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Residual effect of Organic Garden Pea Cultivation on Succeeding Amaranth Growth and Soil properties in the Foot Hills of Eastern Himalayan Region

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ABSTRACT: Conventional organic garden pea cultivation suffers from lower fruit yield due to the use of traditional nutrient sources like farmyard manure. Selection of proper nutrient management practices can enhance crop growth, yield and as well as soil health. The residual nutrients after proper nutrient management practices can be better utilized by cultivating succeeding crop in the same field. A field experiment was conducted during 2020-21 and 2021-22 at the UBKV Instructional farm, Pundibari, Coochbehar, West Bengal, India to find out the effect of organic amendments of garden pea cultivation and its residual effect on succeeding Amaranth crop growth and soil fertility status. The garden pea crop was grown in split plot design with three replications by combining four main plot factors and four sub plot factors. Succeeding leafy vegetable crop Amaranth was raised on the same plots of garden pea field. The findings of this study suggested that organic manure application on garden pea crop significantly influence the Amaranth growth and soil quality over the foliar spray. The organic amendments i.e., biofertilizer enriched farmyard manure @ 20 t/ha recorded the highest individual plant weight (6.68 g), fresh plant yield/plot (2.20 kg), fresh plant yield/ha (3.88 ton) and plant biomass (0.78 t/ha) of Amaranth crop. The same organic amendments also recorded the highest residual nitrogen (222.36 kg/ha), phosphorous (18.62 kg/ha) and potassium (99.85 kg/ha) content in the soil after harvesting of Amaranth crop. The experimental findings demonstrated that *Azophos* biofertilizer enriched farmyard manure may be adopted for organic garden pea cultivation to achieve higher green leaf yield and sustainable soil health in garden pea- Amaranth cropping system.

Keywords: Residual effect, garden pea-Amaranth cropping system, organic, soil fertility, biofertilizers enriched manure.

INTRODUCTION

Legume crop particularly garden pea (*Pisum sativum* var. *hortense*) has been well known, easily digestible protein rich vegetable in national as well as in international markets (Santos-Hernandez *et al.,* 2020). It is the 2ndmost popular legume vegetable in the world (Pawar *et al.,* 2017). Uttar Pradesh is the leading producer of garden peas, accounting for half of total production of the country (Dubey *et al.,* 2012). Pea is a cool season vegetable grown in the cooler part of the world having chromosome number 2n=14 and belongs to family Leguminosae. Fresh and well filled pea pods can be eaten fresh or frozen; dry seed can be used as food; hay feed for animals; and green fertiliser (Bozoglu *et al.*, 2007). Fully developed 100 g edible portion of garden pea contains7.2 g of digestible protein, 15.8 g of carbohydrates, 34 mg of magnesium, 139 mg of phosphorus, 9 mg of vitamin C and 139 IU of vitamin A (Gopalan *et al.*, 2007). The area under garden pea production is growing rapidly throughout the country due to the tremendous health benefits of organic garden peas and subsequent demand in both domestic and international markets (Naidu *et al.,* 2009). Organic manure is the storehouse of all the essential nutrients for plant growth and development. Organic manure like farmyard manure (FYM) is widely used as a source of nutrients in organic farming systems. FYM is a primary source of nitrogen for crops, but continuous use of this manure maybe led to Phosphorus accumulation in the soil (Nagendra, 2009). Again, vermicompost is highly effective as well as treated as soil conditioner also and rich source of vitamins, growth hormones, macro and micronutrients and microflora (Bhavalkar, 1991). Traditional organic manures are poor in nutrient content, they are unable to provide the necessary nutrients for crop growth and development. As a result, including a novel approach for enriching organic manure with biofertilizers can aid in the improvement of nutritional content in manures. Biofertilizers are the substances of living microorganisms that increase various microbial activities in soil and increase nutrient availability for growing plants. Enrichment of organic manures with biofertilizers boosts the microbial population, available nitrogen, phosphorus, and potassium content, enzyme activity, and soil fertility (Sindhu *et al.*, 2020). Nutrient availability improves dramatically in enriched organic manures since microbial decomposition gradually enhances nutrient availability to the plant throughout the growing period.

In general, the mineralization rate of organic manures is very slow and lots of nutrients remain unutilized after harvest of the main crop (Jatoliya *et al.,* 2019). In every cropping sequence, growth and development of succeeding crop are highly influenced by the main crop and nutrient sources applied to them (Patidar and Mali 2002; Mufti *et al.,* 2021). Rani *et al.* (2014) also pointed out that due to long term effect of organic manures, needs to be better utilized after harvesting of main crop like maize due to long term effect can be better utilized by growing a succeeding crop like spinach. After harvesting legume vegetables, the residual fertility of the soil can be better utilised by planting a succeeding crop in the same field. Amaranth (*Amaranthus* sp. L.; family Amaranthaceae) is a potential summer season leafy vegetable rich in several minerals and vitamins. Cultivation of residue free leafy vegetable i.e., Amaranth is gaining popularity as because of organic based Amaranth crop has a minimum nitrate level which ultimately helps in maintain good human health (Mondal *et al.,* 2019). As Amaranth crop is a short duration crop and can be helpful to utilize the organic manures in a great extent. It can be grown organically after harvest of the legume vegetables. Legume based cropping sequence in an organic production system can help in the fixation of atmospheric nitrogen in a tremendous rate and it will help to provide nutrient to the succeeding crop (Suthamathy and Seran 2012). However, information regarding the performance of garden pea based organic cropping system is scanty in the region. Therefore, the present work will help to evaluate the performance of garden pea as a rotational cropping system on the succeeding Amaranth crop growth and quality.

MATERIAL AND METHODS

The garden pea variety 'Azad Pea-3' was grown consecutively for two years in a row (2020-21 and 2021-22) from November to February months at the UBKV Instructional farm in Pundibari, Coochbehar, West Bengal, India (26°19'86"N latitude and 89°23'53"E longitude at an elevation of 43 meters above mean sea level). The soil in the experimental field was sandy loam in texture with a slightly acidic in reaction (pH 5.43). The soil's initial chemical properties were 0.47% organic carbon, and 200.76 kg/ha, 23.26 kg/ha and 98.32 kg/ha, available nitrogen, phosphorous, and potassium content, respectively. The experiments were laid out in a split plot design with four levels of main plot factors (L_1: Control-water spray, L_2: Jeevamrut @ 3%, L_3: Vermiwash @ 3% and L_4: Mustard cake solution @ 3%) and four levels of sub plot factors (E_1: Control- farmyard manure @ 20 t/ha, E_2: Enriched farmyard manure @ 20 t/ha, E_3: Enriched vermicompost @ 5 t/ha and E_4: Enriched poultry manure @ 5 t/ha), obtaining a total of 16 treatment combinations. Seeds of garden pea were sown in 3.6 m × 1.5 m plot size with a spacing of 45 cm (R-R) × 15 cm (P-P). Enrichment was done in different organic manures namely farmyard manure, vermicompost and poultry manure was mixed with biofertilizer (*Azotobacter* and phosphorous-solubilizing bacteria) at 10 g/kg of manure and kept in the shade for 20 days. Organic amendments were applied to the respective plots prior to seed sowing. Succeeding Amaranth crop (var. Jaba Kusum) was raised at 15 cm × 10 cm plant spacing on the same plots of garden pea field during March to April of 2021 and 2022. The observations were recorded for different yield attributing traits of Amaranth (Table 2 and 3). Initial soil samples were collected at a depth of 15-20 cm prior to seed sowing of garden pea to determine the soil's initial fertility condition. Soil samples were also collected following Amaranth harvest to check soil chemical properties after harvest. The soil available nitrogen was analysed using a modified Macro Kjeldahl method (Jackson, 1967). The total nitrogen uptake was calculated using nitrogen content in plant biomass (Tandon, 1999). The nitrogen use efficiency was calculated by comparing the applied nitrogen and total nitrogen removal by the various treatment combinations. The data collected from 2 consecutive years for various parameters were pooled and statistically analysed using the method proposed by Gomez and Gomez (1984).

Table 1: Chemical properties of experimental soil.

Parameter	2020-21	Methods employed
Soil texture	Sandy loam	International pipette method (Piper, 1966)
pH	5.43	pH meter (Jackson, 1967)
Available N (kg/ha)	200.76	Modified Macro Kjeldahl method (Jackson, 1967)
Available P (kg/ha)	23.26	Bray's No.1 Method (Jackson, 1967)
Available K (kg/ha)	98.32	Flame photometer method (Jackson, 1973)
Organic carbon (%)	0.47	Rapid titration method (Walkely and Black 1934)
Electric conductivity (dS/m)	0.19	1:2 soil: water ratio by Jackson (1967)

RESULTS AND DISCUSSION

Performance of Amaranth: The analysed results (Table 2) revealed that soil application of enriched organic manure (farmyard manure, biofertilizer enriched farmyard manure, biofertilizer enriched vermicompost and biofertilizer enriched poultry manure) showed significant effect on yield of succeeding Amaranth crop. Biofertilizer enriched farmyard manure @ 20 t/ha helped significantly increased the yield components of Amaranth. The individual plant weight (6.68 g), yield/plot (2.20 kg/5.4 m^2), highest yield/ha (3.88 ton) and maximum plant biomass (0.78 t/ha) were obtained when Amaranth was grown on biofertilizer enriched farmyard manure amended garden pea plot. Amaranth plants raised on garden pea plots that received a higher amount of nutrients had highest growth and subsequently highest yield attributing factors. This could be due to greater availability of residual nutrients to the plants over biofertilizer enriched vermicompost, poultry manure and without biofertilizer enriched farmyard manure. Whereas, foliar application of Jeevamruth @ 3%, Vermiwash @ 3%, and Mustard cake solution @ 3% on garden pea plants had a non-significant effect on succeeding Amaranth crops. The interaction effect between organic manure and foliar spray of garden pea plots showed a non significant effect on the yield attributes of the succeeding Amaranth crop (Table 3).

Application of farmyard manure has the potential for increased soil aeration, water retention capacity, and higher organic carbon, which may be responsible for the synthesis of more carbohydrates with maximum photosynthetic activity, resulting in translocation and accumulation of photosynthetic product at the sink (Yogananda *et al.,* 2020; Thakur *et al.,* 2018). Due to increasing the organic nitrogen fractions with time, organic carbon also builds up with time in the plot treated with biofertilizer enriched farmyard manure. The most beneficial organic matter compounds found in biofertilizer enriched farmyard manure may have aided in the growth of soil microorganisms and the enhancement in growth parameters of the succeeding crop (Gopinath and Mina 2011). Parmar *et al.* (2016) concluded that highest crop biomass, yield and litter fall was highest in tomato-cauliflower-radish/pea cropping system at the application of 50% nitrogen through farmyard manure enriched with rock phosphate + 50% nitrogen through vermicompost. Chattoo *et al.* (2009) also suggested that application of enriched farmyard manure + spent mushroom waste + poultry manure + vermicompost had a significant effect on pod yield per plot as well as per hectare in succeeding garden pea crop whereas okra was taken as a main crop.

Residual effect of Amaranth cultivation on subsequent soil properties: The data recorded residual available soil nutrient content of Amaranth plants after harvest revealed significant differences in the organic manure source employed in garden pea plots (Table 4). Among the all-organic manure treated plot the maximum residual nitrogen (222.36 kg/ha), phosphorous (18.62 kg/ha) and potassium (99.85 kg/ha) were recorded by the plot received biofertilizer enriched farmyard manure (20t/ha) whereas, pH, organic carbon and electric conductivity were statistically at par with each other. Again, among the foliar application treated plots, the residual nitrogen, phosphorous, potassium, pH, organic carbon and electric conductivity were statistically at par with each other. Among the interaction, the residual nitrogen, phosphorous, potassium, pH, organic carbon and electric conductivity were statistically non-significant. The findings revealed that biofertilizer-enriched farmyard manure releases essential plant nutrients slowly, resulting in a longer period of time required for releasing the nutrients thus Amaranth as the succeeding crop has utilized most of the nutrients and leaving a small portion of residual nutrients even after harvest of Amaranth crop. The finding is similar with Shepherd *et al.* (1996). Mal and Chatterjee (2016) stated that organic manures are beneficial for the growth and yield of succeeding crops. Parmar *et al.* (2016) concluded that maximum soil organic carbon, available nitrogen, available phosphorous and available potassium in tomato-cauliflower-radish/pea cropping system with the application of 50% nitrogen through farmyard manure enriched with rock phosphate + 50% nitrogen through vermicompost.

Soil nitrogen balance: The nitrogen balance sheet helps to find out the addition or removal of applied nitrogen to the soil. The result (Table 4) showed that application of biofertilizer enriched farmyard manure @ 20 t/ha registered highest addition of nitrogen (222.36kg/ha) followed by without enriched farmyard manure (20 t/ha) (201.87 kg/ha) whereas biofertilizer enriched poultry manure recorded on the negative nitrogen balance (-13.09 kg/ha). The increased availability of nitrogen under different organic manure received plots especially either farmyard manure or vermicompost had a favourable soil environment which might be helped in the availability of nitrogen to the succeeding crop for better growth and yield. Sharma *et al.* (2005) also observed in the availability of nitrogen was highest at farmyard manure and as well as vermicompost treated plot. The nitrogen balance (applied-uptake) was found positive response for all the organic manure treated plot. The highest actual nitrogen gains for application of biofertilizer enriched farmyard manure gradually improved the available status of nitrogen due to slow mineralization rate and takes longer time for supplying nutrients to the main crop, whereas in biofertilizer enriched poultry manure mineralization rate is very high results in supplying nutrients to the first crop which has no long-term effect on supplying nutrients to the succeeding crop. Shah (2003) further stated that the integration of legume crops improves the nitrogen content of the cropping system and increases crop yield via additional nitrogen and other soil impacts. Sharma *et al.* (2009) also noticed that enhancement of the available nitrogen content of soil with the use of farmyard manure in okra-onion cropping sequence in Himachal Pradesh.

Table 2: Effect of organic amendments of garden pea on succeeding Amaranth yield attributes and available soil nutrients (pooled mean of 2021 and 2022).

Treatments*	Individual plant weight (g)	Fresh plant yield/plot (kg)	Fresh plant yield/ha (t/ha)	Plant biomass (t/ha)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Organic carbon (%)	pH	Electric conductivity(dS/m)
Main plot (L): Foliar spray										
L_1	5.27	1.73	3.07	0.61	184.91	16.53	87.98	0.51	5.33	0.35
L_2	6.10	2.01	3.54	0.71	189.18	17.86	97.68	0.57	5.37	0.38
L_3	5.33	1.76	3.09	0.62	186.80	16.63	91.66	0.52	5.34	0.36
L_4	5.72	1.89	3.32	0.66	187.38	16.78	96.04	0.56	5.35	0.37
SEm(±)	0.03	0.04	0.08	0.01	1.16	0.68	0.89	0.01	0.05	0.01
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub plot (E): Enriched organic manures										
E_1	6.05	2.00	3.51	0.70	201.87	17.58	97.21	0.54	5.44	0.37
E_2	6.68	2.20	3.88	0.78	222.36	18.62	99.85	0.58	5.46	0.37
E_3	5.33	1.76	3.09	0.62	196.37	16.23	88.10	0.52	5.43	0.36
E_4	5.14	1.70	2.98	0.60	187.67	15.39	87.22	0.51	5.41	0.35
SEm(±)	0.03	0.02	0.07	0.01	0.93	0.52	0.65	0.01	0.04	0.01
CD (0.05)	0.09	0.05	0.19	0.01	2.68	1.47	1.93	NS	NS	NS

***Treatment details:** L_1: Control-water spray, L_2: Jeevamrut @ 3%, L_3: Vermiwash @ 3%, L_4: Mustard cake solution @ 3%, E_1: Control- farmyard manure @ 20 t/ha, E_2: Enriched farmyard manure @ 20 t/ha, E_3: Enriched vermicompost @ 5 t/ha and E_4: Enriched poultry manure @ 5 t/ha

Table 3: Effect of interaction of foliar spray and organic manures of garden pea on succeeding Amaranth yield attributes and available soil nutrients (pooled mean of 2021 and 2022).

Treatments	Individual plant weight (g)	Fresh plant yield/plot (kg)	Fresh plant yield (t/ha)	Plant biomass (t/ha)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Organic carbon (%)	pH	Electric conductivity (dS/m)
Interaction										
L_1E_1	5.85	1.98	3.48	0.69	199.99	17.88	89.95	0.54	5.42	0.37
L_1E_2	6.40	2.11	3.72	0.74	214.94	19.37	102.66	0.58	5.46	0.39
L_1E_3	5.24	1.83	3.21	0.63	188.07	16.69	87.42	0.50	5.38	0.34
L_1E_4	4.59	1.67	2.94	0.59	182.91	15.33	84.30	0.47	5.34	0.32
L_2E_1	6.34	2.09	3.68	0.74	203.28	19.26	97.68	0.56	5.43	0.38
L_2E_2	6.69	2.21	3.88	0.78	226.29	20.38	108.35	0.62	5.49	0.40
L_2E_3	5.56	1.94	3.40	0.68	198.93	17.78	88.57	0.53	5.40	0.36
L_2E_4	4.88	1.80	3.17	0.62	187.45	16.50	86.64	0.50	5.38	0.33
L_3E_1	5.88	1.99	3.50	0.69	201.10	18.24	91.82	0.55	5.42	0.38
L_3E_2	6.45	2.13	3.74	0.75	218.90	19.50	106.30	0.59	5.47	0.39
L_3E_3	5.45	1.86	3.28	0.66	191.78	16.78	87.68	0.51	5.39	0.35
L_3E_4	4.62	1.68	2.95	0.59	185.60	15.68	86.04	0.48	5.36	0.32
L_4E_1	6.10	2.02	3.54	0.71	201.67	18.58	94.37	0.55	5.43	0.38
L_4E_2	6.63	2.19	3.85	0.77	223.31	20.00	107.27	0.61	5.48	0.39
L_4E_3	5.49	1.89	3.33	0.67	197.81	17.17	88.09	0.52	5.39	0.36
L_4E_4	4.69	1.76	3.08	0.60	187.05	16.14	86.34	0.49	5.37	0.33
SEm(±)	0.04	0.04	0.09	0.01	1.57	0.81	1.64	0.01	0.06	0.01
CD (0.05)	NS	NS	NS	NS	4.67	NS	NS	NS	NS	NS

Table 4: Soil nitrogen balance as influence by garden pea-Amaranth cropping sequence/

Treatments*	A	B	C	D	E= (A+B)-C	F= D-A
E_1	200.76	100.00	234.27	201.87	66.49	1.11
E_2	200.76	124.00	255.62	222.36	69.14	21.60
E_3	200.76	92.00	220.75	196.37	72.01	-4.39
E_4	200.76	154.50	207.30	187.67	147.96	-13.09

***Treatment details:** E_1: Control- farmyard manure @ 20 t/ha, E_2: Enriched farmyard manure @ 20 t/ha, E_3: Enriched vermicompost @ 5 t/ha and E_4: Enriched poultry manure @ 5 t/ha

CONCLUSIONS

The present study demonstrated that adoption of Azophos biofertilizer enriched FYM as a source of organic manure for organic garden pea cultivation should be practiced for superior growth, yield of Amaranth crop and soil quality. The practice will help long term sustainability of the soil.

FUTURE SCOPE

This study should be conduct on a long-term basis to understand the extended residual effects of organic garden pea cultivation on Amaranth growth and soil properties over multiple cropping cycles. A study on the microbial diversity of the garden pea-Amaranth cropping system should be conducted for better soil health and quality. Other legume vegetable like French bean, cowpea, lablab bean, cluster bean should be studied for their beneficial effect on succeeding crops under organic production system. By addressing these future thrusts, we can enhance their understanding of the residual effects of organic garden pea cultivation on Amaranth growth and soil properties, leading to more sustainable and productive agricultural practices in the eastern Himalayan region.

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