Optimal Management of Molds in Stored Corn

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Abstract: *Long term storage of corn is becoming more common due to the recent increase in the demand for corn by ethanol plants. Infection of maize kernels by toxigenic fungi remains a challenging storage problem despite decades of research. Experts in storage management propose the use of a combination of preventive and monitoring-based responsive strategies in response to mold risks. In this paper, a stochastic dynamic programming model is solved to determine the expected profitability and optimal combination, timing and intensity of the proposed mold management strategies using farmers' existing infrastructure. The results show that even with relatively high monitoring costs, maintaining high quality grain using a monitoring based optimal mold management strategy costs less than the benefit it fetches. Farmers' current typical practice of aerating the grain until the end of December and doing nothing thereafter bears a high risk of economic losses if grain is to be stored until later during the summer. Generally, the optimal mold management strategy depends on monitoring the biophysical conditions of the grain and the time period under consideration. If the in-bin temperature is high and less than 5% of kernels are mold damaged, then aerating when the outside temperature is at least 3^{o}C less than the in-bin temperature and continuing to store the grain is the optimal strategy.*

Key words: Mold management, stored corn, expected profitability, integrated pest management, monitoring, aeration, stochastic dynamic programming,

1. Introduction

Molds rank second only to insects as a cause of damage in stored grains (CAST, 1989). They cause detrimental changes in grain appearance, quality and dry matter (Ng et al., 1998), and they reduce the energy content and ethanol yield for corn (Hardy et al., 2006). Molds also produce by-products called mycotoxins which are poisonous to humans and animals (MAFRI, 2006). The presence of molds and mycotoxins leads to price discounts or rejections of shipments by buyers. The annual loss due to mycotoxins from US exports of Bt corn is estimated at about $23 million (Wu, 2006). Bt corn accounts for 40% of total US corn production (FBC, 2007). Total US corn production for 2006/7 is about 10.5 billion bushels and the share of exports in total corn production is 21.3% (Hagenbaugh, 2007; Westcott, 2007). Assuming that the proportion of grain containing mycotoxins is the same as the proportion for Bt corn exports, the estimated annual loss to the US due to mycotoxins in corn in 2006/7 is about $270 million. Farmers who enter contracts to deliver food-grade corn late during the storage season report that they either face huge discounts or incur higher costs to meet the minimum mold standards stipulated in the contract (Yigezu and Alexander, 2007). In the face of increasing demand for storing corn due to the recent the rise in the number of ethanol plants, storage mold invasion poses a major challenge for farmers.

Literature on the economics of stored product pest management is scanty, and most of it is devoted to the study of the profitability of an individual intervention or the comparison of a few possible combinations of strategies with fixed input intensities and times of application. Adam et al. (2004) and Rulon et al. (1999) used cost benefit analysis to compare the profitability of different strategies such as fumigation and aeration for controlling insects. Fox and Hennessey (1999) developed an economic loss minimization method which is useful for determining the timing of a given intervention to minimize economic loss during storage and applied it to the case of fumigation to control the lesser grain borer. Our paper is the first to model the economics of optimal mold control in stored grains.

Despite decades of research, mold infection remains a challenging problem **(**Munkvold, 2003)**.** Experts in storage pest management recommend the use of a combination of preventive and monitoring-based integrated pest management (IPM) strategies (Hagstrum and Subramanyam, 2006; Arthur et al., 2001; Maier et al., 1997; Mason et al., 1993; Horn, 1988; Cuero and Smith, 1987; Thompson, 1972). However, it is not clear if any of these strategies are profitable, i.e. cost is less than the expected prevented economic loss. Currently, most Indiana farmers cool their corn during the fall, keep it in their on-farm storage with minimal monitoring during the cold winter period and then sell when temperatures start to rise around the first half of April. By so doing, farmers might be selling corn which is at low risk of mold damage, but they might be forgoing very high premiums during the summer that could more than offset the cost of storage.

The objective of this article is to determine the optimal combination, timing and intensity of mold management and marketing strategies. The expected profitability of the optimal mold management strategies conditional on the biophysical conditions of the grain will also be evaluated. In particular, we evaluate the potential benefits of a monitoring based mold management strategy which involves decisions on aeration and optimal timing of grain sales. For farmers who do not have a contractual commitment, the optimal time for selling their grain will be determined in view of the tradeoffs between higher prices in the future and the higher risk of grain quality and dry matter losses during storage. This analysis will determine which aeration strategies are profitable; when it is optimal to sell the grain conditional on its quality and the bio-physical conditions inside the bin; and what minimum storage fee processors should pay to encourage contract farmers to deliver quality grain later in the storage season.

2. Mold Growth, Control and Farmers' Current Mold Management and Marketing Strategies

Small quantities of spores of storage fungi may be present on grain going into storage or on grain residues from previous harvests or in handling and storage equipment. Moreover, mold spores could be introduced into the bin by winds. Under improper storage conditions, a small amount of inoculums introduced by any of the above means can grow rapidly, leading to grain spoilage (Sweets, no date).

Researchers have developed several mold growth models. Some used the level of water activity (the ratio of the vapor pressure of the product to that of pure water expressed in decimal form) as the only explanatory variable (Gibson et al., 1994; Baranyi et al., 1993). A number of other studies used only temperature to explain fungal/mold growth (Carlile et al., 2001; Shanahan et al., 2003; Cuero and Smith, 1987; Sweets, no date). Still other studies tried to explain mold growth using both temperature and moisture content or water activity (Pitt, 1993; Cuero and Smith, 1987; Northolt and Bullerman, 1982; White et al., 1982a; White et al., 1982b; Schindler et al., 1967). Friday et al. (1989) argue that mold damage levels also depend on the hybrid type. The extent of mechanical damage on the grain kernels is also important in determining the level of mold damage (Wilcke et al., 2001; Gupta et al., 1999). Shanahan et al. (2003) argue that the three major storage conditions that favor continued mold growth and are necessary for mycotoxin formation in stored grain are: high corn kernel moisture content (16 to 30%); warm temperatures (77 to 90^{o}F); and high humidity (80 to 100%).

Conditioning the storage environment is considered the best strategy for controlling molds (Wilcke et al., 2001; Pitt, 1993; Northolt and Bullerman, 1982). Particularly, IPM-based strategies of monitoring and aeration have been found to be very effective in controlling the atmospheric conditions in on-farm storage (Ileleji et al., 2007; Maier et al., 1996; Arthur et al., 1998; Thompson, 1972). Growth of molds is generally low at temperatures below 50^{o}F (10^{o}C), but slow growth will occur even at low temperatures if the moisture conditions are favorable. Moisture levels below 12% will prevent mold formation (Shanahan et al., 2003).

A survey of 8 farmers from different parts of Indiana and Illinois revealed that farmers recognize the importance of maintaining low moisture content in stored grain (Yigezu and Alexander, 2007). As a result, they try as much as possible to dry their corn in the field and put it directly into storage bins, which oftentimes is not feasible because favorable weather to dry corn on the field does not happen very often. They instead artificially dry it using either in-bin driers (via a high air flow rate aeration fans) or continuous flow or batch driers. Once dried to a level of 16% to 16.5% moisture content (MC), grain is moved to storage bins where the hot grain is left to steep for 8 to 24 hours and then is aerated using low air flow rate fans to cool it off and also to dry it further to 14 – 15% moisture content.

Farmers then core the grain by hauling a truck load or two from the bin to remove the fines and foreign material which usually are concentrated at the center, thereby allowing for better air circulation within the grain mass. After coring, aeration usually continues in the fall until in-bin temperature is as low as 4-5 ^{0}C to inhibit pest development. Farmers usually do not aerate their grain during the winter or summer. They do minimal monitoring which usually involves visual inspection and smell testing by opening the hatch on the bins. If the smell and visual tests create a suspicion of pest activity, farmers walk on the surface of the grain to check for pest damage. If traces of mold crusts or hot spots due to high mold activity are observed, they usually scoop them out of the bin or spread them across the surface of the grain mass. If the mold infection is visible and substantial, they may aerate the grain.

When a farmer contracts to deliver corn to a food processor, the contract will specify the minimum quality standards, the premium for meeting the quality standards and penalty for failure to meet them, and a monthly storage fee paid to the farmers for storing the grain on farm. If the farmer fails to meet the minimum quality standards specified in the contract, then the grain will be rejected by the food processor and the farmer must deliver it to a local elevator for the cash price.

Typically, the contract also specifies that the exact delivery date will be chosen by the food processor, with 24 hours notice given to the farmer. The contract will also often specify an expected timeframe for delivery, say the month of June. For the purposes of this model, we assume that the farmer is choosing when to deliver the grain given the premium, penalties and storage fee offered by the food processor.

3. The Bio-economic Model

A stochastic dynamic programming (SDP) approach is used to model the economics of optimal mold control. The approach to solution is based on backward recursion as described by Bellman (1957) and Bellman and Dreyfus (1962). The key is to calculate at each point in time the optimal actions to maximize the current period contribution to net return profit plus the expectation of future returns given the current state of the system.

The state of the system is defined jointly by in-bin temperature (3^oC-38^oC in 5^oC steps), cumulative mold damaged kernels (0% - 21% in steps of 0. 1423%) and whether the grain has already been sold. In this analysis, a proxy state variable – the cumulative dry matter loss in percent *(L)* is used first and then converted to the actual state variable- the cumulative mold damaged kernels *(D)* variable as is explained below. These states are denoted by the set *i*. Each individual state represents an outcome and is weighted by the probability of that individual event occurring. The discrete states of nature and their probabilities can be viewed as an approximation to the continuous distributions that capture the non-stochastic and stochastic relationships among the random variables (Featherstone et al., 1990).

The potential controls (choice variables) in any period are do not aerate, aerate always, aerate only if in-bin temperature is greater than outside (ambient) temperature plus 3^{o}C, sell to the food processor, sell to the local elevator or keep for future sale. These actions are denoted by the following:

A_{ti} = the variable for the aeration strategies which takes values 1 to 3 (1 = do not aerate, 2= aerate unconditionally and 3 = aerate conditionally, i.e., only when the in-bin temperature is greater than the ambient temperature by at least 3^{0}C) in period *t*.

S_{ti} = Selling variable (1= do not sell now, 2 = sell to the elevator now and 3=sell to the food processor now) in period *t* and state *i*.

Mold management decisions in the current period (*t*) affect not only the value of the stored grain in the current period, but also its future values. Let $\pi_t(i)$ denote the current contribution to profit in period *t* given that we are in state *i*. Thus,

$$\pi_t(i) = \begin{cases} -c(A_{ti}) & if\ S_{ti} = 1 and\ A_{ti} \neq 1 \\ -c(A_{ti}) & if\ S_{ti} = 1, and\ A_{ti} = 1 \\ B_{ti} \times Q_{ti} - c(A_{ti}) & if\ S_{ti} = 2, \forall A_{ti} \\ X_{ti} \times Q_{ti} - c(A_{ti}) & if\ S_{ti} = 3, \forall A_{ti} \end{cases} \qquad (1)$$

where,

B_{ti} = price per unit of corn paid by the local elevator in period *t* and state *i*

Q_{ti} = quantity sold in period *t* and state *i*

c = cost function, which depends on the aeration decisions and includes monitoring cost.

X_{ti} = price paid by the food processor per bushel of corn in state *i* in a given time period *t*, which is given by:

$$X_{ti} = Futures + Premium + Storage_t - Penalty_{ti} \qquad (2)$$

where

Futures = Chicago Board of Trade futures price, which farmers can use to establish prices for delivery in December, March, May and July at anytime during the marketing year.

Premium = premium paid by the food processor for meeting minimum quality standards

$Storage_t$ = storage fee per bushel paid by the food processor to the farmer in period t (this is a monthly payment starting in December).

$Penalty_{ti}$ = penalty for failing to meet the minimum quality standards in terms of moisture content, test weight and number of mold damaged kernels when the grain is in state *i* in period *t*.

Suppose that *i*, and *j* are indices reflecting the possible states of the system in the current and next periods. Suppose also that $P_{t,i,j}(S_{ti}, A_{ti})$ is the transition probability from state *i* in the current period (*t*) to state *j* in the next period conditional on the control variables (or decisions made) in period *t* and state *i*. If $V_t(i)$ denotes the maximum expected profit function in period t given state *i*, given that the optimal policy is used for the rest of the time horizon, then the procedure for calculating the optimal policy for the mold management problem is based on the following recurrence relationship (Bellman's equation):

$$V_t(i) = \underset{S_{ti}, A_{ti}}{Max}\left[\pi_t(i) + \alpha \sum_j P_{tij}(S_{ti}, A_{ti}) \times V_{t+1}(j)\right], \forall t, i \qquad (3)$$

where

Max = the maximization operator where maximization takes place over the control (choice) variables (S_{ti}, A_{ti}) and

α = the per period discount factor.

This recursion is initiated by setting the value function in the terminal period to:

$$V_T(i) = \begin{cases} \underset{S_{it}=2 \, or \, 3}{Max}\left(\pi_T(i) - F/\alpha^T\right) & \text{if } i \text{ is a state where sale has not already occured} \\ 0 & \text{otherwise} \end{cases} \qquad (4)$$

where

F = fixed cost of drying and shrinkage incurred at the beginning of storage, and F/α^T is the future value of the fixed costs of drying and shrinkage in the terminal period (this will be discounted to *F* in the first period via the recursion).

By recording the optimal activities in each state for each period, we derive the optimal management policy for this problem. This backward recursion problem is implemented using General Algebraic Modeling Systems (Brooke, et al., 2005) software.

4. Data

Storage is modeled as a bin that is round and made of sheet metal with a diameter of 36ft and height of 32ft and a capacity of 36 thousand bushels of corn (Table 1). Information about the premium and monthly storage fee paid to the farmers has been obtained from a food-grade corn processor.

In this analysis, ten year average futures and cash prices for the Evansville area are used for determining the prices paid by local elevators and food processors. The ten year period chosen was 1994/5-2005/6, with 1995/6 and 2003/04 dropped because they were drought years which have a very different price pattern than a typical year. The contracts with the food processor allow farmers to establish their selling futures prices using several different futures contracts such as the March, May or July contracts. For simplicity, we assume that the only futures price available is the nearby contract, and we have smoothed these futures prices to eliminate price discontinuities that may occur when there is a change in the nearby futures contract, i.e. when the nearby price switches from the March contract to the May contract on the first day of the delivery period (Figure 1).

The smoothed futures prices (*X*) are used in this analysis to establish the food processor's prices. We did not smooth the cash price offered by the local elevator because the farmer will only deliver to the elevator if their grain has been rejected by the food processor, and so this decision does not depend on their expectations of cash prices.

In this study, a model called PHAST-FEM, a post-harvest aeration and storage simulation tool developed by Montross et al. (2002) was used to generate data on the likelihood of transitions between the states (in-bin temperature and cumulative dry matter loss) in a given period conditional on the benchmark bin characteristics and values of the state variables in the previous period. The PHAST-FEM model uses weather data which are taken from 1961-2005 observations of ambient temperature, ambient relative humidity, wind speed and solar radiation for the Evansville area from the National Solar Radiation Data Base (NSRDB).

Simulations using the PHAST-FEM model with initial grain moisture content (MC) of 14.5% using different aeration strategies (including no aeration) resulted in end period moisture content range of (13.3%-15.3%) which exhibits only a small absolute deviation from the initial moisture content (14.5%). As a result, we decided to assume that MC is constant at 14.5% in order to eliminate the need for an additional state variable.

Limited amount of work has been done on the relationship between mold damaged kernels (MDK) and dry matter loss. Gupta et al. (1999) is the only study that has conducted laboratory experiments on the relationship between total damaged kernels and dry matter loss (DML) and also made the link to MDK. We use the Gupta et al. data to estimate the following linear relationship between DML and MDK.

$$MDK = -0.69 + 14.23*DML \qquad (5)$$

The regression statistics for this equation are displayed in Table 2. The estimated relationship resulted in a 6% cumulative number of mold damaged kernels for a dry matter loss value of 0.47%, which is consistent with the literature which finds that a dry matter loss of 0.5% due to mold activity leads to a drop in the USDA grain grade by one level (Ng et al., 1998, Wilcke et al., 1993, Friday at al., 1989, Saul and Steel, 1966), and the presence of more than 6% mold damaged kernels also leads to a drop of the USDA grade by one level (GIPSA, 2007).

The longest period farmers in Indiana typically store corn in their on-farm bins is 9.5 months, usually Mid October – End of July. This planning horizon is divided into roughly two-week (15 or 16 day) periods for modeling purposes. State transition matrices are estimated based on the PHAST-FEM model results for the following seven groups of periods: second half of October, November, December – end of March, first half of April, second half of April, May, and June-end of July. Because weather patterns are similar within each of these groups of periods, the matrices are taken to be constant within them, but they differ across groups of periods. As a result, only 7 distinct transition matrices are estimated. (See Appendix A for the list of periods.)

Given that the favorable temperature levels for mold growth are between 25^0C-33^0C (Shanahan et al., 2003), simulations were performed for 8 discrete initial in-bin temperature levels in a wider temperature range between 3^0C-38^0C at 5^0C intervals. As a result, a total of 7,560 runs of the PHAST-FEM model have been made for 45 years, 3 different aeration strategies, 8 initial in-bin temperature levels and 7 groups of periods. From all of the runs, we found that the maximum possible periodic dry matter loss is 0.41% and the maximum possible cumulative dry matter loss (CDML) over the 19 periods of storage is 4.3%. As a result, we used grids with a spacing of 0.01 and a range of 0.00% to 4.30% to create 430 levels of CDML in the model. The generated data along with equation *5* were used to construct the joint transition probabilities $P_{tij}(S_{ti},A_{ti})$ in each period t. The transition probabilities along with other parameters for the benchmark farmer and benchmark bin (Table 1) have been used to build the bio-economic model described by equations 1-5 above.

5. Results

The optimal mold control method with respect to different aeration strategies and timing of sales depends on grain temperature and cumulative mold damaged kernels (CMDK). Model results based on data from the Evansville area show that generally there is no economic benefit to aerating unconditionally. This is because, in addition to the higher cost of running fans, aerating unconditionally involves the risk of pushing hot air into already cool grain, especially at times when the ambient temperature is high, thereby increasing the risk of mold damage. The exception to this general rule occurs when both the grain and ambient temperatures are high with the ambient temperature lower than the grain temperature throughout the period. In cases like these, aerating continuously for 15 days can help to deter spoilage by molds.

Unlike the current farmer practice where aeration is not used after December, model results show that the optimal mold management strategy involves continuation of conditional aeration even if grain is to be sold to the local elevator in March, when cash prices are the highest. Continuation of conditional aeration after the end of December is even more important if high quality corn is to be delivered to a food-grade corn processor later during the summer (See Appendix B). Even if the grain was cooled to as low as 4-5^{o}C by the end of December, never aerating the grain thereafter leads to a gradual heating of the grain to 18-28^{o}C by the end of June and to 23-38^{o}C by the end of July. Such high grain temperatures lead to accelerated mold damage that would often lead to rejection of the grain by the food processor.

Our model results are summarized in figure 2. Farmers who have signed a contract with the food-grade corn processor can use the following rules of thumb in conjunction with monitoring their bins:

- If in-bin temperature is less than or equal to 5.5^{o}C and the number of mold damaged kernels (MDK) is less than or equal to 4% at any point during the storage period, then do not aerate but keep it at least for another 15 days after which you will have to monitor and decide again (See Figure 2).
- If temperature is greater than 20.5^{o}C and MDK is less than 5% then do not sell yet but aerate the grain conditionally (i.e., when the outside temperature is less than the in-bin temperature by at least 3^{o}C).

- If the in-bin temperature is above 10.5^{o}C and MDK reaches 6.14% any time before the first half of March, then aerate the grain conditionally and keep it until early in March to sell it to the local elevator. If it is any time past March, then sell it to the local elevator right away.
- For the period before December, if MDK reaches 5%, sell to the food processor because, no storage fee is paid until December and hence the risk of losing money from possible mold development is higher than the storage fees earned for the periods after December.
- In the summer months, if the in-bin temperature is between 15.5^{o}C and 35.5^{o}C, and the number of mold damaged kernels reaches 5.29%, then sell it immediately to the food processor. This is because, in these periods, the periodic damage from molds exceeds the storage fee paid per period.

A closer look at the model results reveals that if the farmer has the option of selling to the food processor, then the premium ($0.55 per bushel) and storage fee ($0.03/bushel/month) make selling to the elevator an option of last resort. This is because the total price paid by the food processor is always higher than the local elevator (Fig.1) provided that the grai is not rejected (MDK does not exceed 6%).

From the perspective of the food processor, one important question is whether the premium and storage fee specified in the contract will provide enough incentive to farmers to deliver enough grain of acceptable quality later in the storage season. If we assume that all farmers would deliver their grain by July 31 in order to empty storage bins in preparation for the next harvest, then the food processor’s goal is to have enough grain delivered to meet their processing needs between July 31 and the following harvest which would start late September/early October.

Assuming that the food processor needs a 2 month supply of quality grain delivered on July 31, then in order to have enough grain, at least one-sixth or 16.7% of the farmers' grain must meet the minimum quality standards and be stored until July 31.

For a fixed level of the premium and the price structure discussed in section 2 above, the amount of acceptable grain that farmers can deliver to the food processor at a given time during the storage period depends on the initial biophysical conditions in their grain bin (initial in-bin temperature and number of mold damaged kernels) and the monthly storage fee paid to them by the food processor. To estimate the optimal storage fees the food processor needs to pay to the contract farmers, we consider the following initial in-bin biophysical conditions (Table 3): temperature range of 33^oC-38^oC and MDK range of 0%-2%, both of which are typical of hot grain coming out of a grain drier.

Table 3 summarizes the simulation results for the different levels of initial biophysical conditions and storage fees assumed above. These results show that the food processor can use the storage fee as an instrument to increase the quality and quantity of grain that can be supplied later during the summer. If we assume 1.5% mold damage at the beginning of the storage period, then for the current level of the storage fee (3cents/bushel/month), 19% of the food processing plant's total annual high quality corn demand will be supplied by the farmers, which suggests that the food processor's current monthly storage fee is adequate to motivate farmers to deliver a sufficient quantity of quality grain.

6. Conclusions

The optimal mold management strategy depends on monitoring, the biophysical conditions of the grain and the time period under consideration. If monitoring rshows that in-bin temperature is high and the number of cumulative mold damaged kernels is well below 6%, then the optimal strategy is to aerate conditionally and to keep it for sales in the future thereby capturing the storage fee which is higher than the storage cost. If the number of mold damaged kernels is close to the 6% limit, then the optimal strategy is to sell immediately to the food processor. If monitoring any time before March reveals that the 6% limit for the cumulative mold damaged kernels is exceeded but is still less than 16%, then the optimal strategy is aerating conditionally and keeping it for sales to the elevator in March during which cash prices tend to be the highest. Farmers' current practice of aerating the grain until the end of December and doing nothing thereafter bears a substantial risk of economic losses to the farmer especially if they have signed contracts to deliver good quality grain to the food processor later during the summer. Farmers sign contracts with food processors in order to take advantage of the high premium and storage fee paid by the processors for delivering good quality grain later in the summer. Maintaining grain quality until later during the summer however is very unlikely with farmers' current practices. On the other hand, even with the large number of labor hours and hence high monitoring costs assumed in this paper, the likelihood of maintaining good quality grain using the monitoring based optimal mold management strategy is higher and costs less than the benefit it fetches. Hence, it is in the best interest of the farmer to adopt the monitoring based mold management strategy.

The processor's choice of the monthly storage fee affects the farmers' optimal mold management decisions and therefore the expected quantity of acceptable quality grain available at the end of the storage period. Processors can use this information to design contracts where they pay a high enough storage fee to get the quantity and quality of grain they want but minimize costs by not paying more than they need to. For instance, to ensure a constant supply of corn, processors need to design a pricing scheme that encourages farmers to store about a sixth of their annual corn demand to be delivered not earlier than the end of July. If the initial grain temperature and cumulative mold damaged kernels in mid-October are 38^{o}C and 1.5% respectively, then the minimum storage fee that the processor has to pay to the contract farmers per each period of 15 days (for the fixed premium of $0.55 per bushel) is 3 about cents per month.

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Table 1. Parameters Used in the SDP Program

Parameter	Units	Parameter Value
Drying cost	$ per point per bushel	0.02
Moisture content at harvest	%	22
Wage rate	$/hour	10
Time required for monitoring for molds	Hours per bushel	0.000111
Average bin size	Bushels	36000
Premium	Bushel	0.55
Storage fee	$ per bushel per month	0.03
Penalty for mold damaged kernels	$ per bushel	0.01
Interest rate	% per year	8
Electricity cost (SUFG, 2005)	$ per KWH	0.07

Table 2. Regression of MDK on DML

Variables	Un-standardized Coefficients		Corrected R Square
	Coefficient	Std. Error	
Constant (con)	-0.69	2.607	0.349
Dry Matter Loss (DML)	14.23	4.257	

Table 3. Percentage of Quality Grain that can be Delivered to the Food Processor on July 31^{st}

Initial in-bin Biophysical Conditions: Mid October			Percentage of quality grain that can be delivered to the FP on July 31 for storage charge of:		
Temp	DML (%)	MDK (%)	2.4¢/bushel/month	3¢/bushel/month	3.6¢/bushel/month
	0	0	4.67	100	100
	0.08	0.5	0	99.8	99.9
33^oC	0.12	1	0	76.9	80.3
	0.15	1.5	0	18.2	19.6
	0.19	2	0	1.9	2.5
	0	0	5.04	100	100
	0.08	0.5	0	99.9	99.9
38^oC	0.12	1	0	79.9	83.2
	0.15	1.5	0	19.12	20.7
	0.19	2	0	2.1	2.7

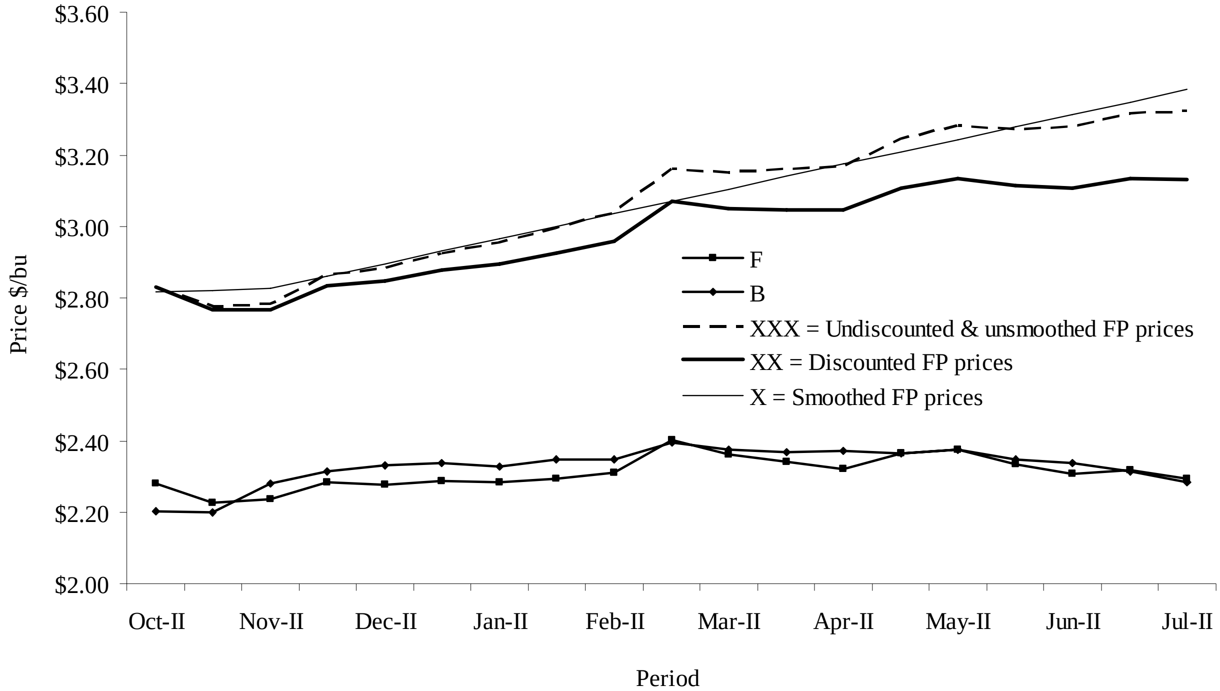
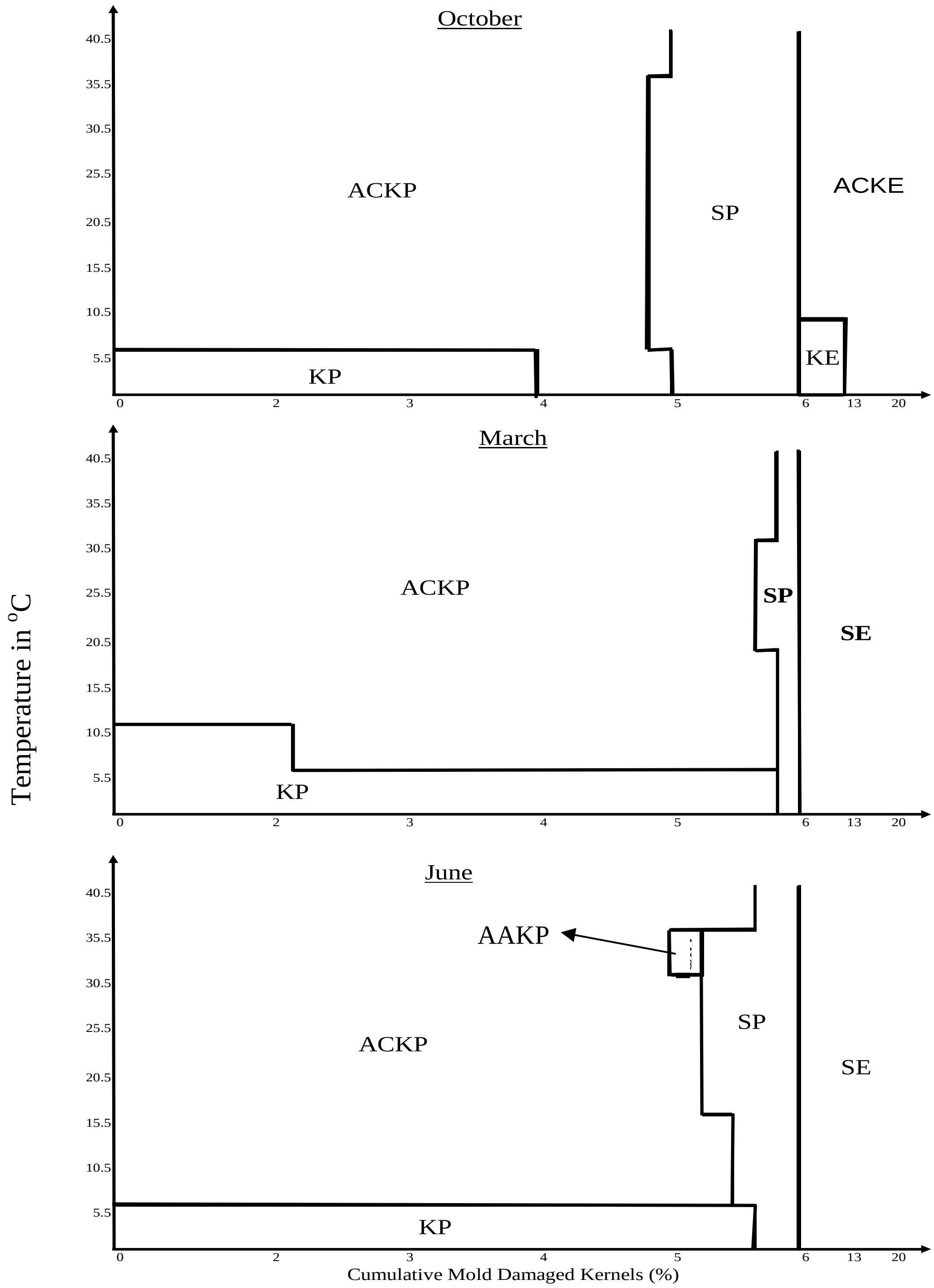


Figure 1: Seasonal Changes in Futures (F), Cash (B) and Smoothed Food Processor (X) Prices



KE Keep without aerating to sell to the elevator
KP Keep without aerating to sell to the food processor
ACKE Aerate conditionally and Keep to sell to the elevator
ACKP Aerate conditionally and Keep to sell to the food processor
AAKP Aerate always and keep to sell to the food processor
SP Do not aerate and sell now to the food processor
SE Do not aerate and sell now to the elevator

Figure 2: Optimal Mold Management Strategies for Different Months

Appendix A: Time Periods and Possible Farmer Actions Assumed for the Model

Time period	Dates	Possible farmer activities	
0	August 1 - september15	Pre-filling sanitation (cleaning, dusting and spraying)	
0	September 15 – October 15	Filling bin, drying, residual pesticide application	
1	October 16 - October 31	Monitoring, Aeration, selling	
2	November 1 - November 15	Monitoring, Aeration, selling	Assumed to have same transition probabilities
3	November 16 - November 30	Monitoring, Aeration, selling	
4	December 1 - December 15	Monitoring, Aeration, selling	Assumed to have same transition probabilities
5	December 16 - December 31	Monitoring, Aeration, selling	
6	January 1 – January 15	Monitoring, Aeration, selling	
7	January 16 – January 31	Monitoring, Aeration, selling	
8	February 1 – February 15	Monitoring, Aeration, selling	
9	February 16 – February	Monitoring, Aeration, selling	
10	March 1 – March 15	Monitoring, Aeration, selling	
11	March 16 – March 31	Monitoring, Aeration, selling	Assumed to have same transition probabilities
12	April 1 – April 15	Monitoring, Aeration, selling	
13	April 16 -April 30	Monitoring, Aeration, selling	
14	May 1 - May 15	Monitoring, Aeration, selling	Assumed to have same transition probabilities
15	May 16 - May 31	Monitoring, Aeration, selling	
16	June 1 - June 15	Monitoring, Aeration, selling	Assumed to have same transition probabilities
17	June 16 - June 30	Monitoring, Aeration, selling	
18	July 1 - July 15	Monitoring, Aeration, selling	
19	July 16 - July 30	Monitoring, Aeration, selling	

Appendix B: Monitoring Based Optimal Strategies for Farmers who have Signed Contracts with the Food Processor

	State of Nature							Actual profit if Sold now		Expected Profit if kept	
Period	Temp(^oC)	DML (%)	MDK (%)	Aeration	Sell/Keep	Sell Corn by	Sell to	Minimum	Max	Minimum	Max
Oct-II	<=5.5	0-33	0-4	None	Keep	8.84-19.999	FP	94156.08	94832.61	97445.86	99861.38
Oct-II	<=5.5	34-40	4.15-5.00	Conditional	Keep	7.466	FP	93731.59	94095.41	95437.87	97325.42
Oct-II	<=5.5	41-42	5.14-5.29	None	Sell	Now	FP	93610.40	93670.99		
Oct-II	5.51-10.5	0-40	0-5.00	Conditional	Keep	4.53-19.999	FP	93731.59	94832.61	94630.87	99818.21
Oct-II	5.51-10.5	41-42	5.14-5.29	None	Sell	Now	FP	93610.40	93670.99		
Oct-II	10.51-15.5	0-39	0-4.86	Conditional	Keep	6.59-20.00	FP	93792.20	94832.61	95224.37	99809.82
Oct-II	10.51-15.5	40-42	5.00-5.29	None	Sell	Now	FP	93610.40	93731.59		
Oct-II	15.51-20.5	0-39	0-4.86	Conditional	Keep	6.53-20.00	FP	93792.20	94832.61	95201.94	99805.94
Oct-II	15.51-20.5	40-42	5.00-5.29	None	Sell	Now	FP	93610.40	93731.59		
Oct-II	20.51-25.5	0-39	0-4.86	Conditional	Keep	6.79-20.00	FP	93792.20	94832.61	95278.13	99812.99
Oct-II	20.51-25.5	40-42	5.00-5.29	None	Sell	Now	FP	93610.40	93731.59		
Oct-II	25.51-30.5	0-39	0-4.86	Conditional	Keep	6.70-20.00	FP	93792.20	94832.61	95256.36	99815.03
Oct-II	25.51-30.5	40-42	5.00-5.29	None	Sell	Now	FP	93610.40	93731.59		
Oct-II	30.51-35.5	0-39	0-4.86	Conditional	Keep	7.14-20.00	FP	93792.20	94832.61	95382.59	99826.56
Oct-II	30.51-35.5	40-42	5.00-5.29	None	Sell	Now	FP	93610.40	93731.59		
Oct-II	35.51-40.5	0-40	0-5.00	Conditional	Keep	5.06-20.00	FP	93731.59	94832.61	94788.61	99833.97
Oct-II	35.51-40.5	41-42	5.14-5.29	None	Sell	Now	FP	93610.40	93670.99		
Nov-I	<=5.5	0-41	0-5.14	None	Keep	8.00-20.00	FP	94362.51	95526.97	95960.76	100317.30
Nov-I	<=5.5	42	5.29	None	Sell	Now	FP	94301.85			
Nov-I	5.51-10.5	0-41	0-5.14	None	Keep	8.00-20.00	FP	94362.51	95526.97	95960.76	100302.20
Nov-I	5.51-10.5	42	5.29	None	Sell	Now	FP	94301.85			
Nov-I	10.51-15.5	0-40	0-5.00	Conditional	Keep	8.93-19.997	FP	94423.18	95526.97	96236.96	100293.50
Nov-I	10.51-15.5	41-42	5.14-5.29	None	Sell	Now	FP	94301.85	94362.51		
Nov-I	15.51-20.5	0-41	0-5.14	Conditional	Keep	7.997-19.997	FP	94362.51	95526.97	95942.29	100297.40
Nov-I	15.51-20.5	42	5.29	None	Sell	Now	FP	94301.85			
Nov-I	20.5-40.5	0-41	0-5.14	Conditional	Keep	8.00-20.00	FP	94362.51	95526.97	95943.96	100298.80
Nov-I	20.5-40.5	42	5.29	None	Sell	Now	FP	94301.85			

	State of Nature							Actual profit if Sold now		Expected Profit if kept	
Period	Temp (^{o}C)	DML (%)	MDK (%)	Aeration	Sell/Keep	Sell Corn by	Sell to	Minimum	Max	Minimum	Max
Nov-II	<=5.5	0-42	0-5.29	None	Keep	8.00-20.00	FP	94993.25	96221.28	96321.06	100750.40
Nov-II	5.51-10.5	0-42	0-5.29	None	Keep	8.00-20.00	FP	94993.25	96221.28	96321.06	100735.40
Nov-II	10.51-15.5	0-42	0-5.29	Conditional	Keep	8.00-20.00	FP	94993.25	96221.28	96281.82	100726.90
Nov-II	15.5.5-40.5	0-42	0-5.29	Conditional	Keep	8.00-20.00	FP	94993.25	96221.28	96304.26	100732.00
Dec-I	<=5.5	0-46	0-5.86	Conditional	Keep	5.00-20.00	FP	95437.92	96911.95	95708.68	101184.40
Dec-I	<=5.5	47	6.00	None	Sell	Now	FP	95377.17			
Dec-I	<=5.5	48-57	6.14-7.24	Conditional	Keep	10	ELV	77393.94	77924.43	77924.43	78521.63
Dec-I	5.5.5-20.5	0-46	0-5.86	Conditional	Keep	5.00-20.00	FP	95437.92	96911.95	95691.88	101167.30
Dec-I	5.5.5-20.5	47	6.00	None	Sell	Now	FP	95377.17			
Dec-I	5.5.5-20.5	48-57	6.14-7.24	Conditional	Keep	10	ELV	77393.94	77924.43	77983.07	78504.83
Dec-I	20.5-30.5	0-45	0-5.71	Conditional	Keep	5.97-20.00	FP	95498.68	96911.95	96012.65	101166.00
Dec-I	20.5-30.5	46-47	5.86-6.00	None	Sell	Now	FP	95377.17	95437.92		
Dec-I	20.5-30.5	48-57	6.14-7.24	Conditional	Keep	10	ELV	77393.94	77924.43	77981.78	78503.54
Dec-I	30.5-40.5	0-46	0-5.86	Conditional	Keep	5.00-20.00	FP	95437.92	96911.95	95691.88	101167.60
Dec-I	30.5-40.5	47	6.00	None	Sell	Now	FP	95377.17			
Dec-I	30.5-40.5	48-57	6.14-7.24	Conditional	Keep	10	ELV	77393.94	77924.43	77983.07	78504.83
Dec-II	0-10.5	0-46	0-5.86	None	Keep	6.00-20.00	FP	96128.94	97606.16	96397.27	101618.70
Dec-II	0-10.5	47	6.00	None	Sell	Now	FP	96068.12			
Dec-II	0-10.5	48-74	6.14-9.84	None	Keep	10	ELV	77036.99	96068.12	77371.31	96068.12
Dec-II	10.5-20.5	0-46	0-5.86	Conditional	Keep	6.00-20.00	FP	96128.94	97606.16	96397.27	101603.80
Dec-II	10.5-20.5	47	6.00	None	Sell	Now	FP	96068.12			
Dec-II	10.5-20.5	48-74	6.14-9.84	Conditional	Keep	10	ELV	77036.99	78568.98	77354.51	78865.00
Dec-II	20.51-25.5	0-45	0-5.71	Conditional	Keep	6.95-20.00	FP	96189.77	97606.16	96691.72	101599.10
Dec-II	20.51-25.5	46-47	5.86-6.00	None	Sell	Now	FP	96068.12	96128.94		
Dec-II	20.51-25.5	48-74	6.14-9.84	Conditional	Keep	10	ELV	77036.99	78568.98	77351.93	78862.41
Dec-II	25.51-30.5	0-45	0-5.71	Conditional	Keep	6.97-20.00	FP	96189.77	97606.16	96698.95	101600.30
Dec-II	25.51-30.5	46-47	5.86-6.00	None	Sell	Now	FP	96068.12	96128.94		
Dec-II	25.51-30.5	48-74	6.14-9.84	Conditional	Keep	10	ELV	77036.99	78568.98	77353.22	78863.71
Dec-II	30.5-40.5	0-46	0-5.86	None	Keep	6.00-20.00	FP	96128.94	97606.16	96380.47	101601.90
Dec-II	30.5-40.5	47	6.00	None	Sell	Now	FP	96068.12			

	State of Nature							Actual profit if Sold now		Expected Profit if kept	
Period	Temp (^{o}C)	DML (%)	MDK (%)	Aeration	Sell/Keep	Sell Corn by	Sell to	Minimum	Max	Minimum	Max
Dec-II	30.5-40.5	48-74	6.14-9.84	Conditional	Keep	10	ELV	77036.99	78568.98	77354.51	78865.00
Jan-I	0-10.5	0-46	0-5.86	None	Keep	7.00-20.00	FP	96819.91	98300.32	97085.82	102053.10
Jan-I	0-10.5	47	6.00	None	Sell	Now	FP	96759.01			
Jan-I	0-10.5	48-91	6.14-12.26	Conditional	Keep	10	ELV	76254.85	78785.80	76739.98	79243.38
Jan-I	5.5.5-20.5	0-46	0-5.86	Conditional	Keep	7.00-20.00	FP	96819.91	98300.32	97069.02	102035.90
Jan-I	5.5.5-20.5	47	6.00	None	Sell	Now	FP	96759.01			
Jan-I	5.5.5-20.5	48-91	6.14-12.26	Conditional	Keep	10	ELV	76254.85	78785.80	76723.18	79226.58
Jan-I	20.5-30.5	0-45	0-5.71	Conditional	Keep	7.00-20.00	FP	96880.81	98300.32	97385.20	102034.70
Jan-I	20.5-30.5	46-47	5.86-6.00	None	Sell	Now	FP	96759.01	96819.91		
Jan-I	20.5-30.5	48-91	6.14-12.26	Conditional	Keep	10	ELV	76254.85	78785.80	76721.89	79225.28
Jan-I	30.5-40.5	0-46	0-5.86	Conditional	Keep	7.00-20.00	FP	96819.91	98300.32	97069.02	102036.30
Jan-I	30.5-40.5	47	6.00	None	Sell	Now	FP	96759.01			
Jan-I	30.5-40.5	48-91	6.14-12.26	Conditional	Keep	10	ELV	76254.85	78785.80	76723.18	79226.58
Jan-II	<=5.5	0-46	0-5.86	None	Keep	8.00-20.00	FP	97510.82	98994.43	97774.31	102487.40
Jan-II	<=5.5	47	6.00	None	Sell	Now	FP	97449.86			
Jan-II	<=5.5	48-91	6.14-12.26	Conditional	Keep	10	ELV	74876.14	78400.27	76105.88	79606.38
Jan-II	5.5.5-20.5	0-45	0-5.71	Conditional	Keep	8.00-20.00	FP	97510.82	98994.43	97757.51	102470.30
Jan-II	5.5.5-20.5	47	6.00	None	Sell	Now	FP	97449.86			
Jan-II	5.5.5-20.5	48-91	6.14-12.26	Conditional	Keep	10	ELV	74876.14	78400.27	76089.08	79589.58
Jan-II	20.5-30.5	0-45	0-5.71	Conditional	Keep	8.97-20.00	FP	97571.80	98994.43	98071.41	102469.10
Jan-II	20.5-30.5	46-47	5.86-6.00	None	Sell	Now	FP	97449.86	97510.82		
Jan-II	20.5-30.5	48-91	6.14-12.26	Conditional	Keep	10	ELV	74876.14	78400.27	76087.79	79588.28
Jan-II	30.5-40.5	0-46	0-5.86	Conditional	Keep		FP	97510.82	98994.43	97757.51	102470.60
Jan-II	30.5-40.5	47	6.00	None	Sell	Now	FP	97449.86			
Jan-II	30.5-40.5	48-91	6.14-12.26	Conditional	Keep	10	ELV	74876.14	78400.27	76089.08	79589.58
Feb-I	0-10.5	0-91	0-12.26	None	Keep	9.00-20.00	FP	98201.69	99688.49	98462.76	102920.90
Feb-I	0-10.5	47	6.00	None	Sell	Now	FP	98140.66			
Feb-I	0-10.5	48-91	6.14-12.26	None	Keep	10	ELV	74555.43	79076.74	75469.02	79970.81
Feb-I	5.5.5-20.5	0-46	0-5.86	Conditional	Keep		FP	98201.69	99688.49	98445.96	102903.80

Period	State of Nature			Aeration	Sell/Keep	Sell Corn by	Sell to	Actual profit if Sold now		Expected Profit if kept	
	Temp (^oC)	DML (%)	MDK (%)					Minimum	Max	Minimum	Max
Feb-I	5.5.5-20.5	47	6.00	None	Sell	Now	FP	98140.66			
Feb-I	5.5.5-20.5	48-91	6.14-12.26	Conditional	Keep	10	ELV	74555.43	79076.74	75452.22	79954.01
Feb-I	20.5-30.5	0-45	0-5.71	Conditional	Keep	9.95-20.00	FP	98262.74	99688.49	98754.10	102902.60
Feb-I	20.5-30.5	46-47	5.86-6.00	None	Sell	Now	FP	98140.66	98201.69		
Feb-I	20.5-30.5	48-91	6.14-12.26	Conditional	Keep	10	ELV	74555.43	79076.74	75450.93	79952.70
Feb-I	30.5-40.5	0-46	0-5.86	Conditional	Keep	9.00-20.00	FP	98201.69	99688.49	98445.96	102904.10
Feb-I	30.5-40.5	47	6.00	None	Sell	Now	FP	98140.66			
Feb-I	30.5-40.5	48-91	6.14-12.26	Conditional	Keep	10	ELV	74555.43	79076.74	75452.22	79954.01
Feb-II	<=5.5	0-91	0-12.26	None	Keep		FP	98892.51	100382.50	99147.60	103349.30
Feb-II	<=5.5	47	6.00	None	Sell	Now	FP	98831.41			
Feb-II	<=5.5	48-91	6.14-12.26	None	Keep	10	ELV	73603.33	79115.22	74829.38	80336.66
Feb-II	5.5.5-20.5	0-46	0-5.86	Conditional	Keep	10.00-20.00	FP	98892.51	100382.50	99130.80	103332.20
Feb-II	5.5.5-20.5	47	6.00	None	Sell	Now	FP	98831.41			
Feb-II	5.5.5-20.5	48-91	6.14-12.26	Conditional	Keep	10	ELV	73603.33	79115.22	74812.58	80319.86
Feb-II	20.5-30.5	0-45	0-5.71	Conditional	Keep		FP	98953.63	100382.50	99440.12	103331.20
Feb-II	20.5-30.5	46-47	5.86-6.00	None	Sell	Now	FP	98831.41	98892.51		
Feb-II	20.5-30.5	48-91	6.14-12.26	Conditional	Keep	10	ELV	73603.33	79115.22	74811.29	80318.55
Feb-II	30.5-40.5	0-46	0-5.86	Conditional	Keep		FP	98892.51	100382.50	99130.80	103332.50
Feb-II	30.5-40.5	47	6.00	None	Sell	Now	FP	98831.41			
Feb-II	30.5-40.5	48-91	6.14-12.26	Conditional	Keep	10	ELV	73603.33	79115.22	74812.58	80319.86
Mar-I	<=5.5	0-46	0-5.86	None	Keep	11-20.00	FP	99579.72	101072.90	99835.95	103768.30
Mar-I	<=5.5	47	6.00	None	Sell	Now	FP	99518.54			
Mar-I	<=5.5	48-145	6.14-19.94	None	Sell	Now	ELV	75002.01	80703.96		
Mar-I	5.51-10.5	0-19	0-2.01	None	Keep	19.98-20.00	FP	100882.80	101072.90	102737.40	103755.90
Mar-I	5.51-10.5	20-26	2.16-3.01	Conditional	Keep	18.75-19.96	FP	100805.40	100872.30	102240.30	102674.50
Mar-I	5.51-10.5	27-28	3.15-3.29	None	Keep	18.17-18.41	FP	100682.60	100744.00	102097.90	102168.20
Mar-I	5.51-10.5	29-30	3.29-3.58	Conditional	Keep	17.75-18.01	FP	100559.90	100621.30	101958.90	102030.00
Mar-I	5.51-10.5	31	3.72	None	Keep	17.4	FP	100498.60		101885.10	
Mar-I	5.51-10.5	32-44	3.86-5.57	Conditional	Keep	13.00-17.18	FP	99702.10	100437.30	100443.80	101814.40
Mar-I	5.51-10.5	45-46	5.71-5.86	None	Keep	11.00-12.00	FP	99579.72	99640.90	99835.95	100149.90

	State of Nature							Actual profit if Sold now		Expected Profit if kept	
Period	Temp (^oC)	DML (%)	MDK (%)	Aeration	Sell/Keep	Sell Corn by	Sell to	Minimum	Max	Minimum	Max
Mar-I	5.51-10.5	47	6.00	None	Sell	Now	FP	99518.54			
Mar-I	5.51-10.5	48-145	6.14-19.94	None	Sell	Now	ELV	75002.01	80703.96		
Mar-I	10.5-20.5	0-46	0-5.86	Conditional	Keep		FP	99579.72	101072.90	99819.15	103751.20
Mar-I	10.5-20.5	47	6.00	None	Sell	Now	FP	99518.54			
Mar-I	10.5-20.5	48-145	6.14-19.94	None	Sell	Now	ELV	75002.01	80703.96		
Mar-I	20.5-30.5	0-45	0-5.71	Conditional	Keep	11.97-20.00	FP	99640.90	101072.90	100126.20	103750.50
Mar-I	20.5-30.5	46-47	5.86-6.00	None	Sell	Now	FP	99518.54	99579.72		
Mar-I	20.5-30.5	48-145	6.14-19.94	None	Sell	Now	ELV	75002.01	10.00		
Mar-I	30.5-40.5	0-46	0-5.86	Conditional	Keep	11.00-20.00	FP	99579.72	101072.90	99819.15	103751.50
Mar-I	30.5-40.5	47	6.00	None	Sell	Now	FP	99518.54			
Mar-I	30.5-40.5	48-145	6.14-19.94	None	Sell	Now	ELV	75002.01	80703.96		
Mar-II	<=5.5	0-46	0-5.86	None	Keep	13.74-20.00	FP	100270.40	101766.80	100524.20	104179.10
Mar-II	<=5.5	47	6.00	None	Sell	Now	FP	100209.20			
Mar-II	<=5.5	48-145	6.14-19.94	None	Sell	Now	ELV	74334.03	80029.55		
Mar-II	5.51-10.5	0-44	0-5.57	None	Keep	13.74-20.00	FP	100393.00	101766.80	101058.50	104168.10
Mar-II	5.51-10.5	45	5.71	Conditional	Keep	12.77	FP	100331.70		100763.40	
Mar-II	5.51-10.5	46	5.86	None	Keep	12	FP	100270.40		100524.20	
Mar-II	5.51-10.5	47	6.00	None	Sell	Now	FP	100209.20			
Mar-II	5.51-10.5	48-145	6.14-19.94	None	Sell	Now	ELV	74334.03	80029.55		
Mar-II	10.5-25.5	0-45	0-5.71	Conditional	Keep	12.68-20.00	FP	100331.70	101766.80	100733.10	104148.80
Mar-II	10.5-25.5	46-47	5.86-6.00	None	Sell	Now	FP	100209.20	100270.40		
Mar-II	10.5-25.5	48-145	6.14-19.94	None	Sell	Now	ELV	74334.03	80029.55		
Mar-II	25.51-30.5	0-45	0-5.71	Conditional	Keep	12.84-20.00	FP	100393.00	101766.80	100784.90	104144.10
Mar-II	25.51-30.5	46-47	5.86-6.00	None	Sell	Now	FP	100209.20	100331.70		
Mar-II	25.51-30.5	48-145	6.14-19.94	None	Sell	Now	ELV	74334.03	80029.55		
Mar-II	30.5-40.5	0-45	0-5.71	Conditional	Keep	12.71-20.00	FP	100331.70	101766.80	100738.60	104150.20
Mar-II	30.5-40.5	46-47	5.86-6.00	None	Sell	Now	FP	100209.20	100270.40		
Mar-II	30.5-40.5	48-145	6.14-19.94	None	Sell	Now	ELV	74334.03	80029.55		
Apr-I	<=5.5	0-46	0-5.86	None	Keep	13.00-20.00	FP	100961.10	102460.60	101212.50	104593.30
Apr-I	<=5.5	47	6.00	None	Sell	Now	FP	100899.80			

	State of Nature							Actual profit if Sold now		Expected Profit if kept	
Period	Temp (^oC)	DML (%)	MDK (%)	Aeration	Sell/Keep	Sell Corn by	Sell to	Minimum	Max	Minimum	Max
Apr-I	<=5.5	48-145	6.14-19.94	None	Sell	Now	ELV	74071.85	79764.94		
Apr-I	5.51-10.5	0-34	0-4.15	None	Keep	17.17-20.00	FP	101083.80	102460.60	101560.60	104581.50
Apr-I	5.51-10.5	35-45	4.29-5.71	Conditional	Keep	13.77-17.01	FP	101022.40	101449.90		
Apr-I	5.51-10.5	46	5.86	None	Keep	13	FP	100961.10	101212.50		
Apr-I	5.51-10.5	47	6.00	None	Sell	Now	FP	100899.80			
Apr-I	5.51-10.5	48-145	6.14-19.94	None	Sell	Now	ELV	74071.85	79764.94		
Apr-I	10.5-25.5	0-45	0-5.71	Conditional	Keep	13.68-20.00	FP	101022.40	102460.60	101419.70	104563.60
Apr-I	10.5-25.5	46-47	5.86-6.00	None	Sell	Now	FP	100899.80	100961.10		
Apr-I	10.5-25.5	48-145	6.14-19.94	None	Sell	Now	ELV	74071.85	79764.94		
Apr-I	25.51-30.5	0-41	0-5.14	Conditional	Keep	15.36-20.00	FP	101267.80	102460.60	101965.90	104558.90
Apr-I	25.51-30.5	42-44	5.29-5.57	**Always**	Keep	13.40-14.67	FP	101083.80	101206.50	101360.50	101716.10
Apr-I	25.51-30.5	45-47	5.71-6.00	None	Sell	Now	FP	100899.80	101022.40		
Apr-I	25.51-30.5	48-145	6.14-19.94	None	Sell	Now	ELV	74071.85	79764.94		
Apr-I	30.5-40.5	0-45	0-5.71	Conditional	Keep	13.70-20.00	FP	101022.40	102460.60	101425.20	104563.90
Apr-I	30.5-40.5	46-47	5.86-6.00	None	Sell	Now	FP	100899.80	100961.10		
Apr-I	30.5-40.5	48-145	6.14-19.94	None	Sell	Now	ELV	74071.85	79764.94		
Apr-II	0-10.5	0-46	0-5.86	None	Keep	14.00-20.00	FP	101651.70	103154.50	101900.70	104991.80
Apr-II	0-10.5	47	6.00	None	Sell	Now	FP	101590.30			
Apr-II	0-10.5	48-145	6.14-19.94	None	Sell	Now	ELV	74180.19	79874.49		
Apr-II	10.5-20.5	0-45	0-5.71	Conditional	Keep	14.00-20.00	FP	101713.10	103154.50	101902.90	104970.70
Apr-II	10.5-20.5	46-47	5.86-6.00	None	Sell	Now	FP	101590.30	101713.10		
Apr-II	10.5-20.5	48-145	6.14-19.94	None	Sell	Now	ELV	74180.19	79874.49		
Apr-II	20.5-30.5	0-45	0-5.71	Conditional	Keep	14.39-20.00	FP	101774.50	103154.50	102036.10	104961.90
Apr-II	20.5-30.5	45-47	5.86-6.00	None	Sell	Now	FP	101590.30	101713.10		
Apr-II	20.5-30.5	48-145	6.14-19.94	None	Sell	Now	ELV	74180.19	79874.49		
Apr-II	30.5-40.5	0-45	0-5.71	Conditional	Keep	14.00-20.00	FP	101713.10	103154.50	101912.50	104962.80
Apr-II	30.5-40.5	46-47	5.86-6.00	None	Sell	Now	FP	101590.30	101651.70		
Apr-II	30.5-40.5	48-145	6.14-19.94	None	Sell	Now	ELV	74180.19	79874.49		
May-I	0-10.5	0-45	0-5.71	None	Keep	15.00-20.00	FP	102403.80	103848.20	102625.60	105407.20
May-I	0-10.5	46-47	5.86-6.00	None	Sell	Now	FP	102280.80	102342.30		

	State of Nature							Actual profit if Sold now		Expected Profit if kept	
Period	Temp (^oC)	DML (%)	MDK (%)	Aeration	Sell/Keep	Sell Corn by	Sell to	Minimum	Max	Minimum	Max
May-I	0-10.5	48-145	6.14-19.94	None	Sell	Now	ELV	73953.21	79645.42		
May-I	10.51-15.5	0-45	0-5.71	Conditional	Keep	15.06-20.00	FP	102403.80	103848.20	102592.30	105386.90
May-I	10.51-15.5	46-47	5.86-6.00	None	Sell	Now	FP	102280.80	102342.30		
May-I	10.51-15.5	48-145	6.14-19.94	None	Sell	Now	ELV	73953.21	79645.42		
May-I	15.51-20.5	0-43	0-5.43	Conditional	Keep	15.13-20.00	FP	102526.70	103848.20	102677.20	105368.50
May-I	15.51-20.5	44-47	5.57-6.00	None	Sell	Now	FP	79645.42	102465.20		
May-I	15.51-20.5	48-145	6.14-19.94	None	Sell	Now	ELV	73953.21	79645.42		
May-I	20.51-25.5	0-42	0-5.29	Conditional	Keep	15.11-20.00	FP	102588.20	103848.20	102715.80	105350.70
May-I	20.51-25.5	43-47	5.43-6.00	None	Sell	Now	FP	102280.80	102526.70		
May-I	20.51-25.5	48-145	6.14-19.94	None	Sell	Now	ELV	73953.21	79645.42		
May-I	25.5-35.5	0-41	0-5.14	Conditional	Keep	15.00-20.00	FP	102649.70	103848.20	102835.10	105351.90
May-I	25.5-35.5	42	5.29	**Always**	Keep	15.02	FP	102588.20		102681.80	
May-I	25.5-35.5	43-47	5.43-6.00	None	Sell	Now	FP	102280.80	102526.70		
May-I	25.5-35.5	48-145	6.14-19.94	None	Sell	Now	ELV	73953.21	79645.42		
May-I	35.51-40.5	0-42	0-5.29	Conditional	Keep	15.00-20.00	FP	102588.20	103848.20	102737.80	105356.20
May-I	35.51-40.5	43	5.43	**Always**	Keep	15	FP	102526.70		102637.20	
May-I	35.51-40.5	44-47	5.57-6.00	None	Sell	Now	FP	102280.80	102465.20		
May-I	35.51-40.5	48-145	6.14-19.94	None	Sell	Now	ELV	73953.21	79645.42		
May-II	0-10.5	0-45	0-5.71	None	Keep	15.00-20.00	FP	103094.30	104541.90	103313.70	105842.40
May-II	0-10.5	46-47	5.86-6.00	None	Sell	Now	FP	102971.30	103032.80		
May-II	0-10.5	48-145	6.14-19.94	None	Sell	Now	ELV	74237.90	79933.07		
May-II	0-10.5	0-45	0-5.71	Conditional	Keep	15.06-20.00	FP	103094.30	104541.90	103264.20	105814.80
May-II	10.51-15.5	46-47	5.86-6.00	None	Sell	Now	FP	102971.30	103032.80		
May-II	10.51-15.5	48-145	6.14-19.94	None	Sell	Now	ELV	74237.90	79933.07		
May-II	10.51-15.5	0-42	0-5.29	Conditional	Keep	16.00-20.00	FP	103279.00	104541.90	103384.30	105780.90
May-II	18-23	43-47	5.43-6.00	None	Sell	Now	FP	102971.30	103217.50		
May-II	18-23	48-145	6.14-19.94	None	Sell	Now	ELV	74237.90	79933.07		
May-II	18-23	0-41	0-5.14	Conditional	Keep	16.04-20.00	FP	103340.60	104541.90	103462.40	105781.70
May-II	25.5-35.5	42	5.29	**Always**	Keep	16	FP	103279.00		103366.30	
May-II	25.5-35.5	43-47	5.43-6.00	None	Sell	Now	FP	102971.30	103217.50		
May-II	25.5-35.5	48-145	6.14-19.94	None	Sell	Now	ELV	74237.90	79933.07		

	State of Nature							Actual profit if Sold now		Expected Profit if kept	
Period	Temp (^oC)	DML (%)	MDK (%)	Aeration	Sell/Keep	Sell Corn by	Sell to	Minimum	Max	Minimum	Max
May-II	25.5-35.5	0-42	0-5.29	Conditional	Keep	16.00-20.00	FP	103279.00	104541.90	103414.30	105784.60
May-II	35.51-40.5	43	5.43	**Always**	Keep	16	FP	103217.50		103325.40	
May-II	35.51-40.5	44-47	5.57-6.00	None	Sell	Now	FP	102971.30	103155.90		
May-II	35.51-40.5	48-145	6.14-19.94	None	Sell	Now	ELV	74237.90	79933.07		
June-I	<=5.5	0-45	0-5.71	None	Keep	17.00-20.00	FP	103846.50	105235.60	104029.70	106326.00
June-I	<=5.5	45-47	5.86-6.00	None	Sell	Now	FP	103661.70	103784.90		
June-I	<=5.5	48-145	6.14-19.94	None	Sell	Now	ELV	73269.68	78955.47		
June-I	<=5.5	0-42	0-5.29	Conditional	Keep	17.00-20.00	FP	103969.80	105235.60	104076.10	106251.40
June-I	5.5-15.5	43	5.43	Conditional	Keep	17	FP	103908.10			
June-I	5.5-15.5	44-47	5.57-6.00	None	Sell	Now	FP	103661.70	103846.50		
June-I	5.5-15.5	48-145	6.14-19.94	None	Sell	Now	ELV	73269.68	78955.47		
June-I	5.5-15.5	0-41	0-5.14	Conditional	Keep	17.00-20.00	FP	104031.40	105235.60	104066.20	106210.80
June-I	15.5-30.5	42-47	5.29-6.00	None	Sell	Now	FP	103661.70	103969.80		
June-I	15.5-30.5	48-145	6.14-19.94	None	Sell	Now	ELV	73269.68	78955.47		
June-I	15.5-30.5	0-40	0-5.00	Conditional	Keep	17.00-20.00	FP	104093.10	105235.60	104153.10	106215.90
June-I	30.51-35.5	41-42	5.14-5.29	**Always**	Keep	17	FP	103969.80	104031.40	104016.80	104078.30
June-I	30.51-35.5	43-47	5.43-6.00	None	Sell	Now	FP	103661.70	103908.10		
June-I	30.51-35.5	48-145	6.14-19.94	None	Sell	Now	ELV	73269.68	78955.47		
June-I	30.51-35.5	0-43	0-5.43	Conditional	Keep	17.00-20.00	FP	103908.10	105235.60	103995.10	106221.20
June-I	35.51-40.5	44-47	5.57-6.00	None	Sell	Now	FP	103661.70	103846.50		
June-I	35.51-40.5	48-145	6.14-19.94	None	Sell	Now	ELV	73269.68	78955.47		
June-II	<=5.5	0-44	0-5.57	None	Keep	18.00-20.00	FP	104533.50	105925.60	104717.80	106769.30
June-II	<=5.5	45-47	5.71-6.00	None	Sell	Now	FP	104348.40	104471.80		
June-II	<=5.5	48-145	6.14-19.94	None	Sell	Now	ELV	72901.38	78583.69		
June-II	<=5.5	0-42	0-5.29	None	Keep	18.00-20.00	FP	104656.90	105925.60	104764.30	106707.20
June-II	5.5-15.5	43	5.43	Conditional	Keep	18.00-20.00	FP	104595.20	104695.50		
June-II	5.5-15.5	44-47	5.57-6.00	None	Sell	Now	FP	104348.40	104471.80		
June-II	5.5-15.5	48-145	6.14-19.94	None	Sell	Now	ELV	72901.38	78583.69		
June-II	5.5-15.5	0-42	0-5.29	Conditional	Keep	18.00-20.00	FP	104656.90	105925.60	104696.90	106681.20
June-II	15.51-20.5	43-47	5.43-6.00	None	Sell	Now	FP	104348.40	104595.20		

	State of Nature							Actual profit if Sold now		Expected Profit if kept	
Period	Temp (^oC)	DML (%)	MDK (%)	Aeration	Sell/Keep	Sell Corn by	Sell to	Minimum	Max	Minimum	Max
June-II	15.51-20.5	48-145	6.14-19.94	None	Sell	Now	ELV	72901.38	78583.69		
June-II	15.51-20.5	0-41	0-5.14	Conditional	Keep	18.00-20.00	FP	104718.60	105925.60	104754.30	106666.70
June-II	20.5-30.5	42-47	5.29-6.00	None	Sell	Now	FP	104348.40	104656.90		
June-II	20.5-30.5	48-145	6.14-19.94	None	Sell	Now	ELV	72901.38	78583.69		
June-II	20.5-30.5	0-40	0-5.00	Conditional	Keep	18.02-20.00	FP	104780.40	105925.60	104841.30	106671.80
June-II	30.51-35.5	41-42	5.14-5.29	**Always**	Keep	18	FP	104656.90	104718.60	104704.90	104766.40
June-II	30.51-35.5	43-47	5.43-6.00	None	Sell	Now	FP	104348.40	104595.20		
June-II	30.51-35.5	48-145	6.14-19.94	None	Sell	Now	ELV	72901.38	78583.69		
June-II	30.51-35.5	0-43	0-5.43	Conditional	Keep	18.00-20.00	FP	104595.20	105925.60	104683.20	106677.20
June-II	35.51-40.5	44-47	5.57-6.00	None	Sell	Now	FP	104348.40	104533.50		
June-II	35.51-40.5	48-145	6.14-19.94	None	Sell	Now	ELV	72901.38	78583.69		
July-I	<=5.5	0-44	0-5.57	None	Keep	19.00-20.00	FP	105224.00	106619.10	105405.80	107201.20
July-I	<=5.5	45-47	5.71-6.00	None	Sell	Now	FP	105038.70	105162.20		
July-I	<=5.5	48-145	6.14-19.94	None	Sell	Now	ELV	72074.22	77748.55		
July-I	<=5.5	0-42	0-5.29	None	Keep	19.00-20.00	FP	105347.60	106619.10	105452.30	107164.60
July-I	5.5-15.5	43	5.43	Conditional	Keep	19.00-20.00	FP	105285.80		105383.50	
July-I	5.5-15.5	44-47	5.57-6.00	None	Sell	Now	FP	105038.70	105224.00		
July-I	5.5-15.5	48-145	6.14-19.94	None	Sell	Now	ELV	72074.22	77748.55		
July-I	5.5-15.5	0-42	0-5.29	Conditional	Keep	19.00-20.00	FP	105347.60	106619.10	105384.90	107138.60
July-I	15.51-20.5	43-47	5.43-6.00	None	Sell	Now	FP	105038.70	105285.80		
July-I	15.51-20.5	48-145	6.14-19.94	None	Sell	Now	ELV	72074.22	77748.55		
July-I	15.51-20.5	0-41	0-5.14	Conditional	Keep	19.00-20.00	FP	105409.40	106619.10	105442.40	107124.30
July-I	20.5-30.5	42-47	5.29-6.00	None	Sell	Now	FP	105100.50	105347.60		
July-I	20.5-30.5	48-145	6.14-19.94	None	Sell	Now	ELV	72074.22	77748.55		
July-I	20.5-30.5	0-40	0-5.00	Conditional	Keep	19.02-20.00	FP	105471.20	106619.10	105530.30	107129.50
July-I	30.51-35.5	41-42	5.14-5.29	**Always**	Keep	19	FP	105347.60	105409.40	105392.90	105454.50
July-I	30.51-35.5	43-47	5.43-6.00	None	Sell	Now	FP	105038.70	105285.80		
July-I	30.51-35.5	48-145	6.14-19.94	None	Sell	Now	ELV	72074.22	77748.55		
July-I	30.51-35.5	0-43	0-5.43	Conditional	Keep	19.00-20.00	FP	105285.80	106619.10	105371.20	107134.80
July-I	35.51-40.5	44-47	5.57-6.00	None	Sell	Now	FP	105038.70	105224.00		
July-I	35.51-40.5	48-145	6.14-19.94	None	Sell	Now	ELV	72074.22	77748.55		

	State of Nature							Actual profit if Sold now		Expected Profit if kept	
Period	Temp (°C)	DML (%)	MDK (%)	Aeration	Sell/Keep	Sell Corn by	Sell to	Minimum	Max	Minimum	Max
July-II	<=5.5	0-44	0-5.57	None	Keep	19.00-20.00	FP	105914.40	107312.70	106132.80	107624.70
July-II	<=5.5	45-47	5.71-6.00	None	Sell	Now	FP	105729.00	105852.60		
July-II	<=5.5	48-145	6.14-19.94	None	Sell	Now	ELV	70929.39	76592.60		
July-II	<=5.5	0-42	0-5.29	None	Keep	20	FP	106038.10	107312.70	106179.40	107610.70
July-II	5.5-15.5	43	5.43	Conditional	Keep	20	FP	105976.30		106110.50	
July-II	5.5-15.5	44-47	5.57-6.00	None	Sell	Now	FP	105729.00	105914.40		
July-II	5.5-15.5	48-145	6.14-19.94	None	Sell	Now	ELV	70929.39	76592.60		
July-II	5.5-15.5	0-42	0-5.29	Conditional	Keep	20	FP	106038.10	107312.70	106111.90	107597.80
July-II	15.51-20.5	43-47	5.43-6.00	None	Sell	Now	FP	105729.00	105976.30		
July-II	15.51-20.5	48-145	6.14-19.94	None	Sell	Now	ELV	70929.39	76592.60		
July-II	15.51-20.5	0-41	0-5.14	Conditional	Keep	20	FP	106100.00	107312.70	106169.50	107584.00
July-II	20.5-30.5	42-47	5.29-6.00	None	Sell	Now	FP	105729.00	106038.10		
July-II	20.5-30.5	48-145	6.14-19.94	None	Sell	Now	ELV	70929.39	76592.60		
July-II	20.5-30.5	0-40	0-5.00	Conditional	Keep	20	FP	106161.90	107312.70	106255.90	107588.50
July-II	30.51-35.5	41-42	5.14-5.29	**Always**	Keep	20	FP	106038.10	106100.00	106120.00	106181.70
July-II	30.51-35.5	43-47	5.43-6.00	None	Sell	Now	FP	105729.00	105976.30		
July-II	30.51-35.5	48-145	6.14-19.94	None	Sell	Now	ELV	70929.39	76592.60		
July-II	30.51-35.5	0-43	0-5.43	Conditional	Keep	20	FP	105976.30	107312.70	106098.20	107593.40
July-II	35.51-40.5	44-47	5.57-6.00	None	Sell	Now	FP	105729.00	105914.40		
July-II	35.51-40.5	48-145	6.14-19.94	None	Sell	Now	ELV	70929.39	76592.60		

DML (%): dry matter loss in %

MDK (%): number of mold damaged kernels (%)

Sell corn by: the code number of the optimal time of sale (decimals indicate that optimal time of sale has a probability distribution)

Sell to: to whom to sell (FP = food processor, ELV = Elevator)

Minimum & Maximum: the actual/expected profit corresponding respectively to the highest and lowest MDKs in the group.