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Effect of different population densities and fertilizer rates on the performance of different maize varieties in two rain forest agro ecosystems of South West Nigeria

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The study aimed at identifying the influence of different plant population density and fertilizer rates on three different maize varieties, it was carried out in two cropping seasons (2007/2008 and 2008/2009) at Ibadan and Ikenne in South-western Nigeria. The experiment was a split-split-plot design with three replications. Maize variety (Swan 1-SR an open-pollinated, Obasuper a hybrid and Quality Protein Maize, an improved) was used as the main plot, the sub-plot comprised three plant population densities determined from spacing combinations which are 53,320 plants ha^{-1} (75 x 50cm), 88,880 plants ha^{-1} (90 x 25cm) and 106,640 plants ha^{-1} (75 x 25cm) while the sub-sub-plot was NPK 20:10:10 fertilizer (applied at 120, 150 and 180 kg N ha^{-1}). The results showed that there were significant differences (P≤0.05) for plant height, stalk diameter, stalk lodging, maize cob weight, cob diameter, cob length and grain yield due to influence of different rates of fertilizer and plant population density at both locations. Irrespective of the rates of fertilizer applied, there were no significant differences for stalk diameter at Ibadan and Ikenne. Also, maize variety did not significantly affect (P≤0.05) maize growth performances. However, the results indicated that, the application of 180 kg N ha^{-1} gave the highest grain yield of 3.8 and 3.5 ha^{-1}at Ibadan and Ikenne, respectively, which was not significantly different from the application of 150 kg N ha^{-1}. Thus, the plant population density of 88,880 plants ha^{-1} gave the highest maize grain yield while the lowest yields were recorded for plant population density of 106,670 plants ha^{-1} at both locations. The hybrid maize (Obasuper) variety gave the highest maize grain yield.

Key words: Plant population density, fertilizer rates, maize varieties, NPK fertilizer, south west.

INTRODUCTION

Plant population densities (PPD) have a significant impact on growth and yield of crops, including maize, a popular C4 cereal crop (Hunter, 1978; Cox, 1996). Therefore, understanding how plants regulate their growth in response to plant population densities has problems, such as determination of optimal sowing density (Cox, 1996). Increased plant populations could lead to increased yields under optimal climatic and

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and management conditions due to greater number of smaller cobs per unit area (Bavec and Bavec, 2002).

Plant population is the prime factor for getting maximum yield which is decided by inter and intra row spacing of crops. Decreasing the distance between neighbor rows at any particular plant population has several potential advantages. First, it reduces competition among plants within rows for light, water and nutrients due to a more equidistant plant arrangement (Olson and Sander, 1988; Porter et al., 1997). The more favorable planting pattern provided by closer rows enhances maize growth rate early in the season (Bullock et al., 1988), leading to a better interception of sun light, a higher radiation use efficiency and a greater grain yield (Westgate et al., 1997).

Secondly, the maximization of light interception from early canopy closure also reduces light transmittance through the canopy (McLachlan et al., 1993). The smaller amount of sun light striking the ground decreases the potential for weed interference, especially for shade intolerant species (Gunsolus, 1990; Teasdale, 1995; Johnson et al., 1998). Thirdly, the quicker shading of soil surface during early part of the season results in less water being lost by evaporation (Karlen and Camp, 1985). This is especially important under favorable soil surface moisture conditions because it allows maize plants to maximize photosynthesis and the proportion of water that is used in growth processes rather than evaporated from the soil (Lauer, 1994). Furthermore, the earlier crop cover provided by smaller row width is instrumental to enhance soil protection, diminishing water runoff and soil erosion (Mannering and Johnson, 1969; Sangoi et al., 1998). The nutrient use efficiency can be improved with the use of optimum plant population (Srikanth et al., 2009). In addition, Carena and Cross (2003) had suggested that higher plant population densities are encouraged for germplasm improvement in order to facilitate foraging of the unwanted plants.

However, according to Duncan (1984) plant population above critical density has a negative effect on yield per plant due to the effects of inter plant competition for light, water, nutrient and other potential yield-limiting environmental factors. Similarly, the majority of farmers do not follow the recommended plant population density. Higher plant densities affect leaf area index (LAI), grain yield, ear size and yield negatively (Wiyo et al., 1999). As population increases, the crushing strength, stalk section mass, stalk diameter and rind thickness decreases, allowing for more complications from stalk rot and stalk lodging (Cox, 1996).

Most soils contain an abundance of elements essential for the plants development but majority of these elements are rarely available for plant use due to nutrient loss. Nutrient depletion and soil degradation have become serious threat to agricultural productivity in Nigeria. According to Mba (2006) vast areas of tropical lands that were once fertile have been rendered unproductive due to continuous cultivation and erosion which caused physical degradation, loss of soils organic matter and decrease cation exchange capacity (CEC) as well as increased Al and Mn toxicity. These soils suffered multi-nutrient deficiencies; application of mineral fertilizers has become mandatory to increase crop yields in such soils (Adeniyan and Ojeniyi, 2005).

According to Srikanth et al. (2009), among the plant nutrients, primary nutrients such as nitrogen, phosphorus and potassium play a crucial role in determining the growth and yield. The nitrogen use efficiency can be improved with the use of hybrids, optimum plant population and application of nitrogen coinciding with peak need by the crop. Optimum nitrogen requirement will vary with plant density. Hence, an attempt was made to study the effect of different plant population densities and fertilizer rates on the growth and yield of different maize varieties.

MATERIALS AND METHODS

The field trials were conducted in 2007 and 2008 at Ibadan (7.38° N, 3.84° E) and Ikenne (6.87° N, 3.72° E); two of the research farms of the Institute of Agricultural Research and Training (IAR&T) Moor Plantation Ibadan, to determine the effect of fertilizer rates and planting maize at different spacing on the performance of different maize varieties. Ibadan (transitional rain forest agro-ecology) is located in the dry rainforest area while Ikenne (high rain forest agro-ecology) is located in the wet rainforest agro ecological zone of South-western Nigeria. Before planting at both locations, surface (0 – 15 cm) soil samples were collected from the experimental sites and were then bulked based on locations. The collected soil samples were air-dried, crushed and allowed to pass through 2 mm sieve. Analyses were carried out according to Juo (1975).

The experiment was a split-split-plot design with three replications. Maize variety (Swan 1-SR an open-pollinated, Obasuper a hybrid and Quality Protein Maize an improved) was the main plot, the sub-plot comprised three plant population densities determined from spacing combinations which are 53,320 plants ha^{-1} (75 x 50cm), 88,880 plants ha^{-1} (90 x 25cm) and 106,640 plants ha^{-1} (75 x 25cm) while the sub-sub-plot was NPK 20:10:10 fertilizer (applied at 120, 150 and 180 kg N ha^{-1}).

Planting was done at the onset of rains in the early planting season of the cropping year. Four seeds were planted in each hole and later thinned to two plants per hole soon after emergence. The two locations received the same standard field management routine for optimum grain yield (fertilizer application, herbicide use, manual and mechanical operations). The entire doses of phosphorus and potassium were applied basally. The nitrogen was applied in two splits; after first weeding operation and at tasselling. The N, P and K fertilizers were applied in the form of compound fertilizer NPK 20:10:10. Urea (46%) was applied to top up for nitrogen. Data were collected on percentage lodging; this was estimated by subtracting the number of plants at harvest from the total number of plants that supposed to be on each of the plots based on population density combinations. Plant height and stalk diameter at harvest were measured for each plot. Percentage stalk lodging was calculated at maturity by counting the number of plants that lodged on weekly basis as from 8 weeks after planting. Only those plants that had produced at least one normal cob were counted. The percent lodged stalks were calculated on plot basis. Stalk diameter and plant height at harvest were measured by randomly selecting 20 plants from the center rows of each plot. Stalk diameter were determined by measuring the middle of the first elongated internodes using calipers. The average stalk diameter by variety and population den-

Table 1. Initial soil chemical and physical characteristics of the 0 - 20 cm layer of the soil before planting of maize in 2007.

Parameter	Pre-planting	
	Ikenne	Ibadan
Sand (%)	80.6	77.5
Silt (%)	8.9	9.2
Clay (%)	10.4	13.5
pH (H_20)	5.1	5.3
Org. C (g kg^{-1})	4.22	4.16
Total N (g kg^{-1})	0.76	0.63
Avail. P ($MgKg^{-1}$)	5.12	5.33
Exchangeable bases ($cmolkg^{-1}$)		
K	0.17	0.14
Ca	1.37	1.77
Mg	0.12	0.09
Zn	0.78	0.67

sities was calculated. Average cob weight and length were determined from the twenty plants randomly selected. All data collected were subjected to analysis of variance (ANOVA). Significant means were separated using Duncan multiple range test (DMRT).

RESULTS

Physico-chemical characteristics of the study areas

The physical and chemical properties of the soils of the study areas, Ibadan and Ikenne are presented in Table 1. The texture of the soils in Ibadan and Ikenne was sandy loam. The soil reaction was acid; pH 5.1 and 5.3 for Ikenne and Ibadan, respectively. Organic carbon was 4.22 and 4.16 g kg^{-1} for Ikenne and Ibadan, respectively, such levels of organic C could translate to corresponding low organic matter contents. Total N in both locations was marginally low; 0.76 and 0.63 g kg^{-1} for Ikenne and Ibadan, respectively. The available P and exchangeable bases were generally low in both locations (Table 1).

Combined maize growth performances as influenced by fertilizer rates at Ibadan and Ikenne for 2008 and 2009

There were significant differences (P≤0.05) for plant height and stalk diameter due to the application of different rates of fertilizer at Ibadan and Ikenne irrespective of plant population density and maize variety (Table 2). The highest values recorded at Ibadan (160.9 cm) and Ikenne (157.5 cm) for plant height were recorded for application of NPK fertilizer at 180 kg N ha^{-1}. These were not significantly different from the application of 150 kg N ha^{-1}. The same trends were observed with stalk diameter; it was the application of 180 kg N ha^{-1} that recorded the highest values: 2.37 and 2.38 cm at Ibadan and Ikenne, respectively. Irrespective of the rate of NPK fertilizer app-lied, there were no significant differences for stalk lodging both at Ibadan and Ikenne.

Combined maize growth performances as influenced by population density at Ibadan and Ikenne for 2008 and 2009

There were significant differences (P≤0.05) for plant height, stalk diameter and stalk lodging due to plant popu -lation density at Ibadan and Ikenne irrespective of fertilizer rates and maize variety (Table 2). Plant population density at 106,670 plants ha^{-1} recorded the highest plant height of 210.8 and 204.5 cm at Ibadan and Ikenne, respectively. The reverse was the case with stalk diameter. It was the plant population density at 53,335 plants ha^{-1} that recorded the highest stalk diameter of 2.78 and 2.57 cm at Ibadan and Ikenne, respectively. The highest stalk lodging of 27.5 and 35.9% were recorded for plant population density at 53,335 plants ha^{-1} at Ibadan and Ikenne, respectively.

Combined maize growth performances as influenced by maize variety at Ibadan and Ikenne for 2008 and 2009

There were no significant differences (P≤0.05) for plant height, stalk diameter and stalk lodging due to planting of different maize varieties at Ibadan and Ikenne irrespective of fertilizer rates and plant population density (Table 2).

Combined maize yield and yield parameters performances as influenced by fertilizer rates at Ibadan and Ikenne for 2008 and 2009

There were significant differences (P≤0.05) for maize cob weight, cob diameter, cob length and grain yield due to the application of different rates of fertilizer at Ibadan and Ikenne (Table 3). At Ibadan, highest values; 237.9 g, 19.0 cm, 28.1 cm and 3.8 t ha^{-1} were recorded for cob weight, cob diameter, cob length and grain yield, respectively, with the application of 180 kg N ha^{-1} which was not significantly different from 150 kg N ha^{-1} (Table 3). The same trend was observed for Ikenne where highest values; 230.3 g, 18.9 cm, 27.6 cm and 3.5 t ha^{-1} were recorded for cob weight, cob diameter, cob length and grain yield, respectively, with the application of 180 kg N ha^{-1} which was not significantly different from 150 kg N ha^{-1}. The lowest values were recorded for 120 kg N ha^{-1} at both locations (Table 3).

Table 2. Effect of fertilizer rates, spacing and variety on growth parameters of maize at Ibadan and Ikenne.

Treatment	Ibadan location			Ikenne location		
	Plant height (cm)	Stalk diameter (cm)	Stalk lodging (%)	Plant height (cm)	Stalk diameter (cm)	Stalk lodging (%)
Fertilizer rate						
120 kg N ha^{-1}	150.8b	2.28b	8.2a	144.6b	2.20b	23.1a
150 kg N ha^{-1}	157.5a	2.34a	9.5a	151.9a	2.35a	25.2a
180 kg N ha^{-1}	160.9a	2.37a	8.5a	157.5a	2.38a	23.9a
Population density						
53,335 plants/ha (75 x 50cm)	137.6c	2.78a	8.70b	133.9c	2.57a	14.8c
88,880 plants/ha (90 x25cm)	184.3b	2.17b	15.8b	180.9b	2.40b	22.6b
106,670 plants/ha (75 x 25cm)	210.8a	1.87c	27.5a	204.5a	1.31c	35.9a
Variety						
QPM	148.8a	2.30a	8.2a	154.6a	2.30a	23.1a
Suwan 1 SR	145.5a	2.31a	9.5a	151.9a	2.35a	25.2a
Obasuper	140.9a	2.33a	8.5a	149.5a	2.33a	23.9a

Numbers within the same column with different letter(s) are significantly different at $P<0.05$.

Combined maize yield and yield parameters performances as influenced by plant population density at Ibadan and Ikenne for 2008 and 2009

Population density significantly affected ($P\leq0.05$) cob weight, cob diameter and cob length at both locations (Table 3). Highest values: 217.3 g, 15.8 cm, and 20.7 cm for cob weight, cob diameter and cob length, respectively, were recorded at Ibadan for plant population at 53,335 plants ha^{-1}. While at Ikenne, highest values: 233.1 g, 16.1 cm and 20.1 cm for cob weight, cob diameter and cob length respectively were recorded for plant population density at 53,335 plants ha^{-1} (Table 3). These values were not significantly different from values recorded for plant population density at 88,880 plants ha^{-1} at both locations. However, the significantly lowest values were recorded for plant population density at 106,670 plants ha^{-1} for Ibadan and Ikenne (Table 3). The significantly highest values; 3.3 and 3.5 t/ha were recorded at Ibadan and Ikenne, respectively for grain yield at plant population density of 88,880 plants ha^{-1}. The significantly lowest values were recorded for plant population density of 106,670 plants ha^{-1} at both locations.

Combined maize yield and yield parameters performances as influenced by maize variety at Ibadan and Ikenne for 2008 and 2009

Maize variety significantly affected ($P\leq0.05$) cob weight and maize grain yield at both locations (Table 3). Obasuper (hybrid) maize variety recorded highest maize cob weight (227.5g) and 3.8 t/ha was recorded for maize grain yield at Ibadan. The same trend was observed at Ikenne, where the highest values: 225.1 g and 3.6 t/ha were recorded for cob weight and grain yield, respectively, for Obasuper (hybrid) maize variety (Table 3).

DISCUSSION

The results clearly indicated that, successive increase in fertilizer from 120 to 180 kg N ha^{-1} had marked influences on the growth parameters of maize but after 150 kg N ha^{-1}, the increase in the growth parameters was comparatively low. The increase in fertilizer levels increased the growth and yield attributes by better uptake of nutrients. The increased fertilizer levels increased the yield attributes by better uptake of all the nutrients and increased translocation of photosynthetic materials from source to sink in hybrid maize could amount to 200 kg as also reported by Parthipan (2000) and up to 225 kg by Singh et al. (1997). Saleem et al. (2003) observed in hybrid maize that response was up to 150 kg P_2O_5 ha^{-1}. Increased doses of phosphorus increased the forage activity, accumulation of food reserves, increased functional leaves and LAI, higher nutrient uptake which lead to higher yield attributes and yield. Ali et al. (2004) reported that with higher dose of K, there is enhancement of LAI, better nutrient translocation from source to sink and better nutrient uptake, hence these factors ultimately result in increase in yield attributes and finally the yield.

The highest plant height and highest percentage stalk lodging that were recorded with the population density of 106,680 plants ha^{-1} could possibly be explained by the added stress from population density pressure. Higher plant population densities increase stress and competition for nutrients, sunlight and water. Increased plant

Table 3. Effect of fertilizer rates, spacing and variety on yield and yield parameters of maize at Ibadan and Ikenne.

Treatment	Ibadan location				Ikenne location			
	Cob weight (g)	Cob diameter (cm)	Cob length (cm)	Grain yield (t/ha)	Cob weight (g)	Cob diameter (cm)	Cob length (cm)	Grain yield (t/ha)
Fertilizer rates								
120 kg N ha^{-1}	222.4b	13.6b	21.8c	2.2b	215.6b	14.4b	21.6c	2.2b
150 kg N ha^{-1}	236.7a	17.2a	26.6ab	3.4a	227.7a	18.6a	25.3ab	3.2a
180 kg N ha^{-1}	237.7a	19.0a	28.1a	3.8a	230.3a	18.9a	27.6a	3.5a
Population density								
53,335 plants/ha (75 x 50 cm)	217.3a	15.8a	20.7a	2.6b	233.1a	16.1a	20.1a	2.9b
88,880 plants/ha (90 x25 cm)	212.4a	14.8a	18.6b	3.3a	232.3a	15.2a	18.6a	3.5a
106,670 plants/ha (75 x 25 cm)	200.6b	11.6b	13.2c	3.6a	205.6b	12.6b	13.1b	3.7a
Variety								
QPM	213.1b	14.8a	20.7a	3.2b	215.1b	14.2a	22.1a	3.2b
Suwan-1 SR	211.4b	15.9a	22.1a	3.2b	218.3b	14.9a	22.6a	3.1b
Obasuper	227.5a	15.6a	23.7a	3.8a	225.1a	15.3a	23.1a	3.6a

Numbers within the same column with different letter(s) are significantly different at $P<0.05$.

stress followed by increased plant height and reduced stalk diameter resulting from high plant population densities could have led to higher stalk lodging. Cox (1996) had stated that, as population increases, the crushing strength, stalk section mass, stalk diameter and rind thickness decreeses, allowing for more complications from stalk rot and stalk lodging. The observed decreased maize cob weight, cob diameter and cob length under increased population densities may be attributed to the statement according to Duncan (1984) that plant population above critical density has a negative effect on yield per plant due to the effects of inter plant competition for light, water, nutrient and other potential yield-limiting environmental factors.

Similarly, Wiyo et al. (1999) had also indicated that higher plant densities affect leaf area index (LAI), grain yield, ear size and yield negatively. The results confirmed that grain yield increased with increasing plant population densities in the order of 20 and 22% for 53,335, 88,880 plants ha^{-1}, respectively but later decreased to 13.3% for 106,670 plants ha^{-1}. Decreased row spacing implies high plant density, which is concomitantly equal to high yield with every successful ear formation per plant so long as critical population density is not exceeded. This finding is supported by Bavec and Bavec (2002) when they reported that increased plant populations could lead to increased yields under optimal climatic and management conditions due to greater number of smaller cobs per unit area. This finding is in contrast to research findings in Argentina by Maddonni et al. (2006) which shows that maize grain yield was stable in response to changes in plant spatial arrangement at all plant population densities. Also, in contrast, Tollenaar et al. (2006) in their research finding argued that a moderate increase in plant-spacing variability does not influence maize grain yield at the canopy level because reductions in grain yield of plants that experience enhanced crowding stress is compensated, in part, by increased yield of plants that experience reduced crowding stress.

However, according to the observation made by Owino (2009), it is worth mentioning that, decreesing row spacing has socio economic implications; high plant population densities mean upward adjustment of the amount of agro inputs used (seed rate and fertilizer). Manual weeding, harvesting and other agronomic maintenance operations would

take more labour and time, as it is difficult working through the dense crop stand.

Conclusion and recommendation

The observed increased maize grain yield under decreesed row spacing may be attributed to reduced competition among plants within rows for light, water and nutrients due to a more equidistant plant arrangement leading to a better interception of sun light, a higher radiation and nutrients use efficiency, and a greater grain yield if the critical population density is not exceeded. However, understanding how plants regulate their growth in response to plant population densities has problems such as determination of optimal sowing density. Decreasing row spacing seems to be an alternative that can be used to intensify crop production per unit land area. It has been clearly indicated that, successive increase in fertilizer from 120 to 180 kg N ha^{-1} had marked influences on the growth parameters of maize but after 150 kg N ha^{-1}, the increase was comparatively low. Planting at row spacing of 90 x 25 cm at 2 plants/hole giving 88,880 plants ha^{-1} and application of 150 kg N ha^{-1} is hereby recommended for the farmers.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES

Adeniyan ON, Ojeniyi SO (2005). Effect of poultry manure, NPK 15-15-15 fertilizer and combinationon of their reduced levels on maize growth and soil chemical properties. Nigerian J. Soil Sci. 15: 34-41.

Bullock DG, Nielsen RI, Nyquist WEA (1988). Growth analysis comparison of corn grown in conventional and equidistant plant spacing. Crop Sci. Madison 28(2):254-258.

Ali T, Anwar S, Shah WA, Ahmad B (2004). Response of maize hybrids/cultivars to various levels of potassium and irrigation frequencies. J. Agron. 3:201-207.

Bavec F, Bavec M (2002). Effects of plant population on leaf area index, cob characteristics and grain yield of early maturing maize cultivars (FAO 100-400). Eur. J. Agron. 16:151-159.

Carena MJ, Cross HZ (2003). Plant density and maize germplasm improvement in the northern Corn Belt. Maydica 48:105-111.

Cox WJ (1996). Whole plant physiology and yield response of maize to plant density. Agron. J. 88:489-496.

Duncan WG (1984). A theory to explain the relationships between corn population and grain yield. Crop Sci., 24:1141-1145.

Gunsolus JL (1990). Mechanical and cultural weed control in corn and soybeans. Am. J. Altern. Agric. Greenbelt 5(1):114-119.

Hunter RB (1978). Selection and evaluation procedures for whole corn silage. Can. J. Sci. 58:661-678.

Johnson GA, Hoverstad TR, Greenwald RE (1998). Integrated weed management using narrow corn row spacing, herbicides and cultivation. Agron. J. Madison 90(1):40-46.

Juo ASR (1975). Selected Methods for Soil and Plant Analysis. Manual Series No.1, IITA, Ibadan.

Karlen DL, Camp CR (1985). Row spacing, plant population and water management effects on maize in the Atlantic Coastal Plain. Agron. J. Madison, 77(2): 393-398.

Lauer J (1994). Should I be planting corn at 30-inch row spacing? Wisconsin Crop Manager Madison 1(6):6-8.

Maddonni GA, Alfredo GC, Otegui ME (2006). Row width and maize grain yield. Agron. J. 98:1532-1543.

Mannering JV, Johnson CB (1969). Effect of crop row spacing on erosion and infiltration. Agron. J. Madison 61(6):902-905.

Mba CN (2006). Influence of organic wastes on plant growth parameters and nutrient uptake by maize (Zea mays L). Nigerian J. Soil Sci. (16):104-108.

McLachlan SM, Tollenaar M, Swanton CJ, Weise SF (1993). Effect of corn induced shading on dry matter accumulation, distribution and architecture of redroot pigweed. Weed Science, Champaign 41(3):569-573.

Olson RA, Sander DJ (1988). Corn production. In: Sprague, G. F.; Dudley, J. W. (Ed.). Corn and corn improvement. Madison: American Society of Agronomy/Crop Science Society of America/Soil Science Society of America, p. 639-686.

Owino CO (2009). Decreased row spacing as an option for increasing maize *(Zea mays L.)* yield in Trans Nzoia district, Kenya. Available online http://www.academicjournals.org/jpbcs ISSN 2006-9758 © 2009 Academic Journals.

Parthipan T (2000). Nitrogen management strategies in hybrid maize (COH 3) using SPAD meter and predictions using CERES - MAIZE model. *M.Sc (Ag.) Thesis.* Tamil Nadu Agric. Univ., Coimbatore.

Porter PM, Hicks DR, Lueschen WE, Ford JH, Warnes DD, Hoverstad T (1997). Corn response to row width and plant population in the Northern Corn Belt. J. Product. Agric. Madison 10 (2).

Sangoi L, Ender M, Merotto Junior A (1998). Dominância apical de híbridos de milho de diferentes épocas em três densidades de semeadura. In: REUNIÃO ANUAL DO MILHO E SORGO, 42, 1997, Erechim. Anais. Erechim: COTREL/EMATER/FEPAGRO, 31-36.

Saleem A, Javed HI, Ullah ZA (2003). Response of maize cultivars to different N P levels under irrigated condition in Peshawar Valley. Pak. J. Biol. Sci. 6:1229-1231.

Singh D, Tyagi RC, Hooda IS, Verma OPS (1997). Influence of plant population, irrigation and nitrogen levels on the growth of spring maize. Haryana J. Agron. 13:54-58.

Srikanth M, Mohamed AM, Muthukrihan P (2009). Influence of plant density and fertilizer on yield attributes yield and grain quality of hybrid maize. Madras Agric. J. 96(1-6):139-143.

Teasdale JR (1995). Influence of narrow row/high population corn on weed control and light transmittance. Weed Technol. Lawrence 9(1):113-118.

Tollenaar M, Deen W, Echarte L, Weidong L (2006). Effect of Crowding Stress on Dry Matter Accumulation and Harvest Index in Maize. Agron. J. 98:930-937.

Westgate ME, Forcella F, Reicosky DD, Somsen J (1997). Rapid canopy closure for maize production in the northern US corn belt: radiation-use efficiency and grain yield. Field Crops Res. Amsterdam 49(2):249-258.

Wiyo KA, Kasmekera ZM, Feyen J (1999). Variability in ridge and furrow size and shape and maize population density on small subsistence farms in Malawi. Soil Tillage 51(1-2):113-119.