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Effect of Weed and Nutrient management on Growth, Productivity and Protein content of Quality Protein Maize (*Zea mays* L.)

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Abstract
A study was conducted at Department of Agronomy, Rajasthan College of Agriculture, Udaipur during 2011 and 2012 crop season to assess the effect of weed management practices and level of fertility with emphasis on improving the productivity and quality of quality protein maize. The treatments were laid out in split-plot design with maize weed management practices as main plots and fertilizer application practices as subplots. Weed management practices significantly influenced the growth attributes as plant height, crop dry matter and leaf area index at different growth stages. Weed management measures during experimentation resulted in significant increase in all growth parameters (plant height, dry matter accumulation, LAI, RGR and NAR) compared to weedy check at different stages of crop growth. Application of Oxyfluorfen *fb* HW 30 DAS and metribuzin *fb* HW 30 DAS with non-significant difference between these treatments were found significantly superior in enhancing grain yield of maize compared to weedy check, atrazine *fb* HW 30 as well as HW 15 & 30 DAS. The results showed 174.55, 163.58, 153.31, 120.10 and 109.48 per cent increase in grain yield by weed free, Oxyfluorfen *fb* HW 30 DAS, metribuzin *fb* HW 30 DAS, atrazine *fb* HW 30 and hand weeding twice, respectively compared to weedy check. The biological yield was found similar result as grain yield. The level of fertility upto 125% RDF significantly improved plant height, crop dry matter accumulation, leaf area index, RGR and NAR at different growth stages and yield and quality of maize.

Keywords: Quality protein Maize, Fertility level, herbicide, productivity

Introduction
Maize (*Zea mays* L.) is one of the most important cereal crop grown over diverse environment and geographical ranges for human food, feed and fodder for livestock and raw materials for industries. Being a C_4 plant, it is capable of utilizing solar radiation more efficiently than several other cereal crops. Despite high genetic potential and photosynthesis explorative crop the average productivity of this crop in Rajasthan is only 10.44 q ha-[1] (Agricultural Statistics, 2015) as against the global and National productivity of 5.12 t ha-[1] and 2.06 t ha-[1], respectively. The QPM is a hybrid variety of maize bred by incorporation of opaque-2 modifier gene. Keeping in view the QPM needs popularization in India to achieved nutritional security as it produce 70-100% more of lysine and tryptophan than most modern varieties of tropical maize. The Karnal centre of AICMIP released the variety HQPM-5 in 2007 which is recommended across the country. The variety may prove a boon for tribal dominated population of Southern Rajasthan, where maize cultivation during rainy season is very common.

The poor productivity of maize in the area is mainly because of inadequate weed and nutrient management. The wide gap between potential productivity and actual yield harvested may be bridged by adopting proper weed management in conjunction with use of adequate supply of nutrients. The infestation of weeds in maize can cause considerable reduction in the yield up to the extent of 100% (Pandey *et al.,* 2001) [13]. Competition of weeds for nutrients can be reduced effectively by weeding operations but increasing labour cost, its availability for agricultural purposes is very scarce, time consuming and not feasible for larger area. Therefore, one can not completely rely on manual weeding; hence it is the time to use a suitable herbicide in combination with manual weeding to harness the yield potential of this crop. Herbicides are effective against many weed species (Narayana *et al.,* 1999) [12] but most of them are specific and are effective against narrow range of weed species.

Amongst the agricultural inputs fertilizers have played vital role in achieving the goal of food security in India. It is the most important input in modern agriculture. The green revolution in India would have not been possible without spectacular increase in fertilizers input which could exploit the potential of fertilizers responsive high yielding varieties as evident from the direct relationship between fertilizer consumption and food grain production in India. All over the world 50–60 per cent increase in productivity of food grain is attributed to fertilizer use (Kanwar & Sekhon, 1998) [10]. Nambiar and Abrol (1989) [11] clearly showed a declined trend in the productivity even with the application of fertilizers under modern intensive farming.

Material and methods

The experiments conducted during both the years were laid out at Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, Udaipur. The site was situated at 24º35' N latitude, 74º42' E longitude and an altitude of 579.5 m above mean sea level. The region falls under agro-climatic zone IVa (Sub-Humid Southern Plain and Aravalli Hills) of Rajasthan. This zone possess a typical sub-tropical climatic conditions characterized by mild winters and moderate summers associated with high relative humidity during the months of July to September. The mean annual rainfall of the region is 637 mm, most of which is contributed by South-West monsoon (80-85 per cent) from July to September. In summers, maximum temperature goes up to 44 ºC. May and June are the hottest months. Winters are generally rainless and minimum temperature during December and January falls as low as 1 ºC. The maximum and minimum temperatures during the crop growth period ranged between 28.2 ºC to 33.5 ºC and 17.3 ºC to 24.8 ºC, respectively during the kharif, 2011. The corresponding fluctuations during second year (kharif, 2012) of experimentation were 27.4 ºC to 35.4 ºC and 15.9 ºC to 23.7 ºC. The total rainfall received during the crop season of the year 2011 was 872.1 mm and 642.4 mm in 2012. The evaporation from the USWB class-A pan evaporimeter during the corresponding crop seasons ranged from 1.8 to 5.2 and 1.9 to 8.1 mm day^{-1}, respectively. The experiment was laid out in Split Plot design with combination of 6 weed management practices (viz., W1 = Weedy check, W2 = Atrazine 0.5 kg ha^{-1} pre-emergence *fb* one hoeing and weeding 30 DAS, W3 = Metribuzin 0.25 kg ha^{-1} pre-emergence *fb* one hoeing and weeding 30 DAS, W4 = Oxyfluorfen 0.15 kg ha^{-1} pre-emergence *fb* one hoeing and weeding 30 DAS, W5 = Two hoeing and weeding 15 and 30 DAS, W6 = Weed free and 4 fertility levels (viz., F1 = 75% RDF, F2 = 100% RDF, F3 = 125% RDF, F4 = 150% RDF) with 3 replications. The maize variety "HQPM-5" was sown at a spacing of 60 cm x 25 cm between rows and plants. The trial was irrigated when required.

For recording of data on growth attributes viz. Plant population, plant height, dry matter accumulation and Relative growth rate (Radford, 1967) [14] and Net assimilation rate at 25-50 DAS. After harvesting the crop, cobs and stalks were properly sun dried and bundled. The bundle weight of each net plot was recorded and was expressed as biological yield in q ha^{-1}. The yield from each plot was recorded seperately as kg $plot^{-1}$ and then converted in q ha^{-1}. Protein was estimated either by the method of AOAC (2002). All the data were subjected to statistical analysis by adopting appropriate method of analysis of variance as described by Cocharan and Cox (1967).

Results and discussion

Growth attributes

Weed management practices did not differ significantly with respect to plant population at 15 DAS. However, plant population non significantly reduced due weed management. Uncontrolled weeds in weedy check plot created conditions similar to water logging, poor aeration and smothering effect on crop plants thus crop became vulnerable against different growth resources and plant start decaying and died leading to thin plant population under this treatment. The result corroborate with the findings of Verma (2009) [18] in Maize. Weed management practices significantly influenced the growth attributes as plant height, crop dry matter and leaf area index at different growth stages. Maximum growth attributes at 25, 50 and 75 DAS and RGR and NAR between 25-50 DAS were recorded under weed free treatment closely followed by Oxyfluorfen *fb* HW 30 DAS. Metribuzin *fb* HW 30 DAS was next in order of superiority and both of these treatments were found significantly superior to other treatments. Increase in overall growth of crop at all stages of observation was mainly due to significant reduction in weed competition, which is a major factor affecting crop yield (Tollenaar *et al.,* 1994) [17]. The similar finding reported by Gupta (1992) [5] and Bibi (2010) [2]. In general, the aforesaid improvements seems to be on account of direct impact of different weed management treatments through least crop-weed competition whereas, indirect effect might be least competition for plant growth inputs *viz.,* light, space, water, nutrients etc. Similarly, under reduced density and dry matter of weeds, plant get sufficient space for optimum expansion of leaves and branches as early as possible (Gul and Khanday, 2015) [4]. All weed management treatments significantly increased relative growth rate between 25-50 DAS. The maximum relative growth rate recorded under Oxyfluorfen *fb* HW 30 DAS closely followed by metribuzin *fb* HW 30 DAS. Application of Oxyfluorfen *fb* HW 30 DAS resulted 7.01 per cent increase in relative growth rate as compared to weedy check. NAR between 25 to 50 DAS maximum net assimilation rate was recorded in plots with weed free, its effect was at par with that of Oxyfluorfen *fb* HW 30 DAS and metribuzin *fb* HW 30 DAS. Due to these treatments net assimilation rate increased by 5.67 and 5.07 per cent, respectively as compared to weed check (Table 1).

Variation in plant population on account of different levels of fertility was found statistically non-significant. The results presented in table 1 revealed that application of fertilizer upto 125% RDF significantly improved plant height, crop dry matter accumulation and leaf area index at different growth stages (25, 50 and 75 DAS) during experimentation which was statistical at par with 150% of RDF. It is well established fact that amongst nutrients N and P are the most important ones for exploiting genetic potential of a crop through better growth and development (Havlin *et al.,* 2005) [7]. Nitrogen is considered to be an essential element for the synthesis of chlorophyll which is of vital physiological significance in the plant system, whereas, P is involved in the root growth of plants. It also plays an active role in the formation of high energy phosphates which are unstable in water and act as carriers for vital reactions like oxidation of sugars through enhancing enzymatic activities and in initial reaction for photosynthesis etc. In fact, it is also considered to be energy currency within the plant system (Havlin *et al.,* 2005) [7]. The significant improvement in overall growth of the crop under the influence of increased fertilization (N and P) is in close

conformity with findings of Imran *et al.* (2015) [8]. Fertility levels reveled a significant effect on relative growth rate and maximum relative growth rate was observed both at 125 and 150% RDF with the same values (0.061) in both of these treatments. On pooled basis per cent enhancement in this parameter under 125% RDF was 7.01, compared to 75% RDF. Soil enrichment with fertility levels significantly increased net assimilation rate and maximum net assimilation rate was observed with 150% RDF compared to their respective counter parts. This treatment increase higher net assimilation rate by 28.99 per cent as compared to 75% RDF (Table 1).

Table 1: Effect of weed and nutrient management practices on growth attributes, productivity and quality of maize (Pooled data of two years)

Treatments	Plant population (000 ha^{-1}) (15 DAS)	Plant height (cm)			Crop dry matter accumulation (g plant^{-1})			Leaf area index			RGR (g g^{-1} day^{-1}) 25-50 DAS	NAR (g m^{-2} leaf area day^{-1}) 25-50 DAS	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Protein (%)
		25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	75 DAS					
Weed management															
W_1	65.7	42.5	91.9	142.4	12.2	50.6	76.8	1.04	1.63	2.14	0.057	1.162	1403	4957	10.48
W_2	66.3	47.2	100.1	167.7	19.2	87.2	137.6	1.81	2.63	3.68	0.060	1.200	3088	9029	10.69
W_3	65.5	52.1	113.0	225.2	21.1	96.4	151.3	2.05	2.90	4.07	0.061	1.221	3554	10148	10.94
W_4	66.1	53.7	117.7	235.0	22.2	101.8	157.5	2.12	3.05	4.20	0.061	1.228	3698	10660	11.47
W_5	66.2	46.7	100.2	165.4	18.6	83.6	134.9	1.89	2.54	3.53	0.060	1.200	2939	8704	10.63
W_6	66.3	56.6	124.2	239.1	23.3	104.7	165.7	2.20	3.20	4.42	0.060	1.240	3852	11072	11.50
SEm+	1.4	0.99	2.57	3.80	0.49	1.88	2.93	0.04	0.05	0.07	0.001	0.009	63.78	172.28	0.14
CD (P=0.05)	NS	2.91	7.57	11.20	1.44	5.55	8.64	0.11	0.15	0.22	0.002	0.026	188.16	508.24	0.41
Nutrient management															
F_1	65.3	42.5	89.5	158.3	16.12	67.48	105.70	1.73	2.49	3.42	0.057	1.021	2470	7762	10.04
F_2	66.1	49.0	108.6	197.1	18.99	85.68	132.59	1.83	2.63	3.62	0.060	1.208	2939	8845	10.96
F_3	66.3	52.9	115.1	211.0	20.90	96.41	154.23	1.92	2.74	3.80	0.061	1.289	3413	9760	11.36
F_4	66.4	54.9	118.3	216.7	21.73	99.95	156.66	1.94	2.77	3.87	0.061	1.317	3536	10014	11.45
SEm+	1.1	0.78	1.84	2.93	0.35	1.40	2.00	0.02	0.03	0.04	0.0004	0.007	45.66	124.34	0.11
CD (P=0.05)	NS	2.18	5.15	8.20	0.98	3.91	5.60	0.07	0.09	0.12	0.0012	0.020	127.87	348.17	0.32

Productivity

The grain yield of QPM was significantly influence by weed control treatments. Application of Oxyfluorfen *fb* HW 30 DAS and metribuzin *fb* HW 30 DAS with non-significant difference between these treatments were found significantly superior in enhancing grain yield of maize compared to weedy check, atrazine *fb* HW 30 as well as HW 15 & 30 DAS. The results showed 174.55, 163.58, 153.31, 120.10 and 109.48 per cent increase in grain yield by weed free, Oxyfluorfen *fb* HW 30 DAS, metribuzin *fb* HW 30 DAS, atrazine *fb* HW 30 and hand weeding twice, respectively compared to weedy check. The biological yield was found similar result as grain yield. The better expression of yield attributes in these plants under these treatments might be due to poor resurgence frequency and growth of weeds as evident from weed dry matter. Hence, weeds were unable to compete with the crop plants for different growth factors. Verma *et al*. (2009) [18], Hatti *et al.* (2014) [6] has also reported improved yield attributes with reduced weed density and dry matter. Variation of fertility levels exhibited a consistent effect on grain yield and biological yield of QPM. During experimentation, the grain and biological yield of maize increased with increasing fertility levels up to 125% RDF and further increase in fertility levels failed to enhance the yield significantly. On pooled basis, the per cent increase in grain yield under the influence of 150, 125 and 100% RDF was 3.60, 16.13 and 18.99 compared to their preceding counter parts. It has been well emphasized that N and P fertilization to the tune of 125% RDF play a vital role in improving three major aspects of yield determinants i.e., formation of vegetative structure for nutrient absorption, photosynthesis and strong sink length through development of reproductive structure and production of assimilates to fill economically improved sink (source strength). Thus, cumulative influence of N and P application seems to have maintained balanced source sink through improving both the events of crop development (vegetative and generative), ultimately resulted in increased yield. The observed results are in close conformity with findings of Abdullah (2008) [1] and Nath *et al.,* (2009). The significant increase in biological yields with application of 125% RDF seems to be due to its direct effect in improving biomass plant^{-1} at successive growth stages as well as at harvest of the crop, while the indirect effect might be on account of increase in various photosynthetic parameters *viz.*, LAI, RGR and NAR. Further, biological yield is a function of grain and stover yield representing reproductive and vegetative growth of the crop. The profound influence of N and P levels on both of these characters mediated via increased photosynthesis efficiency and nutrient accumulation might have ultimately led to production of higher biological yield under its application. The observed results are in close conformity with findings of Das *et al.*(2012) [3], Singh (2010) [15] in different types of maize.

Quality

Significant improvement in protein content in seed was recorded due to reduced crop weed competition for essential resources. Thus, reduced crop- weed competition resulted into overall improvement in crop growth as reflected by plant height and dry matter accumulation consequently resulted into better development of reproductive structure and translocation of photosynthates to the sink. The improvement in protein under the influence of 125% RDF seems to be on account of increased N content of grain. It is well known fact that N is a constituent of protein, enzymes and chlorophyll and participate in several biochemical processes for the

metabolism of carbohydrate, fat and protein in plant system. The results are in close conformity with the findings of Jat and Balyan (2004) [9] and Singh (2012) [16].

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