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The Effect of Urea as Adjuvant on Herbicide Effectiveness, Yield and Weeds of Maize with Full and Reduced Doses of Herbicide

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Abstract

A field experiment was carried out to study the effect of urea as adjuvant for controlling the weeds in maize. The experiment comprised the following treatments; weedy check, manual hoeing, foramsulfuron + isoxadifen + isosulfuron-methyl sodium alone at 228.75 g a.i. ha^{-1}, and with 3% urea solution at 228.75, 190.39 and 152.50 g a.i. ha^{-1}. The maximum reduction in weed density and dry weight was recorded by manual hoeing at 20 and 40 days after spray, however, at harvest minimum weed density and dry weight was recorded with full dose of herbicide along with urea as adjuvant. The grain yield and yield components, except number of cobs per plant and grains per row, were affected significantly and maximum grain yield was obtained with manual hoeing which resulted in 93.05% increase in grain yield over weedy check.

Key Words: Maize, urea, adjuvant, herbicide, weed

Introduction

Maize is the third most important cereal grain after wheat and rice in Pakistan. Its grain contains 72% starch, 10% protein and 4.8% oil (Chaudhry, 1983). It is grown over an area of 896 thousand hectares and its production is 2770 thousand tons with an average production of 3097 kg ha^{-1} (Anonymous, 2006). In Pakistan average yield is low compared with potential due to lack of resources and non-adaptation of modern technology. Among these weed management is the most important as weed-crop competition can lead to 35-79% reduction in yield (Ford and Pleasant, 1994).
Cultural, mechanical and chemical methods are commonly used for controlling weeds. No doubt cultural methods are still useful tool but are getting expensive and time consuming, so chemical control is an important alternative. Post-emergence herbicides are generally absorbed through leaves. Leaf cuticle is composed of waxes and cutin that affect the herbicide absorption. The use of adjuvant in combination with herbicide enhances the herbicide retention, leaf surface penetration through cuticle and thus increases the phytotoxicity of herbicide (Zadorozhny, 2004). The type of adjuvant varies with crop, herbicide and weed species present. In maize for controlling weeds urea fertilizer is the most effective adjuvant (Toloraya et al., 2001). Herbicide application in combination with urea gave 12-13.5% better results than herbicide alone (Getmanetz et al., 1991). The phytotoxic effect of foramsulfuron in maize was increased by using nitrogen fertilizer (Bunting et al., 2004). The combination of herbicide and fertilizer may exceed the weed control three fold in maize (Agladze et al., 2003). The present experiment was, carried out to study the effect of urea as adjuvant on herbicide effectiveness and yield and weeds of maize with full and reduced doses of foramsulfuron + isoxadifen + isosulfuron-methyl sodium and to explore possibilities of reducing the dose of herbicide using urea as adjuvant.

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Materials and Methods

A field experiment was carried out to study the effect of urea as adjuvant for controlling the weeds in maize at Agronomic Research Area, University of Agriculture Faisalabad. The experiment comprised the following treatments; weedy check, manual hoeing, foramsulfuron + isoxadifen + isosulfuron-methyl sodium alone at 228.75 g a.i. ha^{-1}, and with 3% urea solution at 228.75 (full dose), 190.39 (17% reduced dose) and 152.50 g a.i. ha^{-1} (34% reduced dose). The experiment was laid out in randomized complete block design with three replications having a net plot size of 5 x 3m. The crop was sown in 75 cm apart rows with single row hand drill using a seed rate of 30 kg ha^{-1}. Plant to plant distance (25 cm) was maintained by thinning out weaker plants at early growth stage. Fertilizer was applied at 150 kg N and 100 kg P_2O_5 ha^{-1} in the form of urea and diammonium phosphate, respectively. Whole of the phosphorus and half of nitrogen was side dressed after sowing while remaining nitrogen was top dressed at the time of first irrigation. The herbicide was sprayed after emergence of crop and weeds with knapsack sprayer fitted with flat fan nozzle. Spray volume was determined by calibration before spraying. Hoeing was done twice with hand hoe in manual hoeing treatment after 1st and 2nd irrigation. All other agronomic practices were kept normal and uniform for all the treatments. Weed density and biomass was recorded from an area of 0.25 m^2 from two randomly selected places in each plot and was converted to 1 m^{-2}. Ten plants were selected at random from each plot for recording data on plant height, number of cobs per plant, number of grain rows per cob and number of grains per row. Three samples of 100 grains each were used for recording the 100-grain weight. Grain and biological yield were recorded on per plot basis and were converted to kg ha^{-1}. The data collected were analyzed using Fisher's analysis of variance and least significant difference test at 5% probability level was applied to compare the treatment means (Steel et al., 1996).

Results and Discussion

Weed density 20 days after spray. *Trianthema portulacastrum* (Itsit) and *Cyperus rotundus* (Deela) were the dominant weeds in the field 20 days after spray. Individual and total weed density was affected significantly by different weed control practices (Table I). The significantly maximum density of *T. portulacastrum* and *C. rotundus* were recorded in weedy check against the minimum in manual hoeing. Application of urea as adjuvant with full dose of herbicide (W_4) resulted in significantly lower weed density compared with herbicide alone. The use of urea as adjuvant with 17% lower dose of herbicide (W_5) resulted in significantly lower density of *T. portulacastrum* 20 days after spray compared with herbicide alone (W_3) and 34% lower herbicide of herbicide (W_6). Use of urea with 34% reduced dose of herbicide (W_6) gave statistically similar density of *T. portulacastrum* to the full dose of herbicide alone (W_3). However, the use of urea along with reduced doses of herbicide (W_5 & W_6) resulted in similar density of *C. rotundus* to herbicide alone.

The reduction in the weed density 20 days after spray by using urea as adjuvant can be attributed to increase in retention of herbicide due to adjuvant which increased the toxicity of herbicide. The results are in line with those of Bunting et al. (2004) who reported increase in herbicide efficiency due to use of urea. The dose of foramsulfuron for *T. portulacastrum* and *C. rotundus* can be reduced up to 34 and 17%, respectively by using urea as adjuvant. These results are supported by the finding of Borone et al. (2003) who reported 25-35% reduction in herbicide dose by using adjuvant.

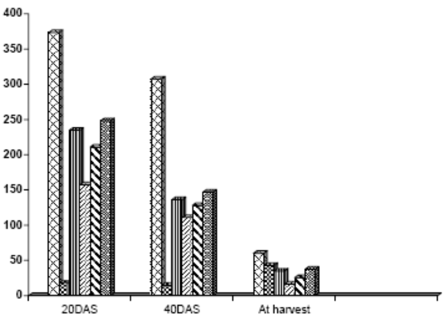

Figure 1: Effect of weed control practices on total weed density

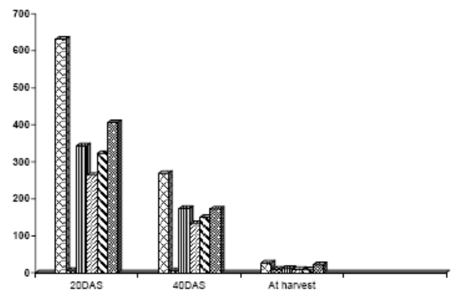

Figure 2: Effect of weed control practices on total weed dry weight

W1= Weedy check; W2= Manual hoeing; W3= Foramsulfuron + isoxadifen + isosulfuron-methyl sodium alone at 228.75 g a.i. ha-1; W4= Foramsulfuron + isoxadifen + isosulfuron-methyl sodium at 228.75 g a.i. ha-1with 3% urea solution; W5= Foramsulfuron + isoxadifen + isosulfuron-methyl sodium at 190.39 g a.i. ha-1 with 3% urea solution; W6= Foramsulfuron + isoxadifen + isosulfuron-methyl sodium at 152.50 g a.i. ha-1 with 3% urea; solution.

Weed density 40 days after spray. *Trianthema portulacastrum* and *Cyperus rotundus* were the dominant weeds in the field 40 days after spray. The maximum weed density 40 days after spray was recorded in weedy check while minimum individual and total weed density was obtained with manual weed control which gave 96.70 and 77.80 % reduction in the density of *T. portulacastrum* and *C. rotundus* (Table I). Use of urea as adjuvant reduced weed densities over herbicide alone and reduced dose up to 17 % (W_5) and 34% (W_6) gave the same results as that of full dose of herbicide alone (W_3). The full dose of herbicide along with urea as adjuvant (W_4) resulted in similar density of *C. rotundus* 40 days after spray as that of manual hoeing (W_2).

The maximum reduction in weed density 40 days after spray was observed with manual weed control. The results are in line with those of Khan and Haq (2004) who also reported minimum weed density with manual hoeing. Use of urea as adjuvant resulted in lower densities of both the weeds. This might have been due to increased retention of herbicide on the leaves (Zadorozhny, 2004). The results are in line with those of Bunting et al. (2004) who reported increase in herbicide efficiency due to use of urea.

Weed density at harvest. *C. rotundus* and *Coronopus didymus* were the dominant weeds in the field at harvest. *T. portulacastrum* had completed its lifecycle and was not present in the field at the time of harvest and another weed *C. didymus* also appeared in the field 40 days after spray and was present at the time of harvest. The density of all the weeds and their total were affected significantly by different weed control practices. The significantly maximum density of *C. didymus* and *C. rotundus* was recorded in weedy check and was followed by manual hoeing. Minimum densities of *C. didymus* and *C. rotundus* were recorded with foramsulfuron + isoxadifen + isosulfuron-methyl sodium @ 228.75 along with 3% urea solution (76.67 & 66.67 % reduction, respectively). This was at par with 17% lower dose of herbicide along with urea (W_5) for *C. didymus* and all herbicide application treatments for *C. rotundus*.

The maximum density in weedy check can be attributed to favorable conditions for weed germination and growth in the absence of weed control practices. Khan and Haq (2004) have also reported maximum weed density in weedy check treatment compared to herbicide treatments. The weed density decreased at the time of harvest compared with 20 and 40 days after spray due to the mortality of almost all *T. portulacastrum* plants and some *C. rotundus* plants also. However, the weed density increased in manual weed control at harvest compared with 20 and 40 days after spray. This increase in density might be due to emergence of weeds after second hoeing. Lower weeds density in herbicide application plots might be due to persistence of herbicide in the soil which might have retarded the weed germination.

Weed dry weight. The dry weight of all the weeds was affected significantly at 20 and 40 days after spray and at harvest except *C. rotundus* at harvest which showed non- significant differences for dry weight at harvest. The significantly maximum dry weight was recorded in weedy check treatment for all the weeds at 20 and 40 days after spray and at harvest. The minimum dry weight was obtained by manual weed control in all the weeds except *C. didymus* at harvest. A minimum dry weight of *C. didymus* at harvest was recorded with 17% reduced dose of herbicide along with urea as adjuvant (W_5). Such a dose of urea as adjuvant with full dose of herbicide (W_4) significantly reduced the dry weight of *T. portulacastrum* but the differences between full dose of herbicide alone (W_3) and adjuvant (W_4) were non-significant for *C. didymus* at 20 and 40 days spray. However, at harvest the *T. portulacastrum* was not present in the field but *C. didymus* emerged.

A maximum weed dry weight in weedy check can be attributed to greatest weed density in this treatment (Table-I). Further, unchecked growth of the weed plants in the absence of any weed control practice also resulted in higher weed dry weight. The results are in accordance with those of Khan and Haq (2004) who also reported maximum dry weight in weedy check compared to herbicide treatments. The decrease in the dry weight of *T. portulacastrum* and *C. didymus* due to the addition of adjuvant can be attributed to increased phytotoxic effect of herbicide and decreased density of these weeds. The results are supported by the findings of the Amanullah (2001) who reported decrease in weed biomass due to use of urea as adjuvant with post-emergence herbicide. The drastic difference in the total dry weight of the weeds at harvest (Fig-2) compared to 20 and 40 days after spray was due to the completion of its life cycle before the cop harvest of the most abundant weed *T. portulacastrum*. The lower dry weight of newly emerged plants of *C. didymus* was also responsible for lower total dry weight at harvest.

Plant height, yield and yield components of maize

The plant height of the maize was affected significantly by different weed control practices (Table-II). The maximum plant height was recorded with manual hoeing and was statistically at par with Foramulsuron + Isoxadifenethyl + Isosulfuron-methyle sodium @ 228.75 g a.i. ha^{-1} alone (W_3) and with 3 % urea (W_4). Decrease in

Table 1 Effect of urea along with full and reduced doses of herbicide on weed density

	Weed density 20 days after spray		**Weed density 40 days after spray**		**Weed density at harvest**	
	T. portulacastrum	***C. rotundus***	***T. portulacastrum***	***C. rotundus***	***C. didymus***	***C. rotundus***
W1=Weedy check	340.00 a	33.33 a	283.33 a	24.00 a	40.00 a	20.00 a
W2=Manual weed contol	10.67 e (96.86%)	6.66 d (80.00%)	9.33 d (96.70%)	5.33 d (77.80%)	28.00 b (30.00%)	14.67 b (26.66%)
W3=Foramulsuron+Isoxadifenethyl +Isosulfuron-methyle sodium @ 228.75 g a.i. ha^{-1} alone	213.33 b (37.25%)	21.33 b (36.00%)	120.06 b (57.64%)	16.00 bc (33.33%)	25.33 bc (36.67%)	9.33 c (53.35%)
W4=Foramulsuron+Isoxadifenethyl +Isosulfuron-methyle sodium @ 228.75 g a.i. ha^{-1} with 3 % urea	144.00 d (57.36%)	13.33 c (60.00%)	100.0 c (64.70%)	10.66cd (55.55%)	9.33 d (76.67%)	6.66 c (66.67%)
W5=Foramulsuron+Isoxadifenethyl +Isosulfuron-methyle sodium @ 190.39 g a.i. ha^{-1} with 3 % urea	193.33 c (43.13%)	17.33 b (48.00%)	114.66 bc (59.52%)	13.33bc (44.45%)	16.00 cd (76.67%)	9.33 c (53.35%)
W6=Foramulsuron+Isoxadifenethyl +Isosulfuron-methyle sodium @ 152.50 g a.i. ha^{-1} alone with 3 % urea	299.33 b (32.54%)	18.66 b (44.00%)	128.00 b (54.82%)	18.66 bc (22.22%)	25.33 bc (36.67%)	12.00 bc (40.00%)
LSD at 5% probability level	19.78	6.43	16.27	7.86	10.55	4.39

Table 2 Effect of different weed control practices of maize

	Plant height (cm)	**Number of cobs per plant**	**Number of grain rows per cob**	**Number of grains per row**	**100-grain weight (g)**	**Grain yield (t ha^{-1})**	**Grain pith ratio**
W1=Weedy check	193.03 d	1.00	12.00 b	31.73	33.70 d	2.56 c	1.75 c
W2=Manual weed contol	214.56 a	1.07	14.66 a	38.96	47.30 a	4.99 a (95.03%)	2.40 bc
W3=Foramulsuron+Isoxadifenethyl +Isosulfuron-methyle sodium @ 228.75 g a.i. ha^{-1} alone	211.23 ab	1.07	12.80 b	34.60	39.00 bc	3.87 ab (50.17%)	3.01 ab
W4=Foramulsuron+Isoxadifenethyl +Isosulfuron-methyle sodium @ 228.75 g a.i. ha^{-1} with 3 % urea	212.46 a	1.20	14.66 a	37.96	45.80 a	4.70 ab (83.70%)	2.37 bc
W5=Foramulsuron+Isoxadifenethyl +Isosulfuron-methyle sodium @ 190.39 g a.i. ha^{-1} with 3 % urea	207.00 bc	1.13	13.53 ab	34.06	40.93 b	4.58 ab (79.02%)	3.62 a
W6=Foramulsuron+Isoxadifenethyl +Isosulfuron-methyle sodium @ 152.50 g a.i. ha^{-1} alone with 3 % urea	205.76 c	1.07	12.73 b	33.13	36.43 cd	3.59 bc (40.35%)	3.07 ab
LSD at 5% probability level	13.87	NS	1.612	Ns	3.955	1.23	1.024

Table 3 Effect of weed control practices on dry weight of weeds

	Weed dry weight 20 days after spray (gm)		**Weed dry weight 40 days after spray (gm^{-2})**		**Weed dry weight at harvest(gm^{-2})**	
	T. portulacastrum	***C. rotundus***	***T. portulacastrum***	***C. rotundus***	***C. didymus***	***C. rotundus***
W_1=Weedy check	625.84 a	5.43 a	264.41 a	4.06 a	23.45 a	3.21
W_2=Manual weed control	4.87 e (99.22)	1.43 c (73.70%)	3.92 e (98.51%)	1.82 b (55.00%)	7.56 c (67.76%)	2.30
W_3=Foramulsuron+Isoxadifen ethyl+Isosulfuron-methyle sodium @ 228.75 g a.i. ha^{-1} alone	339.20 c (45.80)	3.95 ab (27.27%)	170.87 b (35.37%)	2.82 b (30.54%)	9.88 c (57.84%)	1.64
W_4=Foramulsuron+Isoxadifen ethyl+Isosulfuron-methyle sodium @228.75 g a.i. ha^{-1} with 3 % urea	261.24 d (58.25%)	2.20 bc (58.72%)	130.49 d (50.64%)	2.31 b (43.17%)	7.29 c (68.87%)	1.11
W_5=Foramulsuron+Isoxadifen ethyl+Isosulfuron-methyle sodium @190.39 g a.i. ha^{-1} with 3 % urea	319.33 c (48.97%)	2.92 bc (46.20%)	146.77 c (44.50%)	3.01 ab (25.78%)	6.62 c (71.75%)	1.63
W_6 = Foramulsuron+Isoxadifen ethyl+Isosulfuron-methyle sodium @152.50 g a.i. ha^{-1} with 3 % urea	402.70 b (35.65%)	8.02 bc (44.22%)	170.04 b (35.70%)	1.88 b (53.69%)	18.95 b (19.19%)	2.47
LSD at 5% probability level	35.52	1.82	13.95	1.22	4.14	NS

Table 4 Economic analysis of weed control practices of maize.

	W_1	**W_2**	**W_3**	**W_4**	**W_5**	**W_6**
Grain yield (kg ha^{-1})	2560	4990	3870	4700	4580	3890
Adjusted grain yield (kg ha^{-1})*	2304	4491	3483	4230	4122	3231
Grain value (Rs.)	21312	41545	32218	39128	38129	29887
Net grain value (Rs.)**	18812	39041	29718	3663	36629	27369
Weed control cost that varied	-					
(a) Cost of herbicide(Rs.) (b)			995	995	828	656
Cost of hoeing (Rs.)		1000/-				
(c) Labour charges for herbicide application (Rs.)			-	-	-	-
(d) Rent of sprayer			200	200	200	200
(e) Urea as adjuvant			25	25	25	25
			-	90	90	90
Total cost that varied (Rs.)		1000/-	1220	1310	1243	971
Net benefit (Rs.)	18812	38042	28498	38318	35486	26398

W1= Weedy check; W2= Manual hoeing; W3= Foramsulfuron + isoxadifen + isosulfuron-methyl sodium alone at 228.75 g a.i. ha^{-1}; W4= Foramsulfuron + isoxadifen + isosulfuron-methyl sodium at 228.75 g a.i. ha^{-1} (full dose) with 3% urea solution; W5= Foramsulfuron + isoxadifen + isosulfuron-methyl sodium at 190.39 g a.i. ha^{-1} (17% reduced dose) with 3% urea solution; W6= Foramsulfuron + isoxadifen + isosulfuron-methyl sodium at 152.50 g a.i. ha^{-1} (34% reduced dose) with 3% urea solution

Price of maize grain = Rs. 370/40kg

Price of herbicide = Rs. 995/228.75 g a.i.

* 10% adjustment in yield; * * Harvesting and shelling charges @ Rs. 2500 ha^{-1}

herbicide dose (W_5 & W_6) resulted in significant reduction in plant height of maize. The significantly minimum plant height was recorded in weedy check. The minimum plant height in weedy check might have been due to more weed density and dry weight (Table I & III) which deprived the crop plants from more moisture and nutrients. With application of weed control practices the plant height increased due to more availability of resources in the absence or scarcity of the weed plants. The results are supported by the findings of the Khan et al. (2002) who reported lower plant height in weedy check treatment.

The number of cobs per plant and grains per row were not affected significantly by different weed control practices. The number of cobs ranged from 1.00 to 1.20 while number of grains per row ranged from 31.7 to 38.96 among different weed control practices. The non-significant differences among herbicides and manual weed control for number of cobs per plant has also been reported by Khan et al. (2002).

The differences among different weed control practices for number of grain rows per cob were significant. The maximum number of grain rows per cob was recorded with manual hoeing and was statistically at par with full dose of herbicide along with adjuvant (W4) and 17% reduced herbicide dose with urea (W5). The minimum numbers of grain rows per cob were recorded in weedy check.

The higher number of grain rows per cob in manual weed control practices can be attributed to lower weed density and competition for the available resources. The results are supported by the findings of Khan et al. (2002) and Amanullah (2001) who reported minimum number of grain rows per cob in weedy check and maximum with manually hoeing in maize.

A 100-grain weight was also affected significantly by different weed control practices. The maximum grain weight was recorded in manual weed control treatment and was statistically at par with Foramulsuron + Isoxadifenethyl + Isosulfuron-methyle sodium @ 228.75 g a.i. ha^{-1} with 3% urea solution (W_4). The minimum 100-grain weight was observed in weedy check and it was also statistically similar to the Foramulsuron + Isoxadifenethyl + Isosulfuron methyle sodium @ 152.50 g a.i. ha^{-1} with adjuvant (W_6). When urea was used as adjuvant, a significant decrease in grain weight with decrease in herbicide dose was recorded. The lower grain weight in the weedy check treatment can be attributed to the greater weed-crop competition exerted by the maximum number of weeds which resulted in reduced plant growth and plant height (Table-II). The results are in line with those of Khan and Haq (2004) who reported minimum grain weight in weedy check treatment.

Grain yield of maize was also affected significantly by different weed control practices and minimum grain yield was recorded in weedy check and was statistically at par with 34% reduced dose of herbicide along with urea as adjuvant. The maximum grain yield (95.03% increase over weedy check) was recorded in manual weed control and was statistically similar to all herbicide treatments except 34% reduced dose of foramulsuron along with urea (W_6). The results indicate that if we use urea as adjuvant we can get similar results with 17% reduced dose of foramulsuron (W_5) to that of full dose of herbicide alone (W_3). The minimum grain yield in weedy check can be attributed to lower number of grain rows per cob and lower 100-grain weight in this treatment. Similar results have also been reported by Khan et al. (2002), Amanullah (2001) and Bunting et al., (2004) who reported minimum grain yield in weedy check compared to chemical and manual weed control treatments.

Weed control practices also affected the grain pith ratio significantly. The maximum grain pith ratio was recorded when 17% reduced dose of foramulsuron was used along with urea (W_5) and was statistically similar to the 34% reduced dose of foramulsuron (W_6) and full dose of foramulsuron with out adjuvant (W_3). The minimum grain pith ratio was recorded in weedy check treatment.

Although the maximum grain yield was recorded in manual weed control but grain pith ratio was maximum in foramulsuron + isoxadifenethyl + isosulfuron- methyle sodium @ 190.39 g a.i. ha^{-1} with 3% urea solution (W_5). Lower ratio in manual hoeing can be attributed to greater pith weight and higher grain pith ratio in foramulsuron + isoxadifenethyl + isosulfuron-methyle sodium @ 190.39 g a.i. ha^{-1} with 3% urea solution (W_5) was mainly due to lower pith weight in this treatment (data not given). The results are in contrast with those of Porwal (1995) who reported increase in grain pith ratio with manual weed control practice. These contradictory results might have been due to difference in weed species and climatic conditions.

Economic analysis showed that maximum net returns were obtained with full dose of herbicide along with urea (W_4) and was followed by manual weed control whereas minimum net returns were obtained with weedy check (Table IV).

Conclusion

Based on the present findings it can be concluded that the in maize field the maximum net returns can be obtained when weeds are controlled manually or by using full dose of herbicide along with urea as adjuvant. Addition of urea increased the phytotoxicity of herbicide and 17% reduced dose of herbicide along with urea as adjuvant gave similar results as that of full dose of herbicide used without adjuvant.

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