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EFFECTS OF NUMBER OF PLANTS PER HILL AND WITHIN-ROW SPACING ON GRAIN YIELD PERFORMANCE OF OPEN-POLLINATED AND HYBRID MAIZE (*ZEA MAYS L.*).

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Abstract

The performance of two single-cross (one white and one yellow) maize *(Zea mays L.)* hybrids and an open-pollinated (O.P.) white variety was evaluated for optimum grain yield when grown at stand densities of one, two or three plants/hill and four within-row spacinas of 24, 30, 40 and 60cm. Between row spacing was maintained at 75cm.

Both early and late-season plantings were carried out at the Teaching and Research Farm of the Obafemi Awolowo University, Ile-Ife. After initial ploughing and harrowing the maize varieties were sown at the four within-row spacings at 75 cm apart. Each plot consisted of four rows 6m long. The experiment was replicated three times in a randomized complete block design (RCBD) with factorial arrangement.

Grain yield was determined by harvesting ears from plants in the two central rows of each plot at a determined grain moisture (using Dickey John moisture tester) and the final grain yield was expressed at a standard moisture of 15%. Data were analysed by ANOVA and significant means separated using the least significant difference (lsd) test. Regression analysis was performed to determine the grain yield response of the maize varieties to the spacings at one, two or three plants/hill.

The o.p. TZSR-W-1 and white hybrid 8322-13 gave the highest grain yields and the highest number of ears/ha. Highest grain yields were also obtained at one plant/hill ($r^2 = 0.90$) using the 24 cm within - row spacing and 55,530 plants/ha and at two plants/hill ($r^2=0.71$) using 30cm within - row spacing and 88,880 plants/ha.

INTRODUCTION

Grain yields of maize are low in Nigeria especially in the forest areas where the average is only 1 to 2 tons/ha in the early season, and lower still in the late season (Fakorede, 1985). The same trend of low yields is obtained even with genetically improved varieties. It is thus necessary to develop improved agronomic practices that will increase grain yield performance of our maize, whether hybrid or open-pollinated varieties. Such agronomic practices must make the best use of moisture, plant nutrients, and incoming insolation.

Response to using the most adequate number of plants per hill and at the most appropriate within-row spacing is likely to contribute positively to the grain yield performance of our maize cultivars.

Donald (1963) noted that when plant density increased, grain yield increased up to a maximum, and it remained constant within a range. However, as population pressure increased further, yield declined steeply, even when other major factors of production were not limiting. Various plant populations for maize have been used by different researchers under different maize ecologies in Nigeria, but the current recommendations are between 53,330 and 66,660 plants/ha in the forest and savanna zones (Alofe *et al.*, 1986). Under improved technology a tolerant hybrid maize type could produce economic yileds at up to 100,000 plants/ha (Remison *et al.*, 1978).

In most of the plant population studies carried out and reported in the literature, controlling the number of plants/hill as a way of increasing plant population or altering the geometry of the plant has not received much attention. Wolfe and Kipps (1959) and Moll and Kamprath (1977) have noted that the issue of optimum stand density in various stages of corn breeding programmes has not been resolved, and has become more critical with closer spacings being practised in commerical stands. The lack of adoption of improved production technology by farmers has been identified by Fajemisin and Shoyinka (1976) as the main constraint to raising the level of efficiency of, and hence increasing maize production in West Africa.

Many Nigerian maize farmers traditionally grow their maize at irregular spacings due, perhaps, to the fact that other crops have to be grown along with it in the characteristic mixed cropping system. The situation is made more complex by farmers sowing two to five seeds per hill without thinning after emergence. On other farms, maize stands are at sub-optimal densities because soil fertility is low and crop loss from pests is high (Ogunwolu *et al.*, 1981).

Planting maize at spacings closer than 90 x 25cm led to increase in grain yield. With the use of hybrids capable of maximising utilization of environmental resources, higher plant populations are desirable, especially if planting is on the flat (Fayemi, 1963). Spacing of crops determines the amount of insolation that can be let through the canopy. Besides intercepting most of the solar radiation falling on the crop canopy, high plant densities ensure optimum use of other available resources like moisture, carbon dioxide and nutrients to achieve high productivity (Remison *et al.*, 1978).

The number of plants required per unit area of land would depend on the nature of the crop and its environment. The number cannot be too small, otherwise all production factors would not be fully utilized; nor can it be too large, otherwise excessive plant competition would reduce the overall performance of the crop. It thus appears that the appropriate number of plants per population density that will be less laborious for farmers to adopt are current management problems that require a comprehensive research for solution.

The objectives of this study, therefore, were (1) to evaluate hybrid and o.p maize response to the number of plants per hill with a view to determining the optimum number of plants/hill for achieving maximum grain yield; and (2) to determine the most appropriate within-row spacing that would give the optimum grain yields by the maize cultivars.

MATERIALS AND METHODS

The study was conducted at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, on longtitutde 04° 33'E and latitutde 7°28'N, 224m above sea level.

Seeds of maize hybrids 8322-13 and 8425-8 and an open-pollinated variety TZSR-W-1 were obtained from the African Maize Programme (AMP) of the International Institute of Tropical Agriculture (IITA). The white hybrid 8322-13 is a late-maturing single cross hybrid, while 8425-8 is a yellow-grained, late maturing single cross hybrid. The open-pollinated TZSR-W-1 is white-grained. The three cultivars are streak resistant.

The experiment was a randomized complete block design (RCBD) with a factorial arrangement. The maize cultivars were sown each at the four within-row spacings, and at one, two, or three plants per hill. Each plot consisted of four rows 6m long. There were 36 plots per replication and each replication measured 83.5m x 20m. The experiment was replicated three times.

The field was disc-ploughed and harrowed. Weed control was effected by using Atrazine (2-chloro-N-2-methoxy - 1 - methylacetamine) as pre-emergence herbicide one day after sowing at the rate of 3.0kg a.i/ha. Seeds were treated with Aldrex 40 (an emulsifiable concentrate) prior to planting, to protect them from attack by soil - inhabiting pests. Early planting was done on March 28, while the late season-planting was done on August 18.

Fertilizer was applied whole by topdressing about three weeks after planting at the rates of 180 kg N, 90 kg P_2O_5 and 90 kg K_2O ha^{-1} using urea, single superphosphate, and muriate of potash, repectively. Data were collected on number of ears/plot,and grain yield at 15% MC.

All data collected were subjected to ANOVA and means were separated using the least significant difference(lsd) at 5% level of probability, according to the standard method of Steel and Torrie (1980). The effect of within-row spacing on number of ears per ha and grain yield was evaluated by regression analysis and coefficients of determination(r^2) were calculated using the methods of Cochran and Snedecor (1985).

RESULTS AND DISCUSSION

Table 1 shows the ANOVA mean square values of the effects of stand density and within-row spacing on grain yield and number of ears per ha of the three maize cultivars. Grain yield per ha was significantly affected ($P \leq 0.05$) by the main effects of season(s), within-row spacing (sp), number of plants/hill(ph) and cultivar(cv). The two-factor interaction of sp x ph, sxph, sxsp significantly affected ($P \leq 0.05$) the grain yield of the three maize cultivars. Number of ears/ha was significantly affected by s, sp, ph, s cv, sxph, sp x ph x cv ($P \leq 0.05$). So also were sxcv and sp x ph.

Table 1. Mean squares of the effects of stand density and within-row spacing on number of ears/plot, plant height, ear height, and grain yield of three maize cultivars grown for two seasns at Ife.

Source of Variation	DF	Ear/Plot	Plant Height (cm)	Ear Height (cm)	Grain Yield (kg/ha)
Season	1	1756.69**	4577.00**	3947.00**	195618816.00**
Replicate	2	383.88	3615.00	1837.00	11987200.00**
Within-row spacing	3	2118.21**	1265.00	1803.67**	15860138.00**
Plants per hill	2	4376.31**	195.00	1966.00**	11219840.00**
Cultivar	2	358.31**	9811.00**	5991.00**	7133824.00**
Seasons x Within-row spacing x plants/hill	2	96.35	481.00	356.00	157354.63**
Seasons x plants/hill	3	452.56	187.50	674.00	375520.00**
Season x cultivar	2	1455.16**	5188.50**	4716.50**	14812928.00
Within-row spacing x plants/hill	2	325.00**	388.33	251.00	5409792.00**
Within-row spacing x cultivar	6	66.26	499.83	233.17	1818197.00
Plants/hill x cultivar	4	55.05	859.75	399.75	993344.00
Season x Within-row spacing x plants/hill	6	150.78	449.00	148.17	1417301.00
Season x Within-row spacing x cultivar	6	134.25	648.83	426.50	470101.00
Season x Plants/hill x cultivar	4	65.4	1225.50	78.25	388992.00
Within-row spacing x plants/hill x cultivar	12	174.07**	481.50	128.00	1852522.00
Error	154	145.14	897.33	610.90	2101118.63
Total	215	189.58	795.364	88.73	2769992.00

*, **: significant at 5% and 1% levels of probability, respectively.

Table 2 shows the effects of season on number of ears/ha and grain yield of the three maize cultivars. Statistical analysis shows that significantly higher number of ears/ha and grain yield were obtained in the early season than the late season ($P \leq 0.05$). Grain yield and number of ears per ha were 67.9% and 18.3% higher respectively, in the early seasn than the late season. This could be attributed to a more favourable water supply regime necessary for nutrient uptake that is generally not limiting in the early season as compared to the late season. This is in agreement with Giesbrecht (1969) who confirmed that when the moisture was adequate, grain yield increased substantially with each increase in plant population up to an opitmal level. Thus, grain yield of maize can be significantly increased by early planting (soon after the first rains) in the early season.

Table 3 shows the effects of cultivar on the number of ears per ha and grain yield per ha of the three maize cultivars. Grain yield of the o.p., TZSR-W-1 was significantly higher than the hybrids at $P \leq 0.05$. No significant difference was observed in the grain yield performance of the two single cross hybrids. The number of ears/ha harvested for 8322-13 and TZSR-W-1 were comparable and were significantly higher than for 8425-8. The high performance of the op. TZSR-W-1 is perhaps because it is an improved, late maturing cultivar and is also resistant to maize rust and maize streak virus (Obilana and Fajemisin, 1977). Late - maturing maize varieties, according to Giesbrech (1969), are better adapted to competition at high populations than the earlier-maturing hybrids. Late - maturing cultivars have a longer period of grain filling than medium-or early-maturing cultivars, and thus, they produce higher grain yields.

The effect of within-row spacing on the no of ears havested/ha and grain yield of the three maize cultivars is shown in Table 4. The ear numbers harvested at 24 and 30cm were not significantly different but both were significantly higher than for 40cm or 60cm ($P \leq 0.05$). The no of ears harvested at 30cm within-row spacing was 18.79% and 56.0% higher than at 40 and 60cm within-row spacings respectively.

Observatiions on grain yield at different within-row spacings (Table 5) were similar to those observed for the no of ears above. The 30cm within-row spacing significantly outyielded other within-row spacings ($P \leq 0.05$). Grain yield at 30cm within-row spacing was 20.2% higher than at 40cm, and 42.1% higher than 60cm. These results agree with the reports by Hunter *et al.* (1970); Remison *et al.* (1978); Alessi and Power (1974); and ITTA (1986), that grain yield of maize increased as populations increased to an optimum no of plants/unit area, above which it declined due to a reduction in size of number of ears.

Table 2: Effect of season on grain yield and number of ears/ha of three maize cultivars at early and late seasons.

Season	No of ears/ha	Grain Yield (t/ha)
Early Seaon	40,344	4.7
Late Season	34,001	2.8
Lsd .05	2166.6	0.2

Table 3: Effect of cultivar on grain yield and number of ears/ha of three maize cultivars at early and late seasons.

Cultivar	No of Ears/ha	Grain Yield (kg/ha)
V_1	38,666	3707
V_2	34,333	3489
V_3	38,555	4109
Lsd (0.05	2655.5	290.1

Table 4: Effects of Within-row spacing on grain yield and number of ears/ha of three maize cultivars at early and late seasons.

Within-row spacing (cm)	No of ears/ha	Grain Yield (kg/ha)
24	41,111	3905
30	43,333	4405
40	36,666	3664
60	27,778	3100
Lsd(0.05)	3111	334.9

Table 5 also shows that the number of ears harvested and grain yield were highest at 3 plants/hill and lowest at 1 plant/hill. There was no significant difference between grain yields obtained at 2 and 3 plants/hill ($P \leq 0.05$).

Table 6 shows the effect of stand density x within-row spacing interaction on numbers of ears harvested/ha and grain yield of maize. At all within-row spacings the number of ears harvested and grain yield of 2 plants/hill significantly out yielded those at 1 or 3 plants/hill ($p<0.05$). Generally, grain yield at 30cm within-row spacing was significantly higher at each of the three stand densities than the other within-row spacing and their respective stand densities ($p \leq 0.05$). From these results, 2 plants/stand at 30cm within-row spacing appears to be the optimum.

The regression of grain yield on within-row spacing (Fig. 1: a,b,c,) showed at one, two, or three plants/hill that as within-row spacing increased, grain yield decreased. This same trend was obtained for the no of ear/ha (Fig. 2: a,b,c). The coefficients of determination (r^2) between grain yield and within-row spacing were very high at one or two plants/hill, respectively. Thus, r^2 was 0.90 and 0.71 at one and two plants/hill, respectively, and 0.04 at three plants/hill. This means that 90% and 71% of the variation in grain yield at one and two plants/hill, respectively could be explained by variation in within-row spacing. Similarly, only 4% of such variation in grain yield can be explained by variation in within-row spacing at 3 plants/hill. The r^2 values between the no of ears/ha and within-row spacing were very high (r^2 = 0.86 and 0.89) at one and two plants, respectively, and 0.39 at three plants/hill. At three plants/hill, there is an excessive plant popuplation resulting in intra-competition for light, water and gases and resulting from these is low availability of these factors for vegetative and reproductive development. Shibble and Weber (1966) reported that less than full leaf cover permitted solar radiation to escape interception by the photosynthetic apparatus, and also that production was related to the fraction of light that was intercepted when cover was scanty. It can then be suggested that the main effect of spacing on yield is the change in radiant energy distribution within the crop canopy.

Table 5: Effect of stand density on grain yield/ha and no of ears/ha of three maize cultivars at early and late seasons.

Stand density	No of Ears.ha	Grain Yield (kg/ha)
1	27,778	3336
2	37,778	3860
3	45,555	4140
Lsd.05	2666.6	290.1

Table 6: Effect of stand density and within-row spacing interaction on number of ears/ha and grain yield of three maize cultivars at early and late seasons.

Within-row spacing(cm) and stand density		*Number of plants/ha*	*Number of ears/ha*	*Grain yield (kg/ha)*
24	1	55,555	40,410	3,755
	2	111,110	86,000	4,650
	3	166,666	105,600	3,860
30	1	44,444	40,400	3,650
	2	88,888	55,880	4,600
	3	133, 3332	80,000	3,800
40	1	33,333	31,000	3,450
	2	66,666	45,600	3,810
	3	99,999	56,000	3,650
60	1	22,222	21,200	2,960
	2	44,444	33,400	3,352
	3	66,666	45,750	3,010
Lsd, 5%			2,550	312.5

CONCLUSION

Under favourable weather conditions and good cultural practices, TZSR-W-1 and 8322-13 are better adapted for high grain yield than 8428-8 in the southwestern Nigerian ecology. Planting maize at 30cm within-row spacing and at two plants/hill ($r^2 = 0.71$) gave the highest grain yield/ha. However, optimum grain yield appeared to have been obtained at one plant/hill at 24cm within-row spacing (r^2-0.90).

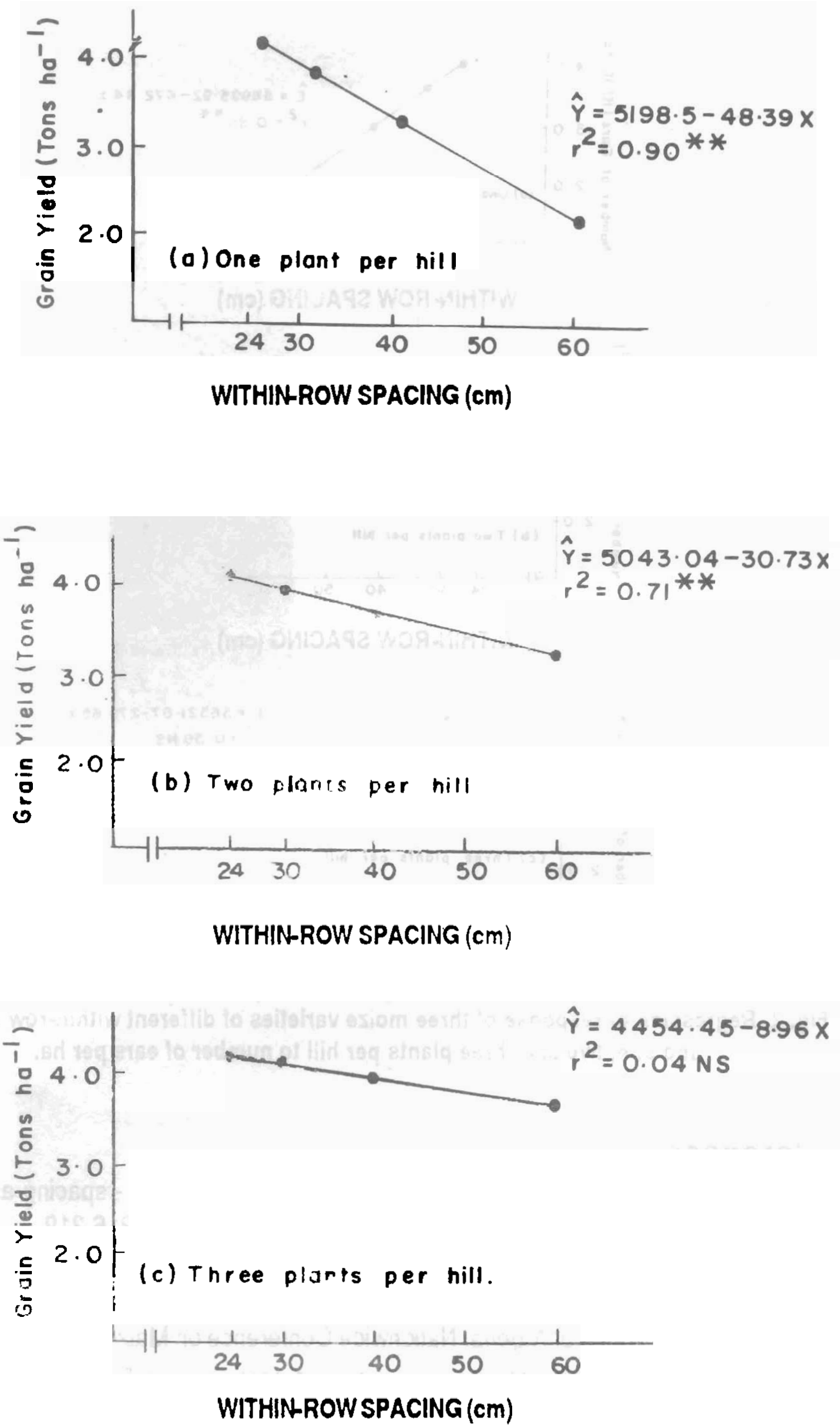

Fig. 1: Regression of response of three maize varieties of different [illegible]-row spacings and one, two and three plants per hill to grain yield (t[illegible] ha)

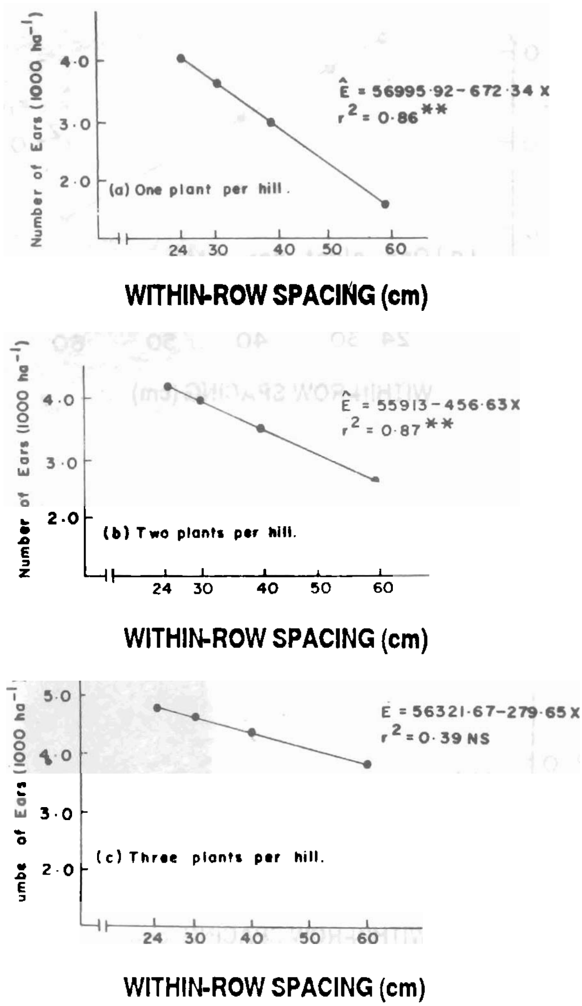

Fig. 2: Regression of response of three moize varieties of different within-row spacings and one, two and three plants per hill to number of ears per ha.

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