EFFECT OF PLANT DENSITY AND NITROGEN ON THE GROWTH AND YIELD OF POPCORN (Zea mays L. Variety everta).

BY

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A thesis submitted to the Postgraduate School Ahmadu Bello University, in partial fulfilment of the requirement for the Degree of Master of Science in Agronomy.

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for higher degree.

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CERTIFICATION

This thesis titled 'Effect of Plant density and nitrogen on the growth and yield of Popcorn (Zea mays L. var. everta)' by Shamsuddeen Rufa'i meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

To my mother, Hajiya Karimatu.

ACKNOWLEDGEMENT

All praise is due to the Lord who endowed me with the health and ability to successfully accomplish the research.

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ABSTRACT

The experiment was conducted during the 1991 rainy season, at the Institute for Agricultural Research Farm Samaru, to investigate the response of popcorn to different plant densities and nitrogen levels. Treatments consisted of all possible combinations of three plant densities; 53, 333, 71 ,111, and 106, 666 plants /ha and four nitrogen levels; 0, 50, 100, and 150 kg/ha. These 12 treatments were laid out in a randomised complete block design replicated four times. Increased plant density significantly reduced stand count at 12 WAS, plant height at 12 WAS and significantly increased cob yield per hectare, and the total grain yield per hectare. Increased nitrogen levels significantly increased most of the growth and yield characters except the number of grains per cob and 100 seed weight. A combination of 100 kg IM/ha and 71,111 plants per hectare gave significantly higher crop yield than any other treatment combination. Optimum N rate was calculated to be 137 kg N/ha using a regression model.

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CHAPTER ONE

1.0 INTRODUCTION.

1.1 Origin.

Popcorn (*Zea mays* L. variety *everta*) is a grass and belongs to the large and important family Gramineae (Eldredge and Thomas, 1959). Popcorn was evidently grown by the American Indians of North and South America. Smith (1968) reported that traces of corn, probably popcorn, found in the Bat Cave of New Mexico, dated up to 2500 B.C. They therefore contended that popcorn was one of the first subspecies to evolve from wild grasses from which corn may have descended.

It was believed that among the early American Indians, there was a conscious preference for corn that would pop and the corn was popped since before the coming of Christopher Columbus to America (Brunson, 1935). The origin of popcorn was therefore ascribed to America and its spread to Europe and other parts of the World (including Nigeria) was due to American travellers and or explorers (Smith, 1968).

1.2 Varieties

All popcorn varieties are divided into two classes: Pearl and Rice (Delorit, 1974). Pearl varieties have short, thick kernels which may be round or flat and have a smooth, rounded crown which is usually deep yellow or orange - yellow in colour (Aldrich, 1975). Rice

varieties, also called "hulless" varieties, have pointed, somewhat curved kernels and are nearly always white in colour. The popcorn plants are short and tend to tiller profusely (Delorit, 1974).

1.3 Economic Importance.

Popcorn contains about 8.34% protein, 69.79% carbohydrates, and 3.46% fat (Anonymous, 1958). In a study at Leningrad (1978 - 1980) some popcorn lines were found to contain high amounts of oil, protein, and Lysine (Matveeva and Chmeleva, 1988). Likewise 9.4% and 10.12% protein respectively were obtained in two popcorn lines (Simeonov, 1988).

The uses of Popcorn include:

1.3.1 Human food:

Popcorn is used for human consumption as freshly popped corn and as a basis for confections (Jugenheimar, 1976). As a food, consumers usually desire a thin, tender hull that disintegrates in the mouth and one with a sweet, pleasant flavour (Brunson, 1955). The right popping technique is very important in obtaining the highest volume and best eating quality (Eldredge and Thomas, 1959).

1.3.2 Livestock feed:

Sometimes popcorn is unfit for use as freshly popped corn and is ground and used as feed for cattle (Eldredge and Thomas, 1959). Because of its extreme hardness,

popcorn is only fed to cattle and pigeons after grinding (Anonymous, 1958).

1.4 Agronomic/Cultural Requirement.

Popcorn may be grown on sandyloam soils that will retain more moisture and provides a better physical environment that serves as an opportunity for the popcorn to mature fully and produce a high quality product (Brunson, 1959).

Popcorn responds to heavy application of fertilizer. The fertilizer is used primarily to increase yields and obtain more rapid growth with more and larger number of ears (Eldredge and Thomas, 1959). The rate of popcorn planting can be heavier than field corn. Experiments indicate that on a fertile soil and with normal rainfall, popcorn seeds can be more closely spaced than any other field corn variety.

Crop rotation is important for popcorn as the smaller popcorn plants do not shade out late weeds. Thus unless crops are rotated, popcorn land soon becomes devastated with weeds. But in the rotation, popcorn should not follow field corn because volunteer field corn may arise in the field resulting in dent ears in the popcorn crop thereby seriously affecting popping quality (Eldredge and Thomas, 1959).

Yield and quality of popcorn are negatively affected by weed growth. The smaller stalks of popcorn do not

compete so well with weeds. Practices helping to control weeds are suitable rotations, heavy planting rate, early and careful land preparation, and thorough cultivation (Anonymous,1988).

In Nigeria, responses of corn to application of nitrogenous fertilizers have been reported by many workers. Godlsworthy (1967) recommended a rate of 65 kg N/ha for maximum yield throughout the savanna area. Jones (1973) recommended 130 kg N/ha for improved corn varieties at Samaru. Ologunde and Ogunlela (1984) recommended 120 kg N/ha for improved varieties at Southern Guinea Savanna.

It has been establised that a low corn population of about 25,000 plants/ha reduces yield in parts of Northern Nigeria (Taylor, 1977). The low yields were attributed to poor light interception. Haggar and Couper (1973) experimenting on effect of plant density on forage corn at Samaru, Nigeria, observed that increasing plant density from 100,000 to 200,000 increased forage yield. However the high plant density led to the development of thinner stems and remarkable increase in plant height leading to high lodging incidence.

1.5 Objectives of the Study.

Hitherto, there was little or no report on the effect of nitrogen and plant population levels on popcorn in the ecological zones of Nigeria. Most of the studies

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Plant Density.

Plant density has been defined as the number of plants per unit area. It determines the size of the area available to each plant. Its influence on the grain yield of corn has been well studied under different agro-ecological conditions.

Roy and Singh (1986) growing popcorn in India at three plant density levels: 60, 70, and 80 thousand plants per hectare, obtained highest yield (3.85 tonnes per hectare) with the highest density level. But a decrease in grain weight per ear with increase in density was observed. Working with about the same density (88,888 plants per hectare), Yousif and Ali (1986) recommended the plant density level as the best for maximising popcorn yield in Baghdad. In Brazil, Merlo (1988) found that growing popcorn at 160,000 plants per hectare gave best result (2.4t/ha) as compared to that at 80,000 plants per hectare. He reported the plant density to affect plant height, height of first ear insertion, and stem diameter. Taller plants showed higher first ear insertion, and grain yield, and greater stem diameter. Howerver Filho et al (1988) working in the same area, reported a decrease in yield with increase in population. They observed that growing popcorn at 80 - 240 thousand

100,000 plants per hectare were obtained by Ifenkwe et al., (1984) and Gardner and Tetio (1986) working in Kuru and Cameroun respectively.

Other workers that obtained increased yield with high plant density of corn plant are Gemma et al., (1984) in Japan with 6.7 tonnes per hectare at 139,000 plants per hectare; West et al., (1985) with 12.35 tonnes per hectare at 30,500 plants per hectare; Pestean (1986) in Romania with 15.0 tonnes per hectare at 100,000 plants per hectare; Araujo et al., (1988) in Brazil and Boquet et al., (1988) in U.S.A. with highest yield at 50,000 and 87,000 plants per hectare respectively.

But in contrast a decline in yield was obtained with increase in population by Elsahookie and Wassom (1984) in Iraq, Monotti (1985) in Italy, Munteanu et al., (1985) in Romania; Quiles - Belen et al., (1988) in Puerto Rico; Hutchinson et al., (1988) in U.S.A, Lima et al., (1988) in Brazil; and Singh and Mongia (1989) in India.

The plant density was also reported to affect yield components. In field trials at Poland between 1976 and 1979, denser corn stands of 130,000 plants per hectare were found to improve ear, leaf, and stem production, but reduced grain number per ear and 1,000 grain weight (Machul, 1988). A decrease in ear length, number of grains per row, number of grains per ear, grain weight per plant, and 1,000 grain weight with increase in plant

density from 33,333 to 99,999 plants per hectare was observed by Babu and Mitra (1989). In a separate trial, plant density was not found to affect early plant growth, culm length, ear height, and silking date in a sweetcorn cultivar grown at 50 to 90 thousand plants per hectare (Back and Lee, 1990). But number of tillers at harvest and thickness of marketable ears decreased with increased plant population. Increasing plant density from 40 - 80 thousand plants per hectare had been reported to decrease weight per ear, number of seeds per ear, weight per 1,000 seeds, and length of ear by 36.8, 12.7, and 19.8% respectively (Ologunde, 1974).

Many growth factors are also known to be affected by plant density. Alessi and power (1975) studied early-maturing corn hybrids in the northern regions of the Great Plains of the U.S. and found that increasing plant densities up to 74,000 plants per hectare produced leaf area index (LAI) as high as 4.9 depending on hybrid and season. Olson and Sander (1988) observed that increasing plant density improved the LAI but increased the susceptibility of stalk to lodging and did not increase grain yields even if total dry matter production was increased.

At Northern latitudes of U.S.A., the optimum LAI for maximum grain yield has been reported to be 3.0 - 3.2 (Tollenaar, 1989). A plant density giving L.A.I. within

nitrogen rate from 0 to 80 kg per hectare, and 15.8% when the nitrogen level was further increased from 80 - 160 kg per hectare. However no further increase was observed at 240 kgN per hectare. Prasad and Singh (1990) obtained an average grain yield of 4.67 tonnes per hectare associated with long ears when corn received increased nitrogen level from 0 - 90 kg per hectare. But Sardaki and Balla (1990) observed that application of 150 kgN/ha was no more effective than 100 kgN/ha. Applying the 100 kgN/ha increased grain yield by 1.0 ton per hectare compared with 50 kgN/ha.

It had been reported that growing corn hybrids using 0 to 220 kg N/ha resulted in grain yields of 7.02 tonnes/ha at 100 kgN/ha. The higher nitrogen rates did not increase yields (Timigaziu et al., 1987). But in a different trial, 150 kgN/ha was found to give maximum grain yields of 8.09 tonnes per hectare (Said and Menyhert, 1986). In another trial with a corn cultivar given 143, 214 or 286 kgN/ha, Abdulhalim (1990) obtained average corn yield increases up to 214 kgN/ha but no further increase was recorded at 286 kgN/ha. In a related work in Ghana, Hardter et al., (1987) using 0 -80 kgN/ha, obtained 2.07 tonnes per hectare at the zero nitrogen and 2.67 tonnes per hectare with the 80 kgN level per hectare.

Balasubramanian (1978) working at Samaru, observed

that applying various nitrogen rates up to 120 kg per hectare resulted in increased grain yield, while increasing the rate to 180 kg per hectare resulted in decrease in yield. However, Ologunde and Ogunlela (1984) working at Mokwa and Omu-Aran recommended 100 - 150 kgN/ha to be the optimum nitrogen level for grain yield. Idem (1989) recommended the use of 120 kgN/ha with half applied at planting and remaining half at six weeks after planting.

At Ile-Ife, corn grown with 0, 100,200, or 300 kgN/ha in two equal split applications at sowing and six weeks later, gave the highest grain yield (6.15 tonnes per hectare) with the highest nitrogen level per hectare (Fapohunda and Hossain, 1986). In contrast, Mbagwu (1990) working in the South-eastern part of Nigeria with 0 - 240 kgN/ha obtained highest yield at 142 kgN/ha and not with the highest nitrogen level.

Related trials that reported yield increases with increasing nitrogen levels include that of Flowerday (1981) in U.S.A., Mazur, et al., (1982) in Poland, Matkevich (1984) in former U.S.S.R., Gheith and El-Hattab (1984) in Egypt, Quiles-Belen (1988) in Puerto Rico, and Hutchinson, et al., (1988) in U.S.A.

Nitrogen had been found to influence many growth and yield parameters of corn. Prasad and Singh (1990) reported a significant increase in ears per plant, grain

weight per ear, 1,000 grain weight, and ear length and a decrease in number of days to 50% silking and tasseling when nitrogen was increased from 0 - 90 kg per hectare. But in trials at Philippines, nitrogen rates were not found to affect flowering dates of the corn plant (Burgos et al., 1989). However, Lee and Choi (1990) using 0,50,100,150 or 200 kgN/ha on sweet corn obtained the earliest silking date, highest LAI, and highest ear yield with the highest level of nitrogen.

Plant height and number of grains per ear of corn, were found to increase with increase in nitrogen levels up to 100 kg per hectare, after which further increases in the nitrogen rate reduced plant height and grains per ear (Arain et al., 1985). Application of rates of nitrogen (ranging from 0 - 336 kg per hectare) in the United States and incorporating into the soil before sowing resulted in increased nitrogen concentration in the corn grain (Cerrato and Blackmar, 1990).

Ologunde (1984) found an increase of 35.5, 26.8, 19.6, and 13.0% in terms of ear weight, number of grains per ear, ear length, and number of ears per plant respectively when nitrogen level was raised from 0 -336 kg per hectare. In a similar trial, Ragheb et al., (1989) using 178 - 321 kgN/ha obtained increased number of leaves per plant, leaf length and width, and total dry matter per plant with increasing nitrogen levels.

Nitrogen was observed to cause a reduction in the number of days to 50% tasseling with increase in its level (Ologunde, 1974). Similarly increased nitrogen rate was found to reduce shelling percentage (Ologunde and Ogunlela, 1984). In a different trial, shelling percentage was reported not to be influenced by changes in nitrogen level (Agboola and Kayode, 1981).

Generally, increased nitrogen in soil leads to increased nitrogen in the corn plant (Ologunde, 1974). The nitrogen supply could either be in organic or inorganic form or a combination of both for maximum yield to be obtained (Giddens et al., 1981).

The response of corn to nitrogen fertilizer is known to be related to the level of soil organic matter, the total N content of the soil, the texture of the soil, and the variety of corn used. Generally, corn planted in sandy loam soil performed better than those planted in loamy sand at all levels of nitrogen applied (Singh et al., 1979).

2.3 Popping Percentage.

The ability to pop is the unique characteristics that distinguishes popcorn from other types of corn. But it should be noted that some corns, especially flint, pop fairly well, while some dent corns pop feebly under optimum conditions (Brunson, 1955).

Exactly why popcorn pops is not well understood.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL SITE

The experiment was conducted during the 1991 rainy season at the Institute for Agricultural Research farm in Samaru (11° 11'N,7°38'E and 686m above sea level) located in the Northern Guinea Savanna ecological zone of Nigeria. Annual rainfall of the area is about 1087mm (Kowal and knabe, 1972). Records of total rainfall of the area and its distribution during the experimental period were collected from the metereological station, I.A.R. and given in Appendix I. The field used for the trial was fallow during the 1990 rainy season.

3.2 Soil Analysis.

Soil samples were collected from four randomly selected locations at the experimental site at depths of 0-15 and 15-30cm soil depth using a hand auger. The samples were bulked, dried, and a composite sample was made and analysed for physico-chemical properties using standard procedures (Appendix 2). (Juo, 1975).

3.3 Treatments and Experimental Design.

Treatments consisted of four nitrogen levels, (0,50,100, and 150 kgN/ha) and three plant densities (53,333,71,111, and 106,666 plants/ha) in all possible factorial combinations. The experiment was laid out in a randomised complete block design. Each treatment was

replicated four times and accomodated on six ridges spaced at 75cm apart and 5m long to give a gross plot size of 22.5m². The four inner rows (net plot) were harvested at maturity for grain yield determination. The net plot size equals to 15.0m². Row lengths were small due to lack of sufficient seeds.

3.4 Variety.

The popcorn variety used for the trial was Sampop I' obtained from the Plant Science Department, Ahmadu Bello University, Zaria. It is a pearl variety that has rounded grains with deep yellow colour.

The variety tillers very well, but the tillers were immediately removed on emergence so as to maintain the required plant population level.

3.5 Cultural Operations

3.5.1 Land Preparation

The experimental site was ploughed, harrowed, and ridged 0.75m apart. Plots were demarcated with a measuring tape and pegged. Each plot was separated from its neighbour by an unplanted border measuring one metre.

3.5.2 Fertilizer Application

Muriate of potash (60% of K_2O) and single superphosphate (18% P_2O_5) were applied basally, each at 60 kg K_2O and P_2O_5/ha respectively . Nitrogen was applied as calcium ammonium nitrate (26%N) at the rates of 0,50,100, and 150 kg per hectare. Each nitrogen rate

was applied in two split doses, one half at planting and the other half six weeks after planting. The first and second nitrogen doses were side banded 7.5cm from the plant and covered with soil immediately after application.

3.5.3 Sowing.

Popcorn seeds were sown by hand at the rate of 4 seeds per hole. Intra-row spacing of 12.5, 18.75, and 25cm between stands were used to achieve the required plant population of 106,666, 71,111 and 53,333 plants per hectare respectively.

3.5.4 Weeding and thinning.

Weeds were controlled manually in the experimental plots at 3 and 6 weeks after sowing and subsequently when found necessary. Thinning to one plant per stand was done at 2 weeks after sowing and missing stands were supplied.

3.6 Observations made.

3.6.1 Stand Count

The number of plants in each treatment that survived 3 weeks after sowing and at harvest (12 WAS) were recorded and expressed as percentage of total number of plants in that treatment. The population was maintained at 6 W A S.

3.6.2 Plant height (cm)

Plant height from ground level to the tip of plant was measured at 6 weeks after sowing and at harvest.

3.6.3 Total dry matter (gm).

Total dry matter per plant was determined at harvesting by sampling five plants and oven-drying to a constant weight at 70°c.

3.6.4 Days to 50% tasselling.

The number of days when 50% of the popcorn plants had tasselled was recorded.

3.6.5 Days to 50% silking.

This was recorded when 50% of the popcorn plants have silked.

3.6.6 Leaf area index.

This was determined by measuring the length and maximum breadth of a functional leaf and multiplying by a factor of 0.7 (Watson, 1947). Five plants were sampled in each plot. The leaf area obtained from the individual leaves were added and then divided by the number of plants sampled. The resultant leaf area per plant was then multiplied by the total number of plants in one square meter ($1m^2$) and divided by the land area.

3.6.7 Plant Anaylsis

Tissue analysis was done to determine nitrogen content of the ear and index leaves at 50% silking using the standard micro-kjeldahl procedure (Juo, 1975)

using 20ml vegetable groundnut oil per 100 seeds sample for a period of 3 minutes. Number of unpopped seeds were then counted.

3.9 Analysis of Data.

Treatment effects were tested for significance using the 'F' test as described by Snedecor and Cochran (1967). Where the 'F' test showed significance, the means were compared using Duncan Multiple Range Test (Duncan, 1955). Correlation and regression analyses were made for some selected variables.

CHAPTER FOUR

4.0 RESULTS.

4.1 Stand Count.

Although plant density did not significantly influence stand count at three weeks after sowing (3 WAS.) it was significantly influenced at 12 WAS (harvesting period) (Table 1). There was a 14.7% decline in stand count by increasing the plant density from 53,333 to 106,666 plants/ha.

Nitrogen application significantly, influenced plant stand count. At harvesting (12 W.A.S.) increasing nitrogen level from zero to 150 kg/ha increased stand establishment by 15.8%.

4.2 Plant Height.

Plant density had significant effect on plant height at harvesting (12 W A S) (Table 2). Increasing plant density from 53,333 to 106,666 plants/ha resulted in a 5.7% decline in height.

Nitrogen application significantly increased plant height at 6 WAS and at harvest. At harvest, application of 50 and 100 kgN/ha increased plant height by 10.6 and 17.6% respectively when compared with zero nitrogen level. However increasing nitrogen level from 100 to 150 kg/ha did not significantly affect plant height.

4.3 Days to 50% Tasselling and Silking.

Plant density had no significant effect on days to 50% tasselling and silking (Table 3).

Table 1. Stand establishment of popcorn as influenced by plant density and nitrogen level at I.A.R Farm, Samaru in 1991.

Treatment	Stand count (%)	
Plant density		
(Plants/ha)	3 W A S	12 W A S
53,333	79	84 a
71.111	78	79 a
106,666	75	72 b
Mean	77.0	78.0
S.E (±)	3.31	2.02
Nitrogen Levels (Kg/ha)		
0	71.0b	73.0c
50	71.0b	75.0bc
100	82.0a	81.0ab
150	86.0a	84.0a
Mean	77.0	78.0
S.E(±)	3.83	2.33
Interaction		
(D x N)	N.S.	N.S

Means followed by the same letter(s) within the same treatment column are not significantly different at 0.05 level of probability using DMRT.

Table 2. Plant height of popcorn as influenced by plant density and nitrogen level at I.A.R Farm, Samaru in 1991.

Treatment	Plant height (cm)	
Plant density (Plants/ha)	6 W A S	12 W A S
53,333	109.0	183.0 a
71.111	113.0	182.0 a
106,666	100.0	173.0 b
Mean	107.0	179.0
S.E(±)	5.18	2.90
Nitrogen Levels (Kg/ha)		
0	80.0c	159.0c
50	104.0b	175.0b
100	122.0a	186.0a
150	123 0a	196.0a
Mean	107.0	179.0
S.E(±)	5.98	3.35
Interaction		
(D x N)	N.S.	N.S

Means followed by the same letter(s) within the same treatment column are not significantly different at 0.05 level of probability using DMRT.

However there was generally a decrease in the number of days as plant density increased from 53,333 to 106,666 plants per/ha.

Application of nitrogen significantly reduced the number of days to 50% tasseling and silking. Increasing nitrogen level from zero to 100 kg/ha significantly influenced 50% tasseling. Further increase to 150 kg/ha led to a 10.3% and 9.9% decrease in number of days to 50% tasseling and silking respectively.

4.4 Nitrogen Concentration in Ear and Index Leaves at 50% Silking.

There was no significant effect of plant density on the nitrogen concentration in ear and index leaves, but nitrogen application significantly influenced the N concentration in ear and index leaves (Table 4). Increasing nitrogen level from 0 to 100 kg/ha increased nitrogen concentration in ear leaf by 26.9%, but increasing the level further to 150 kg per hectare did not confer any further significant increase in N concentration of the ear leaf.

Increasing nitrogen level from 0 to 50 and from 0 to 100 kg per hectare increased index leaf nitrogen concentration by 25.5 and 78% respectively.

4.5 Total Dry Matter Per Plant.

Total dry matter (TDM) declined but not significantly with increasing plant density (Table 5). TDM however, increased with increasing nitrogen levels. Application of 50,100 and 150kgN per hectare increased TDM per plant by 43.2, 59.5 and 64.9% respectively compared with the zero nitrogen level.

Table 3. Days to 50% tasseling and silking of popcorn as influenced by plant density and nitrogen level at I.A.R Farm, Samaru in 1991.

Treatment	Days to tasseling and silking	
Plant density (Plants/ha)	50% tasselling	50% silking
53,333	58.00	67.00
71.111	57.00	64.00
106,666	57.00	65.00
Mean	57.35	65.02
S.E(±)	0.627	0.736
Nitrogen Levels (Kg/ha)		
0	61.00 c	70.00 b
50	58.00 b	64.00 b
100	55.00 a	63.00 a
150	55.00 a	63.00 a
Mean	57.35	65.02
S.E(±)	0.723	0.849
Interaction		
(D x N)	N.S.	N.S

Means followed by the same letter(s) within the same treatment column are not significantly different at 0.05 level of probability using DMRT.

Table 4. Nitrogen concentration in ear and index leaves of popcorn as influenced by plant density and nitrogen level at I.A.R Farm, Samaru in 1991.

Treatment	Nitrogen concentration (at 50% silking)	
Plant density (Plants/ha)	Ear leaf	Index leaf
53,333	1.526	1.994
71.111	1.387	1.880
106,666	1.401	1.697
Mean	1.438	1.857
S.E(±)	0.044	0.081
Nitrogen Levels (Kg/ha)		
0	1.238 b	1.276 c
50	1.344 b	1.601 b
100	1.571 a	2.271 a
150	1.600 a	2.280 a
Mean	1.438	1.857
S.E(±)	0.051	0.093
Interaction		
(D x N)	N.S.	N.S

Means followed by the same letter(s) within the same treatment column are not significantly different at 0.05 level of probability using DMRT.

4.6 Leaf Area Index.

Leaf area index (LAI) was not significantly increased by plant density (Table 5). LAI ranged between 3.3 and 3.6 for all density levels.

Application of 50 and 100 kgN per hectare significantly increased LAI by 25.2 and 47.3% respectively compared with zero nitrogen level. Increasing nitrogen level from 100 to 150Kg per hectare had no effect on LAI.

4.7 Cob Yield Per Hectare.

Plant density significantly affected cob yield per hectare but not number of cobs per plant (Table 6). Increasing plant density from 53,333 to 71,111 plants per hectare gave a 42.62% increase in the yield of cobs per hectare but increasing it further to 106,666 plants/ha reduced cob yield but not significantly.

Increase in nitrogen levels from 0 to 50 and from 0 to 100kg per hectare gave a 53.6 and 105% increase in cob yield per hectare respectively. Increasing the nitrogen level from 100 to 150 kg per hectare had no effect on cob yield/ha.

4.8 Number of Grains Per Cob.

There was generally a decrease in the number of grains per cob with increase in plant density, but such reductions were not significant (Table 7). Nitrogen levels had no effect on number of grains per cob.

Table 5. Total dry matter (TDM) per plant and leaf area index (LAI) of popcorn as influenced by plant density and nitrogen level at I.A.R Farm, Samaru in 1991.

Treatment	TDM/Plant(g) (12 W.A.S)	LAI (Flowering Stage)
Plant density (Plants/ha)		
53,333	80.0	3.28
71.111	78.0	3.54
106,666	75.0	3.56
Mean	77.8	3.46
S.E(±)	5.37	0.187
Nitrogen Levels (Kg/ha)		
0	55.0 b	2.62 c
50	79.0 b	3.28 b
100	87.0 a	3.86 ab
150	90.0 a	4.08 a
Mean	77.8	3.46
S.E(±)	6.2	0.216
Interaction		
(D x N)	N.S.	N.S

Means followed by the same letter(s) within the same treatment column are not significantly different at 0.05 level of probability using DMRT.

Table 6. Number of Cobs per plant and cob yield per hectare of popcorn as influenced by plant density and nitrogen level at Samaru in 1991.

Treatment	Number of cobs per plant	Cob yield (kg/ha)
Plant density (Plants/ha)		
53,333	1.575	3043 b
71.111	1.594	4340 a
106,666	1.563	4239 a
Mean	1.577	3874
S.E(±)	0.059	272.8
Nitrogen Levels (Kg/ha)		
0	1.283	2347 c
50	1.500	3606 b
100	1.717	4808 a
150	1.808	4736 a
Mean	1.577	3874
S.E(±)	0.068	314.99
Interaction		
(D x N)	N.S.	N.S

Means followed by the same letter(s) within the same treatment column are not significantly different at 0.05 level of probability using DMRT.

Interaction between plant density and nitrogen levels on the number of grains per cob was significant (Table 8). Combination of 53,333 plants per hectare with 100 kgN per hectare gave the highest number of grains per cob, while combination of 106,666 plants per hectare with 150kgN per hectare gave the lowest number of grains per cob.

4.9 Grain Yield Per Hectare

Grain yield per hectare increased significantly by 45% when plant density level was increased from 53,333 - 71,111 plants per hectare (Table 7). A 1.6% decline in grain yield was observed when plant density was further increased from 71,111 to 106,666 plants per hectare.

Nitrogen application significantly increased grain yield per hectare. Application of 50 and 100kgN per hectare resulted in 39.1 and 74.42% increase in grain yield respectively as compared with zero nitrogen level. Increasing the level from 100 to 150Kg per hectare had no effect on grain yield.

4.10 Weight of Grains Per Cob and 100 Grain Weight.

Plant density had no significant effect on the 100-seed weight and the weight of seeds per cob (Table 9).

Table 7. Number of grains per cob and grain yield per hectare of popcorn as influenced by plant density and nitrogen level at Samaru in 1991.

Treatment	Number of grains per cob	Grain yield (kg/ha)
Plant density (Plants/ha)		
53,333	592.0	2599 b
71.111	608.0	3772 a
106,666	571.0	3712 a
Mean	590.5	3386
S.E(±)	10.86	205.6
Nitrogen Levels (Kg/ha)		
0	578.0	2299 c
50	582.0	3198 b
100	614.0	4010 a
150	588.0	3937 a
Mean	590.5	3386
S.E(±)	12.53	237.3
Interaction		
(D x N)	*	N.S

Means followed by the same letter(s) within the same treatment column are not significantly different at 0.05 level of probability using DMRT.

Table 8. Interaction between plant density and nitrogen levels on number of grains per cob of popcorn at Samaru in 1991.

Treatment	Plants/ha		
	53,333	71,111	106,666
Nitrogen Levels (Kg/ha)			
0	548.0 cd	620.0 ab	567.0 bcd
50	550.0 cd	604.0 abc	590.0 abcd
100	623.0 ab	625.0 ab	595.0 abcd
150	649.0 a	583.0 bcd	533.0 d
S.E(±) =	21.71		

Means followed by the same letter(s) are not significantly different at 0.05 level of probability using DMRT.

Table 9. Weight of grains per cob and 100 grain weight of popcorn as influenced by plant density and nitrogen levels at Samaru in 1991.

Treatment	Weight of grains per cob (g)	100 - Grain weight (g)
Plant density (Plants/ha)		
53,333	55.2	13.43
71.111	61.8	13.81
106,666	56.9	13.10
Mean	58.0	13.45
S.E(±)	2.58	0.43
Nitrogen Levels (Kg/ha)		
0	45.9 a	12.72
50	57.6 b	13.47
100	67.3 c	13.79
150	61.2 c	13.80
Mean	58.0	13.45
S.E(±)	2.98	0.49
Interaction		
(D x N)	N.S.	N.S

Means followed by the same letter(s) within the same treatment column are not significantly different at 0.05 level of probability using DMRT.

Application of nitrogen increased grain weight per cob significantly. A 46.62% increase was obtained by increasing nitrogen levels from 0 to 100kg per hectare, but increasing nitrogen level from 100 - 150kg per hectare reduced seed weight per cob.

4.11 Shelling Percentage

Shelling percentage was not significantly influenced with increase in plant density (Table 10), but increasing level of nitrogen from 0 to 50kg per hectare tended to increase the shelling percentage.

4.12 Popping Percentage

Increase in plant density levels reduced popping percentage but such reductions were not significant (Table 10).

A significant increase of 15.14% in popping percentage was obtained by increasing nitrogen level from 0 to 100kg per hectare. Increasing the nitrogen level from 100 to 150 kg per hectare tended to reduce popping percentage by 9%.

Table 10. Shelling and popping percentage of popcorn as influenced by plant density and nitrogen level at Samaru in 1991.

Treatment	Shelling %	Popping %
Plant density (Plants/ha)		
53,333	71.93	78.4
71.111	74.30	76.8
106,666	73.18	73.9
Mean	73.14	76.4
S.E(±)	1.263	2.29
Nitrogen Levels (Kg/ha)		
0	64.93 c	72.0 b
50	73.24 b	73.5 b
100	77.85 a	82.9 a
150	76.54 ab	77.0 ab
Mean	73.14	76.4
S.E(+)	1.458	2.39
Interaction		
(D x N)	N.S.	N.S

Means followed by the same letter(s) within the same treatment column are not significantly different at 0.05 level of probability using DMRT.

4.13 Correlation and Regression.

Correlation studies showed that some plant characters were identified as having positively and significantly contributed to grain yield. These are plant height ($r = 0.509^{**}$), total dry matter ($r = 0.390^{**}$), number of cobs per plant ($r = 0.848^{**}$), weight of seeds per cob ($r = 0.751^{**}$), and leaf area index ($r = 0.417^{**}$) (Table 11).

Regression equation showed a quadratic response to nitrogen application. The equation is presented as:

$Y = 2354 + 23.9N - 0.0871N^2$ ($R^2 = 0.334$).

From the equation the optimum nitrogen rate was calculated to be 137.4kg per hectare.

Table 11. Correlation matrix between grain yield and other plant characters of popcorn.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V1	1.000									
V2	0.569**	1.000								
V3	0.390**	0.572**	1.000							
V4	0.374**	0.514**	0.479**	1.000						
V5	0.848**	0.631**	0.410**	0.390**	1.000					
V6	0.751**	0.594**	0.391**	0.367	0.665**	1.000				
V7	0.417**	0.415**	0.455**	0.270	0.434**	0.267	1.000			
V8	-0.005	0.224	0.287	0.149	0.044	0.175	0.112	1.000		
V9	-0.603**	-0.388**	-0.510**	-0.647**	-0.468**	-0.674**	-0.333*	-0.248	1.000	
V10	-0.723**	-0.655**	-0.560**	-0.565**	-0.615**	-0.626**	-0.369*	-0.062	0.781**	1.000

V1 = Grain yield per hectare
V2 = Plant height at 12 W.A.S.
V3 = Total dry matter
V4 = Number of cobs per plant
V5 = Cob yield per hectare
V6 = Weight of seeds per cob
V7 = Leaf area index
V8 = Popping percentage
V9 = Days to 50% tasselling
V10 = Days to 50% silking

* = Significant at 5% level.
** = Significant at 1% level.

CHAPTER FIVE

5.0 DISCUSSION.

5.1 Effect of Plant Density Levels.

Crop stands grown at low density level usually exhibited higher number of leaves and branches and wider plant leaf spread thereby enhancing greater interception of light energy and production of more assimilates. Increasing the density level could decrease productivity per plant due to high degree of competition for available light, water, and nutrients among the crops as well as increased shading effect.

Increase in grain yield with increased density is due to more cobs per unit area which compensate for reduction in yield of individual plants. The result conforms with that of Roy and Singh (1986) and Yousif (1986) who obtained highest grain yield in popcorn at 80 and 88 thousand plants per hectare respectively. The decrease in grain yield when density was increased from 71,111 to 106,666 plants per hectare could be attributed to interplant competition exhibited by the p,ant at high density. Similar result was obtained by Filho et al., (1988) who reported a decrease in popcorn yield with increase in population.

Plants at low density were known to have more room for adequate establishment than densely populated plants due to adequate nutrients and light. This could be the

reason why stand establishment at 3 and 12 WAS was observed to decrease with increasing density level. Berzsenyi (1988) reported that increased plant density level caused a decreased in growth and establishment of corn hybrids grown at 20 - 120 thousand plants per hectare.

The decrease in plant height and total dry matter with increasing plant density level could be attributed to interplant competition for growth factors. However the decrease in height with increasing density is in conflict with what was reported by Shun et al. (1989) who observed increased internode length and plant height with increased plant density, 'but' is in agreement with the findings of Hefni et al., (1984) and Filho et al., (1988) who reported decreased plant height with increasing density. Binderova (1984) reported increase in plant height to be positively correlated with total precipitation. This could have contributed to the lower density plants recording the highest plant height. The decrease in the total dry matter per plant with increased plant density is in conformity with what was obtained by Berzsenyi (1988) and Shun et al., (1989).

The increase in leaf area index with increased plant density could be attributed to higher number of plants per area. Increased plant density had been attributed to improve leaf area index but may not increase grain yields

even if total dry matter production is increased (Olson and Sander, 1988).

The decrease in nitrogen concentration in both ear and index leaves with increased plant density level conforms to the findings of Ologunde (1974) who observed significant decrease in nitrogen concentration of the ear leaf of corn with increased plant density. In a related trial both potassium and crude fibre content in stems where found to decrease with increase in plant density (Shun et al., 1989).

The significant increase in cob yield per hectare obtained by increasing plant density level from 53,333 to 71,111 plants per hectare could be attributed to increased leaf area index. Hunter (1980) observed that increase in leaf area resulted in increased ear yield of corn hybrids. Machul (1988) attributed increased yield to denser crop stands. Reduction in the cob yield with increased plant density beyond 71,111 plants per hectare could be attributed to increased competition, and is in agreement with the findings of Seth and Dhauder (1972) who observed decrease in productivity with increase in plant density level. Similarly, Filho, et al., (1988) reported a decrease in ear yield with increased plant density.

Decrease in percentage popping with increased density could be partly attributed to number of seeds per

cob, which declined after reaching an optimum. Pajic and Babic (1991) reported popping volume to be postively correlated with number of grains.

5.2 Effect of Nitrogen Levels.

Generally the corn plant responded favourably to the application of nitrogenous fertilizers. Nitrogen is an essential constituent of chlorophyll and therefore necessary for promoting vegetative and grain development of the crop.

The increase in grain yield obtained due to increase in nitrogen application from 0 - 100 kg per hectare could be attributed, to ability of nitrogen to promote meristematic and physiological activities and promote plant leaf spread. This resulted in greater photosynthetic capacity and rapid assimilate translocation thereby leading to high grain yield. This is in conformity with the findings of Roy and Singh (1986) who obtained increased grain yield in popcorn with increasing nitrogen rates from 40 - 100 kg per hectare. Similarly, Sinha and Rai (1990) obtained increasing yield from 1.63 to 3.62 ton in corn grown with 0 -120 kgN per hectare.

The inability of the nitrogen to increase grain yield further when increased to 150 kg per hectare might be due to the limited capacity of the popcorn to utilise greater amount of nitrogen beyond certain optimum. Arain

et al., (1985) observed that increasing nitrogen rates beyond 100 kg per hectare on corn resulted in decline of yield.

Reduction in days to 50% tasseling and silking obtained due to increased nitrogen application could be attributed to the ability of the nitrogen to promote vigorous foliage growth, increase meristematic and physiological activities in the plants thereby resulting in the synthesis of more photoassimilates which combined to initiate early flowering of the crop. El-hout and Blackmer (1990) reported a delay in silking of less than two days under nitrogen deficiencies. Lee and Choi (1990) obtained the earliest silking date with a corn cultivar given 200 kg N per hectare. Ologunde (1974) observed a reduction in the number of days to 50% tasseling with increase in nitrogen level.

The increased plant height, total dry matter per plant and leaf area index obtained with increasing nitrogen levels could be attributed to positive effects of nitrogen on the growth characters which consequently led to increased producitivity (Janick, et al., 1974).

The increased 100 grain weight obtained with increase in nitrogen levels could be attributed to accumulation of more photoassimilates on the grain due to improved leaf area obtained by increasing the nitrogen levels than treatments without N. Prasad and Singh

(1990) observed that increasing nitrogen levels generally resulted in an increased 1,000 - grain weight and grain weight per ear.

With better fertilization, soil amendment, and adequate supply of soil moisture, high plant density and nitrogen levels would be required to provide maximum grain yield in corn. When plant density and nitrogen levels fall below the optimum level, all other inputs of production would fail to produce the desired effect on yield. However, an increase in plant density and nitrogen levels above the optimum for a crop brings about a decrease in grain yield of the individual plants.

CHAPTER SIX

6.0 SUMMARY AND CONCLUSION.

A field experiment was conducted during the 1991 growing season at the Institute for Agricultural Research, Ahmadu Bello University, Samaru, Zaria farm to determine the effect of plant density and nitrogen levels on the yield and yield attributes of popcorn (Zea mays L. variety everta). The treatments consisted of all possible combinations of three plant densities; 53,333, 71,111 and 106,666 plants/ha and four nitrogen levels; 0, 50, 100, and 150 kg/ha. These 12 treatments were laid out in a randomised complete block design replicated four times.

Plant density significantly affected plant height at 12 W.A.S., stand count at 12 W.A.S., cob yield per hectare, and total grain yield per hectare. Increase in nitrogen levels significantly influenced stand establishment, plant height, total dry matter, leaf area index, number of cobs per plant, cob yield per hectare, grain yield per hectare, weight of seeds per cob, shelling percentage, and popping expansion. The effect of the nitrogen levels on number of seeds per cob and 100 - seed weight was found to be non-significant.

Based on the results obtained it can be deduced that crops sown at 71,111 plants per hectare and given 100 kg N per hectare significantly out yielded those sown at

other nitrogen and plant density levels. Greatest popping percentage was obtained by the use of 100 kgN rate per hectare.

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Appendix 1: Rainfall distribution in samaru for the year 1991 (mm) courtesy of motcorological research Unit, I.A.R., A. B. U.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec.
1.					19.5			0.6				
2.									4.3			
3.				11.0		26	26.6		0.9	25.6		
4.					7.8				0.2			
5.									14.6	3.1		
6.						16.5		25.7				
7.							8.8	5.7				
8.					9.0		8.0					
9.					5.7		12.2					
10.						5.6	14.6	15.2				
11.					14.0			27.8				
12.					7.7			15.1				
13.					0.9		8.5	4.6		10.4		
14.		1.8	8.7		5.0	3.8	0.6					
15.		42.9			4.7	1.2						
16.						0.4	2.3	26.6		12.8		
17.							6.6	1.0		1.4		
18.					18.7		3.5	3.5				
19.					11.2		11.2	28.1				
20.					0.9	2.1						
21.					17.8		51.0					
22.								15.9		4.1		
23.					6.3							
24.				6.0	11.0	3.5	30.0	33.7				
25.					3.4	4.8		15.5				
26.				5.3	52.5	11.0		10.6				
27.				11.1	18.8			33.0		0.5		
28.				5.7			10.5	10.6				
29.						33.6	3.2			1.5		
30.					4.1			5.9				
31												
Total		44.7	47.8	243.0	87.0	189.6	329.9	51.2		28.7		

Grand Total = 1,021.9mm

APPENDIX 2: Physical and chemical properties of the soil from the experimental site at I.A.R. Farm, Samaru (1991).

Physical composition (%)	0 - 30cm depth
Sand	64
Silt	28
Clay	8
Textural Class	Sandy loam
Chemical composition	
PH in H_2O	5.6
PH in 0.01m $cacl_2$	5.1
Organic carbon (%)	0.62
Available P (PPM)	29.30
Total N (%)	0.042
Exchangeable bases (meq/100g soil)	
ca	2.32
mg	0.66
k	0.25
Na	0.38
C.E.C.	4.10
H+ and Al	0.11

BIOGRAPHY

1. PERSONAL DATA.

(a) Name: Shamsuddeen Rufa'i

(b) Date of Birth September 4, 1964

(c) Place of Birth Zaria

(d) L. G. A. and State: Zaria, Kaduna State.

(e) Nationality: Nigerian

(f) Tribe: Hausa.

(g) Marital Status: Married.

2. Educational Qualification.

(a) Kaura Primary School, Zaria - 1970 - 1977 Certificate

(b) G. S. S. Dutsin-ma - 1977 - 1982 G. C. E.

(c) C. A. S. Zaria - 1982 - 1984 I.J.M.B.

(d) Usman Danfodiyo University

Sokoto - 1984 -1988 B.Sc. (Agric.)

3. Working Experience.

(a) G. S. S. Tsafe, Sokoto State - 1988 - 1989 - N.Y.S.C,

(b) Jama'atu Girls Arabic Sec.School, Zaria - Oct.1989 - March, 1990

(c) Kaduna A.D.P., Maigana Zone -Mar. 1990 to Jan. 1993.

(d) Afribank Nig. Plc. Bauchi - Jan. 1993 to date.

4, Present Study.

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