The Pharma Innovation Journal 2022; 11(3): 2399-2403

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(3): 2399-2403

www.thepharmajournal.com
Received: 06-12-2021
Accepted: 09-01-2022

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Response of Indian mustard (*Brassica juncea* L.) to source and levels of sulphur on oil content and nutrient uptake

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Abstract
The present investigation entitled "Response of Indian mustard (*Brassica Juncea* L.) to sources and levels of sulphur on oil content and nutrient uptake." was carried out during *Rabi* season of 2018 and 2019 at Agronomy Research Farm of the A.N.D. University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.). The 36 treatment combinations having three sulphur sources *viz*. Phosphogypsum, Elemental Sulphur and Single Super Phosphate were investigated with four levels of sulphur *viz*. 0.00 kg ha^{-1}, 20 kg ha^{-1}, 40 kg ha^{-1} and 60 kg ha^{-1} was kept in different plots. The experiment in F-RBD and replicated in three times. The total Nitrogen, Phosphorus, Potassium and Sulphur uptake by crop was highest recorded 106.55, 36.93, 150.63 and 20.93 kg ha^{-1} respectively with phosphogypsum source of sulphur significantly as compared to rest two sources of sulphur in seed, stover and crop during both the years of experimentation. As far as doses of sulphur was concerned, Nitrogen, Phosphorus, Potassium and Sulphur uptake increased with simultaneous increase in S doses resulting maximum value at 60 kg Sulphur ha^{-1}(108.17, 37.50, 152.73 and 21.93 kg ha^{-1} respectively) which exhibited significance over rest of sulphur doses. The trend of increase was similar in uptake by seed, stover and crop during both the years of study. The highest oil content 38.57% and 38.81% in seed was noted during first and second year respectively from phosphogypsum source of sulphur and level of sulphur is 60 kg Sulphur ha-1 which exhibited statistical similarity with rest sources of sulphur and level of sulphur.

Keywords: Indian mustard, oil content, nutrient uptake

Introduction

Indian mustard (*Brassica juncea* L.) is locally called Rai, Raya, Laha and Raiya, whereas, rapeseed is called Sarson, Toria, yellow Toria. Its green tender plants are used for preparing vegetable dish commonly called as "Sarson Ka Saag". The oil is utilized for human consumption throughout northern India for cooking and frying purposes. The whole seed is used as condiment in the preparation of pickles and for flavoring curries and vegetables. The mustard oil is also used in preparing vegetable ghee, hair oil, medicines, soaps, lubricating oil and in tanning industries. The oil content in mustard seeds varies from 37-49 per cent (Bhowmik *et al.*, 2014) [2]. The seeds are highly nutritive containing 38-57% erucic acid, 5-13% linolic acid and 27% oleic acid.

Oilseed crops occupy an important place in Indian agricultural economy as well as in human life. They are not only rich sources of energy and carriers of fat soluble vitamins A, D, E and K but they form the ingredients of foods and flavors; cosmetics and condiments; soap and detergents; lubricants and laxatives and also known for their medical and therapeutic use. Rapeseed-mustard is the third most important edible oilseed crop in India having 30 to 48 per cent oil content after soybean and groundnut.

Mustard seed has content 28 to 36% protein with a high nutritive value. Mustard is one of the major sources of oil in India. Indian mustard (*Brassica juncea* L.) is the most important *rabi* season oilseed crop, which thrives best in light to heavy loam soil in areas having 25 to 40 cm rainfall. Mustard oil is mainly used for cooking, frying and in pickles. The oil cake left after extraction is utilized as cattle feed and manure. Its oil cake contains 5.2, 1.8 and 1.2 per cent N, P and K, respectively.

Sulphur is the fourth major plant nutrient after nitrogen, phosphorus and potassium for Indian agriculture. It is essential for synthesis of amino acids, proteins, oils, and a component of vitamin A and activates enzyme system in plant. Three amino acids *viz*. methionine (21% S), cysteine (26% S) and cystine (27%S) contain S which are the building blocks of proteins about 90% of sulphur is present in these amino acids.

Sulphur is also involved in the formation of chlorophyll, glucosides and glucosinolates (mustard oils), activation of enzymes and sulphydryl (SH-) linkages that are the source of pungency in oilseeds. Adequate sulphur is therefore very much crucial for oilseed crops.

Nitrogen and Sulphur are the most limiting factors for rapeseed production. Apart from various factor, declining level of N and S is evident in decreasing level of the rapeseed productivity. Available soil N supplies are generally inadequate for optimum crop production. Interaction effect of the sulphur and nitrogen are directly related to the alteration of physiological and biochemical responses of crops, and so it should be studied in depth. N could be a significant strategy for improvement of growth and productivity of rapeseed and mustard. The study of the nitrogen and sulphur interaction is so required to help understand nutritional behavior of sulphur in relation to nitrogen and provide guidelines for evaluating the balanced fertilizer combination in order to optimize yield and quality of crops. The productivity of rapeseed has been declining for last many years as reported from various parts of the country. So, this study aims to evaluate rapeseed yield as influenced by N-S interaction and to find economic nutrient dose for farmers of inner-Terai regions for better profitability.

The development of modern agricultural technologies, intensification of cropping system and changed cropping pattern without balanced fertilization has also led to depletion of major as well as micro nutrients from the soil (Prasad, 2006) [7]. Indian mustard (*Brassica juncea*) is being grown on clay loam soil under irrigated conditions after harvest of Urdbean without considering nutrient management which is essential for harvesting good yield. Several studies have also established the synergistic and interactive response of S nutrition with N and P application on enzymatic activities, protein synthesis and nodulation activities (Sheoran *et al*. 2013) [10].

Material and Methods

The experiment was conducted during *rabi* season of 2018-19 and 2019-20 at Agronomy Research Farm of Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.) situated at subtropical zone in Indo Gangetic Plain having alluvial calcareous soil and lies between 24.4^0 - 26.56^0 North latitude and 82.12-83.98^0 East longitude with an elevation of about 113 meter from mean sea level. The climate of the district is semi arid with hot summer and cold winter. The region receives an average annual rainfall about 1040 mm. The 80% of the total rainfall is received during monsoon season from July to September with a few showers in winter season. In context to determine the physico–chemical properties of the soil of experimental field and its fertility status, the soil samples were collected randomly from different places of the experimental field with the help of soil auger up to a depth of 0-15 cm prior to the application of fertilizers. These samples were well mixed together and finally a composite sample representing the whole field was taken and analyzed the composite sample in laboratory. The results obtained from soil analysis indicated that the soil of experimental field was silt loam in texture with a slightly alkaline in reaction. Besides, it was low in available nitrogen and phosphorus, medium in available potassium and deficient in sulphur and boron.

The uptake of nitrogen, phosphorus, potassium and sulphur by crop (seed and stover) was calculated by multiplying the nutrient concentration with dry matter and dividing with 100. (Nutrient uptake in grain/straw (kg ha^{-1}) =

Grain/straw yield (kg ha^{-1}) × Nutrient content of grain /straw (%) × 10-2)

Oil content was estimated by Oxford analytical new part 4000 NMR. The new part analyzer operates on the principle of nuclear magnetic resonance (NMR) to determine the concentration of mobile hydrogen protein with the oil content in mustard. Seed yield (q ha^{-1}) obtained in each treatment was multiplied by respective percentage of oil dividing by 100, thus total amount of oil in quintal ha^{-1} was obtained.

Result and Discussion

Nitrogen uptake (kg ha^{-1})

Data pertaining to N uptake by seed, stover and total N uptake by crop are presented in Table-1. Nitrogen uptake was recorded highest with phosphogypsum S significantly as compared to rest two sources of sulphur in seed, stover and crop during both the years of experimentation.

As far as doses of sulphur was concerned, N uptake increased with simultaneous increase in S doses resulting maximum value at 60 kg S ha-1 which exhibited significance over rest of sulphur doses. The trend of increase was similar in uptake by seed, stover and crop during both the years of study.

Phosphorus uptake (kg ha^{-1})

Data on P uptake by mustard as influenced by different sources and doses of sulphur have been presented in Table-2.

A perusal of data presented in Table-2 showed that sources of sulphur caused significant variation in P uptake of mustard. Application of phosphogypsum S resulted in highest P uptake of 36.93 and 38.03 kg ha^{-1} during 2018-19 and 2019-20 respectively, which was significantly superior over rest sulphur source. However, the lowest P uptake was noted from elemental source of sulphur.

Scrutiny of data presented in Table-2 revealed that variations in P uptake due to doses of sulphur were found significant during both the years of study. The increasing doses of sulphur exhibited the increment in P uptake of mustard up to 60 kg S ha^{-1}. Application of 60 kg S ha^{-1} registered maximum P uptake of 37.50 and 38.25 kg ha^{-1} during 2018-19 and 2019-20 respectively which was at par with 40 kg S ha^{-1} and showed statistical superiority over remaining sulphur doses 0 and 20 kg S ha^{-1} which exhibited significant differences among themselves. The lowest P uptake (28.26 and 28.99 kg ha^{-1}) was recorded from control (0 kg S ha^{-1}) which showed statistical inferiority over rest of the sulphur doses.

Potassium uptake (kg ha^{-1})

Data on K uptake by mustard as influenced by different sources and doses of sulphur have been presented in Table-3.

A perusal of data presented in Table-3 showed that sources of sulphur caused significant variation in K uptake of mustard. Application of phosphogypsum S resulted in highest K uptake of 150.63 and 153.90 kg ha^{-1} during 2018-19 and 2019-20 respectively, which was significantly superior over rest sulphur source. However, the lowest K uptake was noted from elemental source of sulphur.

Scrutiny of data presented in Table-3 revealed that variations in K uptake due to doses of sulphur were found significant during both the years of study. The increasing doses of sulphur exhibited the increment in K uptake of mustard up to 60 kg S ha^{-1}. Application of 60 kg S ha^{-1} registered maximum K uptake of 152.73 and 154.89 kg ha^{-1} during 2018-19 and 2019-20 respectively which was at par with 40 kg S ha^{-1} and showed statistical superiority over remaining sulphur doses 0 and 20 kg S ha^{-1} which exhibited significant differences in among themselves. The lowest K uptake (117.94 and 120.32 kg ha^{-1}) was recorded from control (0 kg S ha^{-1}) which showed statistical inferiority over rest of the sulphur doses.

Sulphur uptake (kg ha^{-1})

Data on S uptake by mustard as influenced by different sources and doses of sulphur have been presented in Table-4.

A perusal of data presented in Table-4 showed that sources of sulphur caused significant variation in S uptake of mustard. Application of phosphogypsum S resulted in highest S uptake of 20.93 and 21.44 kg ha^{-1} during 2018-19 and 2019-20 respectively, which was significantly superior over rest sulphur source. However, the lowest S uptake was noted from elemental source of sulphur.

Scrutiny of data presented in Table-4 revealed that variations in S uptake due to doses of sulphur were found significant during both the years of study. The increasing doses of sulphur exhibited the increment in S uptake of mustard up to 60 kg S ha^{-1}. Application of 60 kg S ha^{-1} registered maximum S uptake of 21.93 and 22.48 kg ha^{-1} during 2018-19 and 2019-20 respectively which was at par with 40 kg S ha^{-1} and showed statistical superiority over remaining sulphur doses 0 and 20 kg S ha^{-1} which exhibited significant differences among themselves. The lowest S uptake (14.29 and 14.66 kg ha^{-1}) was recorded from control (0 kg S ha^{-1}) which showed statistical inferiority over rest of the sulphur doses.

Nutrient uptake (N, P, K and S) in mustard was also significantly affected due to different source of sulphur. The uptake of nutrients (kg ha^{-1}) increased significantly under phosphogypsum source of sulphur, which was at par with single super phosphate and significantly superior over elemental sulphur source of sulphur. The increase in nutrient uptake under phosphogypsum source may be justified that under this source the growth and yield of mustard was better than rest sources. These findings are in close conformity with the findings of Rai *et al*., (2014) [8].

Table 1: Response of sources and levels of sulphur on nitrogen uptake (kg ha^{-1}) by mustard

Treatments	2018-19			2019-20		
	N uptake by seed	N uptake by stover	Total N uptake by crop	N uptake by seed	N uptake by stover	Total N uptake by crop
Sources of Sulphur						
Phosphogypsum	50.22	56.32	106.55	51.99	57.53	109.52
Elemental Sulphur	45.53	51.33	96.86	46.75	52.03	98.77
Single Super Phosphate	48.09	53.78	101.87	49.65	54.22	103.87
S.E(m)+	0.810	1.02	1.66	0.84	1.04	1.82
CD (P=0.05)	2.336	2.93	4.78	2.42	2.99	5.26
Levels of Sulphur (kg ha^{-1})						
0	36.79	44.52	81.32	38.05	45.41	83.45
20	44.11	49.11	93.22	45.65	50.15	95.80
40	48.71	55.18	103.89	50.40	55.75	106.16
60	51.03	57.14	108.17	52.34	57.87	110.21
S.E(m)+	0.94	1.17	1.91	0.97	1.20	2.11
CD (P=0.05)	2.70	3.38	5.52	2.79	3.45	6.07

Table 2: Response of sources and levels of sulphur on phosphorus uptake (kg ha^{-1}) by mustard

Treatments	2018-19			2019-20		
	P uptake by seed	P uptake by stover	Total P uptake by crop	P uptake by seed	P uptake by stover	Total P uptake by crop
Sources of Sulphur						
Phosphogypsum	15.54	21.40	36.93	16.18	21.85	38.03
Elemental Sulphur	14.11	19.50	33.61	14.46	19.78	34.24
Single Super Phosphate	14.81	20.41	35.22	15.36	20.61	35.97
S.E(m)+	0.28	0.41	0.68	0.27	0.36	0.67
CD (P=0.05)	0.81	1.17	1.95	0.79	1.03	1.92
Levels of Sulphur (kg ha^{-1})						
0	11.36	16.91	28.26	11.73	17.26	28.99
20	13.61	18.64	32.26	14.14	19.06	33.19
40	15.04	20.96	36.00	15.61	21.18	36.79
60	15.80	21.70	37.50	16.25	22.00	38.25
S.E(m)+	0.32	0.47	0.78	0.32	0.41	0.77
CD (P=0.05)	0.93	1.35	2.25	0.91	1.19	2.22

Table 3: Response of sources and levels of sulphur on potassium uptake (kg ha^{-1}) by mustard

Treatments	2018-19			2019-20		
	K uptake by seed	K uptake by stover	Total K uptake by crop	K uptake by seed	K uptake by stover	Total K uptake by crop
Sources of Sulphur						
Phosphogypsum	19.15	131.48	150.63	19.77	134.13	153.90
Elemental Sulphur	17.31	119.65	136.96	17.76	121.21	138.96
Single Super Phosphate	18.24	125.23	143.47	18.88	126.62	145.51
S.E(m)+	0.31	2.45	2.60	0.31	2.31	3.04
CD (P=0.05)	0.90	7.07	7.49	0.89	6.66	8.75
Levels of Sulphur (kg ha^{-1})						
0	13.98	103.96	117.94	14.48	105.84	120.32
20	16.77	114.30	131.06	17.32	116.89	134.21
40	18.51	128.75	147.26	19.18	130.08	149.27
60	19.43	133.31	152.73	19.91	134.99	154.89
S.E(m)+	0.36	2.83	3.00	0.36	2.67	3.51
CD (P=0.05)	1.04	8.16	8.65	1.03	7.69	10.11

Table 4: Response of sources and levels of sulphur on sulphur uptake (kg ha^{-1}) by mustard

Treatments	2018-19			2019-20		
	S uptake by seed	S uptake by stover	Total S uptake by crop	S uptake by seed	S uptake by stover	Total S uptake by crop
Sources of Sulphur						
Phosphogypsum	4.71	16.22	20.93	4.87	16.57	21.44
Elemental Sulphur	4.24	14.63	18.86	4.38	14.95	19.33
Single Super Phosphate	4.50	15.44	19.94	4.65	15.62	20.27
SE(m)+	0.08	0.24	0.35	0.08	0.25	0.38
CD (P=0.05)	0.22	0.69	1.02	0.23	0.72	1.11
Levels of Sulphur (kg ha^{-1})						
0	3.10	11.18	14.29	3.21	11.46	14.66
20	3.98	13.48	17.47	4.12	13.75	17.87
40	4.60	15.74	20.34	4.76	15.93	20.69
60	4.87	17.06	21.93	5.02	17.46	22.48
SE(m)+	0.09	0.28	0.41	0.09	0.29	0.44
CD (P=0.05)	0.25	0.80	1.17	0.26	0.83	1.28

Oil content in seed
Data assembled on account of oil content in seed of mustard as influenced by different sources and doses of sulphur are presented in Table-5.

It was observed from the data presented in Table-5 that highest oil content (38.57%) and (38.81%) in seed was noted during first and second year respectively from phosphogypsum S which exhibited statistical similarity with rest sources of sulphur.

Oil content in seed increased gradually with increasing sulphur doses up to 60 kg S ha-1. Application of 60 kg S ha^{-1} registered maximum oil content of 39.15% and 39.05% during 2018-19 and 2019-20 respectively which was at par with 40 kg S ha^{-1} and showed statistical superiority over remaining sulphur doses 0 and 20 kg S ha^{-1} which exhibited significant differences among themselves. The lowest oil content (36.94% and 37.14%) was recorded from control (0 kg S ha^{-1}) which showed statistical inferiority over rest of the sulphur doses.

Oil yield (q ha^{-1})
Data assembled on account oil yield of mustard as influenced by different sources and doses of sulphur are presented in Table 5.

A perusal of data presented in Table-5 showed that sources of sulphur caused significant variation in oil yield of mustard. Application of phosphogypsum S resulted in highest oil yield of 7.22 and 7.47q ha^{-1} during 2018-19 and 2019-20 respectively, which was significantly superior over elemental sulphur source. However, the lowest oil yield was noted from elemental source of sulphur. Differences in oil yield between phosphogypsum and single super phosphate source of sulphur were found not significant.

Scanning of data presented in Table-5 revealed that variations in oil yield due to doses of sulphur were found significant during both the years of study. The increasing doses of sulphur exhibited the increment in oil yield of mustard up to 60 kg S ha^{-1}. Application of 60 kg S ha^{-1} registered maximum oil yield of 7.34 and 7.52 q ha^{-1} which was at par with 40 kg S ha^{-1} and showed statistical superiority over remaining sulphur doses 0 and 20 kg S ha^{-1} which exhibited significant differences in seed yield among themselves. The lowest oil yield (5.29 and 5.47 q ha^{-1}) was recorded from control (0 kg S ha^{-1}) which showed statistical inferiority over rest of the sulphur doses.

Table 5: Response of sources and levels of sulphur on oil content and oil yield of mustard

Treatments	Oil content		Oil yield q ha^{-1}	
	2018-19	2019-20	2018-19	2019-20
Sources of Sulphur				
Phosphogypsum	38.57	38.81	7.22	7.47
Elemental Sulphur	38.19	38.09	6.55	6.72
Single Super Phosphate	38.29	38.43	6.91	7.14
SE(m)+	0.65	0.65	0.11	0.12
CD (P=0.05)	NS	NS	0.33	0.33
Levels of Sulphur (kg ha^{-1})				
0	36.94	37.14	5.29	5.47
20	37.57	37.76	6.34	6.56
40	38.33	38.53	7.00	7.25
60	39.15	39.05	7.34	7.52
SE(m)+	0.75	0.75	0.13	0.12
CD (P=0.05)	2.16	2.16	0.38	0.37

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