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Effect of Integrated Nutrient Management for Environmental Sustainability on Yield and Economics of Horsegram [*Macrotyloma uniflorum* (Lam.) Verdc.]

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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 present study was conducted to evaluate the economic viability of different integrated nutrient management (INM) practices on horsegram cultivation. Economic parameters such as cost of cultivation, gross return, net return, and benefit-cost (B:C) ratio were analyzed to determine the most profitable treatment. Among the treatments, the highest cost of cultivation (₹ 23,259.06 ha^{-1}) was recorded under (50% RDF + 50% N through FYM + Rhizobium culture + PSB), mainly due to the higher requirement of farmyard manure. However, the maximum gross return (₹ 47,588.38 ha^{-1}) and net return (₹ 27,645.26 ha^{-1}) were observed in (100% RDF + Rhizobium culture + PSB), followed by (100% RDF + Rhizobium culture). Correspondingly, the highest B:C ratio (1.39) was

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also recorded in, indicating its superior economic performance. The control plot consistently showed the lowest values across all economic parameters. The study concludes that 100% RDF + Rhizobium culture + PSB is the most economically efficient INM practice for horsegram production, providing the highest profitability with optimal input utilization.

Keywords: Horsegram; Integrated Nutrient Management (INM); cost of cultivation; RDF; Farmyard Manure (FYM); Phosphate Solubilizing Bacteria (PSB).

1. INTRODUCTION

Pulses play important role in agriculture next to cereals. These are the major source of dietary protein, along with minerals and vitamins. It is the second rich source of dietary protein in vegetarian diet in our country and also in other developing countries. Among the pulses, horsegram is an important post season *kharif* crop of the country commonly known as "Kulthi" belongs to the family fabaceae. It has diploid chromosome numbers of 2n = 20 (Cook *et al*., 2005). "Horsegram is grown with mixed crop. The crop duration of horsegram is 100 – 110 days. The average yield is about 350-800 kg ha^{-1}" (Anon., 2018-19). "It is known for its medicinal use and nutritional quality. It is consumed as a whole seed and as sprouts in India. Horsegram used traditionally as a medicinal crop famous for its medicinal uses because different parts of the plant are used for the treatment of asthma, bronchitis, urinary disorder, lowering cholesterol levels and kidney stones" (Ghani, 2003). In India, horsegram occupies an area of 460.40 thousand ha. with a production of 181.29 thousand tonnes with an average national productivity of 394 kg ha^{-1} (Anonymous, 2018-19). "Horsegram is important pulse crop mostly grown in Karnataka, Odisha, Chhattisgarh, Andhra Pradesh, Tamil Nadu and Maharashtra which together contributes about 89.23 per cent area and 86.10 per cent production. Higher productivity of horsegram is obtained in Bihar (1000 kg ha^{-1}). In Chhattisgarh, horsegram occupies an area of 40.15 (000 ha) with a production of 15.20 (000 tonnes) and average productivity of 379 kg ha^{-1}" (Anonymous, 2018-19). Horsegram is an important pulse crop of the state and mostly grown in Sarguja, Jagdalpur, Kanker, Korba and Jashpur which together contributes about 69.74 per cent area and 76.61 per cent production. However, the productivity of horsegram is highest in Janjgir (388 kg ha^{-1}).

2. MATERIALS AND METHODS

The present investigation entitled *"Effect of Integrated Nutrient Management on Growth and Yield of Horsegram [Macrotyloma uniflorum (Lam.) Verdc.] in Chhattisgarh Plain"* was conducted during the post-kharif season of 2020 at the Instructional Farm, BTC College of Agriculture and Research Station, Bilaspur, Chhattisgarh. The experimental site lies in a dry-moist, sub-humid agro-climatic zone at an altitude of 292 meters above mean sea level, located at 22.09°N latitude and 82.12°E longitude. The soil was sandy clay in texture.

The experiment was laid out in a Randomized Block Design (RBD) with nine treatments replicated three times. The treatment details were as follows:

- T1: 100% RDF
- T2: 75% RDF + 25% N through FYM
- T3: 50% RDF + 50% N through FYM
- T4: 100% RDF + Rhizobium culture
- T5: 75% RDF + 25% N through FYM + Rhizobium culture
- T6: 100% RDF + Rhizobium culture + PSB
- T7: 50% RDF + 50% N through FYM + Rhizobium culture
- T8: 50% RDF + 50% N through FYM + Rhizobium culture + PSB
- T9: Control (no nutrient application)

RDF (Recommended dose of fertilizer), Fertilizer dose ratio is 25:50:25 (NPK) Kg ha^{-1}

The sources of nitrogen, phosphorus and potash nutrients are as below:

Urea: Urea is most widely used nitrogenous fertilizer and is produced by heating ammonia with CO_2 under pressure and high temperature (160-170°C). Urea contains the highest percentage of nitrogen 46 per cent among solid fertilizers. It contains nitrogen in the amide formulae form. This organic fertilizer is cheaper than any other solid nitrogenous fertilizer in India.

Single Super Phosphate (SSP): Single super phosphate (ordinary superphosphate) is manufactured by mixing equal parts of rock phosphate and sulphuric acid (batch mix process). Phosphate originally present as apatite is converted into monocalcium phosphate superphosphate formulae is greyish and slightly moist with acid odour. In addition to 16 per cent P_2O_5, it also contains 12 per cent sulphure and 21 per cent calcium.

Muriate of Potash (MOP): Muriate of potash or potassium chloride (KCL) is the most common and cheapest fertilizer among the potassic fertilizers. It contains 60 per cent K_2O.

Horsegram variety 'Bilasa Kulthi' was sown on 11th September 2020 and harvested on 18th December 2020. The seed rate used was 20 kg ha^{-1}. Prior to sowing, seeds were treated with carbendazim (12% WP) @ 2 g kg^{-1}, followed by Rhizobium and PSB cultures @ 10 g kg^{-1} of seed each. Field preparation included one ploughing and two harrowings followed by leveling. Fertilizers used included urea, single super phosphate (SSP), and muriate of potash (MOP), applied as per treatment specifications in furrows as a basal dose. Sowing was done manually at a row spacing of 30 cm and seed depth of 3–4 cm. During the crop growth period, the maximum and minimum temperatures ranged between 28.7°C (September) and 8.0°C (December). Relative humidity varied from 83.05% (maximum) to 43.4% (minimum), with a maximum sunshine duration of 7.8 hours and a peak weekly rainfall of 52.8 mm recorded in the 40th standard week. At harvest maturity, net plot yields were obtained after manual harvesting, threshing, winnowing, and weighing. Border rows were harvested separately and excluded from yield calculations.

Weather and Climate: Agro-climatically, the experimental site comes into a dry, moist, sub-humid area. The average (80 percent) precipitation at the experimental site is 1503 mm (based on an 80 year average) per year, most of which is obtained from June to 11 September during the monsoon season. The maximum and minimum temperature was received 28.7°C and 8.0°C, respectively in the months of September and December. The mean weekly meteorological data was recorded from the Meteorological Observatory of Barrister Thakur Chhedilal College of Agriculture and Research station, Bilaspur, during the crop-growing in Fig. 1. The mean weekly meteorological data was recorded from the Meteorological Observatory of Barrister Thakur Chhedilal College of Agriculture and Research station, Bilaspur, during the crop-growing period (07-9-2020 to 18-12-2020). The weekly maximum and minimum temperature recorded during growing period of crop was 28.7^{o}C in 37th standard week of September and 8.0^{o}C 51th standard week of December and the average maximum and minimum relative humidity was 83.05% and 43.4% on 49th and 45th standard week of (December and November) respectively, the highest sunshine hours during crop growing period was recorded 7.8 hours and the total mean weekly rainfall of 52.8mm was on 40th standard week of September respectively obtained during crop growth period from September to December, 2020.

3. ECONOMICS

1. Cost of cultivation (₹ ha^{-1})

In preparing the cost of cultivation, it is customary to indicate the expenditure incurred on items such as labour (including family labour), seeds, chemicals (fertilizers and pesticides) and power (tractor, power tiller and pumping water). This will help the farmer to choose a crop which uses the resources he has in plenty but demands less on the resources he lacks. It is worked out on hectare basis using the purchase prices of inputs prevailing in the region and expressed in ₹ ha^{-1}. Cost of cultivation for each treatment was calculated separately.

2. Gross return (₹ ha^{-1})

It is the total monetary value of the produce (seeds) and by-products (straw) obtained from the crop raised. It is calculated by multiplying the yields (of both main and by-product) with the prevailing market prices and is expressed as ₹ ha^{-1}.

$$\text{Gross return } (₹\ ha^{-1}) = \text{Seed yield } (t\ ha^{-1}) \times \text{Price of seed } (₹\ t^{-1})$$

3. Net return (₹ ha^{-1})

It is also referred to as net profit and represents the actual income to farmer. It is calculated as follows:

$$\text{Net return } (₹\ ha^{-1}) = \text{Gross monetary return } (₹\ ha^{-1}) - \text{Cost of cultivation } (₹\ ha^{-1})$$

4. Benefit: Cost ratio

This index provides an estimate of the benefit derived from the expenditure incurred in adopting a particular cultivation practice. It is calculated by the following formula.

$$\text{Benefit :Cost ratio} = \frac{\text{Net monetary return } (₹\ ha^{-1})}{\text{Cost of cultivation } (₹\ ha^{-1})}$$

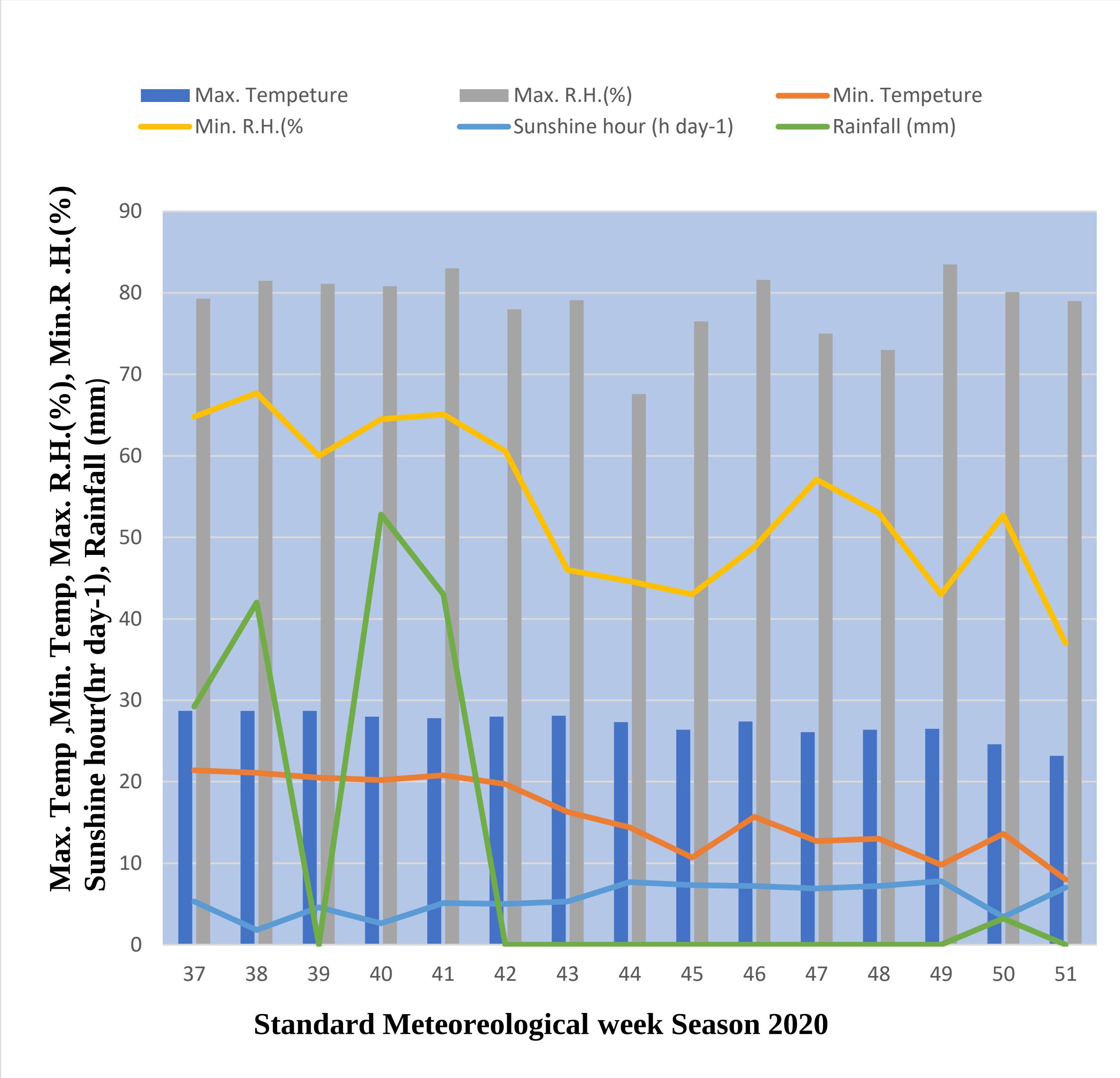

Fig. 1. Mean weekly meteorological data during cropping period

Table 1. Standard weekly meteorological data during the cropping period post *Kharif* season 2020-21 (07-09-2020 to 18-12-2020)

SMW	Tempreture (° C)		Relative Humidity (%)		Rainfall (mm)	Sunshine (hrs.)
	Max.	Min.	Max.	Min.		
37	28.7	21.4	79.3	64.8	29.2	5.3
38	28.7	21.1	81.5	67.7	42.0	1.8
39	28.7	20.5	81.1	60.0	00.0	4.6
40	28.0	20.2	80.8	64.5	52.8	2.6
41	27.8	20.8	83.0	65.1	43.0	5.1
42	28.0	19.7	78.0	60.6	00.0	5.0
43	28.1	16.3	79.1	46.0	00.0	5.3
44	27.3	14.4	67.6	44.6	00.0	7.7
45	26.4	10.7	76.5	43.0	00.0	7.3
46	27.4	15.7	81.6	48.8	00.0	7.2

SMW	Tempreture (º C)		Relative Humidity (%)		Rainfall	Sunshine
	Max.	Min.	Max.	Min.	(mm)	(hrs.)
47	26.1	12.7	75.0	57.1	00.0	6.9
48	26.4	13.0	73.0	53.0	00.0	7.2
49	26.5	9.8	83.5	43.0	00.0	7.8
50	24.6	13.6	80.1	52.7	3.2	3.4
51	23.2	8.0	79.0	37.0	00.0	7.0

Note – SMW (Standard meteorological week)

Table 2. Physiochemical properties of the experimental soil

S.N	Soil stage	Value		Categories	Method adopted
	Physical properties			-	International pipette Method (Piper, 1965)
1.	**Sand (%**	46.58		-	
2.	**Silt (%)**	23.86		-	
3.	**Clay (%)**	29.56			
	Chemical properties	**Initial**	**At harvest**		
4.	**Soil pH (pH 1:2:5)**	6.9	6.8	Neutral	Glass electrode pH meter (Piper, 1965)
5.	**Electrical conductivity (dsm^{-1} at 25ºC)**	0.24	0.27	Good	Electrical conductivity meter (Jackson, 1973)
6.	**Organic carbon (%)**	0.63	0.62	Medium	Walkley and Black method (Jackson, 1967)
7.	**Available N (kg ha^{-1})**	145	138	Low	Alkaline permanganate method (Subbaiah & Asija, 1956)
8.	**Available P (kg ha^{-1})**	12.15	11.23	Medium	Olsen's method (Olsen, 1954)
9.	**Available K (kg ha^{-1})**	203.98	190.17	Medium	Flame photometer (Jackson, 1967)

4. RESULTS AND DISCUSSION

Economics is the final metric to evaluate the best treatments which are economically sound and can be accepted by the farmers. Different parameters of economics like cost of cultivation, gross return, net return and B:C ratio for different integrated nutrient management practices for horsegram computed and presented in Table 3.

1. Cost of cultivation (₹ ha^{-1})

The data pertaining to cost of cultivation showed that highest cost of cultivation (23259.06 ₹ ha^{-1}) was recorded by T_8 (50% RDF + 50% N through FYM + *Rhizobium culture* + PSB) followed by T_7 (50% RDF + 50% N through FYM + *Rhizobium* culture) (23159.06 ₹ ha^{-1}) however lowest cost of cultivation was found in T_9 (Control plot) (16423.00 ₹ ha^{-1}). T_8 is highest cost of cultivation is due to high amount of farm yard manure need.

2. Gross return (₹ ha^{-1})

Data presented in Table 3 recorded that which was significantly influenced by different integrated nutrient management practices for horsegram higher gross return found in T_6 (100% RDF + *Rhizobium culture* + PSB), is (47588.38 kg ha^{-1}) followed by T_4 (100% RDF + *Rhizobium culture*), is (45067.00 ₹ ha^{-1}), T_5 (75% RDF + 25% N through FYM + *Rhizobium culture*), is (40383.20 ₹ ha^{-1}) and lowest gross return was recorded (18883.00 ₹ ha^{-1}) in T_9 Control plot.

3. Net returns ₹ ha^{-1})

Net return from an investment was obtained after deducting all expenses from the gross return generated by the investment. Data pertaining in Table 3. Highest net returns of 27645.26 ₹ ha^{-1} was received by T_6 (100% RDF + *Rhizobium culture* + PSB) followed by T_4 (100% RDF + *Rhizobium culture*) (25223.88 ₹ ha^{-1}), T_5 (75% RDF + 25% N through FYM + *Rhizobium culture*) (18880.98 ₹ ha^{-1}) and lowest (2460.00 ₹ ha^{-1}) in T_9 (control plot). These results are collaborated with the findings of Keshava *et al*., (2007) and Hanif *et al*., (2017).

Table 3. Effect of integrated nutrient management on cost of cultivation gross return net return B:C ratio of horsegram

Treatments		Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net returns (₹ ha^{-1})	Benefit: cost ratio	Seed yield (kg ha^{-1})
T_1	**100% RDF**	19795.12	33275.55	13480.43	0.68	605.01
T_2	**75%RDF + 25% N through FYM**	21452.24	34692.72	13240.48	0.62	630.78
T_3	**50% RDF + 50% N through FYM**	23109.06	31446.62	8337.56	0.36	571.76
T_4	**100% RDF + *Rhizobium* culture**	19843.12	45067	25223.88	1.27	819.40
T_5	**75% RDF + 25% N through FYM + *Rhizobium* culture**	21502.24	40383.2	18880.96	0.88	743.24
T_6	**100% RDF + *Rhizobium* culture + PSB**	19943.12	47588.38	27645.26	1.39	865.24
T_7	**50% RDF + 50% N through FYM + *Rhizobium* culture**	23159.06	35499.93	12340.87	0.53	645.45
T_8	**50% RDF + 50% N through FYM + *Rhizobium* culture + PSB**	23259.06	36382.68	13123.62	0.56	661.50
T_9	**Control plot**	16423	18883.00	2460.70	0.15	343.34
	SEm ±	-	-	-	-	45.37
	CD (P=0.05)	-	-	-		136.01

4. Benefit: Cost ratio

The value of B:C ratio was the most pertinent economical parameter in comparison to net returns as it shows net benefit by investigating one rupee as overall cost of cultivation. When we consider the B:C ratio, different integrated nutrient management practices for horsegram higher B:C ratio found in T_6 (100% RDF + *Rhizobium culture* + PSB), (1.39) followed by T_4 (100% RDF + *Rhizobium culture*) (1.27), T_1 (100% RDF) (0.68) and lowest B:C ratio, was recorded (0.15) in T_9 (Control plot).

5. Seed yield (kg ha^{-1})

Seed yield of horsegram was significantly affected with the integrated nutrient management practices. Among the various treatments the highest seed yield (865.24 kg ha^{-1}) was obtained from application of T6 (100% RDF + Rhizobium culture + PSB), which was statistically at par with T4 (100% RDF + Rhizobium culture) with seed yield (819.40 kg ha^{-1}) and T5 75% RDF + 25% N through FYM + Rhizobium culture) with seed yield is (743.24 kg ha^{-1}). The lowest seed yield (343.34 kg ha^{-1}) was recorded under treatment (T9) control plot. The yield under lower nutrient levels could not satisfy the crop need and ultimately resulted in lower grain yield, this may be due to fact that the supply of nutrients is lower as compare to crop demand. These results were found to be similar with Keshava et al., (2007).

5. CONCLUSION

The economic evaluation of various integrated nutrient management (INM) practices in horsegram cultivation revealed significant differences among treatments. The treatment T6 (100% RDF + Rhizobium culture + PSB) emerged as the most economically viable option, recording the highest gross return (₹ 47,588.38 ha^{-1}), net return (₹ 27,645.26 ha^{-1}), and benefit-cost ratio (1.39), despite not having the highest cost of cultivation. In contrast, the control treatment (T9) consistently showed the lowest economic performance across all parameters. While treatments involving FYM such as T8 incurred higher cultivation costs, they did not necessarily translate into proportionately higher returns. Therefore, integrating full recommended doses of fertilizers with bio-inoculants such as Rhizobium and PSB proved to be the most cost-effective and profitable strategy for enhancing productivity and farm income in horsegram cultivation. Adoption of T6 can thus be recommended to farmers for improving economic returns while maintaining soil health through sustainable nutrient management practices.

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 this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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