

Original Research Article

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Evaluation of Sewage-Sludge, Zinc, Boron and Sulphur Application for Increasing Productivity and quality of Mustard (*Brassica juncea* L.) in an Inceptisol

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ABSTRACT

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. Therefore, the present investigation was planned to study the effect of sulphur, zinc, boron and sewage sludge application on growth and yield of mustard. It is evident from the data that significant increase in periodic plant height was recorded with the application of B, Zn, S and sludge. The maximum plant height was observed in treatment T10 (100% RDF + SS 20 t ha⁻¹) followed by T12 (75% RDF+ SS 20 t ha⁻¹). Highest number of leaves obtained in T10 followed by in T12 which is 14.53 and 13.97, respectively. The maximum number of primary branches *i.e.* 4.87 was recorded with treatment T10 followed by T12 with 4.47 at 90DAS, which was 35.75 and 24.86 % higher over T2 (control). All treatments showed significant increase in SPAD value over control (T2). The maximum SPAD value was recorded in T10 followed by T8, which showed an increase of 30.99 and 25.35%, respectively over control. The maximum seeds yield was found in treatment T10 followed by T12 with 20.90 and 19.13 g pot⁻¹, respectively. The Stover yield ranged between 35.7–60.5 g pot⁻¹. The maximum stover yield was found in treatment T10, followed by T12 with 60.5 and 55.8, g pot⁻¹, respectively. The maximum oil content was found in treatment T10 followed by T12 with 40.4 and 40.1%, respectively. 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 grain, stover yield and higher oil content can be obtained.

Keywords

Mustard, Sewage-Sludge, Oil content, Crop productivity, Boron, Sulphur and Zinc

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Introduction

Indian mustard (*Brassica juncea* L.), is one of the important winter season edible oilseed crop of country. The estimated area, production and productivity of rapeseed-mustard in the world is 34.19 M ha, 63.09 MT and 1,850 kg ha⁻¹, respectively (FAO, 2016). India accounts for 19.29% and 10.07% of the

total acreage and production of rapeseed and mustard (FAO, 2015). The mustard is predominantly cultivated in the states of Rajasthan, U.P., Haryana, M.P., Gujarat, Punjab and Bihar. 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.

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 or both (Yadav *et al.*, 2017). 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 (Golui *et al.*, 2014). Sewage sludge is a mixture of liquid-solid residue resulting from the treatment of urban or industrial effluents. It can be considered as a viable alternative for fertilizer and soil conditioner. Sewage sludge is a good source of micro/macronutrients and also rich in organic matter (Zoubi *et al.*, 2008; Golui *et al.*, 2014). Addition of sludge to agricultural soil is associated with recycling of important major plant nutrients such as N, P, K and S (Kumar *et al.*, 2006; Martinez *et al.*, 2002). 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). The presence of humic substances in sewage sludge will also affect cation exchange capacity (CEC) and thus affect nutrient retaining capacity of the soil. Further, application of sludge is capable of reclamation of acid and sodic soil. 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), maize (Zoubi *et al.*, 2008), rice-wheat (Latara and Singh, 2013; Latara *et al.*, 2014; Latara *et al.*, 2017). 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. Keeping these facts into consideration, the present investigation was planned to study the effect of sulphur, zinc, boron and sewage sludge application on growth and yield of mustard.

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^o 19' North latitude and 83^o 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. The alluvial soil is characterized by higher silt content. Illitic nature of alluvial sediments is clearly demonstrated by higher K₂O content. The

cropping history of the site from where the soil was collected is the maize-wheat. The fertility status of the soil is classed as low to medium with a slightly alkaline reaction.

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:P₂O₅:K₂O :: 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 P₂O₅ and 20 mg K₂O 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: 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 + Sewage Sludge @ 10 t ha⁻¹, T₁₀-100% RDF + sewage Sludge @ 20 t ha⁻¹, T₁₁- 75% RDF + Sewage Sludge @ 10 t ha⁻¹, T₁₂- 75% RDF + Sewage Sludge @ 20 t ha⁻¹

The seeds of mustard were sown on 10th November, 2016. Forty 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. The growth and yield attributes were estimated as per the standard procedure by sampling from three places in each plot. Greenness Index of mustard plants was measured at 90 days after sowing with SPAD meter. 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. After harvesting of crop, seeds were separated and plant samples were kept in paper bags, dried in hot air oven at 60 ± 2 °C till the weight became constant and stover yield (g pot⁻¹) was recorded. The harvest index was calculated by using the following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield (q ha}^{-1}\text{)}}{\text{Biological yield (q ha}^{-1}\text{)}} \times 100$$

Results and Discussion

Plant height

Data pertaining to plant height is given in Table 1. It is evident from the data that significant increase in plant height (30 DAS) was recorded with the application of B, Zn, S and sludge. The maximum plant height was observed in treatment T₁₀ (100% RDF + SS 20 t ha⁻¹) followed by T₁₂ (75% RDF+ SS 20 t ha⁻¹) but both treatment were at par to each other at all the growth stage (30, 60, 90 DAS). Sludge application in T₁₀ and T₁₂ caused an increase in plant height by 73.11 and 60.40%, respectively over control (T₂). Application of

zinc, boron and sulphur caused a significant increase in plant height in T8 (100% RDF + S 30 kg ha⁻¹ + Zn 5 kg ha⁻¹ + B 15 kg ha⁻¹) over absolute control (T₁) and control (T₂ 100% RDF). Almost similar trend was reported was noticed with the plant height at 60 and 90 DAS except a slight increase in plant height as compared to observations recorded at 30DAS.

Also individual application of sewage sludge and fertilizers were found to be statistically significant. The optimum availability of macro and micro nutrients with integrated use of sludge (Yamur *et al.*, 2005) and inorganic nutrient sources might improve source system of plant and also increases its efficiency for enhanced photosynthesis leading to higher plant height. The observed trends is in agreeing with the findings of Naser and Islam (2001), Piri and Sharma (2006). Moreover, favourable effect of optimum level of nutrients (Zn, B and S) through their application along with recommended dose of fertilizers might improve the leaf area which improve sink-source relationship could be one of the reasons for higher plant height and growth of mustard.

Number of leaves plant⁻¹

Data pertaining to Number of leaves ⁻¹ have been presented in Table 2. The number of leaves ranged from 7.70 to 14.53 at 60 DAS. Highest number of leaves obtained in T10 followed by in T12 which is 14.53 and 13.97, respectively. The optimal and balanced supply of macro and micronutrient and their higher uptake with combined use of nutrient inputs such as sludge and inorganic might results in plant growth, dry matter accumulation and ultimately higher number of leaves compared to no application of fertilization and when chemical fertilizer applied alone. Similar results were also reported by many other researchers which state that integration of sludge and in-organic sources led to higher leaf growth and development (Kumar and

Yadav, 2007). Moreover, as we know that nitrogen, boron, zinc and sulphur are the chief constituent of many of the lipids and nucleo-proteins, and an optimum supply of these in the plants with their application along with recommended dose of fertilizer might have helped in higher cell division and multiplication which ultimately led to better leaf growth of mustard and boosted plant growth (Kumar and Kumar, 2007).

Number of primary branches plant⁻¹

Data pertaining to primary branches have been presented in Table 2. The number of primary branches of mustard crop increased significantly from T1 to T12. The number of primary branches ranged from 2.66-4.87 at 90 DAS. The maximum number of primary branches *i.e.* 4.87 was recorded with treatment T10 followed by T12 with 4.47 at 90DAS, which was 35.75 and 24.86 % higher over T2 (control). The minimum number of primary branches *i.e.* 2.66 and 3.58 was reported in T1 and T2, respectively.

The increase in number of primary branches might be due to quick availability of boron, zinc and sulphur during entire growing season. Combined application of nutrient inputs from inorganic fertilizers and sludge might improve the source capacity and photosynthetic rate of the plants which is of fundamental importance for optimum plant growth therefore led to higher dry matter accumulation and number of branches with the combined application of sludge and inorganic fertilization including boron, sulphur and zinc compared to when chemical fertilizer applied alone or no fertilization. Similar results were also reported by many other researchers which reported that integration of chemical fertilization and sludge, zinc, boron and sulphur led to higher crop growth of mustard (Kumar and Kumar, 2007; Patel and Ghosh, 2013; Yadav *et al.*, 2016).

Greenness index

Data pertaining to greenness index of leaves as influenced by different levels of zinc, boron, sulphur and sludge applications is presented in Table 2. All treatments showed significant increase in SPAD value over control (T2). The maximum SPAD value was recorded in T10 followed by T8, which showed an increase of 30.99 and 25.35%, respectively over control. The lowest value was observed in T1 (absolute control) followed by T2 (control). The application of Boron with zinc and sulphur combination in T4, T6, T7, and T8 increased greenness index but T4 and T6 were statistically at par with each other similarly with the T6, T7 and T8. An optimum nutrient supply particularly N

throughout the growing season with use of sludge and inorganic fertilization might improve leaf growth rate and its nitrogen content which led to higher chlorophyll content. Moreover, optimum supply of zinc, boron and sulphur with their application along with recommended dose of fertilizer might improved availability, uptake and utilization of N by crop is one of the reason for higher values of greenness index with compared to control and RDF alone.

Similar results of higher chlorophyll content were also reported by Singh and Agrawal, (2007) for integrated use of sludge and inorganic fertilization, Thapa (2006) for zinc, Singh and Singh (2005) for sulphur, Latare and Singh (2013) for sewage sludge.

Table.1 Effect of sulphur, zinc, boron and sewage sludge application on plant height of mustard

Treatments	Plant Height (cm)		
	30DAS	60DAS	90DAS
T1	12.30g	40.01i	104.60h
T2	14.17f	44.60hi	118.17g
T3	17.93de	54.37ef	137.02def
T4	15.00f	49.07gh	131.17f
T5	16.90e	50.07fg	133.72ef
T6	19.47cd	57.53de	144.23bcde
T7	19.87c	57.33de	141.53cdef
T8	22.57b	66.73ab	154.70ab
T9	21.73b	62.80bc	151.00bc
T10	24.53a	71.13a	165.67a
T11	21.17bc	61.60cd	147.87bcd
T12	22.73ab	67.57ab	156.03ab
CV (%)	5.70	5.20	5.37

Different letters for each parameters show significant different at $p < 0.05$. 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

Table.2 Effect of sulphur, zinc, boron and sewage sludge application on growth parameters (number of leaves, number of branches, greenness index) of mustard

Treatments	Number of Leaves plant-1	Number of Branches plant-1	Greenness Index (SPAD)
	60DAS	90DAS	
T1	7.70h	2.66f	1.32f
T2	8.67h	3.58e	1.42ef
T3	10.63fg	3.86de	1.58cd
T4	9.73g	3.61e	1.50de
T5	10.07g	3.55e	1.52de
T6	11.63de	4.08bcd	1.64bcd
T7	11.47ef	4.04cd	1.70bc
T8	13.43bc	4.37bc	1.78ab
T9	12.93c	4.28bcd	1.76ab
T10	14.53a	4.87a	1.86a
T11	12.50cd	4.17bcd	1.74ab
T12	13.97ab	4.47ab	1.56cde
CV (%)	5.03	6.31	5.36

Different letters for each parameters show significant different at $p < 0.05$. 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

Table.3 Effect of sulphur, zinc, boron and sewage sludge application on seed yield, stover yield and oil content

Treatments	Seed Yield (g pot-1)	Stover Yield (g pot-1)	Oil Content (%)
T1	11.43g	35.70g	34.40a
T2	13.30f	42.37f	36.53a
T3	16.43de	48.18de	37.59a
T4	14.87ef	46.46e	36.73a
T5	14.93ef	47.24e	36.83a
T6	16.97cd	50.72cd	38.47a
T7	16.63cd	49.53cde	37.93a
T8	18.97b	54.67b	39.12a
T9	18.20bc	54.17b	38.94a
T10	20.90a	60.49a	40.37a
T11	17.53bcd	52.90bc	38.79a
T12	19.13b	55.82b	40.10a
CV (%)	6.01	4.06	5.20

Different letters for each parameters show significant different at $p < 0.05$. 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

Seed and stover yield (g pot⁻¹)

Data pertaining to seed yield have been presented in Table 3 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 than 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. A critical perusal of the data presented in Table 3 revealed different levels of zinc, boron, sulphur and sludge application showed significant increase on stover yield, when compared with control (T2). The Stover yield ranged between 35.7–60.5 g pot⁻¹. The maximum stover yield was found in treatment T10, followed by T12 with 60.5 and 55.8, g pot⁻¹, respectively but both these are statistically at par with each other. The minimum stover yield was found in absolute control (T1) and control (T2) with 35.7 and 42.4 g pot⁻¹, respectively.

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). 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). Latare and Singh, (2013) 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).

Oil content in seed

The data contained in Table 3 showed that oil content in seed increased significantly with varying level of boron, zinc, sulphur and sludge application. Oil content ranges between 34.4-40.4%. The maximum oil content was found in treatment T10 followed by T12 with 40.4 and 40.1%, respectively but both these are statistically at par with each other. The minimum oil content was found in absolute control (T1) and control (T2) with 34.4 and 36.5%, respectively. Treatment T10 and T8 showed an increase of 10.51 and 9.77%, respectively over control (T2). Sulphur and boron are essential plants nutrients which known for their important and specific role in the synthesis of proteins, chlorophyll and oil. Therefore, optimum and adequate supply of these nutrients with

combined application of sludge and inorganic fertilization might result in higher oil content compared to control and when chemical fertilizer applied alone (Abid *et al.*, 2014; Yadav *et al.*, 2016). Sahito *et al.*, (2014) also observed that marked improvement in oil content with combined application of sludge and inorganic fertilization.

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 oil 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 grain, stover yield and higher oil content can be obtained.

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