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Role of Locally Available Bioresources of Nutrients in Sustenance of Soil Health, Productivity and Profitability of Vegetable Pea (*Pisum Sativum* L.) under Rainfed Agro Ecosystem of Western Himalayan Region of India

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ABSTRACT: Five years of study (from 2008 to 2012) was conducted to study the effect of different sources of nutrients on productivity, quality and profitability of vegetable pea grown under rainfed conditions of western Himalayan region of India. The experiment was laid out in a randomized block design with five replications having six treatment combinations. The plant height, root length, number of pods per plant and length of pod recorded the highest value in treatment (T₆) receiving nutrients from inorganic source in combination with basal application of FYM plus seed treatment with biofertilizer before sowing. When compared among only organic sources of nutrients, poultry manure plus seed treatment with biofertilizer (T₃) recorded highest plant height, root length, number of pods per plant, pod length and maximum green pod yield (9.0626 t/ha). However, T₆ proved its overall superiority and recorded maximum green pod yield (9.4478 t/ha) and net return (Rs 138993/ha), revealed that combination of inorganic fertilisers, organic manures and biofertilisers provided balance nutrition during crop season and can sustain the productivity and profitability. The uptake of nitrogen, phosphorus and potassium found to be maximum (N:P:K; 142.4:31.3:121.0 kg/ha) under T₆ and minimum (N:P:K; 73.3:14.1:63.2 kg/ha) under T₁. A significant change in soil health indicators was brought by different sources of nutrients. The available nitrogen, phosphorus and potassium showed significant build up over the initial values.

KEYWORDS: biofertilisers, FYM, nutrient uptake, *Pisum sativum*, poultry manure, soil health, vermicompost.

I. INTRODUCTION

India is the second largest producer of vegetables in the world having 9.2 million hectares area and 162.187 million tonnes production (**Anonymous 2013**) but at the same time the production of vegetables is not sufficient to meet out the daily requirement of an individual. Western Himalayan regions are quite suitable for growing off- season vegetables and particularly for vegetable pea, which could be a better option for the farmers to earn very lucrative returns and income. Vegetable pea (*Pisum sativum* L.) is a leguminous cash crop grown successfully during August-November and February-May as off-season vegetable in Himalayan region on small scale (**Nandi, 2008**). Vegetable pea is rich in protein, carbohydrates, vitamin A and C, sugar and minerals calcium and phosphorus (**Choudhary, 1967**). Besides these attributes, it plays a vital role in sustaining soil health through biological nitrogen fixation in association with symbiotic Rhizobia present in their root nodules that contributes about 50-60 kg/ha residual nitrogen in soil (**Erman et al., 2009**). The inorganic fertilizer generally is not accessible to farmers due to topographical limitation in Himalayan region, farmers use various locally available source of nutrients like FYM, vermicompost, poultry manure etc. Organic manures have beneficial effect on soil health, crop growth and quality but the constraint in wider usage is their bulky nature and low analytical values of nutrients. Other cheaper sources are biofertilizers which are eco friendly, cost effective and renewable sources of plant nutrients. Applications of biofertilizers (rhizobium and phosphorus-solubilising microorganisms) fix atmospheric nitrogen and help in solubilisation of nutrients (**Dass et al., 2008**), thereby improve quality and increase 2 to 45% yields in vegetable crops (**Wani, 1994**). The judicious use of organic

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Vol. 6, Issue 11, November 2017

manures and biofertilizers may be effective not only for sustaining crop productivity and soil health, but also in supplementing chemical fertilizers to crop (JaiPaul et al., 2011). The present investigation was carried out to study the effect of different combinations of locally available sources of nutrients viz., organic manures, bio-fertilizers and chemical fertilizers on productivity, profitability of off-season vegetable pea and soil health.

II. MATERIALS AND METHODS

A five year field experiment was conducted during 2008–12 at Organic Block of Veer Chandra Singh Garhwali College of Horticulture, Govind Ballabh Pant University of Agriculture and Technology, Bharsar, Pauri Garhwal (India) , located at latitude of 30°35'N, longitude of 78°42' E and at an altitude of 2200 m above mean sea level. The climate of the area is wet temperate (maximum temperature 26°C, minimum temperature –2°C and annual rainfall 1360 mm. A total of six treatments consisting of different sources of nutrients were selected and replicated five times in a randomized block design.

The treatments were; T₁, control (without any source of nutrient application); T₂, farmyard manure (FYM) @ 25 tonnes/ha + biofertilizers; T₃, poultry manure @ 7.5 tonnes/ha + biofertilizers; T₄, vermicompost @ 10 tonnes/ha + biofertilizers; T₅, farmyard manure @ 10 tonnes/ha + poultry manure and vermicompost each @ 2.5 tonnes/ha + biofertilizers; T₆, recommended doses of nutrients (25 kg N + 75 kg P₂O₅ + 50 kg K₂O) + farmyard manure @ 10 tonnes /ha + biofertilizers. The culture of rhizobium and phosphate-solubilising microorganisms were used as seed treatment before sowing. Each year, vegetable pea (variety - Arkel) was grown during August–November following recommended package of practices under rainfed condition. The biofertilizer treated seed of vegetable pea was sown at a distance of 30 cm × 10 cm in a plot size of 3 × 2 m². Manures as per the treatment were incorporated as basal dose at the time of field preparation. In treatment T₆ i.e. recommended doses of nutrients (25 kg N + 75 kg P₂O₅ + 50 kg K₂O) + farmyard manure @ 10 tonnes /ha + biofertilizers, full doses of N, P and K were applied through urea, single super phosphate and muriate of potash at the time of sowing. Biofertilizers (Rhizobium + phosphorus-solubilising microorganisms) were applied as seed treatment before sowing of vegetable pea. No application of any pesticide was done to control insects or diseases.

The observations for each treatment on plant height, number of nodules/plant, number of pods/plant, pod length, number of grains/pod, per pod weight and total yield of pods were recorded. The economics/profitability of vegetable pea was also worked out.

Random samplings of whole pea plant (shoot and pod) were taken at the time of maturity/harvesting for chemical analysis. The nitrogen content in plant samples was analyzed by Kjeldahl method (AOAC 1970) while phosphorus and potassium were estimated by tri-acid mixture as given by Jackson (1973). The nutrients (N, P and K) uptake by plant shoot and grain samples were obtained as a product of yield and concentration of the nutrient in shoot and grain samples and expressed as kg/ ha. The treatments of experiment were repeated for the five years without disturbing the layout and randomization of treatments. Before initiation and after completion of the experiment the soil samples (0–15 cm depth) were collected, processed and analyzed for various indicators of soil health. Soil pH, electrical conductivity, organic carbon, available nitrogen, available phosphorus and available potassium were estimated as per the methods given by Jackson (1973). The carbon dioxide (CO₂) evolution in soil samples was determined using an alkali absorption method (Pramer and Schmidt 1964). Microbial biomass in the soil samples was quantified by a chloroform (CHCl₃) fumigation- extraction method (Vance et al., 1987) in terms of microbial biomass carbon. The representative data were analyzed using STAT4.0 packages for analysis of variance (ANOVA) as per the procedure given by Gomez and Gomez (1984). Since the presentation of the data of crop in each season from an experiment would be very voluminous, only average values of five years data are presented in this article.

III. RESULTS AND DISCUSSION

Growth and yield attributes: On perusal of data presented in table 1 revealed that different nutrient sources significantly increased the plant height. Maximum plant height (87.14 cm) was observed under T₆ treatment and

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 11, November 2017

minimum plant height (58.78 cm) in control (T_1). However, the application of T_3 attained maximum plant height (81.81 cm) as compared to other organic treatment combinations. The results indicated that integration of nutrients sources proved better owing to the fact that nutrients supply was in balance and synchronized well with the demand of crop. These results have close agreement with those of **Patel et al. (1998)**; **JaiPaul et al. (2011)** and **Sharma and Chauhan (2011)** as they reported maximum plant height of vegetable pea in the treatment comprising of fertilizer in combination with organic manures and biofertilizers in comparison to other treatment combinations.

The root growth which plays an important role in acquisition of nutrients from soil is also affected significantly by the addition of different nutrient sources. The root length varied from 11.26 – 19.12 cm and T_6 recorded longest root length than others. However, T_3 recorded highest value among organics. In pea crop, the root growth also affects the number of nodules and thereby biological nitrogen fixation. Therefore, numbers of effective nodules directly affect the amount of nitrogen fixed. While considering the number of nodule per plant, it was observed that T_4 resulted in maximum number of nodules per plant (33.38) and minimum (9.12) in T_1 . These findings are in line with those of **Parmar et al. (1998)** and **JaiPaul et al. (2011)**. The results (Table1) pertaining to the number of pods per plant, length of pod, number of grain per pod and per pod weight revealed that highest values were recorded with T_6 , whereas, lowest in T_1 . However, among the different combinations of organics T_3 treatment proved its superiority. These results are in close agreement with those of **Parmar et al. (1998)**; **JaiPaul et al. (2011)** and **Sharma and Chauhan (2011)**. They also reported that when pea crop was supplied with a combination of chemical fertilizers, organic manure and biofertilizers in comparison to other combinations of nutrient sources recorded highest values for above parameters, owing to the fact that this combination succeeded in better supply of nutrients.

The average yield of five year experiment revealed that application of nutrients through various sources significantly increased the pod yield over control. It has been observed that treatment T_6 recorded highest pod yield (9.4478 t /ha) and lowest (4.5638 t / ha) in T_1 . Besides treatment T_6 , the different combinations of organic manures have been also differed significantly and T_3 treatment was proved superior and recorded second highest yield value (9.0626 t / ha) followed by T_5 , T_4 and T_2 treatments. The increase in yield attributes and green pod yield might be due to the beneficial effect of bio fertilizers and manures. The combined use of different sources in balanced way increased rate of nutrients absorption, symbiotic activity, stimulated better vegetative and reproductive growth of the crop resulting in higher green pod yield. The trend of results has close agreement with those of **Datt et al. (2003)** and **Parmar et al. (1998)**.

Nutrients uptake: The uptake of nitrogen, phosphorus and potassium by vegetable pea significantly differed among the treatments (Table 2). The uptake of nutrients varied due to the availability of particular nutrient during crop growing period and yield of crop in particular treatment. In pea, maximum uptake of total nitrogen (142.40 kg/ ha) was found under T_6 treatment followed by T_3 and T_5 . However, minimum uptake (73.30 kg/ ha) of total nitrogen was recorded in T_1 .

Similarly, the total uptake of phosphorus was also found maximum (31.38 kg / ha) in T_6 treatment and minimum (14.10 kg/ ha) in T_1 . The organic treatment combinations also showed significant difference among each other and T_3 treatment proved its superiority.

Data presented in table 2 also revealed that combination of organic and inorganic sources i.e. T_6 resulted in maximum uptake of total potassium (121.00 kg/ ha) by pea whereas, minimum (63.20 kg/ ha) in T_1 . The treatment T_3 again proved better in uptake of potassium by pea followed by T_5 and T_4 treatments. **Datt et al. (2003)** and **Parmar et al. (1998)** studied the effect of supplementary use of FYM, chemical fertilizers along with biofertilizers on productivity and nutrient uptake by pea in North West Himalayan agroclimatic zone of India and reported that there was a consistent increase in total uptake of N, P and K and increased significantly with successive increase in their doses with and without FYM compared with control. Similar conclusions have been also reported in other parts of the country on pea (**Kasturikrishna and Ahlawat, 1999** and **Singh et al., 2004**).

Soil health indicators: Data on effect of different nutrient sources on soil health indicators are presented in table3. Bulk density is an index of workability of soils moisture availability, aeration and root penetration. Highest bulk

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Vol. 6, Issue 11, November 2017

density (1.44 Mg/m^3) was observed in control followed in descending order by treatment T_3 (1.33 Mg/m^3) and treatment T_6 (1.29 Mg/m^3). Whereas, lowest bulk density (1.15 Mg/m^3) was recorded in T_2 close to T_5 (1.19 Mg/m^3). It is well established fact that the presence or application of organic matter results in reduction of soil bulk density. This effect was also proved from the results reported by those of **Werner (1997) and Gopinath et al. (2008)**. They also stated that use of organic amendments has been associated with many desirable soil properties including lowering of bulk density.

The data on soil pH (Table 3) varied from 5.43 to 6.35, minimum in T_1 and maximum in T_2 treatment. However, treatment T_3 also significantly increased soil pH (6.17) followed by 5.95 treatment T_5 . The soil pH increased in all the treatments compared to control. The results are consistent with earlier reports (**Clark et al., 1998 and Gopinath et al., 2008**), where organic systems had greater pH levels in mildly acidic soils than their conventional counterparts. This illustrates the important role of organic amendments in soil pH improvement (**Stroo and Alexander, 1986**).

Electrical conductivity is representative of soluble salt content in the soil and varies with the presence and amount of salt in the soil. The electrical conductivity values of the experiment field differed nonsignificantly among the treatments indicated that the salt content was not build up due to leaching and runoff processes.

The results pertaining to soil organic carbon content (Table 3) ranged from 7.06 to 14.10 g/kg, highest in the T_2 plots and lowest in T_1 . However, application of T_5 treatment also significantly increased soil organic carbon content (12.54 g/kg) followed by T_6 and T_4 . These findings are in accordance with **Bulluck et al. (2002)** who reported that soil quality improved through use of alternative fertility amendments and increased total carbon and soil organic matter in the soil. Depending on soil type, climate, management, and the capacity of a soil to store organic matter, soil organic carbon levels may increase linearly with the amount of organic matter input (**Clark et al., 1998**). Similar results were also reported by **Gopinath et al. (2008) and JaiPaul et al. (2014)**.

On perusal of data presented in table 3 showed that application of different nutrient sources significantly increased available nitrogen, phosphorus and potassium content. Maximum available nitrogen, phosphorus and potassium (294.20 kg/ha , 28.56 kg/ha and 384.00 kg/ha , respectively) were recorded in plots applied with treatment T_6 followed by plots applied with treatment T_3 and treatment T_5 . Whereas, minimum available nitrogen, phosphorus and potassium (227.40 kg/ha , 10.59 kg/ha and 341.20 kg/ha , respectively) were recorded in T_1 . These results have close agreement with those of **Gopinath et al. (2009)** who reported that the plots under INM, however, recorded higher N, P, and K contents in soil compared to application of organic manures alone. Lower availability of plant nutrients (N and P) in plots applied with organic amendments is expected due to slower release rates under low temperature prevailing condition (**JaiPaul et al. 2011**).

The microbial biomass carbon contents (Table 3) was found lowest ($238.80 \mu\text{g/g soil/hr}$) in T_1 and highest ($379.20 \mu\text{g/g soil/hr}$) T_2 . A close relationship exists between soil organic matter content, microbial population and soil aggregation (**Chang et al., 2007 Kumar et al., 2012**). Similarly, **Graham et al. (2002)** has found that application of inorganic fertilizers or a combination of inorganic fertilizers and organic amendments increased soil microbial biomass C.

Under field conditions, carbon dioxide evolution represents respiration by plant roots and soil organisms. Consequently, CO_2 evolution is a sensitive indicator of crop residue decomposition, soil organic matter turnover, and ecosystem disturbance (**Paul et al., 1999**). Data presented in table 3 showed that all the treatments used significantly improved CO_2 evolution. Maximum CO_2 evolution ($182.40 \mu\text{g/g soil/hr}$) was found in treatment T_2 , whereas, minimum ($131.60 \mu\text{g/g soil/hr}$) in treatment T_1 . The treatments supplied with organic manures increased the microbial population which resulted in more respiration or CO_2 evolution. Results are also corroborated with the findings of **Liang et al. (2003)**. Fresh biomass additions through manures invariably undergo decomposition to yield CO_2 as its major product (**Paul et al. 1999**). **JaiPaul et al. (2014)** reported that CO_2 evolution indirectly indicated microbial activities and decomposition rate of residues. They also found that CO_2 evolution significantly varied with the amount

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[A High Impact Factor, Monthly, Peer Reviewed Journal] Impact Factor: 7.089| UGC Approved|

Vol. 6, Issue 11, November 2017

of crop residue incorporation or crop residue removal or crop residue burning and significantly increased through incorporation of crop residue and green manuring.

Economics: The total cost of production ranged between Rs. 22645 - 46285/ha for vegetable pea (Table 4). The total production cost was the lowest (Rs 22645/ha) for the T₁ and the highest (Rs 46285/ha) for treatment T₄. The output cost for different treatments ranged between Rs 63201 - 167701/ha for pea. The highest net return (Rs 138993) was obtained from T₆, followed by T₃ (Rs 122945) and then others. The benefit: cost (B: C) ratio was found to be the highest (5.84) in T₆ treatment, followed by T₃, while the lowest B:C ratio (2.67) was recorded from the T₄ treatment. From the economic point of view, the above results indicated that overall, integrated nutrient management (T₆) treatment followed by poultry manure + biofertilizers (T₃) treatment among the organic treatments were proved more profitable for garden pea crop. The lowest B:C ratio in case of vermicompost + biofertilizers (T₄) is due to high price of the vermicompost input. Similar findings were also reported by **Gopinath et al. (2008)**, found that the highest gross margin and B:C ratio were recorded under integrated nutrient management treatment in comparison to treatments containing only organic sources of nutrients.

Finally, it is concluded that integration of organic and inorganic sources of nutrients along with biofertilisers proved better than sole source or organics combination to build up nutrient status and thereby enhanced the crop productivity. Not only, the chemical fertilizers can produce a good yield and fetch a good remuneration but the application of organic manures like poultry manure along with biofertilizers can also achieve the yield target and a good return under better management practices. Simultaneously, the organic manures are locally available, eco-friendly and helpful in sustaining the soil health.

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International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 11, November 2017

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International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 11, November 2017

Table1: Effect of different combinations of nutrient sources on growth and yield attributes of vegetable pea (data presented here is the average of five years of experimentation)

| Treatment | Plant height (cm) | Root length (cm) | No. of nodule/plant | No. of pods/plant | Length of pod (cm) | No. of grains /pod | Per pod weight (g) | Pod yield (t /ha) |
|---------------------|-------------------|------------------|---------------------|-------------------|--------------------|--------------------|--------------------|-------------------|
| T ₁ | 58.78 | 11.26 | 9.12 | 16.08 | 6.01 | 5.17 | 5.55 | 3.5638 |
| T ₂ | 64.68 | 13.94 | 14.54 | 22.24 | 7.13 | 6.05 | 6.77 | 6.0792 |
| T ₃ | 81.81 | 18.80 | 19.64 | 35.66 | 9.50 | 8.73 | 8.80 | 9.0626 |
| T ₄ | 69.42 | 15.46 | 33.38 | 21.78 | 8.00 | 7.26 | 7.95 | 6.9654 |
| T ₅ | 75.42 | 16.44 | 30.38 | 27.62 | 8.89 | 8.02 | 8.58 | 7.3926 |
| T ₆ | 87.14 | 19.12 | 26.58 | 40.92 | 9.98 | 8.89 | 9.49 | 9.4478 |
| LSD _{0.05} | 1.43 | 0.38 | 0.46 | 1.62 | 0.13 | 0.15 | 0.05 | 0.1072 |

Where;

T₁ = control, T₂ = Farmyard manure @ 25 t/ha + biofertilisers, T₃ = Chicken manure @ 7.5 t/ha + biofertiliser, T₄ = Vermicompost @ 10 t/ha + biofertiliser, T₅ = Farmyard manure @ 10 t/ha + chicken manure @ 2.5 t/ha + vermicompost @ 2.5 t/ha + biofertilisers, T₆ = Recommended dose of nutrients + farmyard manure @ 10 t/ha + biofertilisers
Biofertilisers = Rhizobium + PSM

Table2: Effect of different combinations of nutrient sources on total uptake of nutrients by vegetable pea (data presented here is the average of five years of experimentation)

| Treatment | Total nitrogen uptake (kg /ha) | Total phosphorus uptake (kg/ ha) | Total potassium uptake (kg/ ha) |
|---------------------|--------------------------------|----------------------------------|---------------------------------|
| T ₁ | 73.30 | 14.10 | 63.20 |
| T ₂ | 91.60 | 18.20 | 74.70 |
| T ₃ | 130.50 | 28.42 | 112.00 |
| T ₄ | 102.50 | 21.58 | 86.20 |
| T ₅ | 116.46 | 25.42 | 96.90 |
| T ₆ | 142.40 | 31.38 | 121.00 |
| LSD _{0.05} | 2.09 | 1.49 | 1.73 |

Table3: Effect of different combinations of nutrient sources on soil health indicators (data presented here is the average of five years of experimentation).

| Treatment | Bulk density (Mg/m ³) | pH | EC (d S/ m) | Soil organic carbon (g /kg) | Avail-N (kg/ ha) | Avail-P (kg/ ha) | Avail-K (kg/ ha) | MBC ug /g soil /hr | CO ₂ evolution (ug /g soil/ hr) |
|---------------------|-----------------------------------|-------|-------------|-----------------------------|------------------|------------------|------------------|--------------------|--|
| T ₁ | 1.44 | 5.43 | 0.188 | 7.06 | 227.40 | 10.59 | 341.20 | 238.80 | 131.60 |
| T ₂ | 1.15 | 6.35 | 0.206 | 14.10 | 260.60 | 16.52 | 363.60 | 379.20 | 182.40 |
| T ₃ | 1.33 | 6.17 | 0.220 | 9.22 | 287.60 | 24.56 | 377.00 | 316.80 | 137.40 |
| T ₄ | 1.23 | 5.68 | 0.214 | 10.12 | 274.00 | 18.70 | 370.00 | 353.20 | 166.40 |
| T ₅ | 1.19 | 5.98 | 0.226 | 12.54 | 278.40 | 20.48 | 372.20 | 365.00 | 173.40 |
| T ₆ | 1.29 | 5.60 | 0.244 | 11.76 | 294.20 | 28.56 | 384.00 | 327.20 | 146.60 |
| LSD _{0.05} | 0.016 | 0.052 | NS | 0.48 | 2.06 | 0.86 | 3.98 | 3.77 | 3.78 |
| Initial values | 1.41 | 5.41 | 0.20 | 7.30 | 238.50 | 11.60 | 345.50 | 240.20 | 125.00 |

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Table4: Effect of different combinations of nutrient sources on profitability of garden pea during 2008-2012 (average values).

| Treatment | Total pod yield (t/ha) | Input cost (Rs) | Output cost (Rs) | Net return (RS) | B:C ratio |
|---------------------|-------------------------|-----------------|------------------|-----------------|-----------|
| T ₁ | 3.5638 | 22645 | 63201 | 40556 | 2.79 |
| T ₂ | 6.0792 | 31185 | 108119 | 76934 | 3.46 |
| T ₃ | 9.0626 | 37745 | 160690 | 122945 | 4.25 |
| T ₄ | 6.9654 | 46285 | 123603 | 77318 | 2.67 |
| T ₅ | 7.3926 | 37035 | 131273 | 94238 | 3.54 |
| T ₆ | 9.4478 | 28708 | 167701 | 138993 | 5.84 |
| LSD _{0.05} | 0.1072 | | | | |