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Impact of Different Nutrient Management Practices on Soil Physico-chemical Properties and Economics of Soybean in Kymore Plateau and Satpura Hills Agro-climatic Zone

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The field trial was conducted at Krishi Nagar Farm, Department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India, during the kharif season of 2021. The field experiment comprised six treatments and was conducted in a randomized block design (RBD) with four replications. Results showed a slight reduction in soil pH in treatments 100% Organic NM, 50% Organic NM + NF inputs BJG, 50% Organic + 50% Inorganic NM, and 25% Organic + NF inputs BJG + 25% Inorganic NM, while an increase was observed in T5 and T6 compared to the initial soil status. Changes in EC and OC under various treatments were not significant, but available N, P, and K levels varied significantly across treatments, showing increased values from the initial soil status. The treatment with 100% Organic NM had the highest cost of cultivation (Rs.31624), gross monetary return (Rs. 58605/ha), net monetary return (Rs. 26982/ha), and B:C ratio (1.85), followed by the treatment with 50% Organic NM + NF inputs.

Keywords: Soybean; natural farming; beejamrit; jeevamrit; ghanjeevamrit; organic; inorganic; nutrient management; pH; organic carbon; soil fertility.

1. INTRODUCTION

Soybean (*Glycine max L Merill*) is the most significant seed legume globally. Native to northeastern China and belonging to the family Fabaceae, soybean is extensively cultivated in India, particularly in Madhya Pradesh, due to its adaptability to various agro-climatic conditions and high market value. It boasts exceptional nutritive value, with a protein content of 42-43% and oil content of 18-20%, rich in essential fatty acids, vitamins (A and D), carbohydrates (30%), and fiber (4%). Popularly known as the golden bean, wonder crop, and man-made meat, soybean's global production for 2021-22, according to USDA, is estimated at 372.5 million tons from 120.50 million hectares. In India, soybean cultivation covers 11.34 million hectares, with an estimated production of 11.99 million tons in 2021-22. Madhya Pradesh leads with 5.51 million hectares and a production of 5.56 million tons. The integrated application of organic manure and inorganic fertilizers has emerged as an effective approach, enhancing both output and crop production stability. Blending chemical fertilizers with organic manures demonstrates potential in preserving soil fertility while sustaining crop productivity. Microbial activity in soil fertility and crop productivity is crucial, with Jeevamrit, available in solid form as "Ghanjeevamrit," aiding in bolstering microbial activity. The ongoing use of synthetic fertilizers has damaged soil quality and impacted soil microorganisms. Chemical fertilizers, though costlier and potentially harmful, can be supplemented with organic resources for optimal nutrient supply. Integrated nutrient management (INM) stands as a crucial element in sustainable agriculture, balancing resource management to meet evolving human needs without environmental degradation. This holistic approach involves organic manures, green manures, bio-fertilizers, crop rotation with legumes, and minimal chemical fertilizer usage to achieve optimal yields while preserving soil health [1]. Application of organic manure in conjunction with inorganic fertilizers in an integrated manner, proved to be the best alternative. Integrating chemical fertilizer with organic manures has been proven to be highly promising in terms of not only preserving higher output but also increasing crop production stability. When used with lower dosages of inorganic fertilizers, farmyard manure or vermicompost enhanced soil fertility, crop growth, and yield. Chemical fertilizers, on the other hand, have a negative impact on soil fertility leading to unsustainable yields, while integration of chemical fertilizers with organic manures and bio-fertilizers would be able to maintain soil fertility and sustain crop productivity [2]. The INM is made up of components, which possess great diversity in terms of chemical and physical properties, nutrient release efficiencies, positional availability, and crop specificity and farmers acceptability. Only organic manures cannot meet the total nutrient needs of modern agriculture, integrated use of nutrients from fertilizers and an organic resource seems to be a need of the time. The complementary use of chemical fertilizers and organic manures may increase the efficiency of chemical fertilizers in order to maintain a high level of crop productivity [3].

2. MATERIALS AND METHODS

A field experiment was conducted during *kharif* 2021. The field trial was conducted at Krishi Nagar Farm, Department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India, during the *kharif* season of 2021. The district Jabalpur is located in Madhya Pradesh, India, and is located between 23°18' N latitude and 79°98' E longitude, with an average altitude of approximately 411.78 meters (1387.73 ft) above mean sea level with a total area of 5198 km^2. According to the National Agricultural Research Program's criteria, Jabalpur is located in the "Kymore Plateau and Satpura Hills" agro-climatic zone. According to a new concept established by National Bureau of Soil Survey and Land Use Planning, Nagpur, this area is part of agro-ecological sub region No. 10.1, which is a sub-humid (dry) eco-region (Malwa plateau, Vindhyan Scarp Land and Narmada Valley). Temperatures range from a low of 5°C in December and January to a high of 46°C in May and June. in terms of maximum weekly temperature ranges from 26.8^{0}C to 37.7^{0}C and minimum weekly temperature ranges from 21.6^{0}C to 26.7^{0}C, maximum and minimum relative humidity during morning ranges from 74.0 to 94.6% and evening 31.7 to 85.1%, the crop was exposed to a total of 63.2 hours of sunlight throughout the crop growing season, with sunshine hours ranging from 0.2 to 8.2 hours and total seasonal rainfall of 652.4 mm with 45 wet days. As a result, it encouraged crop establishment, followed by crop growth, development, and yield. These conditions were also quite congenial at this stage. Entire weather conditions were almost favorable for proper growth, development and yield of crops. The current study, as previously stated, was a long-term investigation. As a result, data on the initial status of numerous soil physico-chemical properties were evaluated. Soil samples were collected from each plot at a depth of 0-15 cm before sowing. Soil analysis findings from various plots were recorded. The data on the original status of the soil and the values of its chemical properties are presented below: The Physico-chemical properties of experimental field were shown in Table 1. The soil in the experimental field had a Sandy Clay Loam texture, neutral in reaction (pH 7.20) with a medium OC content (0.59 percent), and EC (0.30 dS/m), and analyzed low in available nitrogen (216.50 kg/ha N), medium in available phosphorus (12.42 kg/ha P), and medium in available potassium (240.51 kg/ha K).

2.1 Experimental Techniques

The field experiment consisted with six treatments and they were tested in factorial experiment in a Randomized Block Design (RBD) with four replications. The details of the treatments are given in the Table 2.

2.2 Physico-chemical Properties

A composite soil samples were taken from 0-15 cm depth and kept in polythene bags for analysis of various soil chemical properties. The soil chemical properties were measured before sowing and after the harvest of crop.

2.3 Soil pH

To analysis the soil pH 10 g soil was taken in a clean 50 ml beaker and dissolved in 25 ml of distilled water. The suspension was stirred intermittent for 30 minutes. The pH was recorded using a digital pH meter having glass electrode pH meter [4].

2.4 Soil EC

For determination of EC, 10 g of soil was taken in 50 ml beaker, 25 ml of distilled water was added and the suspension was stirred intermittently for 30 minutes allowing the suspension to settle for about one hour to measure EC in the supernatant solution using EC meter [5].

Table 1. Physico-chemical properties of experimental location

Texture	**Sandy clay loam (Sand:54.5%, Silt:23.51%, and Clay:21.99%**
Soil reaction	7.20
Electrical conductivity (dS/m)	0.30
Soil organic carbon (%)	0.59
Available Nitrogen kg ha^{-1}	216.50
Available Phosphorus kg ha^{-1}	12.42
Available potassium kg ha^{-1}	240.51

Table 2. Treatments Details of Experiments

S. No	Treatments
T_1	100% Organic nutrient management
T_2	50% Organic NM +NF inputs Beejamrit+Jeevamrit+Ghanjeevamrit
T_3	50% Organic NM + 50% Inorganic NM
T_4	25% Organic +NF inputs Beejamrit+Jeevamrit+Ghanjeevamrit 25% Inorganic NM
T_5	Farmer practices
T_6	100% Inorganic nutrient management

Organic NM: Nutrient Management
NF: Natural Farming Inputs

Table 3. Methods used for determination the Physico-chemical properties of soil

Nutrient	Analytical method	Method employed	References
Nitrogen	Alkaline permanganate method	(Subbiah and Asija, 1956)	[6]
Phosphorus	Olsen"s method	(Olsen et al., 1954)	[7]
Potassium	Flame photometermethod	(Chapman and Pratt, 1961)	[4]
Soil pH 1:2.5 (soil water ratio)	Glass electric pH meter	(Piper,1967)	[5]
Electrical conductivity (dS /m)	Solu-bridge method	(Black,1965)	[8]
Organic Carbon (%)	Walkley and Black rapid titration method	(Walkey and Black,1934)	[9]

2.5 Organic Carbon Content of Soil

The organic carbon content in soil was determined by following modified [9] method. An air dried soil sample (0.5g) was placed at the bottom of a dry 500 ml conical flask, and 10 ml of 1 N $K_2Cr_2O_7$ was added with a volumetric pipette and swirled briefly. 20 ml of concentrated H_2SO_4 was then added and swirled 23 times and kept in the flask for 30 min. Then 200 ml of distilled water, 10 ml of H_2PO_4 and 10 ml of 2% sodium fluoride solution and 2 ml of diphenylamine indicator were added titrated the content with 0.5N Fe $(NH4)_2SO_4$ till the colour flashed from blue-violet to green. Organic carbon is calculated by using the following formula:

$$\text{Organic carbon (\%)} = \frac{10\ (B-T \times 0.003 \times 100)}{B \times weight\ of\ soil\ (g)}$$

Where,

B= Volume (ml) of Ferrous ammonium sulphate needed for blank.
T= Volume (ml) of Ferrous ammonium sulphate needed for soil sample.

2.6 Available Soil Nitrogen

The alkaline potassium permanganate method was used to determine available nitrogen in soil [6]. Twenty grams of soil were placed in a distillation flask, and 20 milliliter of water were added. The distillation flask was immediately fitted into the distillation apparatus after adding 100 ml of 0.32 percent $KMnO_4$ and 100 ml of 2.5 percent NaOH solution were added. The delivery tube of the distillation apparatus was then dipped in 25 ml of 4 percent boric acid containing mixed indicator adjusted to pH 4.5 in a conical flask. Distilled ammonia gas collected in boric acid from the distillation flask was back titrated with 0.02 N standards H_2SO_4. The following formula was used to calculate the available nitrogen:

$$\text{Available N (kg/ha)} = \frac{(T-B)\times N \times 0.0003 \times 10^6}{20} \times 2.24$$
$$= (T-B) \times 31.36$$

Where,

B= Volume (ml) of H_2SO_4 needed for blank.
T= Volume (ml) of H_2SO_4 needed for soil sample.
N= Normality of H_2SO_4.

2.7 Available Soil Phosphorus (P_2O_5)

The available phosphorus was extracted using sodium bi-carbonate (0.5 M $NaHCO_3$) adjusted to pH 8.5 according to the method [7]. In a 150 ml conical flask, a 2.5 g soil sample was collected. Fifty milliliters of sodium bicarbonate and one pinch of carbon black (activated charcoal) were mixed into the soil and thoroughly shaken for 30 minutes on a mechanical shaker. After that, the contents were filtered using Whatman No. 42 filter paper. In a 25 ml volumetric flask, 5.0 ml of filtered aliquot was taken. It is treated with 2 drops of p-nitro phenol indicator. Add drops of dilute acid to the yellowish solution to make it colourless. Four ml of reagent B is added to dilute the solution to the mark. The flask is sealed and homogenised by inverting it three or four times. When the blue colour is fully developed than transmittance or absorbance of the content at 730 nm can be measured using a spectrophotometer. The phosphorous concentration was calculated using a standard curve.

$$\text{Soil available Phosphorus (ka/ha)} = \frac{Q \times 2.24 \times 10^6}{A \times S \times 10^6} = \frac{Q \times V \times 2.24}{A \times S}$$

Where,

Q=quantity of P in micro-gram read on X-axis against a sample reading.
V=Volume of extracting reagent used (ml).
A=Volume of aliquot used for colour development (ml).
S= Weight of soil sample (g).

2.8 Available Soil Potassium (K_2O)

Available potassium was determined by neutral ammonium acetate method outlined by [4]. Five gram of soil was taken in 100 ml conical flask and then 25 ml of the neutral 1.0 N ammonium acetate solution was added and shaken for 5 minutes on mechanical shaker. Then the contents were filtered through Whatman No.1 paper. The concentration of K in the filtrate was measured by using flame photometer. The concentration of potassium was worked out with the help of standard curve.

$$\text{Soil available potassium (kg/ha)} = c \times \frac{25}{5} 2.24 = C \times 11.2$$

Where,

C= concentration (mg/L) of potassium in the soil sample filtrate obtained on X- axis, against the reading.

2.9 Economics of the Treatments

2.9.1 Cost of cultivation

The costs of cultivation for each treatment have been worked out on the basis of prevalent market price of different inputs used for raising the crop under different treatments for a hectare area.

2.9.2 Gross monetary returns (GMRs)

The values realized from the produce obtained under each treatment was computed on the basis of existing market price of the produce (both seed and haulm) and computed the gross monetary returns (GMRs) hectare under different treatments as per the following formula.

Gross monetary returns (Rs ha^{-1}) = Value of seed + Value of stover

2.9.3 Net monetary returns (NMRs)

The net monetary returns (NMR) per hectare under each treatment were determined by subtracting the cost of cultivation of a particular treatment from the GMR of the same treatment as per the following formula.

Net monetary returns (Rs ha^{-1}) = Gross monetary returns - Cost of cultivation

2.9.4 Benefit-cost ratio (B:C)

To estimate the benefits under different treatments for each rupee of expenditure incurred, B: C ratio of each treatment was calculated as below:-

$$\text{B: C ratio} = \frac{\text{Gross monetary returns (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

2.10 Statistical Analysis of Treatment

The standard procedure was used to tabulate and statistically evaluate the data related to each crop characteristic. Valid conclusions were reached by testing the relevance of treatments and the analysis of variance for randomized block designs. The 'F' test of significance was used to examine the differences in treatment means based on the null hypothesis. When the F-test variance ratios were deemed significant at the 5% level of significance, the resulting standard error of mean (SEm±) and crucial differences (CD) were computed and interpreted to provide a description of the findings [10].

The significant differences between different treatments were judged by using critical differences (C.D.) which was calculated as follows:

S. Ed. = SEm x √2 CD = SEd X t 5 % for error d.f

Table 4. Skeleton for analysis of variance (ANOVA)

Source of variance	d.f.	SS	MSS	'F' Value		
				Calculated	Tabulated	
					5%	1%
Replication	(r-1) = 3	RSS d.f.	RMSr	RMSe EMSe		
Treatment	(t-1) = 5	TSS d.f.	TMSt	TMSt EMSe		
Error	(r-1) (t-1) = 15	ESS d.f.	EMSe			
Total	(rt-1) = 23	Total SS				

Where,

S. Em= Standard error of treatment means
S.Ed= Standard error of difference between treatment means
C. D. = Critical difference
R =Number of replications
Edf = Error degree of freedom

3. RESULTS AND DISCUSSION

3.1 Impact of Different Nutrient Management Practices on Physico-Chemical Properties of Soil

Data pertaining to various soil chemical properties *viz*., pH, EC, OC and available N, P and K contents were determined before sowing and after harvest of crop under different treatments presented in Table 4 and depicted in Figs. 1 & 2 respectively. It is clear from the results that soil pH slightly reduced in T_1, T_2, T_3 and T_4 and increased in T_5 and T_6 as compared to initial status of soil. While in case of EC and OC of soil under different treatments did not found any remarkable changes but in case of available N, P and K of soil showed significant difference under different treatments with increased values from initial soil status indicated that the maximum pH was observed under 100% Inorganic NM (7.18) followed by Farmer practices (7.17), whereas lowest pH was recorded under the treatment of 100 % Organic NM (7.11). The available N, P and K was influenced statistically significantly by different treatments and maximum nitrogen was registered under treatment of 100% organic nutrient management (244 kg ha^{-1}), phosphorus (12.70 kg ha^{-1}) and potassium (270 kg ha^{-1}) followed by 50 % Organic NM +NF inputs BJG. Whereas lowest value of N, P and K was recorded under the treatments of Farmer Practice 227.75, 12.47 and 247 kg ha^{-1}, respectively. However, in case of EC and OC was not affected significantly by various treatments. It may be due to the significant increase in available N content of soil was due to increased mineralization of organic N by active microorganisms and the regular dynamics of biomass carbon. The higher soluble P in the organic systems is mainly attributed to the release of inorganic P from added organics, inhibition of P adsorption by organic molecules released from the organics. These results are in agreement with the findings [11-15].

Table 5. Impact of different nutrient management practices on physico-chemical properties of soil

Treatment No.	pH	EC (dS/m)	OC (%)	Available nutrients (kg/ha)		
				N	P	K
T_1 100 % Organic NM	7.11	0.32	0.63	244.00	12.70	267.00
T_2 50 % Organic NM +NF inputs BJG	7.12	0.31	0.62	238.75	12.53	260.50
T_3 50% Organic+50% Inorganic NM	7.12	0.29	0.61	238.50	12.50	256.75
T_4 25% Organic + NF inputs BJG +25% Inorganic NM	7.14	0.30	0.62	230.00	12.67	252.00
T_5 Farmer Practice	7.17	0.29	0.61	227.75	12.47	247.00
T_6 100 % Inorganic NM	7.18	0.30	0.60	234.25	12.62	263.50
Initial status of soil	7.20	0.28	0.59	216.50	12.41	240.50
SEm ±	0.01	0.01	0.01	1.57	0.02	1.88
CD (5%)	0.02	NS	NS	4.44	0.07	5.67

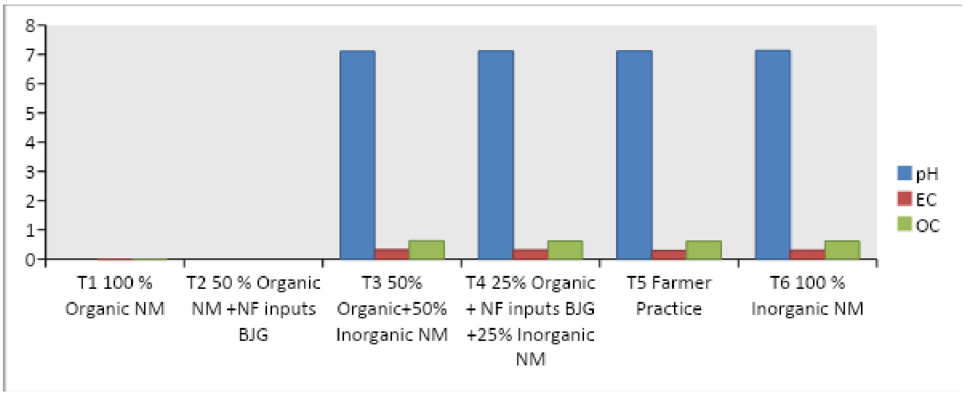

Fig. 1. Impact of different nutrient management practices on pH, EC and OC of soil

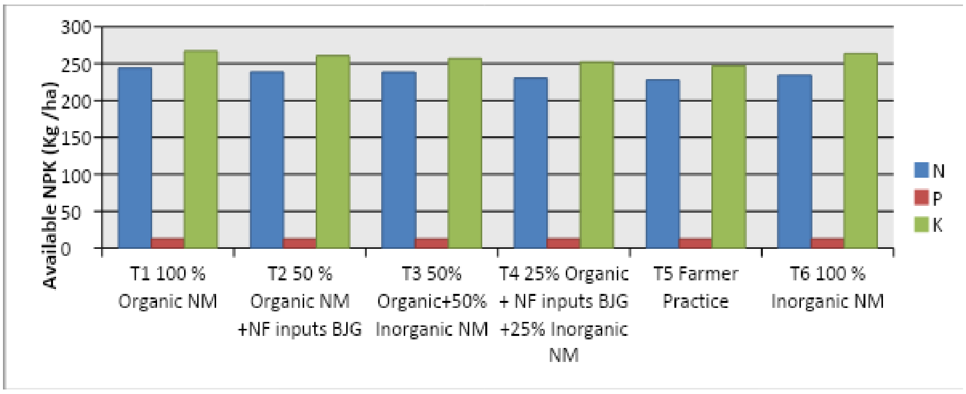

Fig. 2. Impact of different nutrient management practices on Available N, P and K of soil (kg/ha)

3.2 Impact of Different Nutrient Management Practices on Economics

Economic analysis of treatments was determined on per hectare area basis, which includes cost of cultivation, gross monetary return, net monetary return and benefit-cost ratio as affected by various treatments are given in Table 5.

3.2.1 Cost of cultivation (Rs/ha)

Data on cost of cultivation showed variations among the different treatments represent in Table 5 and depicted in Fig. 3. On an average the highest cost of cultivation was found under the treatment of 100% organic nutrient management (Rs. 31624/ha) followed by T_2 (50% organic+ NF inputs (beejamrit +jeevamrit+ ghanjeevamrit) + 50% inorganic NM (Rs.31128/ha) and lowest cost of cultivation was recorded under the treatment of T_5 farmer practice (Rs.20800/ha). These findings are in close conformity with the results of [16,17].

3.2.2 Gross monetary returns (Rs/ha)

Data on gross monetary returns showed variations among the different treatments represent in Table 5 and depicted in Fig. 4. On an average highest gross monetary returns was obtained from T_1 (100% organic nutrient management) (Rs.58606/ha) followed by T_2 (50% organic+ NF inputs (beejamrit +jeevamrit+ ghanjeevamrit) + 50% inorganic NM) (Rs.50712/ha) however, lowest gross monetary returns obtained from (T_5 farmer practice) (Rs.36419/ha). These findings are in close conformity with the results of [18-20].

3.2.3 Net monetary returns (Rs/ha)

Data on net monetary returns showed variations among the different treatments represent in Table 5 and depicted in Fig. 5. The highest net monetary returns were found in T_1 (100% organic nutrient management) (Rs. 26982/ha) followed by T_2 (50% organic+ NF inputs (beejamrit +jeevamrit + ghanjeevamrit) + 50% inorganic NM) (Rs.19584/ha) however, lowest net monetary returns were found in T_5 (farmer practice) (Rs.15619/ha). These results are with close agreement [21-23].

3.2.4 Benefit-cost ratio

Data on B: C ratio showed variation among the different treatments represent in Table 5 and depicted in Fig 6. The highest average benefit cost ratio was found in T_1 (100% organic nutrient management) (1.85) followed by T_5 (Farmer practice) (1.75) and lowest benefit cost ratio was recorded in T_2 (50% Organic NM +NF inputs BJG) (1.62). These results are in with close agreement [24,6, 7,25,26].

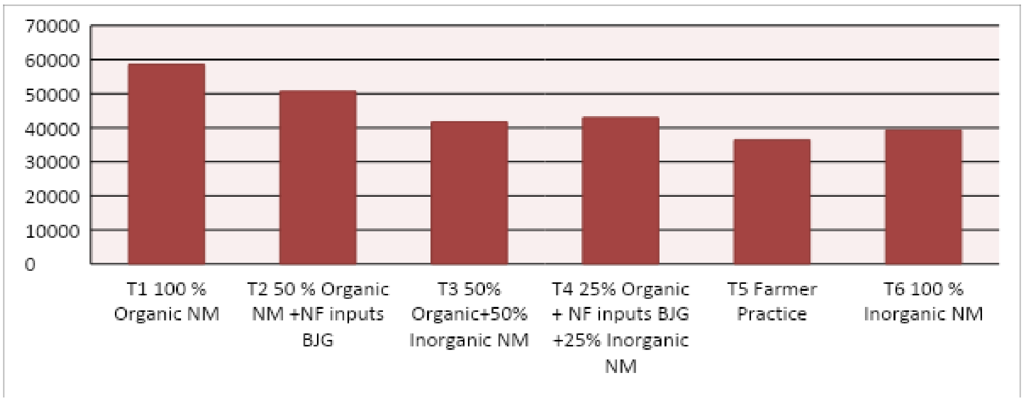

Fig. 3. Impact of different nutrient management practices on cost of cultivation (Rs/ha) of soybean under different treatments

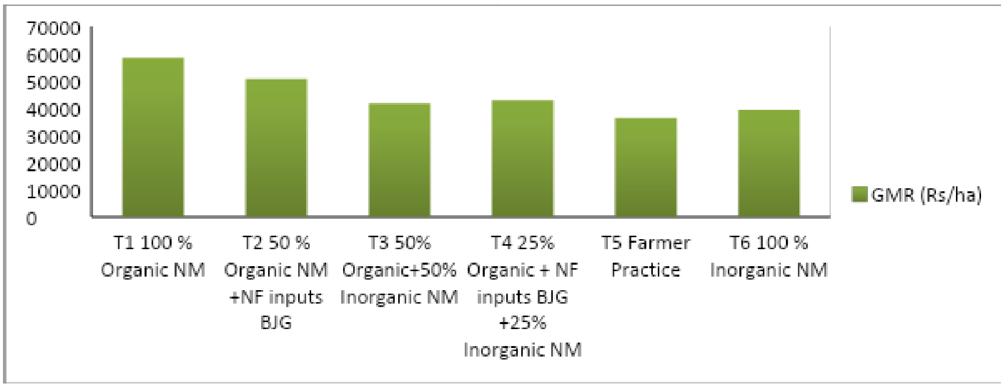

Fig. 4. Impact of different nutrient management practices on gross monetary returns (Rs/ha) of soybean under different treatments

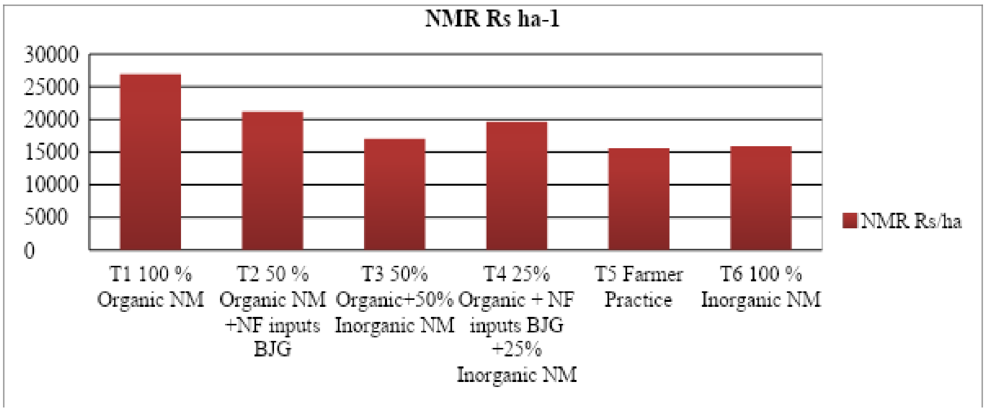

Fig. 5. Impact of different nutrient management practices on net monetary returns (Rs/ha) of soybean under different treatments

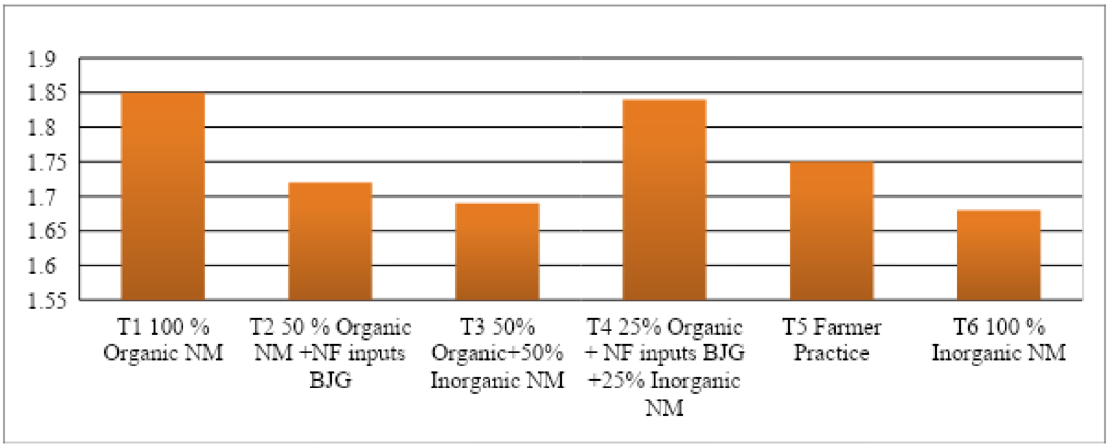

Fig. 6. Impact of different nutrient management practices on B: C Ratio (per rupees investment) of soybean under different treatments

Table 6. Economic analysis of soybean under different treatments

Treatment No.	Cost of Cultivation (Rs/ha)	GMR (Rs/ha)	NMR (Rs/ha)	B:C
T_1 100 % Organic NM	31624	58606	26982	1.85
T_2 50 % Organic NM +NF inputs BJG	31128	50712	19584	1.62
T_3 50% Organic+50% Inorganic NM	24704	41686	16982	1.68
T_4 25% Organic + NF inputs BJG +25% Inorganic NM	24840	42962	18122	1.72
T_5 Farmer Practice	20800	36419	15619	1.75
T_6 100 % Inorganic NM	23484	39349	15865	1.67

4. CONCLUSION

Based on foregoing results and discussion it can be concluded that among different nutrient management practices treatments (100% organic nutrient management) have shown positively impact on soil health with the post-harvest values of available N (244 kg/ha), P (12.70 kg/ha),K (267 kg/ha), pH (7.11), EC (0.32ds/m) and organic carbon (0.63%) where the initial values were available N (216.50 kg/ha), P (12.41 kg/ha), K (240.50 kg/ha), pH (7.20), EC (0.28 dS/m) and organic carbon (0.59 %). Whereas the higher Gross monetary returns (Rs.58606/ha), Net monetary returns (Rs.26982/ha) and in terms of per rupees investment (1.85) were obtained under the treatment (100% organic nutrient management).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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