Indian Journal of Agronomy **58** (4): 534–538 (December 2013)

Research Paper

Effect of weed control and sulphur on productivity of quality protein maize (*Zea mays*), dynamics of associated weeds and relative nutrient uptake

POONAM CHOUDHARY[1], V. NEPALIA[2] AND DILIP SINGH[3]

Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan 313 001

Received : April 2013; Revised accepted : August 2013

ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2009 and 2010 at Udaipur, to study the effects of weed control and sulphur application on quality protein maize (*Zea mays* L.) productivity and associated weeds. Maximum reduction of weed density, dry matter and nutrient uptake by weeds were recorded in crop hand-weeded twice at 15 and 30 days after sowing (DAS) followed by application of tank-mix atrazine + ethoxysulfuron and atrazine + alachlor. Herbicide mixture involving ethoxysulfuron significantly damaged the crop. The highest values of grains/row, grain weight/cob, 1,000-grain weight, grain (4.55 t/ha) and stover (7.72 t/ha) yields and N,P,K and S uptake by crop were observed with 2 hand-weedings, which were at par with that of atrazine + alachlor. The highest net returns of ₹40,917/ha was obtained through tank mix atrazine + alachlor (500 + 1500 g/ha). Application of 40 kg S/ha resulted in significantly higher 1,000-grain weight, seed (4.09 t/ha) and stover (6.58 t/ha) yields and N, P, K and S uptake by crop. It also registered a benefit: cost ratio of 1.72, which was significantly more than 20 kg S/ha.

Key words : Atrazine, Alachlor, Crop protection, Ethoxysulfuron, Pendimethalin, Productivity, Quality Protein Maize, Sulphur

Maize is considered a promising crop for diversifying agriculture in upland areas of India. Popularization of single-cross hybrid quality protein maize has opened a new vista in overcoming the imbalance of protein in terms of desired amino acids, *viz*. tryptophan and lysine (Prasanna *et al*., 2001). Compared to most cereals, maize faces interference of weeds to a greater degree, especially during the rainy season, which is the main growing period in north India. In the absence of appropriate weed management, yield losses may vary from 40 to 60% (Sunitha and Kalyani, 2012). Though farmers are in practice of doing some kind of physical operations to combat against weeds, incessant rains in prolonged spells, non-availability of labour and increased labour wages make the physical weeding non-feasible. Once the critical period of weed interference is over, any effort of weeding becomes futile (Page *et al.,* 2012). Therefore, the only remedy left is to use herbicide at or immediately after sowing to ensure weed suppression for first 30–45 days. Atrazine had been the choicest herbicide of maize-growing farmers over the years (Le Barron *et al.,* 2008), but its application does not control a wide range of weeds. For the control of a variety of weeds including broad leaf, grasses and sedges, herbicide mixtures hold promise (Walia *et al.,* 2007).

Sulphur is considered fourth major nutrient after nitrogen, phosphorus and potassium (Jamal *et al*., 2010) and wide-spread deficiency of sulphur constitute one of the severe negative factors in crop production of semi-arid tropics in many states of India (Sahrawat *et al*., 2007). Inadequate supply may limit maize production (Malik *et al*., 2012). Therefore, the present investigation was undertaken to evolve a suitable weed-control method and to standardize the rate of sulphur application for quality protein maize.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) seasons of 2009 and 2010 at the Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan (24°.35'N, 74°.42'E and of 579.5 m above mean sea–level). The soil was clay loam, alkaline (pH 8.0 and 8.1), low in available nitrogen (274.56 and 279.61 kg/ha), medium in available phosphorus (19.27 and 18.69 kg/ha) and high in available potassium (318.83 and 324.17 kg/ha) during 2009 and 2010, respectively. In general, weather

Corresponding author Email: vnepalia@gmail.com
[1]Agriculture Officer, Pant Krishi Bhawan, Jaipur; [2,3]Professors, Department of Agronomy, MPUAT, Udaipur, Rajasthan 313 001

conditions were favourable for plant growth and no severe pests or diseases were observed during both the years. The study involved 15 treatment combinations, comprising 5 weed-control treatments (weedy check, pre-emergence application of tank-mix of atrazine at 500 g + alachlor at 1500 g, pendimethalin at 750 g and ethoxysulfuron at 15 g/ha and 2 hand-weedings at 15 and 30 days after sowing (DAS) and 3 levels of sulphur (control, 20 and 40 kg/ha). The experiment was laid out in factorial randomized block design and treatments were replicated thrice. The QPM 'HPQM 1' was sown manually in furrows opened 60 cm apart in each plot measuring 5 m × 3 m using seed rate of 20 kg/ha. A uniform dose of 120 kg N and 40 kg P_2O_5/ha was given. Half dose of N and full dose of P_2O_5 and sulphur (as per treatment) were applied basal by drilling the desired quantities of urea, diammonium phosphate and finely ground mineral gypsum in crop rows at about 5 cm below the seedling depth. Remaining 50% N was top-dressed through urea at knee-height stage. The herbicides as per treatment were applied 2 days after sowing by knapsack sprayer using 500 l/ha water. The data on individual major weed species present in experimental field were recorded 60 days after sowing by placing 0.25 m^2 quadrate at 2 places in each plot. Weed count was expressed as number/m^2. The mean data were subjected to square root transformation $\sqrt{(x+0.5)}$ to normalize their distribution. These samples were dried at 70°C till a constant weight was obtained. The dry matter was then computed in terms of g/m^2. Economics was calculated taking into consideration prevailing market prices of inputs output. The dry matter of weeds and crop (seed and stover) at harvest were ground and analyzed for NPK and S contents. The NPK and S uptake by weeds and crop at harvest were computed by multiplying nutrient content with respective dry matter.

RESULTS AND DISCUSSION

Weed growth

The major weeds in the weedy plots included grasses like *Echinochloa* sp. and *Cynodon dactylon* (L.) Pers, broad leaf weeds like *Digera arvensis* Forsk., *Commelina benghalensis* L., *Parthenium hysterophorus* L. and a sedge *Cyperus rotundus* L. The annual grassy weed *Echinochloa* sp. dominated the weed flora and accounted for 50.9% dry matter of total weeds in weedy check plots at 60 days after sowing (Table 1). Various herbicide mixtures and 2 hand weedings exhibited significant reduction in density of various weed flora at 60 DAS. Compared to other treatments, pre-emergence application of atrazine + ethoxysulfuron and 2 hand-weedings resulted in significantly lower density of *Echinochloa* sp., *Commelina benghalensis* and *Parthenium hysterophorus*. However, these 2 treatments were at par in this regard. These 2 treatments also accounted for significant reduction in the density of other weed flora *viz. Cynodon dactylon*, *Digera arvensis*, other broad-leaf weeds and *Cyperus rotundus;* however, the effect of atrazine + ethoxysulfuron was found significantly superior to rest of the treatments. The data explicit that 2 hand-weedings and tank-mix application of all herbicides reduced the total weed count significantly compared with weedy check. Two hand-weedings and atrazine + ethoxysulfuron with identical reduction (75%) in density were found significantly superior to rest of the treatments. These were followed by atrazine + alachlor and atrazine + pendimethalin with 71.1 and 65.3% decrease in weed count. The density of weeds was unaffected due to sulphur application. The maximum reduction in dry matter of total weeds was recorded through atrazine + ethoxysulfuron and 2 hand-weedings. On pooled basis, these 2 treatments reduced 81.4 and 81.9% dry matter compared to weedy check (69.95 g/m^2). Tank-mix application of atrazine + alachlor was next in the order of superiority with 75.0% reduction, followed by atrazine + pendimethalin with 69.4% reduction in dry matter of total weeds. The reduction in weed dry matter due to the application of herbicide mixtures can be attributed to their efficacy to control wide spectrum of weeds. Walia *et al*. (2007) also reported efficient weed control in maize through herbicide mixtures. The rate of sulphur application did not influence the dry matter of total weeds at 60 days after sowing.

Yield attributes and yield

Two hand weedings at 15 and 30 days resulted in the highest grain weight/cob and 1,000-grain weight (Table 2). However, tank-mix application of atrazine + alachlor was at par to that of 2 hand weedings. Further, the results of these 2 treatments were also at par with that of atrazine + pendimethalin for grains/row/and 1,000-grain weight. Under weed stress, grain yield was 2.09 t/ha. Two hand-weedings and pre-emergence application of various herbicides mixtures resulted in significantly higher grain yield compared with the weedy check. The highest grain yield was recorded with 2 hand-weedings at 15 and 30 days, which was at par to that of pre-emergence application of atrazine + alachlor. Amongst all the weed control treatments, atrazine + ethoxysulfuron was the least effective. Weed control through 2 hand-weedings and atrazine based herbicide mixtures with alachlor, pendimethalin and ethoxysulfuron accounted for 98.7, 90.8, 79.0 and 45.8% increase, respectively, in grain yield over the control. The results are in close agreement with those obtained by Rao *et al.* (2009); Sharma and Gautam (2010). Ethoxysulfuron

Table 1. Effect of weed control and sulphur on individual weed density, total dry matter and weed control efficiency at 60 DAS (pooled data of 2 years)

Treatment	Weed No./m²*								Weed dry matter g/m²	Weed-control efficiency (%)
	Echinochloa sp.	*Cynodon dactylon*	*Digera arvensis*	*Commelina benghalensis*	*Parthenium hysterophorus*	Other BLWs	*Cyperus srotundus*	Total weeds		
Weed control										
Weedy check	10.77(115.52)	3.12(9.22)	3.59(12.41)	3.99(15.41)	3.68(13.05)	3.54(12.01)	3.40(11.09)	13.77(189.02)	69.95	-
Atrazine + alachlor	3.05(8.81)	3.16(9.48)	2.38(5.15)	2.23(4.47)	3.43(11.29)	2.47(5.62)	3.17(9.54)	7.42(54.61)	17.49	75.0
Atrazine + pendimethalin	3.71(13.23)	3.20(9.74)	2.66(6.60)	2.66(6.59)	3.51(11.82)	2.75(7.07)	3.28(10.23)	8.13(65.57)	21.43	69.4
Atrazine + ethoxysulfuron	2.60(6.26)	2.30(4.78)	1.82(2.80)	2.14(4.09)	3.14(9.37)	2.26(4.61)	2.65(6.54)	6.27(38.76)	12.62	81.9
Two hand-weedings	2.50(5.76)	2.50(5.76)	2.08(3.83)	2.27(4.67)	3.01(8.57)	2.09(3.87)	2.52(5.84)	6.26(38.65)	12.99	81.4
SEm±	0.07	0.05	0.04	0.05	0.06	0.05	0.05	0.06	0.38	-
CD (P=0.05)	0.20	0.14	0.13	0.15	0.18	0.15	0.16	0.18	1.08	-
Sulphur (kg/ha)										
Control	4.63(20.97)	2.86(7.67)	2.50(5.77)	2.70(6.79)	3.35(10.72)	2.65(6.53)	3.03(8.69)	8.45(70.84)	26.82	-
20	4.48(19.59)	2.82(7.44)	2.51(5.80)	2.67(6.65)	3.38(10.93)	2.61(6.30)	2.99(8.45)	8.34(69.10)	26.93	-
40	4.46(19.40)	2.89(7.85)	2.50(5.77)	2.60(6.28)	3.34(10.63)	2.61(6.30)	2.99(8.43)	8.32(68.66)	26.93	-
SEm±	0.05	0.04	0.03	0.04	0.05	0.04	0.04	0.05	0.30	-
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	

*Data subjected to $\sqrt{x + 0.5}$ transformation and figures in parentheses are original values

is a sulfonylurea herbicide extensively recommended for weed control in rice (Ort, 2012). Its pre-emergence application as a tank mixture with atrazine caused marked phytotoxicity to QPM. Initially at 30 days after sowing, visual observations revealed stunting and discolouration of maize plants. Observations at 60 days after sowing indicated pronounced injury and at 90 days after sowing, the crop injury level became persistent. This negative effect of ethoxysulfuron is self explanatory for poor QPM growth in the plots treated with atrazine + ethoxysulfuron. Significant improvement in protein content of grain was brought about by weed control. Highest protein content (10.06%) was recorded with 2 hand-weedings. Soil fortification with sulphur tended to influence the grain yield in both the years. Raising S dose from control to 20 and from 20 to 40 kg/ha resulted in a significant yield increase 14.6 and 8.8%, respectively. The results of significant increase in grain yield of owing to sulphur application corroborate the findings of Bharathi *et al.* (2009). Almost similar trend was observed in stover yield. Protein content in grain improved significantly by applying 20 kg S/ha.

Economics

Maximum net returns were recorded in plots treated with tank mix application of atrazine + alachlor, which was at par to that of 2 hand-weedings (Table 2). The atrazine + alachlor mixture excelled over rest of the treatments by accounting 250.0% increase in net returns over weedy check; however, its effect was at par with that of 2 hand-weedings. Two hand-weedings and atrazine + pendimethalin, being at par, resulted in 233.3 and 218.4% increase in net returns over weedy check, respectively. The effect of atrazine + ethoxysulfuron was significantly inferior to rest of treatments but statistically superior over weedy check. The maximum benefit: cost ratio (2.19) was recorded by atrazine + alachlor, which was significantly greater than rest of the treatments. The order of significance was followed by atrazine + pendimethalin and 2 hand-weedings.

Soil enrichment with 40 kg S/ha recorded significantly the highest net returns, while 20 kg S/ha was significant over the control. The data show that compared to control, application of 40 and 20 kg S/ha resulted in 39.2 and 23.6% increase in net return, respectively. On an average, the benefit: cost ratio obtained through 40 kg S/ha (1.72) was significantly higher over 20 kg S/ha and control.

Nutrient uptake

In comparisons to weedy check, weed control by any means tended to significantly enhance nutrient uptake by crop. Amongst treatments, significantly higher N,P,K and S uptake were recorded under the influence of 2 hand-weedings at 15 and 30 days after sowing. These results were followed by those of pre-emergence application of atrazine + alachlor except for K uptake for which these 2 treatments were at par. Weed-control through atrazine + pendimethalin followed the order of significance. Out of all weed-control treatments, atrazine + ethoxysulfuron accounted for minimum uptake (Table 3). Nutrient uptake is the function of content and yield. Therefore, increase in grain and stover yields due to weed control can be reasoned for enhanced N,P, K and S uptake by the crop. Nutrient loss through uncontrolled weed growth throughout the crop season resulted in a loss of 7.3 kg N/ha, 1.2 kg P_2O_5/ha, 9.9 kg K_2O/ha and 1.0 kg S/ha (Table 3). Hand-weeding twice and tank-mix application of atrazine + ethoxysulfuron resulted in significantly lower nutrient uptake, whereas the results of these 2 treatments were significantly superior to the other treatments. Reduction in weed dry matter under different herbicide combinations and 2 hand-weedings were accompanied by corresponding reduction in per hectare removal of N,P,K and S.

Thus, in quality protein maize, weeds should be controlled by either 2 hand-weedings at 15 and 30 days after sowing or pre-emergence application of atrazine at 500 + alachlor at 1,500 g/ha and it should be fertilized with sulphur at 40 kg/ha.

REFRENCES

Bharathi, C., Poongothai, S. and Sangeetha, M. 2009. Effect of sulphur application on growth, nutrient uptake, yield and its use efficiency in maize. *Advances in Plant Sciences* **22**: 133–36.

Jamal, A., Moon, Y. and Abdin, M.Z. 2010. Sulphur–a general over-

Table 2. Effect of weed control and sulphur on yield attributes, yield and economics of quality maize protein (pooled data of 2 years)

Treatment	Grains/ row	Grain weight/ cob (g)	1,000-grains weight (g)	Yield (t/ha)		Protein content in grain (%)	Cost of production (× 10³ ₹/ha)	Net returns (× 10³ ₹/ha)	Benefit: cost ratio
				Seed	Stover				
Weed control									
Weedy check	13.8	32.7	178.9	2.09	3.63	9.31	16.6	11.7	0.69
Atrazine + alachlor	24.9	68.3	195.9	4.37	7.44	9.95	18.4	40.9	2.19
Atrazine + pendimethalin	23.8	64.0	193.4	4.10	7.10	9.86	18.6	37.2	1.97
Atrazine + ethoxysulfuron	21.1	53.6	185.9	3.43	5.08	9.77	22.9	22.4	0.97
Two hand-weedings	25.1	71.1	199.4	4.55	7.72	10.06	22.6	39.0	1.71
SEm±	0.56	1.31	2.40	0.08	0.14	0.09	-	0.98	0.05
CD (P=0.05)	1.58	3.70	6.79	0.24	0.40	0.26	-	2.77	0.14
Sulphur (kg/ha)									
Control	20.1	51.3	185.72	3.28	5.75	9.58	16.6	25.0	1.26
20	22.0	58.7	190.36	3.76	6.26	9.81	16.8	30.9	1.54
40	23.1	63.8	196.00	4.09	6.58	9.98	17.0	34.8	1.72
SEm±	0.43	1.01	1.86	0.06	0.11	0.07	-	0.76	0.04
CD (P=0.05)	1.22	2.86	5.26	0.18	0.31	0.20	-	2.15	0.11

Table 3. Effect of weed control and sulphur on nutrient uptake by crop and weeds (pooled data of 2 years)

Treatment	Uptake (kg/ha)							
	By crop				By weeds			
	N	P	K	S	N	P	K	S
Weed control								
Weedy check	61.0	14.5	60.2	10.3	7.3	1.2	9.9	1.0
Atrazine + alachlor	142.4	32.4	128.2	23.6	2.2	0.4	2.9	0.3
Atrazine + pendimethalin	132.0	30.2	121.4	21.9	2.5	0.4	3.4	0.3
Atrazine + ethoxysulfuron	102.3	23.8	89.1	17.3	1.5	0.3	2.0	0.2
Two hand-weeding	150.9	33.9	133.8	24.7	1.5	0.3	2.0	0.2
SEm±	2.1	0.5	2.1	0.4	0.05	0.009	0.06	0.007
CD (P=0.05)	6.1	1.4	5.9	1.1	0.13	0.027	0.17	0.019
Sulphur (kg/ha)								
Control	105.5	23.9	97.5	17.2	3.0	0.5	4.0	0.4
20	119.0	27.4	107.7	19.8	3.0	0.5	4.1	0.4
40	128.6	29.6	114.4	21.7	3.0	0.5	4.1	0.4
SEm ±	1.7	0.4	1.6	0.3	0.04	0.007	0.048	0.005
CD (P=0.05)	4.7	1.1	4.6	0.8	NS	NS	NS	NS

view and interaction with nitrogen. *Australian Journal of Crop Science* **4**: 523–29.

Le Baron, H.M., Farland, J.M. and Burnside, O.C. 2008. The triazine herbicides: 50 years revolutionary agriculture (In) *Herbicide Resistance in Plants*, Le Baron, H.M. and Gressel, J. (eds.) John Wiley & Sons, pp. 9–30.

Malik, Z., Parveen, S. and Khan, A. 2012. Zinc, boron and sulphur effects on yield and nutrient quality of maize. LAP Lambert Academy Publishing GmbH & Co. K.G., Deutshland, USA.

Ort, O. 2012. Newer Sulfonylureas. (In) *Modern Crop Production Compounds*. Kramer, W., Schirmer, U., Jeschke, P. and Witschel, M. (eds.). Wiley–VCH Verlag Gmb H & Co. K Ga A. pp 69–70.

Page, E.R., Cerrudo, D.,Westra, P., Loux, M., Smith. S., Foresman, C., Wright, H., Swanton, C.J. 2012. Why early season weed control is important in maize? *Weed Science* **60**: 423–30.

Prasanna, B.M., Vasal, S.K., Kassahun, B. and Singh, N.N. 2001. Quality protein maize. *Current Science* **81**: 1308–19.

Rao, A.S., Ratnam, M. and Reddy, T.Y. 2009. Weed management in zero-till sown maize. *Indian Journal of Weed Science* **41**: 46–49.

Sahrawat, K.L., Wani, S.P., Rego, S.P., Pardhasaradhi, G. and Murthy, K.V.S. 2007. Widespread deficiency of sulphur, boron and zinc in dryland soils of the semi-arid tropics. *Current Science* **93**: 1,428–32.

Sharma, C.K. and Gautam, R.C. 2010. Weed growth, yield and nutrient uptake in maize (*Zea mays*) as influenced by tillage, seed rate and weed control methods. *Indian Journal of Agronomy* **55**: 290–03.

Sunitha, N. and Kalyani, D.L. 2012. Weed management in maize (*Zea mays* L.)–A review. *Agricultural Reviews* **33**: 70–77.

Walia, U.S., Singh, S. and Singh, B. 2007. Integrated control of hardy weeds in maize (*Zea mays* L.). *Indian Journal of Weed Science* **39**: 17–20.