Staff Paper P95-10 **September 1995**

STAFF PAPER SERIES

A Regression Analysis of the Effects of Planting Date and Variety on Corn Yields in Minnesota

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Gabriel Toichoa Buaha, Jeffrey Apland and Dale Hicks[1]

Introduction

The timely completion of field operations is critical to the productivity and profitability of crop farms. Timeliness in planting is especially critical in corn production since yields fall steadily with each day of delay in planting after the optimum date. Thus an economic trade-off exists since the increased planting capacity necessary to improve timeliness implies increased machinery and perhaps increased labor costs. The planting schedule determines the range of possible harvest schedules and, indirectly, when tillage operations may take place. Thus all machinery capacity decisions, not just planter size, are influenced by the fundamental relationship between planting date and yield. The effective availability of machine services is determined by both the farm's machinery complement and the number of field working days -- an important source of risk to corn producers. The capacity to complete field operations in a timely way is critical to operational decisions, such as variety selection and the overall crop mix.

This paper reports the results of a regression analysis of the relationship between planting date and corn yield. The study is based on experiments done at Agricultural Experiment Stations in Waseca, Lamberton and Morris, Minnesota. The experiments were conducted with several corn varieties. In addition to the date of planting, the estimated yield response equations include relative maturity as an explanatory variable. Other management practices included in the models are seeding and fertilization rates. Interactions among explanatory variables are estimated, also.

Background

Corn (Zea mays L.) is a warm-season, annual crop that requires large amounts of essential minerals. Soil fertility must be high to obtain high yields. Generally, fertilizers must be used to ensure adequate soil fertility. Under ideal climatic conditions in which moisture and temperature are optimum, applications of 100 to 150 pounds of nitrogen

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are needed to obtain yields of more than 200 bushels of grain per acre [Chapman and Carter]. Informed crop management is critical when high seeding rates and heavy fertilization are combined to achieve high yields. Crop management includes all phases of production: seedbed preparation, fertilization, irrigation, variety selection, weed and pest control, harvesting, and storage.

Planting dates vary with location and the variety to be planted. Soil temperature is critical in determining when planting should begin. Yields may be reduced if corn is planted too early or too late. For most of the U.S. Corn Belt, the optimum planting dates range from late April to mid-May. It takes corn from 90 to 150 days to mature, depending on region, temperature, and the number of degree days required by specific varieties [Chapman and Carter]. In regions that have relatively short growing seasons, or if corn is planted late, shorter-season hybrids may be grown. However, with chemical weed control and improved seed quality, earlier seeding may be practical even in areas that have a short, cool growing season.

Agronomic studies have identified planting date as an important determinant of corn yield. Actual yields vary from year to year depending on additional factors such as rainfall, temperature, subsoil moisture, seed and fertilization rates, variety, and location. Previous studies of corn yield response have generally concentrated on the specific response of yield to fertilization [see Mazid and Bailey, 1992; Griffin, Rister, Montgomery, and Turner, 1985; Paris and Knapp, 1989]. A significant portion of the literature has been devoted to model selection, estimation, and the implications of econometric misspecification implied by a particular functional form. Von Liebig and Polynomial response functions have been extensively analyzed [see Ackello-Ogutu, Paris, and Williams, 1985; Frank, Beattie, and Embleton, 1990; Yang, Koo, and Wilson, 1992]. A different line of research has focused on the economic implications of model misspecification in terms of the value of information [see Perrin; Feinerman, 1994].

Most of the above studies have used aggregate state, provincial or national data. We have found no explicit analysis of the appropriateness of aggregation in these studies. This may be a result of data limitations. However, as indicated above, environmental factors which are normally different across locations are important determinants of corn yield.[2] Thus, recommendations derived from aggregate analyses should be applied in a particular location with great caution. For an individual producer, the management decisions of what varieties to purchase and when to plant given available field working days in a specific location are economically significant.[3] Incorporation of planting date and maturity class in corn yield response modeling has been lacking. Dixon et al. employ a response model that includes planting date as a determinant of corn yield. However, the interpolation method they use to estimate Julian days (number of days

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[2] In general even within a state, there are significant differences in soil type, annual rainfall, solar radiation, and topological characteristics.

[3] A field working day is defined as a day during which conditions are satisfactory for field work.

after January 1) introduces additional measurement errors since they were unable to match each yield data point to the true planting date. The error is compounded by the aggregation of the data over crop reporting areas. Furthermore, variety is not considered in their study.

In this paper, two corn yield response models are proposed and estimated. The models represent an extension of previous work through the incorporation of the impacts of planting date and maturity class on yields at three locations in Minnesota. Interactions between planting date and relative maturity are included in the models. The following hypotheses pertaining to corn yield response are tested: (i) yield response is homogeneous across locations, (ii) the impact of relative maturity on yield is independent of location, and (iii) the effect of planting date on yield is independent of location. These propositions can be interpreted as aggregation tests. In particular, rejection of all these hypotheses would imply that pooling the data across locations and applying ordinary least squares (OLS) will result in biased estimators. In the next section of the paper, the experimental data used in the regression analysis is described. Then conceptual models are discussed. Statistical results and yield estimates are reported in the next section.

The Data

The empirical analysis uses experimental data from three Agricultural Experiment Station farms in Minnesota. Agronomic trials were conducted in Waseca at the Southern Experiment Station, Lamberton at the Southwest Experiment Station, and Morris at the West Central Experiment Station.[4] The main factor of these experiments was the planting date with secondary factors including nitrogen rate, plant population, and hybrid maturity. All corn hybrids were planted at different planting dates starting from mid-to-late April to mid-to-late June. Nitrogen was applied at rates of 50, 100, 150, and 200 pounds per acre. In each location, one hybrid was selected to represent 80, 85, 95, 105, 110, and 115 day relative maturity ratings. Relative maturity (RM) is defined as the time a hybrid requires to reach physiological maturity before fall frost. For example, full season RM varieties are those that use the entire growing season to reach physiological maturity. This classification depends upon the location and the planting date [Hicks, 1994]. At Lamberton the trials were conducted in 1967 and 1968, at Morris in 1967 and 1969, and at Waseca in 1968 and 1969. All other management practices were kept constant across locations.

Model Formulation

A polynomial functional form is assumed for the corn yield response function. For each of the locations, the following yield response function is assumed:

[4] The experiments were conducted in 1967, 1968, and 1969. Similar field trials are being conducted this year and will continue for the next two years. The procedures outlined in this paper may be applied to the new data for purposes of comparison.

$$
\begin{aligned}
Y_{ti} = \alpha_{0i} &+ \alpha_{1i}DYEAR1_i + \alpha_{2i}DYEAR2_i + \alpha_{3i}DYEAR3_i + \alpha_{4i}RM_{ti} + \alpha_{5i}PLDATE_{ti} \\
&+ \alpha_{6i}N_{ti} + \alpha_{7i}POP_{ti} + \alpha_{8i}PLDATE^2_{ti} + \alpha_{9i}N^2_{ti} + \alpha_{10i}POP^2_{ti} \qquad [1] \\
&+ \alpha_{11i}RM_{ti}PLDATE_{ti} + \alpha_{12i}RM_{ti}N_{ti} + \alpha_{13i}PLDATE_{ti}N_{ti} + \alpha_{14i}N_{ti}POP_{ti} + e_{ti}
\end{aligned}
$$

where i is an index for location (Lamberton, Morris, Waseca); t represents the observation; Y_{it} denotes yield in bushels per acre; DYEAR1 is a binary variable equal one if year is 1968 and zero if year is 1967 in Lamberton; DYEAR2 equal one if year is 1969 and zero if year is 1967 in Morris; DYEAR3 equal one if year is 1969 and zero if year is 1968 in Waseca; RM is relative maturity defined as a semi-continuous variable taking values 0.80, 0.85, 0.90, 0.95, 1.10, and 1.15; PLDATE is planting date in julian days; N is nitrogen fertilizer in pounds per acre; POP is plant population in thousand plants per acre; e is an error term assumed to be normally distributed with mean zero and constant variance. The literature does not provide any conclusive evidence in favor of using a particular functional form in yield response modeling. The form used here is chosen for its flexibility and ease of estimation.

For model validation, we posit the following expected signs for the regression coefficients. The coefficient on planting date is expected to be positive across locations while that on planting date squared should be negative. This implies an optimum planting date for each variety class in a particular location. Results from agronomic trials suggest that as relative maturity changes from early to full season corn, yield increases. Hence, the coefficient on RM is expected to be positive. Similar agronomic research also indicates that corn yield increases as plant population increases irrespective of location. However after a threshold point, yield decreases as plant density increases.[5] The coefficient on the linear fertilizer term should obviously be positive while that on fertilizer squared is expected to be negative, implying a decreasing marginal productivity for nitrogen. The coefficients on the interaction terms are difficult to sign a priori. However we might expect that for a particular variety, as planting date is delayed yield will decrease, all other factors constant. All fertilizer interactions are expected to be positive.

The time series -- cross sectional nature of our data set allows testing of the hypotheses proposed in this paper. A commonly used procedure to test whether the regression coefficients in different cross sectional units are the same is the Chow test. In this case the residual sum of squares (SSE) of two models is used to calculate an F-statistic for the null hypothesis. To apply this procedure to the yield response function in (1) we need to pool the observations across locations and apply least squares to obtain the residual

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[5] This threshold level may depend on variety class and location.

sum of squares (SSE_r) for the restricted model i.e., homogeneous coefficients across locations.[6] Next, separate regressions are estimated for each location. The residual sum of squares unrestricted (SSE_u) is calculated by adding the SSE of each regression. Both SSE_r and SSE_u are used to calculated the F-statistic. See the Appendix for the explicit formulation of this statistic.

To analyze the specific effect of the interaction between location and planting date and maturity class on yield variation we next propose a least squares dummy variables model (LSDV). The formulation here is:

$$\begin{aligned} y_t = \beta_0 &+ \beta_1 Y68_t + \beta_2 Y69_t + \beta_3 DLOC2_t + \beta_4 DLOC3_t + \beta_5 RM_t + \beta_6 PLDATE_t \\ &+ \beta_7 N_t + \beta_8 POP_t + + \beta_9 PLDATE_t^2 + \beta_{10} N_t^2 + \beta_{11} POP_t^2 \\ &+ \beta_{12} PLDATE_t DLOC2_t + \beta_{13} PLDATE_t DLOC3_t + \beta_{14} RM_t DLOC2_t \\ &+ \beta_{15} RM_t DLOC3_t + \beta_{16} RM_t PLDATE_t + \beta_{17} RM_t N_t + \beta_{18} PLDATE_t N_t \\ &+ \beta_{19} N_t POP_t + e_t \end{aligned} \qquad [2]$$

where t denotes observation; Y68 is a dummy variable for 1968; Y69 is 1969; Y67 is 1967 which is omitted; DLOC2 is a dummy variable for Lamberton; DLOC3 is Morris and DLOC1 is Waseca which is omitted; all other variables are defined as before. This LSDV Model 2 is a generalized form of the so-called fixed effect or covariance model. The model is appropriate in this case since variables such as soil quality which vary across locations but remain constant over time may be correlated with some of the included regressors such as fertilizer. The advantage of the covariance model is that it provides protection against a specification error caused by such correlation. Hence inference concerning the coefficients of the included variables will not depend on the quality of soils of the locations [see Kmenta, p.616 for a detailed discussion of this issue].

Hypotheses (ii) and (iii) proposed earlier can readily be tested with Model 2. For example, the proposition that the effect of maturity class on yield variability is independent of location implies the parametric restriction $\beta_{14} = \beta_{15} = 0$. Whether the impact of planting date on yield is constant across locations can be tested by the restriction $\beta_{12} = \beta_{13} = 0$.

Two versions of each of the models presented above are estimated by OLS procedure. Version 1 incorporates data for all fertilizer application rates. In version 2, fertilizer is held constant at a level close to the average recommended rate. It is not possible to determine a priori which version of these models will produce coefficients that are more

[6] This pooled model implicitly assumes constant variance across locations. If the variances of the regression disturbances of the three locational equations differ, the ensuing heteroskedasticity can easily be corrected by weighing the observations corresponding to different equations by the inverse of their respective estimated variances. However, since only estimates of the variances and not their true values are used, the validity of the Chow test in this case is only asymptotic [Kmenta, p.421].

efficient. However we might expect regression coefficients derived from version 1 to be more efficient since under this framework, not only do we have more observations but it also includes fertilizer as an explanatory variable.

Empirical Results and Yield Estimates

In this section, regression and hypothesis test results for the models described in the previous section are discussed. All regression results reported in this section are obtained by ordinary least squares (OLS). Tables 1 and 2 report parameter estimates for Model 1. In general, estimated coefficients from version 1 of this model are more efficient, in the sense of higher t-values, than those from version 2. However, the signs on all significant coefficients conform to our a priori expectations irrespective of the version. For example in Lamberton, corn yield is positively correlated with increases in planting date, relative maturity, and plant population. The coefficients on the owned interaction terms are all negative for these variables indicating a diminishing-marginal-productivity like effect on yield response. An interesting result in Table 1 is the fact that the linear fertilizer term is not significant in all three locations but the owned squared term (Lamberton), and cross interaction terms between fertilizer and relative maturity (Waseca), and fertilizer and plant population (Lamberton, Waseca) are all significant with the expected signs. This result may be explained by the fact that the effectiveness of fertilizer in corn yield response depends substantially on biological factors such as cultivar genotype and environmental factors such as soil type, moisture and drainage. The overall fit of equation (1) to the locational data appears to be satisfactory as indicated by the R-squares and Durbin-Watson statistics (Tables 1 and 2).

Parameter estimates of the LSDV yield response function (2) are reported in Table 3. A similar trend in parameter efficiency is also detected between version 1 and 2 of this model as in Tables 1 and 2 above. Again, all significant variables have the expected signs. Autocorrelation does not appear to be a problem as shown by the Durbin-Watson statistics. A Breusch-Pagan test for homoskedastic error was conducted in all regressions reported here. The null hypothesis was not rejected at either the 1% or 5% significance levels for the Lamberton, Morris and Waseca regressions (χ^2 values of 16.58, 17.76 and 20.39, respectively, with 12 degrees of freedom). In the LSDV model, the presence of heteroskedasticity could not be rejected (χ^2 value of 44.19 with 19 degrees of freedom). A generalized least squares technique was then used to correct for heteroskedasticity. However, the parameter estimates were not significantly different from the OLS estimates. The intercept in Table 3 represents the reference variables for Waseca in 1967. Note that a more general form of the LSDV model may be estimated by interacting either location or year or both with all other explanatory variables. The version of this model used in this analysis is sufficient for testing the hypotheses (ii) and (iii) proposed in this paper. Table 4 reports results of these propositions. All three hypotheses are not supported by the data. These results are invariant to the version of the model used (Table 4). The implication is that estimation of an aggregate yield response function without allowance for locational differences, will yield biased estimators. And as indicated before, policy recommendations emanating from such models may result in

Table 1: Summary of Regression Results for Model 1, Using All Fertilizer Rates.

Variable	Lamberton	Morris	Waseca	Pooled
Y68[a]	21.299 (14.51)**	---	---	28.442 (15.85)**
Y69[a]	---	-19.052 (10.39)**	-24.314 (14.65)**	-6.951 (3.91)**
RM	564.700 (11.35)**	74.489 (1.04)	432.600 (7.60)**	412.210 (8.37)**
PLDATE	9.770 (7.15)**	5.196 (3.28)**	4.835 (3.36)**	7.570 (6.29)**
N	0.016 (0.12)	0.195 (1.01)	-0.222 (1.31)	0.013 (0.09)
POP	4.349 (2.75)**	-1.548 (0.83)	8.911 (3.63)**	6.439 (4.10)**
$(PLDATE)^2$	-0.025 (5.02)**	-0.021 (3.71)**	-0.011 (2.11)**	-0.021 (4.99)**
$(N)^2$	-0.73722E-03 (5.08)**	-0.28524E-03 (1.61)	-0.20099E-03 (1.16)	-0.48022E-03 (3.39)**
$(POP)^2$	-0.082 (2.37)**	0.577 (1.44)	-0.173 (3.35)**	-0.116 (3.42)**
PLDATE*RM	-3.622 (9.88)**	-0.322 (0.63)	-0.023 (5.40)**	-2.434 (6.67)**
PLDATE*N	0.57854E-03 (0.77)	-0.67953E-03 (0.78)	0.40173E-03 (0.39)	-0.59827E-03 (0.83)
RM*N	0.089 (1.24)	0.180 (0.15)	0.18171E-02 (2.18)**	0.175 (2.38)**
POP*N	0.42379E-02 (2.12)**	-0.003 (0.93)	0.57027E-02 (2.17)**	0.34577E-02 (1.70)*
INTERCEPT	-907.170 (8.83)**	-252.630 (2.04)**	-547.200 (4.98)**	-702.900 (7.60)**
R^2	.840	.606	.867	.727
Adj. R^2	.829	.579	.858	.721
F-Value	78.234**	22.937**	97.325**	115.342**
DW	1.870	1.495	2.118	0.961
# of obs.	192	192	192	576

[a] Y68 is a binary variable for the Lamberton data, Y69 is a binary variable for Morris and Waseca, and both Y68 and Y69 are used in the separate regression analysis.

* Denotes statistical significance at the 10% level. Numbers in parenthesis are t-values.

** Denotes statistical significance at the 5% level.

Table 2: Summary of Regression Results for Model 1, Holding Fertilizer Constant.

Variable	Lamberton	Morris	Waseca	Pooled
Y68[a]	19.956			29.092
	(8.86)**			(11.35)**
Y69[a]		-16.515	-24.571	-7.282
		(5.97)**	(9.75)**	(2.83)**
RM	510.850	68.287	493.920	389.600
	(6.93)**	(0.63)	(6.20)**	(5.65)**
PLDATE	8.758	0.730	3.145	4.073
	(4.25)**	(0.31)	(1.48)	(2.29)**
POP	4.630	-3.994	8.705	5.207
	(1.80)*	(1.43)	(2.37)**	(2.30)**
$(PLDATE)^2$	-0.022	-0.49292E-02	-0.38710E-02	-0.98620E-02
	(3.00)**	(0.58)	(0.50)	(1.55)
$(POP)^2$	-0.074	0.106	-0.151	-0.078
	(1.28)	(1.72)*	(1.93)*	(1.56)
PLDATE*RM	-3.080	-0.187	-0.026	-2.022
	(5.54)**	(0.23)	(4.23)**	(3.89)**
INTERCEPT	-819.480	77.430	-474.240	-451.810
	(5.33)**	(0.42)	(2.96)**	(3.37)**
R^2	.794	.580	.849	.708
Adj. R^2	.778	.547	.837	.700
F-Value	48.439**	17.372**	70.759**	84.561**
DW	1.836	1.249	2.081	0.985
# of obs.	96	96	96	288

[a] Y68 is the binary variable for Lamberton, Y69 is the binary variable for Morris and Waseca in the separate regression analysis.

[*] Denotes statistical significance at the 10% level. Numbers in parenthesis are t-values.

[**] Denotes statistical significance at the 5% level.

Table 3: Summary of Regression Results for LSDV Model 2.

Variable	Including All Levels of Fertilizer Application	Holding Fertilizer Constant
Y68	15.789 (10.64)**	15.803 (7.39)**
Y69	-13.740 (9.25)**	-12.486 (5.83)**
DLOC2	16.872 (1.09)	10.962 (0.52)
DLOC3	116.290 (7.36)**	122.870 (5.53)**
RM	419.980 (11.49)**	437.960 (8.50)**
PLDATE	7.093 (7.82)**	4.381 (3.34)**
POP	1.905 (1.61)	1.318 (0.76)
N	-0.006 (0.05)	---
$(PLDATE)^2$	-0.020 (5.92)**	-0.010 (2.13)**
$(POP)^2$	-0.027 (1.04)	-0.001 (0.04)
$(N)^2$	-0.41567E-03 (3.99)**	---
PLDATE*DLOC2	0.128 (1.31)	0.199 (1.55)
PLDATE*DLOC3	-0.380 (3.90)**	-0.443 (3.37)**
RM*DLOC2	-50.465 (5.65)**	-51.240 (3.91)**
RM*DLOC3	-99.419 (9.74)**	-97.078 (6.62)**
PLDATE*N	-0.59827E-03 (1.14)	---
RM*N	0.175 (3.26)**	---
POP*N	0.34577E-02 (2.34)	---
PLDATE*RM	-2.241 (8.13)**	-2.142 (5.51)**
INTERCEPT	-626.250 (9.11)**	-454.280 (4.58)**
R^2	.856	.846
Adj. R^2	.852	.838
F-Value	174.724**	107.290**
DW	1.557	1.554
# of obs.	576	288

** Denotes statistical significance at the 5% level. Numbers in parenthesis are t-values.

Table 4: Hypothesis Test Results.

Null Hypothesis	F-Statistic (Degrees of Freedom): All Fertilizer Applications	F-Statistic (Degrees of Freedom): Holding Fertilizer Constant
The Yield Response is Homogeneous Across Locations.	29.276** (25, 537)	6.673** (15, 88)
The Impact of Variety on Yield is Independent of Location.	48.351** (2, 556)	22.419** (2, 273)
The Effect of Planting Date on Yield is Independent of Location.	16.479** (2, 556)	12.171** (2, 273)

** Null hypothesis rejected at both 1 and 5% significance.

erroneous management decisions at the local level.

Explicit yield estimates from Model [2] are summarized in Figures 1 through 5. The estimates are derived using a plant population of 28,000 and a nitrogen rate of 150 pounds. Dummy variables for year are all set equal to 1 -- effectively providing an estimate which is averaged over all years in the sample. Figure 1 shows yield as a function of planting date in Waseca, Lamberton and Morris given a relative maturity of 85 days. Results for 115 day corn are in Figure 2. Figures 3, 4 and 5 show yield as a function of planting date for four relative maturities in Waseca, Lamberton and Morris, respectively.

The rate of change in yield as planting is delayed is of particular interest to farmers making varietal choices. Table 5 show the daily rate of change in yield at six planting dates from May 1st to June 5th, and for four relative maturities at Waseca. The value is computed using the partial derivative of regression equation [2] with respect to planting date. The values may be interpreted as the yield loss associated with a one day delay in planting at the date indicated. With the exception of small positive values on May 1st for 85 and 95 day corn, all of the values are negative indicating a decline in yield as planting is delayed. For corn with a relative maturity of 115 days, yields fall by about one half bushel per day in the first week of May, with losses increasing to more than one bushel per day just after the middle of May. The rate of decline in yield reaches 1.77 bushels per day for 115 day corn planted June 5th. For 95 day corn, the mid-May rate on decline in yield is about one-half bushel, increasing to one bushel near the end of May. Ultimately, the value of lost production from planting delays is of concern to managers. Table 6 shows the potential lost in dollars from planting delays using the yield changes in Table 5 and a corn price of $2.35 per bushel. On May 8th, the loss in value goes from close to zero for 85 day corn to $1.54 per acre for each day planting is delayed for 115 day corn -- the range increases to $1.93 - $3.51 on May 29th. For decision purposes, this direct lost of revenue from delays in planting is only part of the economic cost. Later planting will lead to later harvest and/or higher drying costs. Associated delays in tillage can, in some circumstances delay planting in the following spring.

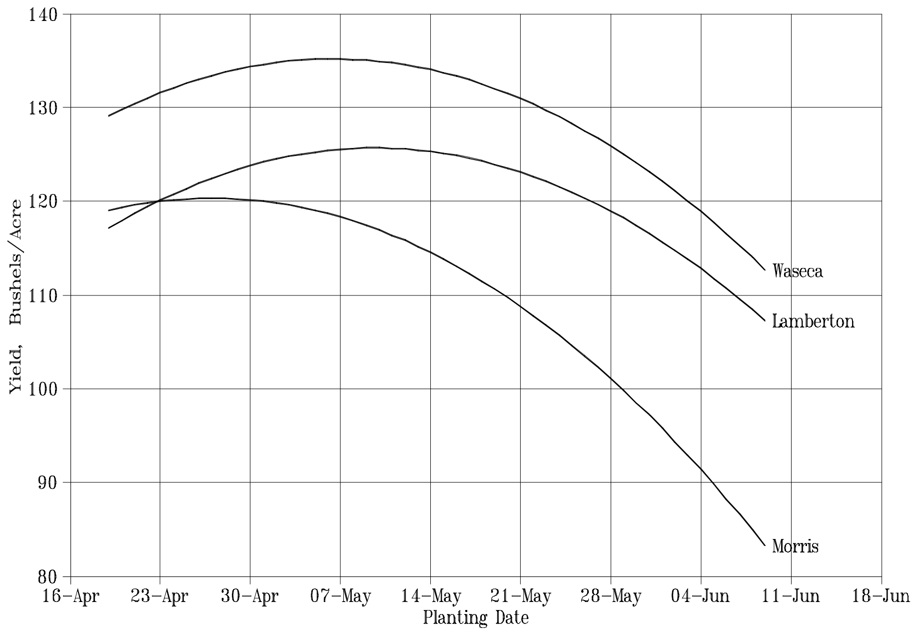

Figure 1: Estimated Corn Yield by Planting Date for Waseca, Lamberton and Morris, With a Relative Maturity of 85 Days.

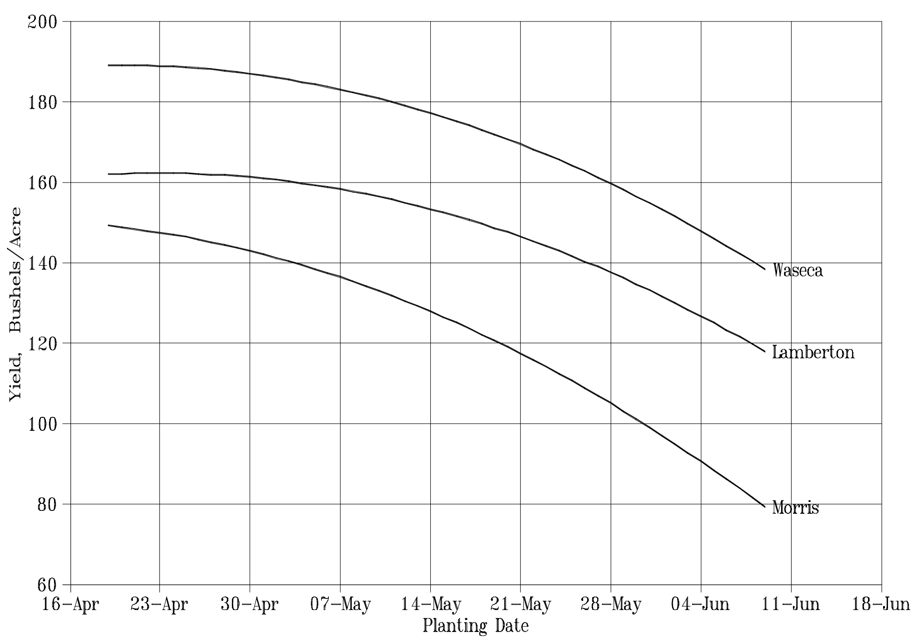

Figure 2: Estimated Corn Yield by Planting Date for Waseca, Lamberton and Morris, With a Relative Maturity of 115 Days.

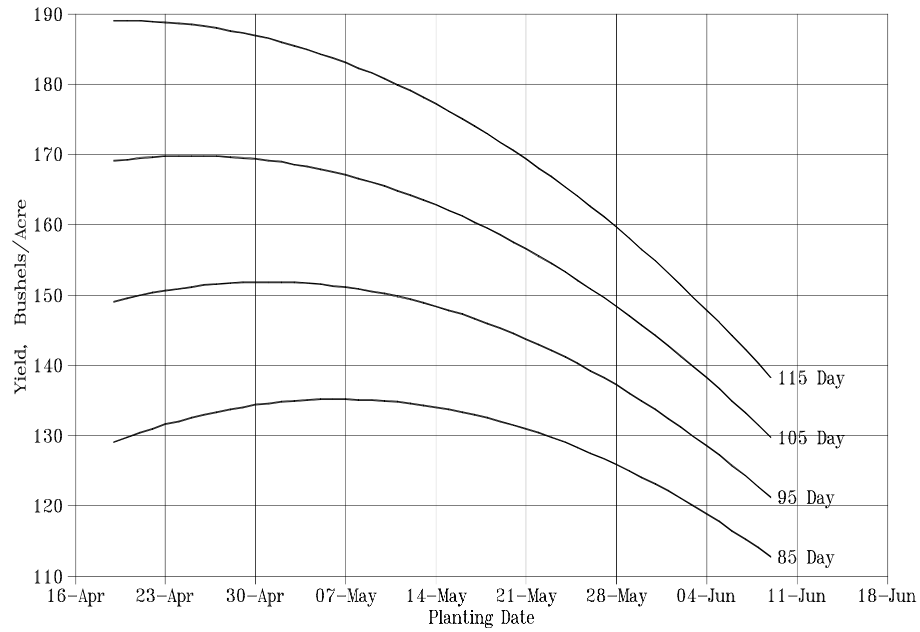

Figure 3: Estimated Corn Yield by Maturity Class for Waseca.

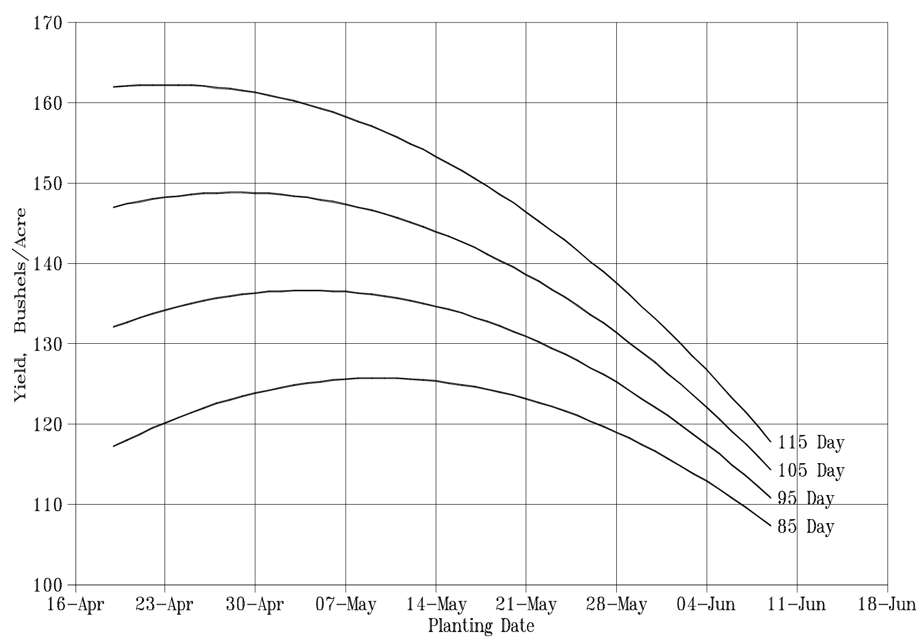

Figure 4: Estimated Corn Yield by Maturity Class for Lamberton.

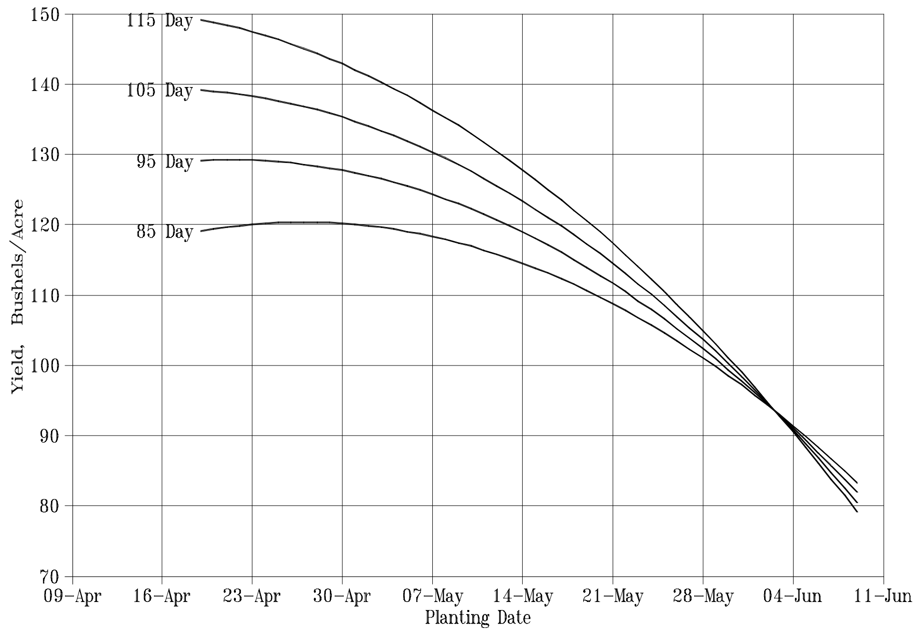

Figure 5: Estimated Corn Yield by Maturity Class for Morris.

Table 5: Daily Rate of Change in Yield, Bushels per Acre, from a Delay in Planting Date by Relative Maturity class for Waseca.[a]

	Planting Date					
Relative Maturity	01-May	08-May	15-May	22-May	29-May	05-Jun
85 Day	0.30	0.02	-0.26	-0.54	-0.82	-1.10
95 Day	0.07	-0.21	-0.49	-0.77	-1.05	-1.33
105 Day	-0.15	-0.43	-0.71	-0.99	-1.27	-1.55
115 Day	-0.37	-0.65	-0.93	-1.21	-1.49	-1.77

[a] The daily rate of change in yield is computed by evaluating the derivative of the yield response function [2] with respect to planting date at the date and relative maturity indicated in the table.

Table 6: Daily Rate of Change in the Value of Corn Production, $/Ac, from a Delay in Planting Date, by Relative Maturity for Waseca.[a]

	Planting Date					
Relative Maturity	01-May	08-May	15-May	22-May	29-May	05-Jun
85 Day	0.70	0.04	-0.61	-1.27	-1.93	-2.59
95 Day	0.17	-0.48	-1.14	-1.80	-2.46	-3.12
105 Day	-0.35	-1.01	-1.67	-2.33	-2.98	-3.64
115 Day	-0.88	-1.54	-2.19	-2.85	-3.51	-4.17

[a] The daily rate of change in output value is computed by multiplying the change in yield from Table 5 by a corn price of $2.35 per bushel.

Summary

In this paper, planting date and variety class are explicitly incorporated in corn yield response modeling. Two functional forms are proposed and estimated for three locations in Minnesota. A least squares dummy variables model is used to evaluate hypotheses on differential effects of explanatory variables on yield across locations. These propositions are rejected by the data.

Given the preliminary results of this paper we can draw the following conclusions: (1) planting date and relative maturity are important determinants of corn yield in Minnesota; (2) fertilizer in itself may not be as significant factor in corn response but in interaction with variety and plant population; (3) estimation of aggregate response functions may not be appropriate in situations where yield response is significantly different across locations or regions within a state, province, or nation.

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Appendix

The Chow test of the proposition of homogeneous regression coefficients across all locations is based on the following F-statistic:

$$F = \frac{(SSE_r - SSE_l - SSE_m - SSE_w) / 2k}{(SSE_l + SSE_m + SSE_w) / 3(n-k)} \qquad \textbf{(A1)}$$

where SSE_r is the error sum of squares for the restricted model; SSE_l, SSE_m, and SSE_w are the error sum of squares of the equations for Lamberton, Morris, and Waseca respectively; **k** is the number of explanatory variables including the intercept; and **n** is the number of observations in each location. F is distributed as an F-statistic with degrees of freedom equal to (2k, 3(n-k)).