International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(4): 363-367

Received: 14-05-2018
Accepted: 15-06-2018

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Assessment of effects of sewage-sludge, zinc, boron and sulphur application on concentration and uptake of nutrients by mustard

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Abstract
The mustard growing areas in India are experiencing the vast diversity in the agro climatic conditions. Nutrient management stands among the most crucial factors in crop production. Exploitation of genetic yield potential of any new plant type depends on availability of all essential nutrients in balanced and optimum amounts. The application of sewage sludge (SS) as a source of plant nutrients and soil conditioner is increasingly being favoured by the farmers not only in our country but across the globe. Keeping these facts into consideration, the present investigation on effect of sulphur, zinc, boron and sewage sludge on growth, yield parameters and uptake and content of nutrient of mustard was carried out at the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P. (India) by growing mustard in a pot experiment conducted in net house. The samples of sewage sludge obtained were tested as source of nutrient for the crop production. Altogether twelve treatments consisted of combinations of sewage sludge and chemical fertilizers, S, Zn, B, along with a control were used for pot experiments. The result concluded that due to application of different level of boron, zinc, sulphur and sewage sludge in mustard crop, a significant increase content as well as uptake of nutrients in grain and stover can be obtained. The maximum NPK content of seed was found in T10 followed by T12. The maximum seeds yield was found in treatment T10 followed by T12 with 20.90 and 19.13 g pot^{-1}, respectively but both these are statistically at par with each other. The minimum seeds yield was found in absolute control (T1). The treatments in which B was applied alone and in combination with the sulphur and zinc show a significant increase in seed yield. Thus boron applied with the combination of sulphur and zinc is more effective to produce more seeds yield then alone application of boron. The treatments T8 shows significant increase over T4, T6 and T7. The treatments T6 and T7 are not significant with each other. The combined application of sludge and inorganic fertilization might be enhanced nutrient content and uptake of nutrient in mustard crop.

Keywords: Mustard, Sewage-Sludge, nutrient content, uptake, Boron, Sulphur and Zinc

Introduction
Indian mustard is an important oilseed crop, next to sunflower. Its seed contains nearly 40% oil and 28-36% protein with a high nutritive value. Mustard oil is considered to be an important constituent of Indian diet and is used as main cooking medium especially in north-India. Both the seed and oil are used as condiment in the preparation of pickles and flavouring curries and vegetables. The cake obtained after the oil extraction is mostly used for cattle feed and manure. Green stem and leaves are a good source of fodder for cattle. The leaves of young plants are used as green vegetables as they supply enough sulphur and minerals in diet. In spite of increased production and productivity of rapeseed-mustard in the country, the per capita consumption (8.2 kg/capita/year) of fats and oils is quite low. The requirements of fats and oils will be much higher in view of increasing population and improved standard of living of the people in 21st century. To meet the minimal nutritional requirements of fats and oils (12 kg/capita/year), needs of food, feed and other industries, and to earn valuable foreign exchange through export of seed meal, oil and value added products, it is estimated that nearly 24 million tonnes of rapeseed-mustard oilseed would be required by 2020 A.D. The mustard growing areas in India are experiencing the vast diversity in the agro climatic conditions. Effective management of natural resources, integrated approach to plant-water, nutrient and pest management and extension of rapeseed-mustard cultivation to newer areas under different cropping systems will play a key role in further increasing and stabilizing the productivity and

production of rapeseed-mustard.

Nutrient management stands among the most crucial factors in crop production. Exploitation of genetic yield potential of any new plant type depends on availability of all essential nutrients in balanced and optimum amounts. It has been noticed that intensive cultivation of modern crop varieties through application of higher doses of NPK fertilizers have increased the crop yields mining out the inherent micronutrients from soils. In many parts of the country, zinc as a plant nutrient stands third in importance i.e. next to N and P (Katyal and Sharma, 1991) [9]. Boron deficiency during flowering prevents pollen tube growth and leads to pollen sterility, flower abortion and poor pod setting. Adequate boron is also required to ensure effective nodulation and nitrogen fixation in legumes. Keeping in view the ever increasing demand of oilseed production of the country, there is a need to maintain adequate supply of nutrients through organic and inorganic sources, both. It has been observed in the earlier studies that sewage-sludge contains a considerable amount of micronutrients particularly Zn, Fe, Cu and Mn. The application of sewage sludge (SS) as a source of plant nutrients and soil conditioner is increasingly being favoured by the farmers not only in our country but across the globe. The total sewage generated from urban areas was estimated 62,000 million litres per day (MLD), while the treatment capacity across India is only 23,277 MLD, or 37% of sewage generated. Sewage sludge is a good source of micro/macronutrients and also rich in organic matter (Zoubi *et al.*, 2008; Golui *et al.*, 2014) [26, 4]. Addition of sludge to agricultural soil is associated with recycling of important major plant nutrients such as N, P, K and S (Nandhakumar *et al*., 1998; Martinez *et al*., 2002) [15]. More importantly, these waste materials add substantial amount of organic matter, besides improving physical properties of soil like bulk density, porosity, water holding capacity, hydraulic conductivity, infiltration rate, water holding capacity of soil and aggregate stability (Singh and Agrawal, 2008) [21]. Improvements in soil health and consequent positive responses have been reported in various crops, viz. sunflower (Morera *et al.,* 2013), wheat (Khan *et al*., 2007) [10], maize (Zoubi *et al*., 2008) [26], rice-wheat (Latare and Singh, 2013; Latare *et al.* 2014; Latare *et al.* 2017) [12, 13, 14].

Though, the sewage sludge is very rich in organic matter and nutrients. Yet, the information on impact of sewage sludge on crop productivity and soil health including nutrients availability, their uptake by plants and accumulation of heavy metals are scanty. The subsequent effect on the crop yield and uptake of heavy metals by plant needs to be also studied which can provide a better knowledge and understanding about the extent to which its use can be beneficial in agriculture.

Materials and methods

The investigation was carried out in a pot experiment under net house at the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P. (India). The study site located in the western bank of river Ganges, Varanasi is situated at an altitude of 80.71 meters above mean sea level and located between 25^0 19’ North latitude and 83^0 10’ East longitudes. The soils of Varanasi are formed on alluvium deposited by the river Ganges and have predominance of illite, quartz and feldspars minerals. Glazed pots having 10 kg capacity were taken, labelled and filled with 10 kg of processed soil. The whole quantity of soil was placed on a polythene sheet and according to the treatments, the required quantities of sewage sludge material was incorporated and mixed thoroughly with the soil. The recommended dose of fertilizer (RDF) for mustard (*Brassica sp.*) was $N:P_2O_5:K_2O$: 80:40:40 kg ha^{-1}. To supply the recommended dose of fertilizer, a nutrient solution was prepared which supplied 40 mg N, 20 mg P_2O_5 and 20 mg K_2O kg^{-1} soil. The nutrient solution was prepared using urea as N source, analytical grade Diammonium phosphate (DAP) as the source of phosphorus and potassium chloride (KCl) as the source of potassium. Water was added to the soil samples to raise the moisture content to 50% of the field capacity. The moist samples were then transferred in the pots and kept in the greenhouse. Altogether twelve treatments consisted of combinations of sewage sludge and chemical fertilizers, S, Zn, B, along with a control were used for pot experiments. The experiment was laid out in a completely randomized design (CRD) with three replications. The treatments detailed are given below: T_1- Absolute Control (No fertilizer), T_2 Control (100% RDF), T_3- 100% RDF + S @ 30 kg $ha^{-1,}$ T_4- 100% RDF + B @ 1.5 kg $ha^{-1,}$ T_5- 100% RDF + Zn @ 5 kg $ha^{-1,}$ T_6- 100% RDF + S @ 30 kg ha^{-1} + B @ 1.5 kg $ha^{-1,}$ T_7- 100% RDF + Zn @ 5 kg ha^{-1} + B @ 1.5 kg $ha^{-1,}$ T_8- 100% RDF + S @ 30 kg ha^{-1} +Zn @ 5 kg ha^{-1} + B @ 1.5 kg $ha^{-1,}$ T_9- 100% RDF + Sewage Sludge @ 10 t $ha^{-1,}$ T_{10}-100% RDF + sewage Sludge @ 20 t $ha^{-1,}$ T_{11}- 75% RDF + Sewage Sludge @ 10 t $ha^{-1,}$ T_{12}- 75% RDF + Sewage Sludge @ 20 t ha^{-1}

The seeds of mustard were sown on 10^{th} November, 2016. Fourty seeds were sown in each pot and the upper layer was moistened with water to ensure proper germination. After germination of seeds, thinning was done to maintain four plants per pot. The plants were maintained in the pot culture and care was taken to ensure proper growth. Irrigation was given as and when required. At maturity, the plants were harvested and seeds were separated from the plant, kept in paper bags and dried in hot air oven at 60 ± 2 °C till the weight became constant and seed yield (g pot^{-1}) was computed. Plant sample containing straw and grain were grinded and grinded samples were digested with concentrated H_2SO_4 and digestion mixture ($K_2SO_4:CuSO_4$:Se powder in the ratio of 10:1:0.1). The total nitrogen content in plant was then estimated by micro-kjeldahl method as suggested by Nelson (1980). Phosphorus content in the extracts was determined by vanadomolybdo phosphoric yellow colour method (Jackson, 1973). Plant powdered sample (0.5 gm) was digested in a diacid mixture ($HNO_3 – HClO_4$). 5 ml of extract was pipette out into a 25 ml volumetric flask. 5 ml of Barton’s reagent was added, volume is made up with distilled water. It was shaken well and allowed to stand for 30 mins for the development of yellow colour. The colour developed was stable for 24 hours. The intensity of yellow colour was measured in a spectrometer using blue filter (420 nm). The potassium content in plant samples extract was determined by Flame Photometery (Ghosh *et al*., 1983) [3].

Result and discussion

Effect of Sulphur, Zinc, Boron and Sewage Sludge application on NPK content

Nitrogen content in seed increased significantly with varying level of boron, zinc, sulphur and sludge application (Table 1). Its content ranges between 1.25- 2.32%. The maximum nitrogen content of seed was found in T10 followed by T12 with 2.32 and 2.13%, respectively, but both these are statistically at par with each other. The minimum N content was found in absolute control (T1) followed control (T2) and T4 with 1.25, 1.41 and 1.41%, respectively. The treatments

T2, T4 and T5 were non-significant which each other similar. The nitrogen content in stover ranged between 0.57–1.16%. The maximum nitrogen content of 1.16% was in T10 and the minimum of 0.57% was in T1. Treatment T10 showed about 2 times increase in nitrogen content over T1. Treatments T3, T4 and T7 were statistically similar with T9, T10 and T11. P content in seed increased significantly with varying level of boron, zinc, sulphur and sludge application. Its content ranges between 0.26–0.44%. The maximum P content in seed was found in T10 followed by T12 with 0.44 and 0.43%, respectively but both these are statistically at par with each other. The minimum P content of 0.26% was found in absolute control (T1). The treatment T10 and T12 showed an increase of 0.33 and 0.30%, respectively over control (T2). The treatments T2, T4 and T7 were statistically at par with each other, similarly T10 and T12 also. The P content in stover ranged between 0.07–0.16%. The maximum phosphorus content of 0.16 % was in T9 and T10 and the minimum of 0.07% was in T1. Treatment T10 showed about 2 times increase in P content over T1. The treatments T9, T11 and T12 were at par which each other.

K content in seed increased significantly with varying level of boron, zinc, sulphur and sludge application. Its content ranges between 0.19 – 0.43 %. The maximum K content in seed was found in T10 followed by T12 with 0.43 and 0.42%, respectively but both these are statistically at par with each other. The minimum K content was found in absolute control (T1) followed control (T2) with 0.19 and 0.24%, respectively. The treatments T9, T10, T11 and T12 are statistically at par with each other. The potassium content in stover ranged between 0.81–1.77%. The maximum K content of 1.77% in T10 and the minimum of 0.81 % was in T1. The treatment T11 showed about 2 times increase in K content over T1. Treatments T6, T8, T9 and T11 were statistically at par with each other. The higher concentration of these nutrients (Nitrogen, phosphorus and potassium) with combined application of sludge and inorganic fertilization might be due to better root development, which enhanced nutrient density in mustard crop due to increased forage area for nutrient extraction ultimately led to higher content of nutrient of NPK in stover and seed. Beside this, the marked improvement in soil physic-chemical and biological properties with combined application of sludge and inorganic fertilization enhances nutrient availability in crop root zone and which might leads to more nutrient uptake. The similar finding of higher NPK content under combined application of sludge and inorganic fertilization were also reported by Walia and Goyal, (2010) [24]; Mehmet, (2013) [16]; Latare *et al.* (2014) [13]; Yadav *et al.* (2016) [25].

Table 1: Effect of sulphur, zinc, boron and sewage sludge application on nutrient concentration in mustard seed and stover of mustard

Treatments	N (%)		P (%)		K (%)	
	Seed	Stover	Seed		Seed	Stover
T1	1.25^{g}	0.57^{f}	0.26^{i}	T1	1.25^{g}	0.57^{f}
T2	1.41^{fg}	0.68^{e}	0.33^{g}	T2	1.41^{fg}	0.68^{e}
T3	1.65^{ef}	0.81^{cd}	0.35^{ef}	T3	1.65^{ef}	0.81^{cd}
T4	1.41^{fg}	0.79^{cd}	0.34^{fg}	T4	1.41^{fg}	0.79^{cd}
T5	1.45^{fg}	0.74^{de}	0.30^{h}	T5	1.45^{fg}	0.74^{de}
T6	1.70^{de}	0.86^{c}	0.38^{d}	T6	1.70^{de}	0.86^{c}
T7	1.73^{de}	0.82^{cd}	0.32^{gh}	T7	1.73^{de}	0.82^{cd}
T8	2.00^{bc}	1.00^{b}	0.40^{bc}	T8	2.00^{bc}	1.00^{b}
T9	1.90^{bcd}	1.12^{a}	0.37^{de}	T9	1.90^{bcd}	1.12^{a}
T10	2.32^{a}	1.16^{a}	0.44^{a}	T10	2.32^{a}	1.16^{a}
T11	1.83^{cde}	1.08^{ab}	0.39^{cd}	T11	1.83^{cde}	1.08^{ab}
T12	2.13^{ab}	1.10^{a}	0.43^{ab}	T12	2.13^{ab}	1.10^{a}
CV (%)	8.62	6.35	3.95	CV (%)	8.62	6.35

T1: Absolute Control (No fertilizer), T2: Control (100 % RDF), T3:100% RDF+ S 30 kg $ha^{-1,}$ T4:100% RDF+ B 1.5 kg ha^{-1}, T5: 100% RDF+Zn 5 kg ha^{-1},T6:100%RDF+ S 30 kg ha^{-1}+ B 1.5 kg ha^{-1},T7: 100% RDF + Zn 5 kg ha^{-1}+ B 1.5 kg ha^{-1},T8: 100% RDF+ S 30 kg ha^{-1}+Zn 5 kg ha^{-1}+ B 1.5 kg ha^{-1},T9: 100% RDF+ SS 10 t ha^{-1},T10: 100% RDF+ SS 20 t ha^{-1},T11: 75% RDF+ SS 10 t ha^{-1},T12: 75% RDF+ SS 20 t ha^{-1}

Effect of sulphur, zinc, boron and sewage sludge application on NPK uptake

A critical observation of the data (Table 2) revealed that the N uptake in the mustard seed varied from 140 to 480 mg pot^{-1} by different modes of boron, zinc, sulphur and sludge application. The maximum N uptake was found in treatment T10 followed by T12 with 480, 410 mg pot^{-1}, respectively. The minimum N uptake 140 mg pot^{-1} was found in absolute control (T1). The N uptake in stover was varied from 200 to 700 mg pot^{-1}. The maximum N uptake was in treatment T10 with 700 mg pot^{-1}. The minimum N uptake 200 mg pot^{-1} was found in absolute control (T1). P uptake in the mustard seed varied from 30 to 90 mg pot^{-1} by different modes of boron, zinc, sulphur and sludge application. The maximum P uptake was found in treatment T10 with 90 mg pot^{-1}. The minimum P uptake 30 mg pot^{-1} was found in absolute control (T1). P uptake in stover was varied from 30 to100 mg pot^{-1}. The maximum P uptake was found in treatment T10 followed by T9 with 100 and 90 mg pot^{-1}, respectively. The minimum P uptake of 30 mg pot^{-1} was found in absolute control (T1).

K uptake in the mustard seed varied from 20 to 90 mg pot^{-1} by different modes of boron, zinc, sulphur and sludge application. The maximum K uptake was found in treatment T10 with 90 mg pot^{-1}. The minimum K uptake 20 mg pot^{-1} was found in absolute control (T1). The K uptake was varied from 290 to 1070 mg pot^{-1}. The maximum K uptake was found in treatment T10 followed by T12 with 1070, and 940 mg pot^{-1}, respectively. The minimum K uptake of 290 mg pot^{-1} was found in absolute control (T1). The higher uptake of these nutrients (Nitrogen, phosphorus and potassium) with combined application of sludge and inorganic fertilization might be due to better root development, which enhanced nutrient density in mustard crop due to increased forage area for nutrient extraction ultimately led to higher uptake of nutrient of NPK in stover and seed. Beside this, the marked improvement in soil physico-chemical and biological properties with combined application of sludge and inorganic fertilization enhances nutrient availability in crop root zone and which might leads to more nutrient uptake. The similar finding of higher NPK content under combined application of sludge and inorganic fertilization were also reported by Singh *et al.*, 2010; Kumar and Trivedi, 2011; Singh *et al.*, 2013; Latare *et al.*, 2017) [22, 11, 20, 14]. Jat and Mehra (2007) [8] also reported that due to application of S in soil the N, P, K and S content in mustard increased significantly at all the stages. N, P, K and S uptake by mustard increased significantly. Jana *et al.* (2009) [7] studied the effect of boron on content and uptake of NPK by mustard plant in seed and stover and found that application of 15-20 kg borax ha^{-1} gave higher values of content and uptake of NPK in seed and Stover.

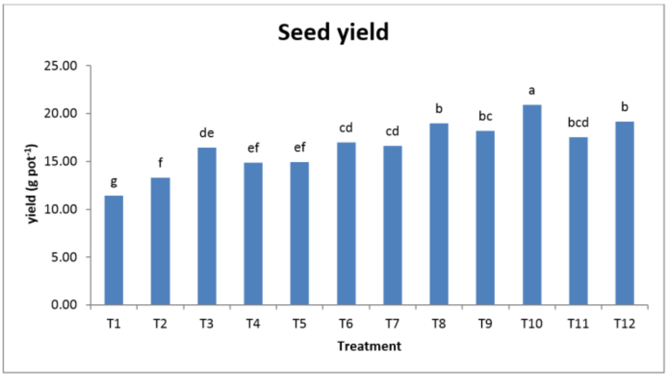
Table 2: Effect of sulphur, boron, zinc and sewage sludge on N, P and K uptake by mustard

Treatment	N uptake (mg pot^{-1})			P uptake (mg pot^{-1})			K uptake (mg pot^{-1})		
	Seed	Stover	Total	Seed	Stover	Total	Seed	Stover	Total
T1	140^{h}	200^{g}	340g	30^{i}	30^{h}	60^{h}	20^{e}	290^{h}	310^{h}
T2	190^{gh}	290^{f}	480^{f}	40^{h}	40^{g}	80^{g}	30^{e}	420^{g}	450^{g}
T3	270^{def}	390^{de}	660^{de}	60^{efg}	60^{ef}	120^{ed}	50^{d}	580^{f}	630^{f}
T4	210^{fgh}	370^{e}	580^{ef}	50^{gh}	60^{f}	110^{fe}	50^{d}	600^{ef}	650^{ef}
T5	220^{efg}	350^{ef}	570^{ef}	50^{gh}	50^{f}	100^{fg}	50^{d}	630^{ef}	680^{ef}
T6	290^{de}	440^{d}	720^{d}	60^{def}	70^{de}	130^{cd}	60^{cd}	770^{cd}	820^{cd}
T7	290^{de}	400^{de}	690^{de}	50^{fgh}	60^{f}	110^{ef}	60^{cd}	710^{de}	760^{de}
T8	380^{bc}	550^{c}	930^{bc}	70^{bcd}	60^{ef}	140^{c}	80^{a}	910^{b}	990^{b}
T9	390^{bc}	650^{ab}	1040^{b}	80^{bc}	90^{ab}	170^{b}	80^{a}	950^{b}	1030^{b}
T10	480^{a}	700^{a}	1190^{a}	90^{a}	100^{a}	190^{a}	90^{a}	1070^{a}	1160^{a}
T11	320^{cd}	570^{c}	890^{c}	70^{cde}	80^{cd}	150^{c}	70^{bc}	860^{bc}	930^{bc}
T12	410^{b}	610^{bc}	1020^{bc}	80^{ab}	80^{bc}	160^{b}	80^{a}	940^{b}	1020^{b}
CV (%)	10.02	6.84	6.71	7.54	8.03	6.43	10.50	8.23	7.43

T1: Absolute Control (No fertilizer), T2: Control (100 % RDF), T3:100% RDF+ S 30 kg $ha^{-1,}$ T4:100% RDF+ B 1.5 kg ha^{-1}, T5: 100% RDF+Zn 5 kg ha^{-1},T6:100%RDF+ S 30 kg ha^{-1}+ B 1.5 kg ha^{-1},T7: 100% RDF + Zn 5 kg ha^{-1}+ B 1.5 kg ha^{-1},T8: 100% RDF+ S 30 kg ha^{-1}+Zn 5 kg ha^{-1}+ B 1.5 kg ha^{-1},T9: 100% RDF+ SS 10 t ha^{-1},T10: 100% RDF+ SS 20 t ha^{-1},T11: 75% RDF+ SS 10 t ha^{-1}, T12: 75% RDF+ SS 20 t ha^{-1}

Crop yield (g pot^{-1})

Data pertaining to seed yield have been presented in Graph 1 which clearly showed that seed yield of mustard as influenced with the application of varying levels of boron, zinc, sulphur and sludge. The maximum seeds yield was found in treatment T10 followed by T12 with 20.90 and 19.13 g pot^{-1}, respectively but both these are statistically at par with each other. The minimum seeds yield was found in absolute control (T1). The treatments in which B was applied alone and in combination with the sulphur and zinc show a significant increase in seed yield. Thus boron applied with the combination of sulphur and zinc is more effective to produce more seeds yield then alone application of boron. The treatments T8 shows significant increase over T4, T6 and T7. The treatments T6 and T7 are not significant with each other. Insufficient nutrients (macro, secondary and micronutrients) supply throughout the growing season under control and with application of only chemical fertilizer perhaps limited the growth rate and development of crop due to low rate of photosynthesis or insufficient cell expansion or both of these factors. Whereas, optimal and balanced supply of nutrients (macro, secondary and micronutrients) from inorganic sludge along with application of sulphur, zinc and boron led to higher growth and development of plants which ultimately resulted in higher seed and stover yield of mustard compared to control and chemical fertilization alone (Tripathi *et al.* (2011) [23]. Moreover, integrated use of sludge and inorganic fertilizers improved the physical (soil structure and water-holding capacity), chemical (buffering capacity, cation exchange capacity, macro and micro nutrients availability and reduce phosphate fixation) and biological properties of soil (organic matter, soil microbial biomass and soil microorganisms) which further provide an optimum environment for higher growth and development of plants and led to higher yield of crop (Pachauri and Trivedi, 2012; Delgado *et al*., 2002; Chatha *et al.*, 2002; Indoria *et al.* (2013) [19, 2, 1]. Latare and Singh, (2013) [12] also find out the effect of conjoint application of sewage sludge and fertilizers showed a significant increase in test weight and seed and stover yield, it also supported by Latare *et al.* (2014) [13]. Yadav *et al.* (2016) [25] also reported significant increase in seed and stover yield of mustard with boron application.



T1: Absolute Control (No fertilizer), T2: Control (100 % RDF), T3:100% RDF+ S 30 kg $ha^{-1,}$ T4:100% RDF+ B 1.5 kg ha^{-1}, T5: 100% RDF+Zn 5 kg ha^{-1},T6:100%RDF+ S 30 kg ha^{-1}+ B 1.5 kg ha^{-1},T7: 100% RDF + Zn 5 kg ha^{-1}+ B 1.5 kg ha^{-1},T8: 100% RDF+ S 30 kg ha^{-1}+Zn 5 kg ha^{-1}+ B 1.5 kg ha^{-1},T9: 100% RDF+ SS 10 t ha^{-1},T10: 100% RDF+ SS 20 t ha^{-1},T11: 75% RDF+ SS 10 t ha^{-1},T12: 75% RDF+ SS 20 t ha^{-1}

Conclusion

Keeping in view the ever increasing demand of oilseed production of the country, there is a need to maintain adequate supply of nutrients through organic and inorganic sources, both. In our pot culture study combined application of boron, zinc, sulphur and sewage sludge in mustard crop resulted in significant increase in crop productivity and nutrient content. Therefore, it can be concluded that due to application of different level of boron, zinc, sulphur and sewage sludge in mustard crop, a significant increase in mustard yield can be obtained.

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