



RESEARCH ARTICLE

Integrated nutrient management enhances cowpea performance under conservation agriculture in rice-wheat cropping system

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Abstract

To investigate the effect of integrated nutrient management on cowpea under conservation agriculture, an experiment was conducted during the pre-Kharif seasons of 2013 and 2014 within a rice-wheat cropping system. The study employed a Factorial Randomized Block Design with three replications, evaluating different fertility levels through the application of inorganic sources, organic sources and biofertilizers. Observation on various parameters viz. growth, yield, quality and uptake of major nutrients under inorganic sources has led to the undisputed conclusion that treatment I₃ (150 % RDF) was superior to the other two levels of inorganic sources (i.e., 50 % RDF and 100 % Recommended Dose of Fertilizer). All growth, yield and quality traits were observed to be highest in O₅ (vermicompost @ 5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds) however, regarding the uptake of NPK, it was peerless under organic sources of treatment O₆ (FYM @ 7.5 t/ha + vermicompost @ 2.5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds). Eventually as the economics cultivation of cowpea the treatment combination of 150 % RDF + FYM @ 15 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds (I₃O₄) (B: C ratio 3.04) followed by 150 % RDF + vermicompost @ 2.5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds (I₃O₆) (B: C ratio 2.77) could be well-suited for the terai region of West Bengal.

Keywords: biofertilizer; conservation agriculture; inorganic sources; organic sources

Introduction

The rice-wheat cropping system is highly nutrient-demanding and its continuous cultivation has depleted the soil's natural fertility, leading to multiple nutrient deficiencies (1). Since the sustainability of this production system relies on responsible soil resource management, it is essential to develop and implement soil management techniques that enhance soil organic matter and biological activity, decrease salinity and improve soil physical properties to maintain long-term land productivity. Additionally, in eastern India, around 40 % of the summer rice area and 60 % of the pre-kharif area remain fallow. As a result, short-duration, low-water-demanding crops like legumes could be integrated into the existing rice-wheat system. Integrating legumes into cereal-based cropping systems can enhance soil fertility and crop productivity sustainably, while also supplying the succeeding cereal crop with the equivalent of 30-40 kg of nitrogen fertilizer per hectare. This approach not only provides essential nutrients for plants but also serves as a source of organic matter, making it more ecologically compatible and economically advantageous than a cereal-cereal cropping system (2). A legume with lush, tender foliage, effective weed suppression and robust nodulation is ideal. Cowpea, a legume adapted to stress conditions with high nutritional value (3), is thus a viable option for

integration into the rice-wheat system. In India, however, despite the development of numerous improved varieties and agro-techniques, cowpea productivity has yet to reach optimal levels. There is a pressing need to incorporate organic fertilizers like farmyard manure (FYM) and bio-fertilizers. Organic manures enhance sustainable soil quality (4) and release nutrients gradually, with approximately 30 % N, 70 % P₂O₅ and 75 % K₂O available to the first crop, while the remainder supports subsequent crops (5). Although organic fertilizers are highly beneficial, combining them with chemical fertilizers can increase nutrient efficiency and improve crop productivity. An integrated nutrient approach can reduce cultivation costs, enhance soil health and boost yield per unit area (6). This study was therefore designed to develop integrated nutrient management practices for cowpea cultivation in the rice-wheat cropping system under zero tillage conditions.

Materials and Methods

The experiment was conducted at the Instructional Farm, Faculty of Horticulture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India, located in the Terai agro-climatic zone of West Bengal, during the pre-kharif seasons of 2013 and 2014. It was

laid out in a Factorial Randomized Block Design with three replications. Different fertility levels were established through applications of inorganic, organic and biofertilizer nutrient sources. Inorganic source consists of three levels i.e., I₁ (50 % Recommended Dose of Fertilizer (RDF)), I₂ (100 % RDF) and I₃ (150 % RDF). While organic sources conjointly with a biofertilizer consists of the seven levels i.e., O₁ (FYM @ 15 t/ha + *Rhizobium* @ 10 g/kg of seeds), O₂ (vermicompost @ 5 t/ha + *Rhizobium* @ 10 g/kg of seeds), O₃ (FYM @ 7.5 t/ha + vermicompost @ 2.5 t/ha + *Rhizobium* @ 10 g/kg of seeds), O₄ (FYM @ 15 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds), O₅ (vermicompost @ 5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds), O₆ (FYM @ 7.5 t/ha + vermicompost @ 2.5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds) and O₇ (control). Fertilizers at the recommended N: P₂O₅: K₂O ratio of 20:50:50 kg/ha were applied, with half of the nitrogen and the full phosphorus and potassium doses applied at sowing and the remaining nitrogen applied in the third week after sowing. Seeds were inoculated with *Rhizobium* and *Phosphate-Solubilising Bacteria* (PSB) at 10 g/kg of seeds. Cowpea seeds var. Lafa Sundari Bangla were sown in early April each year at a spacing of 45 × 20 cm.

Data on various growth and yield metrics, including vine length, root length (cm), root dry weight (g), number of nodules per plant, nodule dry weight (g), pod count, pod length, weight per pod and yield per plant, were collected from ten randomly chosen plants. Additionally, the total yield from each plot across the harvest period was recorded and this yield was ultimately converted to pod yield in tonnes per hectare.

Ascorbic acid was measured using a colorimetric method involving the reduction of 2,6-dichlorophenol indophenol, while the beta carotene content in fresh pods was estimated following Ranganna's method (7). Pod protein content was assessed using Lowry's method (8). The total phenol content in leaves was determined with Folin-Ciocalteu reagent, according to the method of Malick and Singh (9). Peroxidase enzyme activity in leaves was measured based on the technique outlined by Sadasivam and Manickam (10).

Total nitrogen content of plant samples, available nitrogen content in soil, available phosphorus in soil and available potassium in soil were analyzed by using Kjeldahl method as suggested by Jackson (11). Total phosphorus and total potassium content of plant samples was analyzed using the method as suggested by Jackson (12).

Statistical analysis

The data collected, as previously described, were analyzed statistically using the Analysis of Variance (ANOVA) method (13).

Economics of cultivation

Gross returns, cultivation costs, net returns and the benefit-cost ratio were calculated to assess the economics of cultivation, based on yield data and local market prices.

Results and Discussion

Effect of integrated nutrient management on growth parameters of chickpea under conservation agriculture nutrient uptake of cowpea

Growth parameters

It is evident from the data presented in Table 1 that various growth parameters of cowpea as influenced by the different fertility levels of inorganic sources of nutrients. The highest vine length (116.11 cm) was recorded in I₃ (150 % RDF) and lowest (110.04) in I₁ (50 % RDF). Similar results were reported earlier (14). Days taken to 50 % flowering were found to increase with the increasing level of fertility, shortest being 45.15 days in I₁ (50 % RDF) and maximum days of 46.10 days in I₃ (150 % RDF). This may be attributed to the higher fertility levels, which prolong the vegetative phase and consequently delay flowering. Similar findings were noticed (15). The root length (25.95 cm; 30 DAS and 34.76 cm; 60 DAS), root dry weight (0.88 g; 30 DAS and 1.65 g; 60 DAS), nodules number (17.19; 30 DAS and 22.88; 60 DAS) and nodule dry weight (134.67g; 30 DAS and 187.74 g; 60 DAS) was measured at the different stage of growth, plots receiving treatment I₃ (150 % RDF) was found to be more effective than the other treatments. Likewise, the number of days to the first and last harvest (Table 2) grew longer as the fertility levels increased.

Among the various levels of organic nutrient sources, the longest vine length (115.66 cm) was recorded in O₅ (vermicompost @ 5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds) and significantly lowest vine length (109.50 cm) was recorded in O₇ (control). The increase in vine length can be attributed to the conversion of unavailable phosphorus into available forms through PSB inoculation, which is essential for the plant to exhibit early vigor during the vegetative phase (16). The maximum number of days taken to reach 50 % flowering was 45.97 days in treatment O₅ (vermicompost @ 5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10

Table 1. Effect of various levels of inorganic and organic nutrient sources on growth of cowpea (pooled value)

Treatment	Vine length (cm)	Days to flowering (days)	Root length at 30 DAS (cm)	Root length at 60 DAS (cm)	Root dry weight at 30 DAS (g)	Root dry weight at 60 DAS (g)	Number of nodules per plant at 60DAS	Number of nodules per plant at 60DAS	Nodule dry weight at 30 DAS (mg)	Nodule dry weight at 60 DAS (mg)
Inorganic source										
I ₁	110.04	45.15	18.20	26.94	0.82	1.57	14.97	20.50	126.87	177.52
I ₂	113.31	45.60	21.49	30.35	0.84	1.60	16.09	21.71	131.51	183.66
I ₃	116.11	46.10	25.95	34.76	0.88	1.65	17.19	22.88	134.67	187.74
S. Em (±)	0.57	0.28	0.21	0.24	0.01	0.03	0.28	0.31	0.33	0.91
CD	1.60	0.80	0.60	0.69	0.02	0.09	0.81	0.87	0.93	2.54
Organic source										
O ₁	111.46	45.34	20.02	28.81	0.83	1.59	14.68	21.11	129.59	181.04
O ₂	112.96	45.62	21.80	30.59	0.85	1.61	15.27	21.61	130.69	182.95
O ₃	113.43	45.54	21.51	30.33	0.85	1.60	15.59	21.72	131.03	183.13
O ₄	114.95	45.87	23.92	32.74	0.85	1.62	16.00	22.33	133.02	185.03
O ₅	115.66	45.97	24.89	33.72	0.87	1.64	16.31	22.50	134.31	187.12
O ₆	114.12	45.84	22.80	31.62	0.85	1.62	16.13	22.17	131.85	184.56
O ₇	109.50	45.14	18.20	26.99	0.82	1.56	13.85	20.44	126.61	176.99
S. Em (±)	0.87	0.43	0.32	0.37	0.01	0.05	0.44	0.47	0.51	1.39
CD	2.45	1.22	0.91	1.05	0.03	0.13	1.24	1.34	1.42	3.89

g/kg of seeds) while least number of days (45.14 days) was in treatment O₇(control). Similarly, treatment O₅ (vermicompost @ 5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds) was efficacious regarding root length (maximum 24.89 cm and 33.72 cm at 30 DAS and 60 DAS respectively) and root dry weight (maximum 0.87 g and 1.64 g at 30 DAS and 60 DAS respectively). Furthermore, other growth parameters take the same line viz. number of nodules per plant at 30 DAS (16.50) and at 60 DAS (22.50), nodules dry weight at 30 DAS (134.31 mg) and at 60 DAS (187.12 mg) were recorded to be highest in O₅ (vermicompost @ 5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds). While treatment without organic and biofertilizer (O₇) showed to be the less benignant toward these parameters. The days for first green pod harvesting decreased with decrease in organic and biofertilizer level as depicted in Table 2.

Effect of integrated nutrient management on yield parameters of chickpea under conservation agriculture

Yield parameters

The presented data (Table 2) yield attributes like pod length (44.54 cm), pods per plant (24.69), fruit yield per plant (216.61 g), individual pod weight (14.35 g), pod yield per plot (8.52 kg) and total pod yield (15.17 tonnes/ha) were highest in the treatment I₃ (150 % RDF).

The organic and biofertilizer as a source of nutrients had significantly affected the yield parameters. Although looking at Table 2 it can be said that, treatment O₅ is the most efficient. Such as, the highest pod length (44.25 cm), maximum number of fruits per plant (23.98), highest pod yield per plant (211.44 g) and highest pod yield per plot (8.31 kg) was found from O₅ (vermicompost @ 5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds). While heaviest individual pod of 13.61 g was recorded in treatment O₄ (FYM @ 15 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds) and the lowest pod weighing 12.04 g was recorded in plot O₇ (control). This might be due to the variation of fruits produced under different fertility levels. Again, among the seven treatments, the highest pod yield per hectare (14.77 tonnes/ha) was found from treatment O₅ (vermicompost @ 5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds). Differences in yield related to the levels of organic manure and fertilizer (17, 18).

Effect of integrated nutrient management on quality parameters of chickpea under conservation agriculture

A perusal of data (Table 3) revealed that maximum Beta carotene content (933.50 IU) was found in treatment I₃ (150 % RDF). Whereas the minimum (852.25 IU) was observed in treatment I₁ (50 % RDF).

Recurrently, the treatment I₃ (150 % RDF) also produced maximum ascorbic acid content of fresh pod (20.05 mg/100 g) and highest protein content of pod (4.84 %).

Beta carotene content under the varied level of organic sources was variant, the maximum amount of 911.30 IU was recorded in O₆ (FYM @ 7.5 t/ha + vermicompost @2.5 t/ha + PSB @10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds). Concerning ascorbic acid content, a maximum of 20.07 mg/100 g was found in O₅ (vermicompost @ 5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds). The increase in vitamin C content with the addition of organic manures and biofertilizers can be attributed to the stimulating effect of readily available plant nutrients, which may have boosted the synthesis of its precursor, such as glucose-6-phosphate, during the conversion of starch into different sugars, similar variation in ascorbic acid content (19). Finally, the highest protein content of 4.77 % was under the treatment O₅ (vermicompost @ 5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds) against the minimum values of 4.44 % in the control.

Residual nutrient of soil

Data noted on soil nutrient (NPK) content after harvest of cowpea plants provided in the (Table 3) indicates that the highest amount of nitrogen (179.36 kg/ha) in the rhizosphere soil was recorded in the plots which received I₃ treatment (150 % RDF) and the lowest nitrogen level was observed in the treatment that included only 50 % of the recommended inorganic fertilizer (I₁). Available phosphorus and available potassium of soil also followed the similar trend, highest in the treatment I₃ (150 % RDF) lowest in treatment I₁ (50 %RDF).

Among the different level of organic treatment, O₁ (FYM @ 15 t/ha + *Rhizobium* @ 10 g/kg of seeds) produced maximum amount of nitrogen in the rhizosphere soil (196.37 kg/ha). FYM and *Rhizobium* inoculation may have increased atmospheric nitrogen fixation, contributing additional nitrogen to the soil. On the other hand, maximum available phosphorus of soil (51.70 kg/ha) was recorded in the treatment O₄ (FYM @ 15 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds). The greater availability of phosphorus in the soil of PSB-inoculated plots may result from improved solubilization of phosphorus facilitated by PSB. Regarding the available potassium of soil, maximum amount (129.99 kg/ha) was recorded in treatment O₁(FYM @ 15 t/ha + *Rhizobium* @ 10 g/kg of seeds). Incorporating microorganisms along with organic manures may have aided in converting

Table 2. Effect of various levels of inorganic and organic nutrient sources on yield parameters and yield of cowpea (pooled value)

Treatment	Days taken to first harvesting (days)	Days taken to last harvesting (days)	Pod length (cm)	Number of pods/plant	Yield/Plant (g)	Individual pod weight (g)	Plot Yield (Kg/4.5 m ²)	Yield (t/ha)
Inorganic source								
I ₁	53.14	72.62	41.68	19.72	126.94	11.06	4.94	8.79
I ₂	53.63	73.09	43.40	20.38	173.23	13.03	6.77	12.04
I ₃	54.05	73.53	44.54	24.69	216.61	14.35	8.52	15.17
S. Em (±)	0.21	0.20	0.40	0.19	1.08	0.16	0.05	0.10
CD	0.59	0.58	1.12	0.53	3.05	0.45	0.15	0.27
Organic source								
O ₁	53.32	72.88	42.45	20.84	153.37	12.19	5.98	10.64
O ₂	53.59	73.07	43.08	21.24	165.86	12.69	6.48	11.51
O ₃	53.63	73.06	43.30	21.11	168.36	13.13	6.59	11.71
O ₄	53.93	73.30	43.89	23.97	197.40	12.54	7.74	13.73
O ₅	54.01	73.47	44.25	23.98	211.44	13.50	8.31	14.77
O ₆	53.73	73.25	43.65	22.29	190.10	13.61	7.45	13.28
O ₇	53.04	72.54	41.81	17.75	119.28	12.04	4.67	8.30
S. Em (±)	0.32	0.31	0.61	0.29	1.66	0.24	0.08	0.15
CD	0.91	0.88	1.71	0.82	4.66	0.69	0.23	0.41

Table 3. Effect of various levels of inorganic and organic nutrient sources on quality, residual of nutrient and nutrient uptake of cowpea (pooled value)

Treatment	Beta carotene (IU/100 g fresh)	Ascorbic acid (mg/100g fresh)	Pod protein (per cent)	Residual soil nitrogen (kg/ha)	Residual soil phosphorus (kg/ha)	Residual soil potassium (kg/ha)	Nitrogen uptake (kg/ha)	Phosphorus uptake (kg/ha)	Potassium uptake (kg/ha)
Inorganic source									
I ₁	852.25	19.15	4.48	171.48	40.87	108.90	54.22	19.01	83.19
I ₂	884.25	19.66	4.67	174.79	47.23	124.27	72.35	29.73	101.65
I ₃	933.50	20.05	4.84	179.36	51.56	134.99	85.11	36.08	117.47
S. Em (±)	7.91	0.14	0.01	0.71	0.34	0.66	0.67	0.23	1.00
CD	22.25	0.38	0.03	2.01	0.94	1.85	1.90	0.63	2.82
Organic source									
O ₁	880.15	19.42	4.60	196.37	46.78	129.99	64.19	25.61	93.89
O ₂	878.35	19.62	4.72	169.00	45.04	126.26	71.61	28.20	100.63
O ₃	896.65	19.58	4.68	176.21	45.42	127.21	73.06	29.07	104.02
O ₄	886.20	19.87	4.71	182.55	51.70	125.37	68.89	26.78	98.09
O ₅	902.55	20.07	4.77	165.85	50.22	119.89	76.27	30.53	106.79
O ₆	911.30	19.69	4.72	172.27	50.58	125.56	78.68	33.53	110.89
O ₇	874.55	19.11	4.44	157.85	36.12	104.76	61.23	24.18	91.06
S. Em (±)	12.08	0.21	0.02	1.09	0.51	1.01	1.03	0.34	1.53
CD	33.98	0.58	0.05	3.07	1.44	2.83	2.90	0.97	4.31

unavailable potassium into a form that is accessible in the soil solution.

Effect of integrated nutrient management on nutrient uptake of chickpea under conservation agriculture

The treatment I₃ (150 percent RDF) demonstrated the highest uptake of nitrogen, potassium and phosphorus in cowpea, with values of 85.11 kg/ha, 117.47 kg/ha and 36.08 kg/ha, respectively, followed by I₂ (100 % RDF) and I₁ (50 % RDF). Previous researchers reported that 100 % RDF significantly increase the uptake of nitrogen, phosphorous and potassium (20).

Among the treatments that utilized organic sources and biofertilizers for nutrient supply, the treatment O₆ (FYM @ 7.5 t/ha + vermicompost @ 2.5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds) recorded the maximum nitrogen uptake (78.68 kg/ha). The application of vermicompost along with *Rhizobium* and *Pseudomonas* may have contributed to increased nitrogen availability, leading to enhanced root enzymatic activities and resulting in greater root vigour and density due to nitrogen fixation, which ultimately improved nitrogen uptake. With regards to the phosphorus and potassium, uptake was elevated under the treatment O₆ (FYM @ 7.5 t/ha + vermicompost @ 2.5 t/ha + PSB @ 10

g/kg of seed + *Rhizobium* @ 10 g/kg of seeds). While its uptake scaled down in the cowpea growing without organic and biofertilizer (O₇).

Economics of cultivation

From the economic evaluation of fresh pod production (Table 4) it is evident that the highest net return (₹ 259251) was recorded in the treatment combination I₃O₅ (150 % RDF + vermicompost @ 5t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10g /kg of seeds). The economics of cultivation of cowpea the treatment I₃O₄ combination of 150 % RDF + FYM @ 15 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds (B: C ratio 3.04) could be suitable for the terai region of West Bengal.

Conclusion

Based on the current study, it can be concluded that treatment I₃ (150 % RDF) outperformed the other two levels of inorganic treatments regarding all growth, yield and quality attributes. In other hand, the organic sources the treatment O₅ (vermicompost @ 5 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds) was the best performed in growth parameters viz. vine length, root dry weight, nodule dry weight, number of nodules per plant, yield

Table 4. Economic evaluation of fresh cowpea production

Treatments	Cost of cultivation (Rs. /ha)	Gross return (Rs. /ha)	Net return (Rs. /ha)	B:C Ratio
I ₁ O ₁	77683	138600	60917	0.78
I ₁ O ₂	87683	151400	63717	0.73
I ₁ O ₃	82683	171200	88517	1.07
I ₁ O ₄	78183	212800	134617	1.72
I ₁ O ₅	88183	233200	145017	1.64
I ₁ O ₆	83183	197800	114617	1.38
I ₁ O ₇	62183	125400	63217	1.02
I ₂ O ₁	80866	217600	136734	1.69
I ₂ O ₂	90866	237400	146534	1.61
I ₂ O ₃	85866	235200	149334	1.74
I ₂ O ₄	81366	271400	190034	2.34
I ₂ O ₅	91366	299400	208034	2.28
I ₂ O ₆	86366	259000	172634	2.00
I ₂ O ₇	65366	165000	99634	1.52
I ₃ O ₁	84049	281800	197751	2.35
I ₃ O ₂	94049	302000	207951	2.21
I ₃ O ₃	89049	296000	206951	2.32
I ₃ O ₄	84549	341200	256651	3.04
I ₃ O ₅	94549	353800	259251	2.74
I ₃ O ₆	89549	337600	248051	2.77
I ₃ O ₇	68549	208000	139451	2.03

parameters viz. pod length, fruit yield per plant, pod yield per hectare and quality parameters viz. protein and ascorbic acid. The economics of cultivation of cowpea the treatment I_3O_4 combination of 150% Recommended Dose of Fertilizer + FYM @ 15 t/ha + PSB @ 10 g/kg of seed + *Rhizobium* @ 10 g/kg of seeds (B: C ratio 3.04) could be suitable for the terai region of West Bengal.

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Authors' contributions

DM conducted the fieldwork and prepared the manuscript. SD performed the data analysis and AS reviewed and corrected the manuscript. All authors read and approved the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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