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Residual effect of weed management and nutrient application in succeeding wheat (*Triticum aestivum* L.) following an application to quality protein maize (*Zea mays* L.)

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Abstract
A field experiment was conducted during *kharif* and *rabi* seasons of 2015-16 and 2016-17 at Udaipur to evaluate the effect of weed and nutrient management on quality protein maize and their residual effect on succeeding wheat. The experiment consisted of nine weed management treatments *viz*., weedy check, hand weeding at 15 DAS and 35 DAS, tembotrione 0.125 kg ha^{-1} at 20 DAS, alachlor 2.0 kg ha^{-1} as PE *fb* hand weeding at 35 DAS, atrazine 0.5 kg ha^{-1} as PE*fb* hand weeding at 35 DAS, tembotrione 0.125 kg ha^{-1} at 20 DAS *fb* hand weeding at 35 DAS, alachlor 2.0 kg ha^{-1} + atrazine 0.5 kg ha^{-1} as PE *fb* hand weeding at 35 DAS, alachlor 2.0 kg ha^{-1} as PE *fb* tembotrione 0.125 kg ha^{-1} at 20 DAS and atrazine 0.5 kg ha^{-1} as PE *fb* tembotrione 0.125 kg ha^{-1} at 20 DAS with three nutrient management treatments *viz*., NPK, NPK+Zn and NPKS+Zn, thereby making 27 treatment combinations. The experiment was laid out in split plot design, assigning weed management to main plots and nutrient management to sub plots. The treatments were replicated thrice. Maize cv. Pratap QPM-1 and wheat cv. Raj.4079 used as test crops. Maximum reduction of weed density and dry matter as well as highest weed control efficiency (72.07%) was recorded in crop subjected to atrazine *fb*tembotrione closely followed by alachlor *fb* tembotrione and two hand weeding at 15 and 35 DAS. Atrazine *fb*tembotrione produced significantly higher grain (4516 kg ha^{-1}) and stover (7459 kg ha^{-1}) yield compared to other treatments. Nutrient management had no significant effect on weed density during both the years while weed dry matter was significantly affected by different nutrients. Nutrient application of NPKS+Znrecorded significantly higher grain (4275 kg ha^{-1}) and stover (7227 kg ha^{-1}) yield. Under residual response on succeeding wheat, no significant effect of weed and nutrient management treatments applied in QPM was observed on weed density and dry matter as well as grain and straw yield of wheat during both the years of experimentation.

Keywords: Atrazine, alachlor, tembotrione, quality protein maize, weed management, nutrient management, grain yield, stover yield, residual effect, wheat

Introduction
Maize (*Zea mays* L.) also called as the queen of cereals, is one of the major cereal crops with wide adaptability under various diversified agro-climatic edaphic conditions around the world. In this crop, the content of essential amino acids *viz.*, lysine and tryptophan is low while leucine and isoleucine content is high (Jat *et al.*, 2013) [8]. The QPM is a hybridized variety of maize specially bread by addition of *Opaque*-2 mutant gene, which improve lysine and tryptophan and reduce leucine and isoleucine contents and produce quality protein with balanced composition of amino acids. Major area of maize in India is during *kharif* season in which weed is one of the most important yield limiting factor and significantly reduces the yield. Maize is infested by a wide range of weed flora, *viz.*, *Echinochloa colona*, *Cyperus rotundus*, *Cynodon dactylon*, *Commelina benghalensis*, *Digeraarvensis and Trianthema portulacastrum* dominate during early stages of the crop growth and toward the tasseling and maturity of the crop. However, the most critical period for crop weed competition are first six weeks after planting of crop which may reduce yield by 28-100% (Dass *et al*., 2012) [3]. During this critical period weeding is essentially required by either chemical or non-chemical means. Weeding by hands (labour) and mechanical means are expensive and many a times timely operations are not possible due to continuous rains in monsoon season. However, application of single herbicide does not provide satisfactory weed control for the desired period. Atrazine and alachlor have been widely recommended for effective control of weeds in maize (Tahir *et al*., 2011) [24]. Atrazine, recommended as a pre-emergence herbicide, is not effective against some of the weeds,

both grassy and non-grassy as well as the sedge *Cyperus rotundus* (Singh *et al.*, 2015) [15]. Hence, there is need for some alternate post-emergence herbicide like tembotrione which can provide broad spectrum weed control in *kharif* maize without affecting the crop growth and yield of crop (Singh *et al*., 2012b) [21]. Nutrient management also plays key role in sustaining the productivity of this system, QPM is high nutrient requiring ones and respond well to higher levels of chemical fertilizers. Quality protein maize is a nitrogen exhaustive crop and requires very high dose of the nutrient (Singh, 2010 and Om *et al.*, 2014) [19, 13]. Thus higher yield of QPM can be obtained through the judicious and higher uses of two major nutrients (N and P) as these two nutrients alone contribute 40-60 per cent of the crop yield (Das *et al.*, 2010) [2]. Among the secondary and micronutrients, S and Zn have also a specific vital role in growth and development of crops. It is proven fact that productivity of any crop cannot be further increased by use of high doses of fertilizer alone. So the nutrient management with balanced use of nutrients increases the yield and also maintains soil health.

Materials and Methods

A field experiment was conducted during *kharif* and *rabi* seasons of 2015-16 and 2016-17 at Instructional Farm (Agronomy), Rajasthan College of Agriculture, Udaipur. The site is situated at South-Eastern part of Rajasthan at an altitude of 579.5 metre above mean sea level with 24º35' N latitude and 74°42' E longitude. The region falls under agro-climatic zone IVa (Sub-Humid Southern Plain and Aravalli Hills) of Rajasthan. This zone possesses a typical sub-tropical climatic conditions characterized by mild winters and moderate summers associated with high relative humidity. The mean annual rainfall of the region is 637 mm. Soil of experimental site was clay loam in texture and slightly alkaline in reaction (pH 8.1 and 8.0) and medium in available nitrogen (285.0 and 279.61 kg ha^{-1}) and phosphorus (20.42 and 19.27 kg ha^{-1}) and high in available potassium (324.16 and 318.15 kg ha^{-1}) and low in available sulphur (9.7 and 9.3 kg ha^{-1}) during both the years *i.e.*, 2015-16 and 2016-17, respectively. The experiment consisted of nine weed management treatments *viz*., weedy check, hand weeding at 15 DAS and 35 DAS, tembotrione 0.125 kg ha^{-1} at 20 DAS, alachlor 2.0 kg ha^{-1} as PE *fb* hand weeding at 35 DAS, atrazine 0.5 kg ha^{-1} as PE*fb* hand weeding at 35 DAS, tembotrione 0.125 kg ha^{-1} at 20 DAS *fb* hand weeding at 35 DAS, alachlor 2.0 kg ha^{-1} + atrazine 0.5 kg ha^{-1} as PE *fb* hand weeding at 35 DAS, alachlor 2.0 kg ha^{-1} as PE *fb* tembotrione 0.125 kg ha^{-1} at 20 DAS and atrazine 0.5 kg ha^{-1} as PE *fb* tembotrione 0.125 kg ha^{-1} at 20 DAS with three nutrient management treatments *viz*., NPK, NPK+Zn and NPKS+Zn, thereby making 27 treatment combinations. The experiment was laid out in split plot design, assigning weed management to main plots and nutrient management to sub plots. The treatments were replicated thrice. Maize cv. Pratap QPM-1 was used as test crop, sown at the seed rate of 20 kg ha^{-1} at inter row of 60 and plant to plant spacing of 25 cm. Furrows were opened through desi plough and seeds were sown manually at the depth of 5 cm. As per the treatment full dose of phosphorus, potash, sulphur and zinc and half dose of nitrogen were applied at sowing by drilling in crop rows through urea, DAP, mineral gypsum and zinc sulphate. The remaining dose of nitrogen was top dressed at knee height stage through urea. As per treatment, both atrazine and alachlor were sprayed one day after sowing (as pre-emergence) while tembotrione was applied twenty days after sowing (as post-emergence) with knapsack sprayer. In each plot narrow and broad leaved weeds were counted from two randomly selected area of 0.25 m^2 using 0.5 m x 0.5 m quadrate and expressed as number m^{-2}. The mean data were subjected to square root transformation $\sqrt{(x+0.5)}$ to normalize their distribution. These weeds were dried at 65 ^{0}C temperature in oven till a constant weight was obtained which was expressed as weed dry matter in terms of g m^{-2}. After harvest of maize, the field was irrigated and prepared for wheat cultivation. The plots were demarcated precisely on the same points as they were done for maize crop. The experimental field was prepared for sowing without disturbing the original layout. After final preparation of the field, wheat cv. Raj 4079 was sown in lines at 22.5 cm spacing using 100 kg seed ha^{-1}. The wheat crop was fertilized with recommended dose of fertilizer (N_{120} P_{60} K_{40}). Five irrigations were applied at the most critical stages of the crop in addition to pre-sowing irrigation during both the years. During the crop period up to 45 DAS, no inter cultivation operation was performed because of residual study of previously crop of wheat. Harvesting was done when plants turned yellow and produce of net plot was tied in bundles and left for sun drying on threshing floor for few days. Thereafter, these bundles were weighed to record biological yield and then crop bundles were threshed to obtain grain and straw yields.

Results and Discussion

Effect on weeds

All the weed management treatments caused significant reduction in weed density of narrow-leaved weeds, broad-leaved weeds and total weeds as well as their dry matter accumulation at various growth stages during both the years of study. The data showed that *Echinochloa colona* was most dominating weed at the experimental sites during both the years. During both the years, atrazine *fb* tembotrione was found the most effective in order to reduce the density and dry matter of all categories of weeds at all stages compared to other treatments. The data of total weed density and dry matter at all successive stages indicated overall superiority of atrazine *fb* tembotrione followed by alachlor *fb* tembotrione, two hand weedings and alachlor+atrazine*fb* hand weeding (Table 2). The herbicide combination of atrazine *fb* tembotrione was more effective and had activity on a wide spectrum of weeds including grasses and broad leaved weeds in maize. Atrazine belongs to triazines group of herbicides which are widely known to inhibit growth of emerged seedlings. Alachlor applied as pre-emergence inhibit seed germination by interfering with the metabolic activities *i.e.* inhibition of α-amylase and protease production induced by GA_3. Tembotrione is currently registered as an important post-emergence herbicide use in corn and has showed quite satisfactory results on weed control, particularly for grasses (Waddington and Young, 2006) [25]. As a member of the triketone family of active ingredients, tembotrione shows properties of a weak acid and HPPD inhibitor. Two hand weeding at 15 and 35 DAS removed the weeds completely and created condition more favourable for crop growth and ultimately resulted in the lowest density of later emerged weeds and their lowest biomass with higher weed control efficiency during the crop growth period. Among all the herbicide treatments atrazine *fb* tembotrione recorded the highest weed control efficiency (72.07%) followed by alachlor *fb* tembotrione and two hand weeding (Table 2). The

possible reason might be due to the fact that performance of crop is directly proportional to the weed control efficiency. The higher weed control efficiency under these treatments could be attributed to the lower weed population and total weed dry matter as well. The results corroborated with the findings of Choudhary *et al.* (2013) [1], Idziak and Woznica (2014) [7], Sanodiya *et al.* (2014) [17], Kumar and Jha (2015) [12], Swetha *et al.* (2015) [23], Stanzen *et al.* (2016) [22] and Rana *et al.* (2017) [16]. Varying nutrient management treatments failed to affect the weed density while weed dry matter was significantly affected by different nutrients (Table 2) during both the years. Profound effect of different nutrient management treatments on weeds has also been reported by Choudhary *et al.* (2013) [1] and Owla *et al.* (2015) [14].

Effect on crop

By controlling weeds with the use of different measures significantly higher grain (4516 kg ha^{-1}) and stover (7459 kg ha^{-1}) yield were recorded during both the years of investigation (Table 3). Atrazine *fb* tembotrione followed by alachlor *fb* tembotrione and two hand weeding was found significantly superior in this regard. The increased grain and stover yields were obviously the results of better weed management. El-Metwally *et al.* (2012) [5], Deshmukh *et al.* (2014) [4], Owla *et al.* (2015) [14], Kour *et al.* (2016) [11] and Rana *et al.* (2017) [16] also reported similar results. Across the years different nutrient management treatments resulted in increased grain (4275 kg ha^{-1}), stover (7227 kg ha^{-1}) yield of QPM and application of NPKS+Zngave maximum grain and stover yield during both the years. Significant increase in grain and stover yield could be ascribed to the fact that yield of the crop is a function of several yield components. The results of present investigation indicated higher production of maize under influence of balanced fertilization are in close conformity with findings of Jena *et al.* (2013) [9], Paramesh *et al.* (2014) [15], Gul and Kanday (2015) [6] and Joshi *et al.* (2016) [10].

Residual effect on succeeding wheat

Under residual study on succeeding wheat, no significant effect of weed and nutrient management treatments applied in QPM was observed on weed density and dry matter as well as dry matter accumulation, grain and straw yield of wheat during both the years of experimentation.

Table 1: Effect of weed management and nutrient application on weed density, weed dry matter, weed control efficiency, grain and stover yield (pooled data of 2 years)

Treatments	Total Weed density at 60 DAS (No. m^{-2})	Total Weed dry matter at harvest (g m^{-2})	Weed control efficiency at harvest (%)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
Weed management					
Weedy check	17.52 (306.9)	478.11	0.00	2628	4669
Hand weeding 15 & 35 DAS	8.41 (70.40)	135.35	71.67	4500	7352
Tembotrione	9.84 (96.39)	236.06	50.61	4042	7011
Alachlor*fb*hand weeding	9.41 (88.10)	180.86	62.17	4179	7132
Atrazine *fb*hand weeding	9.26 (85.27)	172.53	63.89	4290	7162
Tembotrione*fb*hand weeding	9.69 (93.51)	197.93	58.57	4100	7076
Alachlor+atrazine*fb*hand weeding	8.78 (76.72)	145.19	69.61	4315	7221
Alachlor*fb*Tembotrione	8.54 (72.56)	134.38	71.88	4497	7448
Atrazine *fb*Tembotrione	8.35 (69.27)	133.57	72.07	4516	7459
S.Em. ±	0.07	1.85	-	95	131
C.d. (P = 0.05)	0.20	5.32	-	275	378
Nutrient management					
NPK	9.97 (106.4)	200.43	-	3976	6743
NPK+Zn	9.99 (106.7)	200.97	-	4105	6873
NPKS+Zn	9.98 (106.6)	203.32	-	4275	7227
S.Em.±	0.03	0.40	-	40	51
CD (P=0.05)	NS	1.13	-	112	144

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count m^{-2}

Table 2: Residual effect of weed management and nutrient application on weed density, weed dry matter, dry matter accumulation, grain andstraw yieldin succeeding wheat (pooled data of 2 years)

Treatments	Total Weed density at 30 DAS (No. m^{-2})	Total Weed dry matter at 30 DAS (g m^{-2})	Dry matter accumulation (g plant^{-1}) at harvest	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Weed management					
Weedy check	11.20 (125.61)	86.24	297.52	4005	4815
Hand weeding 15 & 35 DAS	10.78 (115.68)	86.85	298.12	4084	4711
Tembotrione	11.00 (120.63)	85.99	298.26	4183	4798
Alachlor*fb*hand weeding	10.84 (117.05)	85.05	298.29	4198	4702
Atrazine *fb*hand weeding	10.73 (114.76)	84.15	299.60	4149	4772
Tembotrione*fb*hand weeding	10.77 (115.58)	84.12	297.29	4186	4735
Alachlor+ atrazine*fb*hand weeding	10.86 (117.51)	84.94	298.53	4004	4824
Alachlor *fb* Tembotrione	10.76 (115.38)	84.60	297.84	4160	4733
Atrazine *fb* Tembotrione	10.70 (114.27)	84.64	298.13	4049	4726
S.Em. ±	0.08	0.97	2.67	60	80
C.d. (P = 0.05)	NS	NS	NS	NS	NS
Nutrient management					
NPK	10.81 (116.46)	85.63	298.04	4102	4720
NPK+Zn	10.87 (117.92)	84.99	298.36	4111	4793
NPKS+Zn	10.87 (117.78)	84.91	298.13	4126	4760

S.Em.±	0.04	0.56	1.48	37	30
CD (P=0.05)	NS	NS	NS	NS	NS

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count m^{-2}

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