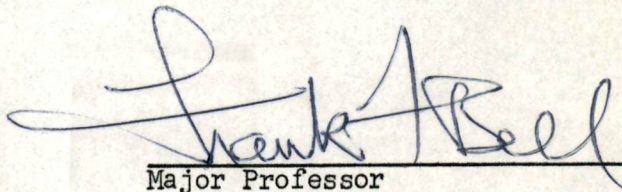


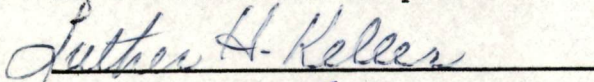
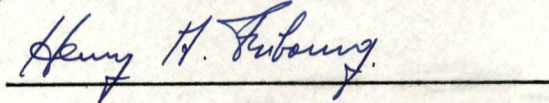
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To the Graduate Council:

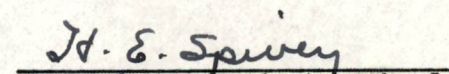
I am submitting herewith a thesis written by Gurushiddappa V. Havanagi entitled "Effect of Certain Crop and Soil Management Factors on the Size of Kernels and Yield of Corn." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.


Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:


Dean of the Graduate School

EFFECT OF CERTAIN CROP AND SOIL MANAGEMENT FACTORS
ON THE SIZE OF KERNELS AND
YIELD OF CORN

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Gurushiddappa V. Havanagi

August 1961

ACKNOWLEDGMENTS

The writer wishes to express his gratitude and appreciation to:

Dr. Frank F. Bell for directing the study,

Dr. Henry A. Fribourg and Dr. Luther H. Keller for serving on the author's graduate committee,

Dr. W. L. Parks and Mr. R. A. Peace for making the data available from their experiments,

Mr. Joe Elder and Mr. Charles R. Graves for assisting in certain computations of the data,

Mr. Raymond E. Cobble and Mr. J. Guthrie for assisting in grading of corn kernels,

Dr. L. M. Josephson, Dr. H. A. Henderson and Dr. D. G. Paris for helpful suggestions,

Mr. J. W. Vinyard for processing of statistical computations at the Computing Center, Chattanooga,

The Soil Conservation Service, the Tennessee Valley Authority, the National Plant Food Institute and the University of Tennessee for making this study possible.

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CHAPTER I

INTRODUCTION

I. THE PROBLEM

Yields of corn can be increased by adopting certain levels of crop and soil management factors, such as plant population, variety, nitrogen, phosphate and potash fertilizers, lime and date of planting, as well as growing corn on suitable soils. During the past few years considerable interest has been manifested in efficient management of these factors for optimum yields. One of the objectives of this study was to estimate the extent to which certain of these management factors affect the optimum yield of corn. Management practices also affect size of corn kernels. Due to the greater demand for particular sizes of corn kernels for seed by some farmers, the seed-corn producer is interested in adjusting his management practices to produce the desired size of corn kernels.

In view of these facts the study of the effect of certain crop and soil management factors on the corn yield and size of kernels was undertaken, using the data available from certain experiments conducted in Tennessee.

II. IMPORTANCE AND NATURE OF STUDY

Studies of Factors Affecting Yield of Corn

Many workers, including Mooers (19), Long (18), Osgood (23), Rounds (28) and Russ (29) reported optimum¹ levels of crop and soil management

¹/Optimum level means the level of management input which gives the most profitable yield.

factors such as plant population, nitrogen, variety, soils and other practices, to obtain optimum yields of corn. Yield is a function of a number of factors and certain factors may affect the corn yield to a greater extent than others. When the farm manager decides to adopt certain practices to enhance his income, it is necessary to know the extent to which each of the different factors, and their interactions, affect the corn yield.

Studies of soil productivity and the estimation of yield have been made by some workers. Odell (21) indicated that cropping systems and soil treatments should be considered for determining levels of management to be used when measuring and comparing soil productivity. Smith and Smith (30) indicated that, with sufficient yield data available and at a given management level, the productivity of a given soil can be estimated with a reasonable degree of accuracy. Odell and Smith (22) further substantiated this by citing evidence from crop records that showed a distinct tendency for long-time average farm yields to cluster about the mean of the soil type and management group to which each belonged. Bell and Springer (4) gathered information on corn yields from some of the key soils of Tennessee. They said that there is a need for a knowledge of yields of various crops under defined levels of management inputs, that could reasonably be expected on a sustained basis for each of the more significant soils.

Recently, emphasis in economic-agronomic research has centered around estimation of empirical crop yield equations. Jensen and Pesek (14) considered quadratic yield equations which were fitted to data from particular initial soil fertility situations. The same authors (14) while working

with restrictive two variable quadratic equation, concluded that the equations generated from the restrictive equations within a soil type estimate the same parametric generalized yield equation, characteristic of the population. Pesek (25) has outlined a procedure for including initial soil fertility variables in a generalized quadratic equation. In a generalized two factor yield equation involving soil fertility variables, his procedure algebraically separates total available nitrogen and phosphorus into the soil component and the fertilizer component.

In Tennessee, similar studies to measure the productivity of major soils, and the estimation of yields as affected by certain crop and soil management variables, were started in 1956. Walker (35) who studied mean yield of corn at different levels of management found significant differences among the soil groups, such as bottom land and terrace soils, when they were compared at the same specified level of management. Graves (10) used an equation giving an exponential curve which included 8 variables, i.e. pH, P test, P added, K added and K test, organic matter, planting date, nitrogen added and plant population. He used this equation for predictions of corn yield in Tennessee for Huntington, Waynesboro and Dickson soils. He concluded that pH had its greatest influence upon corn yield on Dickson and Waynesboro soils, population was positively associated with yield under all conditions, potassium showed a negative correlation with yield, and time of planting had a greater influence on Dickson than on other soils.

The data have been collected in Tennessee for the last five years and it is now possible to include large numbers of variables like soil, pH, P (soil) test, K (soil) test, N applied, P applied, lime applied,

plant population, variety, previous crop, date of planting and year, and to study their effect on the yield of corn. The large number of observations involved would enable also to predict corn yield with greater accuracy.

Studies of Practices Affecting the Size of Corn Kernel

Commercial production of hybrid seed corn and standardization of grading² has made it possible to obtain uniformly sized corn kernels. This in turn facilitates accurate planting of corn by a corn planter. The proportion of different grades of kernels produced in the field vary considerably. Normally, the bulk of seed corn produced (15) consists of 5 percent of extra large flat kernels, 35 percent of large flat kernels, 40 percent of medium and regular flat kernels, the remaining 20 percent being round and discard kernels. The Tennessee Crop Improvement Associations records³ show that, of the Tennessee certified hybrid seed corn sold (only flat kernels are graded) 25 percent is extra large flat kernels, 55 percent is large flat kernels and 20 percent is regular and medium flat kernels. This indicates that, in Tennessee, there is a greater demand for large and extra large flat kernels than for medium and regular flat kernels. However, the use of large flat or medium flat kernels is different in East and in West Tennessee. East Tennessee

^{2/}The term 'Grade' as used in the hybrid seed corn trade, represents a description of seed size as measured by its width, thickness and length. The determination of grades will be described in detail later.

^{3/}Private communication from Mr. Raymond E. Cobble, Executive Secretary, Tennessee Crop Improvement Association, Nashville.

farmers grow a lesser corn acreage and use extra large and large flat kernels. West Tennessee farmers grow larger corn acreage and prefer to use medium and regular flat kernels. Medium and regular flat kernels plant more area per bushel of corn seed than extra large and large flat kernels. For similar reasons, the medium flat kernels are extensively used in corn-growing regions of Iowa and the large flat kernels from these regions are being transported to states where smaller acreages of corn are grown.⁴

Kiesselback (16) and Barnes (3) indicated that there was little difference in corn yield obtained from large and small seeds, though plants from large seeds reached a more uniform maturity at a slightly faster rate than did those from small seeds. Dugan et al. (7) using results of 11 station corn yield tests, indicated that round grades are fully as satisfactory as flat grades. The cost of seed is less for small round kernels than for flat grades because of the greater number of kernels per bushel. The large round grades usually cost less per bushel than large flat kernels. Thus, the use of large flats by some Tennessee farmers instead of medium flats or rounds seems to be the consequence of the value system held by these farmers, since there is no scientific evidence that either the flat kernels or large kernels produce higher yields than round kernels or small kernels.

Due to these conditions, stated above, corn producers have to discard all the round kernels and regular flat kernels (at times) and use

⁴/Personal communication from J. Guthrie, Manager, Tennessee Seed Producers, Inc., Nashville.

them for feed rather than for seed. There is a great difference in the price per bushel of seed and feed corn. Therefore, the greater the amount of regular flats, discards and round kernels, the lesser will be the profit from the yield produced.

The seed corn grower is interested to know if the percentage of desirable grades of corn kernels can be increased by altering certain soil and crop management practices. Very few studies have been reported showing the effect of crop and soil management practices on the size of corn kernels. Some studies have been reported showing the relationship of ear and kernel characteristics with yield. Hughes et al. (13) estimated relationships between the ear and kernel characteristics such as length of ear, weight of ear, number of ear, kernel development and yield. Hinkle (12) stated that, for optimum yield, corn should be planted in hills with 42" drill rows spaced 12" to 14" apart to provide a plant population of 10,000 to 12,000 plants per acre. He further stated that the weight of the ear corn produced per stalk was reduced by closer spacing. Dungan et al. (6) in tests conducted in northern Illinois found 12 percent barrenness with 8,000 plants per acre, 9.3 percent with 12,000 plants per acre, 15.7 percent with 16,000 plants per acre and 23.6 percent with 20,000 plants per acre. Stringfield and Thacker (34) reported that in Ohio the silking period for a stand of 5 plants per 42" row and 40" within row was roughly 2 days later than for a stand of 3 plants. It is reported (5) that small ears with unfilled tips were caused by a deficiency of nitrogen at a critical time, that ears with poorly filled tips and choppy kernels may indicate a potash shortage, and that small twisted ears with undeveloped kernels indicate a lack of phosphorus.

Dungan et al.(6) reported that size of corn kernels was reduced by increasing plant population. They further stated that general observations and extensive data at the Illinois Experiment Station showed that small ears on thick plants had larger proportion of round, odd shaped kernels than the ears produced on medium stands. They did not take into consideration the requirements of a particular size of corn kernels by the corn planter.

Pioneer Hibred Corn Company, Iowa (8, 20, 26, 27, 32) has done some research on the effect of plant population, rate of fertilizer and varieties, on the size of corn kernels, i.e., large flats, medium flats and round kernels. The results of their experiments showed: (1) as the planting rate increased there was a tendency for the percentage of rounds to increase and for the percentage flats to decrease. (2) It was profitable, in certain cases to practice heavier plant population and levels to benefit from the additional yield rather than to increase the desirable kernel sizes by low level of plant population. (3) The percentage flats and total bushels of flats increased as nitrogen fertilizer was increased. (4) A starter fertilizer of 150 lbs. of 3-12-12 gave a smaller percentage of flats and a higher percentage of rounds than no starter fertilizer.

Similar studies, under Tennessee conditions, to assess the effect of certain soil and crop management practices on the proportion of different grades of corn kernels were taken up. The practices studied were spacing, plant population, nitrogen, phosphate and potash fertilizers and growing corn on low productive (Dickson), medium productive (Waynesboro) and high productive (Huntington) soils. The findings of these

studies may enable the corn seed grower to adopt certain practices and obtain higher proportion of desired grade of kernels and increase the net profit.

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CHAPTER II

METHODS AND PROCEDURES

For the purpose of studying the effect of crop and soil management practices on the (1) yield and (2) size of corn kernels, the data from three experiments currently being conducted in Tennessee were used. (1) "The effect of plant spacing on yield and nitrogen utilization" on Hartsells soil at the Plateau Experiment Station¹; (2) "To determine the maximum productive capacity for Dickson, Waynesboro and Huntington Soils at high levels of management inputs" in Putnam County², both conducted during the year 1960. (3) "To measure the soil productivity at different levels of management", conducted in a number of counties in East Tennessee³ during 1956 through 1960.

The data from experiments 1 and 2 were used for studying the effect of (1) spacing (2) plant population, (3) soils, (4) nitrogen and (5) phosphate and potash fertilizers on the size of corn kernels. The data from experiment 3 were used for studying the effect of several

¹/ This will be hereafter referred to as "Spacing and plant population experiment on Hartsells Soil" for sake of convenience.

²/ This will be hereafter referred to as "Plant population, nitrogen and phosphate and potash experiment on three soils in Putnam County" for sake of convenience.

³/ This will be hereafter referred to as "Measurement of the effect of certain crop and soil management factors on the yield of corn in Tennessee soils" for sake of convenience.

variables, i.e., (1) soil, (2) pH⁴, (3) available phosphate test⁴, (4) available potash test (exchangeable potash)⁴, (5) nitrogen applied, (6) phosphate applied, (7) potash applied, (8) lime applied, (9) plant population, (10) variety, (11) date of planting, (12) previous crop and (13) year, on the yield of corn.

I. LOCATIONS, SOILS, EXPERIMENTAL DESIGN AND TREATMENTS

Spacing and Plant Population Experiment

on Hartsells Soil, 1960

1. Location and soils. This experiment was conducted at the Plateau Experiment Station. Hartsells is an upland soil with smooth to rolling topography. The texture of this soil is sandy loam to silt loam with adequate drainage.

2. Design of the experiment. A split plot factorial randomized block design was used with spacing as main treatment and plant population as the split-plot treatment. The area of the main treatment was 28' x 60' and of the split-plot treatment was 28' x 15'. There were 4 replications of the main treatments.

3. Treatment levels. There were five levels of spacing, i.e., 1½ foot, 2 foot, 2½ foot, 3 foot and 3½ foot, and four levels of plant population, i.e., 9,000, 12,000, 15,000 and 18,000 plants per acre.

^{4/} The available P test and available K test were made by the University of Tennessee Agricultural Experiment Station soil testing laboratory.
 pH - Beckman pH meter using a soil paste.
 Available P₂O₅ - Modified Troug method.
 Exchangeable cations (Ca, K) - Beckman flame photometer using ammonium acetate extraction.

The corn variety Dixie 29 was planted during the latter half of April.

Plant Population, Nitrogen, Phosphate and
Potash Experiment on Three Soils in Putnam
County, 1960

1. Location and soils. This study was conducted in Putnam County, which is located in Middle Tennessee, on three different soils, i.e., Dickson, Waynesboro and Huntington. The Dickson soil series consists of well drained to moderately well drained upland, possessing a distinct brittle fragipan. This fragipan limits the root zone and also the water-supplying power of this soil. Waynesboro soil series consists of deep, well drained soils developed on relatively old, high-stream terraces. The Huntington soils are deep, friable and well-drained bottom lands, occupying levels of gently sloping flood plains and narrow bodies of local alluvium along small drainage-ways and areas at the base of slopes. Considering the natural fertility and other physical and chemical properties, Dickson, Waynesboro and Huntington soils correspond to low, medium and high productive soils, respectively, in Putnam County.

2. Design of the experiment. A split-split-split-plot-factorial design was used with soil as the main treatment. The phosphate and potash, nitrogen and plant population treatments were used as split-plot treatment, split-split-plot treatment and split-split-split-plot treatment, respectively. For each of the three soils the experiment was conducted

at five locations⁵. The area of the experimental plot was 310' x 70', dividing it into two sub plots longitudinally with a buffer zone in the middle. The design was adopted for ease of mechanical operations.

3. Treatment levels

a) Soils--Dickson (low productive), Waynesboro (medium productive) and Huntington (high productive).

b) Phosphate and potash--220 lbs. and 420 lbs. P_2O_5 and K_2O per acre.

c) Nitrogen--220 lbs. and 420 lbs. N per acre.

Twenty pounds per acre of N, P_2O_5 and K_2O were applied, as 200 lbs. of 10-10-10 at the time of planting for all the plots. Two hundred and 400 lbs. of N, P_2O_5 and K_2O (according to treatments) were applied broadcast with a fertilizer distributor and thoroughly disked into the soil about one week prior to planting.

d) Plant population--Two plant population levels were used on each soil. The plant population was varied among the soils to allow for apparent differences among these soils. On Dickson, the plant populations were 8,000 and 16,000 plants per acre; on Waynesboro, 12,000 and 24,000 plants per acre; and on Huntington, 16,000 and 32,000 plants per acre.

The corn variety Dixie 29 was planted between April 26th to May 6th.

^{5/} The names of the cooperating farmers and the different soils are given in Appendix S.

Measurement of the Effect of Certain
Soil and Crop Management Factors on
the Yield of Corn in Tennessee Soils:
1956-1960

This experiment was started in 1956 jointly by the Agronomy Department of the University of Tennessee and the Soil Conservation Service. Since then it has been conducted every year. The plots⁶ were selected with the assistance of Conservationists from corn fields of cooperating farmers.

A schedule of questions⁷ was asked to each owner or operator of each selected plot by the Work Unit Conservationist to determine the more significant soil and crop management practices. Some of the practices recorded were date of planting, variety planted, cropping history of the plot, amounts of past fertilization and liming. The plots selected, included the major soils of east Tennessee and an attempt was made to include at least three categories of soil, i.e., "excellent corn soil", "good corn soils", and "poor corn soil". The experimental plot was made up of the same soil mapping unit⁸ at least to an extent of 90 percent. Yield data from 225 plots were considered for this study.

⁶/As used in this study a plot was defined as a soil mapping unit from which harvest data were obtained.

⁷/William M. Walker "Measurement of Soil Productivity on Selected Soils in terms of Corn Yields" unpublished M.S. Thesis. University of Tennessee, Knoxville, Tennessee.

⁸/Soil mapping units are catographic separations of soils usually based on soil type, slope gradient and degree of erosion.

II. HARVEST METHODS

The procedures adopted in each of the experiments are given below:

Spacing and Plant Population Experiment

on Hartsells Soil 1960

The number of rows in each of the treatments varied according to the spacing given. One bulk sample of corn was collected from the harvest of all rows, except for two border rows one on each side. The area harvested for each of the different treatments was as follows:

1.5 foot spacing--1/129.6 acre

2 foot spacing--1/155.6 acre

2.5 foot spacing--1/172.9 acre

3 foot spacing--1/172.9 acre

3.5 foot spacing--1/122 acre

The ears collected from the harvested area were shelled at the Tennessee Seed Producers, Inc., Nashville and graded for size.

Plant Population, Nitrogen, Phosphate and

Potash Experiment on Three Soils in Putnam

County 1960

A systematic row method of sampling similar to that described by Walker⁹ was used to locate the harvest areas. Out of eight rows, six rows of fifty feet each were harvested, leaving two rows, one on each side, as borders. Two samples of 12 ears each were collected at random for grading of kernels. One sample came from the first three rows and

⁹/William M. Walker, op. cit., p. 6.

another sample from the other three rows. These samples were shelled in a mechanically operated corn sheller at the Main Experiment Station, Knoxville, and graded for size at the Tennessee Seed Products, Inc., Nashville.

Measurement of the Effect of Certain
Soil and Crop Management Practices on
the Yield of Corn in Tennessee Soils:
1956-1960

A systematic row method of sampling similar to the one described by Walker¹⁰ was used. Six rows of 50' or 75' each were harvested. Plant population also was estimated from these rows. The yields were converted to bushels per acre at 15.5 percent moisture¹¹.

III. KERNEL SIZE NOMENCLATURE AND GRADING OF CORN KERNELS

Kernel Size Nomenclature

Dividing shelled corn into groups of sizes according to width, thickness and length of kernels is referred to as grading (or sizing). The round hole screens were used for dividing the corn into width sizes. The slotted hole screens (with 3/4 inch length holes) were used for thickness sizes. Both round hole and slotted hole screens are shown in Figure 1.

^{10/}Ibid., p. 12.

^{11/}Ibid., p. 42.

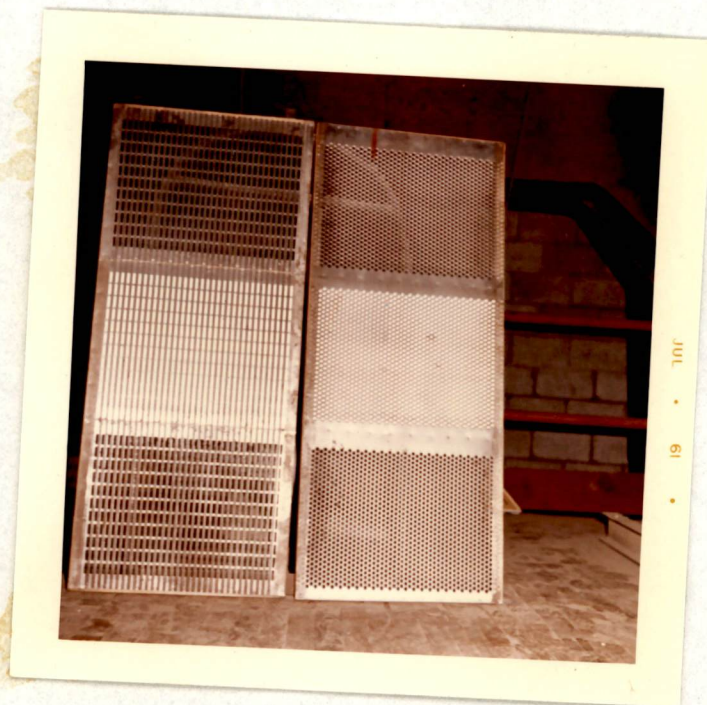


Figure 1.--The slotted hole screen (left) and the round hole screen (right) used in the grading machine.

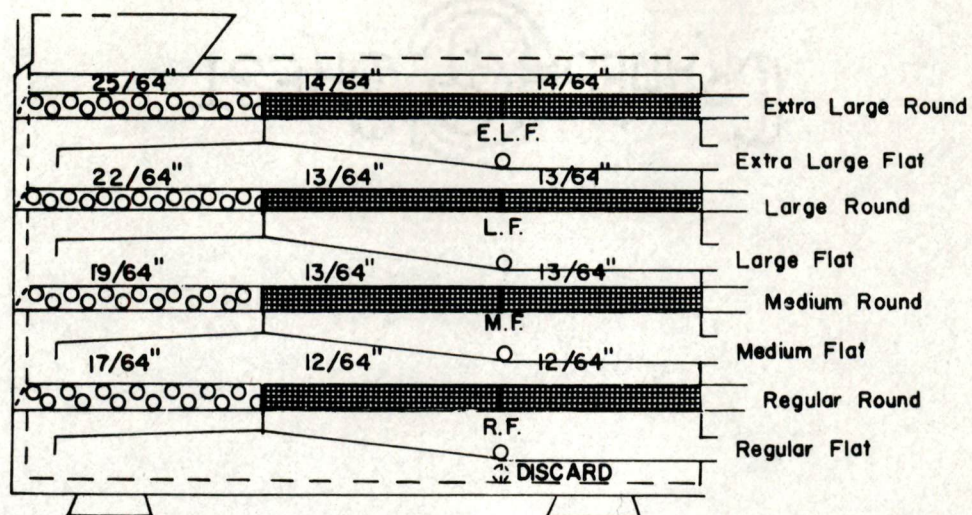
All the corn kernels are divided into 9 grades, i.e., four flats, four rounds and one discard. The names of the grades and the dimensions of kernels are as shown below:

- A. 25/64" to 28/64" --a) Kernels retained across
 (round hole screens) 14/64" slotted hole screens --Extra large round
- b) Kernels pass through
 14/64" slotted hole screens --Extra large flat
- B. 22/64" to 25/64" --a) Kernels retained across
 (round hole screens) 13/64" slotted hole screens --Large round
- b) Kernels pass through
 13/64" slotted hole screens --Large flat
- C. 19/64" to 22/64" --a) Kernels retained across
 (round hole screens) 13/64" slotted hole screens --Medium round
- b) Kernels pass through
 13/64" slotted hole screens --Medium flat
- D. 17/64" to 19/64" --a) Kernels retained across
 (round hole screens) 12/64" slotted hole screens --Regular round
- b) Kernels pass through
 12/64" slotted hole screens --Regular flat
- E. The kernels which are retained above the round hole screens of 28/64" and all those which pass through the minimum of round and slotted hole screens are designated as -----Discard

Grading Corn Kernels

The machine used for grading corn kernels consisted of series of round hole (17/64" to 25/64") and slotted hole (12/64" to 14/64") screens. The cross section of the machine is depicted in figure 2.

The quantity in the sample of corn kernels was 25-30 pounds for each treatment for experiment on Hartsells soil. Each grade was weighed to the nearest of 1/4 lb. In the case of the Putnam County Experiments, the quantity of the sample was 5 to 8 lbs. and each grade was weighed to the nearest gram.



A. Schematic Diagram



B. Actual Machine

Figure No. 2 Machine for Grading of Corn Kernels

IV. METHODS OF STATISTICAL ANALYSIS

Studies on the Size of Corn Kernels

The proportion of different grades of kernels in the samples were converted to a percentage basis (by weight), for equivalent comparisons of different treatment effects. Since the quantity of total flat kernels in bushels per acre is of economic importance to the corn grower, it was also calculated as follows:

$$\begin{array}{rcl} \text{Yield in Bushels of Corn} & & \text{Percentage of total} \\ \text{(all kernels) per acre} & \times & \text{flat kernels (out of} \\ & & \text{all kernels)} \\ & & = \text{Total flat} \\ & & \text{kernels, in} \\ & & \text{bushels per acre.} \end{array}$$

1) Analysis of variance. The percentages of extra large flats, large flats, medium flats, round flats, discards, total flats and total round kernels and yield of flat kernels in bushels per acre were subjected to statistical analysis. The total flat kernels were analyzed separately.

Analysis of variance, using the results of one sample graded, for each treatment, was done in the case of the experiment on Hartsells soils, to determine the effect of spacing, plant population and their interactions, on different grades of kernels. In the case of the experiments in Putnam County, the total figure of two samples graded for size was used for analysis of variance. The effect of soil, P_2O_5 and K_2O , nitrogen and plant population, and their interactions also were studied. The statistical significance was tested by F test at 0.01, 0.05, 0.10 and 0.25 levels of probability. In the case of Putnam County experiments, one sample was missing and it was calculated by standard missing plot technique. This technique was used separately for all the grades of corn kernels, which would be expected to be 100, might vary up to an extent of 0.05 percent.

2) Comparison of Means. Duncan's Multiple Range test was used to compare experimental results where there were more than two means and the Least Significant Difference test was used for comparison of two means only.

Studies on the Yield of Corn

The results of the experiments to study the effect of certain soil and crop management factors on the yield of corn included 13 independent variables as follows:

X ₁ Soil	X ₆ P applied	X ₁₁ Date of planting
X ₂ pH	X ₇ K applied	X ₁₂ Previous crop
X ₃ P test(available P in soil)	X ₈ Lime applied	X ₁₃ Year
X ₄ K test (available K in soil)	X ₉ Plant population	
X ₅ N applied	X ₁₀ Variety	

Yield (Y) of corn was used as dependent variable. Since yield was hypothesized to be a function of all these variables, parameters of a multiple linear regression equation were computed, using the method of least squares. Each of the regression parameters were tested using the 't' test. The regression equation was fitted first for the entire set of 13 independent variables and then refitted several times, one variable being excluded each time. The order of exclusion of variables was (1) year, (2) previous crop, (3) variety, (4) lime applied, (5) K test, (6) P test, (7) K applied, (8) P applied, (9) date of planting, (10) pH, (11) nitrogen applied, and (12) soils. The last variable, plant population was expected to affect the yield most, whereas the first variable excluded, year, was expected to affect the yield least. The

order of exclusions of variables was made on the basis of previous data of response to similar treatments.

1) Coding of variables. To work out the multiple linear regression analysis, a few of the variables, i.e., soil, variety, date of planting and previous crop, which were descriptive rather than numerical, had to be coded. The system followed for coding was to divide the entire range of variables into appropriate groups, e.g., 8 groups of soils, 2 groups of varieties. The variables in each group were similar in regard to certain of their characteristics and had little supposed variation in their effect on the corn yield. Then these groups were arranged in the order of their effect on increasing or decreasing the yield of corn. The numerical value was raised by 10 units from one group to next higher group, i.e., Group I. Soil - Dewy, Code No. 11; Group II Soil - Claiborne, Code No. 21. The variables within the group also were arranged in the order of their effect on increasing or decreasing yields and the numerical value varied by #1 unit from one variable to the next higher variable, i.e., Dewy 11, Decatur 12. The details of coding for each of the variables are described below:

Soils. The data included 17 soils. The seven groups of soils were made of soil series each having certain common characteristics of topography, available water supply, and textural behavior, rooting depth and fertility level¹². No soil on 'D' slope was included for analysis.

^{12/} Joe Elder, Assistant State Soil Scientist, assisted to code these soils.

Later these groups were arranged in the order of their high yielding capacity (considering the effect of soil alone if all the other management inputs were the same). The ratings of the soils coded were as follows:

Group I	Dewy	11	Group V	Etowah	51
	Decatur	12		Hermitage	52
II	Claiborne	21		Minvale	53
	Fullerton	22	VI	Hartsells	61
III	Dunmore	31	VII	Emory	71
IV	Sequatchie	41		Greendale	72
	State	42		Staasser	73
	Hayter	43		Congaree	74
				Huntington	75

Variety. The data included 15 varieties. These varieties were divided into 2 maturity groups, of full-season and mid-season varieties. Numerical values for each group were based on yielding capacity as per its performance trials for one or three to five year averages. The ratings of varieties coded were as follows:

I.	Full season varieties	--	Funks-G. 711	-	11
			P.A.G. 488	-	12
			Tenn. 90	-	13
			Funks-G. 779W	-	14
			Dixie 22	-	15
			Dixie 29	-	16
			Dixie 33	-	17
			Dixie 77	-	17
II.	Mid season varieties	--	Funks-G. 134	-	21
			Stull 400	-	22
			Stull 100	-	22
			Funks-G. 512W	-	22
			Pioneer 309A	-	22
			Tenn. 501	-	23

Previous crop. There were about 30 to 40 crops mentioned as "previous crop" to corn. It was not feasible to code all of them as individual units, if so, the accuracy was difficult to maintain. Therefore, all these crops were divided into 8 groups of cropping patterns,

each including a few prominent cropping systems which are used as rotations with corn. Some of the considerations given for dividing the crops were (1) if the crop is a legume, (2) if heavy fertilizers are usually applied for this crop, (3) if it is a heavy feeder, and (4) according to its residual effect on the corn. The ratings and the code numbers are as follows:

I. Tobacco	11	IV. Improved pasture -	
Raspberries	12	(legume / grass)	41
II. Alfalfa	21	Improved pasture -	
Red clover	22	(grass)	42
Soybeans	23	V. Small grains	51
Lespedeza	24	VI. Corn	61
III. Bottom clover		Summer crop (grass)	62
and vetch	31	VII. Fallow	71
Legume and small		VIII. Unimproved grass	
grain	32	pasture	81

Date of planting. The date of planting was rated as per the climatological year and days which run from March 1st to February 29th, numbering the days from 1 through 366.

The plantings of corn in different fields took place during April, May and June. The dates of planting were coded by appropriate climatological day numbers. This rating is expected to give the effect of early and late planting in linear function.

Other variables. For the other variables, their actual numerical values were used, i.e.,

pH	--Soil pH units
P test in soil	--pounds per acre
K test in soil	--pounds per acre
N applied	--N pounds per acre
P applied	--P ₂ O ₅ pounds per acre
K applied	--K ₂ O pounds per acre
Lime applied	--tons per acre
Plant population	--plants per acre
Year	--1956, 1957, 1958, 1959 and 1960

Statistical computations. The statistical computations were made, according to the available program for Multiple Regression Comprehensive Analysis, written up for use on I.B.M. 704 at the Computing Center of the Tennessee Valley Authority, Chattanooga. Data cards were also punched by the computing center.

Information printed on the output included the following:

- 1) Triangular summation matrix S.
- 2) Prediction value to each observation and prediction error (both of these for the first run with 13 independent and 1 dependent variable only).
- 3) Inverse matrix A and solution to simultaneous equations, along with 'a' and 'b' values.
- 4) Standard deviation of coefficients for each 'b' value.
- 5) Unadjusted regression sum of squares, residual sum of squares, total sum of squares adjusted for the mean, correlation coefficient, square root of residual variance and square root of variance of mean.

It was possible from these computations to:

- 1) obtain multiple regression analysis and to make F test for variation due to regression,
- 2) work out multiple linear regression equation, and
- 3) calculate (percentage) coefficients of determination (R^2).

CHAPTER III

RESULTS AND DISCUSSION

I. EFFECT OF CERTAIN CROP AND SOIL MANAGEMENT PRACTICES ON SIZE OF CORN KERNELS.

The results are discussed by individual treatment effects studied. The effects of (1) plant population, (2) spacing, (3) soil, (4) phosphate and potash, and (5) nitrogen on the size of corn kernels are presented separately. The effect of interactions among these treatments are presented also.

Effect of Plant Population on the Size of Corn Kernels

Comparison of mean percentages of different grades of corn kernels at various plant population levels on Hartsells soil. The F tests (Appendices A through G) show that the effect of plant population on the different grades of corn kernels, i.e., large flat, regular flat and discard kernels, were highly significant¹ and the effect on extra large flat and medium flat kernels were significant². The effect of plant population on total round kernels were significant at the 0.25 probability level³.

¹/The term "highly significant" is used to indicate that the results are significant at the 0.01 probability level.

²/The term "significant" is used to indicate that the results are significant at the 0.05 probability level.

³/Whenever the results are tested at the 0.10 and any other probability level, such level will be clearly stated.

The multiple range tests and comparison of mean percentages of different grades of corn kernels at the plant population levels of 9,000, 12,000, 15,000 and 18,000 plants per acre are presented in Table 1. The results show that plant population of 9,000 plants per acre resulted in a significantly higher percentage of extra large flat and large flat kernels than the other levels whereas there was no significant difference among the 12,000, 15,000 and 18,000 plant populations. The low population of 9,000 plants per acre resulted in a significant decrease in the percentage of medium and regular flat kernels than 18,000 plants per acre. There was no significant difference between 9,000 and 15,000 plants per acre in the case of medium flats, and among 12,000, 15,000 and 18,000 plants per acre in the case of both medium flat and regular flat kernels. Thus these results indicate that a population of 9,000 plants per acre resulted in an increase in the size (thickness) of corn kernels as compared to populations of 12,000, 15,000 and 18,000 plants per acre.

The comparison of the mean percentages of total flat kernels at various plant population levels in Table 1 shows that 9,000 plants per acre resulted in a significantly higher percentage of total flat kernels over 12,000, 15,000 and 18,000 plants per acre. The population level of 12,000 plants per acre also produced significantly higher percentage of total flat kernels than 15,000 and 18,000 plants per acre. However, there was no significant difference of total flat kernels between 15,000 and 18,000 plants per acre. These results indicated that, as the plant population increases, the percentage of total flats tends to decrease.

Table 1.--Comparison of mean percentages of different grades of kernels from corn grown at various plant population levels, Hartsells soil, 1960.

Multiple Range Tests¹

Grade of corn kernels	Mean percentage of kernels			
	(P ₄)	(P ₂)	(P ₃)	(P ₁)
Extra large flats	<u>3.23</u>	<u>3.87</u>	<u>3.94</u>	4.88
Large flats	<u>24.49</u>	<u>26.45</u>	<u>26.56</u>	31.43
Medium flats	<u>48.52</u>	<u>50.22</u>	<u>51.19</u>	52.54
Regular flats	<u>4.85</u>	<u>6.57</u>	<u>7.18</u>	7.42
Total flats	<u>87.68</u>	<u>87.80</u>	88.20	89.77
Total rounds ²	<u>7.46</u>	<u>8.27</u>	<u>8.58</u>	8.89
Discards	<u>2.74</u>	<u>3.42</u>	<u>3.51</u>	3.62

Legend: P₁ - 9,000 plants per acre

P₂ - 12,000 plants per acre

P₃ - 15,000 plants per acre

P₄ - 18,000 plants per acre

¹Any two means underscored by the same line are not significantly different from each other at the 0.05 probability level.

²F test significant at the 0.25 probability level.

The comparison of mean total round kernel percentages at different plant populations per acre indicated that higher plant populations per acre tended to give numerically higher percentage of total round kernels. The comparison of mean percentages of discard kernels in Table 1 shows that a 9,000 plant population per acre produced significantly lower percentage of discard kernels than 12,000, 15,000 and 18,000 plant populations per acre. There was no significant difference for discard kernels among 12,000, 15,000 and 18,000 plant populations per acre.

Dungan et al. (6) reported that size of kernels was reduced by increasing plant population. They further stated that general observation and extensive data at the Illinois Experiment Station showed that small ears on thick plants had a larger proportion of round odd shaped kernels than ears produced on medium stands. The results of a rate of planting experiment with 7,000, 11,000 and 15,000 plants per acre conducted by Pioneer Hibred Corn Company, Iowa (26) in 1949 showed that, as the planting rate increased, there was a tendency for the percentage of rounds to increase and the percentage of flats to decrease. The results of experiment on Hartsells soil indicates that plant population levels of 12,000, 15,000 and 18,000 plants per acre resulted in a decrease of the total flat kernels and in an increase in the total round and discard kernels, as compared with the effect of 9,000 plants per acre. These findings are in accordance with the findings of Pioneer Hibred Corn Company, Iowa.

Comparison of mean percentages of different grades of corn kernels at two plant population levels in Putnam County experiments. In the Putnam County experiments, only two (low and high) plant population

levels for each soil series were attempted, i.e., for Dickson 8,000 and 16,000 plants per acre; for Waynesboro 12,000 and 24,000 plants per acre, and for Huntington soil 16,000 and 32,000 plants per acre. The plant population levels which were actually obtained in the field were, on an average, for Dickson, 10,000 and 16,000 plants per acre; for Waynesboro, 12,000 and 24,000 plants per acre; and for Huntington, 15,500 and 25,000 plants per acre. The F tests for the effect of plant population on extra large flat, regular flat and discard kernels were highly significant. The effect on large flat and medium flat kernels were significant and the effect on total round kernels was not significant (Appendices I-O). The comparison of mean percentages of different grades of corn kernels between low and high plant population levels are presented in Table 2.

The results show that the effect of low plant population significantly increased the percentage of extra flat and large flat kernels and significantly decreased the percentage of medium flat and regular flat kernels, as compared with higher plant populations. The mean percentages of total flats and total rounds at low and high plant population levels, though were not significant, indicated that low plant population resulted in a numerically higher percentage of flat kernels and lower round kernels. It was reported earlier that on Hartsells, the total flat kernels was affected significantly by plant population. The reason for not observing significant differences of total flat kernels between low and high plant population levels in these experiments may be due to the fact that both the plant population levels had been adjusted to soil productivity variations and were more nearly at optimum levels.

Table 2.--Comparison of mean percentages of different grades of kernels from corn grown at two plant population levels in Putnam County, 1960.

Grade of corn kernels	Plant populations per acre		L.S.D. ² at probability levels		
	Low ¹ Mean percentage	High ¹ Mean percentage	0.01	0.05	0.10
Extra large flats	5.47	4.12	1.09	--	--
Large flats	34.89	32.94	N.S	1.53	--
Medium flats	41.97	44.26	N.S	1.73	--
Regular flats	5.66	6.53	0.86	--	--
Total flats	87.99	87.76	--	--	N.S.
Total rounds	10.27	10.11	--	--	N.S.
Discards	1.72	2.18	0.28	--	--

Legend: Dickson - Low 8,000 plants per acre
- High 16,000 plants per acre

Waynesboro - Low 12,000 plants per acre
- High 24,000 plants per acre

Huntington - Low 16,000 plants per acre
- High 32,000 plants per acre

¹The mean percentages of different grades of corn kernels show the main effect of low and high plant populations for all the soils.

²Least significant difference.

The mean percentages of discard kernels in Table 2, for low and high plant population levels, show that the effect of lower plant population has significantly reduced the discard kernels as compared to higher plant population. The discard kernels consist of the undeveloped, very small corn kernels from the tip of corn ear. High plant populations may interfere with proper pollination and kernel development, and increase the proportion of discards.

Comparison of mean percentages of different grades of corn kernels for three soils at two plant population levels. The F tests for the effect of interaction of soil and plant population in the Putnam County experiments were highly significant in the case of large flat kernels, and significant for medium flat kernels (Appendices J and K). The mean percentages of different grades of corn kernels for the interaction between three soils and two plant population levels are given in Table 3. The results indicate that Dickson soil with low plant population resulted in an increase in percentage of the large flat kernels and resulted in a decrease of the medium flat kernels significantly over the other combinations of soil and population. The low plant population level for Dickson soil was 10,000 plants per acre whereas for the Waynesboro and Huntington soils the levels were 14,000 and 15,500 plants per acre, respectively. This difference in the number of plants per acre for the low plant population level may have had an effect on the results obtained. Huntington which is a high productive soil, with 15,500 plants per acre, increased the large flats significantly over Waynesboro with 14,000 plants per acre. These results show that plant population effects on the size of corn kernel were greater than the effects of

Table 3.--Comparison of mean percentages of flat kernels from corn grown on three soils at two plant population levels in Putnam County, 1960.

Multiple Range Tests¹

Grade of corn kernels	Mean percentage of kernels					
	(HP ₂)	(HP ₁)	(DP ₂)	(WP ₂)	(DP ₁)	(WP ₁)
Extra large flats ²	3.97	4.01	4.18	4.20	6.19	6.22
Large flats	(WP ₁)	(WP ₂)	(HP ₂)	(DP ₂)	(HP ₁)	(DP ₁)
	30.97	32.26	32.75	33.81	34.56	39.14
Medium flats	(DP ₁)	(HP ₁)	(WP ₂)	(DP ₂)	(WP ₁)	(HP ₂)
	38.53	43.12	44.11	44.21	44.25	44.45
Regular flats	(DP ₁)	(HP ₁)	(DP ₂)	(HP ₂)	(WP ₁)	(WP ₂)
	4.47	6.11	6.21	6.37	6.38	7.00

Legends: H - Huntington
W - Waynesboro
D - Dickson

P₁ - Low plant population
P₂ - High plant population

¹Any two means underscored by the same line are not significantly different from each other at the 0.05 probability level.

²F test significant at the 0.10 level of probability.

³F test significant at the 0.25 level of probability.

Waynesboro, Dickson and Huntington soils.

Yield in bushels of corn and flat kernels for various plant population levels on Hartsells soil and in Putnam County. The percentages of different grades of corn kernels in Tables 1 and 2 show that the lower levels of plant populations used in these experiments resulted in an increase of 1 to 5 percent in extra large flat kernels and a decrease of 2 to 3 percent in medium flat and regular flat kernels. The total kernels were affected by about 0.5 to 2 percent. Thus it appeared to be of interest to study the extent to which this variation in size of kernels would affect the yield in bushels per acre of particular grades of kernels. Since all the flat kernels have economic value for seed (the round and discard kernels are not marketed usually for seed) the yield in bushels per acre of total flat kernels for different plant populations were calculated and are presented in Table 4.

Twelve thousand plants per acre on Hartsells soil produced 87.8 bushels of corn per acre, as compared to 82.2, 84.4 and 83.3 bushels of corn per acre for 9,000, 15,000 and 18,000 plant population per acre, respectively. Thus, a reduction of about 5 bushels of corn (all kernels) per acre (about 6 percent)⁴ from 12,000 to 9,000 plants per acre would mask the effect of a 2 percent increase in the flat kernels produced by 9,000 plants per acre, as compared to 12,000 plants per acre. In Putnam County experiments, the increase in the total flat kernels by using low plant population level was less than one percent and a decrease of 1.1

⁴/ Decrease of 5.6 bushels of corn was for 87.7 bushels of corn; therefore, there was a decrease of 6.2 bushels per 100 bushels of corn. Similar calculations are made for other comparisons.

Table 4.--Mean total yield of corn (all kernels) and yield of total flat kernels from corn grown at various levels of plant population on Hartsells soil and in Putnam County, 1960.

Plant population Per acre	Yield in bushels per acre ¹	
	All kernels	Flat kernels
Experiment on Hartsells soil		
9,000	88.2	73.8
12,000	87.8	77.8
15,000	84.4	74.6
18,000	83.3	74.1
Experiments in Putnam County		
Low	117.8	104.0
High	118.9	104.6

¹F test not significant at the 0.25 level of probability.

bushels of all kernels (about one percent) by using low plant population level. Therefore the effect of increase in the yield of all kernels by higher plant population masked the effect of decrease in flat kernels. Thus both these experiments gave similar trends. Therefore, as long as the percentage increase in yield of all kernels is greater than the percentage decrease in total flat kernels, the effect of lower plant population on the increase in the size of kernels is not advantageous. The results of experiment on rate of planting with 2, 3, 4 and 5 kernels per hill conducted in 1946 by Pioneer Hibred Corn Company, Iowa (27) show that, in general, the total bushels for kernel size follow the grading percent, although the higher total yield with an increase in planting rate helps to compensate for reduction in grading percent. The results of these experiments also indicated that even with a small seeded variety such as 330, it was more profitable to plant a heavier rate and benefit from additional yield than to increase the desirable kernel size percentages with lower rates of planting.

The results of the experiments on both Hartsells soil and Putnam County also show that yield of all kernels is a major factor affecting the yield of total flat kernels produced.

Effect of Spacing on the Size of Corn Kernels

Comparison of mean percentages of different grades of corn kernels at various spacing levels on Hartsells soil. The experiment on Hartsells soil included five different row spacings. The effect of these spacings, i.e., 1.5 foot, 2 foot, 2.5 foot, 3 foot and 3.5 foot, was not significant (Appendices A through G) for any of the grades of corn kernels. The

mean percentages of different grades of corn kernels for these spacings are given in Table 5.

The percentages of different grades of flat kernels and discard kernels do not show any trend of the effect of spacings on the size of corn kernels. The percentage of total flat kernels in Table 5 for different spacings showed a numerical increase by less than one percent from 1.5 foot or 2 foot spacings to 3.5 foot spacing. The percentage of round kernels showed a numerical decrease by about one percent from 1.5 foot spacing to 3.5 foot spacing. It is probable that wider spacing will have the same effect as lower plant population and the total flat kernels might increase. As the spacing between rows is increased keeping the plant population constant, the spacing between plants within the row will be decreased. Therefore wider spacing with low plant population may have a favorable effect (increase in size of corn kernels) than higher plant population at the same spacing. Thus an optimum combination of both spacing and plant population may be necessary to obtain the desired grade of corn kernels. The combined effect of spacing and plant population on the different grades of corn kernels is discussed below.

Comparison of mean percentages of different grades of corn kernels for five spacings and four plant populations on Hartsells soil. The F tests for the interaction between spacing and plant population (Appendices A through G) show that the results were significant at the 0.25 level of probability for total flat, total round and discard kernels. There was no significant difference between the various spacing levels for the different grades of flat kernels.

Table 5.--Comparison of mean percentages of different grades of kernels from corn grown at various spacing levels, Hartsells soil, 1960.

Grade of corn kernel	Spacing between rows in feet ¹				
	3½	3	2½	2	1½
Extra large flats	4.14	3.58	3.92	4.00	4.28
Large flats	27.24	26.54	29.07	25.49	27.87
Medium flats	51.00	51.31	49.69	51.10	50.00
Regular flats	6.42	7.06	5.59	6.95	6.01
Total flats	88.82	88.53	88.28	88.04	88.15
Total rounds	7.62	8.04	8.58	8.44	8.80
Discards	3.52	3.40	3.10	3.50	3.02

¹F test not significant at the 0.25 level of probability.

The mean percentages of different grades of corn kernels for the interaction between spacing and plant population are presented in Table 6. The results showed that 3.5 foot spacing, combined with 9,000 plants per acre resulted in an increase in extra large flat kernels by about 2 percent and in a decrease in the proportion round and discard kernels by about 1 to 2 percent, as compared to the 3.5 foot spacing and 12,000, 15,000 and 18,000 plants per acre. It can be seen also from Table 6 that higher plant populations of 12,000, 15,000 and 18,000 plants per acre increased the discard kernels for the 3, 2.5 and 2 foot spacings.

Yield in bushels of corn (all kernels) and flat kernels for various spacing levels on Hartsells soil. The F test for the effect of spacing on flat kernels in bushels per acre was significant at the 0.10 level of probability (Appendix H). It can be seen in Table 7 that 1.5 foot and 3.5 foot spacings produced more flat kernels per acre than other spacings. The same trend is evident in the case of yield of all kernels. As discussed previously the percentages of total flat kernels were affected by less than one percent by the different spacings. The total yield of corn (all kernels) was affected by about 15 bushels per acre (16 percent). Therefore the optimum spacing for the maximum yield of corn also produced maximum yield of flat kernels.

Effect of Soils on the Size of Corn Kernels

Comparison of mean percentages of different grades of corn kernels for Dickson, Waynesboro and Huntington soils in Putnam County. The F tests for the effect of soil on the size of corn kernels (Appendices I through O) were significant at the 0.25 level of probability for large

Table 6.--Comparison of mean percentages of different grades of kernels from corn grown at five spacings and four plant population combinations on Hartsells soil, 1960.

Spacing between rows in feet	Plants per acre	Grade of corn kernels (mean of 4 replications)						
		Extra ² large flats	Large ² flats	Medium ² flats	Reg-2 ular flats	Total ¹ flats	Total ¹ rounds	Discards ¹
3½	9,000	6.55	33.03	47.19	4.05	90.84	6.51	2.61
	12,000	3.13	25.11	52.76	7.34	88.35	7.56	4.07
	15,000	3.33	24.65	52.07	7.88	87.93	7.79	4.26
	18,000	3.56	26.19	51.99	6.40	88.15	8.64	3.20
3	9,000	3.44	31.56	49.16	5.87	90.03	7.08	2.86
	12,000	3.67	26.26	53.61	6.54	90.08	6.49	3.40
	15,000	4.64	25.73	48.96	7.53	86.87	9.33	3.78
	18,000	2.56	22.75	53.49	8.32	87.13	9.29	3.56
2½	9,000	4.07	31.35	50.77	4.25	90.44	7.23	2.30
	12,000	3.74	28.05	48.47	6.00	86.26	9.99	3.73
	15,000	4.57	30.20	47.53	5.72	88.03	8.91	3.06
	18,000	3.29	26.68	51.99	6.41	88.37	8.21	3.40
2	9,000	4.93	28.93	49.88	5.70	89.45	7.58	2.95
	12,000	4.01	23.82	50.93	7.91	86.68	9.45	3.86
	15,000	3.30	26.72	52.12	6.97	89.11	7.37	3.50
	18,000	3.75	22.52	51.43	9.23	86.93	9.38	3.69
1½	9,000	5.43	32.65	45.61	4.41	88.11	8.90	2.97
	12,000	4.80	29.54	50.18	5.08	89.61	7.87	2.51
	15,000	3.88	24.95	50.42	7.82	87.07	9.51	3.40
	18,000	2.99	24.33	53.78	6.72	87.82	8.91	3.26

¹F test significant at the 0.25 level of probability.

²F test not significant at the 0.25 level of probability.

Table 7.--Mean corn yield of all kernels and the flat kernels at various levels of spacing on Hartsells soil, 1960.

Spacing between rows in feet	Yield in bushels per acre	
	All kernels ¹	Flat kernels ²
3½	88.5	79.71
3	75.9	67.34
2½	83.2	73.39
2	83.7	74.43
1½	90.8	80.63

¹F test significant at the 0.25 level of probability.

²F test significant at the 0.10 level of probability.

flat and total flat kernels. For the other grades of kernels, the effect was not significant. The percentages of different grades of corn kernels for three soils are presented in Table 8.

The results indicate that Dickson soil resulted in an increase of less than one percent of total flat kernels, and 3 to 5 percent of large flat kernels as compared with Waynesboro and Huntington soils. This is likely to be misleading, since the low or high populations on Dickson were not comparable to the plant population levels on Waynesboro or Huntington. Pioneer Hibred Corn Company, Iowa from the results of experiment (8) with planting rates of $2\frac{1}{2}$, 3, $3\frac{1}{2}$, and 4 plants per 40" x 40" hill found a final stand of 12,000 plants per acre gives optimum yield of corn. A certain high yielding plot produced still higher yield of flats at 15,700 plants per acre. In view of these results it is expected that high productive soils like Huntington will produce higher percentage of flat kernels, even with higher plant population per acre, than the low productive soils like Dickson at the same plant population per acre. This type of interaction between soils and plant population was studied and is presented below.

Yield in bushels of corn (all kernels) and flat kernels for Dickson, Waynesboro and Huntington soils at two plant population levels.

The F test for the interaction between population and soils (Appendix P) was significant for total flat kernels and highly significant (24) for total yield of corn (all kernels). The results from Table 9 show that yield of corn increased with higher plant populations in the case of Dickson soil. The yield decreased with higher plant populations for both Waynesboro and Huntington soils. This was probably due to the fact

Table 8.--Comparison of mean percentages of different grades of kernels from corn grown on Dickson, Waynesboro and Huntington soils in Putnam County, 1960.

Grade of corn kernels	Soil series		
	Dickson	Waynesboro	Huntington
Extra large flats ²	5.19	5.21	3.99
Large flats ¹	36.47	31.61	33.66
Medium flats ²	41.37	44.18	43.79
Regular flats ²	5.35	6.69	6.24
Total flats ¹	88.38	87.69	87.69
Total rounds ²	9.84	10.49	10.24
Discards ²	1.77	2.03	2.06

¹F test significant at the 0.25 level of probability.

²F test not significant at the 0.25 level of probability.

Table 9.--Mean corn yield of all kernels and flat kernels, for Dickson, Waynesboro and Huntington soils at two plant population levels in Putnam County, 1960.

Soil series	Yield in bushels per acre					
	All kernels			Flat kernels		
	Low plant population	High plant population	Mean ¹	Low plant population	High plant population	Mean ²
Dickson	102.4	111.1	106.7	90.44	98.23	94.33
Waynesboro	124.8	121.0	122.9	109.75	105.76	107.76
Huntington	126.3	124.5	125.9	111.87	109.76	110.81

¹F test significant at the 0.01 level of probability.

²F test significant at the 0.05 level of probability.

that, in the case of Waynesboro, optimum plant populations were reached while increasing from 12,000 to 24,000 plants per acre and for Huntington from 16,000 to 32,000 plants per acre. In the case of Dickson the increase of 8,000 to 16,000 plants per acre had a beneficial effect. Comparison of total flat kernels in bushels per acre for Dickson with high plant population (16,000 plants per acre) and Huntington with low plant population (15,500 plants per acre) show that Huntington yielded 13.50 bushels of flat kernels more than the Dickson Soil. Therefore, high productive soils like Huntington with low plant population may produce a higher proportion of total flat kernels than the lower productive soils like Dickson, at the same plant population levels.

Effect of Nitrogen on the Size of Corn Kernels

Comparison of mean percentages of different grades of corn kernels for two nitrogen levels. The F tests for the effect of nitrogen (Appendices I through O) on the size of corn kernels were significant at the 0.25 level of probability for large flat, regular flat, discard and total flat kernels. The F tests were not significant for extra large flat, medium flat and total round kernels.

The mean percentages of different grades of corn kernels for both 220 lbs. of nitrogen per acre and 420 lbs. nitrogen per acre are presented in Table 10. The results show that the percentages of total flat kernels tended to increase, the percentage of total round and discard kernels tended to decrease as the level of nitrogen applied was increased from 220 lbs. to 420 lbs. per acre. Application of 440 lbs. nitrogen per acre increased the percentage of extra large flat kernels and decreased

Table 10.--Comparison of mean percentages of different grades of kernels from corn grown with 220 lbs. and 420 lbs. per acre of nitrogen in Putnam County, 1960.

Grade of corn kernels	Nitrogen in lbs. per acre	
	220 lbs.	420 lbs.
Extra large flats ²	4.82	4.77
Large flats ¹	33.24	34.59
Medium flats ²	43.28	42.94
Regular flats ¹	6.34	5.84
Total flats ¹	87.70	88.06
Total rounds ²	10.26	10.12
Discards ²	2.24	1.88

¹F test significant at the 0.25 level of probability.

²F test not significant at the 0.25 level of probability.

regular flat kernels. It has been reported (5) that small ears with unfilled tips are caused by the nitrogen deficiency at a critical time. In Putnam County experiments no marked effect of nitrogen on the different grades of corn kernels was observed. This may be due to the fact that nitrogen levels used in these experiments, i.e., 220 lbs and 420 lbs per acre are sufficiently higher levels than the levels usually practiced by farmers.

Comparison of mean percentages of different grades of corn kernels for three soils at two nitrogen levels. The interaction between soils and nitrogen was significant for large flat and regular flat kernels, but not significant for other grades of kernels. Multiple range tests for these first two grades of corn kernels are presented in Table 11.

The results in Table 11 indicate that, for Huntington soil, application of 440 lbs. nitrogen per acre gave significantly more large flats and less regular flat kernels than the 220 lbs. nitrogen per acre. There was no significant difference for these two grades of kernels at 220 lbs. and 440 lbs. nitrogen per acre in the case of both Dickson and Waynesboro soils. Response for nitrogen is expected in the case of Huntington, since it is a bottom soil with more available moisture supply. Thus, Huntington soil at the higher level of nitrogen resulted in an increase in the size (thickness) of corn kernels. It can be seen further also from Table 11 that Dickson soil with both low and high nitrogen levels resulted in a higher percentage of large flat kernels than other soils. This may have been due to the lower plant population levels in Dickson soil.

Table 11.--Comparison of mean percentages of different grades of kernels from corn grown on three soils and two nitrogen levels in Putnam County, 1960.

Multiple range tests¹

Grade of corn kernels	Percentage kernels					
	(HN ₁)	(WN ₂)	(WN ₁)	(HN ₂)	(DN ₂)	(DN ₁)
Large flats	<u>31.21</u>	31.29	<u>31.94</u>	<u>36.10</u>	36.37	36.57
	(HN ₂)	(DN ₂)	(DN ₁)	(WN ₁)	(WN ₂)	(HN ₁)
Regular flats	<u>5.26</u>	5.31	5.38	<u>6.43</u>	6.95	7.22

¹Any two means underscored by the same line are not significantly different from each other at the 0.05 level of probability.

Legend: H - Huntington
W - Waynesboro
D - Dickson

N₁ - 220 lbs. nitrogen per acre

N₂ - 420 lbs. nitrogen per acre

Comparison of mean percentages of different grades of corn kernels for two plant populations and two nitrogen levels. Interaction between nitrogen and plant population was significant for extra large flat kernels, (Appendix I), and significant at the 0.10 level of probability for medium flat kernels. For the other grades of kernels, the interaction was not significant. The mean percentages of extra large flat and medium flat kernels and the multiple range tests for the combinations of nitrogen and plant population are given in Table 12.

The results show that low plant population, in combination with 440 lbs. nitrogen per acre, resulted in a higher percentage of extra large flats, as compared with high plant population and 440 lbs. nitrogen per acre. The percentage of the medium flats tended to decrease with the low plant population and 440 lbs. nitrogen per acre, as compared with high plant population and 440 lbs. nitrogen per acre.

Yield in bushels of corn (all kernels) and flat kernels for low and high nitrogen levels in Putnam County. The F test for the effect of nitrogen on the yield of flat kernels was significant at the 0.10 level of probability, whereas in the case of total corn (all kernels) yield, it was significant (24) at the 0.05 level of probability. The yields in bushels per acre of all kernels and the total flat kernels are presented in Table 13.

Since application of high level of nitrogen (440 lbs. per acre) increased the total flat kernels by 0.3 percent only and the yield of all kernels was decreased by 3 to 4 percent, the total yield of flat kernels also decreased. The reduction in the yield of kernels by increasing the level of nitrogen from 220 lbs. to 420 lbs. further

Table 12.--Comparison of mean percentages of different grades of kernels from corn grown at two plant populations and two nitrogen levels in Putnam County, 1960.

Multiple range tests¹

Grade of corn kernels	Percentage kernels			
	(P ₂ N ₂)	(P ₂ N ₁)	(P ₁ N ₁)	(P ₁ N ₂)
Extra large flats	3.66	<u>4.58</u>	5.06	5.89
	(P ₁ N ₂)	(P ₁ N ₁)	(P ₂ N ₁)	(P ₂ N ₂)
Medium flats ²	<u>41.67</u>	42.87	43.66	44.81

¹Any two means underscored by the same line are not significantly different from each other at the 0.05 level of probability.

²Significant at the 0.10 level of probability.

Legend: P₁ - Low population

N₁ - 220 lbs. nitrogen per acre

P₂ - High population

N₂ - 420 lbs. nitrogen per acre

Table 13.--Mean corn yield of all kernels at two levels of nitrogen in Putnam County, 1960.

Nitrogen lbs. per acre	Yield in bushels per acre	
	All kernels ¹	Flat kernels ²
220 lbs. N. per acre	120.73	106.30
420 lbs. N. Per acre	116.30	102.57

¹F test significant at the 0.05 level of probability.

²F test significant at the 0.10 level of probability.

confirms that even 220 lbs. of nitrogen is a high level for corn. The findings of Pioneer Hibred Corn Company, Iowa who experimented with application of 60 lbs. N, P_2O_5 and K_2O fertilizers found (20) that the percentage flat kernels and total bushels of flat kernels increased as nitrogen was increased in the fertilizer. These findings are not in accordance with the findings in Putnam County experiments.

Effect of Phosphate and Potash on the Size of Corn Kernels

Comparison of mean percentages of different grades of corn kernels for two levels of phosphate and potash. Two levels (220 lbs. and 420 lbs. P_2O_5 and K_2O per acre) of phosphate and potash applications were included in experiments in Putnam County. The F tests for the effect of phosphate and potash were highly significant for regular flat kernels, significant for large flat kernels, and significant at the 0.25 level of probability for medium flat and discard kernels (Appendices I through O). For the other grades of corn kernels the F tests were not significant.

The mean percentages of different grades of corn kernels are given in Table 14. The results show that with the application of 420 lbs. of phosphate and potash, the percentages of large flat kernels decreased significantly and the percent of regular flat kernels increased significantly, as compared with the application of 220 lbs. of P_2O_5 and K_2O per acre. The application of 440 lbs. of P_2O_5 and K_2O tended to decrease numerically the total flat kernels and increase the rounds and discard kernels. The findings of Pioneer Hibred Corn Company, Iowa (26) show that the plots with 100 lbs. of 3-18-9 starter fertilizer had a higher percent of flats and lower percent of round kernels than the check. For another

Table 14.--Comparison of mean percentages of different grades of kernels from corn grown with 220 lbs. and 420 lbs. per acre of P_2O_5 and K_2O in Putnam County, 1960.

Grade of corn kernel	P_2O_5 and K_2O in		L.S.D. ³ at probability levels		
	Lbs. Per Acre 220 lbs.	420 lbs.	0.01	0.05	0.10
Extra large flats ¹	4.73	4.87	--	--	N.S.
Large flats	35.08	32.75	N.S.	1.81	--
Medium flats ¹	42.50	43.72	--	--	N.S.
Regular flats	5.72	6.47	0.73	0.52	--
Total flats ²	87.94	87.81	--	--	N.S.
Total rounds ²	10.15	10.23	--	--	N.S.
Discards ¹	1.89	2.02	--	--	N.S.

¹F test significant at the 0.25 level of probability.

²F test not significant at the 0.25 level of probability.

³Least significant difference.

variety, when 150 lbs. of 3-12-12 starter fertilizer was applied, a smaller percentage of flats and a higher percentage of rounds was obtained. In the experiments in Putnam County, out of the 220 or the 420 lbs. of P_2O_5 and K_2O fertilizer applied, 20 lbs. was the starter fertilizer. It is reported also (5) that ears having poorly filled tips and loose chaffy kernels may indicate a potash shortage, and small twisted ears with undeveloped kernels indicate lack of phosphorus. The results of experiments in Table 14 did not indicate the reduction of discard kernels (which are mostly undeveloped kernels) with the application of 220 lbs and 440 lbs of P_2O_5 and K_2O per acre. This may be due to the fact that the levels of phosphate and potash are higher levels than usually practiced.

Comparison of mean percentages of different grades of kernels for Dickson, Waynesboro and Huntington soils at two levels of nitrogen and phosphate and potash in Putnam County. The F tests for the interaction among nitrogen, phosphate and potash and soil was significant for total flat, total round and discard kernels, significant at the 0.10 level of probability for extra large flats and large flat kernels and significant at the 0.25 level of probability for medium flat kernels. This interaction was not significant for regular flat kernels. (Appendices I through O). The mean percentages of different grades of corn kernels for the three soils at two levels of phosphate and potash and two levels of nitrogen are presented in Table 15.

The results show that the application of 220 lbs. P_2O_5 and K_2O and 420 lbs. of nitrogen tended to give higher percentage of flats and a lower percentage of rounds and discard kernels in Waynesboro and

Table 15.--Mean percentages of different grades of kernels from corn grown on three soils with two nitrogen and two phosphate and potash levels in Putnam County, 1960.

Grade of corn kernel	Dickson P ₂ O ₅ and K ₂ O				Waynesboro P ₂ O ₅ and K ₂ O				Huntington P ₂ O ₅ and K ₂ O			
	220 lbs./A	420 lbs./A	220 lbs./A	420 lbs./A	220 lbs./A	420 lbs./A	220 lbs./A	420 lbs./A	220 lbs./A	420 lbs./A	220 lbs./A	420 lbs./A
	220	420	220	420	220	420	220	420	220	420	220	420
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Extra large flats ²	5.84	4.65	4.66	5.58	4.77	5.49	5.48	5.12	3.98	4.10	4.70	3.68
Large flats ²	38.67	36.87	34.45	35.87	30.90	33.95	32.98	28.62	31.93	38.12	30.48	34.86
Medium flats ³	39.78	41.04	42.56	42.13	45.15	42.82	42.76	45.87	45.18	41.08	44.30	44.57
Regular flats	4.42	5.46	6.33	5.17	6.35	6.57	6.50	7.32	6.98	4.88	7.84	5.63
Total flats ¹	88.67	88.03	88.02	88.76	87.18	88.34	87.70	87.03	87.21	88.19	87.36	87.97
Total rounds ¹	9.56	10.24	10.03	9.52	10.63	9.93	10.21	11.12	10.54	9.92	10.50	9.91
Discards ¹	1.75	1.70	1.92	1.69	2.08	1.70	2.07	2.29	2.23	1.36	2.07	2.05

¹/Significant at the 0.05 level of probability.

²/Significant at the 0.10 level of probability.

³/Significant at the 0.25 level of probability.

Huntington soils as compared to other levels of nitrogen, P_2O_5 and K_2O for the same soils. For Dickson, 220 lbs. N with 220 lbs. P_2O_5 as well as 440 lbs. nitrogen and 440 lbs. P_2O_5 and K_2O produced more flat kernels and less round and discard kernels.

Yield in bushels per acre of all kernels and flat kernels at 220 lbs. and 420 lbs. of P_2O_5 and K_2O . The F test for the effect of P_2O_5 and K_2O on the total flat kernels was not significant (Appendix P). The percentage of total flat kernels decreased by less than one percent as the level of P_2O_5 and K_2O was increased from 220 lbs. to 420 lbs. per acre. The yield of all kernels was also decreased from 119 to 117 bushels per acre. Therefore the yield of flat kernels was decreased from 106 bushels per acre to 102 bushels per acre.

II. EFFECT OF CERTAIN CROP AND SOIL MANAGEMENT FACTORS ON THE YIELD OF CORN

The study included 13 crop and soil management factors (independent variables) which affect the yield of corn (dependent variable).

These independent variables were as follows:

X_1 - Soil	X_8 - Lime applied
X_2 - pH	X_9 - Plant population
X_3 - Available P (in soil) test	X_{10} - Variety
X_4 - Available K (in soil) test	X_{11} - Date of planting
X_5 - Nitrogen applied	X_{12} - Previous crop
X_6 - P_2O_5 applied	X_{13} - Year
X_7 - K_2O applied	

The statistical computations were made for 13 combinations of independent variables, by excluding one variable each time as described

in methods and procedures. The statistical computations are discussed separately for (1) Multiple linear correlation coefficients, (2) Multiple linear regression equations, and (3) Standard partial regression coefficients.

Multiple linear correlation coefficients and coefficients of determination (R^2) for various combinations of independent variables.

The multiple linear regression analysis for the various combinations of independent variables are presented in Appendix Q. The F tests, for regression, for all the combinations of independent variables were highly significant.

The multiple linear correlation coefficients and the coefficients of determination, for all the combinations of independent variables are presented in Table 16. The results show that highest coefficient of determination (R^2) in percentage, 56.5 was obtained when all the 13 independent variables were included. The percentage was 33.50 when plant population alone was included as the independent variable. The effect of exclusion of a particular variable in the reduction of R^2 value was estimated by obtaining the difference between two combinations of independent variables. The percentage explanations (R^2) reduced by exclusion of each of the variables are also presented in Table 16. The results show that, when year, nitrogen and soil were excluded, the percentage explanations were reduced to the order of 8.8, 7.2 and 3.5, respectively. All the remaining variables together explained less than 5 percent. However, it should be recognized that unless the independent variables are truly independent, the order of dropping variables is

Table 16.--Multiple linear correlation coefficients and coefficients of determination (R^2) for various combinations of independent variables with yield of corn as dependent variable.

Combination of independent variables	R Multiple correlation coefficient	R^2 Coefficient of determination in percentage	Difference due to independent variable	R^2 Percent
1. X_1 through X_{13}	0.7514	56.462		
2. X_1 through X_{12}	0.6903	47.657	Year	8.805
3. X_1 through X_{11}	0.6898	47.594	Previous crop	0.063
4. X_1 through X_9, X_{11}	0.6894	47.530	Variety	0.064
5. X_1 through X_7, X_9, X_{11}	0.6877	47.298	Lime applied	0.232
6. $X_1, X_2, X_3, X_5, X_6, X_7, X_9, X_{11}$	0.6833	46.702	K test	0.596
7. $X_1, X_2, X_5, X_6, X_7, X_9, X_{11}$	0.6833	46.695	P test	0.007
8. $X_1, X_2, X_5, X_6, X_9, X_{11}$	0.6797	46.203	K applied	0.492
9. $X_1, X_2, X_5, X_9, X_{11}$	0.6778	45.944	P applied	0.259
10. X_1, X_2, X_5, X_9	0.6720	45.168	Date of planting	0.776
11. X_1, X_5, X_9	0.6657	44.324	pH	0.844
12. X_1, X_9	0.6086	37.049	Nitrogen	7.275
13. X_9	0.5788	33.505	Soil	3.544

likely to affect this estimate of the separate effect of particular variables.

Multiple linear regression coefficients ('b' values) and multiple linear equations for several combinations of independent variables. The multiple linear regression equations were fitted by the method of least square to various combinations of independent variables with yield of corn as dependent variable. The prediction equation for each set of variables is presented in Appendix R. The multiple linear regression coefficients and their standard errors for all the combinations of independent variables corresponding to the above equations are presented in Table 17.

The 't' tests for different 'b' values (equation 1 which included all the 13 independent variables), show that (1) year (X_{13}), soil (X_1) and plant population (X_9) were significant at the 0.001 level of probability, (2) pH (X_2) was significant at the 0.01 level of probability, (3) the available K in soil (X_4) and date of planting (X_{11}) were significant at the 0.05 level of probability, (4) the ~~P~~^K applied (X_7), ~~N~~^K applied (X_5) were significant at the 0.20 level of probability and (5) available P in soil (X_3), lime applied (X_8), variety (X_{10}) and previous crop (X_{12}) were not significant even at the 0.20 level of probability.

Effect of plant population and soil on the yield of corn. The regression coefficients in all the equations for plant population (X_9) were significant at the 0.001 level of probability. All the 'b' values were positive. The estimates indicated that on an average an increase of 1,000 plants per acre would result in an increase of corn yield by

Table 17.--Multiple regression coefficients, their standard error for various combinations of independent variables with yield of corn as dependent variable.

Combination of independent variables		X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	X ₁₀	X ₁₁	X ₁₂	X ₁₃
1. X ₁ through X ₁₃	b	0.3508	6.1416	0.1773	0.0372	-0.0832 ²	0.0792 ²	0.0799 ²	-0.3700	0.0052	0.1613	-0.1994 [*]	0.1109	16.6311
	Sb	±0.0794	±2.3283	±0.1385	±0.0164	±0.0649	±0.0630	±0.0668	±0.2618	±0.0005	±0.3189	±0.0957	±0.0957	±2.5460
2. X ₁ through X ₁₂	b	0.2413	5.3174	0.0551	-0.0208	0.2364	0.0554	-0.0975 ²	-0.2819	0.0041	0.1737	-0.1764 ¹	0.0507	--
	Sb	±0.0849	±2.5431	±0.1501	±0.0150	±0.0467	±0.0688	±0.0668	±0.2860	±0.0006	±0.3488	±0.1046	±0.1001	--
3. X ₁ through X ₁₁	b	0.2477	5.2540	0.0522	-0.0200 ²	0.2355	0.0582	-0.1008 ²	-0.2723	0.0041	0.1770	-0.1711 ¹	--	--
	Sb	±0.0838	±2.5356	±0.1497	±0.0149	±0.0465	±0.0685	±0.0663	±0.2850	±0.0006	±0.3481	±0.1039	--	--
4. X ₁ through X ₉ , X ₁₁	b	0.2506	5.1073	0.0587	-0.0203 ²	0.2377	0.0593	-0.1011 ²	-0.2768	0.0041	--	-0.1671 ²	--	--
	Sb	±0.0835	±2.5148	±0.1489	±0.0149	±0.0463	±0.0683	±0.0662	±0.2844	±0.0006	--	±0.1034	--	--
5. X ₁ through X ₇ , X ₉ , X ₁₁	b	0.2458	5.0694	0.0511	-0.0229 ²	0.2341	0.0535	-0.1056 ²	--	0.0041	--	-0.1693 ²	--	--
	Sb	±0.0833	±2.5142	±0.1487	±0.0146	±0.0461	±0.0681	±0.0661	--	±0.0006	--	±0.1034	--	--
6. X ₁ , X ₂ , X ₃ , X ₅ , X ₆ , X ₇ , X ₉ , X ₁₁	b	0.2515	5.0824	-0.0237	--	0.2329	0.0393	-0.0905 ²	--	0.0040	--	-0.1466 ²	--	--
	Sb	±0.0835	±2.5225	±0.1412	--	±0.0462	±0.0677	±0.0656	--	±0.0006	--	±0.1027	--	--
7. X ₁ , X ₂ , X ₅ , X ₆ , X ₇ , X ₉ , X ₁₁	b	0.2498	5.0314	--	--	0.2325	0.0416	-0.0919 ²	--	0.0040	--	-0.1508 ²	--	--
	Sb	±0.0827	±2.4980	--	--	±0.0461	±0.0662	±0.0649	--	±0.0006	--	±0.0994	--	--
8. X ₁ , X ₂ , X ₅ , X ₆ , X ₉ , X ₁₁	b	0.2619	4.9060	--	--	0.2297	-0.0369	--	--	0.0041	--	-0.1681 ¹	--	--
	Sb	±0.0824	±2.5027	--	--	±0.0462	±0.0361	--	--	±0.0006	--	±0.0989	--	--
9. X ₁ , X ₂ , X ₅ , X ₉ , X ₁₁	b	0.2709	4.4996 ²	--	--	0.2080	--	--	--	0.0040	--	-0.1751 ²	--	--
	Sb	±0.0820	±2.4713	--	--	±0.0411	--	--	--	±0.0005	--	±0.0987	--	--
10. X ₁ , X ₂ , X ₅ , X ₁₁	b	0.2325	4.5702 ¹	--	--	0.2131	--	--	--	0.0039	--	--	--	--
	Sb	±0.0794	±2.4829	--	--	±0.0411	--	--	--	±0.0005	--	--	--	--

Table 17.--- Continued

11.	X ₁ , X ₅ , X ₉	b Sb	*** 0.2482 0.0794	--	--	--	**** 0.2210 0.0411	--	--	--	**** 0.0041 0.0005	--	--	--	--
12.	X ₁ , X ₉	b Sb	**** ± 0.2961 0.0837	--	--	--	--	--	--	--	**** 0.0055 ± 0.0005	--	--	--	--
13.	X ₉	b Sb	--	--	--	--	--	--	--	--	0.0059 ± 0.0005	--	--	--	--

Legend:

b - Multiple regression coefficient
 Sb - Standard error of 'b'
 **** - 't' test significant at 0.001 probability
 *** - 't' test significant at 0.005 probability
 ** - 't' test significant at 0.010 probability
 * - 't' test significant at 0.05 probability
 1 - 't' test significant at 0.10 probability
 2 - 't' test significant at 0.20 probability

Independent variables:

X₁ - Soil
 X₂ - pH
 X₃ - P test
 X₄ - K test
 X₅ - N applied
 X₆ - P applied
 X₇ - K applied

X₈ - Lime applied
 X₉ - Plant population
 X₁₀ - Variety
 X₁₁ - Date of planting
 X₁₂ - Previous crop
 X₁₃ - Year

about 5 bushels. The average plant population of the observations included in this study was 9,000 plants per acre.

The regression coefficients ('b') for soil (X_1) in equation 1 (all independent variables) and equation 12 (plant population and soil variables) were significant at the 0.001 level of probability. The 'b' values in other equations were significant at the 0.005 level of probability. All of the 'b' values for the soil variable were positive. The coded values used for soils had a numerical difference of 65 between the lowest and the highest productive soils. The 'b' values indicated that the difference between the lowest and highest productive soils might account for 15 bushels of corn yield.

Effect of year and nitrogen on the yield of corn. Since year (X_{13}) was the first variable excluded, it was included in equation 1 only. The 'b' value was significant at the 0.001 level of probability. The regression coefficient for year was positive and this suggested that later years of the 5 year period were more favorable for corn production than the earlier years. The 'b' values suggested an increase of 16.6 bushels of corn per year over the period. Since the climatological data could not be included for lack of such information, this finding will only show that the seasonal variations affect the corn yield considerably.

The 'b' value for nitrogen applied was negative when all the independent variables were included and was significant at the 0.20 level of probability. In the remaining combinations of independent variables, when year and some variables were excluded, the 'b' values

for nitrogen were positive and were significant at the 0.001 level of probability. This suggests that the nitrogen effect has been masked in the presence of year as one variable. This type of masking effect might be expected as higher yields are produced during the years of favorable moisture conditions, when nitrogen will also have positive response on corn yields.

Effect of pH and date of planting on the yield of corn. The 'b' values for pH (X_2) were positive. It can be also estimated from these values that 4-6 bushels of corn might increase per 1.00 unit in pH. The 't' test was significant at the 0.01 level of probability when all the 13 variables were included and was significant at 0.05 level and 0.10 level of probability in the case of equations 2 through 8 and equations 9 and 10, respectively. In these experiments the pH varied from 4.5 to 7.5. Graves (12) also found that pH had an influence on corn yields on Dickson and Waynesboro soils (pH values ranged from 4.5 to 7.0).

The equations 1 through 8 show that 'b' values for date of planting (X_{11}) were negative. This indicates later planting reduced the yield. From the 'b' values it can be estimated that a delay of about 5-10 days may reduce corn yield by one bushel. The 'b' values for this variable were significant at the 0.05 level of probability for equation 1 and at the 0.10 level of probability where year, previous crop and pH were excluded at the 0.20 level of probability for other equations.

Effect of available P in soil, P applied and lime applied on the yield of corn. The results show that all 'b' values except in equation 6, P tests (X_3) were positive. In the case of P applied (X_6) the 'b' values

were positive in all the combinations independent variables (whenever it was included) except in equation 8. The 't' test for P applied in equation 1 was significant at the 0.20 level of probability. It was not significant for the other combinations. All the 'b' values for lime applied were negative and the 't' tests were not significant. This indicates that these variables did not affect the yield of corn under these conditions.

Effect of previous crop and variety on the yield of corn. The previous crops were rated from low to high in the order of expected decreasing effect on yield of corn and the 'b' values were expected to be negative. The 'b' values for previous crop (X_{12}) as given in Table 17 were positive. This suggests that coding of previous crop needs further confirmation as to its validity. The 't' tests were not significant even at the 0.20 level of probability.

The 'b' values for variety (X_{10}) in Table 17 were positive and as the varieties were coded in the order of increasing effect on yield, this is expected. However, the 't' tests were not significant even at the 0.20 level of probability.

Effect of available K in soil and K applied on the yield of corn. The available K test (X_{14}) also gave positive regression coefficient for equation 1 where all the variables were included but equations 2 through 5 show that, K test gave a negative regression coefficient when year, previous crop, variety were dropped. Graves (10) found similar results and stated that the response was probably due to the high potassium content of the soils associated with low population, late planting date,

and low levels of nitrogen rather than increasing quantities of potassium decreasing yields. Graves (10) included both K test and K applied as one variable. In the present studies K test and K applied were included as separate independent variables. The equations 2 through 7 show that the K applied (X_7) also gave negative regression coefficient. It is, therefore, possible that both potassium test and added potassium individually or combined have little prediction values. The 't' tests for all these 'b' values for K applied (Table 17) were significant at the 0.20 level of probability.

Comparison of standard partial regression coefficients for equation 1 with all the 13 independent variables. To determine the relative importance of the various independent variables under study in relation to the dependent variable, the standard partial regression coefficients were computed using the method outlined by Steel, et al. (33) as follows:

$$b' = b \frac{S_1}{S_y}$$

where b' = Standard partial regression coefficient
 b = Partial regression coefficient
 S_1 = Standard deviation of X_1
 S_y = Standard deviation of Y

Since b' for all the 13 variables are in the same units of measurement, they are comparable. This information is expected to give the same information as coefficients of partial correlation, as per Exekiel (9). The calculated 'b' values for the different independent variables are presented in Table 18.

If the standard partial regression coefficients are interpreted in terms of absolute values, the results show that the order of decreasing

Table 18.---Comparison of standard partial regression coefficients for prediction equation which included all the independent variables.

Independent variable		Standard partial regression coefficient	
Soils	b'_1	0.228	3.5
pH	b'_2	0.127	
P test	b'_3	0.067	
K test	b'_4	0.136	
N applied	b'_5	- 0.113	
P applied	b'_6	0.133	
K applied	b'_7	0.130	
Lime applied	b'_8	- 0.071	
Plant population	b'_9	0.513	33.5
Varieties	b'_{10}	0.023	
Date of planting	b'_{11}	- 0.104	
Previous crop	b'_{12}	0.057	
Year	b'_{13}	0.515	8.8

importance of the independent variables affecting corn yield was:

year > plant population > soils > K test > P applied > K applied > pH > N applied > date of planting > lime applied > P test > previous crop > varieties. Then these results also indicate that year, soil and nitrogen factors are important for predicting yield of corn.

The results of the multiple linear regression analysis indicated certain limitations of the study. They are as follows:

1. Coding of different variables by numerical numbers needed to be more precise than attempted in this study. It might be desirable to assign the numerical values from one level to the next higher or lower level, based on the proportion of response in the corn yield.
2. The order of exclusion of the variables need to be decided considering the partial correlation coefficients.
3. The 'b' values of a few variables had been affected considerably, when some other variables were excluded. This suggested that some independent variables were not really independent, and were interacting with each other.
4. The percent explanation (R^2) of yield, with all the 13 independent variables were included, was of the order of 57 percent. It might be possible to get a higher percentage of explanation if the curvilinear model or the interaction terms are introduced.

III GENERAL DISCUSSION

The results have been studied separately, for the effect of certain crop and soil management factors on (1) size of corn kernels and

(2) yield of corn. The data from two sets of experiments were used for this study. Some of the important crop and soil management practices, i.e., plant population, productivity of soil, nitrogen, phosphate, and potash fertilizers, were included in both the studies.

The results discussed in Sections I and II indicated that plant population was the major factor affecting both the yield of corn and size of kernels. A level of 9,000 plants per acre in Hartsells soil resulted in higher percentage of extra large and large flat kernels and in lower percentage of medium and regular flat kernels as compared to the other higher levels of plant population. In the same experiment it was also observed that a plant population of 12,000 plants per acre produced maximum yield of corn (all kernels) and total flat kernels compared to 9,000, 15,000 and 18,000 plants per acre. The study on the effect of plant population on yield of corn in Section II suggested an increase of 5 bushels of corn for each increase in 1,000 plants per acre. The average population level in this study was 9,000 plants per acre (for all the soils). Thus it is evident that lower plant populations increased the size (thickness) of kernels whereas higher plant population levels (till optimum level is reached) increased the yield of corn.

The results in Section II show that highly productive soils like Huntington might produce approximately 15 bushels of corn more than the low productive soils. The results of the study of size of corn kernels show that Huntington produced higher percentage of total flat kernels than the low productive soils at the same plant population level. However as discussed in Section II the percentage explanation was reduced

by 3.5 when soil factor was excluded. The explanation obtained by plant population alone was 33.5 percent. Thus, contribution of soil series in influencing the corn yields was much lower than expected. This lack of response may be due to the masked effect on yields by the low plant population levels.

The nitrogen factor contributed greatly to yield and it was seen that 7 percent explanation was reduced when nitrogen was excluded. Higher response in corn yields are expected with higher levels of nitrogen applied. The average level of nitrogen applied to different plots was 55 pounds per acre. The study on the size of corn kernels included the levels of 220 pounds and 420 pounds nitrogen per acre. These levels are very high compared to the amount of nitrogen applied, normally. Phosphate and potash applied did not affect the yield of corn to a large extent. The average levels of phosphate and potash applied to different plots were 55 lbs. P_2O_5 and 50 lbs. K_2O per acre. In the case of the size of corn kernel study, 220 lbs. and 420 lbs. of P_2O_5 and K_2O levels were used. There was no increase in the flat kernels obtained. Since the levels of nitrogen, phosphate and potash applied to different plots were much higher than the levels applied normally, the effect on the size of kernels could not be clearly expressed.

The total effect of any one or a combination of factors, i.e., plant population, soil, nitrogen, phosphate and potash, did not change the proportion of flat kernels more than 1-2 percent. Whereas these factors affected the yield of corn (all kernels) to a much larger extent than 1 to 2 percent. Therefore, the optimum level of the factors for

maximum production of yield, also produced maximum yield of flat kernels.

In view of these studies, it can be stated that the yield factor should be of greater concern for the corn seed producer than the size of kernels.

CHAPTER IV

SUMMARY AND CONCLUSIONS

The objectives of this study were to assess the effect of certain soil and crop management practices on the size of kernels and yield of corn. The corn kernel samples were collected from two experiments conducted in Tennessee during 1960, which included soil, plant population, spacing, nitrogen and phosphate and potash treatments. The effect of these practices on the size of corn kernels was studied. The corn yield data and the related factors affecting yield, such as soil, pH, available P test, available K test, nitrogen, phosphate, potash and lime applied, plant population, date of planting, previous crop and variety, were collected from a number of plots in East Tennessee during the years from 1956 through 1960. This data was utilized to study the effect of these management factors in view of predicting the corn yield.

On Hartsells soil, a plant population of 9,000 per acre resulted in an increase in the percentage of extra large flat (1 percent) and large flat kernels (5 to 9 percent) kernels and in the decrease in medium flat (1 to 4 percent) and regular flat (2 to 3 percent) kernels as compared to higher levels, (12,000, 15,000, 18,000 plants per acre). However, there was no significant difference for the different grades of corn kernels among 12,000, 15,000 and 18,000 plants per acre. There were also indications that 9,000 and 12,000 plants populations per acre increased the total flat kernels by 1 to 2 percent as compared to 15,000 and 18,000 plants per acre. A population of 9,000 plants per acre

resulted in decrease in the discard kernels by 0.5 to 1.0 percent as compared with higher plant populations. Dickson soil with 10,000 plants per acre resulted in increase in large flats (5 to 9 percent) and decrease in medium flats (5 to 6 percent) as compared to Dickson soil with 16,000 plants per acre, Waynesboro with 14,000 and 24,000 plants per acre, and Huntington with 15,500 and 25,000 plants per acre. The greater effect of Dickson was due to the lower plant population level in this soil as compared with other soils.

The application of 440 pounds of nitrogen per acre to Huntington soil produced higher large flat (5 percent) and lesser regular flat kernels (2 percent) than 220 pounds nitrogen per acre on the same soil. There was no significant difference in the proportion of large and regular flat kernels for Waynesboro and Huntington soils between 220 pounds and 420 pounds nitrogen per acre.

Low plant population (the level varied for different soils) with application of 440 pounds nitrogen per acre increased the extra large flat kernels (2 percent) and decreased the medium flat kernels (3 percent), as compared to the same population but 220 pounds nitrogen per acre. There was no significant variation in the proportion of these grades of kernels for low nitrogen with both high or low plant population levels.

The various spacing levels (1.5, 2.0, 2.5, 3.0 and 3.5 feet) showed no significant difference in the proportion of different grades of corn kernels.

The average response of two different levels of nitrogen (220 lbs. and 420 lbs.) on all soils did not show any significant difference

between the proportion of different grades of corn kernels. The application of 420 lbs. of P_2O_5 and K_2O on an average decreased the large flats (2.5 percent) and increased the regular flats (0.75 percent) as compared with 220 lbs. P_2O_5 and K_2O . Due to the fact that both 220 and 420 lbs. of nitrogen, phosphate and potash were higher levels than usually practiced, the response was not greater and the effect could not be clearly observed.

The variation in the proportion of total flat kernels by these different crop and soil management practices was of the order of 1 to 2 percent only, the response in the total corn yield produced was much higher and therefore, the total yield of flat kernels per acre was not affected. Hence, the total yield of corn (all kernels) contributed largely to the particular grade of kernel produced in bushels.

The coefficients of determination (R^2) for several combinations of crop and soil management practices affecting the yield of corn showed the order of the increasing influence of each of them was as follows:

Plant population > year > nitrogen > soils > pH > date of planting > available K in soil > K applied > P applied > lime applied > variety > previous crop > available P in soil.

All these factors together explained 56.5 percent of total variation in yield whereas plant population, year, nitrogen and soils explained 33.5, 8.8, 7.2 and 3.5 percent respectively.

The plant population, soil, pH, previous crop, available P in the soil, P added and variety gave positive regression coefficients and date of planting, available K in soil, K added and lime added gave negative

regression coefficients. The regression coefficients indicated (1) a favorable year may affect the yield of corn to an extent of 16 bushels, (2) delay of about 5 to 10 days in planting corn might reduce one bushel of yield, (3) increase of pH to 1.00 unit might increase 4 to 5 bushels of corn, (4) an increase in 1,000 plants per acre might increase about 5 bushels of corn and (5) a difference of 15 bushels of corn may be expected (as per the present coding of soils) from the low to the high productive soils.

The comparison of the standard partial regression coefficients for all the variables together, showed that year and plant populations affected yield of corn most and to about the same extent. Soil, available K and P applied were next in importance. Lime applied, available P, previous crop and varieties did not affect the yield of corn greatly and had less predictive values.

In view of certain limitations of the use of linear model for the regression equation, the conclusions are tentative and probably should be subjected to more detailed investigation using curvilinear model and interaction terms.

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LITERATURE CITED

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APPENDICES

APPENDIX A

PERCENTAGE OF EXTRA LARGE FLAT KERNELS FROM CORN GROWN AT VARIOUS SPACINGS AND PLANT POPULATIONS ON HARTSELLS SOIL, 1960

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Replications	3	12.76	3.15*	
Spacings	4	1.09	0.27	N.S.
Error (a)	12	4.05	-	
Plant populations	3	9.27	4.06*	
Spacings X plant populations	12	2.95	1.29	N.S.
Error (b)	45	2.28	-	
Total	79			

*Significant at the 0.05 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX B

PERCENTAGE OF LARGE FLAT KERNELS FROM CORN GROWN AT VARIOUS SPACINGS AND PLANT POPULATIONS ON HARTSELLS SOIL, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Replications	3	36.68	1.90	N.S.
Spacings	4	28.91	1.50	N.S.
Error (a)	12	19.24	-	
Plant populations	3	178.77	12.92**	
Spacing X plant populations	12	12.34	0.89	N.S.
Error (b)	45	13.83	-	N.S.
Total	79			

** Significant at the 0.01 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX C

PERCENTAGE OF MEDIUM FLAT KERNELS FROM CORN GROWN AT VARIOUS SPACINGS AND PLANT POPULATIONS ON HARTSELLS SOIL, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Replications	3	63.66	2.3 ¹	
Spacings	4	8.40	0.31	N.S.
Error (a)	12	26.77	-	
Plant populations	3	57.04	4.22*	
Spacings X plant populations	12	15.37	1.13	N.S.
Error (b)	45	13.52	-	
Total	79			

* Significant at the 0.05 level of probability.

¹ Significant at the 0.25 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX D

PERCENTAGE OF REGULAR FLAT KERNELS FROM CORN GROWN AT VARIOUS SPACINGS AND PLANT POPULATIONS ON HARTSELLS SOIL, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Replications	3	7.54	1.25	N.S.
Spacings	4	9.15	1.52	N.S.
Error (a)	12	6.03	-	
Plant populations	3	26.74	12.04**	
Spacings X plant populations	12	2.84	1.27	N.S.
Error (b)	45	2.22	-	
Total	79			

** Significant at the 0.01 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX E

PERCENTAGE OF TOTAL ROUND KERNELS FROM CORN GROWN AT VARIOUS SPACINGS AND PLANT POPULATIONS ON HARTSELLS SOIL, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Replications	3	4.89	1.30	N.S.
Spacings	4	3.45	0.92	N.S.
Error (a)	12	3.74	-	
Plant populations	3	7.46	1.99 ¹	
Spacings X plant populations	12	5.13	1.36	N.S.
Error (b)	45	3.75	-	
Total	79			

¹ Significant at the 0.25 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX F

PERCENTAGE OF DISCARD KERNELS FROM CORN GROWN AT VARIOUS SPACINGS AND PLANT POPULATIONS ON HARTSELLS SOIL, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Replications	3	0.52	0.69	N.S.
Spacings	4	0.82	1.09	N.S.
Error (a)	12	0.75	-	
Plant populations	3	3.08	7.00**	
Spacings X plant populations	12	0.66	1.50 ¹	
Error (b)	45	0.44	-	
Total	79			

**Significant at the 0.05 level of probability.

¹Significant at the 0.25 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX G

PERCENTAGE OF TOTAL FLAT KERNELS FROM CORN GROWN AT VARIOUS SPACINGS AND PLANT POPULATIONS ON HARTSELLS SOIL, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Replications	3	6.72	1.81	N.S.
Spacings	4	1.54	0.41	N.S.
Error (a)	12	3.71	-	
Plant populations	3	18.87	4.71*	
Spacings X plant populations	12	6.40	1.41 ¹	
Error (b)	45	4.52	-	
Total	79			

*Significant at the 0.05 level of probability.

¹Significant at the 0.25 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX H

BUSHELS PER ACRE OF TOTAL FLAT KERNELS AT VARIOUS SPACINGS AND PLANT POPULATIONS ON HARTSELLS SOIL, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Replications	3	146.20	0.92	N.S.
Spacings	4	471.46	2.98 ¹	
Error (a)	12	158.82	-	
Plant populations	3	69.23	0.54	N.S.
Spacings X plant populations	12	115.82	0.90	N.S.
Error (b)	45	127.90	-	
Total	79			

¹Significant at the 0.10 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX I

PERCENTAGE OF EXTRA LARGE FLAT KERNELS FROM CORN GROWN ON
DICKSON, WAYNESBORO AND HUNTINGTON SOILS AT TWO LEVELS
OF PHOSPHATE AND POTASH, NITROGEN AND PLANT
POPULATION, PUTNAM COUNTY, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Locations	4	21.62	1.55	N.S.
Soils	2	19.35	1.38	N.S.
Error (a)	8	13.97	-	
P_2O_5 and K_2O	1	0.59	0.25	N.S.
P_2O_5 and K_2O X soils	2	0.68	0.29	N.S.
Error (b)	12	2.32	-	
Nitrogen	1	0.06	-	N.S.
Nitrogen X soils	2	0.45	0.14	N.S.
Nitrogen X P_2O_5 and K_2O	1	0.28	0.08	N.S.
Nitrogen X P_2O_5 and K_2O X soils	2	10.21	3.23 ¹	
Error (c)	24	3.61	-	
Population	1	54.73	10.97 ^{**}	
Population X soils	2	12.99	2.60 ¹	
Population X P_2O_5 and K_2O	1	1.27	0.25	N.S.
Population X nitrogen	1	23.11	4.63 [*]	
Population X soils X nitrogen	2	7.13	1.43 ²	
Population X soils X P_2O_5 and K_2O	2	9.50	1.90 ²	
Population X nitrogen X P_2O_5 and K_2O	1	0.09	-	N.S.
Population X soils X nitrogen X P_2O_5 and K_2O	2	3.00	0.60	N.S.
Error (d)	48	4.98	-	
Total	119			

* Significant at the 0.05 level of probability.

** Significant at the 0.01 level of probability.

¹ Significant at the 0.10 level of probability.

² Significant at the 0.25 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX J

PERCENTAGE OF LARGE FLAT KERNELS FROM CORN GROWN ON DICKSON, WAYNESBORO AND HUNTINGTON SOILS AT TWO LEVELS OF PHOSPHATE AND POTASH, NITROGEN AND PLANT POPULATION, PUTNAM COUNTY, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Locations	4	91.78	1.18	N.S.
Soils	2	237.86	3.07 ²	
Error (a)	8	77.40	-	
P ₂ O ₅ and K ₂ O	1	162.27	7.81 [*]	N.S.
P ₂ O ₅ and K ₂ O X soils	2	3.71	0.17	
Error (b)	12	20.77	-	
Nitrogen	1	54.37	2.39 ²	N.S.
Nitrogen X soils	2	94.63	4.17 [*]	
Nitrogen X P ₂ O ₅ and K ₂ O	1	38.20	1.68 ²	
Nitrogen X P ₂ O ₅ and K ₂ O X soils	2	70.70	3.11 ¹	N.S.
Error (c)	24	22.69	-	
Population	1	114.37	6.62 [*]	
Population X soils	2	109.72	6.35 ^{**}	N.S.
Population X P ₂ O ₅ and K ₂ O	1	0.49	-	
Population X nitrogen	1	13.33	0.77	
Population X soils X nitrogen	2	16.93	0.98	N.S.
Population X soils X P ₂ O ₅ and K ₂ O	2	10.05	0.58	N.S.
Population X nitrogen X P ₂ O ₅ and K ₂ O	1	0.16	-	N.S.
Population X soils X nitrogen X P ₂ O ₅ and K ₂ O	2	18.55	1.07	N.S.
Error (d)	48	17.27	-	
Total	119			

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

¹Significant at the 0.10 level of probability.

²Significant at the 0.25 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX K

PERCENTAGE OF MEDIUM FLAT KERNELS FROM CORN GROWN ON DICKSON, WAYNESBORO AND HUNTINGTON SOILS AT TWO LEVELS OF PHOSPHATE AND POTASH, NITROGEN AND PLANT POPULATION, PUTNAM COUNTY, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Locations	4	85.72	1.16	N.S.
Soils	2	92.53	1.25	N.S.
Error (a)	8	73.59	-	
P ₂ O ₅ and K ₂ O	1	44.38	2.58 ²	
P ₂ O ₅ and K ₂ O X soils	2	6.30	0.36	N.S.
Error (b)	12	17.20	-	
Nitrogen	1	3.54	-	N.S.
Nitrogen X soils	2	18.53	1.10 ¹	N.S.
Nitrogen X P ₂ O ₅ and K ₂ O	1	55.65	3.40 ¹	
Nitrogen X P ₂ O ₅ and K ₂ O X soils	2	38.37	2.34 ²	
Error (c)	24	16.36	-	
Population	1	157.17	6.99*	
Population X soils	2	91.58	4.07*	
Population X P ₂ O ₅ and K ₂ O	1	0.05	-	N.S.
Population X nitrogen	1	63.72	2.83 ¹	
Population X soils X nitrogen	2	19.22	0.85	N.S.
Population X soils X P ₂ O ₅ and K ₂ O	2	5.81	0.25	N.S.
Population X nitrogen X P ₂ O ₅ and K ₂ O	1	6.84	0.30	N.S.
Population X soils X nitrogen X P ₂ O ₅ and K ₂ O	2	33.60	1.49 ²	N.S.
Error (d)	48	22.47	-	
Total	119			

*Significant at the 0.05 level of probability.

¹Significant at the 0.10 level of probability.

²Significant at the 0.25 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX L

PERCENTAGE OF REGULAR FLAT KERNELS FROM CORN GROWN ON DICKSON,
WAYNESBORO AND HUNTINGTON SOILS AT TWO LEVELS OF PHOSPHATE
AND POTASH, NITROGEN AND PLANT POPULATION,
PUTNAM COUNTY, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Locations	4	8.39	0.71	N.S.
Soils	2	18.71	1.59	N.S.
Error (a)	8	11.75	-	
P ₂ O ₅ and K ₂ O	1	17.01	9.62**	
P ₂ O ₅ and K ₂ O X soils	2	0.79	-	N.S.
Error (b)	12	1.76	-	N.S.
Nitrogen	1	7.56	1.62 ²	
Nitrogen X soils	2	16.78	3.61*	
Nitrogen X P ₂ O ₅ and K ₂ O	1	3.67	0.79	N.S.
Nitrogen X P ₂ O ₅ and K ₂ O X soils	2	4.98	1.07	N.S.
Error (c)	24	4.64	-	
Population	1	22.85	7.29**	
Population X soils	2	5.99	1.91 ²	
Population X P ₂ O ₅ and K ₂ O	1	4.97	1.58 ²	
Population X nitrogen	1	0.51	-	N.S.
Population X soils X nitrogen	2	2.06	-	N.S.
Population X soils X P ₂ O ₅ and K ₂ O	2	6.47	2.06 ²	
Population X nitrogen X P ₂ O ₅ and K ₂ O	1	1.37	0.71	N.S.
Population X soils X nitrogen X P ₂ O ₅ and K ₂ O	2	2.25	-	N.S.
Error (d)	48	3.13	-	
Total	119			

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

²Significant at the 0.25 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX M

PERCENTAGE OF TOTAL ROUND KERNELS FROM CORN GROWN ON DICKSON,
WAYNESBORO AND HUNTINGTON SOILS AT TWO LEVELS OF PHOSPHATE
AND POTASH, NITROGEN AND PLANT POPULATION,
PUTNAM COUNTY, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Locations	4	0.14	-	N.S.
Soils	2	4.30	1.46	N.S.
Error (a)	8	2.93	-	
P ₂ O ₅ and K ₂ O	1	0.21	-	N.S.
P ₂ O ₅ and K ₂ O X soils	2	0.56	-	N.S.
Error (b)	12	1.32	-	
Nitrogen	1	0.63	-	N.S.
Nitrogen X soils	2	1.57	1.15	N.S.
Nitrogen X P ₂ O ₅ and K ₂ O	1	0.25	-	N.S.
Nitrogen X P ₂ O ₅ and K ₂ O X soils	2	5.17	3.81*	
Error (c)	24	1.36	-	
Population	1	0.81	0.61	N.S.
Population X soils	2	0.72	0.54 ²	N.S.
Population X P ₂ O ₅ and K ₂ O	1	2.73	2.06 ²	
Population X nitrogen	1	1.13	0.85	N.S.
Population X soils X nitrogen	2	1.23	0.93	N.S.
Population X soils X P ₂ O ₅ and K ₂ O	2	0.99	0.75	N.S.
Population X nitrogen x P ₂ O ₅ and K ₂ O	1	2.03	1.53 ²	
Population X soils X nitrogen X P ₂ O ₅ and K ₂ O	2	0.53	-	N.S.
Error (d)	48	1.32	-	
Total	119			

*Significant at the 0.05 level of probability.

²Significant at the 0.25 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX N

PERCENTAGE OF DISCARD KERNELS FROM CORN GROWN ON DICKSON, WAYNESBORO AND HUNTINGTON SOILS AT TWO LEVELS OF PHOSPHATE AND POTASH, NITROGEN AND PLANT POPULATION, PUTNAM COUNTY, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Locations	4	0.29	-	N.S.
Soils	2	1.03	0.86	N.S.
Error (a)	8	1.19	-	
P ₂ O ₅ and K ₂ O	1	0.51	1.88 ²	
P ₂ O ₅ and K ₂ O X soils	2	0.20	0.74	N.S.
Error (b)	12	0.27	-	
Nitrogen	1	0.56	2.07 ²	
Nitrogen X soils	2	0.03	-	N.S.
Nitrogen X P ₂ O ₅ and K ₂ O	1	0.21	0.77	N.S.
Nitrogen X P ₂ O ₅ and K ₂ O X soils	2	0.92	3.40*	
Error (c)	24	0.27	-	
Population	1	6.26	19.25**	
Population X soils	2	0.27	0.84	N.S.
Population X P ₂ O ₅ and K ₂ O	1	0.12	0.37	N.S.
Population X nitrogen	1	0.13	0.40	N.S.
Population X soils X nitrogen	2	0.53	1.65 ²	
Population X soils X P ₂ O ₅ and K ₂ O	2	0.02	-	N.S.
Population X nitrogen X P ₂ O ₅ and K ₂ O	1	0.01	-	N.S.
Population X soils X nitrogen X P ₂ O ₅ and K ₂ O	2	0.66	2.06 ²	
Error (d)	48	0.32	-	
Total	119			

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

²Significant at the 0.25 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX O

PERCENTAGE OF TOTAL FLAT KERNELS FROM CORN GROWN ON DICKSON,
WAYNESBORO AND HUNTINGTON SOILS AT TWO LEVELS OF
PHOSPHATE AND POTASH, NITROGEN AND PLANT
POPULATION, PUTNAM COUNTY, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Locations	4	0.74	-	N.S.
Soils	2	7.62	1.97 ²	
Error (a)	8	3.86	-	
P ₂ O ₅ and K ₂ O	1	0.51	-	N.S.
P ₂ O ₅ and K ₂ O X soils	2	0.19	-	N.S.
Error (b)	12	1.59	-	N.S.
Nitrogen	1	4.01	2.73 ²	
Nitrogen X soils	2	1.51	1.03	N.S.
Nitrogen X P ₂ O ₅ and K ₂ O	1	0.36	-	N.S.
Nitrogen X P ₂ O ₅ and K ₂ O X soils	2	6.95	4.73*	
Error (c)	24	1.46	-	
Population	1	1.49	0.86	N.S.
Population X soils	2	0.86	-	N.S.
Population X P ₂ O ₅ and K ₂ O	1	0.06	-	N.S.
Population X nitrogen	1	2.42	-	N.S.
Population X soils X nitrogen	2	0.21	-	N.S.
Population X soils X P ₂ O ₅ and K ₂ O	2	2.25	1.30	N.S.
Population X nitrogen X P ₂ O ₅ and K ₂ O	1	1.04	-	N.S.
Population X soils X nitrogen X P ₂ O ₅ and K ₂ O	2	1.51	-	N.S.
Error (d)	48	1.73	-	
Total	119			

*Significant at the 0.05 level of probability.

²Significant at the 0.25 level of probability.

N.S. - Not significant at the 0.25 probability level.

APPENDIX P

BUSHEL PER ACRE OF TOTAL FLAT KERNELS FROM CORN GROWN ON DICKSON,
WAYNESBORO AND HUNTINGTON SOILS AT TWO LEVELS OF PHOS-
PHATE AND POTASH, NITROGEN AND PLANT POPULATION,
PUTNAM COUNTY, 1960.

Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F	
Locations	4	494.29	4.13 ¹	
Soils	2	768.68	2.66 ²	
Error (a)	8	185.72		
P ₂ O ₅ and K ₂ O	1	36.17	0.68	N.S.
P ₂ O ₅ and K ₂ O X soils	2	139.93	0.64 ²	
Error (b)	12	52.91	-	
Nitrogen	1	89.39	2.33 ²	
Nitrogen X soils	2	30.15	0.78	N.S.
Nitrogen X P ₂ O ₅ and K ₂ O	1	25.62	0.66	N.S.
Nitrogen X P ₂ O ₅ and K ₂ O X soils	2	4.66	-	N.S.
Error (c)	24	38.30	-	
Population	1	2.34	-	N.S.
Population X soils	2	100.19	5.15*	
Population X P ₂ O ₅ and K ₂ O	1	0.02	-	N.S.
Population X nitrogen	1	12.67	0.65	N.S.
Population X soils X nitrogen	2	1.86	-	N.S.
Population X soils X P ₂ O ₅ and K ₂ O	2	41.64	2.14 ²	
Population X nitrogen X P ₂ O ₅ and K ₂ O	1	0.14	-	N.S.
Population X soils X nitrogen X P ₂ O ₅ and K ₂ O	2	15.90	0.81	N.S.
Error (d)	48	19.44	-	
Total	119			

*Significant at the 0.05 level of probability.

¹Significant at the 0.10 level of probability.

²Significant at the 0.25 level of probability.

N.S. - Not significant at the 0.25 level of probability.

APPENDIX Q

MULTIPLE REGRESSION ANALYSIS FOR VARIOUS COMBINATIONS OF INDEPENDENT VARIABLES WITH YIELD OF CORN AS DEPENDENT VARIABLE

Combination of independent variables	Source	Degrees of freedom	Mean squares	F
1. X_1 through X_{13}	Regression Error	13 211	8427.34 400.36	21.4 ^{****}
2. X_1 through X_{12}	Regression Error	12 212	7705.95 479.06	16.08 ^{****}
3. X_1 through X_{11}	Regression Error	11 213	8395.31 477.38	17.59 ^{****}
4. X_1 through X_9, X_{11}	Regression Error	10 214	9222.50 475.73	19.38 ^{****}
5. X_1 through $X_7, X_9,$ X_{11}	Regression Error	9 215	10197.14 487.77	20.82 ^{****}
6. $X_1, X_2, X_3, X_5, X_6,$ X_7, X_9, X_{11}	Regression Error	8 216	11327.21 478.77	23.67 ^{****}
7. $X_1, X_3, X_5, X_6, X_7,$ X_9, X_{11}	Regression Error	7 217	12943.45 476.62	27.15 ^{****}
8. X_1, X_2, X_5, X_6, X_9 X_{11}	Regression Error	6 218	14941.60 478.82	31.20 ^{****}
9. $X_1, X_2, X_5, X_9, X_{11}$	Regression Error	5 219	17829.66 478.92	37.23 ^{****}
10. X_1, X_2, X_5, X_9	Regression Error	4 220	21910.54 483.59	45.30 ^{****}
11. X_1, X_5, X_9	Regression Error	3 221	28667.94 488.81	58.66 ^{****}

APPENDIX Q (Continued)

Combination of independent variables	Source	Degree of freedom	Mean squares	F
12. X_1, X_9	Regression	2	35944.03	65.32****
	Error	222	550.20	
13. X_9	Regression	1	65102.03	112.52****
	Error	223	578.56	

Legend: **** Significant at 0.001 level of probability

X_1 Soil	X_6 P applied	X_{11} Date of planting
X_2 pH	X_7 K applied	X_{12} Previous crop
X_3 P test	X_8 Lime applied	X_{13} Year
X_4 K test	X_9 Plant population	
X_5 N applied	X_{10} Variety	

APPENDIX R

PREDICTION EQUATIONS FOR VARIOUS COMBINATIONS OF INDEPENDENT VARIABLES WITH YIELD OF CORN AS THE DEPENDENT VARIABLE.

1. Independent Variables. X_1 through X_{13}

$$\hat{Y} = -32592.77 + 0.035 X_1 + 6.141 X_2 + 0.1773 X_3 + 0.037 X_4 - 0.0832 X_5 \\ + 0.0792 X_6 + 0.0799 X_7 - 0.3700 X_8 + 0.0052 X_9 + 0.1613 X_{10} \\ - 0.1994 X_{11} + 0.1107 X_{12} + 16.63 X_{13}$$

2. Independent Variables. X_1 through X_{12}

$$\hat{Y} = 3.080 + 0.2413 X_1 + 5.317 X_2 + 0.055 X_3 - 0.0208 X_4 + 0.2364 X_5 \\ + 0.0554 X_6 - 0.097 X_7 - 0.2819 X_8 + 0.0041 X_9 + 0.1737 X_{10} \\ - 0.1764 X_{11} + 0.0507 X_{12}$$

3. Independent Variables. X_1 through X_{11}

$$\hat{Y} = 4.877 + 0.2477 X_1 + 5.254 X_2 + 0.0522 X_3 - 0.0200 X_4 + 0.2355 X_5 \\ + 0.05829 X_6 - 0.100 X_7 - 0.2728 X_8 + 0.0041 X_9 + 0.1770 X_{10} \\ - 0.1711 X_{11}$$

4. Independent Variables. X_1 through X_9 , X_{11}

$$\hat{Y} = 7.555 + 0.2506 X_1 + 5.107 X_2 + 0.0587 X_3 - 0.0203 X_4 + 0.2377 X_5 \\ + 0.0593 X_6 - 0.1011 X_7 - 0.2768 X_8 + 0.0041 X_9 - 0.1671 X_{11}$$

5. Independent Variables. X_1 through X_7 , X_9 , X_{11}

$$\hat{Y} = 8.960 + 0.2458 X_1 + 5.069 X_2 + 0.0511 X_3 - 0.0229 X_4 + 0.234 X_5 \\ + 0.0535 X_6 - 0.1056 X_7 + 0.0041 X_9 - 0.1693 X_{11}$$

6. Independent Variables. X_1 , X_2 , X_3 , X_5 , X_6 , X_7 ,
 X_9 , X_{11}

$$\hat{Y} = 5.617 + 0.2515 X_1 + 5.082 X_2 - 0.0237 X_3 + 0.2329 X_5 + 0.0393 X_6 \\ - 0.0905 X_7 + 0.0040 X_9 - 0.1466 X_{11}$$

APPENDIX R (Continued)

7. Independent Variables $X_1, X_2, X_5, X_6, X_7, X_9, X_{11}$

$$\hat{Y} = 5.850 + 0.2498 X_1 + 5.031 X_2 + 0.2325 X_5 + 0.0416 X_6 - 0.0919 X_7 + 0.0040 X_9 - 0.1508 X_{11}$$

8. Independent Variables $X_1, X_2, X_5, X_6, X_9, X_{11}$

$$\hat{Y} = 6.092 + 0.2619 X_1 + 4.906 X_2 + 0.2297 X_5 - 0.0369 X_6 + 0.0041 X_9 - 0.1681 X_{11}$$

9. Independent Variables $X_1, X_2, X_5, X_9, X_{11}$

$$\hat{Y} = 8.467 + 0.2709 X_1 + 4.499 X_2 + 0.2080 X_5 + 0.0040 X_9 - 0.1751 X_{11}$$

10. Independent Variables X_1, X_2, X_5, X_9

$$\hat{Y} = -1.999 + 0.2325 X_1 + 4.570 X_2 + 0.2131 X_5 + 0.0039 X_9$$

11. Independent Variables X_1, X_5, X_9

$$\hat{Y} = 22.59 + 0.2482 X_1 + 0.2210 X_5 + 0.0041 X_9$$

12. Independent Variables X_1, X_9

$$\hat{Y} = 19.64 + 0.2961 X_1 + 0.0055 X_9$$

13. Independent Variables X_9

$$\hat{Y} = 29.73 + 0.0059 X_9$$

X_1	Soil	X_4	K test	X_7	K applied	X_{10}	Variety
X_2	pH	X_5	N applied	X_8	Lime applied	X_{11}	Date of planting
X_3	P test	X_6	P applied	X_9	Plant population	X_{12}	Previous crop
						X_{13}	Year

APPENDIX S

FARMER PARTICIPANTS, LOCATION ON DICKSON, WAYNESBORO AND HUNTINGTON SOILS FOR THE EXPERIMENTS IN PUTNAM COUNTY, 1960

Location no.	Soil	Name of farmer
1.	Dickson	Asbury Ramsey
2.	Dickson	Jones and Chaffin
3.	Dickson	E. L. Stones
4.	Dickson	Curtis Williams
5.	Dickson	Charlie Cambell
1.	Waynesboro	Roley Bullington
2.	Waynesboro	Dallas Jackson
3.	Waynesboro	Plees Deering
4.	Waynesboro	Harlin Mullins
5.	Waynesboro	Jeff Burton
1.	Huntington	Howard Hutchinson
2.	Huntington	Logan Halfacre
3.	Huntington	Vance Bartlett
4.	Huntington	Horace Henry
5.	Huntington	Arnold Hunter