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Impact of integrated nutrient management on production and economics under pearlmillet-mustard cropping sequence in Inceptisol

Vinay Arya, SK Trivedi, PS Tomar, SK Verma and Muneshwar Singh

Abstract
Use of inadequate and unbalanced fertilizers accompanied by prohibited use of organic manures have made the soils not only deficient in the nutrients, but also deteriorated the soil health resulting in poor crop response to the recommended dose of NPK fertilizers in the region. In order to make the soil enriched with all the essential plant nutrients and also to maintain it health, it is much necessary to use organic source like FYM, vermicompost in conjunction with fertilizers. Such manures (FYM, vermicompost) not only supply macronutrients but also meet the requirement of micronutrients. In view of emerging deficiencies in recent time integration of inorganic, organic and bio-fertilizer is essential for maintaining soil health and productivity. Keeping these points in view, the experiments were conducted during 2017-19 on pearlmillet-mustard with sixteen treatments in R. B.D. with three replications.
Results indicated that the subsequent increase in the levels of NPK from 50% to 150% resulted in enhancement of yield of pearlmillet and mustard suggesting that these crops need higher quantities of nutrients than recommended which is obvious as very high yields were achieved with 150% NPK. Devoid of P and K from fertilizer schedule adversely affected the yield of pearl millet. Supplementing each level of NPK with FYM produced beneficial effect on yield of both crops. Maximum grain yield and harvest index was observed with 100% NPK + FYM + Azo + PSB treatment followed by 100 % NPK + FYM and both were significantly higher to yield obtained with inorganic fertilizers applied treatments. Maximum net return (Rs. 69077.5/ha) was found in treatment 100% NPK + FYM + Azo + PSB closely followed by treatment 100% NPK + FYM treatment with Rs. 67606.8/ha while minimum net return (Rs. -1093/ha) was in control. Application of potassium and sulphur in adequate amount for stainable production under peralmillet-mustard cropping sequences and application of FYM is also recorded beneficial results in terms of economics because cost of FYM may be compensate by higher yield obtained with FYM treated plots.

Keywords: Economics, fertilizers, FYM pearlmillet-mustard, yield

Introduction
Nutrient management through fertilizers is an important key operation in crop production. But imbalance and indiscriminate or sole use of inorganic fertilizers has led to the adverse effect on soil health. Therefore, integrated nutrient management (INM) practices with the combined use of inorganic and organic sources of nutrients have long been advocated to farmers with a goal to enhance soil health and ecosystem services. Adopting the INM strategy is important to maintain and improve SOC.
Balanced and integrated use of fertilizer with farm yard manure significantly only improve soil organic carbon (SOC) contents but also improve overall soil quality which are developed by encompassing different physical, chemical and biological properties of soil. The treatments where inorganic fertilizers were applied in conjunction with organic sources recorded significantly higher organic carbon in soil (Satyajeet Nanwal and Kumar 2007) [9].
Pearlmillet-mustard is a crucial cropping system with pearlmillet as a Kharif and mustard as a Rabi crop in northern plains of India and fund to be, potential and sustainable cropping system (Parihar *et al*., 2009) [8].
Pearlmillet (*Pennisetum glaucum*) is that the fourth most vital cereal and widely grown in India due to its tolerance to drought and heat and suits to sil having low fertility. Pearlmillet grain is the staple diet in many parts of Indian and dwellers of several countries having low rainfall with dry land. It is good source of energy and vitamins, minerals plays a big role in nutrional security. It is rich in calcium, potassium, magnesium, iron, zinc, manganese, riboflavin, thiamine, niacin, lysine and tryptophan made a part of baby food. Pearlmillet

stover may be a valuable livestock feed the growing regions in India. At the present it's occupying 7.4 million ha area with a complete production of 9.13 million tonnes (Economic Survey, 2017-2018).

Indian mustard (*Brassica juncea* [L.] Czern. & Coss.) is that the second largest oilseed crop in India after soybean. It accounts for nearly 20-22% of the entire oil seed produced within the country. India have fourth rank in producing mustard seed contributing to around 11% of world's total production. Its diverse sorts of plants, which are grown as vegetables, spices, fodder for animal and sources of oils and condiments, and participate in our agriculture economy by occupying 6.41 million ha area and 6.33 million tonnes production (Economic Survey, 2017-2018). Thus in this study effect of different nutrient management options on yield of pearl millets and mustard and their economics in 28 years old experiments,

Material and methods

For this study soil samples from 28 years old experiment were drawn during 2018 to *rabi* 2019, is in progress since 1995 at the research farm of the Department of Soil Science and Agricultural Chemistry, College of Agriculture, R.V.S.K.V.V., Gwalior, situated in Grid zone at the latitude of 26^0 13'N and longitude 76^0 10'E with an altitude of 197 meters from mean sea level (MSL). The soil of the experimental field is alluvial, sandy clay loam in texture and classified as Typic Ustochrepts at sub group level. The soil samples were collected from various depths (0-15, 15-30, 30-60 and 60-100 cm) of soil profile with the help of screw and tube auger to study the impact of various fertility treatment on soil properties of profile of experimental site. The experiment was laid out with randomized block design with three replications comprising of 16 treatments. The treatment details are as follows.

S. No.	Treatments	Symbols used
1	Control	T_1
2	50 % NPK	T_2
3	75 % NPK	T_3
4	100 % NPK	T_4
5	150 % NPK	T_5
6	100 % NP	T_6
7	100 % N	T_7
8	100 % NPK-S	T_8
9	100 % NPK + 25 Kg ZnSO4/ha	T_9
10	100 % NPK + 50 Kg FeSO4/ha	T_{10}
11	100 % NPK + 1% FeSO4 spray at 25 and 45 DAS	T_{11}
12	100 % NPK + Azotobacter + PSB	T_{12}
13	50 % NPK + FYM	T_{13}
14	75 % NPK + FYM	T_{14}
15	100 % NPK + FYM	T_{15}
16	100 % NPK + FYM + Azotobacter + PSB	T_{16}

Cultural operations

Land preparation

Land was ploughed with tractor after the harvest of previous crop and harrowed twice to crush the clods and smoothened to get fine tilth.

Application of fertilizers

The recommended fertilizer dose for pearlmillet and mustard as per the treatments were applied (80:40:20 and 100:60:40 N, P_2O_5 and K_2O kg ha^{-1}, respectively) in the form of urea, single superphosphate and muriate of potash, 5 cm away from the seed line and 5 cm deep in the soil. In all, 50 per cent of nitrogen and entire dose of P_2O_5 and K_2O was applied at the time of sowing and remaining 50 per cent of nitrogen was top dressed in the form of urea for pearlmillet at 30 days after sowing and for mustard after first irrigation. In treatment 100 % NPK-S, P was added through DAP to make it S free treatment. As per treatment FYM was added @10 tonnes ha^{-1} yr^{-1} before sowing of *kharif* crop. The seeds were inoculated with *azotobactor* (AZO) and phosphate solubilising bacteria (PSB) both @10 g Kg^{-1} seed.

Seed rate and Sowing

The pearlmillet (Cv. JBV-3) and mustard (Cv. Pusa bold) @ 5 kg ha^{-1} were sown by driving about 3 cm deep in furrows. Chemical fertilizers were applied below the seed in furrows before sowing and seeds were covered with soil to level the opened furrows. Row to row distance in pearlmillet and mustard maintained was 45 cm and 30 cm, respectively. Plant to plant distance 10 cm was maintained under both crops.

After care

Optimum plant population was maintained by gap filling and thinning operations keeping healthy seedling under both crops. Hand weeding was carried out twice at 15 and 25 DAS (days after sowing) and one inter-cultivation operation was carried out at 40 DAS.

Irrigation

Sowing was taken up immediately after receiving seasonal rains (1^{st} week of July) in *kharif* (pearlmillet) and 1-2 irrigation provided as per the requirement of crop according to growth stages and depending on the rainfall. Mustard seeds were sown in last week of October to 1^{st} week of November at optimum soil moisture level and 1^{st} irrigation was provided in standing crop at 35 days and second irrigation at 75 days after sowing.

Harvesting, threshing and winnowing

The crop was harvested at maturity stage, when the foliage was shaded off and the cobs of pearlmillet and the pods of mustard turned yellowish brown to brown in colour. One border row from both sides and 30 cm from either ends of each plot were harvested in order to eliminate the border effect, thus leaving a net area of 4.4 × 2.4 m. The five tagged plants, for recording the post-harvest observations, were harvested separately from the net experimental plots. The next experimental plot was harvested by sickles and the harvested materials of each plot were tied in bundles. Bundles were kept for drying for 3-4 days, and then weighed to record biological yield per plot.

Threshing was done by manual labour separately with wooden sticks, followed by winnowing with the help of indigenous winnower *Supa* (Local name). Yield per plot was recorded after cleaning the seeds. Straw yield was calculated by subtracting grain yield from bundle weight (biological yield) of total produce.

Grain yield (t ha^{-1})

After shelling cobs of pearlmillet and the pods of mustard, the grain yield per net plot was recorded and the yield per hectare was calculated.

Stover yield (t ha^{-1})

The stover yield per net plot area was calculated by subtracting grain yield from biological yield of total produce.

Results and Discussion

Effect of integrated nutrient management on crop productivity

Grain and straw yield (t ha^{-1})

The grain yield of pearlmillet and seed yield of mustard was significantly affected by the various fertility treatments (fig: 5.7.1.a and 5.7.1.b). The integrated application of nutrient (100%NPK+FYM@10 t ha^{-1}yr^{-1}+*Azotobactor* +PSB and 100%NPK +FYM@10 t ha^{-1}yr^{-1}) to pearlmillet and mustard significantly enhanced the grain and straw yield over the control and chemical fertilizer sources (100%NPK-S and 100%NPK). In addition to major nutrients, availability of micronutrients as well as other benefits rendered by farmyard manure might have helped in improvement of yield. The results are in conformity with those with Nandapure *et al.* (2011) [6] and Patel *et al.* (2014) [7].

The imbalanced fertility treatments 100%N, 100%NP and sub-optimal dose fertility treatments (50%NPK and 75%NPK) increased grain and straw yield over control. Treatment receiving 100%NPK +*Azotobactor* +PSB showed increased yield (grain and straw) over treatment 100% NPK in pearlmillet and mustard. This increase in yields might be ascribed to additional advantages provided by organic and bio-fertilizers besides seed inoculation with *Azotobactor* and PSB having ability to produce growth substances and anti-fungal substances in addition to the contribution of atmospheric nitrogen made available to plant (Mishra *et al.*, 2008) [5].

Grain yield of pearl millet and seed yield of mustard presented in revealed that with the increase in nutrient dose from 50 to 150 per cent, concomitant increase in economic yields of both the crops was noted. Increase in amount of applied nutrients (NPK) from 50 to 150% resulted in an increase in C sequestration, which is ascribed to increase in total biomass or primary productivity of crops (Kundu *et al.* 2001, 2007) [2-3]. Data also indicated that continuous absence of N, P, K and S from fertilizer schedule resulted response of both the crops to these nutrients. Response of Zn is also visible. Incorporation of organic manure along with fertilizer further increased the crop productivity. Increase in yields in both the crops is obviously due to supply of nutrients. However increase in yields on conjunctive use of manure with fertilizer is due to supply of their nutrients like Zn Fe etc. Cakmak (2008) [1] reported that highest increase in grain yield with soil + foliar application of Zn. Application of organic manure over and above fertilizer ruled out hidden hunger of secondary and micronutrients. As evident from yield data that crops responded to applied Zn. A visible response of crop to biofertilizer is seen.

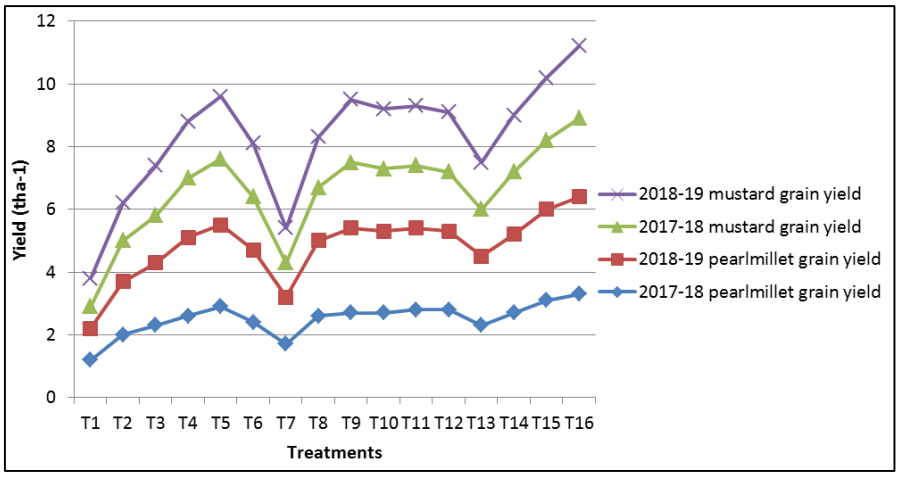

Fig 3.1.1: Effect of integrated nutrient management on grain yield of pearlmillet and mustard (t ha^{-1}) during study period (2017-19)

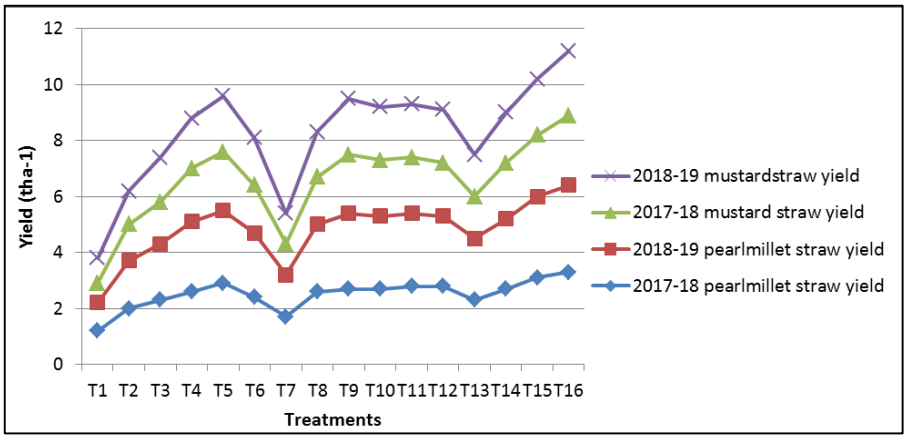

Fig 3.1.2: Effect of integrated nutrient management on straw yield of pearlmillet and mustard (t ha^{-1}) during study period (2010-12)

Table 3.3.1: Grain and straw yield (t ha^{-1}) of pearl millet and mustard (2017-2019) as affected by integrated nutrient management

	Grain Yield (t ha^{-1})						Straw Yield (t ha^{-1})					
	Pearlmillet			Mustard			Pearlmillet			Mustard		
Treatments/ year	**2017**	**2018**	**pooled**	**2018**	**2019**	**Pooled**	**2017**	**2018**	**pooled**	**2018**	**2019**	**Pooled**
T_1-CONTROL	1.2	1.0	1.1	0.7	0.9	0.8	3.8	3.1	3.5	2.3	3.0	2.6
T_2-50%NPK	2.0	1.7	1.8	1.3	1.2	1.3	5.9	5.0	5.5	3.7	3.8	3.7
T_3-75%NPK	2.3	2.0	2.1	1.5	1.6	1.5	6.5	5.5	6.0	4.6	4.2	4.4
T_4-100%NPK	2.6	2.5	2.6	1.9	1.8	1.9	7.1	7.0	7.1	4.9	4.5	4.7
T_5-150%NPK	2.9	2.6	2.7	2.1	2.0	2.0	7.4	7.2	7.3	5.5	4.8	5.1
T_6-100%NP	2.4	2.3	2.4	1.7	1.7	1.7	6.8	7.1	7.0	4.8	4.5	4.6
T_7-100%N	1.7	1.5	1.6	1.1	1.1	1.1	4.9	4.8	4.8	3.7	3.8	3.7
T_8-100%NPK-S	2.6	2.4	2.5	1.7	1.6	1.6	7.1	7.0	7.0	4.9	4.7	4.8
T_9-100%NPK+25 Kg/ha ZnSO4	2.7	2.7	2.7	2.1	2.0	2.1	7.2	7.0	7.1	5.3	4.8	5.0
T_{10}-100%NPK+50 Kg/ha FeSO4	2.7	2.6	2.6	2.0	1.9	2.0	7.0	7.1	7.0	5.3	4.7	5.0
T_{11}-100%NPK+1% spray at 25 and 45 DAS	2.8	2.6	2.7	2.0	1.9	2.0	7.5	7.2	7.3	5.2	4.7	5.0
T_{12}-100%NPK+AZO+PSB	2.8	2.5	2.6	1.9	1.9	1.9	7.2	7.2	7.2	5.0	4.7	4.8
T_{13}-50%NPK+FYM	2.3	2.2	2.3	1.5	1.5	1.5	5.7	6.1	5.9	4.4	3.5	3.9
T_{14}-75%NPK+FYM	2.7	2.5	2.6	2.0	1.8	1.9	7.0	6.7	6.8	5.3	4.3	4.8
T_{15}-100%NPK+FYM	3.1	2.9	3.0	2.2	2.0	2.1	7.8	7.5	7.6	5.4	4.8	5.1
T_{16}-100%NPK+FYM+AZO+PSB	3.3	3.1	3.2	2.5	2.3	2.2	7.9	7.7	7.8	5.5	4.9	5.2
SEm±	0.09	0.07	0.06	0.05	0.11	0.06	0.28	0.14	0.16	0.08	0.13	0.08
CD(P=0.05)	0.25	0.21	0.16	0.15	0.31	0.17	0.81	0.42	0.45	0.24	0.38	0.22

Note: AZO: Azotobactor, PSB phosphate solubilizing bacteria, FYM: farmyard manure

Economics

Cost of cultivation and net returns

The data (2017-2019) for cost of cultivation indicated that use of higher quantity of chemical fertilizers and FYM as per treatment increased the cost of cultivation for pearlmillet (₹ 26,697 ha^{-1}) under treatment T_{16} and for mustard (₹ 28,324.25 ha^{-1}) in T_5.The Net returns were higher for treatment 100%NPK+FYM @ 10 t ha^{-1}+*Azotobactor*+PSB for pearlmillet and mustard due to higher production over other fertility treatments.

Perusal of annual return data indicated that the year 2017-18 was given better return to 2018-19 for both the crops hence we can say that the year 2017-18 was much better to 2018-19 as far as returns are concerned.

B: C ratio and System productivity (Pearlmillet equivalent yield: PEY)

The higher value (2017-19) of B: C ratio for pearlmillet was recorded in T_{12} and T_{16} in mustard, as a result of lower cost of cultivation, while the treatments receiving FYM in combination with optimal dose of fertilizer having lower B: C ratio in pearlmillet (1.85 and 1.82) is because of higher quantity of organic manure as FYM used before sowing of *kharif* crop that raised cost of cultivation (Upadhyay *et al*., 2011) [10].

The productivity of system computed by summation of individual production units on annual basis known as the system productivity. As regards, the system productivity in terms of pearlmillet equivalent yield (PEY) and profitability played a vital role in determining the most productive and profitable treatment on a basis of overall return. The PEY value was far better in the year 2017-18 as compared to the year 2018-19 regardless of the treatments. The pooled analysis (2017-19) of different treatments revealed that treatment 100%NPK+FYM @10t ha^{-1}+*Azotobactor* +PSB (T_{16}) produced highest (2.8 t ha^{-1}) PEY which was higher than the other treatments and was followed by treatment 100%NPKS+FYM @10 t ha^{-1} yr^{-1} (2.6 t ha^{-1}), and 150%NPK (2.4 t ha^{-1}). The integrated nutrients application (T_{16}) to pearlmillet and mustard markedly increased the system productivity (2.8 t ha^{-1}) over control and other fertility treatments.

Table 3.2.1: Economics for pearlmillet - mustard cropping sequence (2017-2019) under different treatments

Treatments/ year	Cost of cultivation ₹ ha^{-1}						Net returns (ha^{-1})					
	Pearlmillet			Mustard			Pearlmillet			Mustard		
	2017-18	**2018-19**	**Pooled**	**2017-18**	**2018-19**	**Pooled**	**2017-18**	**2018-19**	**Pooled**	**2017-18**	**2018-19**	**Pooled**
T_1-CONTROL	19300.0	19300.0	19300.0	21150	21150	21150	1156.6	-3342.5	-1093.0	8668.6	13088.5	10878.6
T_2-50%NPK	20898.5	20898.5	20898.5	23547.75	23547.75	23547.75	11872.6	7259.7	9566.2	31560.3	30494.7	31027.5
T_3-75%NPK	21697.8	21697.8	21697.8	24746.63	24746.63	24746.63	15781.6	10585.9	13183.8	42065.3	42953.1	42509.2
T_4-100%NPK	22497.0	22497.0	22497.0	25945.5	25945.5	25945.5	20502.3	19360.4	19931.4	55086.5	54144.9	54615.7
T_5-150%NPK	24095.5	24095.5	24095.5	28343.25	28343.25	28343.25	22298.5	19003.9	20651.2	62243.3	59799.1	61021.2
T_6-100%NP	21969.0	21969.0	21969.0	24889.5	24889.5	24889.5	17651.8	16289.1	16970.5	48399.7	47758.2	48079.0
T_7-100%N	20344.0	20344.0	20344.0	22452	22452	22452	7610.5	4622.6	6116.6	25530.7	26465.1	25997.9
T_8-100%NPK-S	23393.8	23393.8	23393.8	27290.47	27290.47	27290.47	18648.1	17131.4	17889.8	46602.9	44465.2	45534.1
T_9-100%NPK+25 Kg/ha ZnSO4	23872.0	23872.0	23872.0	27320.5	27320.5	27320.5	20495.8	19210.5	19853.2	61663.4	60728.5	61196.0
T_{10}-100%NPK+50 Kg/ha FeSO4	23997.0	23997.0	23997.0	27445.5	27445.5	27445.5	19394.9	19168.7	19281.8	60663.7	58290.2	59477.0
T_{11}-100%NPK+1% spray@ 25 and 45 DAS	23847.0	23847.0	23847.0	27295.5	27295.5	27295.5	22145.0	19711.6	20928.3	59388.4	57321.5	58355.0
T_{12}-100%NPK+AZO+PSB	22697.0	22697.0	22697.0	26145.5	26145.5	26145.5	21952.8	21486.0	21719.4	57186.5	56107.5	56647.0
T_{13}-50%NPK+FYM	24898.5	24898.5	24898.5	23547.75	23547.75	23547.75	12796.7	11817.3	12307.0	42593.5	40948.0	41770.8

T_{14}-75%NPK+FYM	25697.8	25697.8	25697.8	24746.63	24746.63	24746.63	17687.2	15576.6	16631.9	60250.6	56995.1	58622.9
T_{15}-100%NPK+FYM	26497.0	26497.0	26497.0	24875	24875	24875	23029.3	20126.8	21578.1	68663.6	66550.0	67606.8
T_{16}-100%NPK+FYM+AZO+PSB	26697.0	26697.0	26697.0	25075	25075	25075	24021.2	21318.7	22670.0	69795.6	68359.3	69077.5

Note: AZO: *Azotobactor*, PSB phosphate solubilizing bacteria, FYM: farmyard manure

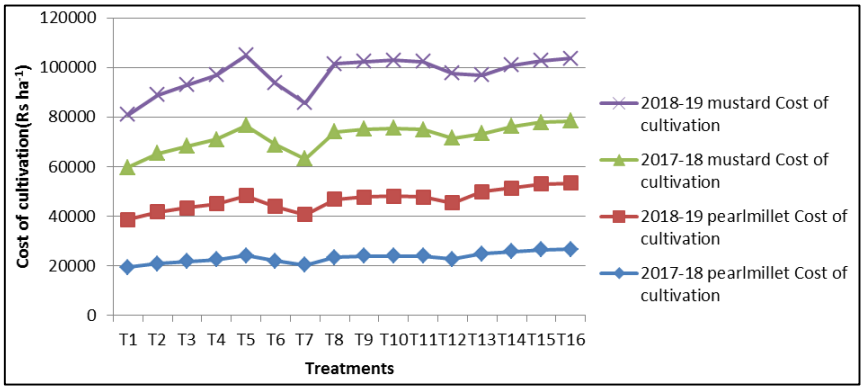

Fig 1.2.1: Cost of cultivation for pearlmillet - mustard cropping sequence (2017- 2019) under different treatments

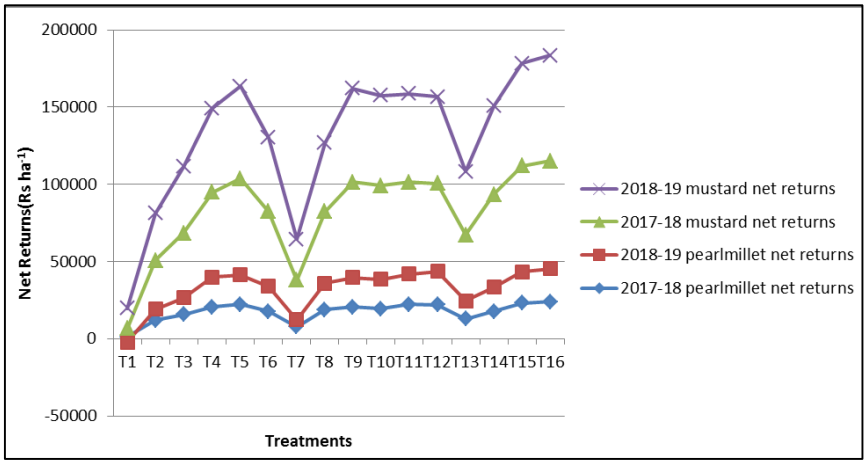

Fig 3.2.2: Net returns for pearlmillet - mustard cropping sequence (2017- 2019) under different treatments

Table 3.2.2: Economics for pearlmillet - mustard cropping sequence (2017-2019) under different treatments

	B:C ratio						**System Productivity**		
	Pearlmillet			**Mustard**			**Pearl millet equivalent yield (t ha^{-1})**		
Treatments/ year	**2017-18**	**2018-19**	**Pooled**	**2017-18**	**2018-19**	**Pooled**	**2017-18**	**2018-19**	**Pooled**
T_1-CONTROL	1.06	0.83	0.95	1.41	1.62	1.52	1.1	0.8	1.0
T_2-50%NPK	1.57	1.35	1.46	2.34	2.30	2.32	1.9	1.3	1.6
T_3-75%NPK	1.73	1.49	1.61	2.70	2.74	2.72	2.2	1.6	1.9
T_4-100%NPK	1.91	1.86	1.89	3.12	3.09	3.11	2.6	1.9	2.2
T_5-150%NPK	1.93	1.79	1.86	3.20	3.11	3.16	2.8	2.1	2.4
T_6-100%NP	1.80	1.74	1.77	2.94	2.92	2.93	2.4	1.7	2.0
T_7-100%N	1.37	1.23	1.30	2.14	2.18	2.16	1.6	1.1	1.4
T_8-100%NPK-S	1.80	1.73	1.77	2.71	2.63	2.67	2.5	1.7	2.1
T_9-100%NPK+25 Kg/ha ZnSO4	1.86	1.80	1.83	3.26	3.22	3.24	2.7	2.1	2.4
T_{10}-100%NPK+50 Kg/ha FeSO4	1.81	1.80	1.81	3.21	3.12	3.17	2.7	2.0	2.3
T_{11}-100%NPK+1% spray at 25 and 45 DAS	1.93	1.83	1.88	3.18	3.10	3.14	2.7	2.0	2.3
T_{12}-100%NPK+AZO+PSB	1.97	1.95	1.96	3.19	3.15	3.17	2.7	1.9	2.3
T_{13}-50%NPK+FYM	1.51	1.47	1.49	2.81	2.74	2.78	2.3	1.5	1.9
T_{14}-75%NPK+FYM	1.69	1.61	1.65	3.43	3.30	3.37	2.6	1.9	2.3
T_{15}-100%NPK+FYM	1.87	1.76	1.82	3.76	3.68	3.72	3.0	2.1	2.6
T_{16}-100%NPK+FYM+AZO+PSB	1.90	1.80	1.85	3.78	3.73	3.76	3.2	2.4	2.8

Note: AZO: *Azotobactor*, PSB phosphate solubilizing bacteria, FYM: farmyard manure

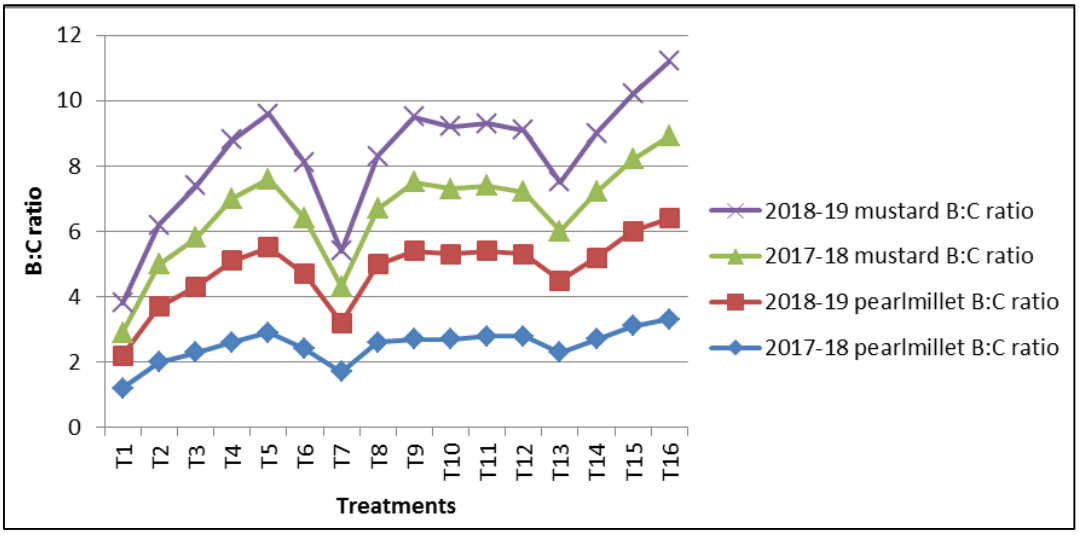

Fig 3.2.2: B:C ratio for pearlmillet - mustard cropping sequence (2017-2019) under different treatments

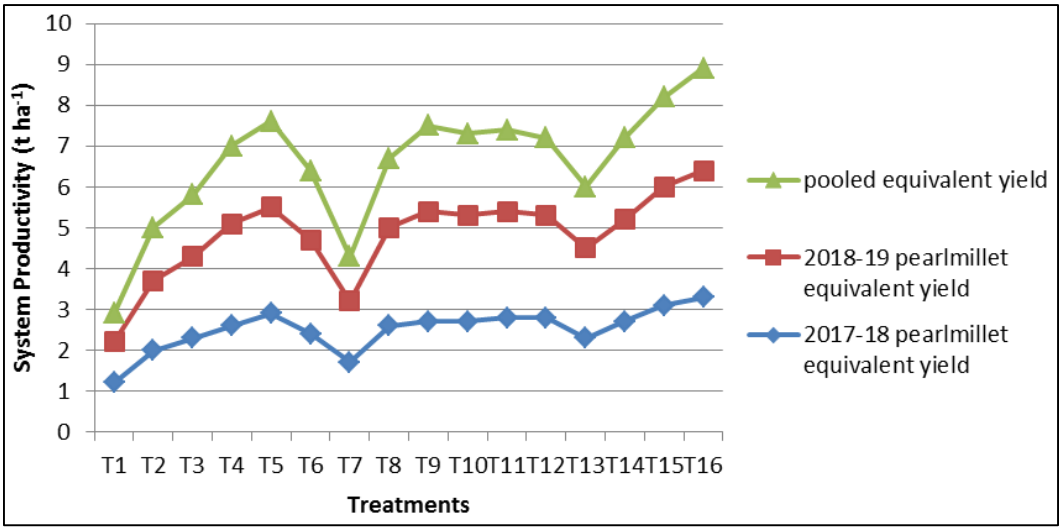

Fig 3.2.3: System Productivity (t ha^{-1}) for pearlmillet - mustard cropping sequence (2017-2019) under different treatments

Conclusion

The results indicated that, of all the treatments tested, balanced N–P–K fertilization along with an adequate amount of FYM in addition with Azotobactor and PSB as seed inoculants was a 'win–win' technology for sustainability of system, and increasing farm income.

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