Chapter 7

# Role of Organic Sources of Nutrients in Rice (*Oryza sativa*) Based on High Value Cropping Sequence

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Additional information is available at the end of the chapter

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**Abstract**

The organic nitrogen (N) nutrition of organic manuring with biofertilizers had the highest rice equivalent grain yield, production efficiency, net energy return, as well as net monetary return and profitability in rice-based cropping sequence. The different rice-based cropping sequences did not differ with respect to yield and quality parameters. However, the organic N nutrition with organic manures along with biofertilizers proved significantly superior with respect to yield and quality parameters of rice, potato, and onion, respectively. The different rice-based cropping sequences differ with respect to nutrient uptake, e.g., rice-maize-onion had the highest removal of major (N, P, K), secondary (S), and micronutrients (Zn, Fe, Mn, Cu) than the rest of cropping sequence, which was significantly superior to the rest of the sequences. The organic N nutrition with organic manures along with biofertilizers proved superior due to its visible favorable effect on soil health with respect to nutrient status and microbial count and this indicates the utilization of this low-cost but long-term beneficial practice under high-intensity cropping for sustainable crop production.

**Keywords:** Biofertilizers, organic farming, high value crops, cropping sequence

## 1. Introduction

Organic farming is a production system that avoids or largely excludes the use of synthetic fertilizers, pesticides, growth regulators, and livestock feed additives. The objectives of environmental, social, and economic sustainability are the basics of organic farming.

The maintenance of good soil fertility is essential for sustainable crop production, which requires the regular use of organic sources of nutrient-like organic manure and biofertilizers to keep the farm income higher of the farming community. Organic agriculture is a holistic production management system, which promotes sustainable agriculture and enhances agro ecosystem health, including biodiversity, biological cycle, and soil biological activity. The organic farming practices on scientific principles are as productive as the conventional system. Organic systems showed greater soil health benefits reduced cost on production, are found better than inorganic practices, and enhanced profit margin with quality food. Interestingly, while exports of organic commodity are growing, domestic market demand is galloping for high-value crop produce, supports from government are increasing and innovation system support has started to grow. In such situation, it is necessary to develop suitable technology for meeting the challenges of the coming generation by providing good quality produce without deteriorating the socio-economic conditions of the farmer and with minimum environmental pollution. The farmers of ancient India adhered to the natural laws and this helped in maintaining the soil fertility over a relatively longer period of time [1]. These organic sources, besides supplying N, P, K, also make unavailable sources of elemental nitrogen, bound phosphates, micronutrients, and decomposed plant residues into available form in order to facilitate the plants to absorb the nutrients. Organic cultivation practices are very effective to improve the population of beneficial microorganisms in the soil having direct effect on enhancing the availability of macronutrients and micronutrients through correcting the deficiency induced by the conventional practices with the application of synthetic fertilizers, and consequently capable of sustaining high crop productivity and soil biological properties by modification of the soil environment [2].

The farmers can in turn, get good remuneration from the organically produced crops and vegetables if included in high-value crop sequences, e.g., aromatic rice–table pea and onion [3] due to their heavy demands in domestic, national, as well as international markets that may help the country in earning some foreign exchange. Therefore, a book chapter entitled "Role of organic sources of nutrient in rice (*Oryza sativa*) based on high value cropping sequence" was planned and executed with the following objectives:

1. To identify potential high-value cropping sequence suitable for irrigated ecosystem;
2. To study the effect of organic nitrogen sources on yield and quality of crop produce;
3. To study the effect of organic nitrogen sources on nutrient acquisition by the sequence.

## 2. Experimental details

### 2.1. Treatment details

#### *2.1.1. Main plot: Cropping sequences (7)*

- Sequence-1: Rice-Potato-Onion
- Sequence-2: Rice-Green Pea-Onion
- Sequence-3: Rice-Potato-Cowpea (Green Pod)
- Sequence-4: Rice- Green Pea -Cowpea (Green Pod)

- Sequence-5: Rice-Rajmash (Green Pod)-Onion
- Sequence-6: Rice-Rajmash (Green Pod)-Cowpea (Green Pod)
- Sequence-7: Rice-Maize (Green Cob)-Cowpea (Vegetable)

*2.1.2. Sub plot: Manurial treatments (3)*

- Control (without organic manures)
- 100% RDN through organic manures as 1/3 FYM + 1/3 Poultry Manure (PM) + 1/3 Vermicompost
- 100% RDN through organic manures as 1/3 FYM + 1/3 Poultry Manure (PM) + 1/3 Vermicompost + Azotobacter + PSB

| Crop | Variety | Seed rate (kg ha$^{-1}$) | Spacing (cm) |
|---|---|---|---|
| **Rainy season** | | | |
| Rice | HUBR 2-1 | 40 kg | 20 x 15 |
| **Winter season** | | | |
| Maize (Green Cob) | Pioneer Hybrid | 20 kg | 60 x 20 |
| Green Pea | Early Apoorva | 80 kg | 30 x 10 |
| Rajmash | HUR-137 | 80 kg | 30 x 10 |
| Potato | Kufri Badshah | 2,000 kg | 50 x 25 |
| **Summer season** | | | |
| Onion | Agrifound Light Red | 10 kg | 20 x 15 |
| Cowpea | Tokito Hybrid | 10 kg | 50 x 20 |

**Table 1.** Details of the variety of hybrid seed rate and spacing of different crops.

## 3. Rainy season (rice)

### 3.1. Field preparations

Proper field preparation and timely planting are essential for good crop yield. These factors influence the soil's physical property, particularly soil moisture, aeration, and plant nutrient availability. With a view to have good experimental unit for planting, initial ploughing was done by a soil turning plough followed by disking. The seed beds were properly prepared as per crop requirements before planting various crops.

### 3.2. Raising rice nursery

A well-drained fertile land having good irrigation facility was selected for raising rice seedlings. The nursery plot was ploughed twice and puddled in standing water to convert the upper layer of soil into fine soft mud. The field was leveled properly and 10 x 1.5 $m^2$ beds were prepared. A requisite amount of 36 kg organic manure was applied to each nursery of 15 $m^2$. Healthy, genuine, certified, and sprouted seeds at 40 kg per ha were properly spread, keeping a thin water film for a week. The seedbed was irrigated to maintain shallow, submerged rice.

### 3.3. Field preparation for transplanting

Proper field preparation is essential for a healthy rice crop. The experimental area was ploughed with a tractor during the summer and ploughed twice again before rice transplanting. Thereafter, the field was puddled with the cultivator. Finally, the field was laid out to meet the requirements of the experimental design. The field was puddled thoroughly, and four-week-old seedlings were transplanted at 3 seedlings per hill in rows 20 cm apart with hill to hill distance of 10 cm. As per treatment, full recommended doses of all the manures were applied just before transplanting. Irrigations were given to the crop at 16, 30, 18, and 32 DAT during the two years of experimentation. Two hand weedings were done at 26 and 65 DAT during both the years of experimentation. Except minor appearances of gundhi bugs, no major pests or diseases appeared. Hence, even bio-insecticides were not used due to the negligible impact of the gundhi bugs. Rice plants were harvested at physiological maturity of the crop after 108 DAT during the first and 109 DAT in the second year of experimentation. First of all, the border rows were harvested, bundled, and removed from the plots. Thereafter, the experimental rows from the net plot area were harvested. Plot wise harvested materials were carefully bundled, tagged, and taken to the threshing floor. Each bundle was weighed after complete sun drying and threshing. The grain yield was recorded separately after winnowing and cleaning. The straw yields was calculated by subtracting grain yield from the bundle weight and were converted to kg per ha based on net plot size harvest.

### 3.4. Biometric observations of rice

For recording biometric observations at different stages of crop growth, four hills in the net plot area were randomly selected and tagged. However, for the dry matter production, four hills were randomly selected from the sample rows (border rows) at different growth stages. The plants were then tagged and brought to the laboratory for the study. Four biometric observations were recorded at 30 DAT (tillering stage), 60 DAT (late jointing stage) and at harvest during both years. The plant samples collected randomly from the border row of the field were kept in an oven at 60°C till the constant weight arrived for determining the dry matter production per unit area. The panicle-bearing tillers were counted from the one square meter marked area after full anthesis. Ten panicles were randomly selected from tagged plants and the length was measured from the neck node to the tip of the upper most spikelet and average length was recorded. Ten randomly selected panicles were weighed and averaged to record per panicle weight. The filled grain of each of the ten panicles from each plot were counted and averaged. Grain samples were taken from the threshed and cleaned produce of each net plot and 1,000 grains were counted and weighed. Grain yield was recorded (kg $plot^{-1}$) after threshing, winnowing, cleaning, and drying. Thereafter, it was computed to kg per ha.

The difference of the bundle weight and grain yield gave the straw yield (kg plot$^{-1}$). Thereafter, it was computed to kg per ha.

## 4. Winter season

### 4.1. Field preparation

During the winter season, potato, green pea, rajmash, and maize are grown. The following packages of practices were adopted for these crops. Field preparation operations were common for all the *rabi* season crops. As a general rule, these crops require a well pulverized but compact seedbed for good and uniform germination. To avoid the mixing of soil under treatments, the individual plot was ploughed thrice by power tiller at proper tilth and finally the planking was done.

### 4.2. Weed management

During both years of experimentation, the weeding was done using a hand rotary weeder during the beginning of the first appearance of a thick flush of weed, e.g., 25 days after sowing followed by a second weeding at 45–50 days after sowing. The first weeding was done after recording observations for weed flora. However, to the wheat crop, only one weeding was given.

### 4.3. Irrigation

In both years of the experiment, irrigation was given according to the requirements of the different crops as per the schedule. In all, one irrigation was given to lentil, pea, and chickpea, two irrigations to mustard, three irrigations to potato and wheat, and as much as four irrigations was given to maize. Only minor appearances of pests or diseases occurred. Hence, even bio-insecticides were not used due to the negligible impact of the insect pests and diseases.

### 4.4. Harvesting

In general, all the crops were harvested by serrated edge sickle manually at the maturity of the respective crops. However, in case of potatoes, tubers were dug out at maturity. In green peas, two to three pickings of green pods were done; whereas, the green cobs of maize were harvested at the milky stage of the grains. Haulms of pea and maize stover were used as cattle fodder. In all the crops, the border rows and 0.5 m either side of plot rows were harvested and removed around the individual plots leaving only the net plot area. The harvesting of each net plot area was done separately and the harvested material from each plot was carefully bundled, tagged, and taken to the threshing floor and kept individually for sun drying.

### 4.5. Threshing

Each bundle was weighed after proper sun drying and then threshed individually. The grain/seed/pod/tuber yield of different crops were weighed and recorded separately after winnowing and cleaning. The straw stover yield were calculated/recorded separately and converted to q ha$^{-1}$ based on the net plot size harvest.

## 5. Summer season

### 5.1. Field preparation

Onions and cowpeas were taken during summer season in different cropping sequences. Field preparatory operations were common for all summer season crops. After the harvesting of winter season crops in different sequences, pre-sown irrigation was given and individual plots were tilled thrice with a power tiller at proper tilth and finally planking was done.

### 5.2. Raising of onion seedling

Seeds of Agrifound light red variety were used. The seeds used for the nursery had more than 80% germination. The nursery beds (4 m x 2.6 m) were prepared carefully by incorporating sufficient quantity of well-rotten farm yard manure (20 kg bed$^{-1}$). Seeds were sown on the bed at 52 g per bed. After sowing, beds were given light and frequent water application through a water cane at the beginning to maintain moisture for seedling growth. Two light irrigations were also given at sowing and 10 DAS to maintain the growth of a thin layer of FYM was given to cover the seeds. The beds were covered with a thin layer of paddy straw on the same day to maintain congenial moisture and temperature condition. The paddy straw was removed after seed germination (10 DAS). Seedlings were transplanted at 60 DAS on 26.02.04 during the first year and 20.02.05 during the second year. However, cowpea seeds were treated with *Rhizobium* culture to improve the nitrogen fixation capacity before sowing the crop. Details of crop varieties used, seed rate, and spacing are given in Table 1.

### 5.3. Weed management

During both years of the experimentation, one weeding was done in the inter-row spaces by hand rotary weeder at 20 days after sowing and the weeds on the crop rows were removed manually.

## 6. Qualitative character of rice-based cropping sequence

### 6.1. Hulling of rice (%)

Two hundred grams of rice grains after threshing, winnowing, cleaning, and drying were taken for dehusking, and the brown rice thus obtained was weighed and then hulling (%) was calculated by the following formula:

$$\text{Hulling}\,(\%) = \frac{\text{Brown rice obtained after threshing (g)}}{\text{Total rice grain taken for dehusking (g)}} \times 100$$

### 6.2. Milling of rice (%)

One hundred grams of brown rice obtained after hulling was taken and kept for polishing by removing rice bran, embryo, and alurone layer and polished white kernels were thus obtained using the following formula:

$$\text{Milling}\,(\%) = \frac{\text{White polished kernels obtained (g)}}{\text{Brown rice taken for polished (g)}} \times 100$$

### 6.3. Head rice recovery (%)

Total white polished rice obtained after milling was taken and whole white kernels were separated, weighed and the percentage was calculated using the formula:

$$\text{Head Rice Recovery}\,(\%) = \frac{\text{Whole white kernels obtained (g)}}{\text{White polished kernels obtained after milling (g)}} \times 100$$

### 6.4. Shelling of maize (%)

Five randomly selected cobs were weighed and grains were separated and weighed. The shelling percentage was calculated by using the following formula:

$$\text{Shelling}\,(\%) = \frac{\text{Weight of kernels per cob (g)}}{\text{Weight of cob (g)}} \times 100$$

### 6.5. Protein content of each crop (%)

The protein content (%) in the grains was worked by multiplying the nitrogen content in grain by the factor 6.25 (A. O. A. C., 1960).

### 6.6. Protein yield

The protein yield (kg $ha^{-1}$) was obtained by the following formula:

$$\text{Protein Yield}\,(\text{kg/ha}) = \frac{\text{Protein content per cent } \times \text{Yield (kg/ha)}}{100}$$

### 6.7. Starch content of potato (%)

It was extracted and determined according to Carillo et al (2005).

**Pungency estimation of allyl-propyl-disulphide onion:** Allyl-propyl-disulphide content in the onion bulb was determined as Pyruvic acid (Hort and Fisher, 1970) using the following relationships:

$$\text{Pyruvate content}=\frac{\begin{array}{c}\text{Pyruvate content from}\\ \text{standard curve }(\mu\text{ mol})\end{array}}{\begin{array}{c}\text{Alliquat of test control solution}\\ \text{taken color development }(\text{ml})\end{array}}\times\frac{\begin{array}{c}\text{Total volume of soln.}\\ \text{of sample made }(\text{ml})\end{array}}{\begin{array}{c}\text{Wt of sample}\\ \text{taken for assay }(\text{g})\end{array}}$$

**Carbohydrate content (%):** It was determined by the method described by Loomis and Shull (1937).

**Nutrient content:** The seed and plant samples at harvest were used for chemical analysis of N, P, and K contents. The plants and seeds were dried in an oven and grained thoroughly in a wily mill to pass through a 30-mesh sieve. These were presented in labeled polythene bag for chemical analysis.

**Total nitrogen:** The total nitrogen was analyzed at harvest. The N content in seeds was also analyzed separately. Alkaline permanganate method [4] was employed for their estimation.

**Total phosphorous:** Total phosphorus was estimated during the harvest of the crop 0.05 M $NaHCO_3$ using Barten's reagent was employed for this purpose.

**Total potassium:** Total potassium was determined with the help of a flame photometer [5] during the harvest of both seed and straw.

**Micronutrient:** Micronutrient was determined with the help of an atomic absorption sector-photometer at the time of harvesting of both seed and straw.

**Nutrient uptake:** Nutrient uptake in grain (seed/bulb) and straw/haulm of the crops were calculated in kg/ha in relation to yield by using the following formula:

$$\text{Nutrient Uptake (kg/ha)}=\frac{\text{Nutrient content (\%)}\times\text{Yield (kg/ha)}}{100}$$

## 7. System study

**Equivalent yield:** Rice equivalent as well as system productivity were worked out by converting the yields of crops into rice equivalent, taking the help of price values used for the calculation of the economics. The productivity of cropping sequence was converted into rice equivalent yield using the formula:

$$\text{Rice Eq.Yield (kg/ha)} = \frac{\text{Productivity of component (kg/ha)} \times \text{Price of component (Rs/kg)}}{\text{Cost of Rice (Rs/kg)}}$$

Equivalent yields of potato and onion were also calculated as same manner as fallow in calculating rice equivalent yield.

**Production efficiency of the system (PES):** Production efficiency of the system was calculated by dividing the equivalent yield of rice in a sequence through 365.

$$\text{PES (kg/ha/day)} = \frac{\text{Rice equivalent yield of the system (kg/ha) in a year}}{365}$$

**Nutrient uptake in the system:** Nutrient uptake in the system was worked out by making a sum of nutrient uptake of a sequence.

**Economic analysis**

**a.** Cost of cultivation: The cost of cultivation of various sequences was worked out based on the most recent standard rate of materials.

**b.** Gross return: The yield of different component crops in the sequence were converted into gross return in rupees based on the current market price.

**c.** Net return: Net return for each crop sequence was calculated by deducting the cost of cultivation from the gross return.

Cost of cultivation, gross return, and net return under different treatments were worked out on the basis of prevailing cost of different inputs. Power and labor for different operations were calculated on a per hectare basis as per normal rates prevalent in the country. The costs of other inputs were considered as per market price. The total gross return was taken as the total income received from the produce of economic and stover yield. Net return was calculated with the help of following formula:

Net Return = Gross Return - Cost of Cultivation

**Energy equivalent:** The total energy return of the system was obtained by the conversion of economic yield of the sequence into energy equivalent; whereas, the net energy return was worked out by deducting total input involved in the sequence in energy term from the total energy return. The energy output: input ratio and energy productivity were obtained as follows:

$$\text{Energy Output: Input Ratio}=\frac{\text{Total energy return}}{\text{Total input involved in terms of energy}}$$

The various practices involved in crop production and economic yield of component crops in the sequences were converted into the equivalent value of chemical energy (MJ/ha). For these conversions, standard values as given by [6] were used (Table 2).

| S. No. | Particulars | Units | Equivalent energy (MJ/ha) |
|---|---|---|---|
| **Input** | | | |
| 1. | Human labor | | |
| | Adult men | Man hours | 1.96 |
| | Women | Woman hours | 1.57 |
| 2. | Diesel | Liter | 56.31 |
| 3. | Electricity | KWH | 11.93 |
| 4. | Chemical fertilizer | | |
| | (a) Nitrogen | Kg | 60.6 |
| | (b) $P_2O_5$ | Kg | 11.1 |
| | (c) $K_2O$ | Kg | 6.7 |
| 5. | Plant protection (Superior) | | |
| | Granulated chemical | Kg | 120 |
| | Liquid chemical | ml | 0.102 |
| 6. | Seeds | | |
| | Potato | Kg | 4.06 |
| | Rice, maize | Kg | 14.7 |
| | Onion | Kg | 15.8 |
| | Cowpea, pea, rajmash | Kg | 14.7 |
| **Output** | | | |
| 1. | Rice | Kg (dry mass) | 14.7 |
| | Cowpea, table pea, rajmash | Kg (pod) | 3.89 |
| 2. | Onion | Kg (bulb) | 2.60 |
| 3. | Potato | Kg (tuber) | 4.06 |
| 4. | Maize | Kg (green cob) | 4.41 |

**Table 2.** Energy coefficients.

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## 8. Effects of organic sources in rice based on cropping sequence

### 8.1. Effect of weather in crops

Plants growing in natural environment are often prevented from expressing their full genetic potential for production as they are subjected to various biotic and abiotic stresses. Environmental factors are relatively more dynamic in determining the extent of growth and development of plants and play major roles in the completion of the plant life cycle. Every crop requires a definite set of environmental conditions for its proper growth and development. Matching the crop phenology to the climatic environment prevailing during the growing season is an important aspect to maximize genetic yield potential.

### 8.2. Economic yield of rice

In organic nitrogen sources, the application of 100% RDN through organic manure along with biofertilizers recorded the highest grain yield during both years of investigation. This might be due to better availability of nutrients through superimposition of organic manure along with biofertilizers. It was also observed that plants were well supplied with nitrogen, senescence of flag leaf was delayed, and respiratory losses were low. Potassium also had expressed, in addition of $CO_2$ assimilation rates, resulting in more supply of photosynthates along with micronutrients responsible for the effective translocation of photosynthates that probably accounted for the highest economic yield. In addition to these, *Azotobacter* produced growth promoting substances that improved seed germination and growth with extended root systems. It also produced polysaccharides that improved soil aggregation; whereas, PSB in the rhizosphere of rice rendered insoluble soil phosphate available to plants due to their production and secretion of organic acids, as well as due to the release of sufficient amounts of nitrogen by mineralization at a constant level, which in turn resulted in better crop growth and improvement in various yield components of rice.

### 8.3. Potato equivalent yield of winter season crops

The maximum potato equivalent yield was recorded under the sequence rice-potato-cowpea (green pod). It may be emphasized here that PEY of crops is the function of market price along with the yield of a particular crop. The potato itself produced higher economic yield and this is accompanied with better market value as a result of potato equivalent yield that were higher as compared to other sequences. Further nitrogen application through organic manures significantly augmented the potato equivalent yield due to the continuous raising of organic potato bio-dynamically on the same site, which improved tuber production by enriching soil fertility.

### 8.4. Onion equivalent yield of summer season crops

The maximum onion equivalent yield was recorded under the sequence rice-green pea-onion. The onion itself produced higher economic yield due to the inclusion of legume as a previous crop and this accompanied with better market value as a result of onion equivalent yield that were higher compared to other sequences. Further nitrogen application through organic manures significantly augmented the onion equivalent yield, which was due favorable growth and yield of onion crop.

## 9. Effect on quality parameters

### 9.1. Rice

The application of organic nitrogen also influenced protein content and protein yield due to the increase in the concentration of nitrogen in grains, which might have modified the proportion of grain constituents. The higher uptake of nutrients, particularly nitrogen, in the organic nitrogen treatments was probably responsible for the higher grain protein. Accumulation of protein in seeds may also be increased due to the continuous nitrogen supply and its translocation in seed buds and optimal nutrition. It is known that protein content imparts strength to the grain; higher protein content thus resulted in higher head rice recovery.

### 9.2. Potato

Amongst various nitrogen substitution treatments, maximum starch content was recorded under organic sources of nitrogen along with biofertilizers, especially due to higher concentration of potassium in poultry manure, which might have modified the proportion of tubers constituents with respect to starch.

### 9.3. Onion

Application of organic nitrogen significantly increased the allyl-propyl-disulphide and carbohydrate content (%) in onion bulbs might be due to increased volatile fatty oil content resulting in significantly higher production of allyl-propyl-disulphide in onion bulbs. Increased allyl-propyl-disulphide content with increasing organic nitrogen application was in close agreement with findings of [7, 8].

## 10. System analysis

### 10.1. Rice Grain Equivalent Yield (RGEY)

The maximum RGEY was recorded under the sequence rice-potato-onion. The higher production potential of potato and onion and better market prices were instrumental for attaining higher REY by this sequence [9, 10]. Rice equivalent yield is directly associated with the yield of respective crops in the sequence and so organic manure alone or along with biofertilizers enhanced the yield potential of crops, which ultimately increased the rice equivalent yield of the sequence.

### 10.2. Production efficiency

The sequence rice-potato-onion had recorded maximum production efficiency compared to the rest of the treatments and this was due to the better market price of potato and onion in the sequence [11]. Organic manures along with bio-fertilizers recorded the significantly highest production efficiency of the system and this was due to the highest rice grain equivalent yield of crops in the system.

### 10.3. Energetics

The maximum energy input was recorded in the rice-potato-onion sequence. The energy consumed by the potato through fertilizer, seeds, and human labor and that of the onion for irrigation (electricity) and inter-culture operations resulted in higher energy input. The energy involved in N fertilizer was particularly higher in sequences involving potato and onion, which relatively consumed a large proportion of energy in seeds. The pooled data indicated that the maximum gross energy output, net energy return, and employment generation was obtained in the rice-potato-onion sequence. This clearly exhibited that besides having more energy input, this sequence also produced the highest energy equivalent, resulting into maximum gross energy output, net energy return, and employment generation [12]. In general, the gross energy output, net energy return, and employment generation of the system remained comparatively higher during the second year than that of the first year. Application of nitrogen through organic manures along with bio-fertilizers recorded maximum average energy input, gross energy output, net energy return, and employment generation of the system because this sequence was more input intensive as well as had the highest productivity level.

### 10.4. Economics

Data related to economics as affected by various cropping sequences and organic nitrogen treatments of two years of experimentation are presented. The maximum cost of cultivation, gross return, net return, and profitability was recorded under the sequence rice-potato-onion, which was significantly higher than that of the other sequences. This was mainly due to the higher production potential of potato, accompanied with good monetary return from the onion. The highest values of cost of cultivation, gross return, net return, and profitability were associated with the application of nitrogen through organic manures along with biofertilizers. This was mainly due to higher productivity without a proportionate increase in the cost of cultivation.

### 10.5. Nutrient uptake

Nutrient uptake by different cropping sequences is the function of crop yield and nutrient content. The increase in these factors was responsible for the increased nutrient uptake during both years of experimentation of the system, which was at the maximum under the rice-cowpea-maize sequence. This was significantly superior to the rest of the sequences in this respect, which could be a higher productivity potential of maize ascribed to the increase in the available nitrogen, phosphorus, potassium, sulfur, zinc, iron, copper, and manganese contents in the soil resulting from the increased availability of nutrients through organic sources particularly through organic manure along with biofertilizers.

### 10.6. Soil fertility status

Data on the nutrient status of soil organic carbon, major (nitrogen, phosphorus potassium), secondary (sulfur), and micronutrients (zinc, iron, copper, and manganese), recorded maximum improvement, in this respect, was observed where pulse crops were incorporated in the sequence. Application of either organic manure alone or with biofertilizers significantly improved the soil status with respect to organic carbon and nutrients under study. It is quite obvious that this might have added greater organic sources and biofertilizer to the soil, ultimately improving the soil's organic carbon. Similarly, [13] also reported that 100% nitrogen (1/3 each from cow dung manure, neem cake, and composed crop residue) appreciably increased the organic carbon (6.3 g $kg^{-1}$) over the initial value (5.8 g $kg^{-1}$).

### 10.7. Soil health

The application of organic manure along with biofertilizer significantly improved soil pH, as well as electrical conductivity was associated with the decline in soil reaction might be due to organic compounds added to the soil in the form of organic manure and biofertilizer that produced more humus and organic acids in decomposition. The role of organics is attributed to the supply of essential nutrients by the continuous mineralization of organic manures, nutrient supplying capacity of the soil, and its favorable effect in the soil's biological (bacteria, actinomycetes and fungi) properties [14,15]

## 11. Conclusion

1. The inclusion, of the two high-value vegetable crops in sequence having 300%, rice-potato-onion had the highest rice equivalent grain yield, production efficiency, net energy return, as well as net monetary return and profitability. However, the best benefit ratio was highest in the sequence rice-potato-cowpea (green pod). Thus, rice-potato-onion was observed as the most intensive, stable, and profitable high-value cropping sequence for irrigated ecosystems.
2. The organic N nutrition of organic manuring with biofertilizers had the highest rice equivalent grain yield, production efficiency, net energy return, as well as net monetary return and profitability on rice-based cropping sequence.
3. The different cropping sequences of rice did not differ with respect to yield and quality parameters. However, the organic N nutrition with organic manures along with biofertilizers proved significantly superior with respect to the yield and quality parameters of rice, potato, and onion.
4. The different cropping sequences of rice differ with respect to nutrient uptake, i.e., rice-maize-onion had the highest removal of major (N, P, K), secondary (S), and micronutrients

(Zn, Fe, Mn, Cu) than the rest of the cropping sequences and was significantly superior to rest of the sequences.

**5.** The organic N nutrition with organic manures along with biofertilizers had the highest nutrient acquisition of major (N, P, K), secondary (S), and micronutrients (Zn, Fe, Mn, Cu).

**6.** The different cropping sequences of rice did not differ with respect to nutrient status as well as microbial count. However, inclusion of pulses in sequences showed positive improvement on soil health and the effect can be quite effective and visible on a long term basis.

**7.** The organic N nutrition with organic manures along with biofertilizers proved superior due to its visible favorable effect on soil health with respect to nutrient status and microbial count and this indicates the utilization of this low-cost but long-term beneficial practice under high intensity cropping for sustainable crop production.

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