



## **Influence of Nutrient and Weed Management on Zn and S Uptake by Crop and weeds in Mustard**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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### **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<sub>1</sub>-soil test-based recommended dose of fertilizer (RDF), N<sub>2</sub>-100 % RDF, N<sub>3</sub>-125 % RDF) in main plot; eight weed management practices (W<sub>1</sub>-Weedy, W<sub>2</sub>- Hand weeding (HW), W<sub>3</sub>- pendimethalin, W<sub>4</sub>-pendimethalin followed by (*fb*) quizalofop, W<sub>5</sub>-pendimethalin *fb* clodinafop, W<sub>6</sub>- oxyflourfen, W<sub>7</sub>-oxyflourfen *fb* quizalofop, W<sub>8</sub>-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<sup>-1</sup> PE *fb* quizalofop 5 EC 60 g a.i. ha<sup>-1</sup> 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<sup>-1</sup> PE *fb* quizalofop 5 EC 60 g a.i. ha<sup>-1</sup> 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<sup>-1</sup> PE *fb* quizalofop 5 EC 60 g a.i. ha<sup>-1</sup> PoE. In 2019-2020, hand weeding at 25 and 50 DAS along with 125% RDF exhibited

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highest Zn uptake by mustard. Among herbicides, application of pendimethalin 30 EC @ 1.0 kg a.i. ha<sup>-1</sup> PE fb clodinafop 15 WP @ 60 g a.i. ha<sup>-1</sup> 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<sup>-1</sup> PE fb quizalofop 5 EC 60 g a.i. ha<sup>-1</sup> 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<sup>-1</sup> PE fb quizalofop 5 EC 60 g a.i. ha<sup>-1</sup> PoE along with 125% RDF registered highest S uptake by mustard.

**Keywords:** 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 [1]. 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% [2]. 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 [3]

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 [4] reported that sulphur content in plant increased with increasing sulphur

application up to 30 kg S ha<sup>-1</sup>. Sulphur content in stover increased significantly with each successive increase in level of sulphur in mustard. Moniruzzaman et al. [5] applied zinc at the concentrations of 0, 2.5, 5.0 and 7.5 kg ha<sup>-1</sup> and suggested 8 kg Zn ha<sup>-1</sup> 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<sup>-1</sup>, available P 26.19 kg ha<sup>-1</sup> and K 168.51 kg ha<sup>-1</sup>. The experiment comprised of three nutrient levels viz., N<sub>1</sub>-soil test-based recommended dose of fertilizer (RDF) (100:40:40:20:6.25 kg ha<sup>-1</sup> N P K S Zn), N<sub>2</sub>-100 % RDF (80:40:40:20:5 kg ha<sup>-1</sup> N P K S Zn), N<sub>3</sub>-125 % RDF (100:50:50:25:6.25 kg ha<sup>-1</sup> N P K S Zn) placed in main plot and eight weed management practices viz. W<sub>1</sub>-Weedy, W<sub>2</sub>-Hand weeding (HW) at 25 & 50 DAS, W<sub>3</sub>-pendimethalin 30 EC @ 1.0 kg a.i. ha<sup>-1</sup> as pre emergence (PE), W<sub>4</sub>-pendimethalin 30 EC @ 1.0 kg a.i. ha<sup>-1</sup> PE followed by (fb) quizalofop 5 EC @ 60 g a.i. ha<sup>-1</sup> as post emergence (PoE), W<sub>5</sub>-pendimethalin 30 EC @ 1.0 kg a.i. ha<sup>-1</sup> PE fb clodinafop 15 WP @ 60 g

a.i. ha<sup>-1</sup> PoE, W<sub>6</sub>-oxyflourfen 23.5 EC @ 150 g a.i. ha<sup>-1</sup> PE, W<sub>7</sub>-oxyflourfen 23.5 EC @ 150 g a.i. ha<sup>-1</sup> PE *fb* quizalofop 5 EC @ 60 g a.i. ha<sup>-1</sup> PoE, W<sub>8</sub>-oxyflourfen 23.5 EC @ 150 g a.i. ha<sup>-1</sup> PE *fb* clodinafop 15 WP @ 60 g a.i. ha<sup>-1</sup> 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<sup>-1</sup> on 22<sup>th</sup> November, 2018 and on 20<sup>th</sup> November, 2019 and harvested on 11<sup>th</sup> March, 2019 and 08<sup>th</sup> 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<sup>-1</sup>. 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<sup>0</sup>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 [6]. 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 [7].

### 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<sub>3</sub>W<sub>2</sub>) exhibited minimum zinc uptake by weeds of zero value which was significantly lower than weedy plot with 125% RDF (N<sub>3</sub>W<sub>1</sub>). Application of Pendimethalin 1.0 kg a.i. ha<sup>-1</sup> PE *fb* Quizalofop 60 g a.i. ha<sup>-1</sup> PoE with 125% RDF (N<sub>3</sub>W<sub>4</sub>) exhibited the lowest Zn uptake (0.17 kg ha<sup>-1</sup>) by weeds which was found at par with N<sub>3</sub>W<sub>8</sub> 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 [8]. The effective control of broad-leaved weeds was done due to combined activity of pre- and post-emergence herbicides [9].

In 2019-20, hand weeding at 25 and 50 DAS with 125% RDF (N<sub>3</sub>W<sub>2</sub>) exhibited minimum Zn uptake by weeds of zero value which was significantly lower than weedy plot with 125% RDF (N<sub>3</sub>W<sub>1</sub>). Application of Pendimethalin 1.0 kg a.i. ha<sup>-1</sup> PE *fb* Quizalofop 60 g a.i. ha<sup>-1</sup> PoE with 125% RDF (N<sub>3</sub>W<sub>4</sub>) registered significantly the lowest Zn uptake (0.020 kg ha<sup>-1</sup>) by weeds which was found at par with N<sub>3</sub>W<sub>7</sub> and was significantly inferior over rest of the treatments.

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. [10] and Mukherjee [11]. 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 1. Effect of different treatments on Zn uptake (kg/ha) by weeds during 2018-2019**

Weed management Nutrient Levels	W <sub>1</sub> - Weedy	W <sub>2</sub> - Two HW at 25 & 50 DAS	W <sub>3</sub> - Pendi methalin 1.0 kg a.i. ha <sup>-1</sup>	W <sub>4</sub> -Pendi methalin 1.0 kg a.i. ha <sup>-1</sup> PE + Quizalofop 60 g a.i. ha <sup>-1</sup> PoE	W <sub>5</sub> - Pendi methalin 1.0 kg a.i. ha <sup>-1</sup> PE + Clodinafop 60 a.i. ha <sup>-1</sup> PoE	W <sub>6</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup>	W <sub>7</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup> + Quizalofop 60 g a.i. ha <sup>-1</sup> PoE	W <sub>8</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup> + Clodinafop 60 g a.i. ha <sup>-1</sup> PoE	MEAN
N <sub>1</sub> -Soil test 100:40:40:20:6.25 kg NPKSZn ha <sup>-1</sup>	0.118	0.00	0.061	0.032	0.055	0.065	0.039	0.053	0.053
N <sub>2</sub> -100% RDF 80:40:40:20:5 kg NPKSZn ha <sup>-1</sup>	0.129	0.00	0.076	0.037	0.069	0.075	0.053	0.065	0.061
N <sub>3</sub> -125% RDF 100:50:50:25:6.25 kg NPKSZn ha <sup>-1</sup>	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		

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

Weed management Nutrient Levels	W <sub>1</sub> - Weedy	W <sub>2</sub> - Two HW at 25 & 50 DAS	W <sub>3</sub> - Pendi methalin 1.0 kg a.i. ha <sup>-1</sup>	W <sub>4</sub> -Pendi methalin 1.0 kg a.i. ha <sup>-1</sup> PE + Quizalofop 60 g a.i. ha <sup>-1</sup> PoE	W <sub>5</sub> - Pendi methalin 1.0 kg a.i. ha <sup>-1</sup> PE + Clodinafop 60 a.i. ha <sup>-1</sup> PoE	W <sub>6</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup>	W <sub>7</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup> + Quizalofop 60 g a.i. ha <sup>-1</sup> PoE	W <sub>8</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup> + Clodinafop 60 g a.i. ha <sup>-1</sup> PoE	MEAN
N <sub>1</sub> -Soil test 100:40:40:20:6.25 kg NPKSZn ha <sup>-1</sup>	0.121	0.00	0.068	0.037	0.055	0.075	0.038	0.059	0.057
N <sub>2</sub> -100% RDF 80:40:40:20:5 kg NPKSZn ha <sup>-1</sup>	0.130	0.00	0.074	0.044	0.066	0.081	0.062	0.065	0.065
N <sub>3</sub> -125% RDF 100:50:50:25:6.25 kg NPKSZn ha <sup>-1</sup>	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 [12] 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 [13] and Chander et al. [14].

### 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 ( $1.80 \text{ kg ha}^{-1}$ ) by weeds was observed under application of Pendimethalin  $1.0 \text{ kg a.i. ha}^{-1}$  PE *fb* Quizalofop  $60 \text{ g a.i. ha}^{-1}$  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  $1.0 \text{ kg a.i. ha}^{-1}$  PE *fb* Quizalofop  $60 \text{ g a.i. ha}^{-1}$  PoE with 125% RDF ( $N_3W_4$ ) recorded significantly the lowest S uptake ( $1.82 \text{ kg ha}^{-1}$ ) 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 @  $1.0 \text{ kg a.i. ha}^{-1}$  PE *fb* quizalofop  $60 \text{ g a.i. ha}^{-1}$  PoE. Similar results were reported by Patel [13] in pigeonpea and Chauhan [15] in chickpea.

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. [10] and Singh [16,17].

### 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 ( $127.25 \text{ kg ha}^{-1}$ ) under  $N_3$ , 125% RDF (100: 50: 50: 25:  $6.25 \text{ kg N P K S Zn ha}^{-1}$ ) 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:  $5 \text{ kg N P K S Zn}$ ). 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 ( $134.15 \text{ kg ha}^{-1}$ ) 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 ( $127.84 \text{ kg ha}^{-1}$ ) by mustard crop was recorded with  $W_4$  (Pendimethalin 30 EC @  $1.0 \text{ kg a.i. ha}^{-1}$  PE *fb* Quizalofop 5 EC @  $60 \text{ g a.i. ha}^{-1}$  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 [13] and Chauhan [15].

In 2019-2020, hand weeding at 25 and 50 DAS with 125 % RDF ( $N_3W_2$ ) exhibited significantly highest Zn uptake ( $157.08 \text{ kg ha}^{-1}$ ) by mustard which was superior over all other herbicide treatments except  $N_3W_5$ . Application of Pendimethalin  $1.0 \text{ kg a.i. ha}^{-1}$  PE *fb* Clodinafop  $60 \text{ g a.i./ha PoE}$  ( $N_3W_5$ ) registered significantly highest Zn uptake ( $145.18 \text{ kg ha}^{-1}$ ) 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. [14] and Mukherjee [11] in mustard. Minimum Zn uptake in mustard was noticed in weedy check that might be attributed to least seed yield [16,17].

**Table 3. Effect of different treatments on S uptake (kg ha<sup>-1</sup>) by weeds during 2018-2019**

Weed management Nutrient Levels	W <sub>1</sub> - Weedy	W <sub>2</sub> - Two HW at 25 & 50 DAS	W <sub>3</sub> -Pendi methalin 1.0 kg a.i. ha <sup>-1</sup>	W <sub>4</sub> -Pendi methalin 1.0 kg a.i. ha <sup>-1</sup> PE + Quizalofop 60 g a.i. ha <sup>-1</sup> PoE	W <sub>5</sub> - Pendi methalin 1.0 kg a.i. ha <sup>-1</sup> PE + Clodinafop 60 a.i. ha <sup>-1</sup> PoE	W <sub>6</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup>	W <sub>7</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup> + Quizalofop 60 g a.i. ha <sup>-1</sup> PoE	W <sub>8</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup> + Clodinafop 60 g a.i. ha <sup>-1</sup> PoE	MEAN
N <sub>1</sub> -Soil test 100:40:40:20:6.25 kg NPKSZn ha <sup>-1</sup>	7.89	0.00	4.02	2.06	2.58	4.40	2.98	2.66	3.32
N <sub>2</sub> -100% RDF 80:40:40:20:5 kg NPKSZn ha <sup>-1</sup>	8.88	0.00	4.48	2.67	2.77	5.15	4.02	3.60	3.95
N <sub>3</sub> -125% RDF 100:50:50:25:6.25 kg NPKSZn ha <sup>-1</sup>	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		

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

Weed management Nutrient Levels	W <sub>1</sub> - Weedy	W <sub>2</sub> - Two HW at 25 & 50 DAS	W <sub>3</sub> - Pendi methalin 1.0 kg a.i. ha <sup>-1</sup>	W <sub>4</sub> -Pendi methalin 1.0 kg a.i. ha <sup>-1</sup> PE + Quizalofop 60 g a.i. ha <sup>-1</sup> PoE	W <sub>5</sub> - Pendi methalin 1.0 kg a.i. ha <sup>-1</sup> PE + Clodinafop 60 a.i. ha <sup>-1</sup> PoE	W <sub>6</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup>	W <sub>7</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup> + Quizalofop 60 g a.i. ha <sup>-1</sup> PoE	W <sub>8</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup> + Clodinafop 60 g a.i. ha <sup>-1</sup> PoE	MEAN
N <sub>1</sub> -Soil test 100:40:40:20:6.25 kg NPKSZn ha <sup>-1</sup>	6.25	0.00	3.98	2.33	2.86	4.31	2.89	3.07	3.21
N <sub>2</sub> -100% RDF 80:40:40:20:5 kg NPKSZn ha <sup>-1</sup>	7.81	0.00	4.85	2.52	3.24	5.07	4.21	3.42	3.89
N <sub>3</sub> -125% RDF 100:50:50:25:6.25 kg NPKSZn ha <sup>-1</sup>	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		

**Table 5. Effect of different treatments on Zn uptake (g ha<sup>-1</sup>) and S uptake (kg ha<sup>-1</sup>) by crop in 2018-2019**

Treatments	Zn uptake (g ha <sup>-1</sup> )	S uptake (kg ha <sup>-1</sup> )
<b>Nutrient levels</b>		
N <sub>1</sub> - Soil test-based fertilizer application	116.81	15.13
N <sub>2</sub> - 100% RDF (80: 40: 40: 20: 5 kg N P K S Zn ha <sup>-1</sup> )	108.80	14.48
N <sub>3</sub> - 125% RDF (100: 50: 50: 25: 6.25 kg N P K S Zn ha <sup>-1</sup> )	127.25	16.48
SEm±	3.38	0.38
CD (P=0.05)	13.29	1.48
<b>Weed management</b>		
W <sub>1</sub> - Weedy	75.34	9.16
W <sub>2</sub> - Two hand weeding at 25 and 50 DAS	134.15	18.22
W <sub>3</sub> - Pendimethalin 30 EC 1.0 kg a.i. ha <sup>-1</sup> PE	116.98	14.90
W <sub>4</sub> - Pendimethalin 30 EC 1.0 kg a.i. ha <sup>-1</sup> PE <i>fb</i> Quizalofop 5 EC @ 60 g a.i. ha <sup>-1</sup> PoE	127.84	16.75
W <sub>5</sub> - Pendimethalin 30 EC 1.0 kg a.i. ha <sup>-1</sup> PE <i>fb</i> Clodinafop 15 WP @ 60 g a.i. ha <sup>-1</sup> PoE	127.20	16.64
W <sub>6</sub> - Oxyflourfen 23.5 EC @ 150 g a.i. ha <sup>-1</sup> PE	113.04	14.34
W <sub>7</sub> - Oxyflourfen 23.5 EC @ 150 g a.i. ha <sup>-1</sup> PE <i>fb</i> Quizalofop 5 EC @ 60 g a.i. ha <sup>-1</sup> PoE	123.78	16.45
W <sub>8</sub> - Oxyflourfen 23.5 EC @ 150 g a.i. ha <sup>-1</sup> PE <i>fb</i> Clodinafop 15 WP @ 60 g a.i. ha <sup>-1</sup> 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.

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 [18]. Upadhyay [19] observed that the sulphur and zinc uptake increased significantly upto 60 kg S and 8 kg Zn ha<sup>-1</sup> application except for zinc uptake in seed whereas a significant increase was recorded only upto 40 kg S ha<sup>-1</sup>. 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 [20] 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<sup>-1</sup>) under N<sub>3</sub>, 125% RDF (100: 50: 50: 25: 6.25 kg N P K S Zn ha<sup>-1</sup>) which was found at par with N<sub>1</sub> (Soil test based fertilizer application) and was found significantly superior over N<sub>2</sub>, 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 [21] reported that S uptake increased significantly with increasing levels of sulphur up to 60 kg S ha<sup>-1</sup>. Application of 60 kg S ha<sup>-1</sup> increased S uptake by 7.8, 4.8 and 3.9% over 0, 20 and 40 kg S ha<sup>-1</sup>, respectively.

**Table 6. Effect of different treatments on Zn uptake (g ha<sup>-1</sup>) by mustard at harvest during 2019-2020**

Weed management Nutrient Levels	W <sub>1</sub> - Weedy	W <sub>2</sub> - Two HW at 25 & 50 DAS	W <sub>3</sub> -Pendi methalin 1.0 kg a.i. ha <sup>-1</sup>	W <sub>4</sub> -Pendi methalin 1.0 kg a.i. ha <sup>-1</sup> PE + Quizalofop 60 g a.i. ha <sup>-1</sup> PoE	W <sub>5</sub> - Pendi methalin 1.0 kg a.i. ha <sup>-1</sup> PE + Clodinafop 60 a.i. ha <sup>-1</sup> PoE	W <sub>6</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup>	W <sub>7</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup> + Quizalofop 60 g a.i. ha <sup>-1</sup> PoE	W <sub>8</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup> + Clodinafop 60 g a.i. ha <sup>-1</sup> PoE	MEAN
N <sub>1</sub> -Soil test 100:40:40:20:6.25 kg NPKSZn ha <sup>-1</sup>	69.96	140.99	126.86	130.45	124.03	118.16	124.88	118.32	119.20
N <sub>2</sub> -100% RDF 80:40:40:20:5 kg NPKSZn ha <sup>-1</sup>	45.07	124.55	118.67	121.74	117.94	112.46	116.42	114.63	108.93
N <sub>3</sub> -125% RDF 100:50:50:25:6.25 kg NPKSZn ha <sup>-1</sup>	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		

**Table 7. Effect of different treatments on S uptake (kg ha<sup>-1</sup>) by mustard at harvest during 2019-2020**

Weed management Nutrient Levels	W <sub>1</sub> - Weedy	W <sub>2</sub> - Two HW at 25 & 50 DAS	W <sub>3</sub> - Pendi methalin 1.0 kg a.i. ha <sup>-1</sup>	W <sub>4</sub> -Pendi methalin 1.0 kg a.i. ha <sup>-1</sup> PE + Quizalofop 60 g a.i. ha <sup>-1</sup> PoE	W <sub>5</sub> - Pendi methalin 1.0 kg a.i. ha <sup>-1</sup> PE + Clodinafop 60 a.i. ha <sup>-1</sup> PoE	W <sub>6</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup>	W <sub>7</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup> + Quizalofop 60 g a.i. ha <sup>-1</sup> PoE	W <sub>8</sub> - Oxyflourfen 150 g a.i. ha <sup>-1</sup> + Clodinafop 60 g a.i. ha <sup>-1</sup> PoE	MEAN
N <sub>1</sub> -Soil test 100:40:40:20:6.25 kg NPKSZn ha <sup>-1</sup>	8.80	18.81	14.97	17.22	16.96	14.78	16.90	16.72	15.64
N <sub>2</sub> -100% RDF 80:40:40:20:5 kg NPKSZn ha <sup>-1</sup>	7.25	16.25	14.87	15.86	15.05	14.48	15.69	14.53	14.25
N <sub>3</sub> -125% RDF 100:50:50:25:6.25 kg NPKSZn ha <sup>-1</sup>	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		



In 2018-2019, hand weeding at 25 and 50 DAS exhibited significantly highest S uptake (18.22 kg ha<sup>-1</sup>) by mustard crop which was found significantly superior over all other treatments. Among herbicides, maximum S uptake (16.75 kg ha<sup>-1</sup>) by mustard crop was recorded with W<sub>4</sub> (Pendimethalin 30 EC @ 1.0 kg a.i. ha<sup>-1</sup> PE fb Quizalofop 5 EC @ 60 g a.i. ha<sup>-1</sup> PoE) which was at par with rest of the herbicide treatments except W<sub>6</sub>, W<sub>3</sub> and W<sub>1</sub>. Malviya et al. [22] reported that sulphur applied at the rate of 60 kg S ha<sup>-1</sup> produced significantly higher nutrient uptake than 30 kg S ha<sup>-1</sup>. Sah et al. [23] reported that the application of sulphur @ 45 kg ha<sup>-1</sup> increased nutrient uptake of mustard. Sah et al. [23] observed that an increase in S levels significantly improved S uptake upto 60 kg ha<sup>-1</sup>. Singh et al. [24] 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<sub>3</sub>W<sub>2</sub>) exhibited significantly highest S uptake (21.34 kg ha<sup>-1</sup>) by mustard crop which was significantly superior over rest of the treatments. Among herbicide treatments, application of Pendimethalin 1.0 kg a.i. ha<sup>-1</sup> PE fb Quizalofop 60 g a.i. ha<sup>-1</sup> PoE (N<sub>3</sub>W<sub>4</sub>) registered significantly highest S uptake (17.63 kg ha<sup>-1</sup>) by mustard crop which was found at par with rest of the treatments except N<sub>3</sub>W<sub>6</sub>, N<sub>3</sub>W<sub>5</sub> and N<sub>3</sub>W<sub>1</sub>. 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. [25] and Chaudhry et al. [26].

Dubey et al. [27] 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<sup>-1</sup>. Faujdar et al. [28] 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. [29] and Singh and Pal [24]. Zizale et al. [30] 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<sup>-1</sup> PE fb Quizalofop @ 60 g a.i. ha<sup>-1</sup> PoE along with 125% RDF (100:50:50:25:6.25 kg NPKSZn ha<sup>-1</sup>) 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<sup>-1</sup>) exhibited significant improvement in Zn and S uptake by crop and weeds over weedy and herbicide treatments.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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