DEPARTMENT OF AGRICULTURAL ECONOMICS

OKLAHOMA STATE UNIVERSITY

OKLAHOMA STATE UNIVERSITY · 1890 ·
INSTRUCTION RESEARCH EXTENSION

Agricultural Hall, Room 308
Stillwater, Oklahoma 74078-0505

AAEA 1988

#1666

Influence of Alternative Planting Dates and Tillage Systems on Winter Wheat Production Response: A Random Coefficients Approach

Epplin, Francis M.

Francis M. Epplin, Kama Berte, Eugene G. Krenzer, Jr., and William F. Heer

Francis M. Epplin is an associate professor and Kama Berte is a doctoral student, Department of Agricultural Economics, Eugene G. Krenzer, Jr., is an associate professor, Department of Agronomy, Oklahoma State University. William F. Heer is an assistant professor, Department of Agronomy, Kansas State University. This is professional paper PP-2743 of the Oklahoma Agricultural Experiment Station selected for presentation at the American Agricultural Economics Association annual meeting July 31-August 3, 1988, Knoxville, Tennessee.

Influence of Alternative Planting Dates and

Tillage Systems on Winter Wheat Production Response:

A Random Coefficients Approach

Abstract

The random coefficients model was used to estimate grain yield response to alternative planting dates for both conventional and zero tillage continuous monoculture winter wheat production systems. Expected grain yields from zero tillage production systems are lower. Cash production costs are currently substantially greater for the zero tillage system.

Influence of Alternative Planting Dates and

Tillage Systems on Winter Wheat Production Response:

A Random Coefficients Approach

Because of a unique combination of weather, soils, and wheat plant adaptability, forage from early planted winter wheat hectares in the Southern Plains can be grazed by stocker cattle during the fall and winter months. If the cattle are removed from the wheat prior to the plant's stem elongation (jointing stage, typically in early March), the plant will also produce a grain crop.

It has been hypothesized that zero tillage winter wheat production systems would enable growers to seed wheat earlier than conventional tillage systems and thus increase the potential for fall and winter forage production. Zero till grain drills, which plant seeds directly into the stubble of the previous wheat crop, are available from manufacturers. Herbicides, which are essential components of zero till production systems, have been registered for use for continuous winter wheat production. However, information regarding the influence of alternative tillage systems and alternative planting dates on grain yield response has not been available.

Yields from rainfed (dryland) winter wheat in the Southern Plains are highly variable. Weather associated factors such as rainfall, temperature, wind, and solar radiation all contribute to the variability of wheat plant response. Producers currently must rely upon their subjective estimates regarding the likelihood of particular yield outcomes associated with alternative planting dates. In general, as new technologies such as zero tillage production systems are introduced, information regarding impact of the system upon yield variability is initially limited. Often growers have limited prior information upon which to base subjective estimates of yield distributions. Thus, to the extent possible, information regarding the expected yield response to an alternative technology or production system should be accompanied with information regarding the yield variability associated with the system.

Prior studies have been conducted to estimate the relationship between planting date and wheat grain yield under conventional tillage (e.g. Knapp and Knapp, Russelle and Bolton). However, the interaction between tillage systems, planting date, wheat yield, and yield variability has not been established.

The objective of the research reported in this paper is to determine the influence of alternative planting dates on wheat grain yield and yield variability for both zero tillage and conventional tillage systems. The ultimate objective is to provide information to growers of continuous winter wheat in the Southern Plains regarding the economic consequences of zero tillage production systems relative to conventional tillage systems.

Methodological Considerations

Procedures for obtaining empirical estimates of the variance as well as the expected value of yield distributions for alternative input levels have long been of concern to agricultural economists (Dillon). Fuller demonstrated a procedure for estimating response functions to simultaneously derive estimates of means and variances associated with alternative input levels. Just and Pope noted that many production function estimates do not contain valid information regarding variability and thus are of little use for evaluating risk-reducing policies.

Langham and Mara suggested that the random coefficients model, originally proposed by Hildreth and Houck and extended by Swamy, is an appropriate procedure for fitting relationships in which the producer's utility is influenced by income variability. With the random coefficients model, the impact of alternative factor levels on the variance as well as the impact on the expected value of the dependent variable, is explicitly recognized. Smith and Umali used the random coefficients model to investigate the effect of risk aversion on level of fertilizer use. They estimated rice yield response and yield variability associated with alternative levels of nitrogen fertilization.

For the present study, the random coefficients model is used to estimate the influence of alternative planting dates on wheat grain yield and yield variability for both zero tillage and conventional tillage systems. Sections which follow include discussions of the data used for the analysis, a brief description of the random coefficients model, and results of the analysis.

The Data

Data were obtained from a study conducted over four growing seasons at two experiment station locations (Site L and Site S). Planting dates were varied from the middle of August to the middle of November at approximately 30-day intervals. Four replications of both the conventional tillage and zero tillage planting systems were conducted for each planting date (month) at each site. At both locations, zero tillage consisted of planting directly into the residue of the previous season's winter wheat crop. Because the objective was to evaluate continuous monoculture systems, data obtained from the first year of the study were not used for the statistical estimation.

The Model

The random coefficients model was used to estimate the relationship between wheat grain yield and planting date. The model as presented by Swamy is designed for situations in which the parameters of the function to be estimated may reasonably be expected to vary over time or space. Thus, the estimated generalized least squares coefficients are random. Since wheat yield response to planting date varies from season to season with weather and weather related variables, the random coefficients model was considered to be an appropriate estimation procedure.

Sixteen observations on wheat yield response to planting date over three seasons were available for both conventional tillage and zero tillage production systems. The response vector for each period (season), β_i can be regarded as a random vector drawn from a probability distribution with mean $\bar{\beta}$ and covariance matrix Δ.

For the ith season the model can be written as:

$$Y_i = X_i \beta_i + e_i \qquad i = 1, \ldots, 3 \text{ seasons}$$

with

$$\beta_i = \bar{\beta} + v_i$$

$$E(v_i) = 0$$

$$E(v_i v_i') = \Delta$$

$$E(v_i v_j') = 0 \text{ for } i \neq j$$

also

$$E(e_i e_i') = \sigma_{ii} I \text{ and}$$

$$E(e_i e_j') = 0 \text{ for } i \neq j$$

where:

Y_i = yield of wheat,

X_i = values of the independent variables,

β's = the random coefficients to be estimated,

v_i's = the stochastic variation of the coefficients, and

e_i = random disturbance vector.

The model specification implies that the disturbances across seasons are heteroscedastic but uncorrelated. A full description of the model, and procedures for estimation can be obtained elsewhere (e.g. Swamy, Judge et al. p. 347, Johnston, p. 410).

Estimation Results

Prior to estimating the model under the assumption of random coefficients, Swamy suggests that a test of the hypothesis that the β values are not equal over time be conducted. The null hypothesis that the β values are homogeneous, or fixed, over time was rejected for both sites and both tillage systems. Computed F values are reported in table 1. Procedures

Table 1. Quadratic wheat grain yield response to planting date functions estimated with the random coefficients model for two locations and two tillage systems.[a]

	Coefficient Estimates and Standard Errors				
	Intercept	Day[b]	Day Squared	Tillage[c]	Homogeneity Statistic[d]
Site L	-18238.1*[e]	161.73*	-0.3083*	212.3	32.3*
	(859.9)[f]	(4.29)	(0.0075)	(197.7)	
Site S	-21954.8*	191.03*	-0.3650*	635.0*	150.1*
	(6850.0)	(60.02)	(0.1170)	(185.3)	

[a]The dependent variable is wheat grain yield in kilograms per hectare.

[b]Day is defined to be a continuous variable with January 1 assigned a value of 1 and December 31 a value of 365.

[c]Tillage is 1 for conventional tillage and 0 for zero tillage.

[d]The homogeneity statistic is an F with 8 and 84 degrees of freedom calculated to test the hypothesis that the coefficients are fixed over time.

[e]Asterisks denote statistically significant at the 1% level.

[f]Values in parenthesis are estimates of asymptotic standard errors.

for conducting the test of homogeneity are described elsewhere (e.g. Swamy, Judge et al. p. 351, Johnston, p. 415).

Because the soil type and climate differs, independent models were used for each location. Calendar day of planting was defined to be a continuous variable with January 1 assigned a value of 1 and December 31 a value of 365. Several standard functional forms were used to obtain estimates with the annual data. Interaction terms between planting date and tillage system, included in the initial models, were not statistically significant and were dropped from the analysis. The quadratic provided the best statistical fit and was selected for the generalized least squares random coefficients procedure.

$$Y_{ij} = \beta_0 + \beta_1 D_{ij} + \beta_2 D_{ij}^2 + \beta_3 T_{ij} + e_{ij}$$

where Y_{ij} = yield (kg/ha) of observation j in time period i;

D_{ij} = calendar day of planting for observation j in time period i;

T_{ij} = tillage dummy for observation j in time period i; 1 for conventional tillage; 0 for zero tillage; and

e_{ij} = error term for observation j in time period i.

Results of the estimation procedure are included in table 1. For both models, the sign on the tillage dummy is positive indicating larger yields for conventional tillage. While the difference is statistically significant for Site S it is not significant for Site L. All other estimated coefficients are statistically significant at the 1% level of probability.

Graphs of the expected yields for alternative planting dates from both models are included in figure 1. In some respects the models for the two sites are similar. For example, both models predict that the maximum yield results when wheat is planted on day 262 (September 19). Both models indicate a relatively constant expected yield response over a period extending from early September to the middle of October. For example, over the range from day 244 (September 1) to day 283 (October 10) all yields are within 96% of the maximum predicted yield. Over this period, the maximum difference in estimated predicted yield is only 166 kg/ha for Site S and 132 kg/ha for Site L.

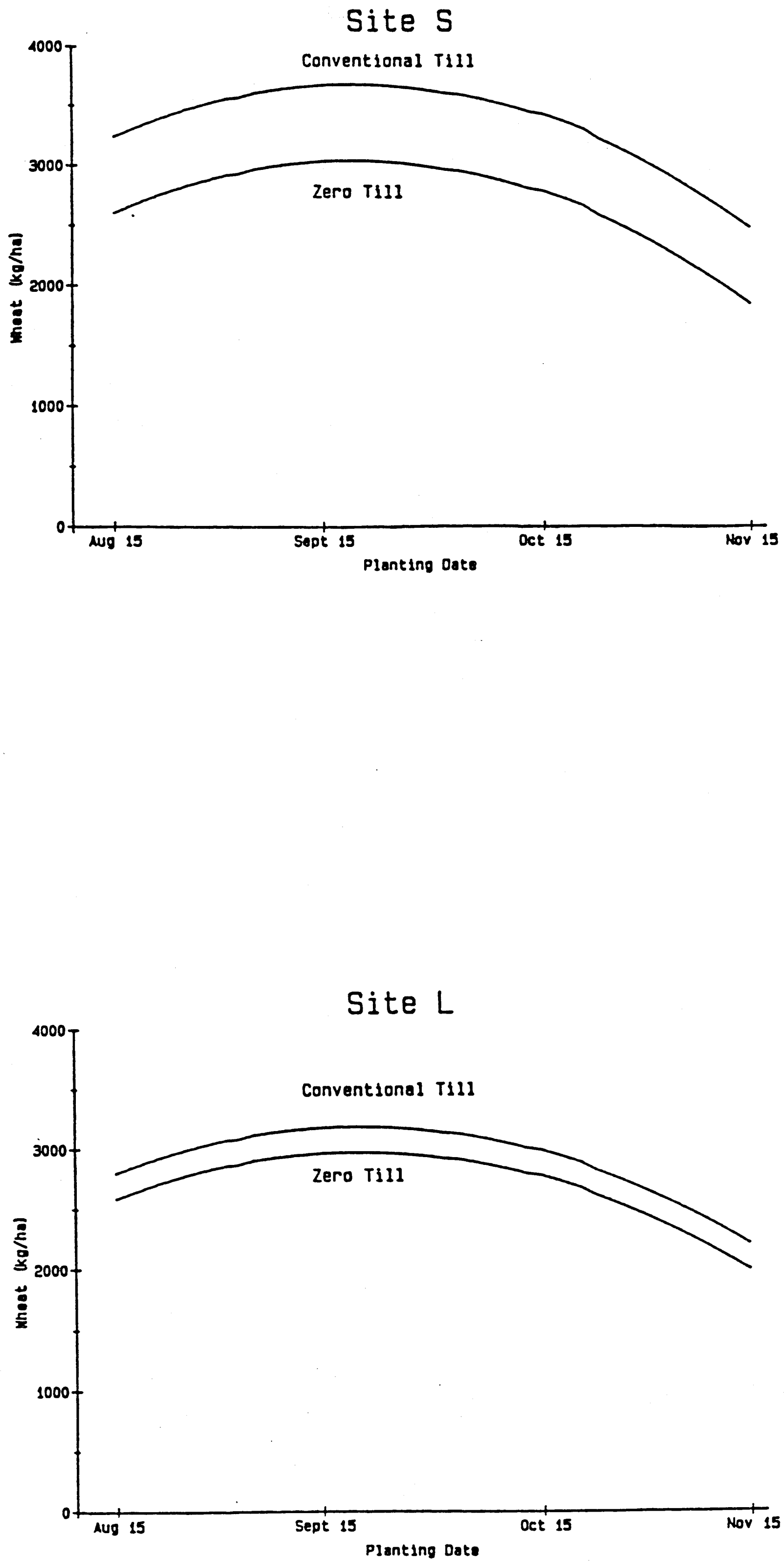

Figure 1. Expected wheat grain yields for alternative planting dates, alternative tillage systems and two locations.

Variance estimates for selected predicted values were computed and are reported in table 2. The estimates indicate that the variance of the predicted grain yields are significantly greater for Site S than for Site L. However, there is no significant difference between the variance in predicted yields between conventional and zero tillage at the same site. These results suggest that adoption of zero tillage is not likely to reduce or increase yield variability. Factors other than the tillage system, perhaps soil and weather, are responsible for yield variability.

Estimates of preharvest cash costs of production per hectare for both systems are included in table 3. The zero tillage system requires fewer field operations and hence $10.88 less per hectare for machinery fuel and repairs. However, to achieve equivalent weed control an additional $100 per hectare is required for the intensive herbicide program necessary with the zero tillage system. A comprehensive comparison of the machinery investment requirement differences for the two production systems remains to be conducted. However, prior research has found that machinery investment savings in switching to a zero tillage production system may be minimal unless a grower makes a complete machinery complement adjustment (Epplin et al.). Zero tillage grain drills are substantially heavier and cost 2.5 to 3 times more than conventional grain drills.

Limitations

The random coefficients model provides estimates only of the mean and variance of the yield distribution. If yields are normally distributed this information would be sufficient for utility analysis. However, Day has noted that since yields are truncated at zero, the normality assumption is not necessarily plausible. For the current problem, the question is whether the assumption of normality provides an adequate approximation. The Shapiro-Wilk W-Statistic was computed for each planting month for both locations and tillage systems. For 11 of the 16 situations, the test failed to reject the null hypothesis that

Table 2. Predicted yields and variance of yields from the random coefficients model for two locations and two tillage systems.

	Planting Date	Day	Estimated Yield (kg/ha)	Estimated Variance (000)
Site L				
Conventional Tillage	Aug. 15	227	2,800	5,795
	Sept. 15	258	3,179	6,926
	Oct. 15	288	2,981	8,245
	Nov. 15	319	2,193	9,873
Zero Tillage	Aug. 15	227	2,588	5,678
	Sept. 15	258	2,967	6,809
	Oct. 15	288	2,768	8,128
	Nov. 15	319	1,981	9,756
Site S				
Conventional Tillage	Aug. 15	227	3,236	806,950
	Sept. 15	258	3,670	1,042,320
	Oct. 15	288	3,422	1,319,865
	Nov. 15	319	2,476	1,665,885
Zero Tillage	Aug. 15	227	2,601	806,847
	Sept. 15	258	3,035	1,042,217
	Oct. 15	288	2,787	1,319,762
	Nov. 15	319	1,841	1,665,782

Table 3. Estimated preharvest cash production costs for producing winter wheat with conventional tillage and zero tillage production systems.

Item	Conventional Tillage ($/ha)	Zero Tillage ($/ha)
Seed	9.88	9.88
Seed treatment		1.24
Fertilizer	44.40	44.40
Chemicals	9.12	109.14
Machinery fuel and repairs	32.20	21.32
Interest on operating inputs	5.51	9.17
Total preharvest cash costs	101.11	198.15

the yields for the month in question are normally distributed. Thus, for the analysis the normality assumption was accepted.

As indicated, forage from early plantings may be grazed. However, forage production response for alternative planting dates and tillage systems was not determined by the present study. Additional research will be required to determine the influence of alternative planting dates and production systems on forage yield and on the interaction between forage yield and grain yield.

Summary and Conclusions

A study was conducted to determine the influence of alternative planting dates on wheat grain yield and yield variability from both zero tillage and conventional tillage systems. Data for the analysis were obtained from a study conducted over three growing seasons at two experiment station locations. The random coefficients model was used to estimate wheat grain yield and yield variability response to alternative planting dates for both locations and both tillage systems.

The estimates indicate that conventional tillage results in larger predicted yields. However, the yield difference between tillage system is not significant at Site L. Both models indicate a relatively constant expected yield response over a period extending from early September to the middle of October. November plantings result in lower expected yields. The estimates indicate that the variance of the predicted grain yields are significantly greater for Site S than for Site L. However, there is no significant difference between the variance in predicted yields between conventional and zero tillage at the same site. Zero tillage is not likely to reduce or increase yield variability.

Estimates of preharvest cash costs of production indicate that the increased costs associated with the additional herbicides required for the zero tillage system are substantially more than the cost savings resulting from reduction in machinery fuel and repairs. Estimates of differences in machinery investment requirement and machinery costs were not computed. However, it is unlikely that reductions in machinery costs would offset the increases in herbicide expenditure currently required for zero tillage.

In summary, zero tillage continuous winter wheat production systems are not currently economically competitive with conventional tillage systems. The expected grain yields are lower but not more variable and cash production costs are currently substantially greater for zero tillage systems.

References

Day, Richard. "Probability distributions of field crop yields". J. Farm Econ. 47(1965):713-741.

Dillon, John L. The Analysis of Response in Crop and Livestock Production, 2nd ed. New York: Pergamon Press, 1977.

Epplin, Francis M., Thomas F. Tice, Alan E. Baquet, and Steven J. Handke. "Impacts of reduced tillage on operating inputs and machinery requirements". Amer. J. Agr. Econ. 64(1982):1039-1046.

Fuller, Wayne. "Stochastic fertilizer production functions for continuous corn". J. Farm Econ. 47(1965):105-119.

Hildreth, Clifford and J. P. Houck. "Some estimators for a linear model with random coefficients". J. of the Amer. Stat. Assn. 63(1968):584-595.

Johnston, J. Econometric Methods, 3rd ed. New York: McGraw-Hill Book Co., 1984.

Judge, George G., William E. Griffiths, R. Carter Hill, and Tsoung-Chao Lee. The Theory and Practice of Econometrics. New York: John Wiley and Sons, 1980.

Just, Richard E. and Roulon D. Pope. "Production function estimation and related risk considerations". Amer. J. Agr. Econ 61(1979):276-284..

Knapp, W. R. and J. S. Knapp. "Response of winter wheat to date of planting and fall fertilization". Agronomy J. 70(1978):1048-1053.

Langham, Max R. and Michael Mara. "More realistic single equation models through specification of random coefficients". S. J. Agr. Econ. 5(1973)161-166.

Russelle, M. P. and F. E. Bolton. "Soil temperature effects on winter wheat and winter barley emergence in the field". Agronomy J. 72(1980):823-827.

Smith, Joyotee and Gloria Umali. "Production risk and optimal fertilizer rates: A random coefficient model". Amer. J. Agr. Econ. 67(1985):654-659.

Swamy, P. A. V. B. "Efficient inference in a random coefficient regression model". Econometrica 38(1970):311-323.