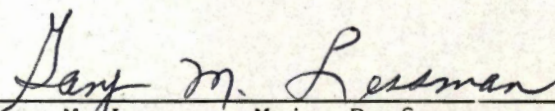


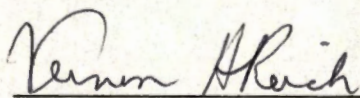
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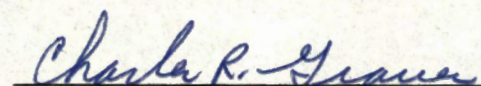
I am submitting herewith a thesis written by Daniel Nathanael Good entitled "Effects of Nitrogen, Population, and Hybrid on Yield and Protein Content of Corn." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Science.



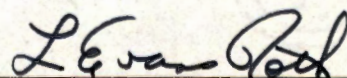
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We have read this thesis
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EFFECTS OF NITROGEN, POPULATION, AND
HYBRID ON YIELD AND PROTEIN
CONTENT OF CORN

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Daniel Nathanael Good

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ABSTRACT

The primary objective of this study was to determine the effects of three Nitrogen (N) rates, 112, 168, and 224 kg per hectare, and three plant populations, 39,540, 49,420, and 59,300 plants per hectare on the protein content and yield of a medium season (Pioneer brand 3184) and a full season (DeKalb XL-394) corn hybrid (*Zea mays* L.) at Milan and Crossville, Tennessee. Other characteristics measured were lodging, prolificacy, and mineral composition of the ear leaf at silking.

Ear leaf samples were collected at silking and analyzed for their N, P, K, Mg, and Ca content. At harvest, yields were determined and sub-samples were taken for protein analysis. Soil samples were taken to establish if plant nutrient levels were related to the soil fertility.

In general, increasing the N rate from 112 kg to 168 kg of N per hectare significantly increased the yield and protein content of the corn grain. Increasing N to 224 kg per hectare had no influence on increasing the yield or protein content.

Yields were increased when the plant population was increased from 39540 to 59300 plants per hectare, despite small increases in lodging. The plant population had little effect on the percent protein found in the grain, or in the total protein produced per hectare. The one exception being the lowest population at Milan which had a significantly higher protein content than at the two higher populations.

At Milan, Pioneer brand 3184 produced the same yield and total protein as KeKalb XL-394. At Crossville, where the growing season is shorter, Pioneer brand 3184 out performed DeKalb XL-394.

There were minor differences in percent P, K, Mg, and Ca in the ear leaves at different N rates, Hybrids, or populations. Differences did exist in nutrient composition between locations. The most obvious difference was noted with ear leaf Mg. Corn at Milan contained three times greater Mg concentrations than did the corn at Crossville. This effect was also noted in the amount of extractable Mg in the soil profile, where six times more Mg was found in the soil at Milan.

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CHAPTER I

LITERATURE REVIEW

Major developments in the technology of fertilizer use have occurred in the past thirty years. Between 1964 and 1970, the average nitrogen (N) rate applied to fertilized acres in the Corn Belt increased approximately 83 percent. Corn (*Zea mays* L.) receives about one-half of the N used in the United States (30). One of the main objectives of research, extension, and the fertilizer industry has been achieving optimum use of applied N.

Nitrogen fertilization is influenced by a number of factors which include; (a) recommendations based on field plot research, (b) climatic factors, (c) experience of crop growers, (d) crop yield expectations, and (e) economic factors. The first essential step leading to a meaningful recommendation for corn production is to estimate the amount of N needed to produce a given yield. Nitrogen recommendations in Tennessee are based on yield trial studies and on expected yields. Burns in 1978 (3) reported recommendations for corn in Tennessee to be 101 kg of N per hectare for expected yields up to 6,272 kg, 134 kg of N per hectare for yields of 6,272-7,840 kg, and 168 kg of N per hectare for yields of 7840-9408 kg.

In general, N is the major soil fertility factor which influences the growth and yield of corn (5, 6, 38), followed by K and P, respectively (27). A 9480 kg corn crop requires 190 kg N, 39 kg P₂, and

and 196 kg K. About two-thirds of the N and P, and one-quarter of the K is found in the corn grain (17).

Within the plant, N comprises from one to four percent of the dry weight, and is found as a constituent of amino acids, chlorophyll, proteins, purines, nucleic acids, alkaloids, vitamins, and other important organic compounds (13).

Nitrogen deficiency symptoms are often confused with drought symptoms. This deficiency first appears as a loss of dark green color in the leaves. This is then followed by "firing," a condition where the lower leaves turn yellow at the tip and midrib and the yellowed area progressively increases toward the edges of the leaf. Necrosis eventually occurs if this deficient situation is not corrected, or if the deficiency is severe (6).

Nutrient deficiency symptoms also occur when the fertility of the soil is unbalanced (6, 10). For instance, a study conducted by Dumenil (6) has shown that an application of 90 kg of N per hectare on an Iowa soil that was extremely deficient in both N and P gave an increase of only 188 kg of corn per hectare. When P was applied by itself at 90 kg of available P_2O_5 , corn yield increased 878 kg per hectare. But when both were applied, there was a yield increase of 2,822 kg per hectare. In this case, N fertilization was of limited value unless there also was a P application (6).

Nitrogen deficiency symptoms on corn growing on N deficient soils are intensified by K application (35). Bennett (2) found that a significantly correlation exists between additions of N and increases of P content in the ear leaves when sampled at tasseling. A possible reason why

P content increases as N increases may be a result of a more extensive root system that is in contact with more soil P (9).

Two main schools of thought exist when discussing the critical nutrient level. Academically, it can be defined as a narrow range of concentrations where plant growth or yield first declines when compared to plants of higher nutrient levels, or at that concentration which is just adequate for maximum growth (22, 34, 35). From an economic point of view however, it would be considered as those nutrient levels of a plant where the cost of additional fertilizer is greater than the revenue received from an increase in yield (22).

The critical nutrient level of any particular element in a plant is not only affected by the fertility level of that element, but it is also affected by the genetics of the plant (39), the amounts of other related elements, and by environmental factors (25).

Tyner in 1946 (34) established that the critical nutrient level for N in corn leaves is 2.90 percent. Bennett, Stanford, and Dumenil in 1953 (2) reported that when the N content of the leaves was 2.8 percent or above, no further yield increases were obtained by the addition of N.

Nitrogen efficiency is the term used to signify the number of pounds of elemental N that is needed to produce one bushel of corn. This efficiency, or percent N utilized is influenced by the rate of application, and the growing conditions affecting yield potential (29). The efficiency of N fertilizer applied to corn is reduced when there is an inadequate supply of other nutrients, adverse seasonal conditions, low plant populations, or poor soil structure (2, 11). The greatest demand in corn for nutrients begins about 10 days before tasseling and ends

about 25 to 30 days after tasseling. The key to efficient fertilizer use is to provide ample nutrients, especially N, during this five to six week period (17).

Field plot research in eastern Oregon by Hunter and Yungen in 1955 (15) has shown that the percent N applied that was recovered in the grain decreased with increasing N fertilizer applications. The maximum recoveries of N applied at rates of 50, 100, 150, and 200 pounds of N per acre were 56.4, 46.1, 38.4, and 26.6 percent, respectively.

The degree of response to applied N is influenced mainly by climatic conditions and the levels of N already present in the soil. Dry weather may increase percent nutrient composition by decreasing growth (25) or in other words produce less grain of a higher protein content (17).

Plant growth is a function of the quantity of readily available nutrients in the soil and their balance. Nitrogen application to the soil has a direct effect on the N content of the leaves (18). Correlations between corn yield and total leaf N content is greatest when ear leaf samples are taken at silking (38). Tissue testing is a reasonably good procedure since it may indicate a deficiency before the plant shows visual symptoms (26).

In the range of 50 to 100 percent of the maximum yield the N content of the corn grain has the greatest value for determining adequate N. As the percent of the maximum yield declines from 100 percent, similar yields may occur over increasingly wider ranges of nutrient composition. This phenomenon was observed at varying combinations of N and P in the ear leaf (7).

The supply of N has a direct effect on the protein content of the grain (27, 37). Earley and DeTurk (28) stated that grain protein values above 9.5 percent usually indicate sufficient soil N for maximum yield of corn. The germ of the kernel contains the highest concentration of N with the endosperm next in order. The hull and cap have the lowest N content (28).

Another problem often associated with N supply is lodging (20, 38). Lodging may be classified in two types: stalk breakage and root lodging. The plant is considered lodged if the stalk breaks below the highest ear or if the plant leans more than 30 degrees from the vertical (20,21). There may be an increase in mechanical harvest loss or rotting of the ears which lay on the ground. Difficulty in planting winter cover crops or double cropping with small grains between lodged rows may also be a problem (20).

Lodging may be reduced by increasing K fertilization levels and by breeding for lodging resistance (18, 20). Krantz and Chandler (18) decreased lodging and increased yield with an application of 90 kg per hectare of K on K deficient soils in North Carolina. Additional increments of K however, had no effect on yield or lodging. Likewise, K applications had no effect on lodging or yield on corn where no visual K deficiency symptoms were found.

Work in Tennessee by Long (20), indicates that N fertilization between 67 and 134 kg of N at 29,560 plants per hectare had only a slight tendency to increase lodging. Plant population considered to be more of a factor in lodging than is the rate of N application (20, 21). Increased percent lodging with an increase in plant population was also reported by

Krantz and Chandler (18) when applied to stands ranging from 30,890 to 49,420 plants per hectare.

Yield is influenced by soil fertility, plant population and to a lesser extent, differences among hybrids (8, 37). A well fertilized plant influences yield primarily by increasing the leaf area produced early in the growing season, and the length of time that the leaves are alive and functioning during grain formation (14). A fairly good correlation existed between the concentrations of nutrients in the plant tissue and yield on Alabama, Georgia, and Mississippi soils (5). Initial applications of N increased grain yield, but had little effect in the grain protein content, but when larger additions of N are added, the protein content was increased with little effect on yield (17, 40). Excesses of N decreased crop production by increasing lodging, or by producing excess vegetation (10).

Partial regression analysis has shown that the leaf N content is possibly the dominant factor of yield, and that the leaf P content is also sometimes important (38). Iowa workers have suggested that for each change of 0.1 percent N in the leaf at tasseling, there should be a change of two bushels per acre in yield (2).

Before 1910, authors recommended populations of 24,710 to 32,120 plants per hectare for optimum yields with an open pollinated type corn. Hybridization of corn in the early 1900's has increased the yield of corn through increased vigor by about 20 percent (4). Since then, Duncan (8) concluded by summarizing Shubek's work that the population should be increased to the point where it is not the limiting factor in yield. Parks (24) established that on highly productive soils in Tennessee, the

population of 49,420 plants per hectare gave optimum yields. On poor or dry soils, the best grain yield may be obtained by limiting plant population (32).

Stringfield and Thatcher (32) and others (8, 18) recognized that the effect of high and low populations was greater on highly fertile soils having lower levels of fertility.

Except at very low populations, less than 20,510 plants per hectare, density had little or no effect on the relationship between relative yield and the percent N in the ear leaf (8). Yield increased, even though ear size and prolificacy decreased with an increase in plant population (21, 34).

In a study conducted by Zuber, Smith, and Gehrke from 1951 to 1952 (40) an increase in plant population from 20,000 to 41,500 plants per hectare decreased the percent protein content in corn. This increase in population however increased the yield. Although corn is sold primarily for its carbohydrate content, farmers would need smaller quantities of high priced protein concentrates if they fed livestock corn containing higher protein contents. When protein production is calculated on a hectare basis, the effect of N fertilization becomes more apparent. Where no N was applied in Zuber, Smith, and Gehrke's study (40), the protein in grain per hectare was 190 kg, but the application of 280 kg of N increased the protein production to 582 kg per hectare.

The primary objective of this study was to evaluate the effects of three N rates and plant populations on the protein content and yield of two corn hybrids at Milan and Crossville, Tennessee. Other characteristics

measured were lodging, prolificacy, and mineral composition of the ear leaf at silking.

CHAPTER II

MATERIALS AND METHODS

Two corn hybrids were grown at three population rates and three N rates at Crossville and Milan, Tennessee in 1978. The nutrients measured were N, P, K, Mg, and Ca content in the ear leaf at silking. Lodging, yield, and protein content of the grain were also measured.

A split-plot design (19) was used with four replications. Three N rates, 112, 168, and 224 kg of N per hectare were used as main plot treatments. Two hybrids, DeKalb XL-394 and Pioneer brand 3184, and three populations, 39,540, 49,420, and 59,300 plants per hectare were randomly arranged as the split treatments.

Each plot consisted of four 9.14 m rows, 102 cm apart at Milan and 96 cm spacing at Crossville. The sampling unit consisted of the center two rows of each plot, with the outer two rows of each plot considered the border rows. Plots were overplanted 10 percent by hand and thinned to the desired populations when the plants were 30 to 61 cm high.

The Milan test was planted on April 12 on a Vicksburg sandy loam (coarse-silty, mixed, acid, thermic Typic Udifluvent) with 0-3 percent slopes. The Crossville test was planted on May 24 on a Hartsells loam (fine-loamy, siliceous, thermic Typic Hapludult) with 0-3 percent slopes.

At Milan, 90 kg of P and K, and the desired rate of N as urea per hectare were broadcast before planting. The test at Crossville received the desired rate of N as urea prior to planting. Atrazine was applied

at 2.2 kg active ingredient per hectare at both locations to control weeds. Lasso was also applied at Milan at 2.2 kg active ingredient per hectare.

Ear leaf samples were taken at silking and were dried in a forced air oven at 70° C. They were then ground in a Wiley Mill to pass through a 2 mm sieve and stored in six ounce sealed plastic bags. Using a modification of the wet oxidation procedure of Gieseiking, Snider, and Getz (12), the samples were ashed (See Appendix A) and tested for their P, K, Mg, and Ca content using the Technicon Auto-Analyzer as described by Steckel and Flanery (31).

Grain samples were taken at harvest and dried in a forced air oven at 50°C to approximately 8 percent moisture and stored in glass bottles. Grain samples were ground using a tissue homogenizer to pass through a 2.0 mm sieve. A modification of the procedures of Thomas, Sheard, and Moyer (33) were used to test both ear leaf and grain samples for their total N content (See Appendix B). Crude protein is determined by multiplying N by 6.25 (17).

Crude grain protein was also analyzed from each plot by Kjeldahl analysis, using the method described by the AOAC (1), and also by using the Neotec Grain Quality Analyzer (GQA) as described by Hymowitz (16).

Soil samples were bulked for each replication at 0-15, 15-30, 30-46, and 46-61 cm depths. Samples were dried and ground to pass through a 2.0 mm sieve, and analyzed for their P, K, Mg, and Ca content using the North Carolina Double Acid extraction method and the Technicon Auto-Analyzer. A soil:solution ratio of 1:5 was used with a shaking time of 5 minutes. The supernatant liquid was filtered and analyzed.

Lodging percentages were obtained by counting all stalks for each plot which were broken below the highest ear, or standing at an angle greater than 30 degrees from the vertical, and dividing by the total number of stalks in the plot.

Yield data were obtained by mechanically harvesting all plots and recording field weights, which were then converted to kg/ha of shelled corn on a 15.5 percent moisture basis.

Analyses of variance were applied to the data from each location and to the combined experiments between locations. All analyses were performed on an IBM 360/65 computer utilizing the Statistical Analysis System. Treatment means were subjected to the Duncan's New Multiple Range Test. All tests for significance were conducted at the 0.05 level of probability. Regression analyses were also used for determining correlation coefficients among factors.

CHAPTER III

RESULTS AND DISCUSSION

Yield

At Milan and Crossville the grain yields for the 168 and 224 kg N rate were significantly higher than the 113 kg per hectare rate (Table 1). No increase was obtained by increasing the N rate from 168 to 224 kg of N per hectare at either location. These data are in agreement with the present recommendation of 168 kg of N per hectare for expected yields of 9408 kg per hectare.

The highest average yield at Milan occurred when 168 kg of N was applied to the high population (Table 2). At Crossville, however, the highest mean yield occurred when 224 kg of N was applied to the high population. There was also a greater response to N at Crossville. There was a range of 3,970 kg between the highest and the lowest mean yield at Crossville, but only a 2,126 kg difference occurred at Milan.

There was no significant yield increase at Milan from 39,540 to 49,420 plants per hectare, but there was a significant yield increase from 49,420 to 59,300 (Table 3). At Crossville, a significant yield increase was observed when the population increased from 39,450 to 49,420 plants per hectare, but no yield increase was obtained by further increasing the plant population. These data seem to support the current recommendation of 49,420 plants per hectare for production of corn grain on highly productive soils.

Table 1. Combined treatment means for yield, lodging, and prolificacy grown at three N rates at Milan and Crossville.

Location	N Rate	Yield	Lodging	Prolificacy
	kg/ha	kg/ha	%	ears/plant
Milan	112	8513b ¹	2.0a	1.1b
	168	9358a	2.3a	1.2a
	224	9182a	2.7a	1.2a
Crossville	112	8426b'	2.5a'	1.1a'
	168	9232a'	2.3a'	1.1a'
	224	9494a'	2.7a'	1.1a'

¹Values followed by the same notation within each column do not differ at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 2. Treatment means for yield, lodging, and prolificacy at three N rates, two hybrids and three populations at Milan and Crossville.

N Rate	Hybrid	Population	Yield		Lodging		Prolificacy	
			Milan	Crossville	Milan	Crossville	Milan	Crossville
kg/ha		plants/ha	----- kg/ha-----	----- %-----	----- ears/plant-----			
112	Pioneer brand 3184	39,540	8,775	8,869	0.0	0.3	1.1	0.8
		49,420	8,292	9,559	0.0	2.3	1.0	1.0
		59,300	9,283	9,427	0.7	2.2	1.0	1.2
	DeKalb XL-394	39,540	7,959	7,106	3.7	2.9	1.3	1.1
		49,420	8,404	7,464	4.1	3.1	1.2	1.0
		59,300	8,367	8,129	3.6	4.2	1.0	1.3
168	Pioneer brand 3184	39,540	8,517	9,659	1.0	0.9	1.3	1.0
		49,420	9,571	10,299	0.5	2.1	1.1	1.0
		59,300	10,085	10,656	1.1	1.9	1.0	1.3
	DeKalb KL-394	39,540	9,019	7,953	2.7	2.0	1.4	1.0
		49,420	9,333	8,436	3.3	2.2	1.2	1.0
		59,300	9,621	8,386	5.5	4.3	1.1	1.2
224	Pioneer brand 3184	39,540	8,731	9,314	0.7	0.6	1.2	0.9
		49,420	9,464	10,775	1.1	2.3	1.1	0.9
		59,300	9,703	11,076	0.7	3.4	1.0	1.3
	DeKalb XL-394	39,540	9,138	7,947	2.7	2.0	1.5	1.1
		49,420	8,856	9,220	4.6	3.4	1.2	1.1
		59,300	9,207	8,630	4.1	4.5	1.0	1.2

Table 3. Combined treatment means for yield, lodging, and prolificacy grown at three populations at Milan and Crossville.

Location	Population	Yield	Lodging	Prolificacy
	plants/ha	kg/ha	%	ears/plant
Milan	39,540	8687b ¹	2.2a	1.3a
	49,420	8988b	2.3a	1.1b
	59,300	9377a	2.6a	1.0c
Crossville	39,540	8536b'	1.5b'	1.0b'
	49,420	9295a'	2.6ab'	1.0b'
	59,300	9383a'	3.5a'	1.2a'

¹Values followed by the same notation within each column do not differ at the 0.05 level of significance, according to Duncan's Multiple Range Test.

There were no differences between the two hybrids when grown at Milan, however at Crossville at a higher elevation and shorter growing season, Pioneer brand 3184, a medium season hybrid, out yielded DeKalb XL-394, a full season hybrid (Table 4). There were no significant differences in mean yield between Milan and Crossville (Table 5).

Lodging

In general, lodging was not severe at either location (Table 2). There was a significant increase in lodging at Crossville when the population was increased from 39,540 to 59,300 plants per hectare, however at Milan, there was no difference in lodging between these two populations (Table 3).

There was no difference in lodging among the nitrogen treatments at either location (Table 1). Long (20) found that the rate of N application had little affect on lodging, and that increasing the plant population was a major factor in increasing lodging.

Pioneer brand 3184 lodged significantly less than DeKalb XL-394 at both locations, 4.0 percent versus 0.6 percent (Table 4).

Prolificacy

At Milan, increasing the plant population significantly decreased the prolificacy of the corn plants (Table 3). Increasing the plant population increased the competition for available nutrients, water, and light and can decrease an individual plant's performance even though the yield of the higher population may increase. These data are in agreement with work done by Tyner (34). At Crossville however, increasing the plant population from 49,420 to 59,300 plants per hectare increased the

Table 4. Combined treatment means for yield, lodging, and prolificacy for two hybrids at Milan and Crossville.

Location	Hybrid	Yield	Lodging	Prolificacy
		kg/ha	%	ears/plant
Milan	Pioneer brand 3184	9157a	0.6b	1.1b
	DeKalb XL-394	8881a	4.0a	1.1a
Crossville	Pioneer brand 3184	10,004a'	1.8b'	1.1a'
	DeKalb XL-394	8141b'	3.1a'	1.1a'

¹Values followed by the same notation within each column do not differ at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 5. Combined treatment means for yield, lodging, and prolificacy at two locations

Location	Yield	Lodging	Prolificacy
	kg/ha	%	ears/plant
Milan	9082a ¹	2.3a	1.1a
Crossville	9019a	2.5a	1.1a

¹Values followed by the same notation within each column do not differ at the 0.05 level of significance, according to Duncan's Multiple Range Test.

prolificacy of the corn plants. This may be a result of better moisture conditions during the growing season.

A significant increase in prolificacy occurred at Milan when N levels were increased from 112 kg to 168 kg of N per hectare was applied (Table 1, page 13). There was no difference between 168 and 224 kg of N per hectare. At Crossville, increasing the rate of N applied had no effect on the amount of prolificacy.

DeKalb XL-394 exhibited greater prolificacy than did Pioneer at Milan, but at Crossville, there were no differences between hybrids (Table 4). There were also no differences in prolificacy between locations (Table 5).

Mineral Composition

While all average treatment ear leaf N values were found to be below the critical nutrient level for N at 3.00 percent as established by Melstead, Motto and Peck (23), significant increases occurred at Crossville when added N was applied to the soil (Tables 6 and 7). All plots at both locations were found to be above the 1.90 percent critical nutrient level established for K. The critical nutrient level as established by Melstead and others (23) for Mg is 0.25 percent in the ear leaf at silking. Milan was well above this critical nutrient level, however Crossville ear leaves showed deficient levels. Soil analyses (Table 8) have shown that there were more than five times the amount Mg found in the soil at Milan than at Crossville. Soil values for Ca at Crossville were one-third that of the values at Milan. A significant increase in Ca in the ear leaf was observed at Milan as a result.

Table 6. Treatment means for N, P, K, Mg, and Ca content as percent in the ear leaf at three N rates, two hybrids, and three populations at Milan.

N Rate	Hybrid	Population	N	P	K	Mg	Ca
kg/ha		plants/ha	-----%				
112	Pioneer brand 3184	39,540	2.39	0.31	2.26	0.31	0.63
		49,420	2.17	0.30	2.45	0.32	0.58
		59,300	2.16	0.27	2.61	0.32	0.58
	DeKalb XL-394	39,540	2.44	0.25	1.98	0.31	0.62
		49,420	2.34	0.26	2.25	0.34	0.64
		59,300	2.37	0.27	2.29	0.32	0.74
168	Pioneer brand 3184	39,540	2.54	0.33	2.14	0.36	0.67
		49,420	2.24	0.31	2.28	0.34	0.54
		59,300	2.19	0.29	2.01	0.36	0.54
	DeKalb XL-394	39,540	2.92	0.31	1.97	0.34	0.54
		49,420	2.76	0.30	2.14	0.34	0.75
		59,300	2.37	0.29	2.00	0.31	0.57
224	Pioneer brand 3184	39,540	2.22	0.31	2.17	0.42	0.79
		49,420	2.58	0.29	2.24	0.44	0.66
		59,300	2.39	0.29	2.20	0.33	0.61
	DeKalb XL-394	39,540	2.62	0.30	2.18	0.37	0.58
		49,420	2.65	0.27	2.02	0.32	0.51
		59,300	2.85	0.30	1.97	0.35	0.55

Table 7. Treatment means for N, P, K, Mg, and Ca content as percent in the ear leaf at three N rates, two hybrids and three populations at Crossville.

N Rate	Hybrids	Population	N	P	K	Mg	Ca
kg/ha		plants/ha	-----%				
112	Pioneer brand 3184	39,540	2.67	0.28	2.68	0.15	0.45
		49,420	2.59	0.27	3.14	0.14	0.46
		59,300	2.69	0.24	2.95	0.14	0.42
	DeKalb XL-394	39,540	2.31	0.25	2.98	0.14	0.51
		49,430	2.47	0.25	2.91	0.16	0.59
		59,300	2.52	0.25	3.13	0.16	0.61
	Pioneer brand 3184	39,540	2.65	0.27	2.77	0.15	0.44
		49,420	2.65	0.27	3.07	0.15	0.44
		59,300	2.57	0.27	3.20	0.15	0.40
168	DeKalb XL-394	39,540	2.24	0.29	3.03	0.17	0.52
		49,420	2.35	0.26	2.96	0.15	0.53
		59,300	2.41	0.26	2.98	0.16	0.49
	Pioneer brand 3184	39,540	2.40	0.29	3.44	0.13	0.41
		49,420	2.41	0.28	3.25	0.15	0.41
		59,300	2.41	0.28	3.19	0.14	0.41
	DeKalb XL-394	39,540	2.01	0.29	3.04	0.16	0.73
		49,420	2.09	0.29	3.15	0.17	0.53
		59,300	2.24	0.27	3.07	0.17	0.58

Table 8. Double acid extraction levels for P, K, Mg, and Ca at four depths in the soil profile at Milan and Crossville.

Location	Depth	P	K	Mg	Ca
	cm	----- ppm-----			
Milan	0-6	44.2 ¹	96.7	141.6	487
	6-12	18.5	59.6	203.8	523
	12-18	10.1	32.9	224.1	577
	18-24	17.5	28.3	224.5	418
	-				
	x	22.5	54.4	198.5	476
Crossville	0-6	47.4	100.6	45.0	221
	6-12	33.3	116.7	59.4	287
	12-18	7.9	43.0	24.2	134
	18-24	3.0	23.6	11.2	78
	-				
	x	22.9	71.0	35.0	180

¹Mean values of 4 replications.

At Milan, the lowest leaf N content was obtained at the 112 kg per hectare treatment and was significantly different from the other two treatments (Table 9). At Crossville, a higher P content occurred when 224 kg of N was applied as opposed to lower rates of N application. Bennett (2) based this same conclusion on a more extensive root system which would come in contact with more soil P. The K content in the ear leaf was significantly greater when the corn was grown at the 112 kg N rate as opposed to higher rates of N. This data contradicts work done by Bennett (2), who showed that the rate of N applied had no observable effect on the K content of the ear leaf. Corn grown at Milan had significant increases in leaf Mg with an increase in N application, however these differences were not observed at Crossville.

There was a significant decrease in leaf N when the population was increased from 59,300 to 39,540 plants per hectare at both locations (Table 10). There were no differences found among plant populations at Milan or Crossville for K, Mg, or Ca.

DeKalb XL-394 had greater concentrations of N in the ear leaf than did Pioneer brand 3184 (Table 11). Pioneer brand 3184, however, contained more K in the ear leaf than did DeKalb XL-394 at Milan, while at Crossville, these differences were not observed. Pioneer brand 3184 had greater levels of Mg in the leaves than did DeKalb XL-394 when soil Mg levels were sufficient. The reverse occurred when the level of Mg in the soil was deficient.

There were no significant differences, in general, for ear leaf N between Milan and Crossville, however, corn at Milan contained greater

Table 9. Combined treatment means for N, P, K, Mg, and Ca as percent in the ear leaf grown at three N rates at Milan and Crossville.

Location	N Rate	N	P	K	Mg	Ca
	kg/ha	-----%				
Milan	112	2.31b ¹	0.28b	2.31a	0.32c	0.63a
	168	2.50a	0.30a	2.09b	0.34b	0.60a
	224	2.55a	0.29ab	2.13ab	0.37a	0.61a
Crossville	112	2.49c'	0.26b'	2.96b'	0.15a'	0.51a'
	168	2.69b'	0.27b'	3.00b'	0.16a'	0.47a'
	224	2.85a'	0.28a'	3.19a'	0.15a'	0.51a'

¹Values followed by the same notation within each column do not differ at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 10. Combined treatment means for N, P, K, Mg, and Ca as percent in the ear leaf grown at three populations at Milan and Crossville.

Location	Population	N	P	K	Mg	Ca
	plants/ha	-----%-----				
Milan	39,540	2.52a ¹	0.30a	2.12a	0.35a	0.64a
	49,420	2.46a	0.29ab	2.23a	0.35a	0.61a
	59,300	2.39b	0.29b	2.18a	0.33a	0.60a
Crossville	39,540	2.76a'	0.28a'	2.99a'	0.15a'	0.51a'
	49,420	2.68ab'	0.27ab'	3.09a'	0.15a'	0.49a'
	59,300	2.58b'	0.26b'	3.08a'	0.15a'	0.48a'

¹Values followed by the same notation within each column do not differ at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 11. Combined treatment means for N, P, K, Mg, and Ca as percent in the ear leaf for two hybrids at Milan and Crossville.

Location	Hybrid	N	P	K	Mg	Ca
-----*						
Milan	Pioneer brand 3184	2.32b ¹	0.30a	2.26a	0.36a	0.62a
	DeKalb XL-394	2.59a	0.28b	2.09b	0.33b	0.61a
Crossville	Pioneer brand 3184	2.55b'	0.27a'	3.08a'	0.14b'	0.43b'
	DeKalb XL-394	2.80a'	0.27a'	3.02a'	0.162'	0.57a'

¹Values followed by the same notation within each column do not differ at the 0.05 level of significance, according to Duncan's Multiple Range Test.

amounts of P, Mg, and Ca (Table 12). Plants sampled at Crossville contained higher levels of K.

Grain Protein

Grain protein values were determined by three chemical methods; (1) Kjeldahl analysis, (2) wet digesting the grain samples and determining the protein content using a Technicon Auto-Analyzer, and (3) by a Neotec Grain Quality Analyzer. Protein values are contained in Table 13.

A correlation coefficient of only 0.55 existed when comparing the standard Kjeldahl procedure with the analysis by a Technicon Auto-Analyzer. There was a correlation coefficient of 0.91 however when comparing the Kjeldahl method with a Neotec Grain Quality Analyzer. Care must be taken in using the GQA, as the values obtained can be seriously affected by temperature, particle size, packing density within the sample cell, and homogeneity of the sample. Only a small change in near-infrared reflectance is needed to change the protein content value dramatically.

Protein values obtained by the Kjeldahl method were lowest at the 112 kg N rate and were significantly different from the other two treatments. However, there was no difference between the 168 and 224 kg N rate (Table 14). No increase was observed by increasing the N rate from 168 kg to 224 kg of N at either location by the Kjeldahl analysis. On a per hectare basis, the total protein produced was increased when the rate of N applied increased from 112 kg to 168 kg of N per hectare, but no additional protein was produced when the N rate was increased from 168 kg to 224 kg of N per hectare.

Table 12. Combined treatment means for N, P, K, Mg, and Ca as percent in the ear leaf at two locations.

Location	N	P	K	Mg	Ca
	-----%				
Milan	2.46a ¹	0.29a	2.17b	0.35a	0.62a
Crossville	2.43a	0.27b	3.05a	0.15b	0.50b

¹Values followed by the same notation within each column do not differ at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 13. Treatment means for percent grain protein as analyzed by Kjeldahl, Technicon Auto-Analyzer, and a GQA, and total protein per hectare based on Kjeldahl analysis and yield at three N rates, two hybrids, and three populations at Milan and Crossville.

N Rate	Hybrid	Population	Protein by Kjedahl		Protein by Auto analyzer		Protein by GQA		Total Protein	
			Milan	Crossville	Milan	Crossville	Milan	Crossville		
		plants/ha	-----kg/ha-----							
112	Pioneer brand 3184	39,540	8.53	6.35	8.37	6.60	8.78	6.15	733	586
		49,420	8.27	6.27	7.56	6.85	8.46	6.35	687	600
		59,300	8.00	6.22	6.98	6.60	7.64	5.84	744	586
	DeKalb XL-394	39,540	8.88	7.30	8.41	5.35	8.75	7.01	705	519
		49,420	8.45	6.92	7.96	6.67	8.48	6.91	713	522
		59,300	8.70	6.73	7.79	6.87	8.68	7.32	727	546
168	Pioneer brand 3184	39,540	9.10	6.88	8.83	7.11	9.20	7.16	783	663
		49,420	8.62	6.68	8.13	7.53	8.77	6.68	824	687
		59,300	8.42	6.57	7.66	6.78	8.42	6.77	849	701
	DeKalb XL-394	39,540	9.25	7.50	8.21	7.48	8.73	7.62	835	596
		49,420	9.05	7.52	8.47	7.52	8.79	7.38	843	635
		59,300	9.15	7.48	8.72	7.50	8.76	7.53	880	628
224	Pioneer brand 3184	39,540	9.13	7.15	8.19	7.22	9.26	7.51	795	666
		49,420	8.80	6.80	8.19	8.00	8.89	6.92	832	732
		59,300	8.23	6.77	8.31	6.06	8.27	6.87	802	751
	DeKalb XL-394	39,540	9.20	7.50	9.10	7.15	8.98	7.66	848	599
		49,420	9.15	7.80	8.65	7.21	8.88	7.75	811	719
		59,300	9.15	7.70	8.78	7.95	8.76	7.31	842	665

Table 14. Combined treatment means for percent grain protein analyzed by Kjeldahl, a Technicon Auto-analyzer, and a GQA, and total protein per hectare based on Kjeldahl analysis and yield at three N rates at Milan and Crossville.

Location	N Rate	Protein by Kjeldahl	Protein by Auto-analyzer	Protein by GQA	Total Protein
	kg/ha	-----%			kg/ha
Milan	112	8.47b ¹	7.85b	8.45b	717b
	168	8.95a	8.34a	8.78a	836a
	224	8.93a	8.53a	8.84a	820a
Crossville	112	6.49b'	6.49b'	6.58b'	560b'
	168	7.10a'	7.32a'	7.15a'	652a'
	224	7.29a'	7.26a'	7.33a'	689a'

¹Values followed by the same notation within each column do not differ at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Percent protein decreased as plant population increased from 39,540 to 49,420 plants per hectare at Milan (Table 15). Plant population had no effect on percent grain protein at Crossville.

DeKalb XL-394 usually had a higher protein content than did Pioneer 3184 at both locations, regardless of the analytical procedure used (Table 16). In general, corn at Milan had a higher protein content in the grain than did the corn at Crossville, regardless of the method used (Table 17).

No differences were observed in total protein among populations or hybrids at Milan, however at Crossville, Pioneer brand 3184 produced more protein per hectare than did DeKalb XL-394. Corn grown at Milan significantly outyielded that grown at Crossville in terms of protein production.

Table 15. Combined treatment means for percent grain protein analyzed by Kjeldahl, a Technicon Auto-analyzer, and a GQA, and total protein per hectare based on Kjeldahl analysis and yield at three populations at Milan and Crossville.

Location	Population	Protein by Kjeldahl	Protein by Auto- Analyzer	Protein by GQA	Total Protein
	plants/ha	-----%			kg/ha
Milan	39,540	9.05a ¹	8.52a	8.96a	782a
	49,420	8.73b	8.16ab	8.71a	785a
	59,300	8.61b	8.04b	8.42b	807a
Crossville	39,540	7.11a'	6.81a'	7.23a'	605a
	49,420	7.00a'	7.30a'	7.02a'	649a
	59,300	6.91a'	6.96a'	6.89a'	646a

¹Values followed by the same notation within each column do not differ at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 16. Combined treatment means for percent grain protein analyzed by Kjeldahl, a Technicon Auto-analyzer, and a GQA, and total protein per hectare based on Kjeldahl analysis and yield for two Hybrids at Milan and Crossville.

Location	Hybrid	Protein by Kjeldahl	Protein by auto- analyzer	Protein by GQA	Total Protein
-----%					kg/ha
Milan	Pioneer brand 3184	8.58b ¹	8.03b	8.63a	785a
	DeKalb XL-394	8.99a	8.46a	8.76a	799a
Crossville	Pioneer brand 3184	6.63b'	6.97a'	6.72b'	664a'
	DeKalb XL-394	7.38a'	7.08a'	7.43a'	603b'

¹Values followed by the same notation within each column do not differ at the 0.05 level of significance, according to Duncan's Multiple Range Test.

Table 17. Combined treatment means for percent grain protein analyzed by Kjeldahl, a Technicon Auto-analyzer, and GQA, and total protein per hectare based on Kjeldahl analysis and yield at Milan and Crossville.

Location	Protein by Kjeldahl	Protein by Auto-analyzer	Protein by GQA	Total Protein
-----%				kg/ha
Milan	8.79a ¹	8.24a	8.69a	792a
Crossville	7.01b	7.02b	7.05b	633b

¹Values followed by the same notation within each column do not differ at the 0.05 level of significance, according to Duncan's Multiple Range Test.

CHAPTER IV

SUMMARY

The purpose of this study was to determine the effects of N rate applications and plant populations on the protein content and yield of two corn hybrids (*Zea mays* L.) at two locations in Tennessee. Other characteristics measured were lodging, prolificacy, and mineral composition of the ear leaf at silking.

As the rate of N applied was increased, there was a general increase in ear leaf N at silking. Significant increases in the quantity and protein content of the corn grain occurred at the 0.05 level of probability when the N rate was increased from 112 to 168 kg of N per hectare. Further increases to 224 kg of N per hectare had little influence on increasing the yield and grain protein content.

Yields were improved at both locations when the plant population was increased from 35,540 to 59,300 plants per hectare. The plant population had little effect on the percent protein found in the grain at Crossville, or in the total protein produced per hectare at Milan.

At Milan, Pioneer brand 3184, a medium season corn, produced the same yield and protein as DeKalb XL-394 which is a full season hybrid. The shorter growing season at Crossville, however, significantly decreased the performance of the full season hybrid without affecting the medium season corn.

The rate of N used had no effect on lodging or on prolificacy of the corn plants. At Crossville, increasing the plant population decreased

the prolificacy of the corn plants, and increased the amount of lodging.

Generally, differences in percent P, K, Mg and Ca were not affected by location, rate of N application, hybrid, or population.



LITERATURE CITED



LITERATURE CITED

1. Association of Official Agricultural Chemists. 1965. Official Methods of Analysis of the Association of Official Agricultural Chemists. AOAC Washington D. C. Tenth edition. p. 957.
2. Bennett, William F., G. Stanford, and L. Dumenil. 1953. Nitrogen, phosphorus, and potassium content of the corn leaf and grain as related to nitrogen fertilization and yield. Soil Sci. Soc. Amer. Proc. 17:252-258.
3. Burns, J. D. 1978. More corn per acre. Tenn. Agr. Ext. Serv. Pub. 443.
4. Crabb, Richard A. 1947. The hybrid corn makers: Prophets of plenty. Rutgers University Press, New Brunswick.
5. Drake, Mack. 1944. Nutrient balance in corn growing in southern states as revealed by Purdue plant tissue tests. Agron. J. 36:1-9.
6. Dumenil, Lloyd. 1952. Nitrogen fertilizers for corn. Iowa Agr. Exp. Sta. Bull. p. 114.
7. Dumenil, Lloyd. 1961. Nitrogen and phosphorus composition of corn leaves and corn yields in relation to critical levels and nutrient balance. Soil Sci. Soc. Amer. Proc. 25:295-298.
8. Duncan, E. R. 1954. Influences of varying plant population soil fertility and hybrid on corn yields. Soil Sci. Soc. Amer. Proc. 18:437-440.
9. Ellis, B. G., C. J. Knauss and F. W. Smith. 1956. Nutrient content of corn as related to fertilizer application and soil fertility. Agron. J. 48:455-459.
10. Fisher, Flake L. and O. E. Smith. 1960. The influence of nutrient balance on yield and lodging of Texas hybrid corn no 28. Agron. J. 52:201-204.
11. Fitts, J. W., W. V. Bartholomew, and H. Heidel. 1953. Correlation between nitrifiable nitrogen and yield response of corn to nitrogen fertilization on Iowa soils. Soil Sci. Soc. Amer. Proc. 17:119-122.
12. Gieseking, J. E., H. J. Snyder, and C. A. Getz. 1935. Destruction of organic matter in plant material by the use of nitric and perchloric acids. Ind. and Eng. Chem. Anal. Ed. 7:185-186.

13. Goss, James A. 1973. Physiology of plants and their cells. Pergamon Press Inc., New York. p. 183-194.
14. Hanway, J. J. 1962. Corn growth and composition in relation to soil fertility: II Uptake of N, P, and K and their distribution in different plant parts during the growing season. Agron J. 54:217-222.
15. Hunter, Albert S., and J. A. Hungen. 1955. The influence of variations in fertility levels upon the yield and protein content of field corn in eastern Oregon. Soil Sci. Soc. Amer. Proc. 19:214-218.
16. Hymowitz, T., J. W. Dudley, F. I. Collins, and C. M. Brown. 1974. Estimation of protein and oil concentration in corn, soybean, and oat seed by near-infrared light reluctance. Crop Sci. 14:713-715.
17. Kranz, B. A. 1949. Fertilize corn for higher yields. North Carolina Agr. Exp. Sta. Bull. 366.
18. Kranz, B. A., and W. V. Chandler. 1955. Lodging leaf composition and yield of corn as influenced by heavy applications of nitrogen and potash. Agron. J. 43:547-552.
19. Little, Thomas M., and F. J. Hills. 1978. Agricultural experimentation design and analysis. John Wiley and Sons, Inc., New York.
20. Long, O. H. 1953. Nitrogen and spacing experiments with corn. Tenn. Agric. Exp. Sta. Bull 232.
21. Long, O. H. 1961. Nitrogen and plant population in corn production. Tenn. Agr. Exp. Sta. Bull. 337.
22. Macy, Paul. 1936. The quantitative mineral nutrient requirements of plants. Plant Physiol. 11:749-764.
23. Melstead, S. W., H. L. Motto, and T. R. Peck. 1969. Critical plant nutrient composition values useful in interpreting plant analysis data. Agron. J. 61:17-20.
24. Parks, W. L., J. A. Odom, J. R. Overton, and E. J. Chapman. 1965. Plant population and row spacings for corn. Tenn. Agr. Exp. Sta. Bull. 392.
25. Pierre, W. H., L. Dumenil, V. D. Jolley, J. R. Webb and W. D. Shrader. 1977. Relationship between corn yield, expressed as a percentage of maximum, and the N percentage in the grain. I. Various N-rate experiments. Agron. J. 69:215-220.

26. Scarseth, George D. 1943. Plant-tissue testing in diagnosis of the nutritional status of growing plants. *Soil Sci.* 55:113-120.
27. Scarseth, George D., H. L. Cook, B. A. Krantz, and A. J. Ohlrogge. 1943. How to fertilize corn effectively in Indiana. *Purdue Univ. Agr. Exp. Sta. Bull.* 482.
28. Schneider, E. O., E. B. Earley, and E. E. DeTurk. 1974. Nitrogen fractions of the component parts of the corn kernel as affected by selection and soil nitrogen. p. 138. In J. W. Dudley (ed.) *Seventy Generations of Selection for Oil and Protein in Maize.* Crop Science Society of America, Madison, Wisc.
29. Stanford, George. 1973. Rationale for optimum nitrogen fertilization in corn production. *J. Environ. Qual.* 2:159-165.
30. Statistical Reporting Service, USDA. 1971. *Cropping Practices. 1964-1970.* SRS-17, Washington, D. C.
31. Steckel, Joseph E. and R. L. Flannery. 1971. Simultaneous determinations of phosphorus, potassium, calcium, and magnesium in wet digestion solutions of plant tissue by auto-analyzer. p. 97-112. In L. M. Walsh (ed.) *Instrumental Methods for Analysis of Soils and Plant Tissues.* Soil Science Society of America, Madison, Wisc.
32. Stringfield, G. H., and L. E. Thatcher. 1947. Stands and methods of planting for corn hybrids. *Agron. J.* 39:995-1010.
33. Thomas, R. L., R. W. Sheard, and J. R. Moyer. 1967. Comparison of conventional and automated procedures for nitrogen, phosphorus, and potassium analysis of plant material using a single digestion. *Agron. J.* 59:240-243.
34. Tyner, Edward H. 1946. The relation of corn yield to leaf nitrogen, phosphorus, and potassium content. *Soil Sci. Soc. Amer. Proc.* 11:317-323.
35. Tyner, Edward H. and J. R. Webb. 1946. The relationship of corn yields to nutrient balance as revealed by leaf analysis *Agron. J.* 38:173-185.
36. Ulrich, A. 1952. Physiological bases for assessing the nutritional requirements of plants. *Ann. Rev. of Plant Physiol.* 3:207-228.
37. Viets, Frank G., Jr., and C. E. Domingo. 1948. Yields and nitrogen content of corn hybrids as affected by nitrogen supply. *Soil Sci. Soc. Amer. Proc.* 13:303-306.

38. Viets, Frank G., Jr., C. E. Nelson, and C. L. Crawford. 1954. The relationships among corn yields, leaf composition and fertilizers applied. Soil Sci. Soc. Amer. Proc. 18:297-301.
39. Woodward, C. M., E. R. Leng, and R. W. Jugenheimer. 1974. Fifty generations of selection for protein and oil in corn. p. 121-132. In J. W. Dudley (ed.) Seventy Generations of Selection for Oil and Protein in Maize. Crop Science Society of America, Madison, Wisc.
40. Zuber, M. S., G. E. Smith, and C. W. Geehrke. 1954. Crude protein of corn grain and stover as influenced by different hybrids, plant populations, and nitrogen levels. Agron. J. 46:257-261.

APPENDIXES



APPENDIX A

Procedure for wet ashing plant tissue for P, K, Mg, and Ca analysis.

1. Weigh 0.500 gm of finely ground plant tissue and place into a 50 ml digestion tube in the technicon digestion block.
2. Add 4.0 ml of concentrated nitric acid, two glass beads, and a small glass funnel in the mouth of each tube to act as a condenser. Allow the samples to pre-digest at room temperature overnight.
3. Turn the heating block on and heat samples to 150°C, digesting for one hour. Remove and allow to cool to room temperature.
4. Add 2.0 ml of 60 to 70 percent perchloric acid and heat to 235°C for two hours. Allow samples to cool to room temperature.
5. Add one ml of concentrated hydrochloric acid, and digest at 150°C for 15 to 20 minutes.
6. Allow the samples to cool to room temperature and transfer to 100 ml volumetric flasks. Bring to volume using distilled and deionized water.
7. Mix the contents of the flasks and let stand six to eight hours before analysis with the Technicon Auto-Analyzer.
8. The K and Ca content is determined by flame emission, while the P and Mg content is determined colormetrically.

APPENDIX B

Procedure for wet ash digesting for total N analysis.

1. Weigh 0.200 gm of finely ground plant tissue and place into a 125 ml Erlenmeyer flask.
2. Add 10.0 ml of concentrated sulfuric acid and let predigest overnight.
3. Heat to approximately 200°C on a hot plate for approximately 2.5 hours. Remove samples from the hot plate and allow to cool.
4. When cool enough to hold in palm of hand, add 20 ml of 35 percent hydrogen peroxide to each flask.
5. Return to hot plate and heat to 200°C until 45 minutes after clearing has occurred.
6. Transfer to 250 ml volumetric flasks, and bring to volume using distilled and deionized water.
7. Mix sample, let stand for enough time to stabilize, and analyzed on the Technicon Auto-Analyzer.
8. The total N is determined colormetrically.

VITA

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