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Nutrient uptake as influenced by weed management in winter maize + potato intercropping system

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ABSTRACT

A field experiment was conducted during *Rabi* 2009-10 and 2010-11 at research farm of Sher-e-Kashmir University of Agriculture Science and Technology, Jammu with four intercropping treatments, *viz.* sole maize, sole potato, maize + potato (additive Series) and maize + potato (replacement series) in main plots and six methods of weed control practices, *viz*. weedy check, weed free, alachlor1.5 kg/ha pre-emergence, atrazine 0.5 kg/ha pre-emergence, alachlor 2.0 kg/ha early post-emergence and atrazine 0.75 kg/ha post-emergence in sub plots to assess the productivity and profitability of winter maize + potato intercropping system.These treatments were evaluated under split plot design with three replications. Results revealed that sole stands of winter maize and potato removed highest amount of N, P and K which were followed by additive series and replacement series whereas among the weed management practices, highest amount of N, P and K was removed by weed free treatment *fb* atrazine PE 0.75 kg/ha and alachlor 1.5 kg/ha while the lowest N, P and K was removed by alachlor 2.0 kg/ha early post emergence. Among the different intercropping treatments, weeds removed significantly highest N, P and K from sole crops followed by additive series and replacement series. Among weed management practices, the uptake of N, P and K in weeds was found to be significantly less in all the weed management practices as compared to weedy check treatment.

Key words: Intercropping, Nutrient uptake, Potato, Weed management, Winter maize

The crop diversification involving maize in place of wheat during winter has been found an effective approach in minimizing weed competition especially of *Phalaris minor.* Maize is very susceptible to competition from weeds especially in the early stages of growth; therefore, efficient control at the pre- and early post-emergence stages is essential. Once, maize reaches approximately 0.5 m in height, weed control no longer affects yield (Marshall 2004). Weed competition not only results in crop losses but also increases insect pest damage, harvesting difficulties and crop contamination (Ohene 1998). Weeds are a constant source of concern for the successful growth and development of economic crop. They compete with crops for light, moisture, space and nutrients and consequently interfere with the normal growth of crops. Weed control therefore, is very essential in maize cultivation. Further, wide space provided to the maize, allows fast growth of variety of weed species causing a considerable reduction in yield by affecting the growth and yield attributing components. Thus, the extent of reduction in grain yield of maize has been reported to be in the range of 33 to 50% depending on type of weed species in standing crop (Shantveerayya and Agasimani 2012). The present study was, therefore, undertaken to assess the losses of nutrients caused by weeds in winter maize + potato intercropping and to minimize these losses by controlling them.

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MATERIALS AND METHODS

The field experiments were conducted during *Rabi* season of 2009-10 and 2010-11 at the research farm of Division of Agronomy, Sher-e-Kashmir University of Agriculture Science and Technology, Jammu situated at 32° 40¹ N latitude and 74⁰ 58¹ E longitude and at an altitude of 332 m above the mean sea level. The soil was sandy loam, neutral in reaction, low in organic carbon and available N, medium in available P and K. The experiment was conducted in spilt plot design with three replications in a fixed lay out. The main plot treatments consisted of four intercropping systems; (i) Sole maize (ii) Sole potato (iii) Maize + potato (additive Series) (iv) Maize + potato (replacement series) while the sub plot treatments were six methods of weed control practices (i) Weedy check (ii) Weed free (iii) Alachlor at1.5 kg/ha pre-emergence (2 days after sowing) (iv) atrazine at 0.5 kg/ha pre-emergence (2 DAS) (v) Alachlor at 2.0 kg/ha early post-emergence (10 DAS) and (vi) Atrazine at 0.75 kg/ha post-emergence 30 (DAS). Winter maize '*Bulland*' of 175 days duration and potato '*Kufri Sinduri*' of 120 days duration were sown at row to row

spacing of 60 cm. Application of fertilizer in sole maize was 175-60-30 kg N-P-K /ha. Full dose of P and K along with one third of N were applied as basal dose at the time of sowing and rest of N was applied in two equal splits, one third in mid of January at knee high stage and the one third was applied at pre-tasseling stage, whereas in case of sole potato was 120-60-120 kg N-P-K/ha. Herbicides were sprayed by knapsack sprayer fitted with flat fan nozzle using a spray volume of 500 l/ha. Weedy check plots remained infested with native population of weeds till harvest. Observations on weeds were recorded with the help of quadrate (0.5 x 0.5 m) placed randomly at two spots in each plot at harvest. The data on weeds were subjected to square root transformation ($\sqrt{x + 0.5}$) to normalize their distribution. The total N, P and K content in crops and weeds (at harvest of crops) was determined by Kjeldahl method. The uptake of N, P and K by crops was calculated by multiplying with yield of crops while uptake of nutrients by weeds was calculated by multiplying with the dry matter accumulation of weeds at harvest by the respective percentage composition of N, P and K.

RESULTS AND DISCUSSION

The major weeds in experiment field were *Medicago sativa* (19.09%), *Anagallis arvensis* (10.12%), *Trachysperum* sp. (7.69%), *Phalaris minor* (7.27%), *Cyanodon dactylon* (8.28%) and *Cyperus rotundus* (32.7%) and other minor species are *Dacus carota*, *Melilotus alba*, *Chenopodium album*, *Poa annua* and *Convolvulus arvensis*. The annual monocot weeds dominated the weed flora throughout the crop growth seasons during both the years. Different intercropping system and sole potato proved significantly superior over sole maize in reducing weed density and weed dry matter at 120 days after sowing. Winter maize + potato (additive series) and sole potato were more effective in controlling weeds than winter maize + potato (replacement series) and sole maize. Additive series of maize + potato registered (20.32 and 21.00 %) and (28.60 and 30.99%) reduction in total dry matter over replacement series and sole winter maize, respectively (Table 1). Similar effects due to planting pattern were also reported by Singh *et al*. (2005). Highest population of weeds was observed in weedy check over weed free treatment. The weed control treatments significantly reduced the total number of weeds during both the years. Application of atrazine at 0.5 kg/ha pre-emergence was highly effective in controlling the weeds and the lowest weed population of all the species was registered under this application in comparison to other treatments during both the years (Table 1).

Productivity

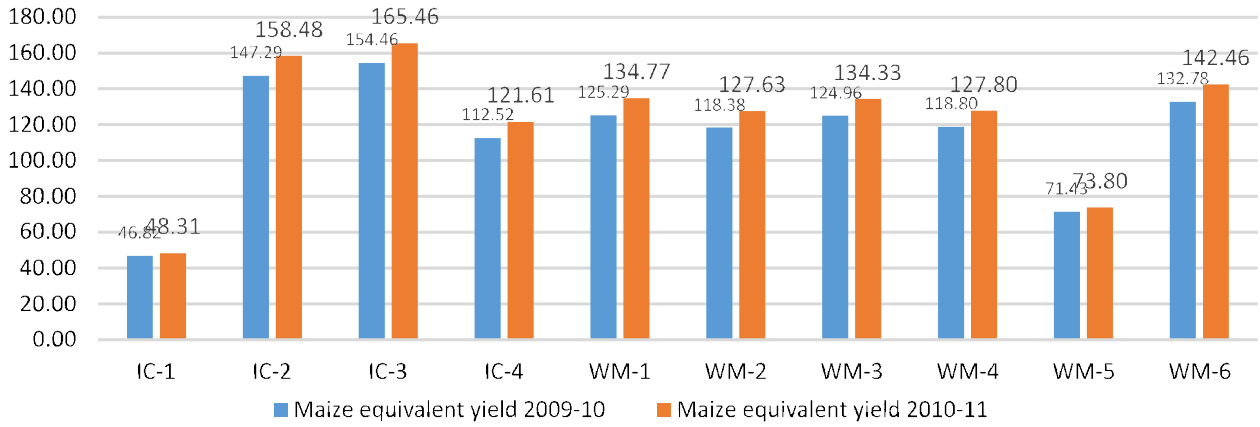
Winter maize: Among intercropping systems, winter maize in sole stand recorded significantly higher grain and stover yield and was followed by additive and replacement series which was probably because of more number of plants per unit area and less competition for sunlight, space, water and nutrients for sole crop as compared to intercropping treatments wherein the competition of crop plants might have curtailed efficient utilization of natural resources and restricted growth of winter maize from initial stages to harvest resulting in yield competition for main and intercrops. However, between additive and replacement treatments, significantly higher grain and stover yield of winter maize under additive series mainly might have happened due to significantly higher plant population as compared to replacement series (Table 1). Higher yield of maize under sole stand than intercropping was reported by Khola *et al.* (1999) and Singh and Singh (2001). The pronounced effect of increased yield after weed free treatment was observed with pre-emergence application of atrazine at 0.5 kg/ha. This treatment recorded significantly higher grain and stover yield which was statistically at par with post emergence application of atrazine at 0.75 kg/ha and pre emergence application of alachlor at 1.5 kg/ha.

The increase in yield under various weed-management treatments may be attributed to significant reduction in weed dry matter (Table 1), thereby reduction in crop weed competition which provided congenial environment to the crop for better expression of vegetative and reproductive potential. The lowest grain and stover yield of winter maize was noticed in weedy check as a consequence of stiff competition imposed by weeds resulting in poor source and sink development with poor yield contributing characters and higher weed index. The above results could be corroborated with the findings of Rout and Satapathy (1996) and Kolage *et al.* (2004). Highest maize equivalent yield was achieved higher in winter maize + potato (additive series) and was statistically at par with sole potato. Amongst the herbicidal treatments, significantly higher maize equivalent yield was recorded with pre-emergence application of alachlor 1.5 kg/ha which was statistically at par with pre-emergence application of atrazine 0.5 kg/ha due to superiority in yield attributes of crop components as a result of reduced crop-weed competition and increased water and nutrient availability (Roy *et al.* 2008) (Fig. 1).

Potato: Potato in sole stand also recorded significantly higher values of tuber and haulm yields as compared to intercropping systems. The optimum space as available for potato plants under sole stand reduced the com-

Table 1. Influence of weed management practices on weed growth and yield of winter maize and potato

Treatment	Weed density (no./m^2 at 120 DAS)		Weed dry weight (at 120 DAS) (g/m^2)		Grain yield of winter maize yield (t/ha)		Tuber yield of potato (t/ha)		Stover yield of winter maize yield (t/ha)		Haulm yield of potato (t/ha)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Intercropping												
Sole maize	9.25 (110)	9.14 (107)	9.96 (124)	9.74 (119)	46.8	48.3	-	-	94.9	96.5	-	-
Sole potato	8.50 (91.50)	8.30 (87.0)	9.21 (102)	8.82 (97.9)	-	-	235.7	237.7	-	-	105.6	107.6
Winter maize + potato (additive series)	7.36 (71.50)	6.71 (50.3)	8.44 (88.5)	8.19 (82.6)	35.2	36.7	190.8	193.1	87.3	88.8	97.0	99.4
Winter maize + potato (replacement series)	9.12 (108)	8.26 (76.6)	9.39 (111)	9.06 (105)	22.5	24.1	144.0	146.2	72.1	73.5	69.5	71.1
LSD (P= 0.05)	0.15	0.51	0.22	0.23	2.43	2.45	14.89	15.11	2.69	2.67	3.38	2.80
Weed management												
Weedy check	16.90 (286)	14.3 (212)	16.48 (272)	16.25 (264)	17.9	17.1	123.8	121.9	57.4	55.8	64.4	62.8
Weed free	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	43.3	45.3	214.0	217.0	98.4	100.3	99.9	101.9
Alachlor pre- at 1.5 kg/ha	8.22 (67.7)	8.65 (74.7)	9.45 (87.5)	9.29 (85.6)	37.3	39.3	207.6	210.6	88.5	90.8	97.6	100.3
Alachlor early post at 2.0 kg/ha	10.3 (106)	9.31 (87.7)	11.44 (127)	11.85 (140)	32.9	34.9	199.9	202.9	82.7	84.8	94.9	97.7
Atrazine pre- at 0.5 kg/ha	6.80 (46.0)	6.82 (46.2)	7.89 (62.3)	7.05 (49.3)	39.3	41.3	203.8	206.8	91.4	93.8	96.5	98.8
Atrazine post- at 0.75 kg/ha	8.12 (66.2)	7.05 (51.7)	9.25 (89.8)	8.25 (67.2)	38.4	40.4	192.0	195.0	90.2	92.2	90.8	94.8
LSD (P = 0.05)	0.08	0.58	0.39	0.009	1.97	1.97	9.47	9.54	2.48	2.70	2.92	2.79



IC - Intercropping, WM - Weed management, IC_1- Sole maize, IC_2 - Sole potato, IC_3 -Winter maize + potato (additive series), IC_4 - Winter maize + potato (replacement series), WM_1 - Alachlor pre- 1.5 kg/ha, WM_2 - Alachlor early post 2.0 kg/ha, WM_3 - Atrazine pre 0.5 kg/ha, WM_4 - Atrazine post 0.75 kg/ha, WM_5 - Weedy check, WM_6 - Weed free

Fig. 1. Effect of different intercropping and weed control treatments on maize equivalent yield in winter maize potato intercropping system

petition for moisture, nutrients and light among the potato plants than other intercropping combinations which might be responsible for the production of higher yield attributes of sole crop of potato (Table 1). This indicated that inter-specific competition in intercropping was more than intra-specific competition of sole stand. Among different intercropping system, additive treatments recorded significantly higher potato yield than replacement treatment. The possible reason for higher yield of potato in additive treatment rather than the replacement treatment might have been achieved due to the fact besides the single plant yield remaining inferior in additive treatment. The overall yield per unit area improved due to cumulative effect of higher plant populations in additive treatment during first and second years of cropping.

Among the weed management practices, higher tuber and haulm yields of potato were recorded where weed free environment was provided to the crop throughout its crop growing period. The potato tuber yield reduced due to weed by 42.14% and 43.82% during 2009-10 and 2010-11, respectively. Among the herbicidal treatments, alachlor application at 1.5 kg/ha as pre-emergence resulted in highest potato tuber yield which was being significantly higher to application of atrazine at 0.75 kg/ha as post-emergence might be due to reduced crop-weed competition and enhancement in most of the crop growth parameters under the favourable environmental situation. These results were in conformity with the findings of Sinha *et al.* (1999). Under this treatment, weeds were unable to compete with the crop plants which resulted in better expression of yield attributing characters and thus gave higher tuber yield.

Nutrient removal by crops

Winter maize: Irrespective of the treatments, highest N, P and K removal from grain and stover of winter maize was recorded with sole stand followed by additive series and replacement series during both the cropping seasons of *Rabi* 2009-10 and 2010-11, respectively (Table 2). The higher removal of these nutrients by sole winter maize as compared to intercropping treatments probably happened due to vigorous growth and better root system under optimum spacing which had helped in adequate supply of these nutrients resulting in higher biological yield coupled with their effective transfer to the ultimate sink *i.e*. the grains thus leading to numerically higher winter maize grain nutrient contents of N, P and K. Obviously, this was due to lesser competition from weeds and ultimately better growth of crop. Among weed management practices, highest N, P and K removal from grain and stover of winter maize was removed from weed free treatment during 2009-10 and 2010-11, respectively. Similar result was also reported by Banga *et al.* (2002). Among the herbicides, highest N, P and K from grain and stover of winter maize was removed from atrazine pre-emergence 0.5 kg/ha followed by alachlor pre-emergence 1.5 kg/ha during both the seasons respectively. This could possibly be attributed to higher weed-control efficiency resulting in more favourable environment for growth and development of crop plants apparently due to the lesser weed competition. The results conformed to the findings of Srinivas and Satyanarayana (1996) and Mundra *et al.* (2002).

Potato (tuber and haulm): N removal by potato tuber was observed under sole stand of potato followed by additive series and replacement series which were seen to be significantly influenced by intercropping systems whereas numerically highest N and significantly higher P and K uptakein potato haulm was recorded with sole stand followed by additive series and replacement series which in turn P and K found significantly different to one another during 2009-10 and 2010-11, respectively (Table 3). Similar result was also reported by Sharma *et al.* (1998). Among the herbicidal treatments, significantly higher value of NPK uptake was recorded with pre-emergence application of alachlor1.5 kg/ha followed by atrazine pre-emergence 0.5 kg/ha. The possible reason for beneficial effect of the weed control treatments in reducing the nutrient drain by weeds was reflected in significantly increased uptake of N, P and K by potato tuber as compared to the weedy check plots. Similar findings were noticed by Banga *et al.* (2002).

Table 2. Influence of weed management treatments on uptake of N, P and K (kg/ha) of winter maize

Treatment	N				P				K			
	Grain		Stover		Grain		Stover		Grain		Stover	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Intercropping												
Sole maize	42.9	45.1	18.1	19.3	10.0	11.3	16.6	18.3	12.4	12.8	51.5	54.5
Winter maize + potato (additive series)	32.1	34.2	12.1	13.9	7.3	8.4	12.0	13.3	8.6	8.77	45.1	48.6
Winter maize + potato (replacement series)	20.6	22.5	12.9	14.1	4.9	5.8	13.4	14.8	5.9	6.38	37.5	39.7
LSD (P=0.05)	2.38	2.53	1.86	0.67	0.60	0.66	0.73	0.24	0.72	1.30	1.92	4.60
Weed management												
Alachlor pre- at 1.5 kg/ha	33.8	36.4	15.1	16.5	9.0	9.0	15.1	16.2	9.7	10.5	48.6	50.5
Alachlor early post- at 2.0 kg/ha	30.1	32.6	9.4	11.5	8.1	8.1	12.9	15.3	8.1	8.8	42.0	47.8
Atrazine pre- at 0.5 kg/ha	36.4	39.1	18.6	19.9	9.7	9.8	15.8	17.1	10.3	11.1	52.0	53.3
Atrazine post- at 0.75 kg/ha	35.0	37.6	16.7	18.1	9.3	9.3	15.5	16.9	9.8	10.4	49.5	51.3
Weedy check	16.3	15.5	3.2	2.3	3.8	3.8	7.5	8.0	4.3	2.72	21.3	24.8
Weed free	39.8	42.5	23.3	25.4	10.9	10.9	17.3	19.1	11.5	12.4	54.9	57.8
LSD (P=0.05)	1.90	1.93	1.19	1.13	0.52	0.56	1.42		0.67	0.80	1.95	1.87

NPK uptake by weeds

At harvest, significantly higher N, P and K was removed by sole cropping of potato followed by sole cropping of winter maize, replacement and additive series during 2009-10 and 2010-11, respectively. This might have happened due to growing of intercrop in spaced winter maize rows which while utilizing the space efficiently reduced the intensity and dry matter of weeds leading to lower NPK uptake by weeds. The removal of N, P and K by weeds were reduced significantly by various herbicidal and manualweeding treatments and it was almost nil under weed free treatment whereas significantly highest N, P and K uptake by weeds was recorded in the weedy check treatment (Table 4). The results confirm to the findings of Rafey and Prasad (1992). The removal of N, P and K by weeds was reduced significantly by various herbicidal and manual weeding treatments and it was almost nil under weed free treatment whereas significantly highest N, P and K uptake by weeds was recorded in the weedy check treatment. This might be attributed to luxuriant growth of unchecked weeds in weedy check treatment which competed dominantly with the crop plants for nutrients. The results confirm the findings of Srinivas and Satyanarayana (1996) and Mundra *et al*. (2002). Among the herbicidal treatments, significantly lowest values of N, P and K uptake were recorded in atrazine pre-emergence 0.5 kg/ha followed by alachlor pre-emergence 1.5 kg/ha whereas, significantly highest values of N, P and K uptake by weeds were recorded with alachlor early post 2.0 kg/ha which showed relatively lower efficacy against weeds whose infestation was predominantly higher in these plots but not to the extent observed in weedy check plots.

Economics

Intercropping of maize with potato under different intercropping system resulted in higher net returns and benefit cost ratio than sole maize and sole potato (Table 4). The intercropping of maize with potato in additive treatment gave maximum net returns (` 80,585. and ` 1,03,590/ha) followed by replacement treatments. However, replacement treatment registered maximum B:C ratio (2.01 and 2.49) followed by additive and sole maize treatments. Padhi and Panigrahi (2006) and Pathak and Singh (2008) also reported the economic viability of intercropping systems over sole crops. All the weed control treatments were superior in terms of net returns and benefit cost ratio than unweeded check. Among weed management treatments, highest net returns and B: C ratio were obtained in treatment atrazine pre-emergence application 0.5 kg/ha followed by alachlor pre-emergence 1.5 kg/ha where as the lowest net returns and B: C ratio were observed in weedy check treatment followed by weed free treatment. Net return per rupee investment was more with herbicidal treatments than hand weeding and weedy check treatment due to lower cost involved under herbicidal treatments. Similar results were also reported by Prasad and Srivastava (1990) and Roy *et al*. (2008).

In conclusion, the study revealed that winter maize + potato intercropping system along with the application of atrazine pre-emergence 0.50 kg/ha and alachlor pre-emergence 1.5 kg/ha was found effective in reducing weed population and resulted in higher maize equivalent yield. The highest uptake by crops and lowest removal of nutrients by weeds was also with the application of atrazine pre-emergence 0.50

Table 3. Influence of weed management treatments on uptake of N, P and K (kg/ha) of potato

Treatment	N				P				K			
	Tuber		Haulm		Tuber		Haulm		Tuber		Haulm	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Intercropping												
Sole potato	92.4	93.2	31.5	32.8	14.3	15.2	4.53	5.04	89.4	91.0	31.8	33.4
Winter maize + potato (additive series)	75.2	76.1	28.0	29.2	8.98	9.73	3.40	3.87	63.2	64.6	29.3	30.9
Winter maize + potato (replacement series)	57.3	58.2	23.2	24.2	6.75	7.35	2.73	3.08	57.1	58.5	20.5	21.7
LSD (P= 0.05)	5.71	5.80	4.01	3.74	1.59	1.46	0.77	0.79	6.71	6.53	1.37	1.70
Weed management												
Alachlor pre- at 1.5 kg/ha	82.0	83.2	30.9	31.6	11.9	12.8	4.18	4.62	78.0	79.9	30.3	31.4
Alachlor early post- at 2.0 kg/ha	77.7	78.9	27.2	29.1	9.55	10.3	3.37	3.92	71.7	73.5	27.4	29.7
Atrazine pre- at 0.5 kg/ha	79.2	80.3	29.2	30.4	10.9	11.7	3.73	4.21	75.2	77.0	29.0	30.4
Atrazine post- at 0.75 kg/ha	75.6	76.8	26.3	29.5	8.52	9.29	2.66	3.32	66.7	68.4	24.9	28.4
Weedy check	48.3	47.5	19.2	18.7	6.25	6.57	2.28	2.42	42.4	42.1	20.2	19.8
Weed free	87.0	88.2	32.9	33.2	13.0	13.9	5.10	5.49	85.3	87.2	31.4	32.2
LSD (P = 0.05)	4.52	4.56	1.34	1.12	1.33	1.35	0.51	0.50	3.64	3.75	1.29	1.12

Table 4. Influence of weed management treatments on uptake of N, P and K (kg/ha) of weeds and economics of the system

Treatment	N		P		K		Net returns (x10^3 `/ha)		B:C ratio	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Intercropping										
Sole maize	13.1	11.9	4.55	4.06	15.2	13.9	23.31	28.83	1.65	1.97
Sole potato	18.0	17.4	4.11	3.98	19.8	19.4	71.95	94.40	1.57	1.96
Winter maize + potato (additive series)	9.43	8.44	3.37	3.03	10.0	8.96	80.59	103.6	1.87	2.29
Winter maize + potato (replacement series)	11.3	10.7	4.16	3.93	14.1	13.3	60.12	78.12	2.01	2.49
LSD (P= 0.05)	0.93	0.56	0.42	0.38	1.86	1.53	-	-	-	-
Weed management										
Alachlor pre- at 1.5 kg/ha	10.5	9.70	3.21	2.86	10.9	9.97	68.46	87.76	2.15	2.62
Alachlor early post- at 2.0 kg/ha	14.6	16.8	4.94	5.24	16.3	18.9	62.61	80.10	1.95	2.39
Atrazine pre- at 0.5 kg/ha	7.39	5.16	2.12	1.46	8.39	5.87	68.90	88.06	2.22	2.68
Atrazine post- at 0.75 kg/ha	11.7	7.45	3.30	2.32	12.7	8.24	63.83	82.04	2.05	2.49
Weedy check	33.7	33.5	10.7	10.6	40.4	40.2	26.36	34.21	0.86	1.06
Weed free	0.00	0.00	0.00	0.00	0.00	0.00	63.78	84.35	1.50	1.92
LSD (P= 0.05)	0.94	0.75	0.33	0.31	1.18	0.93	-	-	-	-

kg/ha and alachlor pre-emergence 1.5 kg/ha. Therefore, for efficient utilization of applied nutrients the weed should be kept under control.

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