AATCC Review

14 September 2024: Received
17 October 2024: Revised
15 November 2024: Accepted
01 December 2024: Available Online

https://aatcc.peerjournals.net/

Original Research Article

Open Access

Response of organic integrated nutrient modules on yield and economics of pigeonpea based intercropping systems

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ABSTRACT

Continuous use of chemical fertilizers in intensive mono cropping system has led to reduction in crop yield and has adverse effect on soil health. Organic agriculture addresses the concerns about the deteriorating soil health by adopting various cropping systems which complement each other meanwhile maintaining the good health of the soil. Intercropping aims to get increased total productivity per unit time, besides equitable and judicious utilization of land resources and farming inputs including labour, insurance against failure of one or the other crops could be achieved. Hence, a field experiment was conducted at research farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, (Maharashtra) during Kharif 2018-19 to find out the ressponse of organic integrated nutrient modules on yield and economics of pigeonpea based intercropping systems. The experiment was laid out in Strip Plot Design (SrPD) with three replications. The four main plot factors consist of sole pigeonpea, pigeonpea + soybean, pigeonpea + foxtail millet, and pigeonpea + cotton and was taken up with three sub plot factors i.e. integrated organic nutrient modules (OINM) viz., 100% FYM (Farm Yard Manure) + vermicompost, 75% farm yard manure + vermicompost + 25% neem cake, and control (No manure). Yield, economics and system profitability were calculated and the results shows that, the highest seed yield (1043.6 kg ha^{-1}), stalk yield (3241.7 kg ha^{-1}), gross monetary returns (1,32,756 Rs. ha^{-1}), net monetary returns (96,163 Rs. ha^{-1}), benefit-cost ratio (3.60) and system profitability (Rs. 263 ha^{-1} day^{-1}) was recorded in pigeonpea + soyabean-based intercropping system, and among the organically integrated nutrient modules, 75% farm yard manure + vermicompost + 25% neem cake recorded the similar trend. Hence, application of 75% farm yard manure + vermicompost + 25% neem cake is an economically viable method for optimizing the yield in pigeonpea based intercropping systems.

Keywords: *Economics, intercropping system, organic integrated nutrient modules, pigeonpea, system profitability, yield*

Introduction

Pigeonpea (*Cajanus cajan*) generally known as redgram, arhar, tur is one of the most important pulse crops in India. Pigeonpea is excellent source of high quality protein and occupies an important place in vegetarian population. Globally, pigeonpea is grown in an area of 63.57 lakh hectares with a production of 54.75 lakh tonnes and productivity of 861.25 kg ha^{-1} [1]. In India, pigeonpea occupies 5.05 million hectares area with a production of 4.34 million tonnes and productivity of 859 kg ha^{-1} [2]. In Maharashtra area, production and productivity under pigeonpea is 11.95 lakh hectares, 9.71 lakh tonnes and 8.13 q ha^{-1}, respectively [3]. The productivity of pulses in our country including pigeonpea is not sufficient enough to meet the domestic demand of the population. Hence, there is need for enhancement of the productivity of pigeonpea by proper agronomic practices.

The excessive/imbalanced use of chemical fertilizers has negative impacts on soil health. Repetitive use of chemical fertilizers can lead to soil compaction, nutrient imbalances, and soil acidification. This can cause a decline in soil fertility, crop yield reduction over time, increase the risk of soil erosion and runoff and have negative impacts on the environment.

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DOI: https://doi.org/10.21276/AATCCReview.2024.12.04.501

To optimize the crop production in the agricultural sector as well as maintaining the soil health, safeguarding the environment and economic sustainability organic supplements play a complementary role to chemical fertilizers. Organic inputs like crop residues, bulky and concentrated organic inputs, on farm cheap inputs, composts not only reduce the cost but help to build up soil humus and beneficial microbes, besides improving the soil's physical properties. The scientific community all over the world is desperately looking for an 'economically viable, socially safe and environmentally sustainable' alternative to the agro-chemicals. Interest in food production without chemical fertilizer and pesticide practices is increasing. Such food is commonly referred as organic [4].

Organic manure is attributed in supplying of adequate quantities and balanced proportion of plant nutrients of the crop as per the need [5]. Farmyard manure is an effective and efficient source of nutrients to plants and soil microorganisms; additionally it improves physical, chemical and biological properties of the soil [6]. Vermicompost has been recognized as an eco-friendly approach for converting organic wastes into high value organic manure rich in nitrates, available form of phosphorus, calcium, vitamins and natural plant growth regulators in balanced form which helps in restoration of natural fertility of soil [7]. Neem cake applied as a soil amendment, it binds several macro and micro-nutrients, allowing their controlled release and limiting their loss by leaching [8] and added advantage by its insecticidal and nematicidal activity.

Intercropping has been considered as beneficial cropping system compared to monocropping. Intercropping helps in preventing total crop failure due to abnormal weather or pest epidemics [9]. Pigeonpea and other leguminous companions have the ability to fix atmospheric nitrogen through their root nodules. This process benefits the entire intercropping system, as the fixed nitrogen becomes available to all plants, supporting their growth [10].

Further its wider row spacing and long duration forms an ideal intercrop with other crops *viz.,* soybean, foxtail millet and cotton. The space in between the rows is usually unutilized in the early growth stages by pigeonpea, so it is indispensable to raise intercrops in between the pigeonpea rows that will smother the growth of weeds and improves organic matter of the soil by leaf litters. Organic manures being slow in release of nutrients, assume greater significance in a cropping sequence than individual crops and their usefulness needs to be investigated on long term basis [11].

Hence, integration of organic nutrient modules along with pigeonpea based intercropping system would surely influence agricultural sustainability by enhancing productivity along with maintaining dynamic soil nutrient status and safe environment. Based on the above points in view, the field experiment was conducted to evaluate the response of organic integrated nutrient modules on yield and economics of pigeonpea based intercropping systems.

Materials and Methods

The field experiment was carried out to find out the response of organic integrated nutrient modules on yield and economics of pigeonpea based intercropping systems during *Kharif* season of 2018-19 at research farm of Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, Akola, Maharashtra. The soil of experimental plot was clayey in texture and medium in organic carbon, low in available nitrogen (193.7 kg ha^{-1}), very low in available phosphorus (14.6 kg ha^{-1}) and high in available potassium (324.0 kg ha^{-1}).

The experiment was laid out in strip plot design (SrPD) with four main factors (intercropping system) *viz.,* T_1 - sole pigeonpea, T_2 - pigeonpea + soybean (1:4), T_3 - pigeonpea + foxtail millet (1:4) and T_4 - pigeonpea + cotton (1:4) and three sub factors (organic integrated nutrient modules) *viz.,* N_1 - 100% FYM + vermicompost, N_2 - 75% FYM + vermicompost + 25% neem cake and N_3 - control (No manure). The experiment was replicated thrice, the gross plot size is 9.0 x 10.0 m^2 and the net plot size is 7.2 x 8.0 m^2. Pigeonpea (PKV-Tara), soybean (AMT-1001), foxtail millet (Co-1) and cotton (AKA-7) were selected for the study as the varieties are most recommended for the region and are highly suitable Desi varities for organic agriculture and all the varieties were early maturing, short duration and high yielding. Seed rate of 12-15 kg ha^{-1} (pigeonpea), 75 kg ha^{-1} (soybean), 3-4 kg ha^{-1} (foxtail millet), and 12-15 kg ha^{-1} (cotton) were recommended. The spacing for pigeonpea, soybean, foxtail millet and cotton were 225 x 20 cm (paired row), 45 x 5 cm, 45 x10 cm and 45 x15 cm respectively. The crop was fertilized as per the treatments. Other cultural operations were done as per the crop requirements. Finally, the crop was harvested and produce was threshed, cleaned, dried and weighed. The total value of produce i.e., seed and straw yield was calculated treatment wise as per the prevailing market price and gross monetary return (GMR) was calculated. The total cost of cultivation (TCC) was negated from the GMR to obtain net monetary return (NMR). The benefit cost ratio was calculated by dividing the GMR with TCC.

The system profitability of each treatment is calculated by using the formula,

$$\text{System Profitability (Rs. ha}^{-1}\text{ day}^{-1}\text{)} = \frac{\text{Net marginal returns (Rs/ ha)}}{\text{365 (days)}}$$

The data were analyzed statistically following the procedure given by [12]. Critical differences were worked out at five per cent level of significance. The treatment differences that were non-significant were denoted as NS.

Results and Discussion

Seed yield

Seed yield (kg ha^{-1}) was significantly influenced by intercropping system. The highest seed yield was recorded under pigeonpea + soybean (1043.6 kg ha^{-1}) followed by sole pigeonpea (721.8 kg ha^{-1}), pigeonpea + cotton (618.6 kg ha^{-1}) and was least with pigeonpea + foxtail millet (609.2 kg ha^{-1}) (Table 1). The probable reason behind the increase in seed yield could be due to improved aeration by wider spacing of pigeonpea and soybean, there by scope for light interception, the benefit of more preserved moisture and its support at critical growth stages such as flowering, pod initiation and development. These results were in line with the findings of [13]. Seed yield was significantly influenced by the organic integrated nutrient management and the treatment 75% FYM + vermicompost + 25% neem cake had the highest seed yield of 922.2 kg ha^{-1} and followed by 100% FYM + vermicompost (825.2 kg ha^{-1}) (Table 1). Improvement in yield could be due to higher quantity of macro and micronutrients added to soil in the form of FYM and vermicompost resulting in increased availability of nutrients in root zone thus more uptake by crop resulting in higher values of yield attributing characters and yield. This could be earlier emphasized by [14] and [15]. Vermicompost along with intercropping was found to be effective in increasing the yield and nutritional value of crops [16]. Neem cake application gave additional benefit in terms of insect and disease control. The treatment N_3 (no manure) registered the lowest seed yield (497.5 kg ha^{-1}).

Stalk yield

Stalk yield was significantly influenced by intercropping system. The highest stalk yield was recorded under pigeonpea + soybean (3241.7 kg ha^{-1}) followed by sole pigeonpea (2493.4 kg ha^{-1}), pigeonpea + foxtail millet (1808.3 kg ha^{-1}) and was least with pigeonpea + cotton (1754.6 kg ha^{-1}) (Table 1). These results were in line with the findings of [17]. The legume and legume as main crop and intercrop might have symbiotic effect with each other and reduced the competition for moisture and nutrients between the component crops and significantly increased the grain and stalk yield of both component crops [18].

Stalk yield was significantly influenced by the organic integrated nutrient management. The treatment combination of 75% FYM + vermicompost + 25% neem cake had registered the highest stalk yield of 2730.3 kg ha^{-1} and at par with 100% FYM + vermicompost (2425.1 kg ha^{-1}). This result was earlier reported by [19]. The combined application of organic nutrients could have helped in balanced availability of nutrients at all the growth stages of crop which ultimately led to better translocation of photosynthates from source to sink resulting in higher number of yield attributes and stalk yield [20]. Better growth parameters and higher accumulation of dry matter in stem parts with application of vermicompost that contributed for the higher stalk yield production [21]. The lowest stalk yield (1818.1 kg ha^{-1}) was recorded under N_3 (no manure).

Economics

Total cost of cultivation

The Cost of cultivation was highest in treatment with pigeonpea + soybean (Rs.36,593 ha^{-1}) (Table 2) and was least in treatment with sole pigeonpea (Rs.28,644 ha^{-1}). Among the organic nutrient modules, the highest cost of cultivation was incurred under treatment with 100% FYM + vermicompost (Rs.39,020 ha^{-1}) followed by 75% FYM + vermicompost + 25% neem cake (Rs.33,680 ha^{-1}) and the least cost incurred under control treatment (Rs.23,603 ha^{-1}).

Gross monetary returns (GMR)

The highest GMR (Rs.1,32,756 ha^{-1}) was observed in treatment with pigeonpea + soybean and least in treatment with sole pigeonpea (Rs.45,951 ha^{-1}) (Table 2). This result was supported by [22] in comparison to a sole crop. Inclusion of soybean and pigeonpea has been shown to reduce soil fertility exhaustion, minimizes crop weed competition at the early growth stages of the crop due to their smothering effects on weeds, that allows the crop to utilize nutrients more effectively for its growth and development, thus resulting in higher seed and stalk yield. Higher yield of grain and straw is positively correlated to the higher gross monetary return.

Among the organic nutrient modules the highest GMR was under treatment with 75% FYM + vermicompost + 25% neem cake (Rs.1,01,308 ha^{-1}) followed by 100% FYM + vermicompost (Rs.91,785 ha^{-1}) and least GMR obtained was under control treatment (Rs.45,102 ha^{-1}). Application of farmyard manure along with vermicompost increases the nutrient availability in the soil that is very essential to the nourishment of plants. Better growth and development of plants by the availability and uptake of nutrients reflects on yield that leads to obtain the highest GMR.

Net monetary returns (NMR)

The NMR was highest for treatment with pigeonpea + soybean (Rs.96,163 ha^{-1}) being highly profitable and least in treatment with sole pigeonpea (Rs.17,307 ha^{-1}) (Table 2). The pigeonpea + soybean intercropping system emerges as the most favorable [23] indicating it's potential for enhancing agricultural productivity and economic returns [24] and [25]. The similar trend of higher net monetary returns of pigeonpea + soybean was also reported by [26].

Among the organic nutrient modules, the highest NMR was under treatment with 75% FYM + vermicompost + 25% neem cake (Rs.67,628 ha^{-1}) followed by 100% FYM + vermicompost (Rs.52,765 ha^{-1}) and least NMR obtained under control treatment (Rs.21,499 ha^{-1}). The highest gross monetary return with the lowest cost of cultivation in the treatment 75% FYM + vermicompost + 25% neem cake might be the reason for the highest NMR.

Benefit Cost Ratio (BCR)

The BCR was maximum for treatment with pigeonpea + soybean (3.6) being highly profitable and minimum in treatment with sole pigeonpea (1.6) (Fig.1). Similar trend of the highest BCR in pigeonpea + soybean has also been observed by [27] and [28]. Among the organic nutrient treatments maximum BCR was under treatment with 75% FYM + vermicompost + 25% neem cake (2.9) followed by 100% FYM + vermicompost (2.3) and minimum BCR obtained was under control treatment (1.9). The results were in harmony with results recorded by [29].

System profitability (Rs. ha^{-1} day^{-1})

The system profitability was highest for treatment with pigeonpea + soybean (Rs. 263 ha^{-1} day^{-1}) and was least in treatment with sole pigeonpea (Rs. 47 ha^{-1} day^{-1}) (Table 2). Similar findings in system profitability in pigeonpea + soybean compared to sole cotton were earlier observed by [30].

Among the organic nutrient modules, the highest system profitability was under treatment with 75% FYM + vermicompost + 25% neem cake (Rs.185 ha^{-1} day^{-1}) followed by 100% FYM + vermicompost (Rs.145 ha^{-1} day^{-1}) and least system profitability obtained was under control treatment (Rs.59 ha^{-1} day^{-1}).

In the light of results summarized above pigeonpea + soybean (1:4) intercropping system and organic integrated nutrient modules with 75% FYM + vermicompost + 25% neem cake application recorded the highest grain yield, stalk yield, benefit cost ratio and system profitability. Hence, this combination is an economically viable method that is recommended for sustaining the productivity of pigeonpea along with efficient utilization of organic nutrient sources in the black soils of Vidarbha region of Maharashtra State.

Future scope of the study

In organic cropping systems designed recommendations on the use of various organic nutrient modules especially on the prevalent pulse based intercropping system is meager. Hence, the present study will be very effective for further research in the subject and in order to demonstrate the impact of different organic nutrient modules on the growth, yield and quality of the pigeonpea based intercropping system and beneficial effect of the different intercropping systems on soil health.

Acknowledgement

This study was conducted in partial requirement for M.Sc. at Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, Akola, Maharashtra and the authors are thankful for the support provided by the Dean, technical staffs of the Department of Agronomy, PGI, Dr. PDKV, Akola.

Conflict of interest

The authors declare that is there is no conflict of interest.

Table 1. Seed yield and stalk yield (kg ha^{-1}) of pigeonpea, soybean, foxtail millet and cotton as influenced by intercropping systems and organic integrated nutrient modules

Treatments	Seed yield (kg ha^{-1})				Stalk yield (kg ha^{-1})			
A) Intercropping systems	Main crop	Intercrop			Main crop	Intercrop		
	PP	Soy	FM	Cot	PP	Soy	FM	Cot
T_1 – PP sole	721.8				2493.4			
T_2 – PP + Soy	1043.6	1802.9			3241.7	2884.6		
T_3 – PP + FM	609.2		774.7		1808.3		1317.1	
T_4 – PP + Cot	618.6			625.0	1754.6			1750.1
SE(m)±	**18.0**				**84.4**			
CD at 5%	**62.1**				**291.9**			
B) Organic Integrated Nutrient Modules (OINM)								
N_1 – 100% FYM + VC	825.2	2282.4	947.3	761.0	2425.1	3634.5	1590.2	2078.7
N_2 – 75% FYM + VC + 25% NC	922.2	2365.2	1083.9	864.6	2730.3	3766.9	1822.4	2368.7
N_3 – Control	497.5	761.0	292.8	249.4	1818.1	1252.3	538.6	802.8
SE(m)±	14.7				98.2			
CD at 5%	57.6				385.5			
C) Interaction (A×B)								
SE(m)±	24.8				192.6			
CD at 5%	**76.5**				**NS**			
GM	**748.3**	**1802.9**	**774.7**	**625.0**	**2324.5**	**2284.6**	**1317.1**	**1750.1**

Note: PP – Pigeonpea, Soy – Soybean, FM – Foxtail millet, Cot – Cotton, FYM – Farm Yard Manure, VC –Vermicompost, NC – Neem Cake.

Table 2. Economics as influenced by intercropping systems and organic integrated nutrient modules

Treatments	Cost of cultivation (Rs. ha^{-1})*	Gross monetary returns (Rs. ha^{-1})	Net monetary returns (Rs. ha^{-1})	System profitability* (Rs. ha^{-1}day^{-1})
A) Intercropping systems				
T1 – PP sole	28644	45951	17307	47
T2 – PP + Soy	36593	132756	96163	263
T3 – PP + FM	31209	64582	33373	91
T4 – PP + Cot	31959	74304	42345	116
SE(m)±	**-**	**1924.5**	**1924.5**	**-**
CD at 5%	**-**	**6659.9**	**6659.9**	**-**
B) Organic Integrated Nutrient Modules (OINM)				
N1 – FYM	39020	91785	52765	145
N2 – FYM + NC	33680	101308	67628	185
N3 – Control	23603	45102	21499	59
SE(m)±	-	1666.7	1666.7	-
CD at 5%	**-**	**6543.1**	**6543.1**	**-**
GM	**32101**	**79398**	**47297**	**130**

*Note: PP – Pigeonpea, Soy – Soybean, FM – Foxtail millet, Cot – Cotton, FYM – Farm Yard Manure, VC –Vermicompost, NC – Neem Cake and *Not analyzed statistically.*

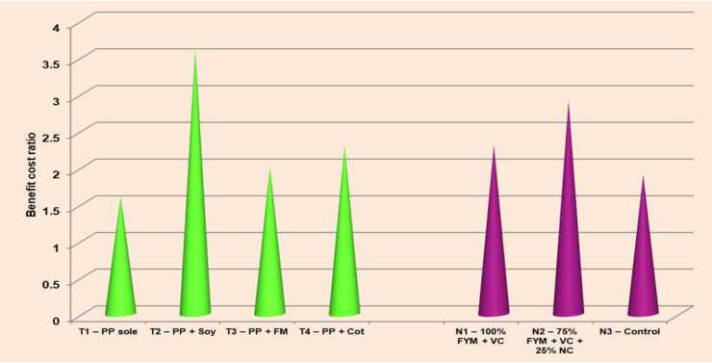

Fig. 1: Benefit cost ratio as influenced by intercropping systems and organic integrated nutrient modules

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