Uttar Pradesh Journal of Zoology

Volume 44, Issue 21, Page 216-226, 2023; Article no.UPJOZ.2862
ISSN: 0256-971X (P)

Effect of Intercropping Farming and Vermicompost System on the Nutritional Quality and Yield of Rice and Pigeonpea

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Authors' contributions

This work was carried out in collaboration between both authors. Author MR did the experimental design, manuscript writing, and data analysis. Author SK did the conceptualization, data analysis, review, editing and visualization Both authors read and approved the final manuscript.

Article Information

DOI: 10.56557/UPJOZ/2023/v44i213691

Editor(s):
(1) Prof. Telat Yanik, Atatürk University, Turkey.
Reviewers:
(1) Ir. Yunus Arifien MSi, Nusa Bangsa University, Indonesia.
(2) Darwin Pangaribuan, Universitas Lampung, Indonesia.

Original Research Article

Received: 25/07/2023
Accepted: 30/09/2023
Published: 06/10/2023

ABSTRACT

The present study explains the application of vermicompost during the cultivation of rice and pigeon pea in relay intercropping farming. This study examined vermicompost's effect on increasing yield and nutrient quality of rice and pigeon pea. In North India, Kharif crops were grown for three seasons from 2019 to 2021 in the intercropping farming system. The main crop (rice) was sown with pigeon peas (legumes) in July 2019 in rows and there were a total of 36 rows each of 6 m, of which nine rows were for rice having a distance of 70 cm between each row and pigeon peas each with a distance of 50 cm between each row and the other nine were for one row of rice and another of pigeon peas having a distance of 50 cm among them. Each type of crop was treated with control

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as urea and treated with vermicompost for analysis of results. The result of the study, exhibited significant increase in macro elements K & P in intercropping along with vermicompost (4320 mg/kg & 1100 mg/kg) as compared to control (4200 mg/kg& 910 mg/kg) as well as microelements Zn & Fe in treated (41.4 mg/kg & 65.6 mg/kg) as compared to control (38.2 mg/kg& 60.2 mg/kg) were found higher in vermicompost treated intercropping. Also, yield (18.01 kg/ha) and HI (Harvest Index) (0.82) were found more in intercropping treated with vermicompost as compared to conventional one treated with urea (14.23 kg/ha) and (0.62). Hence, vermicompost along with intercropping was found to be effective in increasing the yield and nutritional value of crops.

Keywords: Vermicompost; pigeon-pea; rice; intercropping; monocropping.

ABBREVIATIONS

HI : Harvest Index
ICP-OES : Inductive Coupled Plasma with Optical Emission Spectroscopy
NPK : Nitrogen Phosphorus Potassium

1. INTRODUCTION

The World population has been increasing at a faster rate since the last decade. This increases the urgent need for more amount of food [1]. In addition to this, the nutritional value of food in the diet is the main concern nowadays because of the overuse of different chemical fertilizers in farming systems. Moreover, these chemical fertilizers cause the emission of greenhouse gases and contamination of groundwater as well as surface water and also harm the environment [2,3]. So there is an urgent need to find a suitable alternative to chemical fertilizers.

Vermicompost is the best alternative to replace chemical fertilizers like urea [4]. According to Ramnarain et al. [5], vermicompost is a solid organic fertilizer produced by composting organic materials (e.g., animal manures) by using species of earthworms (Fig. 1). A research study conducted by Piya et al. [6] concluded that using vermicompost also improved soil and crop quality, yield, nutritional value, and growth. Epigenic earthworms mainly employed for vermicomposting are *Eisenia fetida, Eudrilus eugeniae, Perionyx excavates* and *Lumbricus rubellus* [7].

According to Nafziger [8], intercropping farming is the method of sowing two crops in the same field simultaneously, in which each crop is sown in a separate row so that there will be potential competition between the crops regarding nutrients, space utility, light, and water. Crop selections must be properly chosen to establish a mutually symbiotic relationship in intercropping. According to Notaris et al. [9], sowing time, sowing methods and proper seeding rate in

Fig. 1. Vermicompost with earthworms is useful in terms of degrading complex macromolecules in the soil to a simple form. Vermicompost contains a combination of different fertilizers the ratio of vermicompost used in this experiment contained 3.06% N, 2.6% P, and 1.05% K [12]

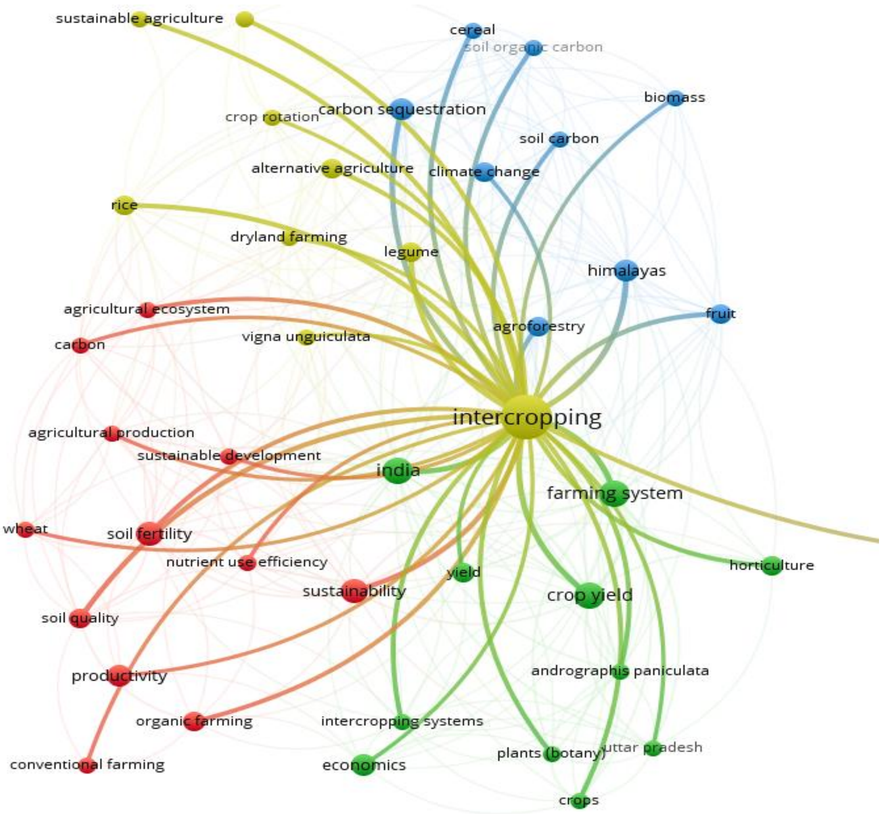


Fig. 2. Bubble map showing, publications of SCOPUS from 2019 to 2023 on intercropping farming has been defined in term of various keywords like yield, organic farming, conventional farming, crop rotation, etc. The size of each bubble defined the number of citations for those keywords in different journals. Two keywords are linked with each other with different colors in terms of correlation with intercropping

spring cereal-forage legume intercropping systems determine plant competition. Intercropping practices are generally done by combining both legume and non-legume-like cereal crops. It has been used to produce a higher yield than monocropping, for example, in maize soybean intercrop [10]. Also, vermicompost with intercropping is also a method of organic farming in a combined form. Because organic farming is a type of farming in which organic inputs are used to get maximum output.

According to a market analysis report that was published in September 2021, the food industry based on organic farming grew at an annual growth rate of 9.7 % in 2021 and it would grow further at a rate of 14.5% up to 2025 [11].

This research study determines the effects of vermicompost on the growth and yields of rice-pigeon pea intercropping as compared to monocropping as well as conventional intercropping with urea.

A bubble map of intercropping having a correlation with soil fertility, nutrient use efficiency, and organic farming has been described in (Fig. 2) [13].

2. MATERIALS AND METHODS

2.1 Site Description

During July 2019, two kharif crops summer rice (*Oryza sativa*) variety “PUSA Basmati Rice” were sown in intercropping with Pigeon-pea (*Cajanus cajan*) variety “Manak (H77-216)” at the site of North India at agroecological zone 6 (Trans Gangetic plane), Haryana, district-Jind, tehsil-Julana, village Karela (Fig. 3). The plot size was 144 m^2 (24 m X 6 m), and three replicates for each crop were used per treatment. The coordinates of the main experimental site are 29°

7’17.6664’’N and 76 ° 23’51.7920’’ E and an altitude of 223 meters above sea level (Fig. 3). The district Jind is mainly characterized by semi-arid weather conditions, hot in summer and cold in winter. Previous crops and soil properties were different because intercropping was not done on this field to date. For the experimental setup, the row length was kept at 6m for each type of crop (mono-cropping or intercropping) with or without vermicompost. For sole rice (SR) distance between two rows was 70 cm and for sole pigeon pea (SP) distance between two rows was 50 cm. The intercropping system of a single row of rice and pigeon peas with or without vermicompost named (S1), in which one row of pigeon peas intercropped with one row of rice and the row-to-row distance between rice and pigeon pea rows was 50 cm). All the experiments were done in triplicate. Vermicompost application in solid form as treated one was done in each row of mono as well as intercropping just after sowing and after 15 days of sowing, then after 1 month of sowing as this is the main fertilizer source. Along with this, urea and DAP (Diammonium phosphate) were also done in solid form as a control in the same manner as vermicompost so that a comparable analysis can be done with both types of crops.

Fig. 3. Intercropping field employed for rice and pigeon peas from 2019 to 2021

2.2 Chemical and Reagents

All the chemicals for analysis of analytical grade (HNO_3, H_2O_2) were procured from SRL (Sisco Research Laboratories, Mumbai, India). Vermicompost was purchased from Saini Fertilizer & Chemical Limited, Jind -126102, Haryana (India). The qualitative Filter paper was purchased from (Hi-Media, Mumbai India).

2.3 Yield and Harvest Index (HI):

After a certain time of maturation in August-September, harvesting of both crops was done manually from central rows of each experimental block with the help of a sickle. After that rice and pigeon pea plants were then dried for almost ten days. Then both crops dried rice and pigeon pea plants weighed and their total yield both in terms of monocropping as well as intercropping farming. At the same time, the seed yields of every plant were calculated and converted into kg/ha.

The yield of each crop was calculated by [14]:

Yield (Kg/ha): Total production/Total area

Harvest Index was calculated by Donald et al. [15]:

HI =Grain DW/Total DW

2.4 Analysis of Macroelements and Microelements

All macro and microelements of rice and pigeon pea in monocropping as well as intercropping with or without vermicompost treatment were measured with the help of ICP-OES (Agilent 7900) (Inductive coupled plasma with optical emission spectroscopy). The wet digestion method has been used for the analysis of nutritional value in different crops and vegetables [16]. The rice and pigeon-pea seeds were used for analysis and ground in a high-speed homogenizer. After this, a composite sample of 0.5 grams was weighed and put into a 25 ml volumetric flask. After that samples were digested with a reagent mixture of 65% HNO_3/30%H_2O_2 (7:1), first overnight at room temperature and after that in a water bath at a constant temperature (80℃) for 5 hours. Once all the samples were completely decomposed, all the materials samples were transferred to a volumetric flask of 50 ml. The final volume was increased to fill the line with deionized water. All the samples were then filtered through a quantitative filter paper with a pore size of 2-4μm. All sampling was done in triplicates. The results obtained are presented as mean $\pm$ standard deviation.

2.5 Statistical Analysis

The statistical analysis of all experiments was analyzed by ANOVA (Analysis of Variance) in Graph Pad Prism software and marked by different *P* values when significantly different (*P*=.05) with the help of Graph Pad Prism software. All graphs were plotted in Microsoft Excel.

3. RESULTS AND DISCUSSION

3.1 Harvest Index (HI) and Yield

3.1.1 Harvest index

The Harvest index of monocropping in control (Rice- 0.38 & Pigeonpea- 0.41) was compared to monocropping with vermicompost (Rice -0.47 & Pigeonpea pea-0.53). Further, an increase in harvest index was observed in intercropping along with vermicompost application (0.82) as compared to the control intercropping with urea and DAP treatment (0.62) in the final year of experiments of 2021 (Table 1).

Table 1. Harvest Index from 2019 to 2021 of monocropping and intercropping farming

HI	Monocropping (Rice)	Monocropping (Pigeonpea)	Intercropping (Control)	Intercropping (Vermicompost)
2019 (C)	0.25	0.29	0.42	0.45
(E)	0.29	0.33	0.49	0.50
2020 (C)	0.32	0.39	0.51	0.61
(E)	0.34	0.40	0.53	0.67
2021(C)	0.38	0.41	0.59	0.72
(E)	0.47	0.53	0.62	0.82

(C)- Control experiment with urea as a chemical fertilizer
(E) – Treated experiment with vermicompost as organic fertilizer

Table 2. Yield from 2019 to 2021 of monocropping and intercropping farming (kg/ha)

Yield	Monocropping (Rice)	Monocropping (Pigeonpea)	Intercropping (Control)	Intercropping (Vermicompost)
2019 (C)	11.21	9.45	10.02	10.98
(E)	12.23	10.21	11.20	11.28
2020 (C)	13.24	11.20	12.25	12.15
(E)	14.12	12.10	13.05	14.35
2021(C)	14.56	10.31	13.90	16.05
(E)	17.48	14.22	14.23	18.01

(C)- Control experiment with urea as a chemical fertilizer
(E) – Treated experiment with vermicompost as organic fertilizer

3.1.2 Yield

The yield was found to be higher in monocropping treated with vermicompost (Rice- 17.48 kg/ha, Pigeon pea - 14.22) as compared to control (Rice - 14.56 kg/ha, Pigeon-pea- 10.31 kg/ha). Similarly, the yield was higher in intercropping treated with vermicompost (18.01 kg/ha) as compared to the control (14.23 kg/ha) in the final year of the experiment (Table 2):

3.2 Macroelements and Microelements in Rice and Pigeon Pea

3.2.1 Macroelements

ICP-OES analysis of the crop (rice) and legume (pigeon pea) shows that the macroelements and microelements composition of both rice and pigeon pea increased in each year from 2019 to 2021 (Table 3) (Figs. 4 & 5). Macroelements Potassium (K), Phosphorus(P), Calcium (Ca), and Magnesium (Mg) and microelements Zinc (Zn), Iron (Fe), Copper (Cu), and Manganese (Mn) were analyzed. Application of vermicompost in rice monocropping resulted in an increase in macroelements (K-4270mg/kg, P-2610 mg/kg, Ca- 800 mg/kg, Mg-1100 mg/kg) as compared to control (K-3800 mg/kg, P-2510 mg/kg, Ca-780 mg/kg, Mg-1080 mg/kg). Similarly, vermicompost application was found to be effective in increasing macroelements in pigeon pea monocropping (K-1100 mg/kg, P-380 mg/kg, Ca-150 mg/kg, Mg-140 mg/kg) as compared to control (K- 900mg/kg, P- 370 mg/kg, Ca-110 mg/kg, Mg-136 mg/kg). In the case of intercropping similar trend was observed in macroelement content with higher concentration in vermicompost treatment (K- 5150 mg/kg, P-2900 mg/kg, Ca-910 mg/kg, Mg-1280 mg/kg) as compared to control (K- 4560 mg/kg, P- 2890 mg/kg, Ca- 870 mg/kg, Mg- 1250 mg/kg) (Table 3 & Fig. 4).

3.2.2 Microelements

Microelements zinc (Zn), iron (Fe), copper (Cu), and manganese (Mn) were analyzed. Application of vermicompost in rice monocropping resulted in an increase in microelements (Zn- 46mg/kg, Fe-42 mg/kg, Cu- 10.1 mg/kg, Mn-34 mg/kg) as compared to control (Zn-45 mg/kg, Fe-41 mg/kg, Cu-9.01 mg/kg, Mn-32 mg/kg). Similarly, vermicompost application was found to be effective in increasing microelements in chickpea monocropping (Zn-5.4 mg/kg, Fe-6.1 mg/kg, Cu-1.1 mg/kg, Mn-1.6 mg/kg) as compared to control (Zn- 5.01 mg/kg, Fe- 5.2 mg/kg, Cu-2.10 mg/kg, Mn-1.5 mg/kg). In the case of intercropping similar trend was observed in microelement content with higher concentration in vermicompost treatment (Zn- 52mg/kg, Fe- 55 mg/kg, Cu- 13.7 mg/kg, Mn- 40 mg/kg) as compared to control (Zn- 50, Fe-53 mg/kg, Cu-12.8, Mn- 39.5 mg/kg) (Table 3 & Fig. 5).

4. DISCUSSION

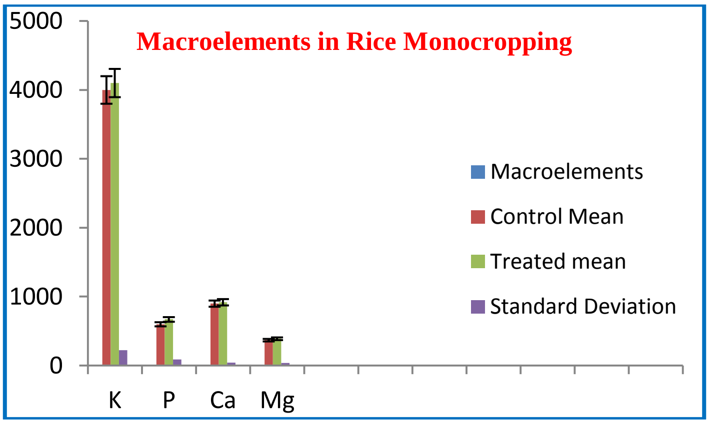
4.1 Impact of Intercropping and Vermicompost on Yield and Harvest Index (HI)

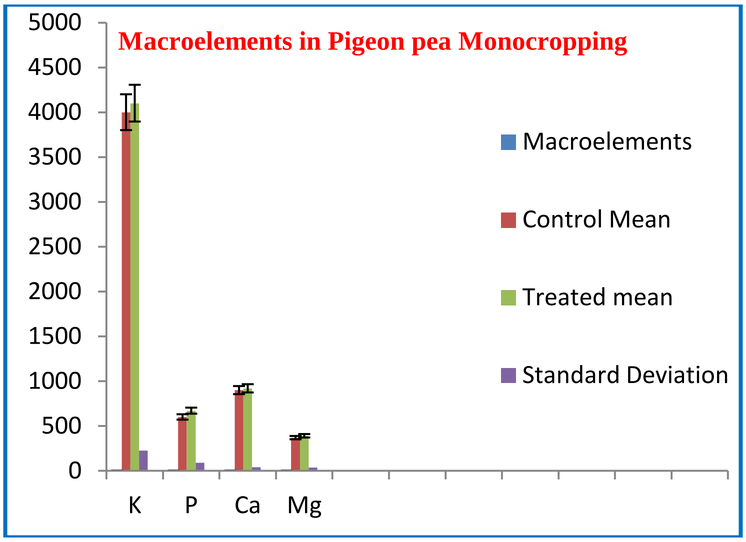
Intercropping with vermicompost application helps to improve the total yield and harvest index. In intercropping two crops are grown in one season so harvesting will be more in this case. Both crops also provide nutritional benefits to each other for example cereal -legume intercropping is the best approach because cereal plants like rice have long stems and need more area for growth as compared to pigeon peas which can be sown along with cereal as they need a very small area also its stem is not so large in length and also there is no competition for maturation of each crop as cereal takes longer time of 3-4 months and legumes can be harvested in 2-3 months. Also, vermicompost application can increase the capillarity action of plants for total nutrient uptake because earthworms used in vermicompost can refine the pores of the soil. Intercropping with vermicompost was effective in increasing yield up to 18.01 kg/ha as compared to monocropping of rice (17.48 kg/ha) and pigeonpeas (14.22 kg/ha) and harvest index up to 0.82 as compared to monocropping of both rice (0.47) and pigeonpeas (0.53). These results are similar to a study of intercropping with vermicompost application in sweet basil that indicates an increase in yield and nutrient uptake [17]. According to Yao et al. [18], intercropping between a cereal crop and a legume can be an effective method to increase the nutrient uptake of both crops as legumes are useful in fixation of nitrogen in the soil and cereal crops can get nitrogen as mineral for growth. Also, yield increased in this type of intercropping system. A research study by Lu et al. [19] found that maize peanut intercropping was useful in increasing the yield as well as nutrient uptake in plants. Research about vermicompost by Dey et al. [20] also found that vermicompost can be beneficial for the growth of plants. Hence intercropping is a novel approach to increase the yield and harvest index and is also cost-effective by using vermicompost as an organic fertilizer.

4.3 Impact of Intercropping and Vermicompost Application on Macroelements and Microelements

In the present study, the content of macroelements and microelements was found to be higher in the intercropping of rice and pigeon peas as compared to monocropping. One of the most important factors in increasing the macro and micro elements in combination with intercropping and vermicompost is that vermicompost itself contains NPK fertilizers in the ratio of 3.06% N, 2.6% P, and 1.05% K along with earthworms [12].

Several earthworm species like *Eisenia fetida* and *Perionyx excavates* also help soil to degrade its humus content into litter form so that soil nutrient quality can be increased. The application of vermicompost further enhanced the macroelement content significantly in K (5150 mg/kg) and P (2900 mg/kg) as control rice (4560 mg/kg) and pigeonpeas (2890 mg/kg). These results support the findings of Fatemi et al. [21] which state that vermicompost and biofertilizers along with intercropping are beneficial to increase the macroelements and microelements in maize and pinto beans. These results are also found to be similar to intercropping of rice and pigeonpea. According to Rax et al. [22], intercropping with pigeonpea and groundnut was also used to increase the NPK nutrient level in the field. A research study by Kalhor et al. [23] also suggests that intercropping farming along with vermicompost is also an effective method to increase the nutritional value of crops and vegetables. A study by Niazi et al. [24] was found to be effective in terms of increasing the yield and nutritional value of maize and mung bean intercropping with vermicompost. Hence both intercropping as well as a solid organic fertilizers can be effective tools to replace chemical fertilizers and also increase the production in plants. Also, intercropping farming type is useful for increasing food production and nutritional quality [25]. According to a research study, Pigeonpea used in this intercropping also helps to improve soil fertility with the help of rhizomediated microbes [26]. A research study suggests that intercropping along with organic farming practices also helps to improve crop production and soil fertility [27].





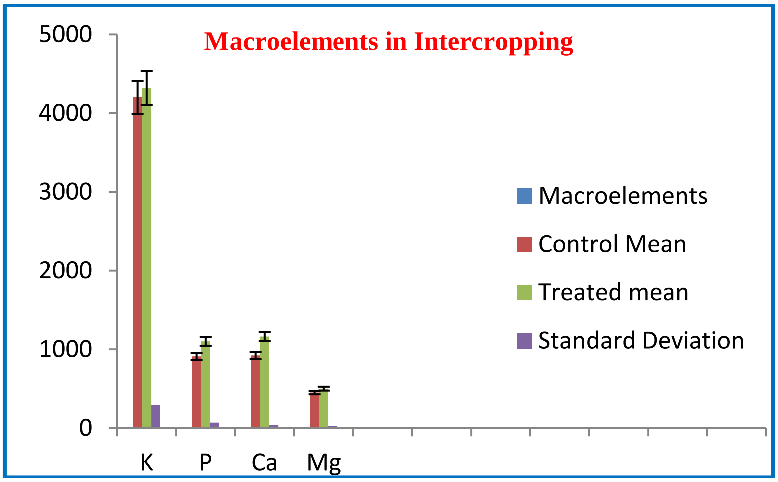
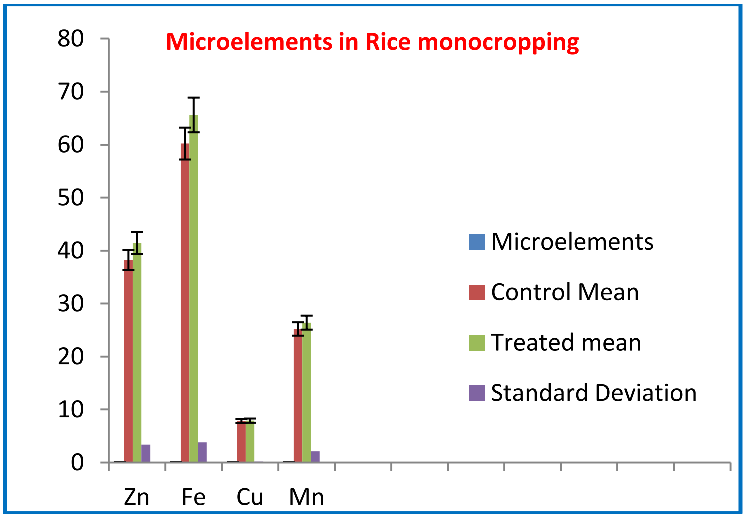
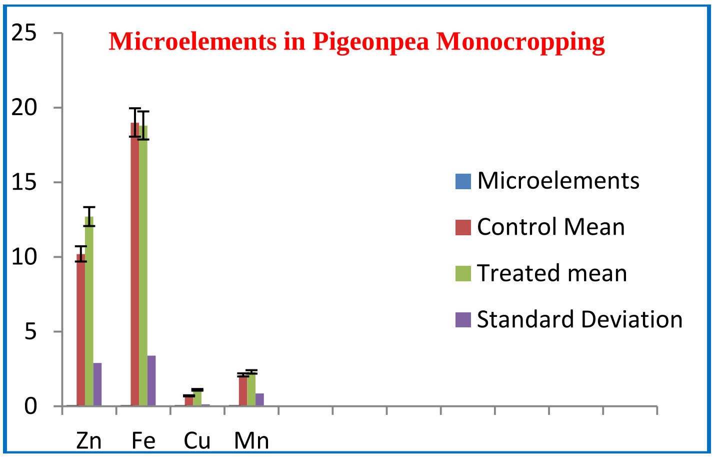


Fig. 4. Macroelements in rice and pigeon pea in monocropping and intercropping from 2019 to 2021





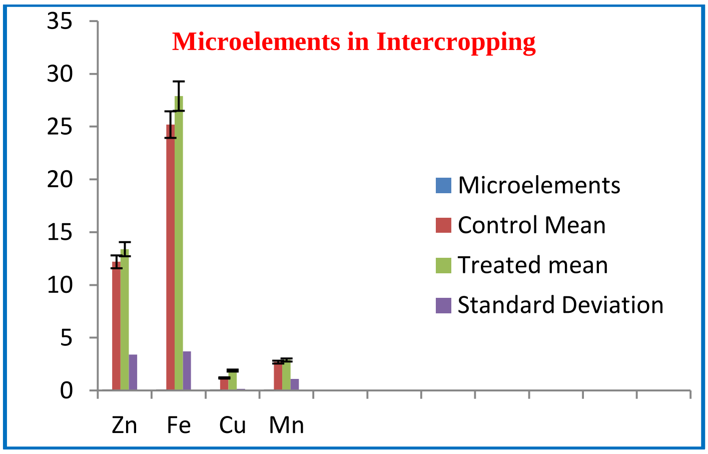


Fig. 5. Microelements in rice and pigeon pea in monocropping and intercropping from 2019 to 2021

Table 3. Impact of macroelements and microelements on rice and pigeon pea in monocropping and intercropping with vermicompost

Year	Crop	Macroelements					Microelements				
2019	**Rice**	**K**	**P**	**Ca**	**Mg**	**P value**	**Zn**	**Fe**	**Cu**	**Mn**	***P* value**
	Control(C)	3500±170	2150±47.910	650±55.1	850± 35.12	0.001	35±2.612	35± 3.5	7.3 ±1.23	28.5 ± 3.4	.001
	Treated (E)	4100 ± 194	2250±56.802	730±56.7	970±30.12	0.002	38±1.902	37±4.1	7.1±1.50	29.2±3.6	.01
2020	(C)	3615± 123	2320 ± 63.190	710±50.1	910±31.10	0.012	40±1.912	39±5.0	8.01±1.3	30±3.2	.03
	(E)	4250± 143	2450 ± 56.120	750±45.1	980± 32.04	0.014	42± 3.210	41±5.4	8.50±1.9	31±2.4	.04
2021	(C)	3800 ± 162	2510 ± 67.320	780±40.4	1080±35.10	0.013	45±2.142	42±5.7	9.01±2.1	32±2.5	.05
	(E)	4270 ± 180	2610 ± 70.208	800±45.2	1100±37.21	0.089	46±2.560	43±5.9	10.1±2.4	34±3.4	.04
2019	Pigeonpea (C)	700 ± 34.2	250 ± 4.56	80 ± 2.5	110 ± 20.4	0.003	3.50 ± 0.8	4.2 ± 0.1	1.5 ± .01	0.4± 0.001	.001
	(E)	720 ± 31.9	310 ± 5.12	85± 2.7	120 ± 22.3	0.013	3.89 ± 0.7	4.5 ± 0.3	1.6 ± .02	0.8 ± 0.003	.05
2020	(C)	800 ± 25.2	320 ± 6.10	89 ± 3.1	129 ± 24.4	0.007	4.01 ± 0.2	4.9 ± 0.4	1.8± .01	1.1 ± 0.002	.07
	(E)	830 ± 28.	345 ± 6.50	90 ± 2.7	130 ± 20.8	0.005	4.12 ± 0.5	5.1± 0.3	2.01± .01	1.3± 0.001	.03
2021	(C)	900 ± 35.9	370 ± 7.10	110 ± 3.1	136 ± 22.6	0.012	5.01 ± 1.1	5.2 ± 0.2	2.10 ±.02	1.5 ± 0.003	.02
	(E)	1100 ± 44	380 ± 6.45	150 ± 3.4	140 ± 23.1	0.009	5.4 ± 0.7	6.1 ± 0.	1.1± 0.01	1.6± 0.001	.04
2019	Intercropping (C)	4200 ± 125	2650±70.129	812±45.1	1150±38.10	0.012	47±2.570	45.1±4.2	10.4±2.6	35±2.8	.09
	(E)	4500 ± 132	2700±71.214	820±40.3	1170±39.01	0.004	48±2.101	46±3.7	11.1±2.9	37±2.9	.05
2020	(C)	4350 ± 135	2750±72.213	850±42.1	1200±40.1	0.003	49±2.011	48±4.1	11.5±2.4	38±3.1	.06
	(E)	4700 ± 245	2790±67.12	860±39.1	1210±37.1	0.009	49.5±2.310	50±5.2	12.5±2.9	39±1.4	.001
2021	(C)	4560 ± 340	2890±56.13	870±40.1	1250±40.2	0.005	50±3.10	53±4.6	12.8±1.9	39.5±2.1	.02
	(E)	5150 ± 420	2900±57.12	910±45.3	1280±42.10	0.002	52±2.10	55±5.7	13.7±3.1	40±2.8	.001

(C) =Control without vermicompost, (E) = Experiment with vermicompost Mean ± Standard deviation and significant level (P = .05) were calculated using Graph Pad Prism at 95 % confidence interval. The less the P value, the more significant the data

5. CONCLUSION

This study has shown the effect of vermicompost a solid organic fertilizer on rice and pigeon peas in monocropping as well as intercropping under field conditions in comparison with chemical fertilizers like urea and Diammonium phosphate. The research was found to be significant in terms of different parameters like yield, harvest index, and nutritional content in both types of crops. The Harvest index was found to be significant with a value of 0.82 in intercropping with vermicompost as compared to control with urea 0.72. Also, the harvest index of intercropping was higher as compared to the monocropping of both crops. The yield of intercropping with vermicompost was 18.01 which is higher than control intercropping with urea 16.05. Also, yield in the case of intercropping was higher than monocropping of both rice and pigeonpeas. Also, macroelements K and P were found higher in intercropping along with vermicompost (5150 mg/kg & 2900 mg/kg) as compared to control (4560 mg/kg& 2890 mg/kg) and microelements Zn & Fe in treated (41.4 mg/kg & 65.6 mg/kg) as compared to control (38.2 mg/kg& 60.2 mg/kg) were found higher in vermicompost treated intercropping as compared to control. Intercropping farming also provides more production in one sowing season as compared to monocropping and by mixing organic fertilizers in soil nutritional value and soil health can be increased. It also suggests an alternative approach for small and marginal farmers to replace chemical fertilizers and use vermicompost as an organic fertilizer as a cost-effective and high-crop production method. So, intercropping with vermicompost is an environmentally friendly approach to enhance nutritional quality and yield and also help to increase the economic returns of the farmers.

ACKNOWLEDGMENTS

We sincerely thank the central library of Maharshi Dayanand University, Rohtak for internet sources, plagiarism check, and literature collection.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Peltzer K, Phaswana-Mafuya N. Fruit and vegetable intake and associated factors in older adults in South Africa. Global health action. 2012;5(1):18668.
2. Lassaletta L, Billen G, Grizzetti B, Garnier J, Leach AM, Galloway JN. Food and feed trade as a driver in the global nitrogen cycle: 50-year trends. Biogeochemistry. 2014;118:225-241.
3. Krol DJ, Forrestal PJ, Wall D, Lanigan GJ, Sanz-Gomez J, Richards KG. Nitrogen fertilisers with urease inhibitors reduce nitrous oxide and ammonia losses, while retaining yield in temperate grassland. Science of the Total Environment. 2020;725:138329.
4. Fahrurrozi F, Muktamar Z, Sudjatmiko S. Agronomic responses of sweet corn-peanut intercropping to liquid organic fertilizer grown in different dosages of vermicompost. AGRIVITA, Journal of Agricultural Science. 2023;45(2):220-229.
5. Ramnarain YI, Ansari AA, Ori L. Vermicomposting of different organic materials using the epigeic earthworm Eisenia foetida. International Journal of Recycling of Organic Waste in Agriculture. 2019;8:23-36.
6. Piya S, Shrestha I, Gauchan DP, Lamichhane J. Vermicomposting in organic agriculture: Influence on the soil nutrients and plant growth. International Journal of Research. 2018;5(20):1055-1063.
7. Zainudin MHM, Zulkarnain A, Azmi AS, Muniandy S, Sakai K, Shirai Y, Hassan MA. Enhancement of agro-industrial waste composting process via the microbial inoculation: A brief review. Agronomy. 2022;12(1):198. (2014,2017) [Cross Ref)
8. Nafziger E. Cropping systems. Illinois agronomy handbook. 2009; 24:49-63.
9. De Notaris C, Rasmussen J, Sørensen P, Melander B, Olesen JE. Manipulating cover crop growth by adjusting sowing time and cereal inter-row spacing to enhance residual nitrogen effects. Field Crops Research. 2019;234:15-25.
10. Raza MA, Feng LY, van der Werf W, Cai GR, Khalid MHB, Iqbal N, Yang W. Narrow-wide-row planting pattern increases the radiation use efficiency and seed yield of intercrop species in relay-intercropping system. Food and Energy Security. 2019;8(3):e170.
11. Reportlinker. Organic food global market report 2021: COVID-19 growth and change to 2030; 2021.

    Available:https://www.reportlinker.com/p06151556/ Organic-Food-Global-Market-

Report-COVID- 19-Growth-And-Change-To.html?utm_ source=GNW

12. Muktamar Z, Sudjatmiko S, Chozin M, Setyowati N, Fahrurrozi F. Sweet corn performance and its major nutrient uptake following application of vermicompost supplemented with liquid organic fertilizer; 2017.
13. Zhang Y, Yang Y, Lu X, Wang A, Xue C, Zhao M, Zhang J. The effects and interrelationships of intercropping on Cotton Verticillium wilt and soil microbial communities. BMC microbiology. 2023; 23(1):1-15.
14. Willey RW, Heath SB. The quantitative relationships between plant population and crop yield Advances in agronomy. 1969;21:281-321.
15. Donald CM, Hamblin J. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. Advances in agronomy. 1976;28:361-405.
16. Popović-Djordjević J, Marjanović ŽS, Gršić N, Adžić T, Popović B, Bogosavljević J, Brčeski I. Essential elements as a distinguishing factor between mycorrhizal potentials of two cohabiting truffle species in riparian forest habitat in Serbia. Chemistry & Biodiversity. 2019;16(4): e1800693.
17. Rezaei-Chiyaneh E, Amani Machiani M, Javanmard A, Mahdavikia H, Maggi F, Morshedloo MR. Vermicompost application in different intercropping patterns improves the mineral nutrient uptake and essential oil compositions of sweet basil (*Ocimum basilicum* L.). Journal of Soil Science and Plant Nutrition. 2021;21:450-466.
18. Yao F, Wu Y, Liu X, Cao Y, Lv Y, Wei W, Wang Y. Research progress and development trends of greenhouse gas emissions from cereal–legume intercropping systems. Agronomy. 2023; 13(4):1085.
19. Lu J, Dong Q, Lan G, He Z, Zhou D, Zhang H, Yu H. Row ratio increasing improved light distribution, photosynthetic characteristics, and yield of peanut in the maize and peanut strip intercropping system. Frontiers in Plant Science. 2023;14.
20. Dey Chowdhury S, Suhaib KH, Bhunia P, Surampalli RY. A critical review on the vermicomposting of organic wastes as a strategy in circular bioeconomy: mechanism, performance, and future perspectives. Environmental Technology. 2023;1-38.
21. Fatemi R, Hoseini SMB, Moghadam H, Motesharezadeh B, Ahmadabadi Z. How biofertilizers and intercropping pattern affect yield and nitrogen efficiency indices of maize?. Arabian Journal of Geosciences. 2023;16(6):378.
22. Rex Immanuel R, Sivasakthi K, Baradhan G, Ravikumar C, Suresh SM. Integrated effects of organic manuring, NPK and foliar fertilization on growth, yield and quality of groundnut and pigeonpea in legume based intercropping system; 2023.
23. Kalhor Monfared R, Ardakani MR, Paknejad F, Sarajuqi M, Naghdi Badi HA. Effects of intercropping forage turnip (*Brassica rapa* L.) and basil (*Ocimum basilicum* L.) and applying vermicompost and biochar as soil amendments on quality and quantity of the forage turnip crop. Biological Agriculture & Horticulture. 2023;39(2):129-147.
24. Niazi PS, Monaem R, Azadi A. Effect of vermicompost on yield and forage quality in intercropping of maize and mung. Journal of Agricultural Science. 2017;9(5):233-239.
25. Paramesh V, Ravisankar N, Behera U, Arunachalam V, Kumar P, Solomon Rajkumar R, Rajkumar S. Integrated farming system approaches to achieve food and nutritional security for enhancing profitability, employment, and climate resilience in India. Food and energy security. 2022;11(2):e321.
26. Gupta G, Dhar S, Kumar A, Choudhary AK, Dass A, Sharma VK, Rajawat MVS. Microbes-mediated integrated nutrient management for improved rhizo-modulation, pigeonpea productivity, and soil bio-fertility in a semi-arid agro-ecology. Frontiers in Microbiology. 2022;13:924407.
27. Aulakh CS, Sharma S, Thakur M, Kaur P. A review of the influences of organic farming on soil quality, crop productivity and produce quality. Journal of Plant Nutrition. 2022;45(12):1884-1905.