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Growth and Development of Quality Protein Maize (QPM) Genotypes As Influenced by Irrigation and Plant Population in a Sudan Savanna Ecology, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author BMS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors IUA, HM and AMF reviewed the manuscript. Author MMJ managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was carried out to assess the growth and development of quality protein maize (QPM) genotypes to various plant populations under different irrigated conditions in a semi arid ecology of Northern Nigeria. Field trials were conducted at the Irrigation Research Station, Institute for Agricultural Research, Kadawa (11º39' N, 08º20' E) and 500 m above sea level) for three years, 2007, 2008 and 2009 during dry seasons to study the effect of three maize (*Zea mays L.*) genotypes (TZE-W Pop X 1368, EV-DT W99 STR and DMR-ESRW), four plant populations (33,333, 44,444, 55,555 and 66,666 plants ha^{-1}) and three irrigation scheduling regimes (40, 60 and 80 centibars soil moisture tension) on the growth and development of QPM. This was a three trial experiment with factors arranged in a split plot design, whereby genotype and irrigation scheduling

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were assigned to the main plot in a factorial style and plant population density assigned to the sub-plots. Factors involved were replicated three times. The treatments were replicated three times. The study revealed that genotype EV-DT W99 STR had significantly higher number of leaves, taller plants and shorter days to attain 50% tasselling and silking. Irrigating at 80 centibars resulted in significantly shorter days to 50% taselling, but significantly longer days to attain 50% silking. Increase in plant population significantly decreased the number of days to attain 50% tasseling. Based on the results found in this study, it could be concluded that genotype EV-DT W99 STR, at 80 centibars irrigation scheduling regime and 55,555 plants ha^{-1} had resulted in good growth and development of QPM under irrigation in a semi arid environment.

Keywords: Quality protein maize genotypes; plant population; irrigation; growth and development.

1. INTRODUCTION

Maize (*Zea mays* L.) is a very important cereal crop in Nigeria ranking third among cereal crops after sorghum and millet [1]. It is the most widely distributed cultivated crop in Nigeria with cultivation from the wet ever green forest zone to the dry ecology of the Sudan savanna [2] and is a major cereal crop for human nutrition and livestock feed. It is the most frequently consumed staple comprising about 18.8% consumption of all food stuff in the dry savanna, 21.9% in the moist savannas, and 19.8% in the humid forest. Maize forms about 10.6% of the most available staple foods that are major sources of energy in Nigeria. Maize grown in Nigeria has traditionally been conventional maize varieties. Maize has the highest yield potential of all cereals in the world [3] and therefore invaluable for nourishment of both humans and animals. Among the cereal crops, maize ranks second to wheat in production [1]. 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 [4]. There is a deficiency 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. Maize production in Nigeria is characterized by low productivity due to a variety of factors like low plant density, poor soil management practices, unavailability of water, pests and diseases and many others. However, low yield due to sub-optimal population density and poor water management practices are some of the problems resulting in low productivity. In farmers' fields, maize plant density varies greatly e.g. 15,000-51,000 plants ha^{-1} [5], but are below the optimum density (66,000 plants ha^{-1}) recommended for high yields [6]. Maize is the agronomic grass species that is most sensitive to variations in plant population. For each production system, there is a plant population that maximizes grain yield. Irrigated agriculture is assumed to be more productive due to the control exerted on moisture supply. As this resource is not limiting, it can be assumed that yield from irrigated agriculture would be higher than for rainfed. The significance of plant population as a factor determining growth and yield of early maize cultivars has been established by many researchers [7-9]. The yield potential in the savanna ecology is higher compared to the wetter (Forest) and drier (Sahel) environments [10] due to adequate moisture, low disease incidence, low night temperatures and high solar radiation. The production of QPM is not widespread despite its advantages. The development of early maturing genotypes implies that QPM can be grown outside its traditional area of growth. Furthermore, most QPM genotypes were bred under rainfed conditions this makes it imperative to evaluate the response of these genotypes under irrigated conditions. This study was therefore carried out to investigate the response of growth factors of QPM genotypes to plant population under irrigated conditions in a semi-arid ecology.

2. MATERIALS AND METHODS

The study was carried out under irrigation for three years during dry seasons of 2007, 2008 and 2009 at the Kadawa Irrigation Research Sub-Station of the Institute for Agricultural Research, Ahmadu Bello University, Zaria. The site is situated in the Sudan Savanna ecological zone of Nigeria (11º39' N, 08º20' 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

11ºC-18ºC in the cool months (November to March) with maximum temperature of 25ºC-40ºC 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 populations (33,333 44,444, 55,555 and 66,666 plants ha^{-1}). This was a three trial experiment with factors arranged in a split plot design, whereby genotype and irrigation scheduling were assigned to the main plot in a factorial style and plant population density assigned to the sub-plots. Factors involved were 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 spacings were 40 cm (33,333 plants ha^{-1}), 30 cm (44,444 plants ha^{-1}), 24 cm (55,555 plants ha^{-1}) and 20cm (66,666 plants ha^{-1}) 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 irrigation was used in supplying water to the crop. Irrigation treatment was imposed beginning from 4 WAS. The irrigation was applied at 40, 60 and 80 centibars soil moisture tension. A tensiometer was installed at each main plot for taking the readings. 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 kg N, 26 kg P and 50 kg K ha^{-1} respectively. Half the N and all P and K were applied at two weeks after sowing by side placement (8-10 cm away from the base of the plant stands). At 6 WAS, the other half of N was applied by side placement followed by irrigation. Harvesting was carried out when the cobs have dried enough and the leaf sheath has turned brown in colour. The data collected were statistically analysed using the SAS software.

3. RESULTS AND DISCUSSION

3.1 Number of Leaves per Plant

The effects of genotype, irrigation scheduling and plant population on number of leaves per plant of QPM genotypes at harvest during the study period is shown in Table 1. The results indicate that genotypic differences significantly influenced number of leaves per plant in 2007 and 2009 only. Genotype EV-DT W99 STR QPM recorded significantly more number of leaves per plant than the two other genotypes. Irrigation and plant population had no significant effect on number of leaves per plant in all the years of the study.

3.2 Plant Height

The effects of genotype, irrigation scheduling and plant population on plant height (cm) of QPM genotypes at harvest during the study period is shown in Table 1. The results indicate that genotypic differences significantly influenced plant height in 2007 and 2009 only. Genotype EV-DT W99 STR QPM recorded significantly higher plant height than the two other genotypes. This could be due to some inherent genetic and physiological differences that exist between the varieties. Irrigation treatments had no significant effect on plant in all the years of the study. Plant population had significant effect on plant height in all three years of the study. The results indicate that plant population of 33,333 plants ha^{-1} recorded significantly taller plants than 55,555 plants ha^{-1}, but was statistically similar to 44,444 and 66,666 plants ha^{-1}.

3.3 Days to 50% Tasselling

The effects of genotype, irrigation scheduling and plant population on days to 50% tasselling of QPM genotypes is shown in Table 2. The results indicate that genotypic differences significantly influenced days to 50% tasselling in 2007 and 2009 only and was not significant in 2008. In 2007, genotype DMR-ESRW QPM recorded statistically shorter days to attain 50% tasselling than genotype TZE-W Pop X 1368 QPM but was statistically similar to genotype EV-DT W99 STR QPM. In 2009, genotype TZE-W Pop X 1368 QPM recorded significantly longer days to attain 50% tasselling than the other two genotypes. Irrigation schedule had a significant effect on days to 50% tasselling in 2008 and 2009. In 2008 irrigating at 80 centibars recorded significantly shorter days to 50% tasselling than irrigating at

Table 1. Effects of genotype, irrigation scheduling and planting density on number of leaves and height for QPM genotypes at harvest in 2007, 2008, and 2009 dry cropping season at Kadawa

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

40 and 60 centibars respectively. In 2009, irrigating at 40 centibars recorded significantly shorter time to 50% tasselling than irrigating at 60 and 80 centibars respectively. Plant population had an effect on days to 50% tasselling only in 2009 where plant population of 33,333 plants ha^{-1} recorded significantly shorter period to 50% tasselling than the other treatments but was statistically at par with 66,666 plants ha^{-1} treatment.

3.4 Days to 50% Silking

The effects of genotype, irrigation scheduling and plant population on days to 50% silking of QPM genotypes is shown in Table 2. The results indicate that genotypic differences significantly influenced days to 50% silking in all years of the study. In 2007, genotype EV-DT W99 STR QPM recorded significantly shorter days to attain 50% silking than both genotypes DMR-ESRW QPM and TZE-W Pop X 1368 QPM. However, genotype TZE-W Pop X 1368 QPM recorded significantly shorter days to attain 50% silking than genotype DMR-ESRW QPM. In 2008, genotypes EV-DT W99 STR QPM and DMR-ESRW QPM recorded significantly shorter days to attain 50% silking than genotype TZE-W Pop X 1368 QPM, while in 2009, genotype EV-DT W99 STR QPM recorded significantly shorter days to attain 50% silking than genotype DMR-ESRW QPM, but was statistically similar to genotype TZE-W Pop X 1368 QPM. Irrigation scheduling had a significant effect on days to 50% silking only in 2007 where irrigating at 80 centibars recorded significantly longer days to attain 50% silking than irrigating at 60 centibars, but was statistically similar to irrigating at 40 centibars. Plant population had no significant effect on days to 50% silking.

4. DISCUSSION

The results of the study indicate that genotype EV-DT W99 STR QPM had significantly higher plant height and number of leaves/plant than the other two genotypes. A similar trend has been observed by [11] with these same genotypes in trials across Nigeria. Genotype TZE-W Pop X 1368 QPM however, exhibited shorter days to 50% tasseling and silking. Many research works have reported growth and yield differentials among different maize varieties and genotypes [11-20]. The results of this study showed a significant response to variations in plant population by many of the parameters. Increasing plant population from the lowest to the highest did not affect plant height significantly. This result is in consonance with [12,21,22] who reported that plant height was not significantly affected by plant population. However, many researchers have reported significant response of plant height to variations in plant population [13,23,24]. The lower plant population of 33,333 plants ha^{-1} took significantly shorter days to tasseling than the higher populations. The reduced competition for resources might have hastened the vegetative growth of the lower population treatment leading to faster attainment of days to 50% tasseling. An increase in population would result in an increased stress to the crop and thus the plant would mature later than the less crowded plants. This has been reported by [25-29]. None of the genotypes exhibited any signicficant difference in growth characters as a result of irrigation. This, despite one of the genotypes being drought tolerant. This result is significant and indicates that all the genotypes can withstand some degree of water stress. The significantly positive and varied response of growth and yield characters among the three genotypes to irrigation scheduling has shown the importance of moisture on growth, development and yield of quality protein maize. The results of the interactions showed irrigating genotype EV-DT W99 STR QPM at 40 and 60 centibars produced significantly higher plant height. Similarly, irrigating genotype TZE-W Pop X 1368 QPM at 80 centibars resulted in significantly longer days to attain 50 tasseling. This has indicated the complementary role played between these factors on vegetative and reproductive growth of quality protein maize, QPM. This could be attributed to the ability of genotypic make up and available moisture to promote vigorous foliage growth, increased meristematic and physiological activities in the plants there by resulting in the synthesis of more photo-assimilates, which are used in producing higher yield. [30] Reported that irrigation improved the efficiency of fertilization and there is strong correlation between fertilizer utilization and the water supply to a plant.

Table 2. Effects of genotype, irrigation scheduling and plant population on days to 50% tasseling of QPM genotypes during 2007-2009 dry season at Kadawa

	Days to 50% tasselling			Days to 50% silking		
Treatment	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
Genotype						
TZE-W Pop X 1368 QPM	55.49a	55.45	56.38a	63.70b	64.28a	63.22ab
EV-DT W99 STR QPM	55.22ab	55.71	53.30b	61.27c	63.31b	62.83b
DMR-ESRW QPM	54.87b	55.74	53.38b	64.15a	63.48b	63.52a
SE (±)	0.19	0.13	0.28	0.33	0.29	0.44
Irrigation scheduling (I)						
40 centibars	55.26	55.90a	54.72a	62.82ab	64.18	63.36
60 centibars	55.20	55.84a	53.83b	63.38a	63.40	63.38
80 centibars	55.12	55.16b	54.52a	62.59b	63.50	62.83
SE (±)	0.19	0.13	0.28	0.33	0.29	0.44
Plant population (P)						
33,333 plants ha^{-1}	55.26	55.23	53.88b	63.13	63.58	63.70
44,444 plants ha^{-1}	55.11	55.63	54.62a	63.13	63.73	62.92
55,555 plants ha^{-1}	55.37	55.80	54.66a	62.81	63.37	63.11
66,666 plants ha^{-1}	55.04	55.80	54.25ab	62.64	64.09	63.03
SE (±)	0.19	0.22	0.19	0.34	0.32	0.25
Interaction						
G x I	NS	NS	NS	NS	NS	NS
G x P	NS	NS	NS	NS	NS	NS
I x P	NS	NS	NS	NS	NS	NS
G x I x P	NS	NS	NS	NS	NS	NS

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

5. CONCLUSION

From the results of the study, it can be concluded that the growth and development of genotype EV-DT W99 STR QPM was significantly better than the other two genotypes in the ecology when irrigated at 80 centibars at a plant population of 55,000 plants ha^{-1}. It is thus recommended for cultivation in similar ecologies under irrigated conditions. Further research on optimum fertilizer requirement may need to be conducted.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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