PROCEEDINGS

OF THE

CARIBBEAN FOOD CROPS SOCIETY

TENTH ANNUAL MEETING
PUERTO RICO

1972

VOLUME X

THE INFLUENCE OF PLANT DENSITY AND ROW WIDTH ON CORN (ZEA MAYS L) YIELD ON THREE SOILS IN THE EASTERN CARIBBEAN

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INTRODUCTION

A reliable supply of good quality cheap grain is urgently needed in the Eastern Caribbean, where increasing emphasis is being given to the production of some meats and meat products, and where high cost animal feeds are considered the major limiting factor in the emergence of a truly competitive livestock industry. Recent work in the area suggested that the new Pioneer tropical corn hybrids, held some promise for an expanded and increasingly efficient grain industry in the Caribbean (Baynes 1969; 1972). Indeed, serious attempts are being made as a result of these factors to encourage grain production. This is evidenced by the increasing use of hybrid corn in commercial plantings in Barbados and Grenada, and by the official policy in Barbados which aims at the local production of a minimm of 4 million pounds of corn annually.

Baynes (1972) showed, that consistent with experience in North America and elsewhere, (Vázquez 1960, Giesbrecht 1969) grain corn yields was extremely sensitive to plant density, in the region. High yields could only be produced with the application of sound agronomic practices, which included the employment of the optimum plant population well suited to the particular ecological situation. He indicated that while 35.8 thousand plants per hectare appeared to be optimal for Barbados and South St. Lucia, the ideal plant density for St. Vincent and Grenada was most probably somewhat in excess of this figure.

This paper describes a series of three field experiments conducted in Barbados, St. Vincent and Grenada, aimed at confirming the optimum plant density for Barbados, and attempting to establish optima for St. Vincent and Grenada. In addition, the influence of narrow rows on grain yield was evaluated.

MATERIALS AND METHODS

The experiments were conducted in Barbados on soil type 30 (The Black Association); in Grenada on Capitol Clay Loam and in St. Vincent on Akers Sandy Clay Loam(Watson et al 1958, Vernon et al 1959; Vernon and Carroll 1965).

Each experiment was arranged in randomized complete blocks with four repplications and the individual plots consisted of six ridges 0.91m wide and 4.9m long. Harvesting was done from a standard net plot of 1/747ha.

The maize cultivar used was a tropical hybrid, X304, produced in Jamaica by Pioneer Hibred Seed Company. The highest plent population was repeated in each experiment in row widths of 0.45m.

The spatial arrangements in respect of the plant densities studied were as follows:

Treatment Code	Plant Density/ha	Dimmensions per plant (m)
(1)	17,932	0.91 x 61.0
(2)	35,864	0.91 x 30.5
(3)	71,729	0.91 x 15.2
(4)	107,593	0.91 x 10.2
(5)	107,593	0.45 x 20.4

Thus the only difference between treatments (4) & (5) was one of rectangularity, the land area per plant being the same in both cases.

Seeding was done at the beginning of the wet season in 1971, this being June in St. Vincent, July in Grenada and August in Barbados, and was at the rate of two seeds per planting point, thinned back to one seedling per point at the 3-5 leaf stage.

Blanket applications of N P K fertilizer mixtures were applied at seeding time as surface bands 7.6cm from the seed row. These mixtures varied from one island to another and were projected to meet the requirements of each soil type used. The actual rates and sources were as follows (kg/ha):-

	Barbados	Grenada	St. Vincent
Sulphate of Ammonia	314	439	502
Triple Superphosphate	63	188	125
Potassium Chloride	126	125	125

Good weed control was achieved by the use of pre-emergence spraying of Gesaprim 80 (Atrazine) at the rete of 2.8 kg/ha (commercial) and handweeding. Insect pest control was effectively done with regular applications of Sevin (Carbaryl) at the rate of 2.24 kg/ha commercial product.

Shelling percentage and grain moisture were determined from a twelve ear random sample from each plot at harvest time. Moisture content was determined by the oven dry method.

Leaf Area Index was calculated from the total leaf area of five plants in each plot selected at random at the full tassel stage. The area of an individual leaf was computed as the product of its length and greatest width, multiplied by 0.75.

Rainfall data were collected at or near each experimental site and are presented in Table I.

Table I. Rainfall (mm) recorded at or near experimental sites 1971
Weekly totals

Week	Barbados Graeme Hall	St. Vincent Carapan	Grenada Mirabeau
0	107	24	24
1	55	2	26
2	28	2	98
3	5	15	71
4	14	10	37
5	5	20	34
6	32	34	30
7	36	31	49
8	40	121	41
9	24	4	60
10	35	53	54
11	63	57	190
12	3	65	36
13	76	76	36
14	29	50	140
15	7	83	46
16	6	7	9
17	-	85	112
Total	565	739	1093

RESULTS

Plant Density

The effects of plant density on grain yield were apparent on all three soil types studied. The lowest plant density 17,932 plants per hectare was in every case associated with very low grain yields, these heing 2.03 T/ha in St. Vincent, 2.75 T/ha in Grenada and 3.13 T/ha in Barbados (Tables 2-4). In Barbados the highest grain yield produced was 5.45 T/ha with a plant density of 71,729 plants per hectare. This, although better than plant densities (1) & (2) were not materially better than treatments (4) & (5) (Table 4).

In Grenada treatments (2), (3) & (4), were essentially the same, these being superior to treatment (1). In St. Vincent there was a clear tendency for an increased grain outturn to be associated with rising plant population, treatments (4) & (5) being appreciably better than all other entries (Table 3).

Mean ear weights tended to follow the inverse pattern of grain yields in relation to plant density. On all three soils, the largest ears were produced at the lowest densities, the mean ear weights falling as the plant density rose (Tables 2-4). Mean ear weights appeared to be highest in Grenada with 286 gms and lowest in Barbados with 103 gms. The influence of plant density seemed to be most dramatic in Grenada where mean ear weights fell most sharply as plant density was increased.

On none of the soils was shelling percentage affected materially by plant density, despite reasonable variations on each site. The ranges recorded being 9%, 6% and 8%, respectively in St. Vincent, Grenada and Barbados (Tables 2-4).

Leaf Area Index appeared to be clearly associated with plant population. On the Akers Sandy Clay Loam in St. Vincent, a progressive increase was observed in L.A.I. from 0.89 for the widest spacing, to 4.56 in respect of the densest seeding (Table 2). On the Capitol Clay Loam in Grenada the same trend was recorded, the range being from 0.98 to 4.18 (Table 3). The extremes in Barbados followed the same pattern, however, the difference between the lowest plant density and the highest was largest on this site suggesting that this parameter was more sensitive to plant density in this situation (Table 4).

Plant heights at full tassel did not appear sensitive to plant density on any of the three sites (Tables 2-4). There was, however, a trend in Grenada - that plant heights may have been reduced with increasing plant density. Low plant density was associated with a mean plant height of 1.83m, which declined progressively to 1.57m for the densest stand at the wider row width (Table 3).

Mean leaf area per plant appeared to be distinctly influenced by plant density. Significant differences being recorded between the highest and lowest population employed (Tables 2-4). This difference was, however, lowest in St. Vincent, being 0.09m and highest in Grenada at 0.15m, while the Barbados difference was intermediary 0.12m (Tables 2-4). There was an apparent consistent relationship between mean leaf area and plant heights, the tallest plants appearing to have produced more leaf area than short plants.

Highly significant correlation between Leaf Area Index and grain yield was observed on all sites. The coefficient for three sites was 0.8589, with a regression of grain yield on L.A.I. of 0.5893 (Fig. 1).

Row Width

On Capitol Clay Loam in Grenada, the narrow row was a distinct advantage in grain yield enhancement. Here treatment (4) was associated with 4.15 T/ha dry grain, while treatment (5) produced 6.20 T/ha (Table 3). In Barbados the difference between row width was a depression of 0.30 T/ha, while this difference was 0.83 T/ha or about 16% increase in St. Vincent.

Mean ear weights were not demonstrated to be significantly altered by row width, although on the Grenada site narrow rows were associated with a mean ear weight of 131 gms as compared with 106 gms in respect of the standard 0.91m row (Tables 2-4).

Both shelling percentage and plant heights were unaffected by row width, however, there was a tendency for the narrow rows in Grenada to be associated with taller plants and a slightly higher grain out-turn (Table 3).

Leaf Area Index and Mean Leaf per plant appeared to follow the same pattern in St. Vincent where neither showed sensitivity to row width. In Grenada by contrast, leaf area index was dramatically increased by narrow rows while mean leaf area per plant was not demonstrated to be seriously altered statistically. In Barbados row width materially affected both leaf area per plant and leaf area index. Narrow rows clearly depressed leaf area index and leaf area per plant, these being 6.59, 5.29, 0.60m^2 and 0.49m^2 for wide and narrow rows, respectively (Table 4).

DISCUSSION

It is apparent from this study that grain yields of the tropical hybrid was intimately related to plant density. This confirms earlier work in the area (Baynes 1972), and is in keeping with observations in the U.S. and Canada (Bondavalli et al 1970; Doss et al 1970, Giesbrecht 1969). It is interesting to note that the economic optimum for Missouri was reported by Bondavalli et al (1970) to be 41,800 plants per hectare. The comparable figure for Barbados under the conditions of this experiment appeared to be 71.7 thousand plants per hectare. In Grenada, however, the economic optimum at the 0.91m row width appeared to be 35.9 thousand plants per hectare while in St. Vincent this was 107.6 thousand plants per hectare.

Brown et al (1970) reported on work from Georgia, that enhanced grain yield was recorded when row widths were reduced from 102cm to 51cm with supplemental irrigation. They reported that optimum plant population was related to plant size, with smaller plants requiring higher population for maximum grain yield. Stivers et al (1971) noted increased grain yields of

4.4% and 7.3% for row widths of 76cm and 51cm, respectively, as compared with a row width of 102cm. They argued that these increases were of economic importance although not statistically significant. Thus the dramatic grain yield increases recorded in Grenada with narrow rows were consistent with U.S. observations. The 16% increase in St. Vincent although not statistically significant appears to be of economic interest. Clearly, the plant density of 107.6 thousand plants per hectare employing the 0.41m row could be expected to give the best economic returns in Grenada and St. Vincent using the tropical hybrid.

The failure of 107.6 thousand plants per hectare treatment, at both spatial arrangements to be associated with elevated yield performance in Barbados was most likely due to the comparatively shallowness of the Black Association soil at Graeme Hall and its consequent lower moisture holding capacity. It is probable that although the rainfall recorded (Table I) appears quite adequate, so that the plants never appeared to be under serious moisture stress, the available moisture must have been inadequate for optimum grain yields when the competition for water and probably nutrients was increased by the pressure of the highest plant density under test. A useful adjunct to this study would have been an assessment of soil water status over the crop cycle.

The narrow row spacing would have been expected to make for a more equitable distribution of roots, as well as for better light distribution in the canopy. Clearly, these advantages could explain yield enhancement associated with narrow rows in St. Vincent and Grenada where soil moisture was apparently adequate during the ear filling phase of the plants' development. The application of the narrow row in commercial production offer the obvious benefits of a quick ground cover, which could reduce soil erosion as well as aid in the suppression of weed proliferation. The narrow row, however, could be a handicap in that it could render some post planting operations difficult, for example, insect pest control during the ear filling stage. It is, therefore, important that production techniques be evolved which will permit the full exploitation of high plant density without concomitant increases in cost or inconvenience.

Hunter et al (1970) reported that maximum grain yields were associated with Leaf Area Index of 3.3 to 4.0 and (Baynes 1972) suggested that the high L.A.I. normally found with the tropical hybrids appeared to be a handicap in the expression of their full yield potential. The L.A.I. of 5.31 in Grenada associated with the good grain yield of 6.20 T/ha presents some hope that the manipulation of row width might be one way of overcoming the apparently excessive leafiness of the tropical hybrids and ensuring that the full benefits of high plant densities are realized.

SUMMARY AND CONCLUSIONS

Three field experiments conducted in Barbados, St. Vincent and Grenada are described, in which a tropical maize hybrid, X304, grown in plant densities ranging from 17.9 to 107.6 thousand plants per hectare was studied. At the highest plant density an additional treatment involving narrow rows, 0.45m, was included for comparison with the standard 0.91m rows.

Plant density was shown to be directly related to grain yield, Mean Ear Weight and Leaf Area Index, however, Shelling % and Plant Height were not observed to be seriously influenced by plant density. Narrow rows appeared to be of distinct advantage in enhancing grain yield in Grenada and St. Vincent, while in Barbados it was associated with a small and non significant depression in grain yield.

In Grenada and St. Vincent, the 0.45 row combined with 107.6 thousand plants per hectare is, therefore, recommended for commercial plantings. For Barbados, it could be concluded that where irrigation was available or in areas with good rainfall distribution, the optimum arrangement would include a plant density of 71.7 thousand plants per hectare combined with 0.91m rows.

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Table 2.- Grain Yield (T/ha), Mean Ear Weight, Shelling %, Leaf-Area Index and Plant Height at Full Tassel (m) of Maize Grown in Varying Plant Densities on Akers Sandy Clay Loam in St. Vincent

Plant Density (10^3plants/ha)	Grain Yields (T/ha)	Mean Ear Weight (gms)	Shelling %	Leaf Area Index	Plant Height (m)	Mean Leaf area per plant (m^2)
17.9	2.03d	194a	69	0.89d	1.81	0.49a
35.9	3.18	171ab	69	1.78c	1.77	0.50a
71.7	4.18bc	144bc	65	2.95b	1.86	0.41b
107.6	5.30ab	104d	68	4.56a	1.89	0.42b
107.6	6.13a	105cd	74	4.35a	1.82	0.40b
S.E.	±0.37	±12	N.S.D.	±0.12		±0.02
C.V.	8.87%	9%		4.14%		4.09%

Table 3.- Grain Yield (T/ha), Mean Ear Weight, Shelling %, Leaf-Area Index and Plant Height at full tassel of Maize grown in Varying Plant Densities on Capital Clay Loam in Grenada.

Plant Density (10^3plants/ha)	Grain Yields (T/ha)	Mean Ear Weight (gms)	Shelling %	Leaf Area Index	Plant Height (m)	Mean Leaf area per plant (m^2)
17.9	2.75c	286a	71	0.98a	1.83	0.54a
35.9	3.85	212b	73	1.88d	1.80	0.52a
71.7	4.00	133c	76	3.13c	1.68	0.44ab
107.6	4.15	106d	74	4.18b	1.57	0.39b
107.6	6.20	131cd	77	5.31a	1.89	0.49ab
S.E.	±0.23	±8.12	N.S.D.	±0.15	N.S.D.	±0.03
C.V.	5.70%	4.70%		4.90%		6.25%

Table 4.- Grain Yield (T/ha), Mean Ear Weight, Shelling %, Leaf-Area Index, and Plant Height at Full Tassel of Maize Grown In Varying Plant Densities on a Black Soil in Barbados

Plant Density (10^3plants/ha)	Grain Yields (T/ha)	Mean Ear Weight (gms)	Shelling %	Leaf Area Index	Plant Height (m)	Mean Leaf area per plant (m^2)
17.9	3.13c	181a	77	1.28c	2.28	0.72a
35.9	4.35b	177a	77	2.40d	2.40	0.67ab
71.7	5.45a	142b	81	4.56c	2.29	0.64ab
107.6	5.18ab	119b	73	6.59a	2.33	0.60b
107.6	4.88ab	103b	77	5.29b	2.29	0.49c
S.E.	±0.32	±13.60	N.S.D.	±0.15	N.S.D.	±0.03
C.V.	7.00%	9.40%		3.75%		4.03%

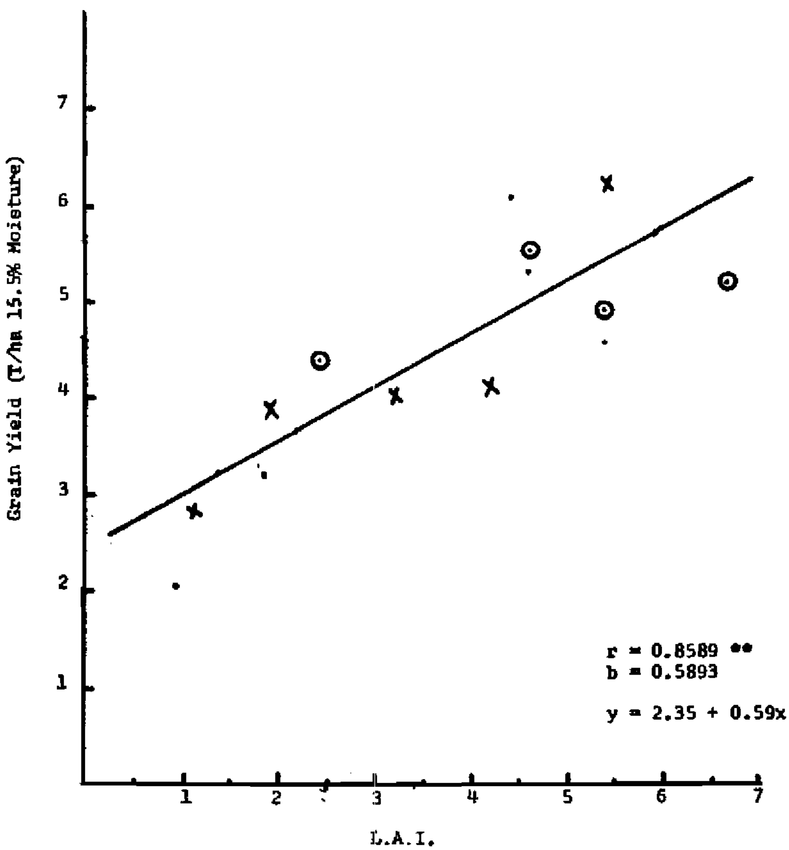

Figure 1.- Relationship between LAI (Leaf Area Index) and grain yield in tropical hybrid corn, cultivar X304, over three sites