Original Research Article

Influence of*Pseudomonas*and Biofertisolas Foliar Spray on Nodulation Attributes and Yield ofVegetable Pea under STCR Approach

Abstract

A field experiment was carried out during the *rabi* season of 2020 in the Experimental Field, Department of Soil Science and Agricultural Chemistry, JNKVV, Jabalpur (M.P.) under RBD design with four replications consisting of five treatments of two types of biofertilizers: *Pseudomonas* and Biofertisol, and scheduled combinations of inorganic fertilizers based on STCR (Soil Test Crop Response) to achieve the desired yield using the vegetable pea variety PSM-3.The response due to treatment of T_4 (TY 100 q (58:110:47) +5 tFYM+1 spray of Pseudomonas+1 spray of Biofertisol) was significantly effective in increasing nodulation attributes (nodulation enumeration, biomass and leghemoglobin content) by 28.46, 47.15, and 35.29%; 78.33, 95.86, and 86.17%; and 21.70, 65.70, and 20.26%, respectively, relative to that of control. Yields of the crop were best harvested due to $T_4$by 81.91% over that of control 56.93 kg ha^{-1}.The continuous application of chemical fertilisers has decreased the fertility of the soil and degraded the soil.The reduction in the fertility of the soil has resulted in poor crop yields.The nutrient management of all the treatments involves the judicious use of organic and inorganic fertilizers, along with microbes, to meet the nutrient needs of the crop while minimising environmental impacts.

Introduction

Vegetable pea is commonly used in human diet and nutritionally it is rich in protein, carbohydrates, vitamin A, calcium, phosphorus and has high levels of amino acids lysine and tryptophan (Bhat *et al*., 2013).For high yielding pulse and oilseed cultivars to reach their full production potential, fertilizer is one of the most vital but expensive inputs. Nevertheless, it also leaves behind a considerable financial load and a lot of environmental issues. The concept of Truog (1960) towards the basis for fertilizer application for targeted yields and the experimental proof provided by Ramamoorthy et al. (1967) are effectively useful fertilizer recommendation for a targeted yield based on soil test value. The Liebig's law of minimum stated that plants growth is limited by the plant nutrient element (N, P, and K) available in the smallest amount. The incorporation of organic manure and biofertilizers, however, as the best method in organic and sustainable agriculture, can limit the usage of chemical fertilizer, according to the most recent idea of STCR approach (Dey, 2015). Even under the STCR concept for giving nutrients with a restricted dosage of inorganic fertilizer up to 25–30%, biofertilizers are a cost–effective and ecologically friendly input with enormous promise in organic and sustainable farming (Rana et al., 2012). The bulky organic manure (FYM) has already been recognized for a number of benefits, including improved soil physical properties (such as structure, water holding capacity, etc.), optimized carbon sequestration, and a way to control parasitic nematodes and fungi with altered but balanced beneficial microorganisms as their source of carbon and energy.

A significant limiting factor for plant development and production is frequently the limited supply of nitrogen molecules in soils. Legumes circumvent this limitation by forming a symbiotic relationship with rhizobia that fix nitrogen for the plant. Legumes generate highly specialised structures called nodules in their roots through symbiotic associations with N-fixing soil bacteria of the genus Rhizobia (Roy et al., 2020). The specialised root structures known as nodules, which are created by an organised and controlled process are responsible for nitrogen fixation and nutrient exchange.

Plant growth-promoting rhizobacteria (PGPR) are slashing agricultural innovations.

Ascophyllum nodosum, a seaweed, and enzymatic fish hydrolysate are combined to create Biofertisol, a novel organic manure that is a very rich source of micronutrients, phytohormones (including cytokinins), and growth regulators. Additionally beneficial for enhancing stress tolerance are organic inputs such volatile betines and pH balancers (Kristinsson and Rasco, 2000).

Material Method

The study trial was established on the vegetable pea crops during rabi season. The field is situated 393 metres above mean sea level in the southeast of Madhya Pradesh at 23^{o}13' North latitude and 79^{o}57' East longitudes. The experimental field has a level topography and proper drainage. The soil in the experimental field is classified as a Vertisol, and it is made of fine montmorillonite from the Kheri series and Typic Haplusterts from the Hyperthermic family, also referred to as "black cotton soil." Analyses of the soil's initial chemical properties included 7.31 pH, 0.24 dS m^{-1} electrical conductivity and the available soil nutrient status was 175.63, 11.56, and 218.41 kg ha^{-1} N, P, and K, respectively. The treatmentcombinations for a vegetable pea crop are given below as:

Treatmentcombinations

T_1: Control

T_2:GRD (30:60: 30) + 3 spray of *Pseudomonas*+ 2 spray of Biofertisol

T_3:T.Y.* 80q (29:72:20) + 5 t FYM + 2 spray of *Pseudomonas*+ 2 spray of Biofertisol

T_4:T.Y.100q (58:110:47) + 5 t FYM +1 spray of *Pseudomonas* +1 spray of Biofertisol

T_5: T.Y.120q (87:147:74) + 5 t FYM

T.Y.* = Targeted Yield

At 30, 45, and 60 days after sowing, nodule enumeration was counted by gently removing five plants per plot without causing any nodule loss or damage. After counting, the nodules were put in little paper bags and stored in a hot air oven at 60 °C for 1–5 days (until a consistent weight) before being weighed using an electronic balance.Leghemoglobin content in nodules measured by Sadasivam and Manickam (2008).

The harvested pods from all of the plots were weighed based on the net plot area, with the use of an electronic balance, the yields were measured in kilograms and converted to quintal per hectare (q ha^{-1}).

To assess the statistical significance of variation among various treatment means as impacted by the application of the treatments under research on various characteristics of vegetable pea, the recorded data were statistically analysed using randomised block design.

Result and discussion

The result of the field experiment with different levels of N, P, and K based on the targeted yield of vegetable pea along with foliar sprays of P. fluorescens and biofertisol with FYM on nodulation attributes and crop yield in the form of data was recorded and statistically analysed.

Nodulation studies

Nodule number

The nodule enumeration in vegetable pea was counted and tabulated in table 1and figure 1. At **30 DAS**, the maximum number of nodules of 27.44 No. plant^{-1} with 28.5% response over that of control (21.36No. plant^{-1}) was recorded due to the application of T_4 (TY 100 q (58: 110:47) +5 t FYM+1spray of *Pseudomonas*+1 spray of Biofertisol).This was followed by the effects from T_3, T_5 and T_2 exhibiting nodulation of 26.6, 25.3 and 23.8 No.plant^{-1} and 24.5, 19.5 and 11.5% response, respectively. At **45 DAS** of the crop, The maximum nodules 42.07 nodules plant^{-1} wascounted due to T_4 (TY100 q (58:110:47) +5t FYM+1 spray of *Pseudomonas*+ 1 spray of Biofertisol) with the percentage response of 47.15 better over that of control (28.59 No. plant^{-1}).This was followed by the response from T_3, T_5 and T_2 with nodulation of 40.4, 38.6 and 35.0 No. plant^{-1} indicating 41.1, 34.9 and 22.2% increment, respectively.Similarly, the maximum number of nodules at**60 DAS** range was 25.15 No. plant^{-1} and35.3% increment over that of control (18.59 No. plant^{-1}) which was observed due to application of T_4 (TY100 q (58:110:47) +5 t FYM+1 spray of *Pseudomonas* +1 spray of Biofertisol). This was followed by the effects of T_3, T_5 and T_2 with nodulation of 24.5, 22.4 and 21.2 No. plant^{-1} with the percent response of 31.7, 20.7 and 13.9, respectively.This may be attributed due to PGPS-colonized plants had improved nodulation with vigorous growth; Promoting the diazotrophic bacteria for better nodulation, nitrogenase activity, and nodular iron assimilation (Tokala *et al.*, 2002), thus helping the crops higher yield by supplying nitrogen particularly during seed development stage (Ritika *et al.*, 2018).

Nodule Biomass

At **30 DAS**, treatment T_4 (TY100q (58:110:47) +5 t FYM+1spray of *Pseudomonas*+ 1 spray of Biofertisol) responded best by 56.44 mg nodule biomass plant^{-1} with 78.33% increment as compared to that of control (31.65 mg plant^{-1}), followed by the effects of T_3, T_5 and T_2 with the nodule biomass of 51.26,45.23 and 38.56 mg plant^{-1} and 62.0, 42.9 and 21.8% increment, respectively (Table1and figure 2). Nodule biomass of vegetable pea at **45 DAS** was89.71 mg plant^{-1} and a89.7% response over that of control (47.29 mg plant^{-1}), which was envisaged due to T_4 (TY 100 q (58:110:47) + 5 t FYM +1 spray of *Pseudomonas*+1 spray of Biofertisol).The next group of nodule biomass was 87.29, 78.39 and 63.51 mg plant^{-1} as the effects from $T_{3,}$ T_5 and T_2 which were 84.58, 65.8 and 34.3% better in response, respectively.At **60 DAS** of the crop, application of STCR based fertilizers for TY 100 q along with *Pseudomonas* and Biofertisol(T_4) performed best with 74.17 mg nodule biomass plant^{-1} and 86.2% response over that of control (39.84 mg plant^{-1}).This was followed by the effects from $T_{3,}$ T_5 and T_2 with the nodule biomass of 71.84, 62.30 and 51.25 mg plant^{-1}having the respective increment of 80.32, 56.38 and 28.64%.

Singh (2005) reported that application of FYM @ 15 t ha^{-1} was increased number of nodules and dry weight of the nodules plant^{-1} which gave a significantly higher grain yield of soybean than without FYM; nitrogen application decreased the number of nodules formed during early growth stages of legumes.

Leghemoglobin content

The maximum content of leghemoglobin in nodules at **30 DAS** range 1.643 mg plant^{-1} representing a 21.7% response over that of control (1.350 mg plant^{-1}) for was estimated due to T_4 (TY100q (58:110:47) +5 t FYM+1spray of *Pseudomonas*+ 1 spray of Biofertisol). This was followed by the content of leghemoglobin of followed by of 1.588 1.528 and 1.440 mg plant^{-1} with 17.6, 13.2 and 6.7% response due to T_3, T_5 and T_2, respectively. The leghemoglobin content in the nodules at different growth stages of vegetable pea is presented in table1and figure 3.At **45 DAS,** application of T_4 (TY100 q (58:110:47) +5 t FYM + 1 spray of *Pseudomonas*+1 spray of Biofertisol) increased leghemoglobin content at 2.618mg plant^{-1} which was 65.7% better over that of control (1.580 mg plant^{-1}). This was followed by the effects from $T_{3,}$ T_5 and T_2 with leghemoglobin content of 2.553, 2.483 and 2.388 mg plant^{-1}with respective increment of 61.6, 57.2 and 51.1%. At **60 DAS,**the maximum content of leghemoglobin of 1.585 mg g^{-1} was estimated due to the treatment effect of T_4 (TY100 q (58:110:47) + 5 tFYM+1 spray of *Pseudomonas* + 1 spray of Biofertisol) which was 20.3% more relative to that of control (1.350 mg g^{-1}). The next group of was due to $T_{3,}$ T_5 and T_2 for the leghemoglobin content of 1.545, 1.493 and 1.430 mg plant^{-1}representing 17.2, 13.3 and a 8.5% response. The finding was in support to that of Eylenbosch*et al*. (2018) that higher leghemoglobin content was due to better root and nodule development. Dutta and Bandyopadhyay (2009) reported that phosphorus and biofertilizer application increased significantly the nodulation, leghemoglobin content, nitogenase activity.

***Table* 1. Effect of *Pseudomonas* and Biofertisol on nodulation attributes of vegetable pea at different growth stages under STCR approach**

Treatment	**Nodule enumeration (No. plant^{-1})**			**Nodule biomass (mg plant^{-1})**			**Leghemoglobin content (mg g^{-1} of nodule)**		
	30 DAS	**45 DAS**	**60 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**30 DAS**	**45 DAS**	**60 DAS**
T_1: Control	21.36	28.59	18.59	31.65	47.29	39.84	1.350	1.580	1.318
T_2: GRD (30:60:30) +3 spray of *Pseudomonas*+ 2 spray of Biofertisol	23.81	34.95	21.17	38.56	63.51	51.25	1.440	2.388	1.430
T_3: T.Y. 80 q (29:72:20) + 5 t FYM+2 spray of *Pseudomonas*+2 spray of Biofertisol	26.59	40.35	24.48	51.26	87.29	71.84	1.588	2.553	1.545
T_4: T.Y.100 q (58:110:47) + 5 t FYM + 1 spray of *Pseudomonas*+ 2 spray of Biofertisol	27.44	42.07	25.15	56.44	92.62	74.17	1.643	2.618	1.585
T_5: T.Y.120 q (87:147:74) + 5 t FYM	25.52	38.58	22.83	45.23	78.39	62.3	1.528	2.483	1.493
Mean	24.94	36.91	22.45	44.63	73.82	59.88	1.509	2.324	1.474
S.Em. ±	0.12	0.17	0.02	0.37	0.25	0.36	0.007	0.006	0.004
C.D. (P=0.05)	0.36	0.49	0.07	1.08	0.72	1.06	0.019	0.018	0.012

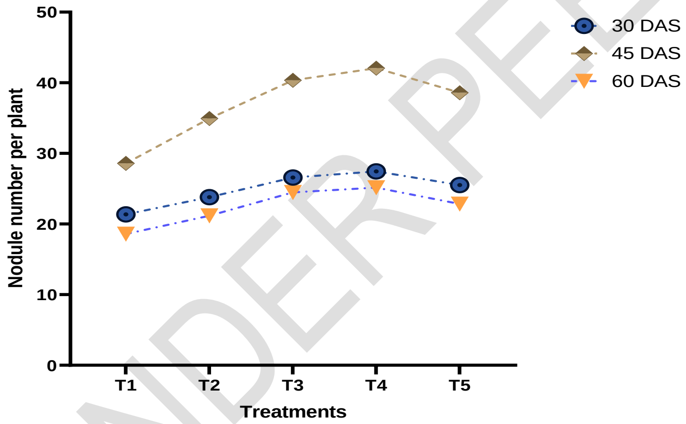

Figure 1. Effect of *Pseudomonas* and Biofertisol on nodulation enumeration of vegetable pea at different growth stages under STCR approach

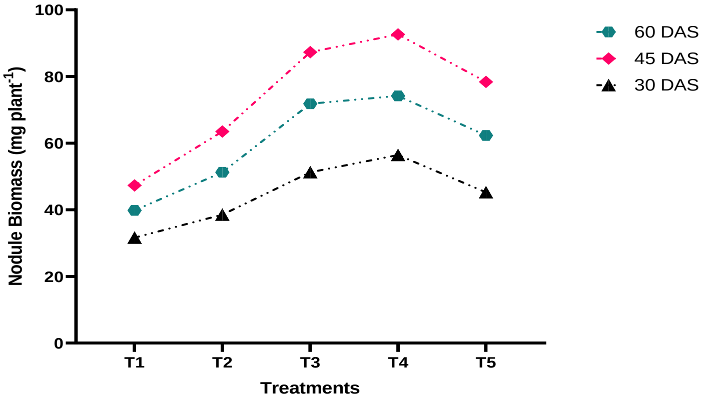

Figure 2. Effect of *Pseudomonas* and Biofertisol on Nodule biomassof vegetable pea at different growth stages under STCR approach

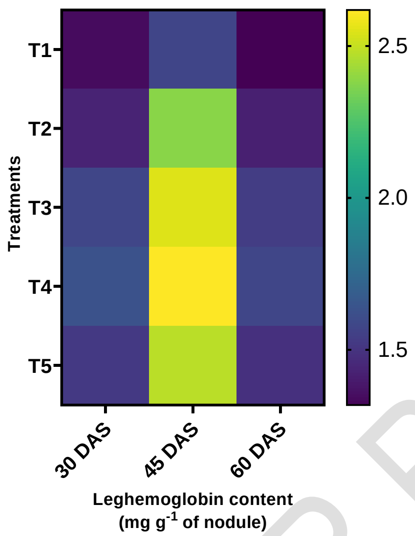

Figure 3. Effect of *Pseudomonas* and Biofertisol on Nodule biomassof vegetable pea at different growth stages under STCR approach

Pod Yield

The maximum yield of a green pod (105.45kg ha^{-1}) was harvested from the treatment T_5 (TY 120 q (87:147:74) +5 t FYM) which was found 85.97% relative that of control (56.70 kg ha^{-1}). However, it was statistically at par with the effect of application of T_4 (TY100 q (58:110:47) + 5 t FYM+1sprayof*Pseudomonas*+1sprayofBiofertisol)yielding 97.17kg pod ha^{-1} with 71.37% response. This was followed by the effects due to T_3 and T_2 with grain yield of 84.56and 75.64kg ha^{-1}corresponding to 49.13 and 33.40% response, respectively (Table 2 and figure 4). To ensure balanced fertilization of the appropriate kind and amount, soil test calibration aims to develop a relationship between the soil nutrient levels measured in the lab and the crop response to fertiliser nutrients applied in the field. As a result, the STCR idea of targeted yield approach is important in recommending balanced fertilisation while taking the level of the soil's available nutrients and the crop's requirements into consideration (Ramamoorthy et al., 1967). The most prevalent plant growth regulators found in commercial extracts of A. nodosum in the current investigation were different cytokinins and cytokinin-like substances. This increase in yield might be attributable to a number of factors (Wally et al., 2013). Plant-PGPR interactions, according to Adesemoye and Kloepper (2009), benefited seed germination, root growth, shoot and root weights, leaf area, chlorophyll content, protein content, nutrient absorption (like N and P), and yield.

Table 2. Effect of Pseudomonas and Biofertisol on yields (green pod) of vegetable pea at harvest under STCR approach.

Treatment	Pod Yield (q ha^{-1})
T_1: Control	56.70
T_2: GRD (30:60:30) + 3 spray of *Pseudomonas* + 2 spray of Biofertisol	75.64
T_3: T.Y. 80 q (29:72:20) + 5 t FYM+2 spray of *Pseudomonas*+2 spray of Biofertisol	84.56
T_4: T.Y.100 q (58:110:47) + 5 t FYM+1 spray of *Pseudomonas* + 1 spray of Biofertisol	97.17
T_5: T.Y.120 q (87:147:74) +5 t FYM	105.45
Mean	82.78
S.Em. ±	5.13
C.D. (P=0.05)	15.09

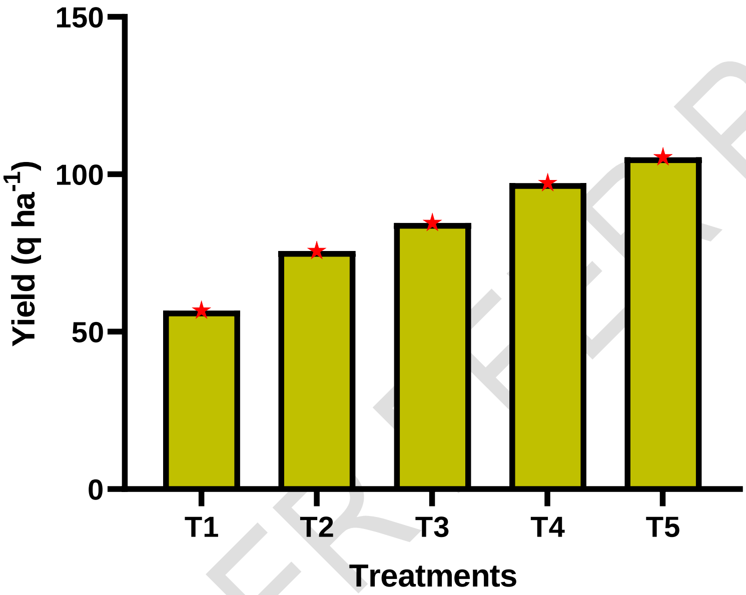

Figure 4.Effect of Pseudomonas and Biofertisol on yields (green pod) of vegetable pea at harvest under STCR approach.

Conclusion

The crop of vegetable pea (cv. PSM-3) thrived successfully with the balanced nutrients supplemented with the application of treatment T4 (TY100q (58:110:47) + 5 t FYM+1 spray of Pseudomonas+1 spray of Biofertisol) under the STCR concept, which increased nodulation attributes and ultimately the yield of the crop. FYM increased availability and supply of essential nutrients (0.5% N, 0.2% P_2O_5 and 0.5% K_2O) including micronutrients, improved soil physical conditions (like structure, water holding capacity etc.) and provided a better congenial environment for multiplication and activity of the beneficial microorganisms viz., *Rhizobium, Pseudomonas, Lactobacillus*. The microbial components of biofertilizers Pseudomonas may have improved the plant's access to nutrients, produced phytostimulators (hormones that promote plant development, usually auxin, cytokinin, and gibberellin), acted as rhizoremediators (degrading organic pollutants), and produced biopesticides (controlling diseases, mainly by the production of antibiotics and antifungal metabolites). With potential characteristics of growth regulators, such as cytokinins and cytokinin-like substances, Biofertisol, an organic source of nutrients (N:P:K = 1.5:0.5:0.4+0.1:0.5:1.0) supplemented with fish hydrolysate and extract of seaweed (Ascophyllum nodosum), improved crop production.Taking a cue from Liebig's law of minimum, that plants growth is limited by the plant nutrient element (N, P and K) present in the smallest amount, concept of Truog (1960) regarding the basis for fertilizer application for targeted yields and the experimental proof given by Ramamoorthy and co-workers (1967) are effectively useful fertilizer recommendation for a targeted yield based on soil test value. In order to minimize the use of chemical fertilizer inclusion of organic manure and biofertilizers might be the best way in organic and sustainable agriculture and as per the new concept of STCR approach as well.

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