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RESEARCH PAPER

Productivity enhancement of mustard through integrated nutrient management practices

P. ANNAPOORNA AND H. T. CHANDRANATH

Department of Agronomy, College of Agriculture, Dharwad
University of Agricultural Sciences, Dharwad - 580 005, Karnataka, India
E-mail: poornimapmjj94@gmail.com

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Abstract: A field experiment was conducted during *rabi* season of 2019-20 at UAS, Dharwad to study the effect of integrated nutrient management on growth, yield, quality and nutrient uptake in mustard under Northern Transition Zone of Karnataka. The study comprised of three doses of fertilizers (100, 75 and 50% RDF) and two different organic manures (Farm yard manure and vermicompost) with three bioinoculants (*Azospirillum*, PSB and Pink Pigmented Facultative Methylobacteria) and these combinations were compared with control. The treatments were replicated thrice using randomized block design. The results of the study revealed that, application of 100% RDF + FYM @ 5 t ha^{-1} + *Azospirillum* @ 4 ml kg^{-1} seed + PSB @ 4 ml kg^{-1} seed + PPFM @ 1% recorded higher growth, yield attributes and increased the seed yield by 77.21% over control. Like wise, higher oil content (36.40%), oil yield (569 kg ha^{-1}), uptake of N, P and K (93.32, 33.81 and 81.13 kg ha^{-1}, respectively), net return (₹ 40870 ha^{-1}) and B:C ratio (2.39) were also recorded with the same treatment. Application of 100 % RDF + FYM @ 5 t ha^{-1} + *Azospirillum* @ 4 ml kg^{-1} seed + PSB @ 4 ml kg^{-1} seed recorded 69.16 % higher seed yield and additional net returns of 20217 ha^{-1} was noticed over no fertilizers (₹ 17703 ha^{-1}).

Key words: *Azospirillum*, Net returns, Seed yield, Vermicompost

Introduction

India is the world's largest rapeseed and mustard producing country, occupying the largest area and second in production after china. Mustard is an oilseed crop, which is nutritionally very rich and it's oil content varies from 37-49%.

The crop is grown in an area of 7.4 million hectare and the production is 7.70 million tonnes with the productivity of 1040 kilogram per hectare. In Karnataka, with a production of 2000 tonnes and a productivity of 400 kilograms per hectare, it is grown in an area of 5000 hectares (Anon., 2019). This is much lower than the national average productivity due to improper fertilization under rainfed condition (Rana *et al.,* 2018; Heba *et al.,* 2020). Because of continuous and sole application of artificial inorganic fertilizer induce the soil sickness, deterioration in soil health and disturb the soil environment resulting in low productivity and unsustainability (Rajanna *et al.,* 2012; Rana *et al.,* 2018). Thus, there is a need for improved suitable nutrient management practices in order to achieve better crop growth and development of the crop.

Rapeseed and mustard is energy rich crop but it is grown under energy starved condition so, the nutrient requirement of rapeseed and mustard in general and micronutrient in particular are high which should be supplied in appropriate quantities. To produce 1 tonne of mustard seed per hectare, crop requires 80-120 kilogram nitrogen per hectare, 12.4-42.7 kilogram phosphorous per hectare, 20-40 kilogram potassium per hectare, 12-20 kilogram sulphur per hectare, zinc 100 gram per hectare and boron 36 gram per hectare of nutrients (Kumar *et al.,* 2010). It requires relatively large amount of nutrients for realization of yield potential but inadequate supply often leads to low productivity (Rathore *et al.,* 2020). Integrated use of organic sources of farm yard manure, vermicompost and inorganic fertilizers like nitrogen, phosphorous, potash and sulphur and micronutrients like Zinc and Borax along with biofertilizers *viz.*, *Azospirillum*, Phosphorous solubilizing bacteria and Pink pigmented facultative methylobacterium (PPFM). It not only ensures that all essential plant nutrients are available, but also enhances the soil physical, chemical and biological properties and increases the mustard crop productivity and sustainability.

Hence, integrated use of organic and inorganic sources of nutrients with biofertilizers plays a major role in improving the soil health and availability of nutrients that are responsible for improved growth and yiled characteristics of mustard, thereby increasing crop yield, oil yield and net returns by practicing integrated nutrient management.

Material and methods

A Field experiment entitled "Integrated nutrient management in mustard (*Brassica juncea* L.)*"* was conducted during *rabi* season of-2019 at the Main Agricultural Research Station, Dharwad, Karnataka under rainfed condition. The study having vertisols with having pH of 7.3 and electrical conductivity of 0.32 dSm^{-1}. The soil was medium in organic carbon (5.2 g kg^{-1}), low in available nitrogen (248 kg ha^{-1}), medium in available P_2O_5 (31 kg ha^{-1}), medium available K_2O (317 kg ha^{-1}) and medium in available sulphur (21.6 kg ha^{-1}). The experiment was laid out in randomized complete block design with fourteen treatments: T_1: 100 % RDF + FYM @ 5 t ha^{-1}, T_2: 100 % RDF + VC @ 3 t ha^{-1}, T_3: 100 % RDF + FYM @ 5 t ha^{-1} + *Azospirillum* @ 4 ml kg^{-1} seed + PSB @ 4 ml kg seed^{-1}, T_4: 100 % RDF + FYM @ 5 t ha^{-1} + *Azospirillum* @ 4 ml kg^{-1} seed + PSB @ 4 ml kg seed^{-1}+ PPFM @ 1 %, T_5: 75 % RDF + FYM @ 5 t ha^{-1}, T_6:75 % RDF + VC @ 3 t ha^{-1}, T_7: 75 % RDF + FYM @ 5 t ha^{-1} + *Azospirillum* @ 4 ml kg^{-1} seed + PSB @ 4 ml kg seed^{-1}, T_8: 75%RDF+FYM@5tha^{-1} +*Azospirillum* @ 4 ml kg^{-1} seed + PSB @ 4 ml kg seed^{-1} + PPFM @ 1 % , T_9: 50 % RDF + FYM @ 5 t ha^{-1}, T_{10}: 50 % RDF + VC @

3 t ha^{-1}, T_{11}: 50 % RDF + FYM @ 5 t ha^{-1} + *Azospirillum* @ 4 ml kg^{-1} seed + PSB @ 4 ml kg $seed^{-1}$, T_{12}: 50 % RDF + FYM @ 5 t ha^{-1} + *Azospirillum* @ 4 ml kg^{-1} seed + PSB @ 4 ml kg $seed^{-1}$ + PPFM @ 1 %, T_{13}: RDF + FYM @ 5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @1kg ha^{-1} and T_{14}: Control (no fertilizer) replicated thrice. Mustard hybrid" NRCHB-101" was sown on 4th October 2019 with a spacing of 45×10 cm. The mean maximum temperatures during the period of experimentation ranged from 27.9 ^{0}C (October) to 29.8 ^{0}C (January), while the minimum temperature ranged from 19 ^{0}C (October) to 15.5 ^{0}C (January) and 352 mm rainfall was received in 15 rainy days during the crop growing period.

Yield attributes and yield of crop was recorded at harvest and chemical properties of soil were analysed after harvest of the crop. Interpretation of the data was carried out in accordance with Gomez and Gomez (1984). The level of significance used in the 'F' and 't' test was p=0.05. The critical difference values were calculated wherever the 'F' test values were significant.

Results and discussion

Yield and yield parameters of mustard

The increase in the growth attributes due to application of organic and inorganic fertilizers along with biofertilizers resulted in significantly higher yield and yield parameters at harvest. Significantly higher seed yield was recorded due to contribution from other yield parameters like, weight of 1000 seed, number of seeds per siliqua and siliqua per plant. At harvest, application of 100 % RDF + FYM @ 5 tonnes per hectare + *Azospirillum* @ 4 ml per kilogram seed + PSB @ 4 ml per kilogram seed + PPFM @ 1 % as foliar spray, recorded significantly higher number of seeds per siliqua (12.2), weight of 1000 seed (4.91 gram), and siliqua per plant (173), which was on par with 100 % RDF + FYM @ 5 tonnes per hectare + *Azospirillum* @ 4 ml per kg seed + PSB @ 4 ml per kg seed (12.1, 4.89 and 170, respectively) and 100 % RDF + FYM @ 5 tonnes per hectare + $ZnSO_4$ @ 20 kilogram per hectare+ Borax @ 1 kilogram per hectare (12, 4.82 and 167s, respectively) (Table 1). The probable reason of highest yield attributing characters might be due to higher availability of major nutrients and simultaneously better nutrition since early stage of growth (Rajanna *et al.,* 2012; Rana *et al.,* 2018; Rathore *et al.,* 2020). It means that *Azospirillum*, PSB and PPFM played an important role in generative growth of mustard therefore to make a significant increase in the number of siliquae per plant, number of seeds per siliqua and weight of 1000 seed. This was mainly due to the balanced nutrition available to translocation of photosynthates from source to sink which resulted in more accumulation of photosynthates (Gopakkali *et al.,* 2012; Rajanna *et al.,* 2011).

Further, improvement in yield attributes might be due to possible role of *Azospirillum* through atmospheric nitrogen fixation, better root proliferation, uptake of nutrients and water. The growth promoters like NAA and cytokinin released by *Azospirillum*, PSB and PPFM might have resulted in breaking of apical dominance and accelerated higher number of branches. The increased nitrogen nutrition might also have accelerated the process of cell division and differentiation. Increase in seedyield (1563 kilogram per hectare) with 100 % RDF + FYM @ 5 tonnes per hectare + *Azospirillum* @ 4 ml per kilogram seed + PSB @ 4 ml per kilogram seed + PPFM @ 1 % was also attributable to adequate and balanced nutrients availability at critical growth stages and thus enhanced photosynthetic efficiency of mustard (Gudadhe *et al*., 2005; Pal and Pathak, 2016; Yadav *et al.,* 2018; Singh *et al.*, 2018).

Among different integrated treatments, seed yield (1563 kg ha^{-1}) was significantly higher with the application of 100 % RDF + FYM @ 5 tonnes per hectare + *Azospirillum* @ 4 ml per kilogram seed + PSB @ 4 ml per kilogram seed + PPFM @ 1 % as foliar

Table 1. Seed yield, biological yield and harvest index of mustard as influenced by integrated nutrient management practices

Treatment	1000-seed weight (g)	Siliqua $plant^{-1}$	Seeds $siliqua^{-1}$	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T_1: 100 % RDF + FYM @ 5 t ha^{-1}	4.51	161	11.4	1368	5208	26.27
T_2: 100 % RDF + vermicompost @ 3 t ha^{-1}	4.53	163	11.5	1395	5255	26.54
T_3: T_1+ *Azospirillum* @ 4 ml kg^{-1} seed+ PSB @ 4 ml kg^{-1} seed	4.89	170	12.1	1492	5522	27.02
T_4: T_1+ *Azospirillum* @ 4 ml kg^{-1} seed+ PSB @ 4 ml kg^{-1} seed + PPFM (1% FS)	4.91	173	12.2	1563	5773	27.08
T_5: 75 % RDF + FYM @ 5 t ha^{-1}	4.11	150	10.1	1181	4801	24.60
T_6: 75 % RDF + vermicompost @ 3 tonnes per hectare	4.15	151	10.2	1215	4855	25.03
T_7: T_5+*Azospirillum* @ 4 ml kg^{-1} seed + PSB @ 4 ml kg^{-1} seed	4.48	158	10.6	1330	5248	25.34
T_8: T_5+ *Azospirillum* @ 4 ml kg^{-1} seed + PSB @ 4 ml kg^{-1} seed + PPFM (1% FS)	4.50	159	10.8	1365	5351	25.51
T_9: 50 % RDF + FYM @ 5 t ha^{-1}	3.79	140	9.27	1010	4210	23.99
T_{10}: 50 % RDF + vermicompost @ 3 t ha^{-1}	3.80	144	9.33	1025	4272	24.00
T_{11}: T_9 + *Azospirillum* @ 4 ml kg-$^{-1}$ seed+ PSB @ 4 ml kg^{-1} seed	3.81	147	9.36	1062	4404	24.11
T_{12}: T_9 + *Azospirillum* @ 4 ml kg-$^{-1}$ seed + PSB @ 4 ml kg^{-1} seed + PPFM (1% FS)	3.82	148	9.47	1122	4572	24.54
T_{13}: T_1+ $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 1 kg ha^{-1}	4.82	167	12.0	1466	5481	26.74
T_{14}: Control (No fertilizer)	3.71	121	9.17	882	4000	22.05
S.Em.±	0.11	2.39	0.13	51	324	0.57
C.D. (p = 0.05)	0.31	6.94	0.39	147	942	1.65

spray, which was on par with 100 % RDF + FYM @ 5 tonnes per hectare + *Azospirillum* @ 4 ml per kilogram seed + PSB @ 4 ml per kilogram seed (1492 kilogram per hectare) and 100 % RDF + FYM @ 5 tonnes per hectare+ $ZnSO_4$ @ 20 kilogram per hectare+ Borax @ 1 kilogram per hectare (1466 kilogram per hectare) as compared to control (882 kilogram per hectare) (Table.1). The higher seed yield was increased to the extent of 6.62 and 77.2 % over 100 % RDF + FYM @ 5 tonnes per hectare+ $ZnSO_4$ @ 20 kilogram per hectare+ Borax @ 1 kilogram per hectare and control, respectively with the combined application of organic and inorganic fertilizers along with biofertilizers. Higher bilogocal yield (5773 kg ha^{-1}) and harvest index (27.08 %) also recorded with same treatments. It might be due to the cumulative effect of all the nutrients might have attributed to attainment highest yield, Azotobacter and PSB besides fixing ambient nitrogen to the soil and solubilize phosphates in the soil can benefit mustard by PPFM producing growth hormones like IAA and Gibberlins, alsoincreased seed and biological yield and harvest index with the increment in supply of essential nutrient to rapeseed and mustard, their availability, accumulation, mobilization and influx into the plant tissue increased and thus improved yield component and yield of mustard.

Oil content and oil yield

Among different treatments higher oil yield (569 kilogram per hectare) was recorded with the application of 100 % RDF + FYM @ 5 tonnes per hectare + *Azospirillum* @ 4 ml per kilogram seed + PSB @ 4 ml per kilogram seed + PPFM @ 1 % at harvest, which was on par with application of 100 % RDF + FYM @ 5 tonnes per hectare + *Azospirillum* @ 4 ml per kilogram seed + PSB @ 4 ml per kilogram seed (542 kilogram per hectare) and 100 % RDF + FYM + $ZnSO_4$ @ 20 kilogram per hectare+ Borax @1 kilogram per hectare (533 kilogram per hectare) (Table 2). The oil yield increased up to the extent of 16.59, 42.61 and 87.78 %, respectively over T_8 (75 % RDF + FYM @ 5 tonnes per hectare + *Azospirillum* @ 4 ml per kilogram seed + PSB @ 4 ml per kilogram seed + PPFM @ 1 %), T_{12} (50 % RDF + FYM @ 5 tonnes per hectare + *Azospirillum* @ 4 ml per kilogram seed + PSB @ 4 ml per kilogram seed + PPFM @ 1 %) and T_{14} (Control). This was mainly due to higher seed yield (1563 kilogram per hectare) and oil content (36.4 %). The higher oil content due to the higher sulphur content from organic and inorganic sources of nutrients involved in electron transport chain and biosynthesis of more glucosides, which produces sulphur rich amino acids like cysteine and methionine, glucosides and synthesis of amino acids ultimately increased the oil content in seed. Muhammad *et al.* (2013) in sunflower and mustard who reported that sulphur is involved in the formation of glucoside, glucosinolate and activation of enzymes, which aid in biochemical reaction within the plant and on hydrolysis produce higher amount of oil and oil yield with combined application of organic and inorganic sources of nutrients with bioinoculants in mustard.Significantly lowest oil yield (303 kilogram per hectare) was recorded with control as compared to all other treatments. The experimental soil was low in sulphur and nitrogen content resulted in reduction of growth and development, photosynthetic activity and translocation of photosynthates to sink further resulted in decreased yield and yield attributes in turn resulted in lower oil yield in control.

Economics analysis

The highest gross returns (₹ 70350 per hectare) and net returns (₹ 40870 per hectare) were obtained with combined application of 100 % RDF + FYM @ 5 tonnes per hectare+ *Azospirillum* @ 4 ml per kilogram seed + PSB @ 4 ml per kilogram seed + PPFM @ 1 %. The benefit cost ratio was also highest (2.39) in the same treatment indicating more profit for the investment which was on par with application of 100 % RDF + FYM @ 5 tonnes per hectare+ *Azospirillum* @ 4 ml per kilogram seed + PSB @ 4 ml per kilogram seed (₹ 67140 and 37920 per hectare, respectively) and 100 % RDF + FYM @ 5 tonnes per hectare + $ZnSO_4$ @ 20 kilogram per hectare+ Borax @1 kilogram per hectare (₹ 65955 and 35567 per hectare, respectively). This was followed by 75 % RDF + FYM @ 5 tonnes per hectare+ *Azospirillum* @ 4 ml per kilogram seed + PSB @ 4 ml per kilogram seed + PPFM at 1 % (₹ 61440 and 33412 per hectare,

Table 2. Oil content and oil yield of mustard as influenced by integrated nutrient management practices

Treatments	Oil content (%)	Oil yield (kg ha^{-1})
T_1 : 100 % RDF + FYM @ 5 t ha^{-1}	36.3	498
T_2 : 100 % RDF + vermicompost @ 3 t ha^{-1}	36.3	506
T_3 : T_1+ *Azospirillum* @ 4 ml kg^{-1} seed+ PSB @ 4 ml kg^{-1} seed	36.3	542
T_4 : T_1+ *Azospirillum* @ 4 ml kg^{-1} seed+ PSB @ 4 ml kg^{-1} seed + PPFM (1% FS)	36.4	569
T_5 : 75 % RDF + FYM @ 5 t ha^{-1}	35.6	421
T_6 : 75 % RDF + vermicompost @ 3 tonnes per hectare	35.7	434
T_7 : T_5+*Azospirillum* @ 4 ml kg^{-1} seed + PSB @ 4 ml kg^{-1} seed	35.7	475
T_8 : T_5+ *Azospirillum* @ 4 ml kg^{-1} seed + PSB @ 4 ml kg^{-1} seed + PPFM (1% FS)	35.7	488
T_9 : 50 % RDF + FYM @ 5 t ha^{-1}	35.1	355
T_{10} : 50 % RDF + vermicompost @ 3 t ha^{-1}	35.2	362
T_{11} : T_9 + *Azospirillum* @ 4 ml kg^{-1} seed+ PSB @ 4 ml kg^{-1} seed	35.5	377
T_{12} : T_9 + *Azospirillum* @ 4 ml kg^{-1} seed + PSB @ 4 ml kg^{-1}- seed + PPFM (1% FS)	35.5	399
T_{13} : T_1+ $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 1 kg ha^{-1}	36.3	533
T_{14} : Control (No fertilizer)	34.3	303
S.Em.±	0.24	17.8
C.D. (p = 0.05)	0.69	51.9

Table 3. Economicanalysis of mustard as influenced by integrated nutrient management practices

Treatment	Gross return (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
T_1 : 100 % RDF + FYM @ 5 t ha^{-1}	61575	28702	32873	2.15
T_2 : 100 % RDF + vermicompost @ 3 t ha^{-1}	62760	36402	26358	1.72
T_3 : T_1+ *Azospirillum* @ 4 ml kg-$^{-1}$ seed+ PSB @ 4 ml kg-$^{-1}$ seed	67140	29220	37920	2.30
T_4 : T_1+ *Azospirillum* @ 4 ml kg-$^{-1}$ seed+ PSB @ 4 ml kg-$^{-1}$ seed + PPFM (1% FS)	70350	29480	40870	2.39
T_5 : 75 % RDF + FYM @ 5 t ha^{-1}	53145	27136	26009	1.96
T_6 : 75 % RDF + vermicompost @ 3 tonnes per hectare	54690	34636	20054	1.58
T_7 : T_5+*Azospirillum* @ 4 ml kg-$^{-1}$ seed + PSB @ 4 ml kg-$^{-1}$ seed	59850	27768	32082	2.16
T_8 : T_5+ *Azospirillum* @ 4 ml kg-$^{-1}$ seed + PSB @ 4 ml kg-$^{-1}$ seed + PPFM (1% FS)	61440	28028	33412	2.19
T_9 : 50 % RDF + FYM @ 5 t ha^{-1}	45444	24863	20581	1.83
T_{10}: 50 % RDF + vermicompost @ 3 t ha^{-1}	46140	32363	13777	1.43
T_{11}: T_9 + *Azospirillum* @ 4 ml kg-$^{-1}$ seed+ PSB @ 4 ml kg-$^{-1}$ seed	47775	25585	22190	1.87
T_{12}: T_9 + *Azospirillum* @ 4 ml kg-$^{-1}$ seed + PSB @ 4 ml kg^{-1}- seed + PPFM (1% FS)	50490	25759	24731	1.96
T_{13}: T_1+ $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 1 kg ha^{-1}	65955	30388	35567	2.17
T_{14}: Control (No fertilizer)	39683	21980	17703	1.81
S.Em.±	2282	-	2282	0.08
C.D. (p = 0.05)	6633	-	6632	0.22

respectively), 100 % RDF + vermicompost @ 3 tonnes per hectare (₹ 62760 and 26358 per hectare, respectively) and 100 % RDF + FYM @ 5 tonnes per hectare (₹ 61575 and 32873 per hectare, respectively). Net returns were lower in 50 % RDF + vermicompost @ 3 tonnes per hectare (₹ 46140 and 13777 per hectare) than control (₹ 39683 and 17703 per hectare). Though the profit was more with application of different rates of organic and inorganic nutrients with biofertilizers compared to control (₹ 17703 per hectareand 1.84), the maximum profit and economically viable could be attained by 100 % RDF + FYM @ 5 tonnes per hectare+ *Azospirillum* @ 4 ml per kilogram seed + PSB @ 4 ml per kilogram seed (₹ 37920 per hectare), as this treatment recorded 77 % higher yield of seed was also recorded as compared to control (882 kilogram per hectare) (Table 3). The higher yield of seed and prevailing market price (₹ 45 per kilogram seed) were the reason for getting higher returns.

Conclusion

Based on the results it was concluded that application of 100 % RDF + FYM @ 5 tonnes per hectare *Azospirillum* @ 4 ml per kilogram seed + PSB @ 4 ml per kilogram seed + PPFM @ 1 % produced 77.21 % higher yield, which was followed by the application of 100 % + FYM @ 5 tonnes per hectare+ *Azospirillum* @ 4 ml per kilogram seed + PSB @ 4 ml per kilogram seed and 100 % RDF + FYM @ 5 tonnes per hectare + $ZnSO_4$ @ 20 kilogram per hectare + Borax @ 1 kilogram per hectare, respectively over control in Northern Dry Zone of Karnataka.

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