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Agro physiological characteristics of quality protein maize genotypes as influenced by irrigation and plant population in a semi arid Region of Nigeria

B. M. Sani[1]*, I. U. Abubakar[2], A. M. Falaki[2], H. Mani[2] and M. M. Jaliya[1]

[1]Agricultural Engineering and Irrigation Department, National Agricultural Extension and Research Liaison Services, NAERLS, Ahmadu Bello University, P.M.B 1067, Zaria, Nigeria.
[2]Department of Agronomy, Faculty of Agriculture/Institute for Agricultural Research, Ahmadu Bello University, P.M.B 1044, Zaria, Nigeria.

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An experiment was conducted to assess the response of agrophysiological characters of quality protein maize genotypes to plant population under irrigated conditions in a semi arid ecology of Northern Nigeria. Field trials were conducted at the Irrigation Research Station, Institute for Agricultural Research, Kadawa (11° 39'N, 08° 20'E) and 500 m above sea level) during 2007, 2008 and 2009 dry seasons to study the effect of (*Zea mays* L.) genotypes (TZE-W Pop X 1368, EV-DT W99 STR and DMR-ESRW), four plant population (33,333, 44,444, 55,555 and 66,666 plants ha^{-1}) and three irrigation scheduling (40, 60 and 80 centibars soil moisture tension) on the growth and yield of quality protein maize. A split plot design was used with combinations of genotypes and irrigation regimes assigned to the main plot and plant population assigned to the sub-plot. The treatments were replicated three times. The study revealed that genotype EV-DT W99 STR recorded significantly higher relative growth rate, crop growth rate and net assimilation rate. Increase in plant population significantly decreased leaf area index and net assimilation rate. Delayed irrigation significantly depressed total dry matter production. Based on the results obtained in this study, it can be concluded that the use of genotype EV-DT W99 STR, at 60 centibars irrigation scheduling and 55,555 plants ha^{-1} had resulted in good agrophysiological characters of QPM at Kadawa.

Key words: Quality protein maize genotypes, plant population, irrigation, agrophysiological characteristics.

INTRODUCTION

Maize grown in Nigeria has traditionally been conventional maize varieties. With improvements in maize breeding, quality protein maize (QPM), a new class of maize was developed at Purdue University, USA, in 1963. QPM combines the nutritional excellence of Opaque-2 maize (whose protein content is twice that of normal maize) with the kernel structure of conventional maize varieties (Vassal et al., 1993). There is a dearth of research on the performance of QPM genotypes under irrigated conditions in semi arid regions of Nigeria. QPM production is being promoted across Nigeria mainly in areas where it is grown in the wet season. Most QPM genotypes were bred under rain fed conditions. The yield potential in the savanna ecology is higher compared to the wetter (Forest) and drier (Sahel) environments (Kassam et al., 1975) due to adequate moisture, low

*Corresponding author. E-mail: bashirsani@yahoo.com; Tel: +234-806-813-4944.

disease incidence, low night temperatures and high solar radiation. With early maturing genotypes developed, production of such QPM genotypes under irrigation is a possibility as moisture supply is not limiting and the ecology's agro-climatological characteristics permit such production. Maize is the agronomic grass species that is most sensitive to variations in plant population. For each production system, there is a population that maximizes grain yield. The importance of plant population as a factor determining growth and yield of early maize cultivars has been established (Gretzmacher, 1979; Zarogiannis, 1979; Bavec, 1988). Maize varieties grown respond differently to various agro management practices especially plant population in the form of different agro-physiological parameters. This variable response is mainly due to differences in agro-physiological parameters such as leaf area index, relative growth rate, net assimilation rate, relative growth rate etc. This study was therefore conducted to study the effect of high plant population on agrophysiological characters of QPM genotypes under irrigated conditions in a semi arid ecology.

MATERIALS AND METHODS

The study was conducted under irrigation during 2007, 2008 and 2009 dry seasons at the Kadawa Irrigation Research Sub-Station of the Institute for Agricultural Research, Ahmadu Bello University, Zaria. The site is located in the Sudan Savanna ecological zone of Nigeria (11° 39'N, 08° 20'E and 500 m above sea level). The area has a cool dry season that has the north-eastern winds, which are cool and contain dust blown from the Sahara Desert. The minimum temperature ranges between 11 to 18°C in the cool months (November to March) with maximum temperatures of 25 to 40°C in the warmer months (April to October) which is ideal for cultivation of wide variety of crops in the dry season. The soils are, in general, moderately deep and well drained with sandy loam textured surface and sandy clay loam textured subsoil.

The treatments consisted of three QPM genotypes (TZE-W Pop x 1368, EV DT-W 99 STR, and DMR-ESRW) three irrigation scheduling regimes (40, 60 and 80 centibars soil moisture tension) and four plant population (33,333 44,444, 55,555 and 66,666 plants ha^{-1}). The experiment was laid out in a split plot design in which a factorial combination of genotype and irrigation scheduling were assigned to the main plot and plant population density was assigned to the sub-plots and replicated three times. Planting was done on February 14, in 2007, February 21 in 2008 and February 17 in 2009 respectively. The inter row spacing was 75 cm whereas the intra row spacing used was 40 cm (33,333 plants/ha) 30 cm (44,444 plants/ha) 24 cm (55,555 plants/ha) and 20 cm (66,666 plants/ha) respectively in order to achieve the desired plant population. The QPM genotypes used for the study were TZE-W Pop x 1368 (open pollinated, white seeded, early maturing, tolerant to *Striga hermonthica,*), EV DT-W 99 STR (open pollinated, white seeded, early maturing, tolerant to *Striga hermonthica),* and DMR-ESRW (open pollinated, white seeded, early maturing, tolerant to *Striga hermonthica* and downy mildew). Furrow method of irrigation was used in supplying water to the crop. Irrigation treatment was imposed beginning from 4 WAS. The irrigation was at 40, 60 and 80 centibars soil moisture tension. A tensiometer was installed at each main plot for the purpose of taking the reading. Weeds were controlled with the use of a pre-emergence herbicide; a mixture of metalachlor + atrazine (2:1) was applied at the rate of 1.5 kg ai/ha (4 l/ha) supplemented by hoe weeding at 6 WAS in the experimental plots and around the field. Fertilizer was applied at the rate of 120 kgN, 26 kgP and 50 kgK per hectare respectively. Half the N and all P and K were applied at two weeks after sowing by side placement 8 to 10 cm away from the base of the plant stands. At 6 WAS, the other half of N was applied by side placement 8 to 10 cm away from the base of the plant stands and followed by irrigation. The following parameters were computed as indicated:

Leaf area index (LAI)

The product of the length and breadth was multiplied by a factor (0.75) to calculate the leaf area (Watson, 1937). The leaf area obtained from the individual leaves was added and divided by the number of plants sampled to obtain LAI. The leaf area per plant was then multiplied by the number of plants/m^2 and divided by the land area covered by the plant (Duncan and Hasketh, 1968).

$$L = \frac{A}{P}$$

Where: L = Leaf area index, A = Assimilatory surface, P = certain ground surface.

Crop growth rate (g/m^2/week)

This was determined at 8 and 12 WAS from the five sampled plants after being oven dried to a constant weight. The following formular was used (Watson, 1952).

$$CGR = \frac{W2 - W1 \times 1}{t_2 - t_1 \quad G_A} = g/m^2/week$$

Where W_1 and W_2 refer to the whole plant dry weight on two successive times, t_1 and t_2, G_A refers to land area covered by the plant.

Relative growth rate (g/g/wk)

This was calculated at 8 and 12 WAS. It was determined after oven drying the sampled plants to a constant weight using the formular; (Fisher, 1921).

$$RGR = \frac{LogeW_2 - LogeW_1}{t_2 — t_1} = g/g/wk$$

Where W_1 and W_2 refer to the whole plant dry weight on two successive times, t_1 and t_2.

Net assimilation rate (g/cm^2/wk)

This was determined at 8 and 12 WAS. The leaf area of each sampled plant was calculated by measuring the length of each leaf and breadth which was measured from the widest portion of the leaf, then the product of length and breadth was multiplied by a factor (0.75). After that the dry weight of each sampled plant was then determined and the net assimilation rate was calculated using

Table 1. Effects of genotype, irrigation scheduling and plant population on net assimilation rate (NAR), crop growth rate (CGR) and relative growth rate (RGR) of QPM genotypes at harvest in 2007, 2008 and 2009 dry season at Kadawa.

Treatment	Net assimilation rate			Crop growth rate (CGR)			Relative growth rate (RGR)		
	2007	2008	2009	2007	2008	2009	2007	2008	2009
Genotype									
TZE-W Pop X 1368 QPM	12.68[b]	13.71	14.89[b]	12.68[b]	13.71	14.89[b]	155.29[c]	175.33	159.55[b]
EV-DT W99 STR QPM	13.96[a]	13.74	16.56[a]	13.96[a]	13.74	16.56[a]	171.33[a]	168.83	172.92[a]
DMR-ESRW QPM	11.70[c]	14.07	15.50[b]	11.70c	14.07	15.50[b]	164.15[b]	162.38	160.87[b]
SE (±) Significance	0.17	0.20	0.36	0.17	0.20	0.36	2.30	2.99	3.43
Irrigation scheduling (I)									
40 centibars	12.64	13.67	15.34	12.64	13.67	15.34	164.31	164.71	170.08
60 centibars	12.75	13.78	15.99	12.75	13.78	15.99	163.72	169.45	173.56
80 centibars	12.95	14.07	15.03	12.95	14.07	15.03	170.30	169.20	177.70
SE (±)	0.17	0.20	0.36	0.17	0.20	0.36	2.30	2.99	3.43
Plant population (P)									
33,333 plants ha^{-1}	12.85	13.95	15.65	12.85	13.95	15.65	172.18[a]	171.52[a]	174.71[a]
44,444 plants ha^{-1}	12.69	13.75	15.29	12.69	13.75	15.29	161.38[ab]	173.90[ab]	161.91[ab]
55,555 plants ha^{-1}	12.76	13.78	15.03	12.76	13.78	15.03	158.12[b]	179.25[b]	162.91[b]
66,666 plants ha^{-1}	12.83	13.89	15.84	12.83	13.89	15.84	165.68[ab]	171.52[ab]	163.52[ab]
SE (±)	0.17	0.20	0.35	0.17	0.20	0.35	2.93	3.53	4.52
Interaction									
G x I	NS	NS	NS	NS	NS	NS	*	**	*
G x P	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x P	NS	NS	NS	NS	NS	NS	NS	*	NS

Means followed by the same letter(s) within a column and treatment group are statistically similar using DMRT, NS - Not significant, *- Significant at 5%.

the relation or formular (Gregory, 1926).

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e L_2 - \log_e L_1}{L_2 - L_1} = g/cm^2/wk$$

Where W_1 and W_2 are initial and final dry weights. L_1 and L_2 are the initial and final leaf area indices and t_2 and t_1 are the length of time interval.

Harvesting was carried out when the cobs have dried enough and the leaf sheath have turned brown in colour. The data collected were statistically analysed using the SAS software.

RESULTS AND DISCUSSION

The trend of net assimilation rate (NAR) and crop growth rate (CGR) of QPM genotypes is shown in Table 1 and indicate that for both parameters, in 2007 and 2009, genotype EV-DT W99 STR QPM had significantly higher NAR than genotypes TZE-W Pop X 1368 QPM and DMR-ESRW QPM except in 2007 when genotype DMR-ESRW QPM had significantly lower NAR and CGR values respectively. Irrigation scheduling and plant population had no significant effect on both NAR and CGR. Relative growth rate (RGR) was significantly affected by genotype in 2007 and 2009 as shown in Table 1. The result indicate that genotype EV-DT W99 STR QPM had significantly higher RGR than genotypes TZE-W Pop X 1368 QPM and DMR-ESRW QPM except in 2007 when genotype DMR-ESRW QPM had significantly lower RGR values respectively than the other two genotypes respectively. Plant population significantly RGR where plant population of 33,333 plants ha^{-1} had significantly higher RGR values than plant population of 55,555 plants ha^{-1} but was statistically similar to RGR values of 44,444 plants ha^{-1} and 66,666 plants ha^{-1} respectively.

Total dry matter per plant

The effects of genotype, irrigation scheduling and plant population on total dry matter per plant (g) of QPM genotypes at harvest during the study period is shown in Table 1. The results indicate that genotypic differences significantly influenced dry matter accumulation across the three years of study. In 2007 and 2009, genotype

Table 2. Effects of genotype, irrigation scheduling and plant population on Leaf area index (LAI) and Total dry matter per plant (g) of QPM genotypes at harvest in 2007, 2008 and 2009 dry season at Kadawa.

Treatment	Leaf area index			Total dry matter per plant (g)		
	2007	2008	2009	2007	2008	2009
Genotype						
TZE-W Pop X 1368 QPM	2.80[b]	2.64	3.47[b]	231.98[b]	215.48[b]	375.79[b]
EV-DT W99 STR QPM	3.88[a]	2.86	5.26[a]	283.25[a]	267.35[a]	523.08[a]
DMR-ESRW QPM	2.93[b]	3.00	3.51[b]	161.71[c]	276.58[a]	298.39[c]
SE (±) Significance	0.16	0.12	0.02	11.95	13.02	21.66
Irrigation scheduling (I)						
40 centibars	3.22	2.88	4.14	242.20[a]	272.50[a]	432.83[a]
60 centibars	3.38	3.02	4.29	232.57[a]	262.75[a]	410.05[a]
80 centibars	3.03	2.60	3.81	202.16[b]	224.16[b]	354.37[b]
SE (±)	0.16	0.12	0.02	11.95	13.02	21.66
Plant population (P)						
33,333 plants ha^{-1}	3.43	3.05[a]	4.36	228.33	259.73	410.13
44,444 plants ha^{-1}	3.17	2.95[ab]	4.01	231.54	256.96	407.25
55,555 plants ha^{-1}	3.30	2.82[ab]	4.28	219.91	250.61	393.37
66,666 plants ha^{-1}	2.98	2.51[b]	3.69	222.79	245.24	385.59
SE (±)	0.19	0.16	0.02	8.17	9.42	14.88
Interaction						
G x I	NS	NS	NS	*	**	*
G x P	NS	*	NS	NS	NS	NS
I x P	NS	NS	NS	NS	*	NS

Means followed by the same letter(s) within a column and treatment group are statistically similar using DMRT, NS- Not significant; *, Significant at 5%.

DMR-ESRW QPM recorded statistically lower TDM/plant than the other two genotypes. In 2008, genotype EV-DT W99 STR QPM recorded significantly higher TDM/plant than TZE-W Pop X 1368 QPM but was statistically similar to DMR-ESRW QPM. This could be due to some inherent genetic and physiological differences that exist between the varieties. Growth characters are genetically controlled and to some extent influenced by the environment. Irrigation scheduling had a significant effect on TDM/plant throughout the course of the study. The result indicates that irrigating at 80 centibars resulted in significantly lower TDM/plant than irrigating at 40 and 60 centibars respectively over the course of the study period. The result indicated that plant population had no significant effect on TDM/plant throughout the course of the study.

Leaf area index (LAI)

The effects of genotype, irrigation scheduling and plant population on leaf area index (LAI) at 8 WAS during the study period is shown in Table 2. The results indicate that genotype significantly influenced leaf area index in 2007 and 2009. In 2007 and 2009, genotype EV-DT W99 STR QPM recorded statistically higher LAI than the other two genotypes. This could be due to some inherent genetic and physiological differences that exist between the genotypes. Growth characters are genetically controlled and to some extent influenced by the environment. Irrigation scheduling had no significant effect on LAI throughout the course of the study. The result indicates that plant population significantly influenced LAI only in 2008 where plant population of 33,333 plants ha^{-1} had significantly higher LAI values than plant population of 66,666 plants ha^{-1} but was statistically similar to LAI values of 55,555 and 44,444 plants ha^{-1} respectively.

DISCUSSION

Genotype EV-DTW99STR QPM had significantly higher relative growth rate and net assimilation rate. Genotype TZE-W Pop X 1368 QPM however, exhibited shorter days to 50% tasseling and silking. Genotype DMR-ESRW QPM did not exhibit any superior traits over the other two genotypes. Many workers have reported growth and yield differentials among different maize varieties and genotypes (Hamidu, 1999; Bello, 2001; Ogunbodede et al., 2001; Mani, 2004; Abdulai et al., 2007; Abdelmula and Sabiel, 2007; Sharifi and Taghizadeh, 2009; Badu-Apraku and Fontem-Lum, 2010). Varying irrigation scheduling had significant effects on many growth parameters assessed. The results of the study indicated that irrigating at the less stressful 0.4 and 0.6 centibars significantly increased crop growth rate and days to 50% tasseling and silking. This may be due to abundant moisture supply which enabled the crop to respond to this growth resource favourably which resulted in good growth. This supported the observation reported by Ibrahim and Kandil (2007). The significant response to irrigation during the vegetative phase of growth may due to the fact that the roots were still developing, and hence had not reached deeper to tap moisture in the lower soil layers and this meant that varying irrigation could affect the crop performance.

Increasing plant population from 33,333 to 44,444 and 55,555 plants ha^{-1} produced similar NAR at 8 weeks after sowing in the first two years, but significantly decreased the net assimilation rate per plant at 66,666 plants ha^{-1}. Similarly, during the first two years, at 12 WAS, 44,444 plants ha^{-1} had significantly lower NAR than the other treatments. In 2009, increasing plant population from 33,333 to 66,666 plants ha^{-1} resulted in significantly lower NAR at both sampling periods. This may be due to the influence of leaf area per plant. The lower plant population may have had larger leaf surfaces resulting in higher leaf area per plant and thus higher net assimilation rates than the higher population treatments. It may also be due to proportionally less increase in dry matter accumulation per unit area as compared to increase in LAI. This results are in line with the findings of Ahmad alias (2010), Ma et al. (2007), Maddonni et al. (2001), Mohsan (1999) and Naeem (1998) who stated that increasing plant population decreased net assimilation rate. Leaf area index, LAI, was also significantly affected by variation in plant population. The results of this study indicated that increasing plant population resulted in significantly higher LAI at 33,333, 44,444 and 55,555 plants ha^{-1} which had similar LAI but were significantly higher than 66,000 plants/ha respectively. Many workers have reported an increase in LAI as plant population is increased (Sulewaska, 1990; Dwyer et al., 1991; Eseche, 1992; Hamidu, 1999; Ahmad alias et al., 2010; Amanullah et al., 2010). This may be due to the fact that since the estimation of LAI is based on LAI/plant, the aggregate sum of the various plants will translate into higher LAI for the more numerous plant populations. The higher the population, the more leaves produced and the greater the leaf area index (LAI). Nunez and Kamprath (1969) and Hunter et al. (1975) found that the total LAI increased linearly with increases in population from 34,000 to 69,000 plants ha^{-1}, after which the LAI would start to decrease. Similarly Luque et al. (2006) and Liu et al. (2004), reported that increase in plant population tends to decrease LAI per plant but increase LAI per unit area. Increase in plant population may cause significant reduction in leaf area per plant due to small leaf size. However, ground area per plant is decreased more steeply with increasing number of plants per unit area thus leading to an increase in LAI. Furthermore, increase in light interception at high than at low plant population may lead to higher LAI.

Conclusion

The results of this study showed a significant response to variations in plant population by many of the parameters. Increase in plant population significantly increased net assimilation rate and days to 50% tasselling, amongst the growth factors. Based on the results obtained, it can be concluded that the use of genotype EV-DT W99 STR QPM, 60 centibars irrigation schedule and 55,555 plants ha^{-1} had resulted in good agrophysiological characters of quality protein maize at Kadawa. Further studies may be necessary to determine the appropriate fertilizer rate which may increase the yield under irrigated conditions.

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