Influence of nutrient and weed management on Zn and S uptake by crop and weeds in mustard

ABSTRACT

A field experiment was conducted in *rabi* season 2018-2019 and 2019-2020 at Research farm of Bihar Agricultural College, Sabour to study the effect of nutrient levels and weed management on zinc and sulphur uptake by crop and weeds in mustard. This experiment consisted of three nutrient levels (N_1-soil test-based recommended dose of fertilizer (RDF), N_2-100 % RDF, N_3-125 % RDF) in main plot; eight weed management practices (W_1-Weedy, W_2- Hand weeding (HW), W_3-pendimethalin, W_4-pendimethalin followed by (*fb*) quizalofop, W_5-pendimethalin *fb* clodinafop, W_6-oxyflourfen, W_7-oxyflourfen *fb* quizalofop, W_8-oxyflourfen *fb* clodinafop) in sub plots, was laid out in split plot design. Results indicated that in both the years 2018-19 and 2019-20, hand weeding at 25 and 50 DAS along with 125% RDF exhibited minimum Zn uptake by weeds. Among herbicides, application of pendimethalin 30 EC 1.0 kg a.i. ha^{-1} PE *fb* quizalofop 5 EC 60 g a.i. ha^{-1} PoE along with 125% RDF exhibited lowest Zn uptake by weeds. In both the years 2018-19 and 2019-20, hand weeding at 25 and 50 DAS along with 125% RDF recorded minimum S uptake by weeds. Lowest S uptake by weeds was noted under application of pendimethalin 30 EC 1.0 kg a.i. ha^{-1} PE *fb* quizalofop 5 EC 60 g a.i. ha^{-1} PoE along with 125% RDF. In 2018-2019, Zn uptake by mustard was maximum under 125% RDF being at par with soil test-based RDF and was superior over 100% RDF. Hand weeding at 25 and 50 DAS exhibited highest Zn uptake by mustard. Maximum Zn uptake by mustard was noted with pendimethalin 30 EC 1.0 kg a.i. ha^{-1} PE *fb* quizalofop 5 EC 60 g a.i. ha^{-1} PoE. In 2019-2020, hand weeding at 25 and 50 DAS along with 125% RDF exhibited highest Zn uptake by mustard. Among herbicides, application of pendimethalin 30 EC @ 1.0 kg a.i. ha^{-1} PE *fb* clodinafop 15 WP @ 60 g a.i. ha^{-1} PoE along with 125% RDF registered highest Zn uptake by mustard. In 2018-2019, hand weeding at 25 and 50 DAS exhibited highest S uptake by mustard. Maximum S uptake by mustard was recorded with pendimethalin 30 EC 1.0 kg a.i. ha^{-1} PE *fb* quizalofop 5 EC 60 g a.i. ha^{-1} PoE. In 2019-2020, although hand weeding at 25 and 50 DAS along with 125% RDF exhibited highest S uptake by mustard, however, pendimethalin 30 EC 1.0 kg a.i. ha^{-1} PE *fb* quizalofop 5 EC 60 g a.i. ha^{-1} PoE along with 125% RDF registered highest S uptake by mustard.

Key words: Mustard, RDF, S uptake, Soil test-based fertilizer, Weed control, Zn uptake

1. INTRODUCTION

Mustard (*Brassica juncea* L.) is mainly used for its edible oil for human consumption. It is grown in poor soils with poor crop management practices; weed infestation is one of the major causes of low productivity (Singh, 1992). Indian mustard suffers more from weed competition especially at the early stage of crop growth. Weeds cause yield reduction to the tune of 10-58% (Malik *et al*., 2012). Among the various factors responsible for the low productivity of mustard, weed control is one of the most important constraints. The yield loss in mustard can be minimized by the management of weeds at the right time and proper method. There is the number of methods available by which weeds can be managed effectively and efficiently in mustard. Among them, manual weeding has been very common and effective but high wages and non-availability of labourer at right time further make it uneconomical, besides, there are many intra row weed which often remain uncontrolled. On the other hand, weed control by herbicides has been found effective to control, both inter and intra row weeds. Hand weeding twice showed the maximum management of weeds, which was significantly superior to other treatments. The two hand weeding being at par

with the herbicides coupled with hand weeding increased the seed yield of mustard significantly by 46.3% over weedy check (Degra *et al*., 2011).

Among agronomic factors known to augment crop production, fertilization stands the most crucial production factor and is considered as one of the most productive input in crop production. Oilseed crops need more sulphur than other crops. Mustard needs an adequate amount of sulphur for the synthesis of these glycosides and other related compounds present to the extent of about 3% of plant dry weight. Piri and Sharma (2006) reported that sulphur content in plant increased with increasing sulphur application up to 30 kg S ha^{-1}. Sulphur content in stover increased significantly with each successive increase in level of sulphur in mustard. Moniruzzaman *et al*. (2008) applied zinc at the concentrations of 0, 2.5, 5.0 and 7.5 kg ha^{-1} and suggested 8 kg Zn ha^{-1} for *brassica* species in view of the significance of zinc in mustard production process.

To increase the productivity, some constraints of low productivity like nutrient and weed management may be taken under consideration. In view of the importance of the problem, the present study was undertaken to assess the influence of nutrient and weed management practices on zinc and sulphur uptake by mustard.

2. MATERIALS AND METHODS

A field experiment was carried out in *rabi* season of 2018-2019 and 2019-2020 at Research Farm of Bihar Agricultural College, Sabour, Bhagalpur situated at latitude 25°15' 40" N and longitude 87°2' 42" E with an altitude of 37.46 meters above mean sea level with the aim to assess the effect of nutrient and weed management on Zn and S uptake by mustard and weeds. The soil of experiment site was sandy loam, pH 7.2, organic carbon 0.48 %, available N 123.47 kg ha^{-1}, available P 26.19 kg ha^{-1} and K 168.51 kg ha^{-1}. The experiment comprised of three nutrient levels *viz*., N_1-soil test-based recommended dose of fertilizer (RDF) (100:40:40:20:6.25 kg ha^{-1} N P K S Zn), N_2-100 % RDF (80:40:40:20:5 kg ha^{-1} N P K S Zn), N_3-125 % RDF (100:50:50:25:6.25 kg ha^{-1} N P K S Zn) placed in main plot and eight weed management practices *viz*. W_1-Weedy, W_2-Hand weeding (HW) at 25 & 50 DAS, W_3-pendimethalin 30 EC @ 1.0 kg a.i. ha^{-1} as pre emergence (PE), W_4-pendimethalin 30 EC @ 1.0 kg a.i. ha^{-1} PE followed by (*fb*) quizalofop 5 EC @ 60 g a.i. ha^{-1} as post emergence (PoE), W_5-pendimethalin 30 EC @ 1.0 kg a.i. ha^{-1} PE *fb* clodinafop 15 WP @ 60 g a.i. ha^{-1} PoE, W_6-oxyflourfen 23.5 EC @ 150 g a.i. ha^{-1} PE, W_7-oxyflourfen 23.5 EC @ 150 g a.i. ha^{-1} PE *fb* quizalofop 5 EC @ 60 g a.i. ha^{-1} PoE, W_8-oxyflourfen 23.5 EC @ 150 g a.i. ha^{-1} PE *fb* clodinafop 15 WP @ 60 g a.i. ha^{-1} PoE put in sub plots was laid out in split plot design with three replications.

To execute the experiment, land preparation operations *viz*., ploughing, cross harrowing and planking was performed as per standard technique. Seeds of mustard were placed into furrows with seed rate 5 kg ha^{-1} on 22th November, 2018 and on 20th November, 2019 and harvested on 11th March, 2019 and 08th March, 2020, respectively. N, P, K, Zn and S doses was applied as soil test based, 100 and 125 % RDF as basal and remaining N was top dressed in split doses. Treatment wise two hand weeding at 25 and 50 DAS, pre-emergence alone and/ or with post emergence herbicide at 25-30 DAS in morning hours after proper sun rise were applied through a manually operated knapsack sprayer having flat fan nozzle with 500 liter water ha^{-1}. Agronomic practice like irrigation is given into plots through check basin method. 25 x 25 cm dimensions quadrates in two quantities were randomly put in each plot and number of weeds within quadrates were uprooted and after drying them in hot air oven (70 ± 10^{0}C for 72 hrs), the dry weight of weeds was measured. The plant samples of mustard crop collected at harvest stage were dried in hot air oven.

The weed and plant samples were analyzed in laboratory for uptake of zinc and sulphur by them as per standard techniques (Jackson, 1973). The nutrients uptake of crop and weed was measured by multiplying their nutrient concentration in crop and weed with their respective crop yield and weed dry matter, respectively. The experimental data were analyzed statistically by applying

analysis of variance (ANOVA) technique prescribed in design to test the significance of treatment difference by using F test at 5% level of probability (Gomez and Gomez, 1984).

3. RESULTS AND DISCUSSION

3.1 Zinc uptake by weeds

Data presented in Table 1 & Table 2 pertinent to zinc uptake by weeds as influenced by nutrient levels and weed management in mustard was found significant.

In 2018-19, hand weeding at 25 and 50 DAS with 125% RDF (N_3W_2) exhibited minimum zinc uptake by weeds of zero value which was significantly lower than weedy plot with 125% RDF (N_3W_1). Application of Pendimethalin 1.0 kg a.i. ha^{-1} PE *fb* Quizalofop 60 g a.i. ha^{-1} PoE with 125% RDF (N_3W_4) exhibited the lowest Zn uptake (0.17 kg ha^{-1}) by weeds which was found at par with N_3W_8 and was found significantly inferior over rest of the treatments. Since uptake is a function of dry matter and content of the nutrients, it follows the trend of dry matter. Thus, zinc and sulphur uptake by weeds was significantly affected under weed control treatments because of effective weed control. Pendimethalin *fb* quizalofop and hand weeding twice remained at par resulted in significantly lower Zn and S removal by weeds. The lower uptake of Zn and S by weeds was due to their effective control by pre- and post-emergence herbicide activity (Nepalia and Jain, 2000). The effective control of broad-leaved weeds was done due to combined activity of pre- and post-emergence herbicides (Sharma *et al*., 2009).

In 2019-20, hand weeding at 25 and 50 DAS with 125% RDF (N_3W_2) exhibited minimum Zn uptake by weeds of zero value which was significantly lower than weedy plot with 125% RDF (N_3W_1). Application of Pendimethalin 1.0 kg a.i. ha^{-1} PE *fb* Quizalofop 60 g a.i. ha^{-1} PoE with 125% RDF (N_3W_4) registered significantly the lowest Zn uptake (0.020 kg ha^{-1}) by weeds which was found at par with N_3W_7 and was significantly inferior over rest of the treatments.

Table 1: Effect of different treatments on Zn uptake (kg/ha) by weeds during 2018-2019

Weed management / Nutrient Levels	W_1-Weedy	W_2-Two HW at 25 & 50 DAS	W_3-Pendimethalin 1.0 kg a.i. ha^{-1}	W_4-Pendimethalin 1.0 kg a.i. ha^{-1} PE + Quizalofop 60 g a.i. ha^{-1} PoE	W_5- Pendimethalin 1.0 kg a.i. ha^{-1} PE + Clodinafop 60 a.i. ha^{-1} PoE	W_6-Oxyflourfen 150 g a.i. ha^{-1}	W_7-Oxyflourfen 150 g a.i. ha^{-1} + Quizalofop 60 g a.i. ha^{-1} PoE	W_8-Oxyflourfen 150 g a.i. ha^{-1} + Clodinafop 60 g a.i. ha^{-1} PoE	MEAN
N_1-Soil test 100:40:40:20:6.25 kg NPKSZn ha^{-1}	0.118	0.00	0.061	0.032	0.055	0.065	0.039	0.053	**0.053**
N_2-100% RDF 80:40:40:20:5 kg NPKSZn ha^{-1}	0.129	0.00	0.076	0.037	0.069	0.075	0.053	0.065	**0.061**
N_3-125% RDF 100:50:50:25:6.25 kg NPKSZn ha^{-1}	0.109	0.00	0.043	0.017	0.034	0.052	0.028	0.027	**0.039**
MEAN	**0.119**	**0.00**	**0.060**	**0.028**	**0.046**	**0.064**	**0.040**	**0.049**	
	SEm(±)=0.003		SEm (±) = 0.003		SEm (±) = 0.004		SEm (±) = 0.01		
	CD (N) = 0.01		CD (W) = 0.01		CD (WxN) = 0.01		CD (NxW) = 0.02		

Zinc and sulphur uptake by weeds varied significantly due to weed management practices. Weeds had lower Zn and S uptake than that of mustard crop. The highest S and Zn uptake by weeds was observed in weedy check and the lowest uptake by two hand weeding 20 and 40 DAS. Reduction in S and Zn uptake by weeds under two hand weeding might be due to lower density and

dry weight of weeds which eventually led to higher uptake of these nutrients by mustard crop. The results of highest S and Zn uptake by weeds are in accordance with the findings of Kour *et al*. (2013) and Mukherjee (2014). This indirectly by reducing nutrient uptake by weeds due to lower weed density and dry matter, these treatments were the best in controlling weeds.

Table 2: Effect of different treatments on Zn uptake (kg/ha) by weeds during 2019-2020

Weed management / Nutrient Levels	W_1-Weedy	W_2-Two HW at 25 & 50 DAS	W_3-Pendimethalin 1.0 kg a.i. ha^{-1}	W_4-Pendimethalin 1.0 kg a.i. ha^{-1} PE + Quizalofop 60 g a.i. ha^{-1} PoE	W_5- Pendimethalin 1.0 kg a.i. ha^{-1} PE + Clodinafop 60 a.i. ha^{-1} PoE	W_6-Oxyflourfen 150 g a.i. ha^{-1}	W_7-Oxyflourfen 150 g a.i. ha^{-1} + Quizalofop 60 g a.i. ha^{-1} PoE	W_8-Oxyflourfen 150 g a.i. ha^{-1} + Clodinafop 60 g a.i. ha^{-1} PoE	MEAN
N_1-Soil test 100:40:40:20:6.25 kg NPKSZn ha^{-1}	0.121	0.00	0.068	0.037	0.055	0.075	0.038	0.059	**0.057**
N_2-100% RDF 80:40:40:20:5 kg NPKSZn ha^{-1}	0.130	0.00	0.074	0.044	0.066	0.081	0.062	0.065	**0.065**
N_3-125% RDF 100:50:50:25:6.25 kg NPKSZn ha^{-1}	0.119	0.00	0.055	0.020	0.038	0.053	0.030	0.040	**0.044**
MEAN	**0.123**	**0.00**	**0.066**	**0.034**	**0.053**	**0.070**	**0.043**	**0.055**	
	SEm(±)=0.001		SEm (±) = 0.002		SEm (±) = 0.004		SEm (±) = 0.004		
	CD (N) = 0.01		CD (W) = 0.01		CD (WxN) = 0.01		CD (NxW) = 0.01		

Mukherjee (2010) conducted trial on the influence of weed and fertilizer management on nutrient uptake in mustard. All weed management treatments significantly reduced nutrient uptake by weeds. Minimum nutrient uptake by weeds was recorded under pendimethalin *fb* quizalofop being at par with hand weeding. These results corroborated with the findings of Patel (2000) and Chander *et al*. (2013).

3.2 Sulphur uptake by weeds

Data depicted in Table 3 & Table 4 pertaining to sulphur uptake by weeds under the influence of nutrient and weed management in mustard was found significant.

In 2018-19, hand weeding at 25 and 50 DAS with 125% RDF (N_3W_2) recorded significantly minimum S uptake by weeds of zero value which was significantly lower than weedy plot with 125% RDF (N_3W_1). Significantly lowest S uptake (1.80 kg ha^{-1}) by weeds was observed under application of Pendimethalin 1.0 kg a.i. ha^{-1} PE *fb* Quizalofop 60 g a.i. ha^{-1} PoE with 125% RDF (N_3W_4) which was found at par with N_3W_8, N_3W_7 and N_3W_5 and was found significantly inferior over rest of the treatments.

In 2019-20, hand weeding at 25 and 50 DAS with 125% RDF (N_3W_2) exhibited minimum S uptake by weeds of zero value which was found significantly inferior over weedy plot with 125% RDF (N_3W_1). Application of Pendimethalin 1.0 kg a.i. ha^{-1} PE *fb* Quizalofop 60 g a.i. ha^{-1} PoE with 125% RDF (N_3W_4) recorded significantly the lowest S uptake (1.82 kg ha^{-1}) by weeds which was found at par with N_3W_7, N_3W_5 and N_3W_8 and was found significantly inferior over rest of the treatments.

The highest removal of nutrients (Zn and S) by weeds were recorded under weedy plot, whereas the lowest nutrient depletion by weeds were recorded under hand weeding treatment and pendimethalin @ 1.0 kg a.i. ha^{-1} PE *fb* quizalofop 60 g a.i. ha^{-1} PoE. Similar results were reported by Patel (2000) in pigeonpea and Chauhan (2000) in chickpea.

Table 3: Effect of different treatments on S uptake (kg ha^{-1}) by weeds during 2018-2019

Weed management / Nutrient Levels	W_1-Weedy	W_2-Two HW at 25 & 50 DAS	W_3-Pendimethalin 1.0 kg a.i. ha^{-1}	W_4-Pendimethalin 1.0 kg a.i. ha^{-1} PE + Quizalofop 60 g a.i. ha^{-1} PoE	W_5- Pendimethalin 1.0 kg a.i. ha^{-1} PE + Clodinafop 60 a.i. ha^{-1} PoE	W_6-Oxyflourfen 150 g a.i. ha^{-1}	W_7-Oxyflourfen 150 g a.i. ha^{-1} + Quizalofop 60 g a.i. ha^{-1} PoE	W_8-Oxyflourfen 150 g a.i. ha^{-1} + Clodinafop 60 g a.i. ha^{-1} PoE	MEAN
N_1-Soil test 100:40:40:20:6.25 kg NPKSZn ha^{-1}	7.89	0.00	4.02	2.06	2.58	4.40	2.98	2.66	**3.32**
N_2-100% RDF 80:40:40:20:5 kg NPKSZn ha^{-1}	8.88	0.00	4.48	2.67	2.77	5.15	4.02	3.60	**3.95**
N_3-125% RDF 100:50:50:25:6.25 kg NPKSZn ha^{-1}	5.38	0.00	3.61	1.80	1.96	3.11	1.93	2.55	**2.54**
MEAN	**7.39**	**0.00**	**4.04**	**2.17**	**2.44**	**4.22**	**2.98**	**2.93**	
	SEm(±)=0.12		SEm (±) = 0.24		SEm (±) = 0.42		SEm (±) = 0.41		
	CD (N)= 0.46		CD (W) = 0.69		CD (WxN) = 1.20		CD (NxW) = 1.20		

The removal of S and Zn by weeds were reduced significantly by herbicidal and manual weeding and it almost nil under hand weeding. These results conformed the findings of Kour *et al*. (2013) and Singh (2015).

Table 4: Effect of different treatments on S uptake (kg/ha) by weeds during 2019-2020

Weed management / Nutrient Levels	W_1-Weedy	W_2-Two HW at 25 & 50 DAS	W_3-Pendimethalin 1.0 kg a.i. ha^{-1}	W_4-Pendimethalin 1.0 kg a.i. ha^{-1} PE + Quizalofop 60 g a.i. ha^{-1} PoE	W_5- Pendimethalin 1.0 kg a.i. ha^{-1} PE + Clodinafop 60 a.i. ha^{-1} PoE	W_6-Oxyflourfen 150 g a.i. ha^{-1}	W_7-Oxyflourfen 150 g a.i. ha^{-1} + Quizalofop 60 g a.i. ha^{-1} PoE	W_8-Oxyflourfen 150 g a.i. ha^{-1} + Clodinafop 60 g a.i. ha^{-1} PoE	MEAN
N_1-Soil test 100:40:40:20:6.25 kg NPKSZn ha^{-1}	6.25	0.00	3.98	2.33	2.86	4.31	2.89	3.07	**3.21**
N_2-100% RDF 80:40:40:20:5 kg NPKSZn ha^{-1}	7.81	0.00	4.85	2.52	3.24	5.07	4.21	3.42	**3.89**
N_3-125% RDF 100:50:50:25:6.25 kg NPKSZn ha^{-1}	5.26	0.00	2.77	1.82	2.33	3.38	2.00	2.67	**2.53**
MEAN	**6.44**	**0.00**	**3.87**	**2.22**	**2.81**	**4.25**	**3.03**	**3.05**	
	SEm(±)=0.12		SEm (±) =0.16		SEm (±) = 0.27		SEm (±) = 0.28		
	CD (N)=0.48		CD (W) = 0.45		CD (WxN) = 0.87		CD (NxW) = 0.91		

3.3 Zinc uptake by mustard

Data depicted in Table 5 & Table 6 pertinent to zinc uptake by mustard crop at harvest stage as influenced by nutrient levels and weed management in mustard was found significant. In 2018-2019, among nutrient levels, Zn uptake by mustard crop was found significantly maximum (127.25

kg ha^{-1}) under N_3, 125% RDF (100: 50: 50: 25: 6.25 kg N P K S Zn ha^{-1}) which was found at par with N_1 (Soil test based fertilizer application) and was found significantly superior over N_2, 100% RDF (80: 40: 40: 20: 5 kg N P K S Zn). Lowest uptake of zinc by the crop was noted under weedy plot.

In 2018-2019, hand weeding at 25 and 50 DAS exhibited significantly highest Zn uptake (134.15 kg ha^{-1}) by mustard crop which was found at par with rest of the treatments except W_6, W_3 and W_1. Among herbicides, maximum Zn uptake (127.84 kg ha^{-1}) by mustard crop was recorded with W_4 (Pendimethalin 30 EC @ 1.0 kg a.i. ha^{-1} PE *fb* Quizalofop 5 EC @ 60 g a.i. ha^{-1} PoE) which was at par with rest of the herbicide treatments except W_6 and W_1. The highest uptake of Zn was recorded under hand weeding treatment. This might be due to better development of crop resulting from lesser crop-weed competition. Further, the higher content and higher crop yield under these treatments boosted zinc uptake. Similar results were reported by Patel (2000) and Chauhan (2000).

In 2019-2020, hand weeding at 25 and 50 DAS with 125 % RDF (N_3W_2) exhibited significantly highest Zn uptake (157.08 kg ha^{-1}) by mustard which was superior over all other herbicide treatments except N_3W_5. Application of Pendimethalin 1.0 kg a.i. ha^{-1} PE *fb* Clodinafop 60 g a.i./ha PoE (N_3W_5) registered significantly highest Zn uptake (145.18 kg ha^{-1}) by mustard which was at par with rest of the treatments except N_3W_3, N_3W_6 and N_3W_1. The higher Zn uptake was due to suppression of weed growth that might have been the driving force behind higher dry matter and Zn uptake in mustard under these treatments. Such higher uptake might be attributed to higher seed yield under better weed management treatments. The results of higher Zn uptake by crop confirmed the findings of Chander *et al*. (2013) and Mukherjee (2014) in mustard. Minimum Zn uptake in mustard was noticed in weedy check that might be attributed to least seed yield (Singh *et al*., 2015).

Table 5: Effect of different treatments on Zn uptake (g ha^{-1}) and S uptake (kg ha^{-1}) by crop in 2018-2019

Treatments	Zn uptake (g ha^{-1})	S uptake (kg ha^{-1})
Nutrient levels		
N_1- Soil test-based fertilizer application	116.81	15.13
N_2- 100% RDF (80: 40: 40: 20: 5 kg N P K S Zn ha^{-1})	108.80	14.48
N_3- 125% RDF (100: 50: 50: 25: 6.25 kg N P K S Zn ha^{-1})	127.25	16.48
SEm±	3.38	0.38
CD (P=0.05)	13.29	1.48
Weed management		
W_1- Weedy	75.34	9.16
W_2- Two hand weeding at 25 and 50 DAS	134.15	18.22
W_3- Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} PE	116.98	14.90
W_4- Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} PE *fb* Quizalofop 5 EC @ 60 g a.i. ha^{-1} PoE	127.84	16.75
W_5- Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} PE *fb* Clodinafop 15 WP @ 60 g a.i. ha^{-1} PoE	127.20	16.64
W_6- Oxyflourfen 23.5 EC @ 150 g a.i. ha^{-1} PE	113.04	14.34
W_7- Oxyflourfen 23.5 EC @ 150 g a.i. ha^{-1} PE *fb* Quizalofop 5 EC @ 60 g a.i. ha^{-1} PoE	123.78	16.45
W_8- Oxyflourfen 23.5 EC @ 150 g a.i. ha^{-1} PE *fb* Clodinafop 15 WP @ 60 g a.i. ha^{-1} PoE	122.63	16.44
SEm±	4.19	0.50
CD (P=0.05)	11.96	1.43

Sulphur and zinc applied in soil increase the height of plant and produce more grain yield. As essential nutrient sulphur and zinc are known to perform several functions inside the plant body and it has been associated with a role in enzyme activator, root booster, stalk strengthener, encourages vegetative growth, increases disease resistant and energy storage.

Table 6: Effect of different treatments on Zn uptake (g ha^{-1}) by mustard at harvest during 2019-2020

Weed management / Nutrient Levels	W_1- Weedy	W_2- Two HW at 25 & 50 DAS	W_3-Pendimethalin 1.0 kg a.i. ha^{-1}	W_4-Pendimethalin 1.0 kg a.i. ha^{-1} PE + Quizalofop 60 g a.i. ha^{-1} PoE	W_5- Pendimethalin 1.0 kg a.i. ha^{-1} PE + Clodinafop 60 a.i. ha^{-1} PoE	W_6- Oxyflourfen 150 g a.i. ha^{-1}	W_7- Oxyflourfen 150 g a.i. ha^{-1} + Quizalofop 60 g a.i. ha^{-1} PoE	W_8- Oxyflourfen 150 g a.i. ha^{-1} + Clodinafop 60 g a.i. ha^{-1} PoE	MEAN
N_1-Soil test 100:40:40:20:6.25 kg NPKSZn ha^{-1}	69.96	140.99	126.86	130.45	124.03	118.16	124.88	118.32	**119.20**
N_2-100% RDF 80:40:40:20:5 kg NPKSZn ha^{-1}	45.07	124.55	118.67	121.74	117.94	112.46	116.42	114.63	**108.93**
N_3-125% RDF 100:50:50:25:6.25 kg NPKSZn ha^{-1}	73.73	157.08	130.19	138.21	145.18	119.32	138.22	142.70	**130.58**
MEAN	**62.92**	**140.87**	**125.24**	**130.13**	**129.05**	**116.65**	**126.50**	**125.22**	
	SEm (±)=2.59		SEm (±) = 2.40		SEm (±) = 4.16		SEm (±) = 4.67		
	CD (N)=10.16		CD (W) = 6.85		CD (WxN) =13.95		CD (NxW)= 15.68		

The superiority of the treatments might be ascribed to the fact that these treatments controlled and suppressed weed growth and provided weed free environment to the crop for long time to utilize available/applied nutrients under reduced crop-weed competition (Kour *et al*., 2014). Upadhyay (2012) observed that the sulphur and zinc uptake increased significantly upto 60 kg S and 8 kg Zn ha^{-1} application except for zinc uptake in seed whereas a significant increase was recorded only upto 40 kg S ha^{-1}. An increase in levels of S and Zn significantly enhanced the respective nutrient content in the seed portion of mustard.

3.4 Sulphur uptake by mustard

The best way to increase the productivity of mustard is by improving crops' nutrition through balanced fertilization. Besides NPK, mustard has an additional requirement of S due to presence of several natural volatile S and N compounds (Seiji and Kameoka, 1985) and for normal growth of plant plays an important role in production of protein and activation of enzymatic and metabolic process during active plant growth.

Data depicted in Table 5 & Table 7 pertinent to sulphur uptake by mustard crop at harvest stage as influenced by nutrient levels and weed management in mustard was found significant.

In 2018-2019, among nutrient levels, S uptake by mustard crop was found significantly maximum (16.48 kg ha^{-1}) under N_3, 125% RDF (100: 50: 50: 25: 6.25 kg N P K S Zn ha^{-1}) which was found at par with N_1 (Soil test based fertilizer application) and was found significantly superior over N_2, 100% RDF (80: 40: 40: 20: 5 kg N P K S Zn). Different weed management treatments showed significant influence on uptake of sulphur by mustard crop at harvest. Significantly the lowest uptake of sulphur by the crop was noted under weedy plot. Kumar and Trivedi (2012) reported that S uptake increased significantly with increasing levels of sulphur up to 60 kg S ha^{-1}. Application of 60 kg S ha^{-1} increased S uptake by 7.8, 4.8 and 3.9% over 0, 20 and 40 kg S ha^{-1}, respectively.

In 2018-2019, hand weeding at 25 and 50 DAS exhibited significantly highest S uptake (18.22 kg ha^{-1}) by mustard crop which was found significantly superior over all other treatments. Among herbicides, maximum S uptake (16.75 kg ha^{-1}) by mustard crop was recorded with W_4 (Pendimethalin 30 EC @ 1.0 kg a.i. ha^{-1} PE *fb* Quizalofop 5 EC @ 60 g a.i. ha^{-1} PoE) which was at par with rest of the herbicide treatments except W_6, W_3 and W_1. Malviya *et al*. (2007) reported that sulphur applied at the rate of 60 kg S ha^{-1} produced significantly higher nutrient uptake than 30 kg S ha^{-1}. Sah *et al*. (2013) reported that the application of sulphur @ 45 kg ha^{-1} increased nutrient uptake of mustard. Sah *et al*. (2013) observed that an increase in S levels significantly improved S uptake upto 60 kg ha^{-1}. Singh *et al*. (2015) reported that significant increase in nutrient uptake might also be the result of the cumulative effect of these higher nutrient content in seed and straw.

In 2019-2020, hand weeding at 25 and 50 DAS with 125 % RDF (N_3W_2) exhibited significantly highest S uptake (21.34 kg ha^{-1}) by mustard crop which was significantly superior over rest of the treatments. Among herbicide treatments, application of Pendimethalin 1.0 kg a.i. ha^{-1} PE *fb* Quizalofop 60 g a.i. ha^{-1} PoE (N_3W_4) registered significantly highest S uptake (17.63 kg ha^{-1}) by mustard crop which was found at par with rest of the treatments except N_3W_6, N_3W_5 and N_3W_1. Application of 125% RDF with hand weeding twice registered more S uptake by the crop. These observations are in agreement with finding of Shekhawat *et al*. (2012) and Chaudhry *et al*. (2011).

Table 7: Effect of different treatments on S uptake (kg ha^{-1}) by mustard at harvest during 2019-2020

Weed management / Nutrient Levels	W_1- Weedy	W_2- Two HW at 25 & 50 DAS	W_3- Pendi methalin 1.0 kg a.i. ha^{-1}	W_4-Pendi methalin 1.0 kg a.i. ha^{-1} PE + Quizalofop 60 g a.i. ha^{-1} PoE	W_5- Pendi methalin 1.0 kg a.i. ha^{-1} PE + Clodinafop 60 a.i. ha^{-1} PoE	W_6- Oxyflourfen 150 g a.i. ha^{-1}	W_7- Oxyflourfen 150 g a.i. ha^{-1} + Quizalofop 60 g a.i. ha^{-1} PoE	W_8- Oxyflourfen 150 g a.i. ha^{-1} + Clodinafop 60 g a.i. ha^{-1} PoE	MEAN
N_1-Soil test 100:40:40:20:6.25 kg NPKSZn ha^{-1}	8.80	18.81	14.97	17.22	16.96	14.78	16.90	16.72	**15.64**
N_2-100% RDF 80:40:40:20:5 kg NPKSZn ha^{-1}	7.25	16.25	14.87	15.86	15.05	14.48	15.69	14.53	**14.25**
N_3-125% RDF 100:50:50:25:6.25 kg NPKSZn ha^{-1}	10.36	21.34	15.85	17.63	15.72	15.08	16.01	17.21	**16.15**
MEAN	**8.81**	**18.80**	**15.23**	**16.90**	**15.91**	**14.78**	**16.20**	**16.15**	
	SEm (±)=0.16		SEm (±) = 0.36		SEm (±) = 0.63		SEm (±) = 0.61		
	CD (N) = 0.62		CD (W) = 1.03		CD (WxN) = 1.88		CD (NxW) = 1.82		

Dubey *et al*. (2013) reported that the nutrient S & Zn uptake in mustard seed significantly increased with increasing dose of sulphur up to 40 kg and zinc 7.5 kg ha^{-1}. Faujdar *et al*. (2008) observed a significant increasing in nutrient S & Zn uptake with increase in seed and stover yield, protein content, and S-containing amino acids in seed with application of Zn and S in Indian mustard. The increased availability of S in root zone coupled with increased metabolic activity at cellular level might increase S uptake and their accumulation in vegetative plant parts. Increased uptake of S seems to be due to the fact that uptake of S is a product of biomass accumulated by particular part and its S content. Thus, positive impact of nutrient application ultimately led to higher accumulation of S. These results are in line with the finding of Chaurasia *et al*. (2009) and Singh and

Pal (2011). Zizale *et al*. (2008) reported that S nutrient uptake increased with increasing level of S but the increase was non significant.

4. CONCLUSION

Thus, it might be concluded that pendimethalin @ 1.0 kg a.i. ha^{-1} PE *fb* Quizalofop @ 60 g a.i. ha^{-1} PoE along with 125% RDF (100:50:50:25:6.25 kg NPKSZn ha^{-1}) enhanced zinc and sulphur uptake by crop and weeds though hand weeding at 25 and 50 days of sowing along with 125% RDF (100:50:50:25:6.25 kg NPKSZn ha^{-1}) exhibited significant improvement in Zn and S uptake by crop and weeds over weedy and herbicide treatments.

REFERENCES

- Chander N, Kumar S, Ramesh, Rana SS. Nutrient removal by weeds and crops as affected by herbicide combinations in soybean-wheat cropping system. Ind. J. of Weed Sci. 2013; 45: 99-105.
- Chaudhry SU, Hussain M, Iqbal J. Effect of different herbicides on weed control and yield of canola (*Brassica napus*). *J. of Agril. Res.* 2011; 49(4):483-490.
- Chauhan CN. Effect of spacing, weeds and phosphorus management on chickpea (*Cicer arietinum* L.). M.Sc. (Ag.) Thesis, 2000; Gujarat Agril. University, NAVSARI, GUJARAT (India).
- Chaurasia A, Singh SB, Namdeo KN. Integrated nutrient management in relation to yield and yield attributes and oil yield of Ethiopian mustard (*Brassica carinata*). *Crop Res*. 2009; 38(1/3):24-28.
- Degra ML, Pareek BL, Shivran RK, Jat RD. Integrated weed management in Indian mustard and its residual effect on succeeding fodder pearl millet. *Ind. J. Weed Sci.* 2011; 43(1&2):73-76.
- Dubey SK, Tripathi SK, Singh, Bhagwan. Effect of Sulphur and zinc levels on growth, yield and quality of mustard (*Brassica juncea* L.) Czerny Coss.]. *J. of Crop Sci. and Tech.* 2013; 2(1).
- Faujdar RS, Mathur AK, Verma AK. Yield and quality of mustard as influenced by different levels of phosphorus and sulphur. *An Asian J. of Soil Sci.* 2008; 3(1):207-208.
- Gomez KA, Gomez AA. Statistical procedures for agricultural research (2 ed.). John Wiley and Sons, New York, 1984; 680.
- Jackson ML. Soil Chemical Analysis, 1973; Prentice Hall of India Pvt. Ltd., New Delhi: 498 p.
- Kour R, Sharma BC, Kumar A, Kour P. Nutrient uptake by chickpea + mustard intercropping system as influenced by weed management. *Ind. J. of Weed Sci.* 2013; 45(3): 183-188.
- Kour R, Sharma BC, Kumar A, Nandan B, Kour P. Effect of weed management on chickpea (*Cicer arietinum*) + Indian mustard (*Brassica juncea*) intercropping system under irrigated conditions of Jammu region. *Ind. J. of Agron.* 2014; 59:242-246.
- Kumar R, Trivedi SK. Effect of levels and sources of sulphur on yield, quality and nutrient uptake by mustard (*Brassica juncea* L.). *Prog. Agri.* 2012; 12(1):69-73.
- Malik RS, Yadav A, Punia SS, Hooda VS, Hasija RC. Efficacy of three dinitroaniline herbicides against weeds in raya. *Environ. and Ecol.* 2012; 30:787-789.
- Malviya A, Tewari SK, Bohra JS. Response of Indian mustard (*Brassica juncea* L.) Czern and Coss to nitrogen, sulphur and boron application under irrigated conditions. *New Agriculturist* 2007; 18(1,2):69-71.
- Moniruzzaman M, Mozumder SN, Islam MR. Effects of sulfur, boron, zinc and molybdenum on yield and profitability of broccoli (*Brassica oleracea* L. var. *italica*). *J. Agric Rural Dev* 2008; 6(1,2):55-61.
- Mukherjee D. Influence of weed and fertilizer management on yield and nutrient uptake in mustard. *Ind. J. of Weed Sci.* 2014; 46:251-255.
- Mukherjee D. Productivity, profitability and apparent nutrient balance under different crop sequence in mid-hill condition. *Ind. J. of Agril. Sci.* 2010; 80(5):420-22.

- Nepalia N, Jain GL. Effect of weed control and sulphur on yield of Indian mustard (*Brassica juncea*) and their residual effect on summer green gram (*Phaseolus radiata*). *Ind. J. of Agron.* 2000; 45:483–488.
- Patel JP. Integrated weed management in *Rabi* pigeon pea [*Cajanus cajan* (L.). Millsp.] M.Sc. (Ag.) Thesis, 2000; Gujarat Agricultural University, NAVSARI, GUJARAT (India).
- Piri ISSA, Sharma SN. Effect of levels and sources of sulphur on yield attributes, yield and quality of Indian mustard (*Brassica juncea*). *Ind. J. of Agron.* 2006; 51(3):217-220.
- Sah D, Sewak R, Singh AK, Swami S. Growth, yield and profitability of Indian mustard (*Brassica juncea* L. Czern & Coss) with different weed control measures and sulphur levels. *Agril. Sci. Digest* 2013; 33(1):15-20.
- Seiji H, Kameoka H. Sulfur- and nitrogen-containing neutral volatile components of cruciferae. *J. Food Sci.* 1985; 50:847-848.
- Sharma A, Sharma P, Brar MS, Dhillion NS. Comparative response to sulphur application in raya (*Brassica juncea*) and wheat (*Triticum aestivum*) grown on light textured alluvial soils. *J. of Indian Socie. of Soil Sci.* 2009; 57(1):62-66.
- Shekhawat K, Premi OP, Kandpal BK, Chauhan JS. Advances in agronomic management of Indian mustard (*Brassica juncea* (L.): an overview. *International J. of Agron*. 2012; 13:1-14.
- Singh NK, Desai BC, Rathore BK, Chaudhari SG. Bio-efficacy of herbicides on performance of mustard, *Brassica juncea* (L.) and Population Dynamics of Agriculturally Important Bacteria. Proceedings of the National Academy of Sci., 2015; India Sector B: *Biological Sciences*, Pp. 1-6
- Singh SP, Pal MS. Effect of integrated nutrient management on productivity, quality, nutrient uptake and economics of mustard (*Brassica juncea*). *Ind. J. of Agron.* 2011; 56(4):381-387.
- Singh SS. Effect of fertilizer application and weed control on the yield of mustard (*Brassica juncea* L.). *Ind. J. of Agron*. 1992; 37:196-198.
- Singh SS. Effect of fertilizer application and weed control on the yield of mustard (*Brassica juncea*). *Ind. J. Agron.* 2015; 37(1):196-198.
- Upadhyay VB. Bio-efficacy of post emergence herbicides in soybean. *Ind. J. of Weed Sci.* 2012; 44: 261-263.
- Zizale VJ, Jadav NB, Gorphrfed PS. Effect of sulphur and zinc on yield, quality and its concentration on mustard. *An Asian J.of Soil Sci.* 2008; 3(1):173-177.