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Effect of integrated nutrient management on growth, productivity, quality and nutrient uptake of irrigated yellow sarson (*Brassica campestris* L var. yellow sarson) in older alluvial soil of West Bengal

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Abstract: A field experiment was conducted during *rabi* (winter) seasons of 2007-08 and 2008-09 to study the effect of integrated nutrient management on growth, yield, oil content and nutrient uptake of yellow sarson (*Brassica campestris* L var. *yellow sarson*) in older alluvial soil of West Bengal. Significantly higher leaf area index (1.75 at 40 days after sowing; DAS), dry matter accumulation (1366.9 g/m^2 at 80 DAS) and highest number of siliquae/plant (118.3), number of seeds/siliqua (21.8), seed yield (1.90 t/ha), stover yield (3.86 t/ha) were recorded significantly (at 5% level) higher with poultry manure (PM) @2.5t/ha +50%RDF (Recommended Dose of Fertilizer *i.e.* 80-40-40 of N-P_2O_5-K_2O kg/ha) + PSB (phosphate solubilising bacteria) + AZ (*Azotobacter*) during both the years and on pooled basis. An average of 30.5% and 233% increase in seed yield by this treatment was recorded over sole application of RDF and control respectively. Integrated application of PM (2.5 t/ha) + 50% RDF + PSB + AZ recorded highest oil content (43.16%) and positive effect on soil fertility status. The highest benefit: cost ratios (2.26 and 2.4 in 2007-'08 and 2008-'09 respectively) were achieved from the use of 50% RDF + PM (2.5 t/ha) +PSB+AZ.

Keywords: Biofertilizer, Nutrient balance, Poultry manure, Vermicompost ,Yellow sarson

INTRODUCTION

Oilseed crops have been the backbone of agricultural economy of India. Amongst different oilseed crops raised in West Bengal, rapeseed-mustard occupies the largest area and contributes around 75% to the edible oil basket of the state. Yellow sarson accounts for 90% coverage in this rape- mustard group in West Bengal, is a winter oilseed crop having high yield potential and relatively high oil content compared to other forms of rapeseed. Although several factors interfere expression of yield potential is restricted mainly due to improper and imbalanced nutrient supply to the crop. Use of chemical fertilizers has increased considerably to meet the higher nutrient requirements of the present day improved varieties. This creates imbalance in nutrient supply leading to decline in soil fertility, crop productivity and sustainability (John *et al.,* 2004). Use of organic matter to meet the nutrient requirement of crops would be an inevitable practice in years to come, particularly for resource poor farmers. However, supplying entire dose of plant nutrients through good quality manures (*e.g.* poultry manure, vermicompost, goat manure, farm yard manure *etc.*) are not feasible because their requirement will be several time higher than that of chemical fertilizers because manures content lower amount of plant nutrients. These sources can reduce the mining of soil nutrient and improve soil organic matter, humus and overall soil productivity (Jenssen, 1993). Organic constituents in the humic substances also act as plant growth stimulants (Jenssen, 1993; Palm *et al.,* 1993). A judicious use of organic manures and biofertilizers may be effective not only in sustaining crop productivity and in soil health, but also in supplementing chemical fertilizers of the crops. Balanced application of nutrient enriched organic manures, chemical fertilizers (both water soluble spray and soil applied chemical fertilizers), biofertilizers in an integrated way would be a viable option to improve crop productivity, soil fertility and for cost effectiveness (Sahai, 2005). Keeping these aspects of oilseed production we have conducted an experiment on integrated nutrient management in yellow sarson in farmer's field to investigate the crop performance and improvement of soil fertility status through diverse nutrient management practices.

MATERIALS AND METHODS

A field experiment was conducted during winter season of 2007-'08 and 2008-'09 at farmer's field (block-Pingla) in Paschim Medinipur District of West Bengal (22°14`N latitude and 87$^\circ$33`E longitude at an altitude of about 14.11 m above mean sea level). During the crop growing period maximum and minimum tempera-

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tures were 36.0 ^{0}C and 7.4 ^{0}C respectively. The total rainfall received during crop growing season in the first year was 4.31 mm. The Soil in the experimental area was medium deep loam, low in organic carbon (0.39%) with mild acidic soil reaction (pH-5.31). The available soil nitrogen (N), phosphorus (P) and potassium (K) were 214.8, 20.4 and 220.12 kg/ha respectively. The total N, P and K content in poultry manure were 2.7%, 2.05% and 2.1% respectively. In vermicompost, total N, P and K were 1.45%, 1.92% and 0.6% respectively. Two- third (2/3 rd) dose of nitrogen and potassium, full recommended dose of phosphorus were applied uniformly in each plot as basal. Remaining 1/3rd dose of nitrogen and potassium were applied at 30 days after sowing (DAS). Organic manures (poultry manure or vermicompost) were pre- inoculated with biofertilizer (phosphate solubilizing bacteria and azotobacter, @ 6 kg/ha each) few days before application and were kept under shed to build up microbial population. Full dose of pre-inoculated poultry manure and vermicompost (5 or 2.5 t/ha) were applied right at the time of final land preparation, two days before sowing in plots of respective treatments.

Foliar grade of chemical fertilizer, NPK: 20-20-20 @0.625% (*i.e.,* 6.25g/lit) and cattle urine (@ 5%) were sprayed well over the crop canopy once at 50% flowering with the help of knapsack sprayer in respective treatments. The sowing of winter (*i.e*., *rabi*) crop yellow sarson, cultivar 'Benoy' (B-9) was done by line sowing method with the help of seed drill. Spacing between two adjacent rows was 30 cm and plant to plant spacing in a row was kept at 10 cm apart. Thus plant population was maintained at the rate of 333333 plants / hectare. Sowing of seeds was done by 25th November during both the year (2007-08 and 2008-09) of experimentation. The preceding crop (*kharif* season) was rice during both the year.

The experiment comprising of fourteen different treatments of Integrated Nutrient supply viz. T_1:Absolute Control (No NPK); T_2:100% RDF{RDF: Recommended dose of fertilizers ($N:P_2O_5:K_2O$=80:40:40 kg/ ha)};T_3: 100% RDF + Zn (zinc foliar spray); T_4:VC (*i.e*.,vermicompost) (5t/ha) + PSB (*i.e*.,phosphate solubilising bacteria) + AZ (*Azotobacter*); T_5: PM (*i.e*.,poultry manure) (5t/ha) + PSB + AZ; T_6: 50% RDF + VC (2.5 t/ha); T_7:50% RDF + PM (2.5 t/ha); T_8: 50% RDF + VC (2.5 t/ha) + PSB +AZ; T_9: 50% RDF + PM (2.5 t/ha) + PSB + AZ; T_{10}:50% RDF + VC (2.5 t/ha) + 1 Foliar Spray of NPK-20-20-20 (@0.625%); T_{11}:50% RDF + PM (2.5 t/ha) + 1 Foliar Spray of NPK-20-20-20(@0.625%); T_{12}: 50% RDF + VC (2.5 t/ha) + 1 Foliar Spray of Cow Urine (5%); T_{13}:25% RDF + VC (2.5 t/ha) + 1 Foliar Spray of NPK -20-20-20 (@0.625%) + PSB + AZ; T_{14}: 25% RDF + PM (2.5 t/ha) + 1 Foliar Spray of NPK-20-20-20 (@0.625%) + PSB +AZ , were laid out in a randomized block design with three replications on older alluvial soil of medium land under irrigated condition. The gross plot size was 5 m x 3 m. The seed yield was calculated on the basis of net plot (4.5 m x 2.5 m) harvested. Observations like growth attributese.g. plant height (cm), leaf area index (LAI), dry weight / m^2, crop growth rate (CGR, g/m^2/day) were taken at 20, 40, 60, 80 day after sowing (DAS) and at harvest. For this purpose, five randomly selected plants from a row of each plot were uprooted, cleaned and observations were recorded and averaged. Plant height was measured by using a meter scale. Dry matter of plants were estimated by weighing above ground parts (all leaves, branches and stems *etc*.,) after being dried them in a hot air oven (at 65^{0}C to 70^{0}C) till the constant weight were obtained. Border rows were not considered for sampling. Yield attributes at the time of harvest were recorded to assess their contribution to yield. Total number of siliquae from five randomly selected plants from each plot were counted, averaged (total siliquae/5) and recorded as siliquae/ plant. The 1000 seeds were counted from the lot of respective treatments, weighed and expressed as 1000 seed weight. The seed and stover yields were computed from net plots (except border rows) and expressed in kg/ha. The economical parameters, like net monetary returns and benefit:cost ratio were worked out by using the prevailing market price of the inputs and produce in the locality. The oil content was estimated by Pulse Nuclear Magnetic Resonance (NMR) technique (Tiwari and Burk, 1980).

Soil samples were analysed as per procedure described by Jackson (1973). Soil organic carbon and the available N were evaluated by the Wakely and Black (1963) method and the micro-Kjeldahl digestion method (Bremmer and Mulvaney, 1982) Available P in soil was extracted by the method of Bray and Kurtz (1945), while available K content was extracted with neutral 1M NH4OAc at a soil solution ratio of 1:10 and measured by flame photometry.Plant sample analysis for nitrogen content was estimated by wet digestion with concentrated sulphuric acid and distillation process (Jackson, 1973), Plant phosphorus and potassium content was estimated by Tri-acid ($HNO_3:HClO_4:H_2SO_4$) digestion process followed by spectrophotometric analysis with vanadomolybdate reagent (Jackson, 1973). Nutrient balance in the soil was worked out on the basis of initial and final values of N, P and K respectively. The statistical analysis of data was performed using Microsoft Excel and MSTAT-C softwares following the procedure of Gomez and Gomez (1984). Statistical significance between mean differences among treatments for various parameters was analyzed using critical differences (CD) at 0.05 probability level. As the error variance of the two year experiment were found to be homogenous (through Bartlett's test) so the results were pooled.

Table 1. Effect of integrated nutrient supply on growth attributes of yellow sarson (data pooled of two years,2007-08 and 2008-09).

Treatments	Plant Height (cm) (at harvest)	Leaf area Index (at 40 DAS)	Dry weight (g/ m^2) (at80 DAS)	Crop growth rate (g/m^2/day) (40-60DAS)
T1	36.53	0.61	811.07	17.76
T2	106.98	1.26	1287.28	25.12
T3	106.66	1.29	1265.67	25.22
T4	93.96	0.91	1284.68	26.56
T5	94.95	0.95	1285.6	26.45
T6	107.69	1.28	1306.92	26.72
T7	108.01	1.28	1334.31	27.33
T8	112.39	1.75	1352.45	27.69
T9	113.6	1.75	1366.92	27.84
T10	108.79	1.27	1305.47	26.53
T11	112.33	1.32	1342.51	27.26
T12	108.84	1.3	1299.07	26.45
T13	108.9	1.27	1318.78	27.01
T14	111.88	1.3	1332.93	27.31
CD (P=0.05)	0.55	0.03	39.64	0.41

T_1: Control; T_2: 100% RDF; T3:100% RDF + Zn; T_4: VC (5t/ha) + PSB + AZ; T_5 : PM (5t/ha) + PSB + AZ; T_6 : 50% RDF + VC (2.5 t/ha); T_7 : 50% RDF + PM (2.5 t/ha); T_8 : 50% RDF + VC (2.5 t/ha) + PSB +AZ; T_9 : 50% RDF + PM (2.5 t/ha) + PSB + AZ; T_{10} : 50% RDF + VC (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%); T_{11} : 50% RDF + PM (2.5 t/ha) + 1 F.S. of NPK-20-20-20(@0.625%); T_{12} : 50% RDF + VC (2.5 t/ha) + 1 F.S. of Cow Urine (5%); T_{13} : 25% RDF + VC (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%) + PSB + AZ; T_{14} :25% RDF + PM (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%) + PSB + AZ. (DAS= Days After Sowing).[g/m^2 = gram per square meter; DAS= Days After Sowing]

Table 2. Effect of integrated nutrient supply on yield components, seed yield, stover yield and seed oil content of yellow sarson {data pooled of two years, (2007-08 and 2008-09) at harvest}.

Treatments	No.of branches/ plant	No.of Siliquae/ plant	No.of seeds/ siliqua	1000-seed weight (g)	seed yield (t/ha)	Stover yield (t/ha)	Seed oil content (%)
T1	5.16	49.51	16.27	1.53	0.57	1.05	35.67
T2	10.55	92.4	20.59	2.11	1.32	2.68	40.59
T3	11.04	94.45	20.21	2.16	1.35	2.78	40.28
T4	9.95	81.55	19.58	2.09	1.04	1.79	39.32
T5	10.24	86.67	19.49	2.15	1.12	1.97	39.27
T6	11.45	94.78	20.69	2.26	1.48	2.65	40.55
T7	12.09	105.9	20.94	2.15	1.6	2.93	41.75
T8	12.83	111.23	21.68	2.17	1.72	3.15	42.67
T9	13.89	118.31	21.81	2.29	1.9	3.86	43.16
T10	11.97	104.19	20.05	2.32	1.46	2.64	43.08
T11	12.16	112.19	20.82	2.25	1.69	2.92	42.88
T12	11.13	94.75	20.56	2.22	1.43	2.45	40.95
T13	11.39	101.07	20.83	2.19	1.52	2.79	40.24
T14	11.9	107.35	20.82	2.23	1.63	3.07	41.06
CD (P=0.05)	0.36	1.62	0.67	0.15	0.04	0.08	0.67

T_1: Control; T_2: 100% RDF; T3:100% RDF + Zn; T_4: VC (5t/ha) + PSB + AZ; T_5 : PM (5t/ha) + PSB + AZ; T_6 : 50% RDF + VC (2.5 t/ha); T_7 : 50% RDF + PM (2.5 t/ha); T_8 : 50% RDF + VC (2.5 t/ha) + PSB +AZ; T_9 : 50% RDF + PM (2.5 t/ha) + PSB + AZ; T_{10} : 50% RDF + VC (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%); T_{11} : 50% RDF + PM (2.5 t/ha) + 1 F.S. of NPK-20-20-20(@0.625%); T_{12} : 50% RDF + VC (2.5 t/ha) + 1 F.S. of Cow Urine (5%); T_{13} : 25% RDF + VC (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%) + PSB + AZ; T_{14} :25% RDF + PM (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%) + PSB + AZ.

RESULTS AND DISCUSSION

Growth attributes: The growth parameters like plant height (cm), leaf area index, dry matter production, crop growth rate (g/m^2/day) were affected significantly by different combinations of organic and chemical plant nutrient sources on pooled basis (Table 1). The tallest plants were observed by application of 50% RDF + PM (2.5t/ha) + PSB + AZ followed by 50% RDF + VC (2.5t/ha) + PSB + AZ which was at par with 25% RDF + PM (2.5t/ha) + PSB +AZ + F.S of NPK 20-20-20 @ 0.625%. The LAI increased significantly with combined application of poultry manure or vermicompost and 50% reduced dose of RDF along with biofertilizer and / or foliar application of NPK. The dry weights of different treatments of yellow sar-

Table 3. Effect of integrated nutrient management on soil nitrogen balance after second year harvest of yellow sarson.

Treatment	Initial available soil N+added N To soil (kg/ha),	Total N uptake, at harvest by crop (kg/ha),	Expected balance (kg/ha)	Actual balance (kg/ha)	Net gain or loss (kg/ha)
T1	168.0	34.45	133.5	184.9	51.36
T2	248.0	146.38	101.6	237.5	135.9
T3	248.0	165.88	82.12	228.5	146.4
T4	240.5	105.46	135.0	264.8	129.8
T5	303.0	114.76	188.2	266.7	78.46
T6	244.3	168.95	75.30	289.6	214.3
T7	275.5	192.94	82.56	301.0	218.4
T8	244.3	223.22	21.03	303.0	282.0
T9	275.5	252.5	23.00	298.0	275.0
T10	244.3	169.32	74.93	265.1	190.2
T11	275.5	189.06	86.44	291.8	205.4
T12	244.3	148.7	95.55	260.2	164.7
T13	224.3	180.97	43.28	305.5	262.2
T14	255.5	201.48	54.02	296	242

Initial value: {available soil N, (second year)} = 168 kg/ha
T_1: Control; T_2: 100% RDF; T3:100% RDF + Zn; T_4: VC (5t/ha) + PSB + AZ; T_5 : PM (5t/ha) + PSB + AZ; T_6 : 50% RDF + VC (2.5 t/ha); T_7 : 50% RDF + PM (2.5 t/ha); T_8 : 50% RDF + VC (2.5 t/ha) + PSB +AZ; T_9 : 50% RDF + PM (2.5 t/ha) + PSB + AZ; T_{10} : 50% RDF + VC (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%); T_{11} : 50% RDF + PM (2.5 t/ha) + 1 F.S. of NPK-20-20-20(@0.625%); T_{12} : 50% RDF + VC (2.5 t/ha) + 1 F.S. of Cow Urine (5%); T_{13} : 25% RDF + VC (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%) + PSB + AZ; T_{14} :25% RDF + PM (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%) + PSB + AZ.

Table 4. Effect of integrated nutrient management on soil phosphorus balance after second year harvest of yellow sarson.

Treatment	Initial available Soil P_2O_5 + added P to soil (kg/ha)	Total P_2O_5 uptake, at harvest by crop (kg/ha)	Expected balance (kg/ha)	Actual balance (kg/ha)	Net gain Or loss (kg/ha)
T1	14.8	6.7138	8.086	13.4	5.314
T2	54.8	31.714	23.09	18.9	-4.186
T3	54.8	33.645	21.15	20.5	-0.655
T4	110.8	25.481	85.32	27.5	-57.82
T5	117.3	28.235	89.07	28.6	-60.47
T6	82.8	36.458	46.34	29.9	-16.44
T7	86.05	42.731	43.32	44.9	1.581
T8	82.8	55.512	27.29	41.8	14.51
T9	86.05	52.875	33.18	47	13.83
T10	82.8	38.243	44.56	39.8	-4.757
T11	86.05	47.163	38.89	43.8	4.913
T12	82.8	35.836	46.96	38.9	-8.064
T13	72.8	44.291	28.51	45.8	17.29
T14	76.05	52.078	23.97	42.7	18.73

Initial value: {available soil P_2O_5, (second year)} = 14.8 kg/ha
T_1: Control; T_2: 100% RDF; T3:100% RDF + Zn; T_4: VC (5t/ha) + PSB + AZ; T_5 : PM (5t/ha) + PSB + AZ; T_6 : 50% RDF + VC (2.5 t/ha); T_7 : 50% RDF + PM (2.5 t/ha); T_8 : 50% RDF + VC (2.5 t/ha) + PSB +AZ; T_9 : 50% RDF + PM (2.5 t/ha) + PSB + AZ; T_{10} : 50% RDF + VC (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%); T_{11} : 50% RDF + PM (2.5 t/ha) + 1 F.S. of NPK-20-20-20(@0.625%); T_{12} : 50% RDF + VC (2.5 t/ha) + 1 F.S. of Cow Urine (5%); T_{13} : 25% RDF + VC (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%) + PSB + AZ; T_{14} :25% RDF + PM (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%) + PSB + AZ.

son crop differed significantly. Integration of different nutritional sources recorded higher dry weights than sole use of chemical fertilizer or sole organic manure (VC / PM) at later growth stages. Significantly higher total dry matter production was recorded at different growth stages of yellow sarson crop in T9 {AZ + PSB + PM (2.5t/ha) + 50% RDF} which was closely followed by T8 {AZ + PSB + VC (2.5t/ha) + 50% RDF} compared to others. Treatments clearly indicated the beneficial effects of *Azotobacter*, PSB in presence of poultry manure and vermicompost. Increased dry matter in these treatments might be due to positive role of the biofertilizer in presence of organic manures. Supply of the required nutrients through organic and inorganic sources and biofertilizer facilitated balanced nutrient of the crop, which resulted in enhanced dry

Table 5. Effect of integrated nutrient management on soil potassium balance after second year harvest of yellow sarson.

Treatment	Initial available soil K_2O + added K_2O to soil (kg/ha)	Total K_2O uptake, at harvest by crop (kg/ha)	Expected balance (kg/ha)	Actual Balance (kg/ha)	Net gain or loss (kg/ha)
T1	213	12.87	200	200	-0.14
T2	253	136.7	116	271	154.6
T3	253	145.7	107	267	159.8
T4	243	91.22	151	226	74.21
T5	318	104.3	213	231	17.49
T6	248	150.6	97.1	322	225.2
T7	285	171.5	114	325	211.4
T8	248	209.6	38.1	327	289.1
T9	285	283.7	1.46	340	338.9
T10	248	153.7	94	263	168.8
T11	285	177.4	108	276	168.4
T12	248	160	87.7	335	247.5
T13	238	166.9	70.8	265	193.7
T14	275	187.5	87.7	273	185

Initial value: {available soil K_2O, (second year)} = 201.01 kg/ha
T_1: Control; T_2: 100% RDF; T3:100% RDF + Zn; T_4: VC (5t/ha) + PSB + AZ; T_5 : PM (5t/ha) + PSB + AZ; T_6 : 50% RDF + VC (2.5 t/ha); T_7 : 50% RDF + PM (2.5 t/ha); T_8 : 50% RDF + VC (2.5 t/ha) + PSB +AZ; T_9 : 50% RDF + PM (2.5 t/ha) + PSB + AZ; T_{10} : 50% RDF + VC (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%); T_{11} : 50% RDF + PM (2.5 t/ha) + 1 F.S. of NPK-20-20-20(@0.625%); T_{12} : 50% RDF + VC (2.5 t/ha) + 1 F.S. of Cow Urine (5%); T_{13} : 25% RDF + VC (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%) + PSB + AZ; T_{14} :25% RDF + PM (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%) + PSB + AZ.

Table 6. Economics of integrated nutrient supply of yellow sarson (two years).

Treatments	Gross return (Rs/ha)		Net return (Rs/ha)		Benefit:Cost ratio	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
T1	25600	22440	10738.3	7572.8	0.72	0.5
T2	54800	55880	37505.3	38576.85	2.16	2.22
T3	56000	57200	37794.5	38986.05	2.07	2.13
T4	43200	44440	8088.3	9319.85	0.22	0.26
T5	46400	47520	16288.3	17399.85	0.53	0.57
T6	61200	62920	34871.8	36583.35	1.32	1.38
T7	66000	68200	42171.8	44363.35	1.76	1.86
T8	70800	73480	44421.8	47093.35	1.68	1.78
T9	78000	81400	54121.8	57513.35	2.26	2.4
T10	61600	61160	34921.8	34473.35	1.3	1.28
T11	70800	71280	46621.8	47093.35	1.92	1.94
T12	60400	59840	33856.8	33288.35	1.27	1.24
T13	62800	64680	36655.05	38526.6	1.4	1.46
T14	67200	69520	43555.05	45866.6	1.83	1.93

T_1: Control; T_2: 100% RDF; T3:100% RDF + Zn; T_4: VC (5t/ha) + PSB + AZ; T_5 : PM (5t/ha) + PSB + AZ; T_6 : 50% RDF + VC (2.5 t/ha); T_7 : 50% RDF + PM (2.5 t/ha); T_8 : 50% RDF + VC (2.5 t/ha) + PSB +AZ; T_9 : 50% RDF + PM (2.5 t/ha) + PSB + AZ; T_{10} : 50% RDF + VC (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%); T_{11} : 50% RDF + PM (2.5 t/ha) + 1 F.S. of NPK-20-20-20(@0.625%); T_{12} : 50% RDF + VC (2.5 t/ha) + 1 F.S. of Cow Urine (5%); T_{13} : 25% RDF + VC (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%) + PSB + AZ; T_{14} :25% RDF + PM (2.5 t/ha) + 1 F.S. of NPK-20-20-20 (@0.625%) + PSB + AZ.

matter production in this crop. Similarly, Maheshbabu *et al*., (2008) reported the combine use of farm yard manure (FYM) and NPK enhanced growths parameters (like; plant height, LAI etc.) in soybean. Patra *et al*., (2013) also reported that biofertilizers helped in increasing plant height and leaf chlorophyll content of sunflower.

Yield components: The results on yield components of rapeseed var yellow sarson (Table 2) revealed that application of different treatments of INM exerted profound influence on important yield contributing characters like number of branches per plant, number of siliquae per plant , number of seeds per siliqua and 1000-seed weight (g). Highest number of branches per plant (13.89), number of siliquae/plant (118.3), seeds/ siliqua (21.81) and second highest seed test weight (2.29 g) were recorded in 50% RDF + PM (2.5 t/ha) + PSB + AZ. Positive role of poultry manure in improving yield components of yellow sarson might be due to mineralization of major and minor plant nutrients at slow pace thus increased their availability throughout the growing period of the crop. Behera (2006) also reported similar effects of poultry manure on wheat crop. The second highest yield attributes were observed in 50% RDF + VC (2.5 t/ha) + PSB + AZ treated plots. Mookherjee *et al*. (2014) also found improvement of yield components and seed yield of yellow sarson by integrated use of vermicompost and chemical fertilizers. Application of PM (2.5 t/ha) / VC (2.5 t/ha) + biofertilizers (PSB + *Azotobacter*) along with 50% RDF pronouncedly improved number of branches per plant in yellow sarson. Improvement in yield attributes might be due to possible role of *Azotobacter* through atmospheric nitrogen fixation, better root proliferation, uptake of nutrients and water. Similarly Gudadhe *et al*. (2005) agreed beneficial role of biofertilizer in improving yield components of Indian mustard. .

Seed yield, stover yield and Seed oil content: Seed yield of yellow sarson was markedly influenced as a result of application of plant nutrients from different compatible sources through integrated nutrient management schedule (Table 2). The application of 50% RDF+PM (2.5t/ha) +PSB+AZ produced significantly (at 5% level) and appreciably higher seed yield (1.9 t/ha) over others as well as control indicating that poultry manure mineralized rapidly and provided optimum nutrients to the crop from beginning to end of the crop growth. Poultry manure contains significant amount of nitrogen in both inorganic and organic forms were readily available for plant uptake (Kara *et al.,* 2006). The enhancement of growth and yield by poultry manure along with chemical fertilizers and bio-fertilizers could be due to release of phosphorus and different essential plant nutrients (Djokoto and Stephen, 1961) which enhanced high photosynthetic activities leading to vigorous vegetative and reproductive growth (John *et al*., 2004). Higher stover yield (3.86 t/ha) was also recorded in 50% RDF + PM (2.5 t/ha) + PSB + AZ treatment.Application of 50% RDF + PM (2.5 t/ha) + PSB + AZ established its superiority in improving the plant growth, leaf-area index, dry matter production as compared to others. This might be attributed to more photosynthesizing leaf area and also conjectured to its promising macro-and -micro-nutrients contents, their early release solublized the applied and native P (Roy, 1986) and increased absorption (Reddy and Reddy, 1998) which in turn resulted in higher stover yield.

Significantly higher oil content (43.16%) was observed with the application of 50% RDF+ PM (2.5 t/ha)+ PSB+ AZ. Higher oil content in seeds of yellow sarson under 50% RDF + PM (2.5 t/ha) + PSB + AZ might be due to certain P-containing enzymes in fatty acid synthesis in seeds. The impact of the treatment which added more phosphorus might play a role in enhancing the glucoside content in seed which upon hydrolysis and esterification resulted in higher oil content in seed (Krishnamurthy and Mathan, 1996; Aulakh and Pasaricha, 1988). The essential elements like secondary and micronutrient contained in poultry manure (PM) probably promoted the synthesis of oils. Oil content decreased appreciably with the increasing level of 100% RDF. The oil content decreased with increasing fertility level could be due to increasing availability of N which increases the proportion of protein substances in seed and hence oil content was low (Padma *et al.,* 2001).

Nutrient uptake, balance of yellow sarson production: The trend of nutrient uptake by rapeseed varied significantly and appreciably due to different treatments (Tables3-5). The NPK uptake differed significantly due to different treatments. Restricting the application of chemical fertilizers up to 50% of the recommended dose with integration of poultry manure and supplementary inoculation of AZ and PSB resulted in general higher uptake of N, P and K. This might be attributed to release of phosphorous from insoluble phosphate and fixation of atmospheric nitrogen by *Azotobacter* in soils. Microorganisms with higher phosphate solubilizing potential increase the availability of soluble phosphate and enhance the plant growth and yield due to better root growth and increases uptake of nutrients (Ponmurugan and Gopi, 2006) which in turn, resulted in physiological changes of the plants on exposure to action of the inoculated microorganisms. In addition, humic acid and micronutrients of poultry manure /vermicompost had greater influence in stimulating roots and regulating metabolism, speeding up the developmental process of plant which, in turn, resulted in better NPK content in yellow sarson plants. Roots also interact extensively with soil microorganism, which further impact plant nutrition either directly by influencing nutrient availability and uptake or indirectly through plant (root) growth promotion. Thus observations are in agreement with those of Singh and Yadav (2008). Integration of organic manure and AZ+PSB with 50% RDF upon decomposition might have improved nutrient availability in soil and thus benefited the crop.

Highest total uptake of N, P and K was observed with 50% RDF + PM (2.5 t/ha) + PSB + AZ than sole application of recommended chemical fertilizer indicating the benefits from the integrated use of fertilizers, manures and bio-inoculants which was also reflected in yield. Higher uptake at 50% RDF + PM (2.5 t/ha) + AZ and inoculation with PSB might be due to more nutrients from soil. Similar results were reported by Prasad *et al.*(2005). The crop was also benefited by some plant growth promoting substances (*viz.,* IAA and gibberellins) released by PSB and *Azotobacter* and enrich soil nutrients in available form (Bais *et al*., 2006 ; Bareae *et al*., 1976 and Bisht *et al*., 2009) which lead to higher nutrients uptake. The lowest uptake of N, P and K was in treatments where N, P and K were omitted (control treatment).

The maximum positive balance of N and P was recorded with 25% RDF + VC (2.5 t/ha) + 1 F.S. of NPK-20-

20-20 (@0.625%) + PSB + AZ. While highest K balance was observed in 50% RDF + PM (2.5 t/ha) + PSB + AZ treated plots. Foliar NPK fertilizer increases the availability of plant nutrient to crop and PSB and *Azotobacter* improved the supply of phosphorus (P) and nitrogen (N) to roots, thus maintaining the N and P balance in soil.

Economics: In this experiment, the benefit: cost ratio was worked out for different levels of NPK fertilizers, organic manures and biofertilizers (Table - 6). The cost of nutrient treatments was marginally higher with the application of PM/VC (2.5t/ha) + 50%RDF + *Azotobacter* + PSB compared to RDF. The net monetary returns and benefit: cost ratio was appreciably higher with 50% RDF integrated with poultry manure (PM @ 2.5t/ha), *Azotobacter* and PSB. The superiority of the treatment clearly indicated that the reduced level of chemical fertilizers in conjunction with organic manure and bio-inoculants is a good proposition from economical point of view. This can be attributed to lower input and application cost of biofertilizer and comparatively higher benefit in yield. The fertilizer applied to yellow sarson recorded the highest benefit: cost ratio with 50% RDF in conjunction with PM (2.5t/ha), *Azotobacter* and PSB. This can be attributed to the lower input cost due to reduced level of 50% RDF and poultry manure but higher seed yield than that of 100% RDF. Singh and Agarwal, (2004) and Mookherjee *et al*. (2014) also reported use of organic manure (like, farm yard manure) in combination with biofertilizers and reduced dose of chemical fertilizers found to increase net return in yellow sarson and wheat respectively .

Conclusion

The above experiment concluded that application of 50% RDF (RDF, N: P_2O_5 :K_2O=80:40:40 kg/ha) along with PM (2.5 t/ha) and biofertilizers(PSB + AZ) have resulted remarkably higher plant height (113.6 cm.), C.G.R(27.84 g/m^2/day between 40-60 DAS), siliquae/plant (118.31), seeds/siliqua (21.81), seed yield (1.9 t/ha) and seed oil content (43.16%) of yellow sarson over other treatments. This treatment has yielded higher soil nutrient balance (298 kgN/ha, 47 kg P_2O_5/ha and 340 kg K_2O/ha) over 100% RDF. Therefor, this combination of nutrient sources can be better nutrient management option of yellow sarson in older alluvial soil of West Bengal.

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