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Response of high quality protein maize (*Zea mays* L.) grown after wheat to spacing and fertilizer in summer season

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Abstract
To determine how spacing and different NPK levels affect high quality protein maize (*Zea mays.* L. Var. HQPM-1), in summer of 2016, a field experiment was carried out in Junagadh (Gujarat). Three different levels of spacings (45 cm × 20 cm, 60 cm × 20 cm, and 75 cm × 20 cm) with four NPK levels (*0*-0-0, 90-45-45, 120-60-60 and 150-75-75 kg N-P_2O_5 and K_2O ha^{-1}) were combined into twelve different treatments. The experiment was set up using three factorial randomized block design replications. The finding showed that, under 45 cm × 20 cm significantly higher values of growth parameters such as plant height, dry matter per plant and number of internodes per plant were observed. Yield attributes *viz.* cob length, number of cobs per plant, number of grains per cob, 100-grain weight, shelling per cent, harvest index, grain and fodder yields, quality parameter *viz.*, protein content and protein yield and N, P, K content, uptake and availability in soil were recorded significant highest under spacing 60 cm × 20 cm over 75 cm × 20 cm. Application of 150-75-75 kg N-P_2O_5 and K_2O ha^{-1} being at par with 120-60-60 kg N-P_2O_5 and K_2O ha^{-1} recorded significantly higher growth parameters *viz.*, plant height, functional leaves per plant, dry matter per plant, leaf SPAD meter value, yield attributes *viz.*, cob length, number of cobs per plant, number of grains per cob, 100-grain weight, shelling percentage, harvest index along with higher grain and fodder yields, quality parameters *viz.*, protein content and protein yield and higher N, P, K content, uptake and availability in soil over 0-0-0 kg N-P_2O_5 and K_2O ha^{-1}. The highest net return (₹ 37106 and ₹ 36303 ha^{-1}) and BCR (2.42 and 2.07) were realized with spacing 60 cm × 20 cm and fertility level 120-60-60 kg N-P_2O_5 and K_2O ha^{-1} respectively.

Keywords: *Zea mays* L., spacing, fertility levels and high quality protein maize

1. Introduction

Being C4 crop, maize (*Zea mays* L. var. $HQPM^{-1}$) is frequently grown effectively throughout the year. Among the numerous forms of maize, high quality protein corn is particularly famous for the use of its green cobs and in overcoming problem of malnutrition throughout the world where maize is raised as staple food crop. Due to rising world demand, the possibility for and higher market prices for HQPM than for local type of maize, there is a great room value addition. Preserving stand density is the primary factor to take into account while trying to boost cobs yield. The spatial arrangements of a plant determine the form and size of its leaf chance to expand the cultivation of this variety of maize. The quality hybrid protein maize or "QPM, that breeders created is a high yielding variety that is widely used to address the issue of malnutrition, which in turn influences the rate at which its roots can grow and function and how well it can absorb solar energy. Plant population will only allow each plant to grow to its greatest capacity and yield its maximum amount of produce when that take place. The optimal population density requires adjusting spacing in relation to other agronomic factors [1].

High-quality protein maize needs a lot of nitrogen, as it is an exhausting crop. Given that N and P account for 40–60% of crop production on their own, judicious and increased application of these two key nutrients can generate higher QPM yields. The most crucial element for plant growth and development is nitrogen. Nitrogen is linked to every live cell's activity and is a necessary component of protoplasm and chlorophyll. Nitrogen stress before flowering reduces leaf area and photosynthesis; nitrogen stress during flowering stage results in kernel and ear abortion; and stress during grain filling accelerates leaf sentence, reduces photosynthesis, and increases kernel weight in the majority of the popular/recommended varieties of QPM. Thus, farmers that cultivate maize are now very concerned about nitrogen fertilization as a means of increasing the grain yield of single cross hybrids of QPM.

Phosphorus is second only to nitrogen in importance for the high energy phosphate bonds of ATP that facilitate energy transfer in living cells. Therefore, it is crucial for the synthesis and translocation of fatty acids, carbohydrates, glycerides, and other vital intermediate molecules. It also has an impact on the grain's protein content for fodder. It is recommended that maize be fertilized with 90 kg of nitrogen and 30 kg of phosphorus per hectare.

2. Materials and Methods

The outcome of field experiment titled "Response of high quality protein maize (*Zea mays* L. var. HQPM-1) grown after wheat to spacing and fertilizer in summer season" carried out in D-7 plot of Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University Gujarat during summer season of 2016.

2.1 Crop husbandry

Dry matter accumulation: Five plants were randomly selected from border lines of each experimental plot at 30, 60 DAS and harvest. After chopping, plant samples were placed separately in perforated paper bags and oven dried at 65℃ till a constant weight is obtained. Later these were weighed and dry matter was expressed as g plant^{-1}. *Relative growth rate (RGR):* The values for relative growth rate were calculated for the stage between 30 DAS, 60 DAS and harvest with the help of following formula. RGR g g-1 day-1 (loge w2-loge w1)/(t2-t1), Where, Loge w1 = Loge of dry weight of plant at time interval t1. Loge w2 = Loge of dry weight of plant at time interval t2. Crop growth rate (CGR): The values for crop growth rate were calculated for the stage between 30 DAS and 60 DAS and then between 60 DAS and harvest with the help of following formula: CGR = 1/p (w2-w1)/(t2-t1) g m-2 day-1. Where, w1 = weight of dry matter of plant at time t1. w2 = weight of dry matter of plant at time t2. p = ground area (m2). Absolute growth rate: The values for absolute growth rate were calculated for the stage between 30 DAS and 60 DAS and harvest with the help of following formula AGR = (w2-w1)/(t2-t1) g day^{-1}. Where, w1 = dry weight of plant at time t1. w2 = dry weight of plant at time t2.

Nevertheless, during 30-60 DAS, spacing of 75 cm× 20 cm (S_3) recorded considerably the higher absolute growth rate (3.41 g/day) which was remained statistically at par with treatment S_2 (60 cm × 20 cm) at 60 DAS and at harvest. Nevertheless, between 30 DAS, 60 DAS and at harvest and treatment S_1 (45 cm × 20 cm), which was discovered statistically at par with treatment S3, absolute growth rate continued to drop and was recognized to be greater (1.41 g/day) (15 cm). Crop growth is a well-established consequence of environmental interaction. In the current study, it was revealed that spacing had a significant impact on crop production for each plant, indirectly dictating the amount of rivalry among plants for different growth inputs as well as the availability of different growth nutrients to individual plants in the community.

It is well known that N, P, and K are essential nutrients for crop development and growth. Plant development through active cell division and elongation may have been promoted by the highest amounts of N, P, and K in the crop's plant part at the suggested spacing (S2) of 60 cm × 20 cm. Because of the improved nutritional status, individual plants tend to accumulate photosynthates more heavily and, as a result, dry matter more heavily when spaced less than 60 cm apart. Broader intra-row spacing was associated with greater values of growth parameters as compared to constrained intra-spacing. In an equidistant spatial arrangement, there may be less plant competition for nutrients and light, which could explain the rise observed with increased intra-row separation [4]. The outcome closely matches the conclusions of Gozubenli and Konuskan [6], Paradkar [8], Bozorgi *et al*. [5], and Hamni and Dadari [7] and Paradkar [8].

2.2 Crop economics

Cost of cultivation: Based on the current local rates, the costs associated with all routine operations, such as threshing, cleaning, and preparatory tillage, were computed. Additionally, the cost of inputs, such as seeds, fertilizer, pesticides, irrigation, etc., applied to each treatment, was also computed. Gross returns: Taking into account the yields of green cob and green fodder from each treatment as well as local market prices, the gross realization in terms of rupees per hectare was calculated independently for each treatment. Net returns: To calculate the net income for each treatment combination, the entire cost of cultivation was subtracted from the gross realization and documented appropriately. Cost-benefit ratio (B:C): The Advantage The cost ratio (B:C) ratio was computed using the formula that follows. B:C is equal to gross returns (₹/ha) / total cultivation costs (₹/ha).

3. Results and Discussion

3.1 Growth attributes

When it comes to the amount of dry matter per plant at 30 DAS, 60 DAS, and harvest, different spacing levels have a notable impact. At 60 DAS and harvest, the dry matter recorded by S3, with spacing of 75 cm × 20 cm, was much greater (30.41 g, 83.09 g, and 152.77 g, respectively). However, S2's treatment, with 60 cm × 20 cm, remained comparable. Under treatment S1 (45 cm × 20 cm), significantly decreased plant dry matter (25.91, 77.03, and 141.97 g at 30 DAS, 60 DAS, and at harvest, respectively) was detected. The evaluation of different spacing values did not significantly affect the absolute growth rate between 30 and 60 DAS. However, 75 cm × 20 cm (S3) recorded a much greater absolute growth rate (30.41 g/day) throughout 45–60 DAS, which was statistically equivalent to treatment S2 (60 cm × 20 cm). Under treatment S1 (45 cm × 20 cm), significantly decreased plant dry matter (25.91, 77.03, and 141.97 g at 30 DAS, 60 DAS, and at harvest, respectively) was detected. One known effect of environmental interaction is crop growth. The results of the current study showed that spacing significantly affected crop yield for each plant, indirectly determining the degree of competition between plants for various growth inputs and the accessibility of certain growth nutrients to specific plants within the community.

It is well known that N, P, and K are essential nutrients for crop development and growth. Plant development through active cell division and elongation may have been promoted by the highest amounts of N, P, and K in the crop's plant part at the suggested intra-row spacing (S3) of 75 cm. Due of the improved nutritional status, individual plants tend to accumulate photosynthates more heavily and, as a result, dry matter more heavily when spaced less than 75 cm apart. Broader spacing was associated with greater values of growth parameters as compared to constrained spacing. In an equidistant spatial arrangement, there may be less plant competition for nutrients and light, which could explain the rise observed with increased intra-row separation [4]. The outcome closely matches the conclusions of Gozubenli and Konuskan [6], Paradkar [8], Bozorgi *et al*. [5], and Hamni and Dadari [7] and Paradkar [8].

Compared to treatment F3 (120 N2O + 60 P2O5 + K2O 60 kg/ha), application of treatment F4 (N2O 150 + 60 P2O5 75+75 K2O kg/ha) produced a significantly greater dry matter accumulation at 60 DAS and harvest (86.43 g and 155.19 g, respectively). Dry matter buildup was much lower at 60 DAS and harvest, weighing 78.13 g and 143.58 g, respectively. A significantly higher absolute growth rate (3.03 g/day) was also seen with the administration of 150-75-75 (F4) between 30 and 60 DAS; this growth rate was statistically equivalent to treatment F3 (120 N2O + 60 P2O5 + 60 K2O kg/ha). In contrast, treatment F2 (90 N2O + 45 P2O5 + 45 K2O kg/ha) occurs between 60 DAS harvest. The growth rate in absolute terms decreased further and was reported at 2.55 g/day. Treatment F3 (120 N2O + 60 P2O5 + 60 K2O kg/ha) significantly increased crop growth rate (0.00272 g m-2 day-1) between 30 and 60 DAS. This treatment was statistically comparable to treatment F4, which was applied (N2O 150 + 60 P2O5 75+75 K2O kg/ha). However, the crop growth rate began to decline and was recorded higher (0.00163 m-2 day-1) between 60 DAS harvest and treatment F4 (N2O 150 + 60 P2O5 75+75 K2O kg/ha), which was determined to be statistically at par with treatment F3 (120 N2O + 60 P2O5 + K2O 60 kg/ha).

Table 1: Effect of spacing and fertility levels on dry matter accumulation on relative growth rate, absolute growth rate and crop growth rate of high quality protein maize

Treatments	Dry matter accumulation			Crop growth rate				Relative growth rate		Absolute growth rate		
	at (g plant^{-1})			at (g m-2 day-1)				(g g^{-1} day^{-1})		(g/day)		
Spacing (cm)	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest		30-DAS	60-DAS	Harvest	30-60 DAS	60 DAS-Harvest
S_1: 45 × 20	25.91	77.03	141.77	0.00163	0.00231	0.00100	0.0535	0.0497	0.0135	1.81	2.58	1.11
S_2: 60 × 20	27.09	82.90	147.55	0.00165	0.00237	0.00106	0.0561	0.0505	0.0139	1.84	2.64	1.18
S_3: 75 × 20	30.41	83.09	152.77	0.00166	0.00259	0.00124	0.0562	0.0525	0.0140	1.85	2.89	1.38
S.Em.±	0.90	1.78	2.85	0.00005	0.00010	0.00004	0.0020	0.0023	0.0003	0.06	0.11	0.05
C.D. at 5%	2.65	5.22	8.37	NS	0.00029	0.00013	NS	NS	NS	NS	0.32	0.14
Fertility levels (N -P_2O_5 -K_2O kg ha^{-1})												
F_1: 0-0-0	25.47	77.96	141.94	0.00163	0.00229	0.00102	0.0535	0.0478	0.0136	1.82	2.55	1.14
F_2: 90-45-45 kg/ha	26.65	78.13	143.58	0.00165	0.00241	0.00107	0.0561	0.0517	0.0139	1.83	2.69	1.20
F_3: 120-60-60 kg/ha	27.84	81.18	149.02	0.00166	0.00260	0.00122	0.0576	0.0534	0.0140	1.85	2.90	1.36
F_4: 150-75-75 kg/ha	31.25	31.25	155.19	0.00168	0.00272	0.00124	0.0595	0.0569	0.0141	1.87	3.03	1.39
S.Em.±	1.06	2.05	3.29	0.00005	0.00010	0.00004	0.0020	0.0023	0.0003	0.06	0.11	0.05
C.D. at 5%	3.06	6.02	9.66	NS	0.00029	0.00013	NS	NS	NS	NS	0.32	0.14
Interaction (S ×F)												
S.Em. ±	1.81	3.56	5040	0.00010	0.00020	0.00009	0.0039	0.0045	0.0006	0.12	0.22	0.10
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C.V. %	11.27	7.61	6.70	10.76	13.91	13.36	11.99	14.99	7.80	10.85	13.91	13.36

Potassium has a positive impact on growth because it promotes cell division and expansion and has a favorable effect on growth. The effect of potassium on phytohormone synthesis is important for meristematic growth. Among the many hormones found in plants, cytokinin is essential for the growth of buds and tillers. Potassium feeding improves pollen germination in the florets, which leads to high spikelet fertility. A possible explanation for this rise could be that plants' root systems are getting adequate potassium from the soil, which boosts photosynthesis and the synthesis of metabolites and enzymes in plants [9]. Potassium increases a plant's potential resistance to disease and insect pests, according to Kumar *et al*. [10]. According to [11, 12], K had beneficial effects on growth.

3.2 Economics

A study of the data (Table 2) revealed that treatment S2, which used a spacing of 60 cm, significantly increased net returns of ₹ 37106/ha, whereas treatment S4, which used a spacing of 75 cm, significantly decreased gross returns of ₹ 55269/ha. Lower net returns of ₹ 29550/ha were accrued under S3 (75 cm), but a significant net return was acquired with spacing of 60 cm (S2), which remained on the same bar as treatment S1 (45 cm). The highest net yields of ₹ 37106/ha and BCR 2.42 were obtained with population maintenance at an intra-row spacing of 60 cm (S2), owing to the increased availability of nutrients, moisture, sun radiation, and space for growth and development.

Table 2: Effect of spacing and NPK levels on economics of HQPM-1 maize

Treatments	Gross returns (₹/ha)	Cost of cultivation (₹/ha)	Net returns (₹/ha)	BCR
Spacing (cm)				
S_1: 45 ×20	62359	24536	34424	2.23
S_2: 60 ×20	63258	22970	37106	2.42
S_3: 75 ×20	55269	22590	29550	2.15
S.Em.±	2152	-	2152	-
C.D. at 5%	6214	-	6214	-
Potassium levels (kg/ha)				
F_1: 0 K_2O + 0 N_2O + 0 P_2O_5 kg/ha	47153	21170	23051	1.96
F_2: 90 K_2O + 45 N_2O + 45 P_2O_5 kg/ha	58456	25681	29997	2.01
F_3: 120 K_2O + 60 N_2O + 60 P_2O_5 kg/ha	70235	29805	36303	2.07
F_4: 150 (N_2O 150 + 75 P_2O_5 +75 K_2O kg/ha)	62036	26782	31545	2.03
S.Em.±	2152	-	2152	-
C.D. at 5%	6214	-	6214	-
Interaction (S × F)				
S.Em.±	4303	-	4303	-

Additionally, S2 with a 60-centimeter spacing obtained the highest benefit-cost ratio of 2.42, but S3 with a 75-centimeter spacing obtained the lowest benefit-cost ratio of 2.15. The data (Table 2) clearly shows that the higher gross returns of ₹ 62036/ha were caused by treatment F4 150 (N2O 150 + 75 P2O5 + 75 K2O kg/ha), which was similar to applying 120 K2O + 60 N2O + 60 P2O5 kg/ha (F4). Lower gross yields were seen in Treatment F1 (0 K2O + 0 N2O + 0 P2O5 kg/ha), with a total of ₹ 47153/ha. The highest cultivation cost (₹ 29805/ha) was seen when NPK was given at a rate of 120 K2O + 60 N2O + 60 P2O5 kg/ha (F4), while treatment F1 (0 K2O + 0 N2O + 0 P2O5 kg/ha) had the lowest cultivation cost (₹ 21170 /ha) [13].

4. Conclusions
Planting 60 cm and 75 cm between rows of high-quality protein maize allows for fertilization with 150 kilogram N2O, 75 kg P2O5, and 75 kg K2O per hectare.

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6. Competing Interests
The authors have stated that there are no conflicting interests.

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