Kentucky Bluegrass Seed Yield Response to Fertilizer, Rainfall, and Temperature in Roseau and Lake of the Woods Counties, Minnesota

D.J. Ruane and F.J. Benson

Miscellaneous Publication 27—1984
Agricultural Experiment Station
University of Minnesota

KENTUCKY BLUEGRASS SEED YIELD RESPONSE TO FERTILIZER, RAINFALL, AND TEMPERATURE IN ROSEAU AND LAKE OF THE WOODS COUNTIES, MINNESOTA

D. J. Ruane and F. J. Benson[1]

Nitrogen was found to be a key element in stimulating seed yields (Wheeler and Hill, 1957) and several studies have focused on the effects of various levels of nitrogen fertilizer on Kentucky bluegrass (Poa praetensis, L.) production (Canode, 1968; Evans and Canode, 1971; Watschke et al., 1976).

Researchers in the Department of Agronomy and Plant Genetics (Elling and McGraw, 1983) and the Department of Soil Science (Grava, 1983) at the University of Minnesota, St. Paul, have been examining the effects of various levels of fertilizer and soil types on seed yields of different varieties of Kentucky bluegrass for many years. The objective of this study was to assess the seed yield response of the Park variety of Kentucky bluegrass to fertilizer and climatic variables in physical and economic terms.

Methods

The data used in this research were from experiments conducted by Dr. L. J. Elling and Dr. J. Grava in the Department of Agronomy and Plant Genetics and the Department of Soil Science at the University of Minnesota, St. Paul, between 1966 and 1982. In these studies, seed production response to different levels of fertilizer application using the Park variety was assessed on mineral soils on farms in Roseau and Lake of the Woods counties in northern Minnesota.

Mixed fertilizer was applied at an N:P:K ratio of 2:1:1. Application levels ranged from 0:0:0 to 175:88:88 with increments of 5 to 25 pounds of nitrogen per acre. Over the years, higher application rates of fertilizer were used; therefore not all levels of fertilizer applications were used each year.

A large historical base was required to capture the variations in rainfall and temperature and the resulting effects on grass seed yields. The climatic data used were recorded at the nearest Weather Reporting Station to each individual site. The weather stations used were Roseau for Roseau County and Warroad for Lake of the Woods County (U.S. Environmental Data and Information Service).

In 1976 and 1980, disastrous low yields were recorded, attributable to low rainfall in the preceding fall and spring (Elling, 1983). Data from these years were included in the analysis.

The experiments were considered continuous since the data were obtained from these farms year after year, even though various fields were used over the course of the study. Mixed fertilizer was applied once in the autumn following a July burning on the older stands. For the purposes of this analysis, the seed production period was considered to commence in the July previous to the June-July harvest period.

Data were obtained for 97 observations over a 17-year period. The variables included in the analysis were yield, fertilizer level (recorded as pounds of nitrogen, but always applied in a 2:1:1 ratio), average rainfall, monthly rainfall, average temperature, and monthly temperature. The climatic data used in the analysis are shown in Table 1. Statistical analysis was carried out using regression and correlation techniques (Weisberg, 1981).

Simple correlation coefficients were obtained for each of the variables with respect to yield and the degree of significance tested. From the correlation analysis, variables were selected to be included in the regression model.

The regression model used is defined as yield (Y) of Kentucky bluegrass (Park) as a function of fertilizer (F); April, May and June rainfall (AR, MR JR); the preceding year's August and September rainfall (AgR, SR); the temperature in April and May (AT, MT) and the interaction term of the mean April and May temperature multiplied times fertilizer {(AT + MT)/2 x F}. The model function used was:

$$Y = B_0 + B_1F + B_2F^2 + B_3AgR + B_4SR + B_5AR + B_6MR + B_7JR + B_8AT + B_9MT + B_{10}\{0.5(AT + MT)\}F$$

The squared term on fertilizer allows for a diminishing rate of yield response as fertilizer levels are increased. The interaction term permits a measurement of the three-way relationship among yield, April and May temperature, and fertilizer level.

[1]D. J. Ruane, Department of Agriculture, University College, Dublin, Ireland; F. J. Benson, Department of Agricultural & Applied Economics, University of Minnesota.

Table 1. Rainfall and Temperature Data Used in Regression Model for Roseau and Lake of the Woods Counties

Year (July-June)	Rainfall (inches)					Temperature (°F.)	
	August	September	April	May	June	April	May
			ROSEAU				
1981-1982	2.41	3.63	0.24	1.38	2.00	40.90	53.50
1980-1981	5.19	4.12	0.56	2.79	6.85	40.50	50.00
1979-1980	1.59	0.45	0.00	0.24	1.75	43.70	58.00
1978-1979	3.25	3.44	2.77	1.89	1.91	32.30	45.90
1977-1978	1.74	3.83	1.00	1.97	1.92	38.20	57.30
1976-1977	3.72	0.34	0.27	2.43	3.71	46.20	64.70
1975-1976	1.75	1.79	0.77	0.54	5.82	42.80	52.60
1974-1975	10.97	0.42	1.40	1.52	4.96	33.00	54.20
1973-1974	2.09	5.67	2.72	4.12	1.56	38.60	48.00
1972-1973	1.53	4.22	0.90	2.46	2.21	39.10	52.20
1971-1972	0.69	3.33	0.70	1.66	5.03	37.50	58.50
1970-1971	0.83	2.77	1.50	2.24	2.99	41.00	50.90
1969-1970	4.28	3.29	2.56	5.93	4.07	34.50	48.00
1968-1969	8.49	2.35	1.27	3.31	2.29	42.80	53.00
1967-1968	1.69	0.83	0.63	1.46	6.47	40.60	50.40
1966-1967	3.30	0.99	2.89	0.89	2.23	36.10	46.50
1965-1966	1.14	4.80	0.92	1.72	3.54	35.20	48.13
MEAN	3.20	2.72	1.24	2.15	3.43	39.00	49.09
			WARROAD				
1972-1973	1.50	4.33	1.80	1.71	2.62	38.20	52.40
1971-1972	0.51	2.50	0.76	1.82	3.62	35.60	57.70
1970-1971	1.41	3.74	0.84	1.74	4.12	38.60	51.20
1969-1970	3.97	1.72	2.23	3.76	3.53	34.70	47.00
1968-1969	5.94	1.89	1.09	2.46	2.18	42.20	52.40
1967-1968	1.09	0.28	1.32	1.78	6.17	40.20	50.30
1966-1967	3.95	1.24	3.59	0.76	3.09	35.80	46.50
1965-1966	1.14	4.80	0.92	1.72	3.54	33.10	46.70
MEAN	2.44	2.56	1.48	1.97	3.61	37.30	50.33

The B's in the model provide the response in yield of grass seed per unit to a one unit change in the input variable. Some variables are combinations; thus, their related B's show the resulting yield change considering a one unit change in an input variable. Climatic influences were the principal uncontrolled factors. Although weather conditions were recorded at each station, no attempt is made in this analysis to correlate the station and the experiment site or to separate climatic influences from other uncontrolled factors or experimental error.

Results and Discussion

No significant trend in yield existed in the data over time.

Table 2 shows the correlation coefficients and degree of significance of Kentucky bluegrass yield with all variables. Significant correlations were recorded for April, May and September rainfall; April, May, August and November temperatures; level of fertilizer; and average rainfall.

Some of the more highly correlated rainfall and temperature variables are included in the predictive model. Average rainfall, which had a significant correlation with yield, was omitted because individual monthly rainfall data are more relevant to the time element of the decision-making period for fertilizer application. It should be noted that there were only two months (February and March) where rainfall had a negative correlation with yields. The only temperature variables included in the model were April and May, which had the strongest correlations with grass seed yields. January through June temperatures were negatively correlated with grass seed yields, i.e., higher temperatures in these months resulted in lower grass seed yields.

Table 3 shows the results of the regression analysis comparing actual and predicted yields for

Table 2. Correlation of Yield and All Variables Considered in the Analysis

Variable	Correlation	Variable	Correlation
Fertilizer[1]	0.3924**	Temperature	
Average Rainfall	0.4438**	July	0.0358NS
Average Temperature	-0.1184NS	August	0.2236*
Rainfall		September	0.0880NS
July	0.1070NS	October	0.0907NS
August[1]	0.1522NS	November	0.2741*
September[1]	0.3510**	December	0.0120NS
October	0.0552NS	January	-0.0782NS
November	0.0854NS	February	-0.0908NS
December	0.0827NS	March	-0.0889NS
January	0.0357NS	April[1]	-0.2991*
February	-0.0744NS	May[1]	-0.3116**
March	-0.0668NS	June	-0.1146NS
April[1]	0.2560*		
May[1]	0.4640**		
June[1]	0.0535NS		

[1]Variables included in the model.
*$P \leqslant 0.05$; ** $P \leqslant 0.01$; NS = not significant.

each level of fertilizer application. Table 4 shows the coefficients, B's, for grass seed yield in the regression model. Lower spring temperatures are correlated with higher seed yields. This indicates that cool weather is good for grass seed development. The weather variables used in the model are those that had a strong correlation with yield and represented the period of the year in which weather conditions might influence a farmer's decision with respect to fertilizer application level for the crop year. A farmer may decide about fertilizer application following the August/September period or again in the spring.

Economic Results

The economic optima, defined as the maximum profit points for various prices of grass seed and costs of fertilizer, are shown in Table 5 for the mean August-September rainfall (2.87 inches). These were found by taking the partial derivatives for yield with respect to fertilizer (represented by the nitrogen component) and the average August-September rainfall (ASR). The partial derivative was then set equal to the price ratio of fertilizer to grass seed:

$$\frac{\$F}{\$GS} = 1.324895 - .002548 \times F + .01014635 \times ASR$$

where:

F = pounds of fertilizer as represented by nitrogen in a 2:1:1 ratio.

ASR = average rainfall for August-September.

$F = cost per 100 pounds of a 2:1:1 ratio fertilizer.

$GS = price per 100 pounds of grass seed.

This converts to:

$$F = \frac{\frac{\$F}{\$GS} - 1.324895 - .01014635 \times ASR}{-.002548}$$

where F is the maximum profit level of fertilizer given the input and output prices and the August-September rainfall.

Table 3. Average Actual and Predicted Grass Seed Yields at the Observed Levels of Fertilizer and the Number of Observations for Each Fertilizer Level (1966-1982)

Fertilizer Level	Grass Seed Yield Actual	Predicted[1]	No. Observations
175:88:88[2]	204	401	1
150:75:75	413	484	10
125:63:63[2]	201	527	1
120:60:60	620	531	11
100:50:50	467	530	17
90:45:45	534	521	6
80:40:40	550	505	11
75:38:38[2]	190	494	1
60:30:30	455	453	7
50:25:25	353	418	10
40:20:20	365	377	9
30:15:15	345	329	4
0 0 0	167	146	9

[1]Predicted yields obtained from model using mean weather variables.

[2]Data came from 1977 plots only; yields are low because of fall and spring drought.

Tables 6 and 7 are the same as Table 5, except that the average August-September rainfall is set at the maximum and minimum levels, respectively.

The results indicate that as the cost of fertilizer increases relative to the price of grass seed, downward adjustments should be made in application levels; as fertilizer becomes less expensive relative to grass seed prices, more fertilizer can be applied to maximize returns over fertilizer costs.

As the price of grass seed increases relative to fertilizer, it pays to add more fertilizer. When grass seed prices are low relative to fertilizer prices, adjustments should be made to apply less fertilizer to attain the economic optimum.

Table 4. Regression Coefficients for the Grass Seed Yield Estimation Model for Lake of the Woods and Roseau Counties

Variable	Constant	Coefficient
Intercept	B_0	1027.19600
Fertilizer	B_1	1.324895
Fertilizer Squared	B_2	-0.001274
August Rainfall	B_3	-0.4477578
September Rainfall	B_4	5.499768
April Rainfall	B_5	-26.80943
May Rainfall	B_6	42.40558
June Rainfall	B_7	8.739233
April Temperature	B_8	-13.75392
May Temperature	B_9	-8.795982
Fertilizer x Mean April-May Temperature Interaction	B_{10}	0.01014635

Variation explained by regression = 0.5962.

Table 5. Economic Optima for Various Cost-Price Ratios Showing the Pounds of Fertilizer which Produce Maximum Returns from Grass Seed Over Fertilizer Cost at the Mean August-September Rainfall[1]

	Fertilizer Cost per 100 lb.		
Seed Production	$7.00	$8.00	$9.00
$30 per 100 lb.	439	427	414
$50 per 100 lb.	476	469	461
$70 per 100 lb.	492	487	484
$90 per 100 lb.	509	496	492

[1]Fertilizer considered as pounds of a 2:1:1 ratio.

As the August-September rainfall level is increased (Tables 5, 6 and 7), the amount of fertilizer to be added is increased in order to attain the economic optimum. A decrease in the August-September rainfall indicates less fertilizer should be applied.

Conclusion

Production of the Park variety of Kentucky bluegrass seed was shown to respond to fertilizer and climatic variables in northern Minnesota. The results of experiments conducted in Roseau and Lake of the Woods Counties from 1966 through 1982 were combined with rainfall and temperature in a predictive model. The model used seed yields, fertilizer levels and climatic variables that showed a strong relationship to seed yields.

Table 6. Economic Optima for Various Cost-Price Ratios Showing the Pounds of Fertilizer which Produce Maximum Returns from Grass Seed Over Fertilizer Cost at the Maximum August-September Rainfall[1]

	Fertilizer Cost per 100 lb.		
Seed Production	$7.00	$8.00	$9.00
$30 per 100 lb.	466	448	435
$50 per 100 lb.	498	490	482
$70 per 100 lb.	514	508	506
$90 per 100 lb.	523	518	514

[1]Fertilizer considered as pounds of a 2:1:1 ratio.

Table 7. Economic Optima for Various Cost-Price Ratios Showing the Pounds of Fertilizer which Produce Maximum Returns from Grass Seed Over Fertilizer Cost at the Minimum August-September Rainfall[1]

	Fertilizer Cost per 100 lb.		
Seed Production	$7.00	$8.00	$9.00
$30 per 100 lb.	435	418	405
$50 per 100 lb.	468	460	452
$70 per 100 lb.	483	478	476
$90 per 100 lb.	495	488	484

[1]Fertilizer considered as pounds of a 2:1:1 ratio.

The resulting model described 59.62 percent of the variation in seed yields.

The model was then used to find the most profitable level of fertilizer input with respect to changing prices of grass seed and fertilizer and August-September rainfall. These are variables that can be easily assessed by the producer and can assist in the decision of how much fertilizer to apply.

Further research which is required in this area is to narrow the scope of research to the most prevalent production practices and to isolate the effects of nitrogen from the effects of phosphorus and potassium. Phosphorus and potassium have been somewhat effective in increasing yields of seed (Wheeler and Hill, 1957), and further study is required to assess the effects of varying levels of phosphorus and potassium at different nitrogen ratios. Further economies may be gained by studying the effects of these three nutrients and planning their use on an individual basis as a custom-blended fertilizer.

REFERENCES

Canode, C. L., 1968, "Influence of Row Spacing and Nitrogen Fertilization on Grass Seed Production," Agronomy Journal, 60:263-267.

Evans, D. W., and C. L. Canode, 1971, "Influence of Nitrogen Fertilization, Gapping, and Burning on Seed Production of Newport Kentucky Bluegrass," Agronomy Journal, 63:575-580.

Elling, L. J., 1983, Department of Agronomy, University of Minnesota, St. Paul, MN 55108, personal communication.

Elling, L. J., and R. L. McGraw, 1983, "Progress Report of Seed Production Research," presented at Grass-Legume Seed Institute, Warroad, MN, March 30, 1983.

Grava, J., 1983, Department of Soil Science, University of Minnesota, St. Paul, MN 55108, personal communication.

U.S. Environmental Data and Information Service, Climatological Data, Minnesota, Volumes 71-88, 1965-1982. National Climatic Center, Asheville, NC 28801.

Watschke, T. L., R. E. Schmidt and R. E. Blaser, 1976, "Responses of Some Kentucky Bluegrasses to High Temperature and Nitrogen Fertility," Crop Science, 10:372-376.

Weisberg, Sanford, 1981, "Multreg"--version 4.0. School of Statistics, Technical Report No. 298, University of Minnesota, St. Paul, MN 55108.

Wheeler, W. A., and D. D. Hill, 1957, Grassland Seeds: A Handbook of Information about the Grass and Legume Seeds Used for Forage, Pasture, Soil Conservation and Other Turf Planting in the United States, Princeton, NJ: D. Van Norstrand Company, Inc., p. 734.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of Dr. L. J. Elling and Dr. J. Grava, Departments of Agronomy and Plant Genetics and Soil Science, University of Minnesota, St. Paul, MN, for their provision of the experimental data and for review of this paper.

The University of Minnesota Agricultural Experiment Station paid for the production of this publication. As a miscellaneous publication, it is intended for a very limited audience. Initial distribution was made by the University of Minnesota, Department of Agricultural and Applied Economics. Copies of this publication are available from the Department of Agricultural and Applied Economics, 231 Classroom Office Building, 1994 Buford Avenue, St. Paul, MN 55108, until the original printing is exhausted.