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Assessment of nutrient and bio-fertilizers for productivity enhancement of Indian mustard (*Brassica juncea* L.)

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Abstract
A field experiment was conducted during *rabi* season of 2020-21 at Agricultural Research Farm TCA, Dholi (Muzaffarpur), a campus of Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur), Bihar, (India). The treatments comprised three fertility levels (F_1-100% RDF, F_2-75% RDF and F_3-Control) in main plots and five microbial consortia (M_1-Phosphate solubilizing organism, M_2-Azotobacter, M_3-Potassium mobilizing bio-fertilizer, M_4-Zinc solubilizing bio-fertilizer and M_5-PSMO + Azotobacter + KMB + ZSB in sub plots. The treatments were replicated thrice in split plot design. Collected soil of experimental site was exhibited sandy loam texture having calcareous alkaline nature (pH 8.24), $CaCO_3$ (25%) low in organic carbon and available N, P_2O_5, K_2O and Zn. The Indian mustard variety 'Rajendra Sufalam' was sown at a distance of 30 cm x 10 cm with seed rate of 5 kg ha^{-1} with RDF (80:40:40 $N:P_2O_5:K_2O$ kg ha^{-1}). The different fertility levels, F_1-100% RDF was significant superior over other fertility levels in term of growth attributes (height of plant, number of branches, dry matter accumulation and relative growth rate), yield attributes and yield as well as higher NPK uptake in grain and straw, availability of N and P in soil were analysed and recorded negative balance while K showed positive balance. Among the microbial consortia, M_4- Zinc solubilizing biofertilizer (ZSB) resulted significantly superior impact over other microbial consortia in respect of growth factors (plant height, number of branches, dry matter accumulation and relative growth rate), yield attributes and yield as well as higher NPK uptake in grain and straw. F_1-100% RDF was recorded higher net return (₹ 53918 ha^{-1}) and B:C ratio (1.26) than others. In terms of economics of mustard M_4- Zinc solubilizing biofertilizer (ZSB) fetched higher net return (₹ 54253 ha^{-1}) and B:C ratio (1.39) as compared to other treatments.

Keywords: Brassica, nutrient, biofertilizers, RDF, economics, Bihar

Introduction
India is the world's largest rapeseed-mustard grower, ranking first in terms of area and second in terms of production volume after China. Rapeseed-mustard is the third important oilseed crop in the world after soybean and palm oil. In India, it accounts for 27% of the total oilseeds production.

Biofertilizers are helpful in soil nutrient transformation in available form, provides better rhizosphere condition and produce plant hormone. They boost many microbial activities in the soil, allowing plants to absorb nutrients more quickly. Bio-fertilizers provide benefits such as improved mineral and water absorption, root and vegetative growth, solubilization of insoluble forms to soluble forms, and nitrogen fixation. Phosphate solubilising bacteria are used as bio-fertilizers is vital for preserving soil nutrient status and structure, and it opens up new opportunities for higher crop production and yields (Ingle and Padole, 2017) [1]. Azotobacter is an effective bio-fertiliser because it provides N without over-dosing situations such as ammonia, nitrate, and amino acids, which are inorganic nitrogen additions (Bhattacherjee and Dey, 2014) [2]. The potassium mobilising bio-fertilizer releases several of the enzymes that convert the immobilising form of potassium to the mobilising form. KSB may be able to provide a different technology for making K available for plant absorption. The solubilization of K minerals will aid in the preservation of current resources and the reduction of pollution issues connected with substantial K-fertilizer use (Archana *et al.*, 2013) [3]. The Bacillus genus has the ability to solubilize Zn from its insoluble form by the excretion of a few organic acids, and these are well-known as zinc solubilizing bio-fertilizers. The use of zinc-solubilizing microbial inoculants with plant growth stimulating properties influences crop output (Kloepper *et al.*, 2004) [4].

Method and Materials

The carried-out experiment was conducted at Agricultural Research Farm TCA, Dholi (Muzaffarpur). During the experiment, the weekly mean highest and lowest temp. around 34.3 ^{O}C to 15.6 ^{O}C & 7.2 ^{O}C to 22.2 ^{O}C together, highest relative humidity in a week varies between 82 to 96 percent, while weekly lowest relative humidity ranged between 42 to 83 percent. There was no rainfall during the experimental period. That research had conducted under split plot design (SPD) and the treatments were replicated thrice.

As per the recommendation, viable seed @ 5 kg/ha were used for sowing and sown at 30 cm row to row spacing and Plant to plant distance of 10 cm was adjusted through thinning. Mustard has been cultivated under irrigated condition & water was applied at pre-flowering stage for obtaining optimum yield. The recommended dose of NPK for mustard crop is 80-40-40 kg $N:P_2O_5:K_2O$ ha^{-1} was applied as per treatment *viz.* 100% RDF (F_1), 75% RDF (F_2) and control (F_3) and five microbial consortia *viz.* M_1- Phosphate Solubilizing Organism (PSMO), M_2-Azotobacter, M_3-Potassium Mobilizing Biofertilizer (KMB), M_4- Zinc Solubilizing Biofertilizer (ZSB) and M_5- PSMO + Azotobacter + KMB + ZSB. NPK applied through urea, diammonium phosphate (DAP) and muriate of potash (MOP). The dose of 50 per cent N and complete rate of P & K had been used in basal amount during the seeding time. Rest 50 per cent N has been top dressed at the time of first irrigation. The crop was not infected by any serious disease but to combat the damage caused by the most serious pest of mustard (aphids), Dimethoate (30 EC) was sprayed @ 1000 ml ha^{-1} in 800 litre of water once during early pod formation stage. Various growth, yield attributing and yield parameters were taken at different stages of crop growth to analyse the crop growth and development.

The usual Variance of analysis (ANOVA) technique has been adopted for analyzing experimental statistically. Method of analysis enunciated by Fisher's (1938) had been used to determine of magnitude & nature of treatment by 'F' test shows the suitable impacts.

Results

Growth attributing characters

Table 1: Dry matter accumulation as influenced by fertility levels and microbial treatments

Treatments	Dry matter accumulation g plant^{-1}			
	30 DAS	60 DAS	90 DAS	At harvest
Fertility Levels				
F_1- 100% RDF	0.48	4.80	19.53	29.24
F_2- 75% RDF	0.47	4.42	18.42	28.16
F_3- Control	0.35	3.26	15.25	21.47
S.Em ±	0.03	0.10	0.28	0.94
CD(P=0.05)	NS	0.40	1.11	3.71
Microbial Consortia				
M_1- Phosphate Solubilizing Organism (PSMO)	0.39	2.95	15.10	21.82
M_2- Azotobacter	0.43	3.79	16.26	23.00
M_3- Potassium Mobilizing Biofertilizer (KMB)	0.43	4.15	17.35	25.69
M_4- Zinc Solubilizing Biofertilizer (ZSB)	0.48	5.08	20.36	31.79
M_5- PSMO + Azotobacter + KMB + ZSB	0.45	4.83	19.60	29.14
S.Em ±	0.02	0.09	0.29	1.03
CD(P=0.05)	NS	0.26	0.84	3.01
Interaction (F x M)	NS	NS	NS	NS

Significantly higher dry matter production achieved in the 100% RDF (4.8, 19.53 and 29.24 g plant^{-1}) and was at par with 75% RDF (4.42, 18.42 and 28.16 g plant^{-1}) over control plot (no fertilization) at 60DAS, 90DAS and at harvest, respectively (Table 1). Dry matter accumulation directly responsible for the photosynthetic activity. Higher the dry matter accumulation has larger surface area which synthesize more photosynthates. Among the microbial consortia, ZSB treated plot gave significantly higher DMA per plant than PSMO, Azotobacter and KMB but found to be at par with PSMO + Azotobacter + KMB + ZSB at 60 DAS, 90 DAS and at harvest. As zinc was not applied during cultivation practice but ZSB made available to the crop from the soil.

Table 2: Plant height as Influenced by different fertility levels and microbial treatments

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
Fertility Levels				
F_1- 100% RDF	13.92	80.145	171.57	173.60
F_2- 75% RDF	13.64	78.752	169.86	171.80
F_3- Control	13.29	72.402	163.35	164.95
S.Em ±	0.20	1.337	1.23	1.19
CD(P=0.05)	NS	5.249	4.82	4.66
Microbial Consortia				
M_1- Phosphate Solubilizing Organism (PSMO)	13.20	74.604	170.17	172.12
M_2- Azotobacter	13.55	77.537	169.41	171.33
M_3- Potassium Mobilizing Biofertilizer (KMB)	13.44	72.999	167.36	169.17
M_4- Zinc Solubilizing Biofertilizer (ZSB)	14.11	80.865	171.47	173.50
M_5- PSMO + Azotobacter + KMB + ZSB	13.79	79.493	162.89	164.46

S.Em ±	0.21	2.165	2.49	2.51
CD(P=0.05)	NS	NS	NS	NS
Interaction (F x M)	NS	NS	NS	NS

Fertility levels did not exert any impact on plant height at 30 DAS (Table 2). But at 60, 90 DAS and harvest the F_1-100% RDF was receiving substantially maximum accumulation of plant height (80.145, 171.57 and 173.60 cm, respectively) and was comparable to F_2-75% RDF (78.752, 169.86, 171.80 cm). However, the control (F_3) plot was recorded lower plant height (72.40, 163.35 and 164.95 cm, respectively) than the other treatments. Under microbial consortia, there was no significant effect on plant height at any stage of crop growth. Among the microbial consortia, M_4- Zinc solubilizing bio-fertilizer recorded considerably maximum plant height at 60 DAS (80.87 cm), 90 DAS (171.47 cm) and harvest stage (173.5 cm). The interaction of fertility levels and microbial consortia had no any significant effect on plant height of Indian mustard.

Table 3: Number of branches and days to 50% flowering as Influenced by different fertility levels and microbial treatments

Treatments	**No. of branches**				**Days to 50% flowering**
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**	
Fertility Levels					
F_1- 100% RDF	2.75	4.13	5.93	7.09	63.77
F_2- 75% RDF	2.63	4.91	5.72	6.79	60.98
F_3- Control	1.15	2.73	3.60	4.15	43.69
S.Em ±	0.05	0.08	0.12	0.14	1.50
CD(P=0.05)	0.19	0.33	0.49	0.54	5.88
Microbial Consortia					
M_1- Phosphate Solubilizing Organism (PSMO)	2.12	3.80	4.70	5.22	50.91
M_2- Azotobacter	2.06	3.55	4.97	5.85	52.17
M_3- Potassium Mobilizing Biofertilizer (KMB)	2.09	3.67	4.56	5.43	54.46
M_4- Zinc Solubilizing Biofertilizer (ZSB)	2.38	4.54	5.84	7.09	64.05
M_5- PSMO + Azotobacter + KMB + ZSB	2.23	4.04	5.36	6.47	59.14
S.Em ±	0.04	0.07	0.10	0.12	1.25
CD(P=0.05)	0.10	0.20	0.28	0.36	3.65
Interaction (F x M)	NS	NS	NS	NS	NS

Days to 50% flowering exerted non-significant effect due to various fertility level and combination of microbial consortia. In the fertility levels, F_1-100 RDF treatment took least number of days to 50% flowering (63.77 day), while lower number of days to 50% flowering was taken by F_3- Control (43.69 day). Among the microbial consortia, M_1- PSMO recorded the least number of days to 50% flowering (50.91 day), while maximum number of days to 50% flowering were receiving under M_2-Zinc solubilizing biofertilizers (64.05 day).

In the various levels of fertility, at 30, 90 DAS and harvest stage, the F_1-100% RDF registered substantially higher number of branches/plant (2.75, 5.93 & 7.09 respectively), whereas, F_3- Control resulted lower number of branches plant^{-1} (1.15, 3.6 and 4.15, respectively) than the other treatments. Among the microbial consortia treatments, the (M_4) ZSB depicted significantly maximum number of branches/plants at30 DAS (2.38), 60 DAS (4.54), 90 DAS (5.84) and at harvest (7.09). However, M_2- Phosphate solubilizing organism recorded significantly a smaller number of branches plant^{-1} at harvest than the other treatments. However, interaction effect between fertility levels and microbial consortia was found to be non-significant in case of number of branches and day to 50% flowering.

Yield attributing characters and yield

Table 4: Yield attributing characters as Influenced by different fertility levels and microbial treatments

Treatments	**No. of siliqua plant^{-1}**	**Length of siliqua (cm)**	**No. of seed siliqua^{-1}**	**1000-seed weight (g)**
Fertility Levels				
F_1- 100% RDF	196	4.32	11.8	5.92
F_2- 75% RDF	184	4.13	11.2	5.26
F_3- Control	113	3.19	8.1	4.35
S.Em ±	3.3	0.10	0.3	0.13
CD(P=0.05)	12.9	0.41	1.3	0.53
Microbial Consortia				
M_1- Phosphate Solubilizing Organism (PSMO)	147	3.51	9.2	4.70
M_2- Azotobacter	160	3.59	9.5	4.80
M_3- Potassium Mobilizing Biofertilizer (KMB)	162	3.76	10	5.02
M_4- Zinc Solubilizing Biofertilizer (ZSB)	180	4.44	12.1	5.91
M_5- PSMO + Azotobacter + KMB + ZSB	173	4.09	11.1	5.45
S.Em ±	6.7	0.09	0.28	0.12
CD(P=0.05)	19.5	0.26	0.81	0.34
Interaction (F x M)	NS	NS	NS	NS

Treatment 100 per cent RDF (F_1) produced significantly higher number of siliqua/plant (195.97), length of siliqua (4.32 cm), number of grains siliqua^{-1} (11.8) and 1000 seed weight (5.29 g) and these were at par with 75% RDF while significantly lower all yield attributing characters were achieved by control plot. Among the of microbial consortia, comparatively a greater number of siliqua/plant (180), length of siliqua (4.44 cm), grains siliqua^{-1} (12.1) and 1000 seed weight (5.91) registered in M_4- Zinc solubilizing bio-fertilizer. whereas, a significantly smaller no. of siliqua/plant were recorded in M_1- Phosphate solubilizing organism (PSMO) (147). Interaction effect was noticed non-significant for the yield attributing characters.

Table 5: Yield (grain, straw and biological) and harvest index as Influenced by different fertility levels and microbial treatments

Treatments	Yield (Kg^{-1})			Harvest Index (%)
	Seed	Straw	Biological	
Fertility Levels				
F_1- 100% RDF	1899	6297	8196	23.2
F_2- 75% RDF	1807	6185	7991	22.6
F_3- Control	1435	5356	6791	21.1
S.Em ±	24	92	81	0.45
CD(P=0.05)	93	360	318	NS
Microbial Consortia				
M_1- Phosphate Solubilizing Organism (PSMO)	1590.1	5798	7388	21.4
M_2- Azotobacter	1707.9	5980	7688	22.2
M_3- Potassium Mobilizing Biofertilizer (KMB)	1614.5	5833	7447	21.6
M_4- Zinc Solubilizing Biofertilizer (ZSB)	1858.5	6128	7986	23.3
M_5- PSMO + Azotobacter + KMB + ZSB	1797.7	5990	7788	23.1
S.Em ±	27	110	109	0.48
CD(P=0.05)	79	NS	318	1.39
Interaction (F x M)	NS	NS	NS	NS

Among the fertility levels, F_1-100% RDF registered substantially higher grain, straw and biological yield (1899, 6297 & 8196 kg ha^{-1}) respectively, over F_3- Control. About 32.3% and 25.9% higher grain yield was achieved under F_1 and F_2 treatment over control. Similarly, 17.5% and 15.5% higher straw yield obtained in 100% RDF and 75% RDF than control. Among the microbial consortia, ZSB had significantly higher grain and total biological yield over other treatments and at par with PSMO + Azotobacter + KMB + ZSB. Treatment ZSB and PSMO + Azotobacter + KMB + ZSB yielded higher grain to the tune of 16.8% and 13% than PSMO while, 13% and 11% higher than KMB respectively. However, straw yield was non-significantly affected by various microbial consortia. Harvest index was non-significant due to various fertility levels while under microbial consortia, ZSB (23.26%) gave significantly higher straw yield than PSMO and KMB.

Economics: In the fertility levels, the treatment F_1-100% RDF recorded substantially higher gross return and net return (₹ 96639 ha^{-1}& ₹ 53918 ha^{-1}) respectively, over F_3- control and it was at par with 75% RDF (Table 6). Gross return net return was achieved higher by the F_1 was to the tune of 30% and 44% and from F_2 treatment, it was 40% and 35% respectively and both were significantly superior than control treatment. Among the microbial consortia, ZSB had significantly higher gross return (15%) and net return (30%) over PSMO and at par return with PSMO + Azotobacter + KMB + ZSB. B:C ratio was significantly higher for 100% RDF (1.26) and at par with 75% RDF while, among microbial consortia, ZSB (1.35) and PSMO + Azotobacter + KMB + ZSB (1.24) had at par return on investment and significantly higher than other treatments. Interaction effect was non-significant for gross and net return while return on investment was significantly affected.

Table 6: Economics as Influenced by different fertility levels and microbial treatments

Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C Ratio
Fertility Levels				
F_1- 100% RDF	42721	96639	53918	1.26
F_2- 75% RDF	41595	92313	50719	1.22
F_3- Control	36769	74221	37452	1.02
S.Em ±		962	962	0.02
CD(P=0.05)		3777	3777	0.10
Microbial Consortia				
M_1- Phosphate Solubilizing Organism (PSMO)	40242	81958	41716	1.03
M_2- Azotobacter	40242	87533	47291	1.17
M_3- Potassium Mobilizing Biofertilizer (KMB)	40242	83108	42867	1.05
M_4- Zinc Solubilizing Biofertilizer (ZSB)	40242	94494	54253	1.35
M_5- PSMO + Azotobacter + KMB + ZSB	40842	91528	50686	1.24
S.Em ±		1176	1176	0.03
CD(P=0.05)		3432	3432	0.09
Interaction (F x M)		NS	NS	S

Discussion

Higher value of growth characters had been obtained from 100% RDF treatment plots which was significantly superior than Control. Because 100% RDF served as adequate amount of nutrients to the plants that contributed to the vegetative growth of plants and subsequently enhanced plant growth attributing characters like plant height, number of branches, dry matter accumulation by cell elongation, cell division, photosynthesis and turgidity of the plant cells. Higher nutrient availability helped for vigorous crop growth improvements because it contains all important plant nutrients, it stimulated quick vegetal development & branching, ultimately enhance the diameter of the sink flowering, fruiting & seeds setting ultimately resulting in higher source to sink conversion. Thereby, higher growth resulting in higher yield attributes therefore result in higher yield and return on investment. This observation is also corroborated by Dhruw *et al*. (2017), Kumar *et al*. (2017) and Singh *et al.* (2010) [8, 9, 7].

Microbial consortia like Azotobacter non-symbiotic nitrogen fixation, PSB help for solubilize insoluble P to soluble form, potassium mobilizing bacteria mobilized immobile potassium to mobile form and zinc solubilizing bacteria solubilized insoluble zinc to soluble form which help for increased in length of siliqua may be beneficial response of these treatments on tissue development and cell division which enhanced the reproductive growth of plants. It is established fact that PSB, azotobacter, KMB and ZSB that provide adequate nutrients in a favourable environment may have enhanced the growth of new tissues and shoots. improved metabolite partitioning and appropriate nutrient distribution to growing plant structures. Another factor might be that enhanced microbial activity helps to give more plants nutrient & also improving considering natural soil nutrient abundance helped crop to achieve higher yield thereby return on investment. These findings agreed with the result of Meena *et al.* (2018) and Kalita *et al.* (2019) [5, 6].

Conclusion

Based on one year of experimentation, the fertility level 100% RDF (80:40:40 $N:P_2O_5:K_2O$ kg ha^{-1}) registered significantly maximum values of growth, grain yield and economics than the Control. Significantly superior value of growth, grain yield was also obtained from Zinc solubilizing bio-fertilizer treatment except PSMO + Azotobacter + KMB + ZSB which were at par among themself. Hence 80:40:40 $N:P_2O_5:K_2O$ kg ha^{-1} with ZSB or may be applied for higher production of Indian mustard.

Future Scope

Long term and multi-location trail need be conducted to know potential benefits of these newly developed microbial consortia for the crop productivity as well as soil health.

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Conflict of Interest: Nil

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