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# EFFECT OF NITROGEN AND PLANT DENSITY ON THE PERFORMANCE OF PWANI HYBRID MAIZE

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## ABSTRACT

**New maize hybrids require specific agronomic recommendations, especially when currently available recommendations are for a low yield potential, open pollinated cultivar. A study was conducted to investigate the performance of a new maize cultivar, Pwani Hybrid I (PHI) at different nitrogen levels and plant densities. The number of ears per plant, ear length and ear girth were reduced by increasing plant density while nitrogen application increased them. In all three years of the study, application of at least 30 kg N ha$^{-1}$ increased maize grain yield. Statistical and economic analysis show that PHI gave highest grain yield at a density of 67,000 plants ha$^{-1}$ and at 60 kg N ha$^{-1}$, the currently recommended rate of nitrogen application.**

*Key Words*: **Nitrogen, plant density, yield**

## RÉSUMÉ

**L'introduction de nouveaux hybrides de maïs doit s'accompagner de recommandations agronomiques spécifiques, surtout si celles en usage sont destinées aux variétés à faible rendement et à pollinisation libre. Une étude a été conduite dans le but d'établir les performances d'une variété nouvelle de maïs, Pwani Hybrid I (PHI) à différents niveaux d'azote et de densités de plants. Un accroissement de la densité a provoqué une dimunution du nombre et de la taille des épis par plant alors que l'azote a induit l'effet contraire. La dose de 30 kg N/ha a accrut le rendement en maïs grains. Une analyse statistique et économique a revelée que PHI donne le rendement le plus élevé à la densité de 67.000 plants et avec 60 kg d'azote à l'hectare. Cette dose d'azote est celle actuellemment recommendée.**

*Mots Clés*: **Azote, densité des plants, récolte**

## INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop grown in the coastal region of Kenya and is the dominant cereal in the coconut-cassava zone described by Jaetzold and Schmidt (1983). The yield potential in this coastal zone is relatively low due to erratic rainfall, and the low water-holding capacity and low inherent fertility of the sandy soils which predominate (Jaetzold and Schmidt, 1983).

The current recommendations for fertilizers, plant spacing and density are based on Coast Composite Maize (CCM), which was released in

1974. These recommendations are 60 kg N ha$^{-1}$, and a plant spacing of 90 x 60 cm, two plants per hill (37,000 plants ha$^{-1}$). In 1989 another maize cultivar, Pwani Hybrid I (PHI), was released for the coastal region of Kenya. PHI, a hybrid developed by the Kenya Seed Company, matures about 20 days earlier than CCM and is substantially shorter, has low ear placement, and excellent standability (Anonymous, 1986). At the recommended density of CCM the yield of PHI is slightly higher (3.78 t ha$^{-1}$) than CCM (3.30 t ha$^{-1}$) (Arnon, 1975).

Improvement in maize yield has been achieved in both the U.S. corn belt (Duvik, 1977) and the tropics (Johnson *et al.*, 1986) through the development of improved genotypes which tolerate higher plant densities in conjunction with increased inputs such as fertilizers. This study was designed to investigate plant densities, fertilizer rates and their interaction on the grain yield of PHI.

## MATERIALS AND METHODS

The experiment was conducted at three locations: Mtwapa, Matuga and Mtomondoni in 1989, 1990 and 1991. Three plant densities (37000, 47000 and 67000 plants ha$^{-1}$) and five nitrogen levels (0, 30, 60, 90 and 120 kg N ha$^{-1}$) were studied.

The experimental design was a randomized complete block design with three replications in a split-plot arrangement. Main plots were plant density and sub-plots were nitrogen levels. Plots consisted of seven 4.5 m-long rows. The experiment was conducted on the same plots throughout the study period. Maize stover was left in the plots after the crop was harvested.

Triple superphosphate fertilizer was applied at planting at the rate of 20 kg P ha$^{-1}$. The crop was weeded twice, at the fourth and tenth leaf stages. Calcium ammonium nitrate (26%N) was applied in two equal splits; the first split at the fourth leaf stage and the second split at the tenth leaf stage. Dipterex 2.5G (trichlorphon) was applied three weeks after sowing at the rate of 3 kg ha$^{-1}$ to control stem borers.

The three middle rows excluding the end plants were harvested. Data on stand count, number of ears per plant, ear size (length and girth) and grain yield were recorded. Harvested weights were converted to yield in tonnes per hectare at 15% moisture content. The data were subjected to statistical and economic analysis.

TABLE 1. Effect of plant density on number of ears per plant and ear girth.

| Density (plants ha$^{-1}$) | Ears per plant | Ear girth (cm) |
|---|---|---|
| 37000 | 0.93 a | 10.77 a |
| 47000 | 0.89 b | 10.38 b |
| 67000 | 0.89 b | 10.07 c |
| SE (±) | 0.011 | 0.066 |
| CV (%) | 12.24 | 5.77 |

Within column means followed by the same letter are not significantly different (P = 0.05)

TABLE 2. Effect of nitrogen application on number of ears per plant and ear girth.

| Nitrogen (kg N ha$^{-1}$) | Ears per plant | Ear girth (cm) |
|---|---|---|
| 0 | 0.84 b | 9.91 c |
| 30 | 0.92 a | 10.35 b |
| 60 | 0.91 a | 10.49 ab |
| 90 | 0.94 a | 10.63 a |
| 120 | 0.92 a | 10.65 a |
| SE (±) | 0.012 | 0.067 |
| CV (%) | 12.24 | 5.77 |

Within column means followed by the same letter are not significantly different (P = 0.05)

## RESULTS AND DISCUSSION

Growing PHI at densities higher than the current recommendation for CCM (37000 plants ha$^{-1}$) reduced the number of ears per plant (Table 1). Stand count was increased by increasing the plant density, so the reduction in the number of ears per plant is a possible indication of increased barrenness with increased plant density. The number of ears per plant was increased by applying, at least 30 kg N ha$^{-1}$ (Table 2). Lang *et al.* (1956) found greater barrenness with increased plant populations at all nitrogen levels and the most barren plants at the lowest nitrogen level and highest plant density. Ear girth was reduced by increasing plant density (Table 1) but increased with an application of at least 30 kg N ha$^{-1}$ (Table 2).

A significant year by plant density by nitrogen interaction occurred with respect to ear length. Ear length was always greater at the lowest plant population when fertilizer was applied, regardless of rate (Table 3). Furthermore, ear length tended to decline with increasing plant populations. The year by density by nitrogen interation was largely

TABLE 3. Effect of plant density and nitrogen application on maize ear length (cm), 1989, 1990 and 1991.

| Density (plants ha$^{-1}$) | Nitrogen rate (kg N ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | 0 | 30 | 60 | 90 | 120 |
| 1989: | | | | | |
| 37,000 | 9.74 | 11.03 | 12.09 | 12.74 | 12.51 |
| 47,000 | 7.93 | 11.31 | 12.23 | 10.44 | 11.03 |
| 67,000 | 7.03 | 7.78 | 9.96 | 10.46 | 9.88 |
| 1990: | | | | | |
| 37,000 | 11.70 | 14.34 | 14.72 | 14.51 | 14.64 |
| 47,000 | 12.74 | 13.78 | 13.28 | 13.91 | 13.42 |
| 67,000 | 12.09 | 11.94 | 12.42 | 12.41 | 12.09 |
| 1991: | | | | | |
| 37,000 | 9.53 | 10.71 | 10.90 | 10.88 | 10.68 |
| 47,000 | 8.50 | 10.06 | 9.82 | 10.69 | 10.58 |
| 67,000 | 8.31 | 8.30 | 9.98 | 9.81 | 10.36 |

S.E. for year by N by density interactions means = 0.47

TABLE 4. Effect of location by density interaction on maize grain yield (t ha$^{-1}$).

| Location | Density (plants ha$^{-1}$) | | |
|---|---|---|---|
| | 37000 | 47000 | 67000 |
| 1. Mtwapa | 4.52 b | 4.76 b | 5.25 a |
| 2. Matuga | 2.83 d | 3.03 d | 2.96 d |
| 3. Mtomondoni | 2.97 d | 2.93 d | 3.50 c |

Means followed by the same letter are not significantly different (P = 0.05)

a result of a relatively large decline in ear length at the two highest populations in the 0 N treatment in 1989 and 1991, while in 1990 there was little difference for ear length between N levels at these densities. Ear length in general was greater in 1990, than the other two seasons. Others have found that early applications of nitrogen can increase ear size (Schreiber *et al.*, 1962). However, the maximum yield per unit area of maize is often obtained when plant densities and nutrienty supplies result in average-sized ears (Arnon, 1975).

Maize grain yield was significantly ($P \leq 0.05$) affected by an interaction of location and plant density (Table 4). At Mtwapa and Mtomondoni (locations 1 and 3), a density of 67,000 plants ha$^{-1}$ gave higher grain yields than the lower densities. Maize grain yield was not affected by increasing plant density at Matuga. Higher grain yields were obtained at Mtwapa than at any of the other locations.

A significant ($P \leq 0.05$) interaction between year and nitrogen application with respect to grain yield also occurred (Table 5). In all three years of the study application of at least 30 kg N ha$^{-1}$ increased maize grain yield. However, in the first year the currently recommended rate (60 kg N ha$^{-1}$) gave a higher grain yield than the application rate of 30 kg N ha$^{-1}$. During this year yield was not affected by nitrogen rates higher than the recommended rate. There was no significant differences were between the 60 and 120 kg N ha$^{-1}$ rates in 1990 and the 30 through 120 kg N ha$^{-1}$ rates in 1991. Grain yields decreased progressively from the first to the third year of study. Where rates of 0 or 30 kg N ha$^{-1}$ were used, a significant reduction in grain yield was realized only during the third year. Since the experiment was conducted on the same plots throughout the experimental period, the reduction in yields over the three years

TABLE 5. Effect of year by nitrogen interaction on maize grain yield (t ha$^{-1}$).

| Year | Nitrogen rate (kg N ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | 0 | 30 | 60 | 90 | 120 |
| 1989 | 3.04 de | 4.00 bc | 4.90 a | 5.21 a | 5.41 a |
| 1990 | 2.95 e | 3.57 cd | 3.94 bc | 4.23 b | 3.84 bc |
| 1991 | 1.87 f | 2.71 e | 2.82 e | 3.13 de | 2.98 e |

Means followed by the same letter are not significantly different (P = 0.05)

TABLE 6. Effect of plant density and nitrogen application on maize grain yield (t $ha^{-1}$).

| Density (plants $ha^{-1}$) | Nitrogen rate (kg N $ha^{-1}$) | | | | |
|---|---|---|---|---|---|
| | 0 | 30 | 60 | 90 | 120 |
| 37000 | 2.46 f | 3.46 de | 3.59 de | 3.87 cde | 3.83 cde |
| 47000 | 2.71 f | 3.54 de | 3.73 de | 3.97 bcd | 3.90 cd |
| 67000 | 2.68 f | 3.28 e | 4.34 abc | 4.73 a | 4.50 ab |

Means followed by the same letter are not significantly different (P = 0.05)

is a possible indicator of the disadvantage of growing maize continuously on the same field. As the results (Table 5) show, this effect is not fully reversed by applying nitrogen.

Maize grain yield was also significantly affected by an interaction ($P \leq 0.05$) between plant density and nitrogen application (Table 6). At all the three plant densities studied, application of at least 30 kg N $ha^{-1}$ increased grain yield. Application rates ranging from 30 to 120 kg N $ha^{-1}$ did not differ significantly in their effect on grain yield when maize was grown at either 37,000 or 47,000 plants $ha^{-1}$. However, at 67,000 plants $ha^{-1}$, the current recommendation (60 kg N $ha^{-1}$) gave a higher yield than the application rate of 30 kg N $ha^{-1}$. Rates higher than the recommended rate of nitrogen did not significantly increase grain yield compared to the recommended rate.

At the rates of 0 and 30 kg N $ha^{-1}$, maize grain yield was not affected by increasing plant density from 37,000 to 67,000 plants $ha^{-1}$. However, at the currently recommended or higher rates of nitrogen application, maize gave higher grain yields when grown at a density of 67,000 plants $ha^{-1}$ than when grown at either 37,000 or 47,000 plants $ha^{-1}$. These results show that it is possible to increase the grain yield of PHI by growing it at a density of 67,000 plants $ha^{-1}$ and using the currently recommended rate of nitrogen application. A similar interaction between plant density and

TABLE 7. Partial budget for nitrogen application[a].

| | Treatments (kg N $ha^{-1}$) | | | | |
|---|---|---|---|---|---|
| | 0 | 30 | 60 | 90 | 120 |
| Average yield (kg $ha^{-1}$) | 2617 | 3425 | 3888 | 4189 | 4076 |
| Adjusted yield (kg $ha^{-1}$) | 2355 | 3083 | 3499 | 3770 | 3668 |
| Gross Field Benefit (Ksh $ha^{-1}$) | 6406 | 8386 | 9517 | 10254 | 9977 |
| <u>Costs that vary:</u> | | | | | |
| N-fertilizer (Ksh $ha^{-1}$) | 0 | 491 | 982 | 1473 | 1964 |
| Fertilizer application (Ksh $ha^{-1}$) | 0 | 30 | 60 | 90 | 120 |
| TOTAL COSTS THAT VARY (Ksh $ha^{-1}$) | 0 | 521 | 1042 | 1563 | 2084 |
| NET BENEFIT (Ksh $ha^{-1}$) | 6406 | 7865 | 8475 | 8691 | 7893 |
| Marginal Rate of Return (MRR) | 280% | 117% | 41% | D[c] | |

[a]Assumptions:

1. Costs associated with harvesting:
(a) Shelling - Ksh. 10/= per bag.
(b) Gunny bags - Ksh. 25/= per bag.
(c) Transport to buying center - Ksh. 20/= per bag.
(d) 1 US $ = 67 Kenya shillings (Ksh) as of 31 December 1993.
2. Price offered at centre = Ksh. 300/= per 90 kg bag.
Field price = Ksh. 245/= per bag = Ksh. 2/72 per kg.
3. One 50 kg bag of calcium ammonium nitrate (CAN) costs Ksh. 212/80 (including transport to the farm).
- Therefore, 1 kg of nitrogen costs Ksh. 16/37.

[b]Yield averaged over the three locations and three seasons.

[c]This treatment is dominated.

nitrogen levels was reported for hybrid maize in India (Sharma and Gupta, 1968).

The partial budget (Table 7) shows that farmers applying 30 kg N $ha^{-1}$ still benefit from the little nitrogen they apply. For each Ksh. 1 $ha^{-1}$ invested in nitrogen fertilizer, farmers applying nitrogen at such a low rate can expect to recover the shilling invested $ha^{-1}$ and Ksh. 2.8 $ha^{-1}$ net benefits. An additional 30 kg N $ha^{-1}$ (making a total of 60 kg N $ha^{-1}$) enables farmers to get Ksh. 1.2 $ha^{-1}$ over and above every shilling invested $ha^{-1}$ in the extra fertilizer.

A further increase of 30 kg N $ha^{-1}$ enables farmers to make only 40 cents $ha^{-1}$ over and above every shilling invested $ha^{-1}$ in the extra fertilizer. Assuming a minimum acceptable rate of return of 50%, the economic analysis shows that application rates above the current recommendation (60 kg N $ha^{-1}$) are not economically feasible. These findings confirm the results obtained from the statistical analysis.

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