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Growth and yield of irrigated mustard (*Brassica juncea* (L.) Czern and Coss) *cv.* NRC-HB-101 as influenced by nutrient sources and secondary nutrients in South Eastern Coastal plain agro-climatic Zone of Odisha

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Abstract
A field experiment entitled "Growth and yield of irrigated mustard (*Brassica juncea* (L.) Czern and Coss) *cv.* NRC-HB-101 as influenced by organic nutrient sources and secondary nutrients in South Eastern coastal plain agro-climatic zone of Odisha was conducted during the rabi season 2022-23 at the Agriculture Research Station, Binjhagiri of Faculty of Agricultural Sciences, SOADU, Bhubaneswar, Odisha. The experiment was laid out in a split-plot design with three replications. The treatments comprised of organic nutrients (RDF, Farm Yard Manure @5tonnes/ha and Vermicompost @2.5 tonnes/ha) along with the RDF assigned in the main plot and four secondary nutrients (control, lime @0.2 LR, sulphur @ 45 kg/ha and combination of lime 0.2LR and sulphur @45kg/ha was assigned in the subplots. The soil of the experimental plot was sandy loam in texture with pH5.8, low in organic carbon (0.45%) available nitrogen 130 kg/ha phosphorus 14.67kg/ha, sulphur 27.21 ppm and available potassium 132 kg/ha. The test variety used in this experiment was NRCHB-101(110 days). The recommended dose of fertilizer (RDF) was (80:40:40 $N:P_2O_5:K_2O$ kg/ha). From the field experiment it was observed that application of RDF+VC@2.5tones/ha increased the growth attributes like plant height (188.90 cm), number of primary (5.50) and secondary branches (11.60), LAI (5.48) and dry matter (55.10g/plant) and the yield attributes i.e number of siliqua/plant, seeds/ siliqua and test weight (g) which was at par with the application of RDF+FYM @5 tonnes /ha. Similarly, among the secondary nutrients, combined application of lime 0.2LR and sulphur@45kg/ha had the highest plant height, branches, LAI dry matter and other yield attributes i.e. no siliqua /plant, seeds/siliqua and test weight. The seed yield (18.63q/ha), stover yield(59.57q/ha), harvest index of 33.94 and oil yield of 12.13q/ha was recorded with the combined application of RDF +VC @2.5 tones /ha along with lime @0.2LR and sulphur @45kg/ha.

Keywords: Secondary nutrients, sulphur, vermicompost, lime, FYM

Introduction
Mustard (*Brassica juncea* (L.) Czern and Coss.) is an important rabi oilseed crop that belongs to the family "Cruciferae". India ranks first in terms of area and third in terms of production, with an yield of 7.36 MT and average productivity of 1190 kg/ha, Indian mustard and rapeseed take up around 6.18 million hectares on the global map. In India concerning both area and productivity, Rajasthan is at the top. The most productive states for rapeseed and mustard are Gujarat and Uttar Pradesh producing 0.76 MT of rapeseed and 1155 kg/ha of mustard. Rapeseed and mustard are cultivated in 6.58 lakh ha of land ie.10% of all oil seed production and making it one of the major oil seed-producing nations in the world. With 13.33% of the total planted area and an estimated value of $10 billion, oilseeds are India's second most important agricultural product after cereals.

Besides the major nutrients, the importance of secondary nutrients particularly sulphur and micronutrients like sulphur in rapeseed and mustard have been well realised all over the country. The soils of Odisha are primarily acidic (pH-5.5.), and 58.6% of soil are deficient in sulphur (3.75 -7.50 mg kg^{-1}). Among the oil seed crops rapeseed and mustard have the highest sulphur requirement (Hedge and Babu., 2007) [4]. Sulphur promotes oil synthesis. It is an important constituent of seed protein, amino acids, and glucosinolate and is required for chlorophyll synthesis (Shekhawat *et al.*, 2012) [13].

The increase in oil content and P uptake at maturity with successive doses of P_2O_5 up to 30 kg/ha was significant (Cousksey *et al.*, 2017). In terms of nutritional requirements, sulphur plays a major role in determining yield, quality and resistance of mustard towards stress factors.

Application of FYM also increases cation exchange capacity and helps in keeping soil micronutrients in available form through its chelating action as well as microbial activity in soil besides supplying macro and micro plant nutrients. Lime was added to permit fertiliser levels to boost mustard production and improve nitrogen uptake when compared to fertiliser alone and other nutrient management methods (Pati and Mahapatra 2015) Lime application in soil accelerates the breakdown of agricultural wastes and soil manure by increasing microbial activity, this, in turn, can improve the availability of plant nutrients in the soil, Liming can also help in ameliorating nutritional deficits (Rahman *et al*. (2021) [11].

Materials and Methods

The study was carried out in the Agricultural Research Station, Binjhagiri, Faculty of Agricultural Sciences, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha during rabi 2022-23. This research station is located in 20^0.26' N latitude and of 85^0.67' E longitude in East and South Eastern Coastal Plain Zone of Odisha.

The experiment was laid out in a split-plot design with three replications. Three levels of organic sources were put in the main plot treatments while sulphur and lime application methods were in the subplots. Main plot treatments were F_1: RDF, F_2: RDF+ FYM @5 t/ha, F_3: RDF+ VC 2.5 @t/ha while subplot treatments were S_1: Control, S_2: Lime @0.2LR, S_3: Sulphur @45 kg /ha, S_4: Lime @0.2LR + Sulphur@ 45 kg /ha (Source of Sulphur Bentonite)

Chemical fertilizer @ 80-40-40 kg N-P_2O_5- K_2O/ha (Recommended dose) was applied in the form of diammonium phosphate (DAP), urea and muriate of potash in furrows. Farm Yard Manure @ 5 t/ha was applied as basal at the time of final ploughing. Bentonite (sulphur containing 90% S) was applied as per the treatment (basal application). Lime was applied as basal for neutralising the soil 20 days before sowing. Various plant growth studies like plant height (cm), LAI(g/m^2/day), CGR(g/m^2/day), NAR(g/m^2/day) and Dry matter accumulation(g/plant) at different growth stages were recorded.

Results and Discussions

The increase in plant height with organic and secondary nutrient sources might be due to higher nutrient supply and rapid conversion of carbohydrates into protein which in turn elaborated into protoplasm. The highest plant height, LAI, CGR, and NAR at 60 DAS were recorded in the treatment F_3S_4 (F_3: RDF+ VC @2.5 t/ha vermicompost and S_4: Lime @0.2LR + Sulphur@ 45 kg /ha). However, the shortest plant height was recorded in F_1S_1(F_1: RDF and S_1: Control), respectively.

The sulphur availability in the soil increases cell multiplication and elongation, chlorophyll content in the leaves which results in an improvement of the rate of photosynthesis and higher dry matter accumulation in plants (Sipai *et al*. 2015) [15]. An increase in plant height by application of sulphur was reported by Kumar and Yadav (2007) [4]. Increased sulphur fertilisation gave better nutrition to plants which resulted in more height, number of branches and dry weight of plants. An increase in plant height by application of sulphur was also reported by Jat (2012) [5] and Pachauri (2012) [9]. Mustard is indeterminate in growth where both the vegetative and reproductive stages simultaneously support the trend in difference in plant height. This corroborates the findings of Kerthi *et al*., (2017) [6] and Kumar *et al*., (2021) [7]. Dry matter production successively increased towards maturity due to the favourable effect of sulphur on the growth and development of plants. An increase in primary and secondary branches per plant, plant height and number of leaves per plant are directly responsible for increasing the dry matter accumulation of plants at higher levels of sulphur (Rajput *et al*. 2018) [12].

The highest number of primary branches and secondary branches in F_3: RDF+VC 2.5 @t/ha, S_4: Lime @0.2LR + Sulphur@ 45 kg /ha which was at par with the treatment F_2S_3(F_2: RDF+ FYM @5t/ha, S_3: Sulphur @45kg/ha). The lowest number of primary secondary branches was recorded by the sole application of RDF.

The highest no of siliqua per plant was recorded in F_3: RDF+ VC 2.5t/ha which was at par with application F_2: RDF+ FYM @5 t/ha. The lowest number of siliqua per plant was recorded in the control treatment (RDF). Among the secondary nutrients, S_4: Lime @0.2LR + Sulphur@ 45 kg /ha had the highest number of siliqua per plant which was significantly superior to either sole application of lime, sulphur or its non-application. Sole application of sulphur recorded 182.2 siliqua per plant while application of lime @0.2 LR recorded 167.9 siliqua per plant (Table 1.2)

The siliqua length varied from 5.3cm to 6.63 cm depending upon different fertility levels. Similarly, among the secondary nutrients it varied between 5.86cm to 7.11 cm. There are significant variations in the length of siliqua as influenced by different fertility levels and secondary nutrients.

The total number of seeds per siliqua varied between 7.38 and 11.99 as influenced by different fertility levels and secondary nutrients. The highest number of seeds (21.76) was recorded by combined application of lime@0.2LR and sulphur @45kg/ha. The lowest number of seeds per siliqua (14.96) was recorded in the control treatment where only RDF was applied.

The test weight (1000 seed weight) in mustard varied from 4.10 g to 6.18 g due to the influence of various combinations of treatment. There was significant variation in the test weight among the fertility levels. The highest test weight of 5.40 g was recorded in the treatment applied with vermicompost which was at par with application FYM @5tones/ha (5.20g). The lowest test weight of 4.10g was recorded in the control treatment, different secondary nutrients also influenced the test weight of the mustard crop. The significantly highest test weight was observed by the combined application of lime @0.2 LR and sulphur 45 kg/ha closely followed by the sole application of sulphur @45 kg/ha (5.5g) and lime 0.2 LR (5.4g). The lowest test weight 4.63g was recorded in the control treatment. Application of recommended dose of N, P, K along with sulphur helped in enhancing the availability of major nutrients in soil resulting in consequent availability to plants by reducing soil pH at microsites, chelating action of organic acid produced by them and in mobility in the fungal filament (Chankar, 2002) [2].

Table 1: Effect of organic and secondary nutrients on growth parameters of mustard at 60DAS

Treatments	Plant height (cm)	LAI	CGR (g/m^2/day)	NAR (g/m^2/day)	Dry matter (g/plant)
Fertility levels					
F_1: RDF	56.03	3.91	9.43	2.18	6.80
F_2: RDF+ FYM@5t/ha	57.92	4.60	10.35	2.37	6.29
F_3: RDF + VC @2.5 t/ha	61.24	4.83	10.47	2.46	7.69
CD (P=0.05)	1.74	0.04	0.47	0.11	0.56
Secondary nutrients					
S_1: Control	96.89	3.90	9.63	2.34	4.45
S_2: Lime @ 0.2LR	99.26	4.17	9.67	2.36	6.35
S_3: Sulphur @45 kg/ha	99.44	4.44	11.09	2.45	9.30
S_4: Lime @0.2LR + Sulphur @45 kg/ha	101.8	4.77	11.26	2.50	7.61
CD(P=0.05)	1.17	0.05	0.82	0.13	0.64

Table 2: Effect of organic and secondary nutrients on yield attributes of mustard

Treatments	Primary branches/plant	Secondary branches/ plant	Siliquae/ plant	Length of siliquae (cm)	Seeds/ siliquae	1000 seed Weight (gm)
Fertility levels						
F_1: RDF	5.0	10.0	146.86	5.37	7.38	4.1
F_2: RDF+ FYM@5t/ha	5.4	10.9	182.55	5.53	7.46	5.2
F_3: RDF + VC @2.5 t/ha	5.5	11.6	187.65	6.63	7.47	5.4
CD (P=0.05)	0.3	0.8	6.3	0.22	0.08	0.11
Secondary nutrients						
S_1: Control	5.0	9.6	`164.7	5.86	10.09	4.63
S_2: Lime @ 0.2LR	5.3	10.6	167.9	6.12	11.38	5.42
S_3: Sulphur @45 kg/ha	5.4	11.1	182.2	6.66	11.85	5.50
S_4: Lime @0.2LR + Sulphur @45 kg/ha	5.6	12.1	192.96	7.11	11.99	6.18
CD(P=0.05)	0.3	0.9	7.3	0.48	0.10	0.12

Yield attributes

The results revealed that the highest seed yield was obtained in S_4: Lime @0.2LR + Sulphur@45kg/ha which was significantly superior to the rest of the fertility levels. The increase in yield attributes might be due to the increased supply of almost 52 plant essential nutrients by translocation of photosynthates accumulated under the influence of the nutrients. Sulphur application increased metabolic activity and promoted meristematic growth leading to improved growth characters and yield. The results are also substantiated by the findings reported by Sing *et al*. 2017.

The results revealed that the highest stover yield was obtained by the application of RDF with VC @5tones/ha, which was 18% more as compared to the application of RDF with FYM @5tones/ha. In the control treatment, the lowest stover yield 51.52 q/ha was obtained. Comparing the secondary nutrients the highest stover yield of 62.37q/ha was obtained by combined application of lime@0.2LR and sulphur @45kg/ha which was 30% and 55% by more either application of sulphur @45kg/ha or lime@0.2LR The lowest stover yield of 53.78q/ha was obtained from the control treatment. Both seed and stover yield were net resultant effects of various Agronomy inputs influencing growth and yield attributing characters during the life cycle of the crop. These findings agree with the findings of Yogesh *et al*. (2017) [16] and Biswas *et al*. (2019) [1].

There are no significant differences observed in the harvest index either due to the application of different organic nutrients and secondary nutrients. The harvest index value varied between 24.45% to 26.50% with different treatment combinations.

Table 3: Effect of organic and secondary nutrients on the yield of mustard

Treatments	Seed yield (qha^{-1})	Stover yield (qha^{-1})	Biological yield (qha^{-1})	Harvest Index (%)
Fertility levels				
F_1: RDF	14.96	51.52	68.18	32.50
F_2: RDF+ FYM@5t/ha	19.04	54.24	72.28	32.79
F_3: RDF + VC @2.5 t/ha	21.76	56.04	79.08	33.79
CD(P=0.05)	0.10	0.25	2.99	NS
Secondary nutrients				
S_1: Control	11.35	53.78	69.01	31.45
S_2: Lime @ 0.2LR	17.23	55.14	75.37	32.00
S_3: Sulphur @45 kg/ha	21.31	59.29	82.06	32.91
S_4: Lime @0.2LR + Sulphur @45 kg/ha	21.76	62.37	85.13	33.94
CD(P=0.05)	0.20	0.30	2.59	NS

Conclusion

The study on “Productivity of irrigated mustard through organic sources and secondary nutrients” conducted during 2022-23 revealed that application of recommended dose of fertiliser with vermicompost@2.5 tones/ha in combination with lime@0.2 LR and sulphur @45kg/ha is the best treatment combination which had maximum plant height, highest LAI, Dry matter, CGR, RGR and NAR and chlorophyll. The same treatment had highest yield attribute contributing to maximum grain yield, straw yield, biological yield, net monitor return and B:C ratio. This was closely followed by application of RDF along with FYM @5tones/ha combined with the secondary nutrients i.e lime @0.2LR and sulphur @45kg/ha.

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Conflict of interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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