Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2021; 9(1): 2189-2197

Received: 19-11-2020
Accepted: 21-12-2020

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Response of nitrogen, phosphorus, potassium, sulphur and zinc on nutrient concentration, uptake and quality of mustard crop

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Abstract
A field experiment was conducted on Pot culture house of Department of Soil Science and Agricultural Chemistry at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur during the *rabi* season 2016-17, In the present experiment 8 treatments T_1 (Control), T_2 (100% RDF), T_3 (100% RDF+S_{30}), T_4 (100% RDF+Zn_5), T_5 (125% RDF), T_6(125% RDF+S_{30}), T_7 (125% RDF+ S_{30} +Zn_5), T_8 (150% RDF), were laid out in Randomized Block Design (RBD) with four replication. Mustard variety Pusa Bold was taken for study. The results revealed that the nutrient concentration, uptake and quality characteristics of mustard respond significantly with the different treatment combination. The highest nutrient concentration was recorded with T_8 (150% RDF), highest nutrient uptake and oil content (43.25%) was obtained in T_7 (125% RDF+ S_{30} +Zn_5). The treatment T_7 was recorded 22.69% higher oil content over control treatment.

Keywords: Mustard, nutrient concentration, uptake, quality, oilcontent, Pusa bold

Introduction
India is the fourth largest oilseed economy in the world. Rapeseed-mustard contributes 28.6% in the total oilseeds production among the seven edible oilseeds cultivated in India and ranks second after groundnut sharing 27.8% in India's oilseed economy (Singh *et al.*, 2017). Indian mustard (*Brassica juncea*.) is predominantly cultivated in the states of Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh and Gujarat and some non-traditional areas of South India including Karnataka, Tamil Nadu, and Andhra Pradesh. Indian mustard (*Brassica juncea*) commonly known as raya, rai or lahi is an important oilseed crop among the Brassica group of the oilseed in India. Rapeseed-mustard is an important group of edible oil seed crops and contributes about 26.1% of the total oilseed production and contributes about 85% of the total rapeseed– mustard produced in India (Meena *et al.*, 2011). The first position in the area and second position in Production after China (Anonymous, 2009).In India 2016-17 the production of oilseed crops was 32.10 million tonnes. More than 65% of the present area under oilseeds is un-irrigated and oilseeds production depends on success to achieve in changing the oilseeds scenario in the country is attributed mainly the expansion of the area under oilseeds and due to favorable price structure, it is evident from the area and production data that nearly half increases in oil seed productivity through improved management.

Primary nutrients *i.e.* nitrogen, phosphorus, potassium, secondary nutrient is sulphur and micro nutrient is zinc plays an important role in crop yield. Various studies indicated that the increasing levels of nutrients resulted in an increasing yield of mustard. Therefore, this study was initiated to evaluate the various levels of nutrients on the productivity, profitability and quality of Indian mustard. The nitrogen, phosphorus, potassium, sulphur and zinc applied in soil increase the height of plants and produce more grain and stover yield. The sulphur improved the quality of mustard oil. The available potassium was adequate in Indian soil but large scale testing of soil fields has provided beyond doubt that in many areas there is a need for potassium along with nitrogen, phosphorus, zinc and other nutrients for increasing crop productivity. As essential nutrient nitrogen, phosphorus, potassium, sulphur and zinc are known to perform several functions inside the plant body and it has been associated with a role in enzyme activator, food farmer, root booster, stalk strengthener, respiration regulator, starch transformers, protein builder, wilt reducer, disease retarder, crop quality improve, encourages vegetative growth, protein constituent, synthesis of auxin, a constituent of chlorophyll, increases disease resistant, energy storage.

It is well known that sulphur comes next to nitrogen and phosphorus in the nutrition of mustard because in addition to the fundamental requirement of sulphur. The crops need 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. Oil seed types need more sulphur than other crops. The study investigated the effect of sulphur and zinc with different levels of nitrogen, phosphorus and potassium to findout superior response with which level of NPK along with sulphur and zinc.

Dubey *et al.* (2013) [1] reported that the protein content 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) [2] observed a significant increasing in seed and stover yield, oil content and oil yield, protein content, chlorophyll

Faujdar *et al.* (2008) [2] observed a significant increase in seed and stover yield, oil content and oil yield, protein content, chlorophyll content and S-containing amino acids in a seed with the application of both P and S in Indian mustard. Kumar and Trivedi (2012) [4] reported that the oil content increased significantly with increasing levels of sulphur up to the highest level of 60 kg S ha-1. Application of 60 kg S ha-1 increased the oil content by 7.8, 4.8 and 3.9% over 0, 20 and 40 kg S ha-1, respectively.

Kumbhare *et al* (2007) [7] reported that nitrogen application up to 60 kg/ha resulted in a significant increase in N uptake by seed and stover and consequently total N uptake by Indian mustard over lower doses at Navsari (Joshi *et al* 1991b). Application of 62.5 kg/ha of N resulted in significantly higher N uptake (47.8 kg/ha) compared to its lower doses viz. 25.0, 37.5, and 50.0 kg/ha at Nagpur

Malviya *et al.* (2007) [19] reported that sulphur applied at the rate of 60 kg S ha^{-1} produced significantly higher oil content than 30 kg S ha-1.

Mishra *et al.* (2010) [10] in a field study at Indian Agriculture Research Institute, New Delhi reported that application of 60 kg ha-1 phosphorus registered (33.1%) oil content, which was about 10.2% higher than the control plots.

Moniruzzaman *et al.*, (2008) [13] 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 the significance of zinc in the crop production process.

Puri and Sharma (2006) [15] reported that the sulphur content increased with increasing rates of 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 crop

Reager *et al.* (2006) [16] at Bikaner (Rajasthan) quoted that an application of increasing levels of nitrogen from 40 to 100 kg ha-1 significantly enhanced the number of siliquae plant-1, number of seeds siliqua-1, siliqua length, test weight, seed yield and NPK uptake of Indian mustard. However, significant increases in stover and biological yields were recorded up to 120 kg N ha-1.

Sah *et al.* (2013) [17] reported that the application of sulphur @ 45 kg ha-1 increased the oil content of mustard.

Saud and Singh (2011) in a field experiment at Hisar (Haryana) observed that an increase in nitrogen levels significantly improved the nitrogen content both in seed and stove upto 60 kg N ha-1. However, P and K content in seed and stover was not influenced during any of the years. The nitrogen application increased significantly the uptake of NPK by seed and stove upto 100 kg N ha^{-1}.

Singh *et al.* (2015) [20] at Kota (Rajasthan) reported that the mustard varieties DMH-1 absorbed significantly higher amounts of nitrogen (100.6 kg ha-1), phosphorus (27.9 kg ha-1) and potassium (66.5 kg ha-1) than other tested varieties. A significant increase in uptake of nutrients might also be the results of the cumulative effect of higher content of these nutrients in seed and straw.

Upadhyay (2012) [21] observed that the nitrogen, phosphorus, potassium and sulphur 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 increased significantly the oil and protein content in the seed of mustard.

Zizale *et al.* (2008) [22] reported that the oil content increased with increasing level of S but the increase was non significant.

Materials and Methods

The experiment was conducted on the mustard crops during the *rabi* season of 2016- 17 under natural conditions at Pot culture house of Department of Soil Science and Agricultural Chemistry at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. The soil of the experimental field was alluvial in origin. Soil sample (0-15cm) depths were initially drawn from randomly selected parts of the field before sowing. The quantity of soil samples was reduced to about 500 gm through the quartering technique. The soil sample was then subjected to mechanical and chemical analysis to determine the textural class and fertility status the soils were sampled to a depth of 0-30 cm of the soil, air-dried and sieved (2 mm) for soil analyses. Some physical and chemical properties of soils are given in Table 1.

Table 1: Some properties of the <2mm fraction of the top 30 cm of soil used for the site.

S. No.	Particulars	Values
1.	Sand (%)	39.00
2.	Silt (%)	40.00
3.	Clay (%)	21.00
4.	Textural Class	Loam
5.	pH (1:2.5)	8.1
6.	EC (1:2.5) (ds/m at 25^0C)	0.34
7.	Organic Carbon (%)	0.40
8.	Available Nitrogen (kg/ha)	185.00
9.	Available Phosphorus (kg/ha)	9.80
10.	Available Potassium (kg/ha)	120.00
11.	Available Sulphur (kg/ha)	12.54
12.	Available Zinc (ppm)	0.40
13.	Particle Density (Mg/m^3)	2.54
14.	Bulk Density (Mg/m^3)	1.30
15.	Pore Space (%)	46.0

Mustard variety Pusa Bold was taken for study. In the present experiment 8 treatments T_1 (Control), T_2 (100% RDF), T_3 (100% RDF+S_{30}), T_4 (100% RDF+Zn_5), T_5 (125% RDF), T_6(125% RDF+S_{30}), T_7 (125% RDF+Zn_5), T_8 (150% RDF), f were laid out in Randomized Block Design(RBD) with four replications having plot size 2 x 2 meter square. Doses of fertilizers are applied @ 80 Kg N, 40 Kg P_2O_5, 40 Kg K_2O/ha 40 Kg S/ha, 5 Kg Zn/ha through Urea, D.A.P and Muriate of

Potash, Elemental sulphur, Zinc oxide. Sowing is done @ 5 kg seed ha^{-1} Mustard variety Pusa Bold was used and sown on 30 October 2016. Row to row and plant to plant distance remain 45 and 20 respectively. Seeds were sown about 1-2 cm deep.

Field Preparation: The experimental field was ploughed once with soil turning plough followed by two cross harrowing. After each operation, planking was done to level the field and to obtain the fine tilth. Finally layout was done and plots were demarcated with small sticks and rope with the help of manual labour in each block.

Application of fertilizers: The crop was fertilized as per treatment. The recommended dose of nutrient i.e. N, P, and K was applied @ 80 : 40 : 40 kg ha^{-1} respectively.

Time and method of fertilizer: Half does N_2 and total phosphorus, potash, zinc and sulphur were applied as basal dressing. Remaining dose of nitrogen was applied through top dressing after 1_{st} Irrigation.

Seed Treatment: To ensure the seeds are free from seed borne diseases, seeds were treated with thiram 75% WDP (1.5g/kg of seed).

Seed and sowing: @ 5 kg seed ha^{-1} Mustard variety Pusa Bold was used and sown on 30 October 2016. Row to row and plant to plant distance remain 45 and 20 respectively. Seeds were sown about 1-2 cm deep.

Intercultural operations: Weeding and hoeing were done with khurpi and hand hoe after germination.

Thinning: To maintain proper distance within row and plant population by thinning of the plants were carried out after 25 days of sowing.

Irrigation: Tube-well was the source of irrigation. Irrigation was provided in the crop as and when required.

Harvesting: The crop was harvested at proper stage of maturity as determined by visual observations.

Threshing: Bundles were dried and weighed, individually of each plot then beaten with wooden sticks and seeds were separated by winnowing.

Yield: The production of each plot collected separately and packed in bags carefully avoiding contamination. The grains of each bag were then weighed and recorded in kg/net plot and there after computed as q/ha. Similarly straw yield was also recorded.

Soil Analysis

Mechanical Separates: Soil separates analyzed by International pipette method as described by the Piper (1966).

pH: pH of the soil determined by using soil water suspension (1:2.5) with the help of digital pH meter.

EC: EC was also determined using soil water suspension (1:2.5) with help of conductivity meter (Jackson, 1967).

Organic Carbon: Organic Carbon was determined by Walkley and Black's rapid titration method as described by Jackson (1967).

Available Nitrogen: It was determined by the Alkaline Potassium Permanganate Method described by Subbiah and Asija (1956).

Available Phosphorus: It is determined by Olsen's method using 0.5 M NaHCO3 (Olsen *et al*. 1954).

Available Potassium: Potassium is determined by using Neutral Normal Ammonium Acetate (pH 7.0) by Flame Photometer.

Available Sulphur:- Available Sulphur was determined by turbidimetric method (Chesnin and Yien, 1950) after extraction with 0.15%$CaCl_2$ solution. Available Zinc:- Available Zn is determined by Atomic Absorption Spectrophotometer with the help of DTPA extractant (Lindsey and Norvell, 1978).

Plant Analysis

Plant samples were dried first in the air then kept in the oven at 70 °C for 8 hr to make the sample free from excess moisture. The samples were grounded in a Wiley mill having stainless parts and stored in polythene bags.

Preparation of extract: Fine ground plant samples were digested in triacid mixture of conc. Nitric acid, sulphuric acid and perchloric acid for P and K determination in 10:4:1 ratio. Diacids (9:4mixture of HNO3 and $HClO_4$) digestion method is adopted for Zn extraction.

Determination of N, P, K, S and Zn in plant

i. **Nitrogen:** N is determined by the Kjeldahl method given by Jackson (1967).
ii. **Phosphorus:** P is determined colorimetrically by the vanadate-molybdate yellow colour method as advocated by Chapman and Pratt (1961).
iii. **Potassium:** K determination has been done using flame photometric method (Chapman and Pratt, 1961) outlined by Jackson (1967).
iv. **Sulphur:** S is determined through the turbidimetric method (Chesnin and Yien, 1956).
v. **Zinc:** Zn is extracted from plants with the help of atomic absorption spectrophotometer (Lindasey and Norwell, 1978).

Uptake

To calculate the uptake of N, P, K and S in grain as well as in straw, the following formula is used-

Uptake of Nutrients (kg/ha)

Statistical Analysis: The data on various characters studied during the course of investigation were statistically analyzed for randomized block design. Wherever treatment differences were significant ("F" test), critical differences were worked out at five per cent probability level. The data obtained during the study were subjected to statistical analysis using the methods advocated by Chandel (1990).

Results

Effects of different treatments on Nutrient Concentration & their uptake these are specified that

Nitrogen concentration in seed and stover

The application of mineral nutrients at increasing level have also significantly increased the nitrogen content in seed and stover. The data depicted to nitrogen content (%) in seed and stover. Nitrogen content (seed + stover) as influenced by different levels of nitrogen, phosphorus, potassium, sulphur and zinc are presented in Table 2. The analysis of variance in seed & stover nitrogen content (%). The perusal of data in Table 2 reveals that nitrogen content (%) in Seed and stover were significantly affected by different levels of N, P, K, S & Zn. Among different levels of N,P&K 150% of RDF and with and without S_{30}+Zn_5 kg ha^{-1} registered significantly Maximum nitrogen content (3.341, 3.238, 3.235%) in seed and (0.489, 0.476, 0.474%) in stover from T_8 ,T_7,T_6 respectively. The lowest nitrogen content 3.055% in seed & 0.409% in stover as recorded in control. The treatment 8 gave the highest nitrogen content percent in both seed and stover.

Table 2: Effects of different treatments on Nitrogen Concentration in seed & stover (Mean Value).

Sr. No.	Treatments	Symbol	Content of N% In Seed	Content of N% In Stover
1	Control	T_1	3.055	0.409
2	NPK(100%)RDF	T_2	3.207	0.447
3	NPK(100%)RDF+S_{30}	T_3	3.209	0.449
4	NPK(100%)RDF+Zn_5	T_4	3.210	0.450
5	NPK(125%)RDF	T_5	3.233	0.471
6	NPK(125%)RDF+S_{30}	T_6	3.235	0.474
7	NPK(125%)RDF+ S_{30} +Zn_5	T_7	3.238	0.476
8	NPK(150%)RDF	T_8	3.341	0.489
	MEAN		3.216	0.458
	SE(d)		0.010	0.007
	C.D (5%)		0.022	0.015

Phosphorus concentration in seed and stover

The application of mineral nutrients at an increasing level have also significantly increased the phosphorus content in seed and stover during the year 2016-17 in pooled analysis. The data pertaining to phosphorus content (%) in seed and stover .The phosphorus content (seed + stover) as influenced by different levels of nitrogen, phosphorus, potassium, sulphur and zinc are presented in Table 3. The analysis of variance in seed and stover phosphorus content (%)

The perusal of data in Table 3 reveals that phosphorus content (%) in Seed and stover were significantly affected by different levels of N, P, K, S & Zn. Among different levels of N,P & K 150% of RDF and with and without S_{30}+Zn_5 kg ha$_{-1}$ registered significantly Maximum phosphorus content (0.787, 0.770, 0.769%) in seed and (0.248, 0.231, 0.129%) in stover from T_8 ,T_7,T_6 respectively. The lowest phosphorus content 0.691% in seed & 0.173% in stover as recorded in control. The treatment- 8 have the highest phosphorus content percent in both seed and stover.

Table 3: Effects of different treatments on Phosphorus Concentration in seed & stover (Mean Value).

Sr. No.	Treatments	Symbol	Content of P% In Seed	Content of P% In Stover
1	Control	T_1	0.691	0.173
2	NPK(100%)RDF	T_2	0.732	0.204
3	NPK(100%)RDF+S_{30}	T_3	0.736	0.206
4	NPK(100%)RDF+Zn_5	T_4	0.739	0.209
5	NPK(125%)RDF	T_5	0.766	0.227
6	NPK(125%)RDF+S_{30}	T_6	0.769	0.229
7	NPK(125%)RDF+ S_{30} +Zn_5	T_7	0.770	0.231
8	NPK(150%)RDF	T_8	0.787	0.248
	MEAN		0.749	0.216
	SE(d)		0.005	0.002
	C.D (5%)		0.011	0.005

Potassium concentration in seed and stover

The application of mineral nutrients at an increase level have also significantly increased the potassium content in seed and stover .The data pertaining to potassium content in seed and stover show in table 4. The analysis of variance in seed &stover potassium content (%). The perusal of data was reveals that potassium content in Seed and stover were significantly affected by different levels of N, P, K, S, & Zn. Among different levels of N, P & K 150% of RDF and with and without S_{30}+Zn_5 kg ha$_{-1}$ registered significantly Maximum potassium content (1.069,1.039,1.036%) in seed and (0.438, 0.421, 0.419%) in stover from $T_{8,}$ T_7, T_6 respectively. The lowest potassium content was 0.931% in seed & 0.340% in stover as recorded in control. The treatment- 8 have highest potassium content in both seed and stover. The perusal of data in Table 4 reveals that K content (%) in Seed and stover were significantly affected by different levels of N, P, K, S & Zn.

Table 4: Effects of different treatments on Potassium Concentration in seed & stover (Mean Value).

Sr. No.	Treatments	Symbol	Content of K% In Seed	Content of K% In stover
1	Control	T_1	0.931	0.340
2	NPK(100%)RDF	T_2	0.978	0.371
3	NPK(100%)RDF+S_{30}	T_3	0.980	0.375
4	NPK(100%)RDF+Zn_5	T_4	0.983	0.377
5	NPK(125%)RDF	T_5	1.032	0.416
6	NPK(125%)RDF+S_{30}	T_6	1.036	0.419
7	NPK(125%)RDF+ S_{30} +Zn_5	T_7	1.039	0.421
8	NPK(150%)RDF	T_8	1.069	0.438
	MEAN		1.006	0.394
	SE(d)		0.002	0.004
	C.D (5%)		0.005	0.009

Sulphur concentration in seed and stover

The application of mineral nutrients at increasing level have also significantly increased the sulphur content in seed and stover during the year 2016-17 in pooled analysis show in Table 5. The sulphur content (seed+ stover) as influenced by different levels of nitrogen, phosphorus, Among different levels of N, P & K 125% of RDF+ S_{30} kg ha_{-1} and with and without Zn_5 kg ha_{-1} registered significantly Maximum sulphur content (1.541,1.536,1.483%) in seed and (0.369, 0.361, 0.331%) in stover from $T_{6,}$ T_3,T_8 ,respectively. The lowest sulphur content was 1.394% in seed & 0.283% in stover as recorded in control. The treatment- 6 gave highest sulphur content percent in both seed and stover.

Table 5: Effects of different treatments on Sulphur Concentration in seed & stover (Mean Value).

Sr. No.	Treatments	Symbol	Content of S% In Seed	Content of S% In Stover
1	Control	T_1	1.394	0.283
2	NPK(100%)RDF	T_2	1.471	0.322
3	NPK(100%)RDF+S_{30}	T_3	1.536	0.361
4	NPK(100%)RDF+Zn_5	T_4	1.474	0.325
5	NPK(125%)RDF	T_5	1.477	0.323
6	NPK(125%)RDF+S_{30}	T_6	1.541	0.369
7	NPK(125%)RDF+ S_{30} +Zn_5	T_7	1.479	0.329
8	NPK(150%)RDF	T_8	1.483	0.331
	MEAN		1.481	0.330
	SE(d)		0.004	0.001
	C.D (5%)		0.008	0.003

Zinc concentration in seed and stover

The application of mineral nutrients at increasing level have also significantly increased the zinc content in seed and stover. The zinc content (seed + stover) as influenced by different levels of N, P, K, S & Zn are presented in Table 6. The analysis of variance in seed and stover zinc content (ppm). The perusal of data in Table 6 reveals that zinc content (ppm) in Seed and stover were significantly affected by different levels of N, P, K, S& Zn. Among different levels of N,P&K 125% of RDF+ Zn_5 kg ha_{-1} and with and without S_{30} kg ha_{-1} registered significantly Maximum zinc content (31.350, 30.951, 26.763 ppm) in seed and (32.493, 31.259, 28.899 ppm) in stover from $T_{7,}$ T_4,T_8 ,respectively. The lowest zinc content was 24.958 ppm in seed & 27.173ppm in stover as recorded in control. The treatment- 7 have highest zinc content ppm in both seed and stover.

Table 6: Effects of different treatments on Zinc Concentration in seed & stover (Mean Value).

Sr. No.	Treatments	Symbol	Content of Zn(ppm) In Seed	Content of Zn(ppm) In Stover
1	Control	T_1	24.958	27.173
2	NPK(100%)RDF	T_2	26.753	28.893
3	NPK(100%)RDF+S_{30}	T_3	26.755	28.895
4	NPK(100%)RDF+Zn_5	T_4	30.951	31.259
5	NPK(125%)RDF	T_5	26.759	28.896
6	NPK(125%)RDF+S_{30}	T_6	26.761	28.898
7	NPK(125%)RDF+ S_{30} +Zn_5	T_7	31.350	32.493
8	NPK(150%)RDF	T_8	26.763	28.899
	MEAN		27.631	29.425
	SE(d)		0.248	0.024
	C.D (5%)		0.520	0.050

Nitrogen uptake by seed and stover

The application of different mineral nutrient supplementation at increasing level individually and in combination significantly increased N uptake of seed and stover at harvest of the crop during the year 2016-17 and in pooled mean analysis. The nitrogen uptake (kg ha^{-1}) in seed, stover and total N was significantly affected by different levels of nitrogen, phosphorus, potassium, sulphur & zinc.

Among different levels of N,P,&K ,0, 100, 125 & 150% of RDF ha^{-1} + with and without $S_{30,}$ Zn_5 kg ha^{-1} recorded significantly highest nitrogen uptake (65.116 kg ha^{-1}) in seed (T_7) and significantly highest nitrogen uptake (20.529 kg ha^{-1})

in stover and (85.645 kg ha^{-1}) in total N uptake and the lowest nitrogen uptake of 41.334 kg ha^{-1} in seed (T_1) and 15.161 kg ha^{-1} in stover (T_1) were recorded in the control show in table 7 & appendices 21 & 22.

Table 7: Effects of different treatments on uptake of Nitrogen mustard seed.

Sr. No.	Treatments	Symbol	Uptake of N by Seed (kg/ha)	Uptake of N by Stover(kg/ha)	Total uptake of N(kg/ha)
1	Control	T_1	41.334	15.161	56.495
2	NPK(100%)RDF	T_2	50.670	17.078	67.748
3	NPK(100%)RDF+S_{30}	T_3	54.328	17.434	71.762
4	NPK(100%)RDF+Zn_5	T_4	60.308	18.418	78.726
5	NPK(125%)RDF	T_5	54.637	18.147	72.784
6	NPK(125%)RDF+S_{30}	T_6	55.739	18.471	74.210
7	NPK(125%)RDF+ S_{30} +Zn_5	T_7	65.116	20.529	85.645
8	NPK(150%)RDF	T_8	64.180	20.161	84.341
	MEAN		55.789	18.174	
	SE(d)		0.033	0.009	
	C.D (5%)		0.069	0.020	

Phosphorus uptake by seed and stover

The data pertaining to P uptake in seed, stover and total, phosphorus uptake (seed + stover) kg ha^{-1} as influenced by different levels of N, P, K, S & Zn are presented in Table 8. The application of different mineral nutrient supplementation at increasing level individually and in combination significantly increased P uptake of seed and stover at harvest of the crop. The phosphorus uptake (kg ha^{-1}) in seed, stover and total P was significantly affected by different levels of N, P, K, S & Zn. Among different levels of N,P,&K 0, 100, 125 & 150% of RDF ha^{-1} + with and without $S_{30,}$ Zn_5 kg ha^{-1} recorded significantly highest, phosphorus uptake (15.484 kg ha^{-1}) in seed (T_7) and significantly highest, phosphorus uptake (10.225 kg ha^{-1}) in stover (T_8) and (25.343 kg ha^{-1}) in total P and the lowest phosphorus uptake of 9.344 kg ha^{-1} in seed (T_1) , 6.431 kg ha^{-1} in stover (T_1) and 15.775 kg ha^{-1}(T_1) in total P uptake were recorded in the control.

Table 8: Effects of different treatments on uptake of Phosphorus in mustard seed

Sr. No.	Treatments	Symbol	Uptake of P by Seed (kg/ha)	Uptake of P by Stover(kg/ha)	Total uptake of P (kg/ha)
1	Control	T_1	09.344	6.431	15.775
2	NPK(100%)RDF	T_2	11.565	7.798	19.363
3	NPK(100%)RDF+S_{30}	T_3	12.460	7.998	20.458
4	NPK(100%)RDF+Zn_5	T_4	13.878	8.554	22.432
5	NPK(125%)RDF	T_5	12.945	8.746	21.691
6	NPK(125%)RDF+S_{30}	T_6	13.249	8.924	22.173
7	NPK(125%)RDF+ S_{30} +Zn_5	T_7	15.484	8.963	24.447
8	NPK(150%)RDF	T_8	15.118	10.225	25.343
	MEAN		13.005	8.579	
	SE(d)		0.002	0.009	
	C.D (5%)		0.005	0.020	

Potassium uptake by seed and stover

The data pertaining to potassium uptake in seed, stover and total potassium uptake (seed + stover) kg ha^{-1} as influenced by different levels of N, P, K, S & Zn are presented in Table 9. The application of different mineral nutrient supplementation at increasing level individual and in combination significantly increased K uptake of seed and stover at harvest of the crop. The potassium uptake (kg ha^{-1}) in seed, stover and total K was significantly affected by different levels of N, P, K, S & Zn. Among different levels of N, P & K 0, 100, 125 & 150% of RDF ha^{-1} + with and without $S_{30,}$ Zn_5 kg ha^{-1} recorded significantly highest, potassium uptake (20.894 kg ha^{-1}) in seed (T_7) and significantly highest, potassium uptake (18.157 kg ha^{-1}) in stover (T_7) and (39.951 kg ha^{-1}) in total K and the lowest potassium uptake of 12.571 kg ha^{-1} in seed (T_1) , 12.603 kg ha^{-1} in stover (T_1) and 25.174 kg ha^{-1}(T_1) in total K uptake were recorded in the control.

Table 9: Effects of different treatments on uptake of Potassium in mustard seed and stover.

Sr. No	Treatments	Symbol	Uptake of K by Seed (kg/ha)	Uptake of K by Stover(kg/ha)	Total uptake of K (kg/ha)
1	Control	T_1	12.571	12.603	25.174
2	NPK(100%)RDF	T_2	15.452	14.183	29.635
3	NPK(100%)RDF+S_{30}	T_3	16.591	14.561	31.152
4	NPK(100%)RDF+Zn_5	T_4	18.460	15.430	33.890
5	NPK(125%)RDF	T_5	17.440	15.778	33.218
6	NPK(125%)RDF+S_{30}	T_6	18.850	16.328	35.178
7	NPK(125%)RDF+ S_{30} +Zn_5	T_7	20.894	18.157	39.951
8	NPK(150%)RDF	T_8	20.535	18.058	38.593
	MEAN		17.599	15.637	
	SE(d)		0.435	0.240	
	C.D (5%)		0.910	0.502	

Sulphur uptake by seed and stover
The data pertaining to sulphur uptake in seed, stover and total sulphur uptake (seed + stover) kg ha^{-1} as influenced by different levels of N, P, K, S & Zn are presented in Table 10. The application of different mineral nutrient supplementation at increasing level individual and in combination significantly increased S uptake of seed and stover at harvest of the crop during the year 2016-17 and in pooled mean analysis.

Among different levels of N, P & K 0, 100, 125 & 150% of RDF ha^{-1} + S_{30} ,with and withoutZn$_5$ kg ha^{-1} recorded significantly highest, sulphur uptake (29.992 kg ha^{-1}) in seed (T_7) and significantly highest, sulphur uptake (14.379 kg ha^{-1}) in stover (T_6) and (44.181 kg ha^{-1}) in total S and the lowest sulphur uptake of 18.860 kg ha^{-1} in seed (T_1) , 10.490 kg ha^{-1} in stover (T_1) and 29.350 kg ha^{-1}(T_1) in total S uptake were recorded in the control.

Table 10: Effects of different treatments on uptake of S in mustard seed & stover.

Sr. No.	Treatments	Symbol	Uptake of S by Seed (kg/ha)	Uptake of S by Stover(kg/ha)	Total uptake of S (kg/ha)
1	Control	T_1	18.860	10.490	29.350
2	NPK(100%)RDF	T_2	23.241	12.310	35.551
3	NPK(100%)RDF+S_{30}	T_3	26.005	14.017	40.022
4	NPK(100%)RDF+Zn_5	T_4	27.681	13.302	40.983
5	NPK(125%)RDF	T_5	24.961	12.450	37.411
6	NPK(125%)RDF+S_{30}	T_6	26.501	14.379	40.880
7	NPK(125%)RDF+ S_{30} +Zn_5	T_7	29.992	14.189	44.181
8	NPK(150%)RDF	T_8	28.488	13.522	42.010
	MEAN		25.716	13.082	
	SE(d)		0.127	0.063	
	C.D (5%)		0.265	0.131	

Zinc uptake by seed and stover
The data pertaining to zinc uptake in seed, stover and total zinc uptake g ha^{-1} as influenced by different levels of nitrogen, phosphorus, potassium, sulphur and zinc are presented in Table 11. The application of different mineral nutrient supplementation at increasing levels as an individual and in combination significantly increased Zn uptake of seed and stover at harvest stage of the crop.

Among different levels of N, P & K 0, 100, 125 & 150% of RDF ha^{-1} + Zn$_5$ kg ha^{-1} ,with and without S_{30} kg ha^{-1} recorded significantly highest zinc uptake (63.040 g ha^{-1}) in seed (T_7) and significantly highest zinc uptake (140.140 g ha^{-1}) in stover (T_7) and (203.180 g ha^{-1}) in total Zn and the lowest zinc uptake of 33.645 g ha^{-1} in seed (T_1), 100.730 g ha^{-1} in stover (T_1) and 134.375 g ha^{-1} (T_1) in total Zn uptake were recorded in the control.

Table 12: Effects of different treatments on uptake of Zinc in mustard seed and stover.

Sr. No.	Treatments	Symbol	Uptake of Zn by Seed (gm/ha)	Uptake of Zn by Stover (gm/ha)	Total uptake of Zn (gm/ha)
1	Control	T_1	33.645	100.730	134.375
2	NPK(100%)RDF	T_2	42.265	110.453	152.718
3	NPK(100%)RDF+S_{30}	T_3	44.730	112.203	156.933
4	NPK(100%)RDF+Zn_5	T_4	58.123	127.940	186.063
5	NPK(125%)RDF	T_5	45.220	111.335	156.555
6	NPK(125%)RDF+ S_{30} +Zn_5	T_6	46.105	112.615	158.720
7	NPK(125%)RDF+Zn5	T_7	63.040	140.140	203.180
8	NPK(150%)RDF	T_8	51.408	119.145	170.553
	MEAN		48.057	116.820	
	SE(d)		0.928	1.329	
	C.D (5%)		1.944	2.783	

Effect of different treatments on quality of mustard crop
Oil content (%) in seed
The experimental data (Table 13) revealed that application of different increasing level of mineral nutrients had significant influence on the oil content of seed of mustard over control during the year 2016-17 and pooled mean. The application of different mineral nutrients supplementation at increasing level individually and in combination significantly increased oil content at harvest of the crop during the year 2016-17 and in pooled mean analysis. The application of mineral nutrients the oil content in seed of mustard ranged between 35.25 to 43.25% in 2016-17 and in pooled mean. Under the treatment of mineral nutrients, the significantly maximum oil content in seed was recorded as 43.25% under the treatment T_7 (NPK 125% RDF+ 30 kg ha^{-1} S +5 kg ha^{-1} Zn) which was 8 per cent higher and significantly superior over control (T1) in the years 2016-17 and pooled analysis mean. The lowest oil content in mustard seed was 35.25% (T_1) recorded in the control.

Oil yield (kg ha^{-1}) in seed
The experimental data (Table 13) revealed that application of different increasing level of mineral nutrients had significant influence on the oil yield in seed of mustard over control during the year 2016-17. The application of different mineral nutrients supplementation at increasing level individually and in combination significantly increased oil yield at harvest of the crop during the year 2016-17 and in pooled mean analysis. The application of mineral nutrients the oil yield in seed of mustard ranged between 476.93 kg ha^{-1} to 869.75 kg ha^{-1} in 2016-17 and in pooled mean. Under the treatment of mineral nutrients, the significantly maximum oil yield in seed was recorded as 869.75 kg ha^{-1} under the treatment T_7 (NPK(125%)RDF+ 30 kg ha^{-1} S +5 kg ha^{-1} Zn) which was

82.36 per cent higher oil yield compare to control and significantly superior over control (T1) in the years 2016-17 and pooled analysis mean. The lowest oil yield in mustard seed was between 476.93 kg ha- (T_1) recorded in the control.

Table 13: Effects of different treatments on oil contents and oil yield in mustard grains.

Sr. No.	Treatments	Symbol	Oil Content (%)	Total yield(kg/ha)
1	Control	T_1	35.25	476.93
2	NPK(100%)RDF	T_2	38.50	608.30
3	NPK(100%)RDF+S_{30}	T_3	40.75	689.89
4	NPK(100%)RDF+Zn_5	T_4	42.25	693.45
5	NPK(125%)RDF	T_5	40.25	680.23
6	NPK(125%)RDF+S_{30}	T_6	41.75	719.35
7	NPK(125%)RDF+ S_{30} +Zn_5	T_7	43.25	869.75
8	NPK(150%)RDF	T_8	42.75	821.23
	MEAN		40.59	694.89
	SE(d)		0.399	11.147
	C.D (5%)		0.835	23.339

Discussion

Effect of N, P, K, S & Zn on the nutrient concentration and its uptake by Mustard crop

Nutrient Concentration

The application of different increasing levels of mineral nutrients significantly influenced the N, P, K, S and Zn content in seed and stover of the crop over control during the year and in pooled analysis (Table 1, 2, 3, 4, 5). The significantly maximum N, P and K content in seed and stover was obtained under the treatment 8 of NPK 150% RDF (T_8) over control during the year and in pooled analysis while, significantly maximum S content in seed and stover was recorded with the application of NPK 125% of RDF + Sulphur 30 kg ha^{-1}in treatment 6 over control during the year and pooled analysis and the significantly maximum Zn content in seed and stover were observed with the application of NPK 125% of RDF + 30 kg ha^{-1} S +5 kg ha^{-1} Zn(T_7) over control during the year and in pooled analysis. Among different levels of N,P&K 150% of RDF and with and without S_{30}+Zn_5 kg ha^{-1} registered significantly Maximum nitrogen content (3.341, 3.238, 3.235%) in seed and (0.489, 0.476, 0.474%) in stover from T_8 ,T_7,T_6 respectively. The lowest nitrogen content 3.055% in seed & 0.409% in stover as recorded in control. Treatment 8 has the highest nitrogen content percent in both seed and stover.

This increased NPK content of nutrient in seed and stover of the crop with the application of 150% NPK of RDF and the increased S content of nutrient in seed and stover of the crop with the application of 125% NPK of RDF +30 kg ha^{-1} S and the increased Zn content of nutrient in seed and stover of the crop with the application of 125% NPK of RDF+ 30 kg ha^{-1} S +5 kg ha^{-1} Zn might be due to improved nutritional environment in the rhizosphere as well as in the plant system, which might have leaded to enhanced translocation of nutrients in plant parts (Sharma *et al.*, 2014, Mishra *et al.*, 2002, Kumawat and Aswal, 2005 [6] and Jat *et al.*, 2013) coupled with increased metabolic activity at cellular level might have increased their accumulation in seed and stover of the crop. Release of nutrients in available form and other physical properties might have influenced the availability of other nutrients leading to their adsorption, thereby showing a higher content with the application of 125% RDF + S + Zn (Jat and Mehra, 2007). Similar findings are noted by Giri *et al.* (2003), Puri and Sharma (2006) [15] and Pachauri *et al.* (2012) [14].

Nutrient Uptake

The application of different increasing levels of mineral nutrients significantly influenced the N, P, K, S and Zn uptake in seed and stover of the crop over control during the year and pooled analysis (Table 6, 7, 8, 9 & 10). The uptake of N, P, K, S and Zn by seed and stover at harvest of the crop also significantly increased with increasing levels of mineral nutrients during the year and in pooled analysis. The significantly highest uptake of these nutrients in seed and stover were observed under the treatment level 125% NPK of RDF + 30 kg ha^{-1} S +5 kg ha^{-1} Zn (T_7) during the year and in pooled analysis over control. This is clear from the data that experimental soil was coarse textured and low in organic carbon, N, P and deficient in S and Zn status. Among different levels of N,P,&K ,0, 100, 125 & 150% of RDF ha^{-1} + with and without $S_{30,}$ Zn_5 kg ha^{-1} recorded significantly highest nitrogen uptake (65.116 kg ha^{-1}) in seed (T_7) and significantly highest nitrogen uptake (20.529 kg ha^{-1}) in stover and (85.645 kg ha^{-1}) in total N uptake and the lowest nitrogen uptake of 41.334 kg ha^{-1} in seed (T_1) and 15.161 kg ha^{-1} in stover (T_1) were recorded in the control.

The increase in uptake of N, P, K, S and Zn seems to be associated with increased availability with a concomitant increase in crop yield with 125% NPK of RDF + 30 kg ha^{-1} S +5 kg ha^{-1} Zn (T_7) application **(Jat *et al.*, 2013).** The increase in uptake of N, P, K, S and Zn attributed to the application of 125% NPK of RDF + 30 kg ha^{-1} S +5 kg ha^{-1} Zn (T_7) might be due to vigorous root and shoot growth resulting in greater absorption of the nutrients from the soil, favourable influence on photosynthates and metabolic process which augments the production of photosynthates and their translocation to different plant parts including seed and stover, and ultimately increased the uptake of N, P, K, S and Zn by seed and stover (Upadhyay, 2012) [21]. Similar results have been also reported by Saranghem *et al.* (2008) [18], Kumar and Trivedi (2012) [4] and Pachauri *et al.* (2012) [14].

Effect of N, P, K, S & Zn on quality parameters of mustard.

Oil content and oil yield

The oil content of seed and oil yield was significantly influenced by the application of different increasing levels of mineral nutrients over control during the year and in pooled analysis (Table 13). The significantly maximum oil content and oil yield were noticed with the application of 125% NPK of RDF + 30 kg ha^{-1} S +5 kg ha^{-1} Zn (T_7) over control during the year and in pooled analysis. It might be due to the fact that sulphur is involved in the formation of glycosides, glucosinolates and activation of enzymes which add in bio chemical reaction within the plant (Ravi *et al.*, 2008). The increase in oil content with the application of sulphur may be due to direct involvement in the synthesis of oil and an increase in oil content of the crop due to sulphur application in the sulphur deficient soils is expected (Jena *et al.*, 2006). Similar results have also been reported on mustard by Mishra *et al*. (2002), Kumawat and Aswal (2005) [6], Sharma and Arora (2008), Deo and Khandelwal (2009), Reddy *et al.* (2009), Pachauri (2012) [14] and Ghatei *et al.* (2013).

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