Effect of plant density on the yield of maize (*Zea mays* L.) in Ghana

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SUMMARY

Studies were conducted in four locations in Ghana in 1986 to determine the effect of seven planting densities: 10, 20, 30, 40, 50, 60 and 70 × 10^3 plants/ha on grain yield of three maize varieties differing in maturity: early, medium and full season. Maize grain yield was significantly influenced by leaf area index, variety and density. Optimum densities ranged between 49 and 65×10^3 plants/ha in three of the environments studied and expected yields ranged between 4.5 and 6.5 tons/ha. The results suggest that maize differing in maturity perform differently in the environments studied. Kwadaso, Ejura and Kpeve represent environments in which maize could give reasonably good yields.

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RÉSUMÉ

ASAFU-AGYEI, J. N.: *Effets de la densité de la plante sur la rendement du maïs (*Zea mays *L.) au Ghana.* Des études ont été faites dans quatre milieux au Ghana en 1986 pour déterminer l'effet de 7 densités de la plante: 10, 20, 30, 40, 50, 60 et 70×10^3 plantes/ha sur le rendement de trois variétés du maïs qui se distingue par leurs périodes différents d'atteindre la maturité, à savoir précoce, moyenne et tardive. Le rendement du grain du maïs était signifcativement influencé par l'indice de l'aire de la feuille,"Leaf Area Index (LAI)", la variété et la densité. Les densités optimum s'écartent entre 49 et 65×10^3 plantes/ha dans trois milieux et le rendement de prévision s'écartent entre 4.5 et 6.5 tons/ha. Les résultats montrent que les différents maïs ont des rendements différents dans des milieux étudiés. Kwadaso, Ejura et Kpeve sont des milieux dans lesquelles le maïs peut donner de bonnes rendements.

Introduction

Light, water and nutrients and in certain instances temperature and wind impose physiological limits to yield in most crops. In the tropics, limitation to yield in many situations is due to water stress and soil infertility. However, the effect of biotic factors in determining yield in crop production is also important and continues to attract research attention. Plant density in particular, with its attendant effect on crop competition, has been used to influence yield over the years. In maize, adequate planting rates are necessary to give optimum stand at harvest.

Maize planting density required for maximum yield has been estimated to vary between 40 and 100 × 10^3 plants/ha depending on location (Larson & Hanway, 1977). Grain yield in maize normally increases to a maximum with density and then declines beyond an optimum (Willey & Heath, 1969). As plant density increases, resources available to the individual plants in the community decrease. Yield per plant, therefore, decreases (Dungan, Lang & Pendleton, 1958). This ultimately leads to yield loss per hectare beyond an optimum density. Maize planting density for maximum yield has been estimated by other workers to range between 40 and 60×10^3 plants/ha (Allison, 1969; Stickler, 1964). In Ghana, optimum density has also been shown to vary between 40 and 60×10^3 plants/ha (GGDP, 1981 - 1984).

Within a location, density interacts with maturity period for a particular germplasm. Grain yields obtained for early maturing hybrids at 2.8 plants/m^2 was less than that of later maturing hybrids at 1.5 plants/m^2 in Florida (Horner & Hull, 1952). At Oxford in England, a tall full season variety gave higher yield at a lower density while a short early maturing variety gave the higher yield at the higher density (Voldeng & Blackman, 1975).

Early maturing varieties should be preferred in certain drought-prone areas because of their greater chance of completion of silk emergence and pollination before drought inhibits such critical processes. In Ghana, drought occurrence cannot be accurately predicted and both early and full season varieties are needed. Varieties in use have been selected based on ability to fit into existing major ecological zones as well as farmer conditions (GGDP, 1981-1984).

The purpose of this study was to investigate the relationship between plant density and grain yield of three of the improved open-pollinated maize varieties in Ghana. The yielding ability of the varieties, in the environments studied, was also investigated.

Materials and methods

Field experiments were conducted in four different locations in Ghana in 1986 major season and in one location in 1986 minor season. The major season rains normally begin in March and end in July. There is a short dry spell in August and then the minor season rains begin and end in October or November. In the major season, the locations used for this study were: Kwadaso in the central forest belt of Ghana, Kpeve in the forest-transitional area in the south-eastern part of Ghana, Ejura in the forest savanna transitional area in the north of the central forest belt and Pokuase in the south coastal savanna area of Ghana. In the minor season, only the Ejura location was planted.

Cultural practices involved planting maize and thinning to desired stand. Desired planting densities were obtained by changing spacings within rows while spacing between rows was maintained at 100 cm. Maize seed was protected from predators by using Furadan 350 ST (*Carbo-furan*) for seed treatment at the rate of 10.5 g a.i. kg^{-1} of seed.

Treatments consisted of three open-pollinated maize varieties and seven planting densities. The three maize varieties were: Dorke CRI (90-day early maturing white dent): Aburotia CRI (110-day medium maturing white dent) and Dobidi CRI (120-day full season white dent). The seven planting densities used are shown in Table 1.

TABLE 1

Planting Densities, Within Row Spacing and Number of Plants per Hill Used in the Four Locations in 1986

Planting density (10^3 plants/ha)	*Within row spacing (cm)*	*Number of plants per hill*
10	100.0	1
20	50.0	1
30	33.3	1
40	50.0	2
50	40.0	2
60	33.3	2
70	28.6	2

Leaf area per plant was obtained as the sum of the surface area per leaf which is given by the length × the width × 0.75 (Montgomery, 1911), for all leaves.

Parameters measured were plant height, leaf area index (LAI) and grain yield as they were affected by plant density (number of plants at harvest) and location. Analysis of variance was performed to test treatment effects. The methods outlined by Duncan (1958) were used to estimate optimum densities and yield expected at these densities by regressing the log of grain yield per plant upon density.

Results and discussion

There were significant varietal differences in plant height at all locations except at Ejura in the major season (Table 2). Season also appeared to affect plant height.

Plant height was also significantly affected by density except at Ejura in the minor season (Table 3).

Plant height increased with density at Ejura in the major season and at Kpeve in the major season. At Kwadaso, plant height increased with density up to 40,000 plants/ha and then declined. The increase in plant height with increasing density is

TABLE 2

Plant Height of Three Maize Varieties Planted in 1986

	Plant height (cm)			
Variety	*Kwadaso*	*Ejura**	*Ejura***	*Kpeve*
Dorke	170 b+	183 a	144 b	221 b
Aburotia	180 b	175 a	152 b	198 c
Dobidi	223 a	193 a	184 a	238 a
Mean	191	184	160	219
SE	7	5	3	4
CV %	16.3	12.5	9.4	8.5

\+ Values within the same column followed by a different letter differ significantly at the 5 per cent level of probability (DMRT).

* Major season

** Minor season

TABLE 4

Effect of Plant Density on Leaf Area Index of Three Maize Varieties Grown at Kwadaso in 1986

Density (10³ plants/ha)	*LAI*
9	0.8 e+
20	1.4 d
30	1.8 c
40	2.4 b
50	2.8 a
60	3.0 a
69	3.0 a
Mean	2.2
SE	0.1
CV%	12.2

\+ Values within the same column followed by a different letter differ significantly at the 5 per cent level of probability (DMRT).

TABLE 3

Effect of Plant Density on Plant Height of Three Maize Varieties Planted in Four Environments in 1986

Kwadaso		*Ejura**		*Ejura***		*Kpeve*	
Density (10³ plants/ha)	*Plant height (cm)*	*Density (10³ plants/ha)*	*Plant height (cm)*	*Density (10³ plants/ha)*	*Plant height (cm)*	*Density (10³ plants/ha)*	*Plant height (cm)*
9	180b+	9	167c	9	155a	10	199d
20	189ab	20	181b	20	158a	20	218bc
30	186b	30	187ab	30	154a	30	228ab
40	200a	36	191ab	38	162a	40	209cd
50	200a	45	181ab	49	166a	46	231a
60	192ab	55	187ab	58	164a	52	223ab
69	190ab	63	194a	66	162a	57	227ab
Mean	191		184		160		219
SE	4		4		5		4
CV %	6.7		6.6		8.6		5.4

\+ Values within the same column followed by a different letter differ significantly at the 5 per cent level of probability (DMRT).

* Major season

** Minor season

in agreement with Fleming & Wood (1967). Though the full season material was the tallest, lodging was not a factor of importance in these trials.

Leaf area index (LAI) increased with increasing plant density up to 60,000 plants/ha (Table 4). A similar trend has previously been reported (Williams, Loomis & Lepty, 1965). LAI was not affected by variety though the later maturing varieties had higher values.

There were no differences in yield between

TABLE 5

Grain Yield of Three Maize Varieties Grown in Three Environments in 1986

Variety	Grain yield (tons/ha)		
	Kwadaso	Pokuase	Kpeve
Dorke	4.1 b+	2.2 a	4.5 c
Aburotia	4.9 a	2.0 a	5.1 b
Dobidi	4.9 a	1.5 b	6.0 a
Mean	4.6	1.9	5.2
SE	0.1	0.1	0.1
CV %	14.6	27.9	10.1

+ Values within the same column followed by a different letter differ significantly at the 5 per cent level of probability (DMRT).

Thompson & Hammond (1968). It is significant to note that at Kwadaso, Dorke which is an early-maturing variety yielded significantly lower than Aburotia and Dobidi, which were not different from each other in yield. Similarly, at Pokuase, Dobibi, a late-maturing variety yielded significantly lower than Aburotia and Dorke. There was no significant difference between the yields of Aburotia and Dorke at Pokuase. At Kpeve, Dobidi yielded the highest, followed by Aburotia and Dorke in that order.

Grain yield significantly increased with increasing density up to a point and then decreased with further increase in density at all locations, except at Ejura in the major season (Table 6). Similar findings have been reported (Lutz, Camper & Jones,

TABLE 6

Effect of Plant Density on Grain Yield of Maize Varieties Differing in Maturity and Grown in Five Environments in 1986

Kwadaso		Ejura*		Ejura**		Pokuase		Kpeve	
Density (10^3 plants/ ha)	Yield (tons/ ha)	Density (10^3 plants/ ha)	Yield (tons/ ha)	Density (10^3 plants/ ha)	Yield (tons/ ha)	Density (10^3 plants/ ha)	Yield (tons/ ha)	Density (10^3 plants/ ha)	Yield (tons/ ha)
9	2.1 d+	9	2.1 c	9	1.0 c	9	1.3 b	10	2.3 e
20	3.7 c	20	3.7 b	20	1.8 c	20	2.0 a	20	4.1 d
30	4.6 b	30	4.4 ab	30	2.5 b	30	2.2 a	30	5.1 c
40	5.3 ab	36	4.7 ab	38	2.8 ab	40	2.2 a	40	5.7 b
50	5.8 a	45	4.6 ab	49	3.2 a	49	2.0 a	46	6.5 a
60	5.6 a	55	5.2 a	58	3.1 a	59	1.9 a	52	5.1 a
69	5.4 a	63	5.2 a	66	2.9 ab	70	1.9 a	57	6.4 a
Mean	4.6		4.3		2.5		1.9		5.2
SE	0.1		0.4		0.2		0.1		0.1
CV %	12.2		17.2		21.4		18.2		13.2

+ Values within the same column followed by a different letter differ significantly at the 5 per cent level of probability (DMRI).

* Major season

** Minor season

varieties at Ejura in both major and minor seasons. There were, however, significant yield differences between varieties at Kwadaso, Pokuase and Kpeve (Table 5). The varieties showed variation in response to location and season as has been found by Rutger & Crowder (1967) and Robertson, 1971). As expected, fewer plants were harvested with increasing densities compared to initial densities planted. Barrenness is a normal occurrence at high densities. This is due to failure of silk emergence because of disturbance in the nitrogen metabolism of the plant due to shading

TABLE 7

Optimum Densities and Yields Expected at These Densities

Location	*Variety*	*Optimum density (plants/ha)*	*Expected yield (tons/ha)*	*Regression coefficient*
Kwadaso	Dorke, Aburotia, Dobidi	55955	5.5	- .99 **
Ejura +	Dorke	58997	5.3	- .97 **
	Aburotia	54142	5.4	- .95 **
	Dobidi	48953	4.5	- .89 **
Ejura ++	Dorke, Aburotia, Dobidi	66597	3.1	- .98 **
Pokuase	Dorke	41393	2.6	- .98 **
	Aburotia	44083	2.4	- .98 **
	Dobidi	24897	2.0	- .99 **
Kpeve	Dorke, Aburotia, Dobidi	65493	6.5	- .99 **

+ Major season
++ Minor season
** Linear regression coefficient of Log of grain yield per plant upon density significantly different from 0.00 at 0.01 level (n=7).

(Knipmeyer *et al.*, 1962).

Table 7 shows the derived optimum densities and expected yields at these densities. Where there was no variety × density interaction, one value is presented for all the three varieties at the location concerned. Varieties performed differently in the five environments studied. Optimum densities ranged between 48 and 66×10^3 plants/ha for all locations except at Pokuase where the range was slightly lower (Table 7). The range obtained for Ejura, Kwadaso and Kpeve conform to those reported (Allison, 1969; Stickler, 1964; Larson & Hanway, 1977; GGDP, 1981-1984).

Optimum densities for the three maturity groups were the same at Kwadaso, Ejura (minor season) and at Kpeve. These results seem to indicate that Dorke and Aburotia have higher capacity for exploiting the three environments efficiently at higher densities than Dobidi. Dorke and Aburotia also performed better at Ejura (major season) and at Pokuase (Table 7). Though varieties appeared to yield differently in the different environments studied, an average yield of 5.5 tons/ha can be expected in three environments represented by Ejura, Kwadaso and Kpeve. These environments need to be fully exploited for their yield potential.

Achievement of optimum density in practice by the farmers can be difficult (Carmer & Jacobs, 1965) and information about yields at densities near the optimum is desirable.

Calculations show that planting densities up to 30 per cent either side of the optimum results in yield reduction of 7 per cent or less. Farmers can, therefore, conveniently plant 15-20 per cent below or above optima without serious yield reduction.

Rainfall figures for the four locations are presented in Table 8. The total amount of rainfall and the number of rainy days are important factors

TABLE 8

Rainfall Figures for the Four Locations in 1986

Location	*Rainfall parameter*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Total*
Kwadaso	Rainfall	-	10	10.2	17.8	21.4	19.8	16.2	2.6	6	19.6	2.4	2	126.0
	No. of rainy days (0-1 cm)	-	-	1	5	5	3	-	3	5	8	-	-	30
	No. of rainy days (above 1 cm)	-	5	4	3	6	6	5	-	2	6	2	-	39
	Total no. of wet days	-	5	5	8	11	9	5	3	7	14	2	-	69
Ejura	Rainfall	-	23.4	20.5	16.5	25.4	21.2	19.9	6.2	17.5	22.4	2.4	-	175.4
	No. of rainy days (0-1 cm)	-	5	2	5	4	9	9	5	7	7	2	-	55
	No. of rainy days (above 1 cm)	-	1	7	5	7	4	2	2	7	8	1	-	44
	Total no. of wet days	-	6	9	10	11	13	11	7	14	15	3	-	99
Pokuase	Rainfall	-	1.33	4.9	11.1	19.0	6.9	5.5	-	7.3	11.4	6.5	0.12	74.05
	No. of rainy days (0-1 cm)	-	4	5	3	4	2	3	-	2	3	4	1	31
	No. of rainy days (above 1 cm)	-	-	1	2	3	4	1	-	3	5	2	-	21
	Total no. of wet days	-	4	6	5	7	6	4	-	5	8	6	1	52
Kpeve	Rainfall	0.43	4.4	15.9	5.9	10.0	14.2	15.0	4.0	13.5	23.4	9.2	-	115.93
	Total no. of wet days	1	6	8	5	10	8	6	3	13	12	6	-	78

which affect maize yield (Adelana, 1977). Total rainfall was low at Pokuase (Table 8) and yields were low as expected in this location.

The minor season rains are unreliable and terminate abruptly with few rainy days in November. Yields are, therefore, also low at Ejura in the minor season (Table 7).

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