	.06	.62	.50
20	.15	.02	.14	.36	.06	.62	.50
21	.13	.02	.14	.36	.06	.62	.50
22	.13	.02	.14	.36	.06	.62	.50
23	.13	.02	1.85	.36	.06	.62	.44
24	.13	.02	1.85	.39	.05	.62	.49
25	.05	.02	1.71	.69	.00	.62	.46
26	.03	.02	1.71	1.22	.00	.62	.33
27	.03	.02	1.71	1.22	.00	.62	.05
28	.00	.02	1.71	1.22	.00	.62	.05
29	.00	.02	1.71	1.22	.00	.62	.05
30	.00	.02	1.71	1.22	.00	.62	.05
Oct 1	.00	.00	1.71	1.19	.00	.62	.05
2	.00	.00	1.71	1.19	.00	.66	.05
3	.00	.00	1.71	.86	.00	.31	.05
4	.00	.00	1.74	.86	.00	.57	.05
5	.00	.00	1.79	.86	.00	.57	.05
6	.00	.00	.08	.86	.00	.57	.05
7	.00	.00	.08	.86	.00	.57	.05
8	.00	.00	.08	.83	.00	.57	.00
9	.00	.00	.08	.53	.00	.57	.00
10	.00	.00	.08	.00	.00	.57	.00
11	.00	.00	.08	.17	.00	.57	.00
12	.00	.00	.08	.17	.30	.57	.00
13	.00	.00	.34	.17	.31	.57	.00
14	.00	.00	.34	.17	.31	.63	.00
15	.00	.17	.34	.17	.31	.63	.00
16	.00	.17	.34	.17	.31	.54	.00
17	.00	.17	.34	.17	.31	.32	.00
18	.00	.17	.31	.17	.31	.06	.00
19	.00	.17	.26	.35	.31	.06	.00
20	.00	.17	.26	.64	.31	.06	.03
21	.00	.17	.26	.74	.31	.06	.03

SOURCE: U.S. Department of Commerce, Weather Bureau, Climatological Data, Utah--1952-1975.

TABLE 26

SNOW FALL DATA, 1959-1974, AT UTAH STATE UNIVERSITY EXPERIMENT STATION

Dates	Snow Total (Inches)	Max. Depth (Inches)	Snow Fall (Inches)	On Ground (Inches)
1959 Sep	0	0		
Oct	0	0		
Nov	0	0		
1960 Sep	0	0		
Oct	0	0		
Nov 4			3.6	4.0
5			.5	
9			1.0	
1961 Sep	0	0		
Oct	19.0			
Oct 22			4.5	5.0
28			6.2	6.0
29			5.3	9.0
Nov	3.3			
1962 Sep	0	0		
Oct	0	0		
Nov	0	0		
1963 Sep	0	0		
Oct	0	0		
Nov 7	T	T	4.0	4.0
16			3.5	3.0
17				2.0
18				1.0
1964 Sep	0	0		
Oct	0	0		
Nov 11	1.0	1.0	3.0	3.0
12			T	1.0
13			2.0	3.0
14				2.0
1965 Sep	T	0		
Oct	0	0		
Nov 24	6.7	5.0	3.4	3.0
25			5.6	7.0
26			.8	6.0

TABLE 26--Continued

Dates	Snow Total (Inches)	Max. Depth (Inches)	Snow Fall (Inches)	On Ground (Inches)
1966 Sep	0	0		
Oct	0	0		
Oct 13			.5	1.0
14			4.5	5.0
21			T	T
Nov	3.0	3.0		
Nov 8			8.5	9.0
9			.3	7.0
10			.3	5.0
11			T	3.0
1967 Sep	0	0		
Oct	0	0		
Nov	0.4	1.0		
1968 Sep	0	0		
Oct	0	0		
Oct 17			T	
Nov	12.8	6.0		
1969 Sep	0	0		
Oct	0	0		
Oct 11			T	
13			T	
Nov	T	0		
Nov 16			T	
18			0.5	1.0
1970 Sep	0	0		
Oct		2.0		
Oct 7			T	
10			T	
11			T	
27			T	
Nov		T	T	
1971 Sep	0	0		
Oct		4.0		
Oct 1			2.0	2.0
18			5.0	5.0
19			T	3.0
27			T	T
28			6.0	6.0

TABLE 26--Continued

Dates	Snow Total (Inches)	Max. Depth (Inches)	Snow Fall (Inches)	On Ground (Inches)
1971 (cont'd)				
Oct 29				2.0
31			3.0	3.0
Nov		3.0		
Nov 1			2.0	3.0
2			T	1.0
3				1.0
1972 Sep	0	0		
Oct		T		
Oct 29			1.2	2.0
30			T	1.0
31				T
Nov	1.0	29.0		
Nov 15			T	
27			0.3	T
29			0.8	
1973 Sep	0	0		
Oct	0	0		
Oct 29			.1	
30			.2	
Nov	3.0	26.0		
Nov 5			1.4	
22			2.8	3.0
1974 Sep	0	0		
Oct	0	0		
Oct 22			T	
Nov	0	0		
Nov 28			T	

SOURCE: U.S. Department of Commerce, Weather Bureau, Climatological Data, Utah--1952-1975.

TABLE 27

ESTIMATED RECEIPTS, COSTS, AND NET RETURN FOR CORN SILAGE PRODUCED ON CLASS II IRRIGATED CROPLAND, UTAH, 1981

Item	Rate	Times Operation Performed	Labor[1]	Power and Machinery	Materials and Service	Total
			-------------	$/acre	-------------------	
Receipts:						
Corn silage, 17 tons	$20/ton					$340.00
Variable Costs:						
Fertilizer, 150 units N	$.31/unit				46.50	46.50
50 units P	$.24/unit				12.00	12.00
Fertilizer application		1			2.00	2.00
Water, operation, & maintenance					10.00	10.00
Plowing--4 acres/hr		1	2.00	12.00		14.00
Disking, harrowing (land prep.)		1	1.00	6.00		7.00
Planting--5 acres/hr		1	1.00	4.00		5.00
Seed, 25#					17.00	17.00
Irrigation		4	8.00		8.00	16.00
Cultivation & furrowing		2	2.00	6.00		8.00
Spraying		1		3.00	5.00	8.00
Chopping--20 tons/hr	$2/ton	1	8.00	26.00		34.00
Hauling & packing	$2.75/ton	1	16.75	30.00		46.75
Interest	18% @ 6 mo.					17.25
Total						$226.00
Fixed Costs:						
Land taxes	$80 assessed @ 70 mills					5.60
Other						10.50
Total						$ 16.10

TABLE 27--Continued

Item	Rate	Times Operation Performed	Labor[1]	Power and Machinery	Materials and Service	Total
Total Costs						$242.10
Net Returns to Land and Operator Management						$ 97.90

SOURCE: Dr. Lynn H. Davis, Professor of Economics, Utah State University.

[1] Labor charged at $5 per hour.