Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(3): 571-575
Received: 20-03-2019
Accepted: 22-04-2019

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Effect of weed management and sulphur fertilization on nutrient content and nutrient uptake by Mustard (*Brassica juncea* (L.) Czern & Coss) under semi arid condition of Rajasthan

Rajesh Kumar, SS Yadav, Pratap Singh, HP Verma and Neelam Yadav

Abstract
A field experiment was conducted during *rabi* 2014-15 and 2015-16 at Agronomy farm, Jobner, Rajasthan to evaluate effect of weed management practices and sulphur fertilization on Nutrient content and nutrient uptake of mustard (*Brassica juncea* (L.) Czern & Coss). The result indicated that among weed management practices, the highest seed & Biological yield (2493 kg/ha & 9628 kg/ha) were obtained with two HW treatment which was significant rest over the treatment. Two HW treatment and pendimethalin @ 0.75 kg/ha (PE) were found significantly better treatments in enhancing N, P & S concentration in Seed and straw as well as their uptake, protein content in seed. Application of Sulphur at 60 kg/ha in mustard improved the nutrient concentration in seed, Straw and their uptake by crop.

Keywords: Mustard, pendimethalin, S fertilization, nutrient uptake and hand weeding

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.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 7.98 mt production and 1208 kg/ha productivity (Anonymous 2017-18) [1]. Indian mustard is predominantly cultivated in the states of Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, Gujarat, Punjab and Bihar. Rajasthan state contributed major part of 2.53 m ha with 3.25 mt production and 1287 kg/ha productivity. Thus, it has major share in area (46%) and production (49%) of mustard in our country. Indian mustard suffers more from weed competition in early growth stage for light, water and nutrient including CO_2. Heavy weed growth is a major recognized bottleneck in realizing the yield potential of mustard. Weeds appear to be the most serious menace in crop production due to their extensive losses. Yield losses due to weeds varied from 25 to 45 per cent depending on the type of weed flora and their intensity, stages, nature and duration of crop weed competition (Singh *et al*., 2001) [10]. Sulphur deficiency also results in poor flowering, cupping of leaves, reddening of stem and petiole and stunted growth. In early 1990s, S deficiency in Indian soils was estimated to occur in about 130 districts (Tandon, 1991) [11]. Recently, Singh (2000) [9] has reported that about 45% districts of the country showed more than 40% S deficiency.

Materials and methods
The field experiment was conducted during the winter (*rabi*) 2014-15 and 2015-16 at Jobner, 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 comprised 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 cultivar '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 oxyfluorfen (Orbit 23.5 EC) was applied one day after sowing as per treatment. Trifluralin (Treflan 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 plots 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 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 '*pora*' 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. At maturity stage, after leaving two rows on each side as well as 50 cm along the width of each side, a net plot area of 3 m x 1.8 m was harvested separately for recording the yield attributes and yields. The harvested material was tied and tagged and kept on threshing floor sun drying. Mustard seeds were cleaned by winnower and yield was recorded. Straw yield was obtained by subtracting seed yield from total biomass yield. Yield was expressed in kg/ha. The Nutrient concentration in seed and straw yield were determined by standard method. The uptake/accumulation of nutrient in mustard seed and straw was calculated by multiplying the dry matter yield with their concentration. All the observation during individual years as well as in pooled analysis were statistically analyzed for their test of significance using the *F*-test (Gomez and Gomez, 1984). The significant of difference between treatment means were compared with t critical difference at 5% level of probability.

Results and Discussion

Yield, Nutrient concentration and uptake by crop

Effect of weed management practices

Weed control: Pooled results showed that two HW done at 25 and 45 DAS produced the maximum seed yield of 2493 kg/ha that was significantly higher over rest of treatments (Table 1). It registered a huge increase of 15.30, 17.20, 30.66, 35.78, 57.38 and 82.37 per cent in seed yield over pendimethalin at 0.75 kg/ha, one HW at 25 DAS, trifluralin at 0.75 kg/ha, isoproturon at 1.0 kg/ha, oxyfluorfen at 0.125 kg/ha and weedy check treatments, respectively. Application of pendimethalin at 0.75 kg/ha was found to be the next better and most effective herbicidal treatment. It produced the mean seed yield of 2162 kg/ha thereby indicating a quantum increase of 254, 326, 578 and 795 kg/ha over trifluralin at 0.75 kg/ha, isoproturon at 1.0 kg/ha, oxyfluorfen at 0.125 kg/ha and weedy check treatements, respectively. Two hand weeding treatment provided the long time weed control and hence resulted in appreciably higher yields over to unweeded plots.

Weed control treatments differed widely in influencing the N, P and S concentration and their uptake in seed and straw of mustard (Table 2 & Fig 1). Pooled analysis showed that all the treatments recorded significantly higher concentration of N, P and S in seed and straw over weedy check, except oxyfluorfen at 0.125 kg/ha in straw. The maximum concentration of N in seed was observed in two HW at 25 and 45 DAS treatment (3.55%) that was closely accompanied by pendimethalin at 0.75 kg/ha (3.49%) and one HW at 25 DAS (3.41%). These three treatments significantly enhanced the N concentration in seed to the tune of 31.8, 21.8 and 16.8 per cent over weedy check treatment, respectively. Similar response under these treatments was also noted in N concentration in straw wherein, the corresponding increase was 28.7, 26.4 and 24.0 per cent. However, the difference in N concentration in seed and straw among these three treatments was not up to level of significance. The maximum concentration of P in seed was observed in two HW at 25 and 45 DAS (0.867%) that was followed in the order of pendimethalin at 0.75 kg/ha (0.842%) and one HW at 25 DAS (0.834%). However, the difference in P concentration among these three treatments was not of statistical significance. Maximum concentration of S in seed was observed in two HW treatment (0.839%) that was closely followed by pendimethalin (0.823%) and one HW at 25 DAS treatment (0.821%). However, these three treatments were at par among themselves. These treatments also showed their superiority in recording higher S concentration in straw of mustard.

A perusal of data indicated that protein content in mustard seed was significantly improved due to all the weed control measures during pooled analysis except oxyfluorfen at 0.125 kg/ha. The maximum protein content (22.19%) was recorded under two hand weeding treatment that was closely followed by pendimethalin at 0.75 kg/ha and one HW at 25 DAS.

Pooled data showed that N, P and S uptake in mustard was significantly improved due to all the weed control treatments in comparison to weedy check. Pooled data showed that recording the highest uptake of 146.9 kg N/ha, two hand weeding treatment excelled rest of the treatments. Pendimethalin at 0.75 kg/ha and one HW at 25 DAS were the next superior and equally effective treatments, wherein, 83.9 and 78.4 per cent increase over weedy check treatment was observed. Being at par with each other, trifluralin at 0.75 kg/ha and isoproturon at 1.0 kg/ha also improved the N uptake by 53.7 and 45.5 per cent over weedy check treatment. The lowest increase of 19.6 per cent over weedy check was observed under oxyfluorfen at 0.125 kg/ha treatment.

Two HW at 25 and 45 DAS produced the highest mean uptake of 41.2 kg P/ha that was significantly superior among all the treatments. This treatment remarkably increased the P uptake to the tune of 15.1, 19.8, 37.8, 48.7, 83.1 and 114.6 per cent over pendimethalin, one HW at 25 DAS, trifluralin, isoproturon, oxyfluorfen and weedy check treatments, respectively. Pendimethalin at 0.75 kg/ha and one HW at 25 DAS were found the next superior and equally treatments in this regards that increased the P uptake by margin of 86.5 and 79.2 per cent, respectively over weedy check. Trifluralin at 0.75 kg/ha and isoproturon at 1.0 kg/ha were next better and statistically similar treatments that enhanced the P uptake by magnitude of 55.7 and 44.3 per cent over weedy check. The lowest increase in P uptake over weedy check was recorded under oxyfluorfen at 0.125 kg/ha treatment.

Recording the highest uptake of 40.6 kg S/ha, two HW at 25 and 45 DAS surpassed rest of the treatments in this respect. It increased the S uptake by huge margin of 17.7, 19.8, 41.0, 51.5, 94.3 and 129.4 per cent over pendimethalin, one HW at 25 DAS, trifluralin, isoproturon, oxyfluorfen and weedy check treatments, respectively. Pendimethalin at 0.75 kg/ha and one hand weeding at 25 DAS were the next superior and equally effective treatments in this regards that witnessed 94.9 and 91.5 per cent higher uptake of S than weedy check, respectively. These were followed in the order of trifluralin at 0.75 kg/ha (28.8 kg/ha) and isoproturon at 1.0 kg/ha (26.8 kg/ha). However, these treatments were also found at par with each other. Oxyfluorfen at 0.125 kg/ha recorded the lowest uptake of 20.9 kg S/ha by crop which was 18.1 per cent more than recorded under weedy check treatment.

Superiority of the treatments described above is directly associated with similar variation in weed control and dry matter accumulation. These treatments provided almost weed free environment to crop at early growth stages, wherein the major portion of the basal dose of fertilizer applied to the soil

was available for crop in contrast to weedy check. Similarly, at later stages, the applied nutrients under weedy check were absorbed mainly by weeds due to their greater competitiveness and better root system. More availability of nutrients for the crop under comparatively weed free situation under superior treatments might have increased their concentration in the plants, which ultimately resulted in higher crop dry matter and yields. Thus, increase in crop dry matter and seed and straw yields with a concomitant increase in nutrient concentration seemed to be the most important reason of higher uptake of nutrients by crop under these treatments. Similar results were also reported by Nepalia and Jain (1998) [7], Chandolia *et al.* (2010) [2], Madhu *et al.* (2005) [6] and Kumar *et al*. (2012) [5]. As protein content in seed is a function of its N concentration, therefore, higher concentration of N in seed under these superior treatments seems to be the only reason of attaining higher protein content in mustard seed (Sharma *et al.,* 2002) [8].

Effect of Sulphur levels

Results showed that increasing levels of S fertilization significantly increased the seed yield of mustard up to 40 kg/ha over lower levels pooled analysis (Table 1). Application of sulphur at 40 kg/ha provided the seed yield 2109 kg/ha that was 5.7 and 47.7 per cent more than obtained under 20 kg S/ha and control, respectively. However, it was found at par with 60 kg S/ha which also increased the seed yield by magnitude of 172 and 739 kg/ha over 20 kg/ha and control, respectively.

It is also evident from the pooled data that every increase in graded levels of S showed significant increase in N concentration and protein content up to 40 kg/ha in seed of crop. However, significant increase in straw during individual years and pooled analysis was noted up to 20 kg S/ha, only. The maximum mean concentration of N was recorded at 60 kg S/ha that was higher by 11.9 and 29.8 per cent in seed and 4.9 and 28.1 per cent in straw over 20 kg S/ha and control, respectively. Application of sulphur at 40 and 60 kg/ha improved the mean protein content by 11.3 and 29.0 per cent over 20 kg/ha and 12.0 and 29.8 per cent over control, respectively. However, the difference between these levels was not of statistical significance. Successive increase in level of S showed significant increase in P concentration up to 40 kg/ha in seed and 20 kg/ha in straw of mustard, respectively during individual years as well as in pooled analysis. The maximum mean P concentration of 0.840 and 0.272 per cent in seed and straw was recorded at 60 kg S/ha. However, it was statistically at par with 40 kg S/ha. Application of sulphur at 40 and 60 kg/ha significantly increased the S concentration by 33.8 and 33.9 per cent in seed and 16.0 and 17.8 per cent in straw of mustard over control. However, these two levels of S fertilization showed statistical equivalence with each other. It is also evident from the pooled data that successive increase in level of S resulted significant improvement in uptake of N and P by crop up to 40 kg S/ha. It attained the mean uptake of 124.3 kg N/ha that was 16.0 and 86.6 per cent more than 20 kg S/ha and control, respectively. This level of S resulted in P uptake of 34.9 kg/ha which was higher by 13.3 and 90.7 kg/ha over 20 kg/ha and control, respectively. Further increase in its level to 60 kg/ha, though maximized the N uptake (129.13 kg/ha), but the increase over 40 kg/ha was not of statistical importance. The maximum uptake of 36.45 kg P/ha was noted at 60 kg S/ha but it showed statistical equivalence with 40 kg/ha. Application of sulphur at 40 and 60 kg/ha significantly increased the S concentration by 33.8 and 33.9 per cent in seed and 16.0 and 17.8 per cent in straw of mustard over control. However, these two levels of S fertilization showed statistical equivalence with each other.

It is also evident from the pooled data that successive increase in level of S resulted significant improvement in uptake of N, P and S by crop up to 40 kg S/ha. It attained the mean uptake of 124.3 kg N/ha that was 16.0 and 86.6 per cent more than 20 kg S/ha and control, respectively. This level of S resulted in P uptake of 34.9 kg/ha which was higher by 13.3 and 90.7 kg/ha over 20 kg/ha and control, respectively. It also recorded the S uptake of 33.8 kg/ha that was higher by 17.8 and 81.7 per cent over 20 kg/ha and control, respectively. Further increase in its level to 60 kg/ha, though maximized the N uptake (129.13 kg/ha), but the increase over 40 kg/ha was not of statistical importance. The maximum uptake of 36.45 kg P/ha was noted at 60 kg S/ha but it showed statistical equivalence with 40 kg/ha. Further increase in its level to 60 kg/ha, though maximized the S uptake (35.1 kg/ha) but the difference between 40 and 60 kg S/ha was not up to the level of significance.

The positive influence of S application on nutrient concentration in crop appears to be due to improved nutrimental environment in rhizosphere as well as in plant system. The adequate supply of S in early crop season resulted in greater availability of nutrients including P and S and of N in particular in the root zone depth of the soil. Increased availability of these nutrients coupled with accelerated metabolic activities at the cellular level probably might have increased the nutrient uptake and their accumulation in various parts of the plant. This accumulation of nutrients especially S in plant parts possibly with greater metabolism led to greater translocation of these nutrients to reproductive parts of the crop which appears to be the most probable reason of higher nutrient concentration in seed and straw due to S fertilization. Nitrogen and sulphur are the main ingredients of protein and increase in their availability increase the utilization of nitrogen for the synthesis of protein (Finalayson *et al*. 1970) [4]. Sulphur synthesized some sulphur containing amino acids like cystine, cysteine and methionine and resulted increase in protein content which is in accordance with the findings of Dubey *et al*. (2013) [3]. Significant variation in S concentration can also be attributed to higher functional activity of roots for longer duration under higher levels of S. Increased biomass production of the crop at harvest in terms of seed and straw yield together with higher nutrient concentration might be assigned as the main reason of significantly higher uptake of N, P and S by crop due to S fertilization.

Interaction effect

Interactive effect of weed control treatments and S fertilization was also found to significantly influence the total uptake of N,P and S by crop in pooled analysis (Table 3 & Fig. 2). Pooled data showed that N uptake under most of the weed control treatments increased with increasing levels of S up to 40 kg/ha except weedy check, where response was noted up to 20 kg S/ha, only. The maximum uptake of 177.0 kg N/ha was recorded when two hand weeding treatment was integrated with 60 kg S/ha (W_2S_{60}) thereby indicating an increase of 133.7 kg N/ha over unfertilized weedy check (W_0S_0), wherein the minimum uptake of 43.3 kg N/ha was recorded. However, it was found at par with W_2S_{40}. Pooled analysis of data showed that response of crop to increasing levels of S application in terms of P uptake under most of the weed control treatments was observed up to 20 kg/ha, though, the maximum uptake was noted with integration of 60 kg

S/ha. The maximum uptake of P (49.9 kg/ha) was recorded when two HW at 25 and 45 DAS was combined with 60 kg S/ha (W_2S_{60}). However, it was found at par W_2S_{40}. These two treatment combinations improved the P uptake to the extent of 315.8 and 289.2 per cent over W_0S_0, wherein the lowest mean uptake of 12.01 kg P/ha was recorded. All the weed control treatments responded positively and significantly to every increase in S level up to 40 kg/ha in regard of recording S uptake except weedy check and pendimethalin, wherein significant response was noted up to 20 kg S/ha, only. However, the maximum values of S uptake under all the treatments was found under their integration with 60 kg S/ha. Two HW at 25 and 45 DAS combined with 60 kg S/ha (W_2S_{60}) recorded the highest uptake of 48.7 kg S/ha. However, it showed statistical similarity with W_2S_{40} (46.59 kg/ha). These two combinations registered quantitative increase of 36.5 and 34.4 kg/ha, respectively in S uptake over unfertilized weedy check (W_0S_0), wherein, the lowest mean uptake of 12.2 kg S/ha was obtained.

Table 1: Effect of weed control and sulphur levels on seed, biological yield (kg/ha) and harvest index (%)

Treatments	Seed yield	Biological yield	Harvest index
Weed control			
Weedy check	1367	5832	23.28
One HW at 25 DAS	2127	8354	25.40
Two HW at 25 & 45 DAS	2493	9628	25.87
Pendimethalin @ 0.75 kg/ha (PE)	2162	8419	25.65
Isoproturon @ 1.0 kg/ha (PE)	1836	7483	24.58
Oxyfluorfen @ 0.125 kg/ha (PE)	1584	6608	23.97
Trifluralin @ 0.75 kg/ha (PPI)	1908	7587	25.16
SEm±	41.34	169.37	0.42
CD (P=0.05)	120.67	494.36	1.24
Sulphur levels (kg/ha)			
0	1428	5861	24.23
20	1995	7770	25.49
40	2109	8468	24.81
60	2167	8706	24.85
SEm±	27.10	111.08	0.26
CD (P=0.05)	76.21	312.40	0.72

Table 2: Effect of weed control and sulphur levels on N, P and S concentration (%) in seed and straw of mustard (Pooled mean of two year)

Treatments	N (%)		P (%)		S (%)		N – uptake	P-uptake	S – uptake	Protein content
	Seed	Straw	Seed	Straw	Seed	Straw				
Weed control										
Weedy check	2.92	0.613	0.712	0.207	0.635	0.198	68.2	19.2	17.7	18.25
One HW at 25 DAS	3.41	0.760	0.834	0.261	0.821	0.256	121.7	34.4	33.9	21.28
Two HW at 25 & 45 DAS	3.55	0.789	0.867	0.267	0.839	0.268	146.9	41.2	40.6	22.19
Pendimethalin @ 0.75 kg/ha (PE)	3.49	0.775	0.842	0.275	0.823	0.260	125.4	35.8	34.5	21.78
Isoproturon @ 1.0 kg/ha (PE)	3.19	0.696	0.764	0.236	0.736	0.230	99.2	27.7	26.8	19.94
Oxyfluorfen @ 0.125 kg/ha (PE)	3.08	0.632	0.727	0.214	0.663	0.204	81.6	22.5	20.9	19.22
Trifluralin @ 0.75 kg/ha (PPI)	3.24	0.729	0.784	0.250	0.774	0.240	104.8	29.9	28.8	20.22
SEm±	0.07	0.012	0.015	0.005	0.015	0.005	2.4	0.8	0.8	0.41
CD (P=0.05)	0.20	0.034	0.044	0.014	0.043	0.015	7.1	2.3	2.2	1.19
Sulphur levels (kg/ha)										
0	2.75	0.599	0.703	0.181	0.622	0.213	66.6	18.3	18.6	17.20
20	3.19	0.731	0.778	0.258	0.735	0.235	107.2	30.8	28.7	19.93
40	3.55	0.755	0.838	0.265	0.832	0.247	124.3	34.9	33.8	22.19
60	3.57	0.767	0.840	0.272	0.833	0.251	129.1	36.5	35.1	22.32
SEm±	0.04	0.009	0.010	0.003	0.010	0.004	1.8	0.6	0.6	0.27
CD (P=0.05)	0.11	0.024	0.029	0.008	0.028	0.010	5.0	1.6	1.6	0.76
Interaction (WxS)	-	-	-	-	-	-	Sig.	Sig.	Sig.	-

Table 3: Combined effect of weed control and sulphur level on total nutrient uptake by crop (kg/ha) at harvest stage (pooled mean of two year

Weed control	Sulphur levels (kg/ha)											
	N uptake				P uptake				S uptake			
	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	43.3	70.1	79.4	80.0	12.0	19.2	23.0	22.7	12.2	17.9	20.5	20.2
W1=One HW at 25 DAS	72.8	125.8	140.6	147.6	21.1	35.6	39.2	41.7	21.3	32.7	39.9	41.5
W2=Two HW at 25 & 45 DAS	90.8	150.2	169.4	177.0	25.7	42.3	46.7	49.9	25.5	41.6	46.6	48.7
W3=Pendimethalin @ 0.75 kg/ha (PE)	79.1	129.2	144.3	149.1	22.5	37.5	40.6	42.7	21.4	36.2	39.2	41.2
W4=Isoproturon @ 1.0 kg/ha (PE)	63.4	99.2	115.6	118.4	17.2	29.0	31.8	33.0	17.3	26.9	31.1	32.1
W5=Oxyfluorfen @ 0.125 kg/ha (PE)	52.7	78.0	96.1	99.4	14.3	22.7	26.3	26.8	14.2	19.8	24.7	25.0
W6=Trifluralin @ 0.75 kg/ha (PPI)	64.1	98.0	124.9	132.3	15.5	29.3	36.5	38.2	18.1	26.0	34.5	36.7
For S at same level of W												
SEm±				4.7				1.5				1.5
CD (P=0.05)				13.1				4.3				4.2
For W at same or different levels of S												
SEm±				4.7				1.6				1.5
CD (P=0.05)				13.4				4.4				4.3

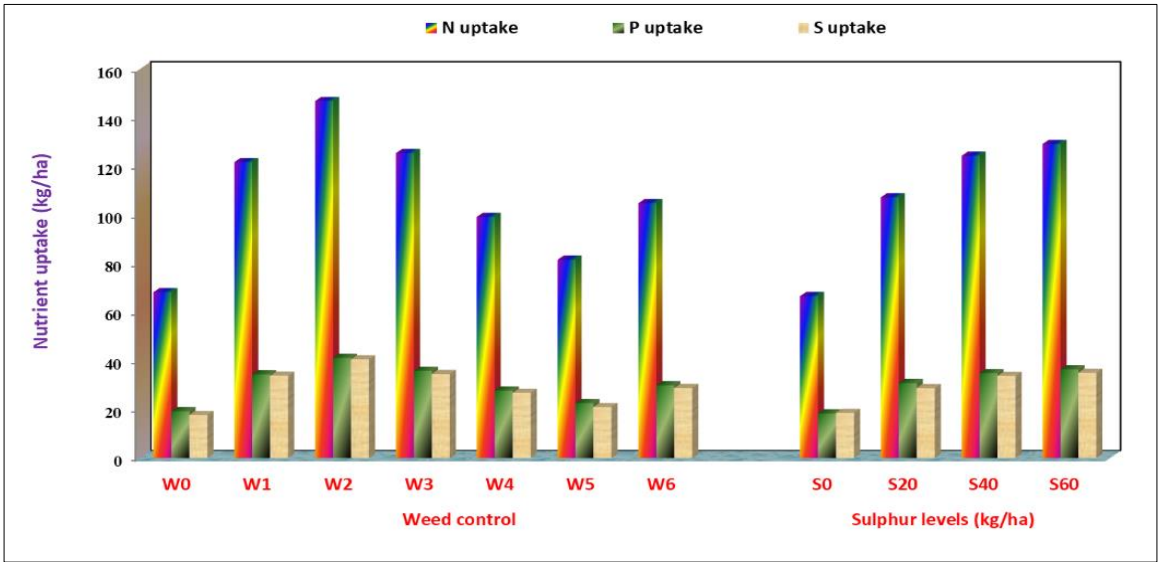

Fig. 1: effect of weed control and sulphur levels on total nutrient uptake (kg/ha) by crop at harvest stage

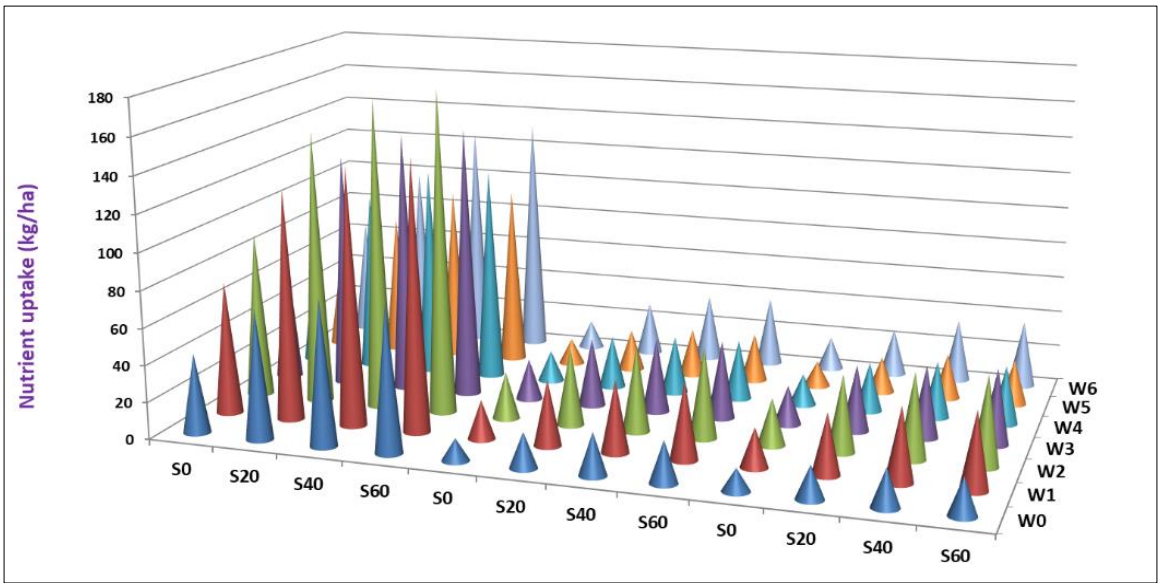

Fig. 2: combined effect of weed control and sulphur levels on N, P and S uptake by mustard at harvest stage (Pooled mean of two years)

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