Research Article

Effect of Weed Management and Sulphur Fertilization on Weed Dynamics, Nutrient Depletion of Weed and Productivity of Mustard in Semi Arid Eastern Plain Zone of Rajasthan

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Abstract

Field experiment was conducted during winter 2014-15 and 2015-16 at agronomy research farm, Jobner, Rajasthan to evaluate the effect of weed management practices and sulphur fertilization on weed dynamics, nutrient depletion and productivity of mustard. Results indicated that two hand weeding at 25 and 45 DAS and pendimethalin at 0.75 kg/ha resulted in significant reduction in weed infestation and weed biomass production at different stages. The maximum weed control efficiency (WCE) was recorded with two hand weeding at 25 and 45 DAS followed by pendimethalin at 0.75 kg/ha being at par with one hand weeding at 25 with lowest N,P and K depletion. Two Hand weeding also remains superior w.r.t. seed yield (2493 kg/ha) and straw yield (7135 kg/ha). Application of pendimethalin also exhibited higher seed yield (2162 kg/ha) with minimum weed competition index (13.30 %). Among S levels application of 40 kg/ha to mustard resulted in significantly higher weed count, weed infestation and their dry weight at all the stages as well as highest N,P and K depletion by weeds at harvest stage. Application of 40 kg S/ha also produced 47.7 and 43.7 % more seed yield and straw yield over control (S_0). Overall pendimethalin and S application @ 40 kg/ha proved their superiority w.r.t. weed management, productivity in mustard in hot semi arid region of Rajasthan.

Keywords: Mustard, Nutrient depletion, Pendimethalin, S fertilization, Weed management

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Introduction

Oilseeds are main source of energy in the diet of Indians. Though, our country has become self-reliant with respect to food grains but still lagging behind in the production of oilseeds. India is a key player in the global oilseeds scenario with 12-15 per cent of oilseeds area, 6-7 per cent of vegetable oils production, 9-11 per cent of the total edible oils consumption and 14 per cent of vegetable oil imports. Indian mustard [*Brassica juncea* (L.) Czern and Coss] occupies a prominent place being next in importance to soybean and groundnut, both in area and production. In India, it is cultivated on 6.5 m ha with 7.8 mt production and 1208 kg/ha productivity [1]. In Indian mustard, weeds caused maximum damages in the initial 20 to 40 DAS [2]. For successful control of weeds during this stage, one HW at 25 to 30 DAS is enough, but in view of scanty availability of labour and ever increasing wages, the manual weed control has become cumbersome, labour intensive, time consuming and costly. Therefore, it has become essential to search out effective pre-plant incorporation (PPI) and/ or pre-emergence (PE) herbicide which can take care of early flush of weeds. It is obvious that sulphur is an important element for protein and oil synthesis in *Brassica* species. It is a component of amino acids like cysteine, cystine (27% S), methionine (20% S) and required for chlorophyll and protein synthesis. Sulphur is also involved in the synthesis of oil in oilseeds. Moreover, it is also associated with the synthesis of vitamins (biotin, thiamine), metabolism of carbohydrates, proteins and fats. Glucosinolates and thioglucosides are very much affected by the deficiency of sulphur in plants. Keeping all these view in mind present study was conducted to evaluate the effect of weed management practices and sulphur fertilization on weed dynamics, nutrient depletion and productivity of mustard.

Materials and Methods

The field experiment was conducted during the winter (*rabi*) 2014-15 and 2015-16 at Jober, Jaipur, Rajasthan ($27^0$05'N; $75^0$28'E, of above mean sea level). The soil was loamy sand having low organic carbon (0.21%) and available N (128.6 kg/ha), medimum in P (15.4 kg/ha) and K (148.6 kg/ha) and slightly alkaline (Ph 8.2). The experiment was laid out in split plot design with three replications. The main plot comprises seven weed – control treatments [weedy check; one HW at 25 DAS; two HW at 25 and 45 DAS; pendimethalin at 0.75 kg/ha (PE); trifluralin at 0.75 kg/ha (PPI); isoproturon at 1.0 kg/ha (PE) and oxyflourfen at 0.125 kg/ha (PE); and three sulphur levels (0, 20, 40 and 60 kg/ha) were taken as subplots. Mustard cultivars 'Lakshmi' was sown with standard package of practices. Three irrigations were applied to the crop. Rainfall received during the crop growing season was 21.40 and 3.60 mm in 2014-15 and 2015-16, respectively. Pre emergence application of pendimethalin (Dost 30 EC), isoproturon (Isoguard 75 WP) and oxyflourfen (Orbit 23.5 EC) was applied one day after sowing as per treatment. Trifluralin (Treflon 48 EC) was applied and mixed into the soil one day before sowing. A knapsack sprayer was used for spraying herbicides using a spray volume of 700 litres/ha. In the plot ear marked for hand – weeding, the operation was done at 25 and 45 DAS with the help of *Kassi* as per treatment. Half dose of nitrogen and full dose of phosphorus was applied as basal dose through urea and DAP, remaining half dose of nitrogen was top dressed at the time of first irrigation. Sulphur was applied and mixed into the soil through zypsum as per treatment before sowing. Sowing was done with 'kera' method in rows spaced at 30 cm with average depth of 5 cm and seed rate of 5 kg/ha. All the plant protection measures were adopted to take health crop. Methyl parathion dust at 25 kg/ha was applied to control mustard aphid. Total number of weeds were counted in each plot and analyzed after subjecting the original data to square root transformation ($\sqrt{(X+0.5)}$). Weed samples were taken for weed dry matter accumulation to find out the effect of various treatments on weed growth. For weed count, an area of 0.25 m^2 was selected randomly by a metallic quadrate of size 0.5x0.5 m at two places at 30 and 60 DAS and at harvest stage. Weed samples were first sun dried and then oven dried at at 70^{o}C till constant weight for dry matter accumulation. The N, P and K analysis was done as per standard method. The original data on weed density at all the stages were subjected to square root transformation before statistical analysis to analyze the significant effect of weed control treatments on weed growth. Net returns were calculated based on the seed, straw and prevailing market prices of mustard during the respective crop seasons. B: C ratio was calculated by dividing the gross returns from cost of cultivation. All the observation during individual years as well as in pooled analysis were statistically analyzed for their test of significance.

Results and Discussion

Weed flora in mustard

Results of continuous survey during experimentation showed that the crop was infested with a number of broad leaf and grassy weeds (**Table 1**). Among these, *Chenopodium album* and *Chenopodium* murale were the major dicot weeds that appear with the emergence of mustard crop. Whereas, *Heliotropium ellipticum*, *Verbasina enceloides* and *Melilotus alba* were found at later stage of crop growth. *Cyperous rotundus* and *Asphodelus tenuifolius* were among the weed species dominating during both the crop seasons.

Table 1 Major weed flora of the experimental fields

S. No.	Botanical name	Common name	English name	Family name	Growth habit
1.	*Chenopodium murale* L.	Khartua	Goosefoot	Chenopodiaceae	AD RS
2.	*Asphodelus tenuifolius Cavan*	Piazi	Wild onion	Liliaceae	AM RS
3.	*Chenopodium album* L.	Bathua	Lambsquarter	Chenopodiaceae	AD RS
4.	*Datura stramonium* L.	Datura	Thorn apple	Solanaceae	AD RS
5.	*Melilotus alba* L.	Safed senji	Sweet clover	Leguminoceae	AD RS
6.	*Spergula arvensis* L.	Satgathia/ ban dhania	Corn spurry	Caryophyllaceae	AD RS
7.	*Cynodon dactylon* L.	Doob grass	Bermuda grass	Poaceae	PM RS & RV
8	*Anagallis arvensis* L.	Krishnaneel	Pimpernel	Primulaceae	AD RS
9	*Launea asplenifolia* L.	Jangli gobhi	Wild gobhi	Asteraceae	AM RS
10	*Heliotropium ellipticum* Ledebour	Kamera	Heliotrope	Boraginaceae	AD RS
11	*Verbesina encelioides* Gray	Jungli surajmukhi	Golden crown	Asteraceae	AD RS
12	*Cyperus rotundus* L.	Motha	Purple nutsedge	Cyperaceae	PM RS & RV
13.	*Portulaca oleracea*	Purslane	Pig weed	Portulacaceae	AD RS

Table 2 Effect of weed control and sulphur levels on weed count (per 0.25 m^2), weed infestation (%) and weed dry matter production (kg/ha) at harvest stage. (pooled mean of two years)

Treatments	Weed count	Weed infestation (%)	Weed dry matter production
Weed control			
Weedy check	6.80 (45.75)	86.82	1523
One HW at 25 DAS	2.22 (4.45)	38.70	498
Two HW at 25 & 45 DAS*	1.55 (1.90)	20.17	155
Pendimethalin @ 0.75 kg/ha (PE)	2.31 (4.85)	39.50	484
Isoproturon @ 1.0 kg/ha (PE)	2.58 (6.16)	46.45	850
Oxyfluorfen @ 0.125 kg/ha (PE)	2.26 (4.62)	39.66	533
Trifluralin @ 0.75 kg/ha (PPI)	2.56 (6.07)	45.66	811
SEm±	0.06	0.58	16
CD (P=0.05)	0.16	1.70	47
Sulphur levels (kg/ha)			
0	2.75 (7.06)	44.02	637
20	2.86 (7.67)	44.76	688
40	2.94 (8.14)	45.64	712
60	3.05 (8.78)	46.69	736
SEm±	0.04	0.73	10
CD (P=0.05)	0.11	NS	28
Interaction (WxS)	NS	NS	Sig.

Table 3 Combined effect of weed control and sulphur levels on weed dry matter production (kg/ha) at different stages (pooled mean of two years)

Weed control	Sulphur levels (kg/ha)							
	60 DAS				At harvest			
	S_0	S_{20}	S_{40}	S_{60}	S_0	S_{20}	S_{40}	S_{60}
W0=Weedy check	960	1301	1267	1293	1363	1514	1555	1660
W1=One HW at 25 DAS	165	232	240	255	460	495	515	523
W2=Two HW at 25 & 45 DAS	89	123	130	135	145	154	159	162
W3=Pendimethalin @ 0.75 kg/ha (PE)	156	223	233	233	455	480	500	500
W4=Isoproturon @ 1.0 kg/ha (PE)	286	406	427	430	801	843	872	884
W5=Oxyfluorfen @ 0.125 kg/ha (PE)	177	223	258	264	491	528	550	563
W6=Trifluralin @ 0.75 kg/ha (PPI)	278	363	436	453	747	801	835	859
For S at same level of W								
SEm±				16.63				26.01
CD (P=0.05)				46.78				73.14
For W at same or different levels of S								
SEm±				16.93				27.75
CD (P=0.05)				48.11				79.05

Weed dynamics and weed dry matter

Effect of weed management practices

All the weed management practices (WMP) significantly reduces the weed count, weed infestation and weed dry matter production. The minimum weed count, weed infestation and dry matter at 60 and at harvest stage was observed with two hand weeding (HW) at 25 and 45 DAS followed by pendimethalin @ 0.75 kg/ha which control the weeds to the extent of 96.55, 90.10 and 89.82 % at 30, 60 and at harvest stage, respectively over the weedy check. However, it remained at par with one hand weeding at 25 DAS. The mean weed dry weight 1523 kg/ha obtained at harvest stage. This increase in density and dry weight of weeds under weedy check might be attributed to uninterrupted growth of weeds throughout the crop season. Heavy infestation of weeds and their dry matter accumulation under weedy check has been also reported by Singh *et al*. (2001) [3], Chandel and saxena (2001) [4] and Dutta *et al.* (2005) [5] in mustard crop.

One HW done at 25 DAS could retain the crop free from weeds for shorter period only and thereafter, population and dry weight of weeds increased progressively under this treatment due to later flushes of weeds and thus relatively higher density and dry weight was recorded at subsequent growth stages. Contrary to this, another HW done at 45 DAS under twice hand weeding treatment, controlled the second flush of weeds that emerged at later growth stages and thus provided the complete weed free environment throughout the season. The luxuriant crop growth observed in a weed free environment due to hoeing and aeration in rhizosphere during early stages and smothered weed growth altogether with a mean weed dry matter of 155 kg/ha recorded at harvest as against 1523 Kg/ha recorded under control. These results are in agreement with the finding of Chauhan *et al.* (2002) [6], Degra *et al*. (2006) [7] and Singh (2006) [8] in mustard. Significant reduction in density and dry matter of weeds at all the stages was also observed due to application of different herbicides as compared to weedy check and other treatments. The magnitude of weed control varied significantly among herbicides.

Pre emergence application of pendimethalin at 0.75 kg/ha recorded the mean weed density of 4.85 per 0.25 m^2 and weed dry weight of 484 Kg/ha at harvest stages, respectively that were significantly lower than weedy check. This treatment controlled the weeds to the extent of 68.1 per cent at harvest stage, in comparison to weedy check. However, it remained at par with one HW at 25 DAS treatment. Application of oxyfluorfen (PE) recorded the mean weed density of 4.62 per 0.25 m^2 and weed dry matter of 533 kg/ha at harvest stage, thereby registering significant decline of 65.0 per cent over weedy check. These results are in close conformity with the findings of Marmat *et al.* (2003) [9] in mustard crop.

The extent of weed control achieved with these herbicides *viz*. pendimethalin and oxyfluorfen seems to be due to their phytotoxic action on weeds. Being a dinitroaniline, pendimethalin exerts its herbicidal effect by inhibiting root and shoot growth of susceptible weed species. The inhibition of root growth is a direct and most spectacular observable symptom following its root absorption. Reduced shoot growth is probably a secondary effect caused by limited root growth. Disruption of ATP formation either by interfering with energy generating mechanism or by blocking the energy transfer mechanism of mitochondria or by both is considered to be the primary mode of action of dintroanilin mainly the pendimethalin applied as pre emergence in susceptible plant species [10]. Pendimethalin is known to be absorbed by germinating weeds and weed seedlings and disrupt cell division, especially mitotic process mostly in the meristematic tissues of weeds which are responsible for lateral and secondary root formation [11]. Hence, most of the weeds die within a few days of their emergence. It also has a role in micro tubular disruption and stops mitosis because it blocks synthesis of protein, nucleic acids (RNA and DNA) and other requisites for mitosis [12]. This herbicide controls broad leaf weeds more effectively than grasses. In present study, the dicots were far dominating than monocots. Hence, the total weed control due to this herbicide was on superior side. Pendimethalin inhibits root and shoot growth of susceptible weed species and prevents weeds from emerging, particularly during the crucial development phase of the crop. Hence, it is fairly conceivable that such inhibitrory effects of pendimethalin might have reduced the density and dry weight of weeds.

Oxyfluorfen is an effective herbicide to control broad leaf and grassy weeds as pre emergence treatment. This herbicide kills broadleaf weeds by destroying cell membranes within leaves and shoots. The most characteristic property of this herbicide is that their fast phototoxic action is strictly light – dependent. The first sign of herbicide injury is water- soaked appearance of the treated tissue, suggesting cell membrane lysis, mainly caused by peroxidative destruction of lipids and other cell constituents including chlorophyll and thus cell integrity is impaired.

Pre plant incorporation of trifluralin at 0.75 kg/ha observed 86.7 per cent lower population of weeds and registered 46.7 per cent reduction in weed dry matter at harvest stages, respectively than weedy check treatment. Application of isoproturon showed statistical equivalence with trifluralin. Trifluralin acts as a classic mitotic disrupter and arrests cell division at prometaphase. It also inhibits polymerization of tubulin, the major protein constituent of microtubules. Oxygen uptake and oxidative phosphorylation in mitochondria are also adversely affected due to its application. The net result is arrestation of cell division, formation of polynucleate cells and inhibition of root and plant growth [13]. Trifluralin is used to control annual grasses and certain broadleaf weeds. Trifluralin applied to the soil kills weed seeds as they germinate. It does not control established weeds. On the other hand, Isoproturon is a selective and systemic herbicide absorbed by the roots and leaves, with translocation. Isoproturon is a photosynthetic electron transport inhibitor at the photosystem II receptor site and thus checks the light dependent hill reaction. It is applied as pre- and post-emergence for control of annual grasses and many annual broad-leaved weeds in spring and winter wheat (except durum wheat), spring and winter mustard, winter rye and triticale at 1.0-1.5 kg a.i./ha. Its application results in chlorosis, growth retardation and ultimately the death of the susceptible plant.

Effect of S fertilization

Significantly higher density of weeds at 60 DAS and at harvest stages was recorded due to sulphur fertilization than control. The maximum value being at 60 kg/ha. Sulphur fertilization in mustard also significantly increased the weed dry matter accumulation at these stages. Being at par with 40 kg/ha, 60 kg S /ha recorded significantly higher weed dry matter than 20 kg/ha and control. Increase in density and dry matter of weeds might be attributed to the availability of sulphur in ample amounts leading to better nutritional environment for sustained growth and development of weeds. As sulphur is one of the important elements for growth and development of plants, increased availability of it in soil due to its external addition at increasing rates might have been directly responsible for huge amount of weed biomass production. Significant variation in weed density may be owing to the very high degree of competition among weed plants for nutrients, especially for S, to meet their growth requirement. The greater availability of S incurred due to its increasing addition sustained the growth of large number of rapidly growing weeds that would have otherwise been exterminated away under poor fertility levels. This could be assigned as the most crucial reason for lower weed density in control than higher levels of S fertilization. Similar findings were also reported by Nepalia and Jain (1998) [14] and Sewak *et al*. (2004) [15].

Nutrient concentration and depletion by weeds

Effect of weed management practice

The N, P and K concentration in weed dry matter and their depletion was significantly influenced due to weed control treatments (**Table 4**). The weedy check plots recorded the maximum mean depletion of 22.4, 3.6 and 21.5 of kg N, P and K/ha, respectively that was significantly higher than rest of the treatments. Contrary to this, minimum depletion of 2.9, 0.5 and 2.6 K/ha was registered under two hand weeding treatment. Pendimethalin at 0.75 kg/ha (8.6, 1.4 and 7.9 kg NPK/ha) and one HW at 25 DAS (8.2, 1.4 and 7.8 kg NPK/ha) were noted to be next superior and equally effective treatments in reducing nutrient depletion by weeds. These treatments reduced the N depletion by 61.6 and 63.4 per cent and P depletion by 61.1 and 61.1 per cent than weedy check treatment, respectively. The corresponding decrease in K depletion was 63.3 and 63.7 per cent. Oxyfluorfen was the next better treatment wherein 59.4, 58.3 and 60.5 per cent lower depletion of N, P and K was observed than weedy check. These treatments were followed by trifluralin at 0.75 kg/ha and isoproturon at 1.0 kg/ha. The reduction in nutrient depletion by weeds under these superior treatments might be attributed to the corresponding reduction in dry matter accumulation of weeds by effective weed control and smothering effect of crop exerted on weed growth. Similar results were also reported by Chandoliya *et al*. (2010) [16] and Mukharjee (2014) [17].

Table 4 Influence of weed control and sulphur levels on nutrient concentration and depletion in weed dry matter at harvest stage, weed control efficiency and weed competition index (pooled mean of two years)

Treatments	Nutrient concentration (%)			Nutrient depletion (kg/ha)			Weed control efficiency (%)		Weed competition index	
	N	P	K	N	P	K	30 DAS	60 DAS	At harvest	
Weed control										
Weedy check	1.46	0.239	1.41	22.4	3.6	21.5				45.17
One HW at 25 DAS	1.64	0.274	1.57	8.2	1.4	7.8	96.46	81.47	67.19	14.70
Two HW at 25 & 45 DAS	1.85	0.298	1.70	2.9	0.5	2.6	96.55	90.10	89.82	
Pendimethalin @ 0.75 kg/ha (PE)	1.77	0.286	1.64	8.6	1.4	7.9	92.42	82.43	68.14	13.30
Isoproturon @ 1.0 kg/ha (PE)	1.53	0.250	1.44	13.0	2.1	12.3	88.04	67.80	43.86	26.35
Oxyfluorfen @ 0.125 kg/ha (PE)	1.70	0.276	1.60	9.1	1.5	8.5	93.68	80.78	64.95	36.48
Trifluralin @ 0.75 kg/ha (PPI)	1.61	0.262	1.51	13.1	2.1	12.3	88.81	68.25	46.52	23.47
SEm±	0.03	0.005	0.03	0.2	0.0	0.3	1.29	1.10	0.92	-
CD (P=0.05)	0.09	0.014	0.08	0.7	0.1	0.7	3.77	3.22	2.68	-
Sulphur levels (kg/ha)										
0	1.47	0.242	1.41	9.0	1.5	8.8	79.42	68.44	53.21	
20	1.66	0.272	1.56	11.0	1.8	10.5	79.42	68.22	54.50	
40	1.73	0.280	1.60	11.9	1.9	11.0	79.42	66.21	54.06	
60	1.75	0.282	1.63	12.3	2.0	11.5	79.42	66.17	55.64	
SEm±	0.02	0.003	0.02	0.2	0.0	0.1	1.04	0.86	0.70	
CD (P=0.05)	0.06	0.009	0.05	0.5	0.1	0.4	NS	NS	NS	
Interaction (WxS)	NS	NS	NS	Sig.	Sig.	Sig.				

Application of trifluralin at 0.75 kg/ha and isoproturon at 1.0 kg/ha both at harvest stage showed comparatively poor performance than above described treatments in minimising the nutrient depletion, though, were found significantly better than weedy check. These treatments recorded 41.5 and 42.0 per cent lower N; 41.7 and 41.7 per cent lower P and 42.8 and 42.8 per cent lower K/ha than weedy check treatment, respectively, but could not control the weeds throughout the crop season as effectively as two HW, pendimethalin, one HW and oxyfluorfen treatments that was apparent in weed dry matter accumulation. Greater biomass of weeds so accumulated under weedy check might be attributed as the principal reason of higher nutrient depletion. Remaining at par among themselves, two hand weeding at 25 and 45 DAS and pendimethalin at 0.75 kg/ha registered higher N, P and K concentration in weeds than weedy check. It can be assigned to the high degree of competition for nutrient absorption among fast growing weeds themselves under infested conditions. On the other hand, due to sparse weed population in superior treatments, nutrient concentration in their dry matter was found to be more or less similar but more than weedy check. These results are in accordance with the findings of Dixit and Gautam (1996) [18] and Kumar *et al*. (2012) [19]

Table 5 Combined effect of weed control and sulphur level on nutrient depletion by weeds (kg/ha) at harvest stage (pooled mean of two years)

Weed control	**Sulphur levels (kg/ha)**											
	N depletion				**P depletion**				**K depletion**			
	S_0	S_{20}	S_{40}	S_{60}	S_0	S_{20}	S_{40}	S_{60}	S_0	S_{20}	S_{40}	S_{60}
W0=Weedy check	17.6	22.5	24.1	25.2	3.0	3.7	3.7	4.1	18.4	21.6	22.2	24.0
W1=One HW at 25 DAS	7.3	8.0	8.8	8.6	1.2	1.4	1.5	1.5	7.1	7.8	8.1	8.4
W2=Two HW at 25 & 45 DAS	2.4	2.8	3.1	3.2	0.4	0.5	0.5	0.5	2.2	2.5	2.9	3.0
W3=Pendimethalin @ 0.75 kg/ha (PE)	7.0	8.6	9.0	9.6	1.2	1.4	1.5	1.5	6.5	7.9	8.5	8.8
W4=Isoproturon @ 1.0 kg/ha (PE)	11.0	13.1	13.8	14.0	1.8	2.1	2.3	2.3	10.7	12.5	12.8	13.1
W5=Oxyfluorfen @ 0.125 kg/ha (PE)	7.3	9.1	9.9	10.1	1.2	1.5	1.6	1.6	7.2	8.6	9.0	9.3
W6=Trifluralin @ 0.75 kg/ha (PPI)	10.0	12.9	14.4	15.3	1.6	2.1	2.4	2.5	9.3	12.3	13.4	14.0
For S at same level of W												
SEm±				0.4				0.1				0.4
CD (P=0.05)				1.2				0.2				1.1
For W at same or different levels of S												
SEm±				0.4				0.1				0.4
CD (P=0.05)				1.3				0.2				1.2

Table 6 Effect of weed control and sulphur levels on seed, straw yield (kg/ha)

Treatments	**Seed yield (kg/ha)**	**Straw yield (kg/ha)**
Weed control		
Weedy check	1367	4465
One HW at 25 DAS	2127	6228
Two HW at 25 & 45 DAS	2493	7135
Pendimethalin @ 0.75 kg/ha (PE)	2162	6257
Isoproturon @ 1.0 kg/ha (PE)	1836	5647
Oxyfluorfen @ 0.125 kg/ha (PE)	1584	5024
Trifluralin @ 0.75 kg/ha (PPI)	1908	5679
SEm±	41.34	130.42
CD (P=0.05)	120.67	380.68
Sulphur levels (kg/ha)		
0	1428	4433
20	1995	5775
40	2109	6359
60	2167	6538
SEm±	27.10	88.04
CD (P=0.05)	76.21	247.61

Effect of sulphur fertilization

The highest concentration of N, P and K in weed dry matter was observed at 60 kg/ha. Significantly higher depletion of N and P by weeds was recorded up to 40 kg S/ha, whereas, K depletion showed significant response up to 60 kg

S/ha. N, P and K depletion by weeds in response to applied S followed the same trend of its effect on dry matter accumulation by weeds. The increased availability of S in rhizosphere due to its addition led to more and more absorption of this nutrient from soil to meet the growth requirement of fast growing weeds in comparison to the plots that were poorly fertilized with S or no fertilization was done. It seems the principal reason of higher nutrient concentration in weeds in response to applied S. The huge biomass of weeds accumulated under 60 kg S/ha with a concomitant increase in its nutrient concentration appeared to be directly responsible for higher depletion of N, P and K depletion by weeds.

Mustard productivity

Effect of weed management practices

Two HW done at 25 and 45 significantly produced the maximum seed (2493 kg/ha) and straw (7135 kg/ha). Two hand weeding treatment provided the long time weed control and hence resulted in appreciably higher yields over to unweeded plots. Pre emergence application of pendimethalin at 0.75 kg/ha and one HW at 25 DAS were the next superior and equally effective treatments in enhancing yield of mustard. These treatments improved the seed yield by margin of 58.2 and 55.6 per cent over weedy check. The corresponding increase in straw yield was 40.1 and 39.5 per cent. Remaining at par with each other, trifluralin at 0.75 kg/ha and isoproturon at 1.0 kg/ha also gave 39.6 and 34.3 per cent higher seed yield and 27.2 and 26.5 per cent higher straw yield over weedy check, but they were found inferior to above described treatments. The higher seed and straw yield obtained under superior treatments could be better explained with effectiveness in weed control in comparison to control. These treatments kept the crop almost weed free up to 40-50 DAS which resulted significant reduction in competition for nutrients and other growth resources by weeds as a consequence of which reduction in dry matter and nutrient depletion by weeds occurred. Reduced weed-crop competition under these superior treatments saved a considerable amount of nutrients for crop growth that led to enhanced crop growth by utilizing greater moisture and nutrients from deeper soil layers. These favourable effects in rhizosphere were more conspicuous in HW twice and one HW treatments as these improved soil tilth by making it loose and porous and thus vulnerable for the plants to utilize water and air. Under weed infested condition, although, the vegetative growth reached up to a level but the sink was not sufficient enough to accumulate the meaningful photosynthates translocating towards seed formation. Similar results were also reported by Degra *et al*. (2011) [20] and Yadav *et al*. (2014) [21].

Effect of sulphur fertilization

The seed and straw yield of mustard significantly increased with progressive increase in level of S up to 40 kg/ha. However, further increase in its level to 60 kg/ha was not up to the level of significance. This may be attributed to the increasing levels of S which resulted in greater accumulation of carbohydrates, protein and their translocation to the reproductive organs, which in turn might have improved all the growth and yield determining characters, resulting more seed yield. As seed yield is primarily a function of cumulative effect of yield attributing characters, the higher values of these attributes can also be assigned as the most probable reason for significantly higher seed yield. Dubey *et al*. (2013) [22] have also documented significant and positive influence of sulphur application on yield of mustard crop. Straw yield also recorded higher with increasing rates of S application. It might be due to improved biomass per plant at successive growth stages and increase in various morphological parameters like plant height, number of branches/plant etc.

Conclusion

Thus, two HW done at 25 and 45 DAS and application of sulphur at 40 kg/ha significantly decreased the weed count, weed infestation and weed control efficiency and increased yield of mustard crop as compared to another treatments. From profitability point of view, pendimethalin at 0.75 kg/ha in combination with 40 kg S/ha proved the best herbicidal treatment in achieving higher profitability under semi arid eastern plan zone of Rajasthan.

References

[1] Anonymous, 2013-14. Strategic Interventions to enhance oilseed production in India. February 19-21, 2015. http://www.isorseminar.com.

[2] Bhan, V.M. and Mishra, J.S. 1993. Improving crop productivity through weed management. Pesticide information 19(3): 25-26.

[3] Singh, H., Singh, B.P. and Prasad, H. 2001. Weed management in Brassica species. Indian Journal of Agronomy 46(3): 533-537.
[4] Chandel, A.S. and Saxena, S.C. 2001. Effect of some new post emergence herbicides on weed parameters and seed yield of soybean (Glycin max.). Indian journal of Agronomy 46(2): 332-338.
[5] Dutta, D., Bandyopadhyay, P. and Paramita, B. 2005. Integrated weed management in rainfed groundnut (Arachis hypogaea) in acid lateritic soils of West Bengal. Journal of crop and weed 2(1): 47-51.
[6] Chauhan D.R., Ram, M, and Singh, I. 2002. Response of Indian mustard to irrigation and fertilization with various sources and levels of sulphur. Indian Journal of Agronomy 47(3): 422-426.
[7] Degra, M.L., Shivran, R.K. and Sharma, R. 2006. Integrated weed management in Indian mustard. Indian Journal of weed sciences 38(3&4): 274-275.
[8] Singh, R. 2006. Effect of cropping sequence, seed rate and weed management on weed growth and yield of Indian mustard in Western Rajasthan. Indian Journal of weed science research 38(1&2): 69-72.
[9] Marmat, K.B., Hussain, Z.K., Ijaz, A., and Gul, B. 2003. Impact of weed management on rapeseed. Pakistan Journal of Weed Science Research 9(3&4): 207-214.
[10] Wang, B., Grooma, S. and Frans, R.F. 1974. Response of soybean mitochondria to subsituted dinitroaniline herbicides. Weed Science 22: 64-66.
[11] Ashton, F.M. and Crafts, A.S. 1973. Mode of action of herbicides. John Willey and Sons, New York.
[12] Devine, M.D., Duke, S.O. and Sedtake, C.A. 1993. Physiology of herbicides action. PTR prentice Hall, Engleweed Cliffs, New Jersey.
[13] Rao, V.S. 2000. Mechanism of action of herbicides. (In) Principles of Weed Science (2nd Edn.). Oxford and IBH Publishing Co. Pvt. Ltd. : 145-198.
[14] Napalia, V. and Jain, L. 1998. Effect of weed and sulphur management on weed dynamics and crop-weed competition for nutrients in Indian mustard (Brassica juncea (L.) Czern & Coss). Indian Journal of Weed Science 30(1&2): 44-47.
[15] Sewak, R., Shah, D. and Singh, A.K. 2004. Effect of weed control measures and sulphur levels on growth and yield of Indian mustard cv. pusa bold. Technofame A journal of Multidisciplinary Advance Research: 73-79.
[16] Chandolia, P.C., Dadheech, R.C., Solanki, N.S. and Mundra, L.S. 2010. Weed management in groundnut under varying crop geometry. Indian Journal of Weed Science 42(3&4): 235-237.
[17] Mukharjee, D. 2014. Influence of weed and fertilizer management on yield and nutrient uptake in mustard. Indian Journal of Weed Science 46(3): 251-255.
[18] Dixit, A. and Gautam, K.C. 1996. Nutrient concentration and its depletion in Indian mustard as influenced by fertilizer, irrigation and weed control. Indian Journal of Agronomy 41(1): 167-169.
[19] Kumar, S., Kumar, A., Rana, S.S., Chander, N. and Angrias, N.N. 2012. Integrated weed management in mustard. Indian Journal of Weed Science 44(3): 139-143.
[20] Degra, M.L., Pareek, B.L., Shivran, R.K. and Jat, R.D. 2011. Integrated weed management in Indian mustard and its residual effect on succeeding pearl millet. Indian Journal of Weed Science 43 (1&2): 73-76.
[21] Yadav, J.P., Banga, R.S., Yadav, A. and Bajiya, R. 2014. Integrated weed management in groundnut (Arachis hypogaea L.). Indian Journal of Agricultural Sciences 70(3): 493-500.
[22] Dubey, S.K., Tripathi, S.K. and Singh, B. 2013. Effect of sulphur and zinc level on growth, yield and quality of mustard. Reserch & Reviews: A Journal of Crop Science and Technology 2(1):1-11.

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