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Response of integrated phosphorus management on growth, yield, nutrients uptake, quality and its economic feasibility in pigeon pea (*Cajanus cajan* L. Millsp.)

PK Singh, Raj Kumar, Anil Kumar, AK Gupta, Sachin Kumar and Vikash Kumar

Abstract
The experiment was conducted during the *Rabi* season of 2014 to 2019 for consecutively five years at Agronomy, Research Block of R.K. (P.G.) College, Shamli, under Randomized Block Design with three replications. The 13 treatments consisted of absolute control, 30 kg P_2O_5 through rock phosphate, 30 kg P_2O_5 through RP+ FYM (1:1), 30 kg P_2O_5 through SSP, 30 kg P_2O_5 through SSP + FYM (1:1), 30 kg P_2O_5 through FYM, 30 kg P_2O_5 through FYM + PSB, 60 kg P_2O_5 through rock phosphate, 60 kg P_2O_5 through RP + FYM (1:1), 60 kg P_2O_5 through SSP, 60 kg P_2O_5 through SSP + FYM (1:1), 60 kg P_2O_5 through FYM, 60 kg P_2O_5 through FYM + PSB. Highest plant plant height (210.6cm), dry matter per plant (193.4g), branches per plant (23.7 branches) and total chlorophyll content as well (62.83 mg/g leaf fresh weight) noticed with 60 kg P_2O_5 through FYM + PSB. Application of 60 kg P_2O_5/ha resulted 41.71 percent higher pods/ plant, 53.21 percent higher per plant seed yield, produced 88.18 percent higher seed yield over 0 kg P per ha. The total NPK uptake and protein content in grains too, was highest with 60 kg P_2O_5throught FYM + PSB inoculation.

Keywords: Biofertilizer, FYM, integrated P management, pigeon pea, quality, yield

1. Introduction
Pigeon pea (*Cajanas cajan* L. Millsp), is the major grain legume crop of the India, and also in the most of the developing countries of the world. Globally, pigeon pea ranks sixth in area and production in comparison to other grains legumes. Pigeon pea is consumed in more diversified ways. Phosphorus is a key element involved in various physiological and bio-chemical functions inside the plant and has a vital role in metabolism of pulses. It is a major limiting nutrient for plant growth in most of Indian soils. The recovery of applied phosphorus is generally 10-30% (Swarup, 2002) [11]. Phosphorus solubilizing bacteria play an important role in increasing phosphorus availability to the crops by solubilizing the natively present phosphorus containing substances present in the soils (Khan *et al*., 2007) [4].
The phosphorus solubilizing microorganism release metabolites such as organic acids and certain growth promoting substances. Thus making the insoluble P material soluble and promote the growth of the plant as well (Khan *et al*., 2009) [3].
Due to the sky rocketing price hike of phosphatic fertilizers and a potential of solubilizing P through PSB the present investigation entitled "Response of Integrated phosphorus management on growth, yield, nutrients uptake, quality and its economic feasibility in pigeon pea (*Cajanus cajan* L.), was undertaken for five consecutive years from 2014-2019 during the *Rabi* season.

2. Materials and Methods
The long term field experiment was conducted during 5 consecutive *Rabi* seasons from 2014 to 2019 at Research Farm of R.K. (P.G.) College, Shamli. A composite representative soil sample was collected from the experimental field each year prior to experimentation and analyzed for different physico-chemical properties of the soil. The soil of the experimental field was low in organic carbon, total and available nitrogen and was medium in P and K status. The soil was slightly alkaline (p^H 7.6) in its reaction.

The experiment was conducted to quantify the level of substitution of chemical phosphatic fertilizer by FYM and PSB inoculation. The treatments comprised of 30 kg P_2O_5 through rock phosphate, 30 kg P_2O_5 through RP+ FYM (1:1), 30 kg P_2O_5 through SSP, 30 kg P_2O_5 through SSP + FYM (1:1), 30 kg P_2O_5 through FYM, 30 kg P_2O_5 through FYM + PSB, 60 kg P_2O_5 through rock phosphate, 60 kg P_2O_5 through RP + FYM (1:1), 60 kg P_2O_5 through SSP, 60 kg P_2O_5 through SSP + FYM (1:1), 60 kg P_2O_5 through FYM, 60 kg P_2O_5 through FYM + PSB. The nitrogen and potash were applied at their recommended rates using urea and MOP, respectively. Standard procedures were followed during plant and soil sampling. Observations on plant growth and yield were done as per standard procedures. The gross and net returns were calculated based on the market rate of grain and stover prevalent during the year 2019-20.
The total chlorophyll content in the leaves was analyzed by Di-methyl Sulphooxide (DMSO) method as per the procedure suggested by Shinano *et al*., (1996) [9]. The total chlorophyll content was calculated with the help of following formula;

$$\text{Total chlorophyll (mg/g leaf fresh weight)} = \frac{[(20.2\times \text{A645}) + 8.20 + \text{A (663)} \times \text{V}]}{1000\times\text{W}}$$

Where,
A, V and W were Absorbance, final volume and weight of sample, respectively

3. Results and Discussion
3.1 Growth
Phosphorus integration had significant influence on different growth parameters. (Table; 1, Fig; 1). Highest plant height (210.6 cm) registered with 60 kg P_2O_5 through FYM + PSB inoculation followed by 60 kg P_2O_5 through SSP + FYM (1:1) (208.9cm). However lowest height was noticed with absolute control (162.5 cm). The difference in plant height between 60 kg P_2O_5 through FYM + PSB inoculation (210.6 cm) with either of 30 kg P_2O_5 levels was significant. Whereas, with 60 kg P_2O_5 levels with either of the phosphorous sources it was statistically non-significant. Amongst 30 kg P_2O_5 level highest plant height was observed with 30 kg P_2O_5 with FYM +PSB (190.5 cm), however lowest height to the plant at maturity was registered with 30 kg P_2O_5 through rock phosphate (171.4 cm).
Similarly highest per plant dry matter at maturity (195.1 g) and number of branches per plant (23.7) were recorded with 60 kg P_2O_5 through FYM + PSB inoculation followed by 60 kg P_2O_5 through SSP + FYM (1:1) (193.4 g dry matter/ plant and 23.1 branches/ plant). The number of branches/ plant and dry matter at maturity with 60 kg P_2O_5 through FYM + PSB inoculation stood significantly superior over all the 30 kg P_2O_5 levels and 60 kg P_2O_5 through rock phosphate (188.9 g dry matter and 21.1 branches/ plant) and 60 kg P_2O_5 through rock phosphate + FYM (1:1) (189.2 g/plant dry matter and 21.9 branches/ plant). The plants receiving 60 kg P_2O_5 through FYM + PSB grew 29.6% tall and accumulated 56.85% higher dry matter over absolute control. The chlorophyll control in plant leaves also was registered highest under and 60 kg P_2O_5 FYM + PSB inoculation (62.83 mg/g leaf fresh weight) at 60 DAS. Whereas, lowest chlorophyll content in leaves was analysed with absolute control (56.03 mg/g leaf fresh weight). Higher response of 60 kg P_2O_5 through FYM + PSB inoculation in respect of plant height, per plant dry matter and branches/ plant might was due to increased availability of phosphorus in response of P solubilisation due to PSB and also due to availability of other essential plant nutrients from farm yard manure. Thus plants maintained higher chlorophyll content in their leaves and higher rate of energy transfer reaction due to higher phosphorus availability and grew tall and accumulated higher quantity of photoassimilates in their body. Similar results were reported by U.K. Ade *et al*., (2018) [12].

3.2 Yield attributes and yield
Application of phosphorus through different sources had significant differences in their response to yield attributes and yield. (Table 2, Fig 2).
Highest number of pods/ plant (215.4 pods / plant), seeds per pod (3.21seeds/pod), seed yield per plant (50.1g) and 1000-seed weight (75.61 g) was observed with application of 60 kg P_2O_5 through FYM + PSB inoculation. Whereas, lowest value for number of pods/ plant (152pods), seeds per pod (2.75seeds) seed yield per plant (32.7 g) and 1000-seed weight (70.30 g) registered under control. The number of pods/ plant recorded with 60 kg P_2O_5 through FYM + PSB inoculation (215.4 pods) was significantly superior to other treatment. Similar trend of response of treatments was noticed for average number of seeds per pod. Maximum per plant seed yield (50.1 g) recorded with 60 kg P_2O_5 through FYM + PSB inoculation which remained statistically at par to the 60 kg P_2O_5 through SSP (49.1 g) and proved significantly superior to the rest of treatments. Similarly, highest 1000-seed weight (75.3 g) registered with 60 kg P_2O_5 through FYM + PSB was on par to 60 kg P_2O_5 through FYM (74.31 g), 60 kg P_2O_5 through SSP + FYM 1:1 (75.15 g), 60 kg P_2O_5 through SSP (75.23 g) and 60 kg P_2O_5 through rock phosphate + FYM 1:1 (72.66 g) and proved significantly superior over other treatments.
The application of 60 kg P_2O_5 through FYM + PSB inoculation resulted 41.71 percent higher pods/plant, 17.58 percent higher seeds/ pod and 53.21 percent higher seed yield per plant over absolute control. Higher value of different yield attributing characters with 60 kg P_2O_5 through FYM + PSB inoculation could be attributed to higher and robust growth of the plants due to ever and regulated supply of phosphorus and other essential plant nutrients from FYM during the entire crop period. The result corroborated the findings of Khan *et al*., (2009) [3].
The biological, seed, stalk yield and harvest index also were significantly influenced due to P fertilization (Table 2, Fig 2).
Highest biological yield (75.61 q/ha) was noticed with 60 kg P_2O_5 through FYM + PSB which was on par to the same observed with 60 kg P_2O_5 through FYM (73.5 q/ha), 60 kg P_2O_5 through SSP + FYM 1:1 (73.68 q/ha) and 60 kg P_2O_5 through SSP (73.56 q/ha) and stood significantly superior to the rest of treatments. Whereas, lowest biological yield (52.61 q/ha) was with absolute control. Maximum seed yield was registered with 60 kg P_2O_5 through FYM + PSB inoculation (21.51 q/ha) which proved its significant superiority over all other treatments. The plant fertilized with 60 kg P_2O_5 through FYM + PSB produced 88.18 percent higher seed yield over unfertilized control. Stalk yield too, was registered highest (54.10 q/ha) under 60 kg P_2O_5 through FYM + PSB inoculation, which was on par to the 60 kg P_2O_5 through FYM (53.75 q/ha) and stood significantly superior over other treatments. Likewise, biological, seed and stalk yield the

harvest index also was greatly influenced due to phosphorus fertilization and was observed maximum with 60 kg P_2O_5 through Rock phosphate + FYM (1:1) (28.61%), which was at par to the same recorded with 60 kg P_2O_5 through FYM + PSB (28.45%), 60 kg P_2O_5 through rock phosphate (28.03%),30 kg P_2O_5 through SSP + FYM 1:1 (28.39%) 30 kg P_2O_5 through SSP (28.29%) and was significantly superior over rest of the treatments. The plants fertilized with 60 kg P_2O_5 through FYM + PSB inoculation had 30.98 percent higher portioning coefficient (harvest index) over absolute control.
The higher value of biological, seed and stalk yield with 60 kg P_2O_5 through FYM + PSB might be due to higher value of different growth and yield attributing characters. Whereas, higher value of harvest index might be, due to respective higher yields. The results are analogous to the findings of Reddy *et al*., (2011) [8].

3.3 Nutrient uptake
Amongst different phosphorus management treatments, highest total nitrogen uptake analysed with 60 kg P_2O_5 through FYM + PSB inoculation (136.33 kg N/ha) followed by 60 kg P_2O_5 through SSP+ FYM 1:1 (132.82 kg N/ha). The total nitrogen uptake recorded with 60 kg P_2O_5 through FYM + PSB inoculation was significantly higher than other treatments and resulted 66.52 percent higher total nitrogen uptake over absolute control (Table 3). Higher total nitrogen uptake with 60 kg P_2O_5 through FYM + PSB might was due to increased microbial transformation of native substances and also due to presence of sizeable quantity of nitrogen in FYM. Similar result was reported by Rana *et al*., (2012) [7].
Total phosphorus uptake also was greatly influenced due to different treatments. Highest total phosphorus uptake (30.25 kg P/ ha) analysed under 60 kg P_2O_5 through FYM + PSB inoculation followed by 29.21 kg P_2O_5/ ha with 60 kg P_2O_5 through SSP+ FYM 1:1. Whereas, lowest phosphorus uptake, was registered with absolute control (17.72 kg P/ ha). The total phosphorus uptake analysed with 60 kg P_2O_5 through FYM + PSB inoculation was significantly higher than other treatments. Application of 60 kg P_2O_5 by FYM along with PSB inoculation resulted 70.71% higher total phosphorus uptake over absolute control. Higher total phosphorus uptake with 60 kg P_2O_5 through FYM + PSB inoculation might was due to solubilisation of native P containing complexes present in the soil due to joint action of PSB and carbonic acid produced while decomposition of FYM. The result is analogous to the findings of Singh *et al*., (2014) [10].
Similar to nitrogen and phosphorus uptake total potassium uptake do was significantly influenced due to different treatments (Table 3). Highest total potassium uptake (89.12 kg K/ha) was observed with 60 kg P_2O_5 through FYM + PSB which stood significantly higher than other treatments. Higher potassium uptake might was due to additional supply of potassium from Farm Yard Manure.
Higher total nitrogen, phosphorus and potassium uptake with 60 kg P_2O_5 through FYM + PSB inoculation might also be due to positive influence of FYM on different physical properties (bulk density, WHC) and chemical properties (soil p^H, CEC) thus plants penetrated their roots deeper and were able to mine the N, P and K even from far away and deeper layers.

3.4 Quality parameters
Protein content (%) as well as total protein yield under pigeon pea grains also was significantly influenced due to different treatments (Table 3).
The plants receiving 60 kg P_2O_5 through FYM + PSB inoculation, assimilated highest protein in their grains (22.4%) followed by (22.3% protein) with 60 kg P_2O_5 through SSP+ FY M (1:1). The protein content analysed with 60 kg P_2O_5 through FYM + PSB inoculation was significantly higher than other treatments except 60 kg P_2O_5 through SSP (22.1% protein), 60 kg P_2O_5 through rock phosphate + FYM (1:1) (22.2% protein), 60 kg P_2O_5 through FYM (22.2% protein) and 60 kg P_2O_5 through rock phosphate (20.1% protein). Lowest protein content was registered with absolute control (20.6%).
Similarly, highest per hectare protein yield was obtained under 60 kg P_2O_5 through FYM + PSB inoculation (474.1kg protein /ha) which stood statistically similar to 60 kg P_2O_5 through rock phosphate + FY M (1:1) (426.2 kg protein /ha), 60 kg P_2O_5 through SSP (437.2 kg protein /ha), 60 kg P_2O_5 through SSP+ FY M (1:1) (446.6 kg protein /ha). The protein yield obtained with 60 kg P_2O_5 through FYM + PSB inoculation was significantly higher than rest of the treatments.
The plant fertilized with 60 kg P_2O_5 through FYM along with PSB inoculation had 8.7 percent higher protein content in their grains as compared to absolute control.
The higher protein content with 60 kg P_2O_5 through FYM + PSB inoculation might be due to supply of all the essential nutrients from FYM (nitrogen, phosphorus & sulphur) required for synthesis / assimilation of protein in the plant body. The higher protein yield could be attributed to higher protein content and respective higher yield. The finding is analogous to the results of Swarup, A. (2002) [11].

3.5 Economics
Different integrated phosphorous management practices had different cost, gross return, net return and B: C ratio (Table 4, Fig 3). Highest cost (Rs 31484.00), gross return (Rs 109310.00), net return (Rs 77826.00) was recorded with 60 kg P_2O_5 through FYM + PSB inoculation. Whereas, highest B: C ratio (2.59) was observed with 60 kg P_2O_5 through SSP+ FY M (1:1). The highest gross and net return with 60 kg P_2O_5 through FYM + PSB was due to higher seed and stalk yields. Whereas, highest B: C ratio with 60 kg P_2O_5 through SSP+ FY M (1:1) might was due to less cost involved in the treatment. Application of 60 kg P_2O_5 through FYM + PSB inoculation resulted 66.38 and 92.71% higher gross and net returns over zero control, respectively.

Table 1: Influence of integrated phosphorus management practice on growth parameters of pigeon pea *Cv.* UPAS 120 (*Cajanus cajan* L.) at maturity (Pooled data of 5 years)

Treatment	Plant height (cm)	Dry matter (g/plant)	Branches/ plant	Chlorophyll content in leaves at 90 DAS (mg/g)
Absolute control	162.5	123.3	14.4	56.03
30 kg P_2O_5 through rock phosphate	171.4	149.4	16.9	57.04
30 kg P_2O_5 through rock phosphate + FYM (1:1)	180.7	153.4	17.1	59.60
30 kg P_2O_5 through SSP	183.2	167.5	20.1	60.03
30 kg P_2O_5 through SSP + FYM (1:1)	186.2	157.7	19.6	61.02
30 kg P_2O_5 through FYM	180.9	146.1	19.4	60.95
30 kg P_2O_5 through FYM + PSB inoculation	190.5	147.7	19.5	61.02
60 kg P_2O_5 through rock phosphate	196.7	188.9	21.1	60.82
60 kg P_2O_5 through rock phosphate + FYM (1:1)	200.3	189.2	21.9	61.90
60 kg P_2O_5 through SSP	203.3	192.4	23.1	62.01
60 kg P_2O_5 through SSP + FYM (1:1)	208.9	193.4	23.1	62.80
60 kg P_2O_5 through FYM	205.8	192.4	22.9	62.51
60 kg P_2O_5 through FYM + PSB inoculation	210.6	195.1	23.7	62.83
S.Em±	7.470	1.11	0.161	0.013
CD at 5%	21.933	3.32	0.473	0.038

Table 2: Influence of integrated phosphorus management practices on yield attributes of pigeon pea (*Cajanus cajan* L.) *Cv.* UPAS 120 (Pooled data of 5 years)

Treatment	Pods/ plant	Seeds/ Pod	Seed weight/ Plant (g)	1000-seed weight (g)	Biological yield (q/ha)	Seed yield (q/ha)	Stalk yield (q/ha)	Harvest Index (%)
Absolute control	152.00	2.73	32.7	70.31	52.61	11.43	41.18	21.72
30 kg P_2O_5 through rock phosphate	160.30	2.74	35.0	70.58	57.71	15.48	42.22	26.82
30 kg P_2O_5 through rock phosphate + FYM (1:1)	170.20	2.81	36.7	71.02	59.04	16.08	42.96	27.23
30 kg P_2O_5 through SSP	182.33	2.86	39.7	72.47	61.72	17.46	44.26	28.29
30 kg P_2O_5 through SSP + FYM (1:1)	181.31	2.84	39.2	72.01	63.74	18.10	45.64	28.39
30 kg P_2O_5 through FYM	181.11	2.77	38.4	71.05	60.93	17.03	43.90	27.95
30 kg P_2O_5 through FYM + PSB inoculation	184.33	2.86	38.8	71.30	61.64	17.31	44.33	28.08
60 kg P_2O_5 through rock phosphate	186.40	2.96	41.2	72.26	63.72	18.50	45.22	28.03
60 kg P_2O_5 through rock phosphate + FYM (1:1)	193.40	2.97	43.1	72.66	67.88	19.42	48.46	28.61
60 kg P_2O_5 through SSP	195.35	3.12	49.1	75.23	73.56	20.30	53.36	27.59
60 kg P_2O_5 through SSP + FYM (1:1)	192.60	3.14	48.2	75.15	73.68	20.27	53.41	27.51
60 kg P_2O_5 through FYM	195.33	3.08	47.9	74.31	73.50	19.85	53.75	27.00
60 kg P_2O_5 through FYM + PSB inoculation	215.40	3.21	50.1	75.30	75.61	21.51	54.10	28.45
S.Em±	1.80	0.019	0.43	0.92	1.60	0.14	0.21	0.059
CD at 5%	5.53	0.056	1.28	2.71	4.70	0.42	0.63	0.174

Table 3: Influence of integrated phosphorus management practice on nutrients uptake and quality parameter of pigeon pea (Cajanus cajan L.) *Cv.* UPAS 120 (Pooled data of 5 years)

Treatment	N uptake (KgN/ha)	P uptake (Kg P/ha)	K uptake (KgK/ha)	Protein (%)	Protein yield (kg/ha)
Absolute control	81.87	17.72	65.36	20.6	231.2
30 kg P_2O_5 through rock phosphate	94.84	21.07	67.62	20.8	317.3
30 kg P_2O_5 through rock phosphate + FYM (1:1)	100.85	22.10	70.82	20.9	331.3
30 kg P_2O_5 through SSP	113.69	24.79	75.76	21.8	376.3
30 kg P_2O_5 through SSP + FYM (1:1)	109.54	23.87	73.63	21.8	388.9
30 kg P_2O_5 through FYM	107.06	23.37	72.95	21.7	364.0
30 kg P_2O_5 through FYM + PSB inoculation	109.01	23.74	73.71	21.8	372.9
60 kg P_2O_5 through rock phosphate	115.65	25.22	75.65	22.1	404.7
60 kg P_2O_5 through rock phosphate + FYM (1:1)	122.84	26.84	80.92	22.2	426.2
60 kg P_2O_5 through SSP	131.91	28.85	88.99	22.1	437.2
60 kg P_2O_5 through SSP + FYM (1:1)	132.82	29.21	88.25	22.3	446.6
60 kg P_2O_5 through FYM	130.51	28.45	88.20	22.2	447.5
60 kg P_2O_5 through FYM + PSB inoculation	136.33	30.25	89.12	22.4	474.1
S.Em±	0.148	0.021	0.026	0.24	17.25
CD at 5%	0.435	0.063	0.077	0.74	51.52

Table 4: Influence of integrated phosphorus management practice on economics of pigeon pea (*Cajanus cajan* L.) *Cv.* UPAS 120

Treatment	Cost of Production (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B: C ratio (₹/₹)
Absolute control	25311	65696	40385	1.59
30 kg P_2O_5 through rock phosphate	26320	81352	55032	2.09
30 kg P_2O_5 through rock phosphate + FYM (1:1)	27311	83935	56624	2.07
30 kg P_2O_5 through SSP	2709s7	89695	62597	2.31
30 kg P_2O_5 through SSP + FYM (1:1)	27704	92714	65010	2.35
30 kg P_2O_5 through FYM	28311	87918	59607	2.10
30 kg P_2O_5 through FYM + PSB inoculation	28481	89166	60685	2.13
60 kg P_2O_5 through rock phosphate	27310	94028	66718	2.44
60 kg P_2O_5 through rock phosphate + FYM (1:1)	29315	98937	69622	2.37
60 kg P_2O_5 through SSP	28893	102883	73990	2.56
60 kg P_2O_5 through SSP + FYM (1:1)	29096	104355	75259	2.59
60 kg P_2O_5 through FYM	31311	104395	73084	2.33
60 kg P_2O_5 through FYM + PSB inoculation	31484	109310	77826	2.47

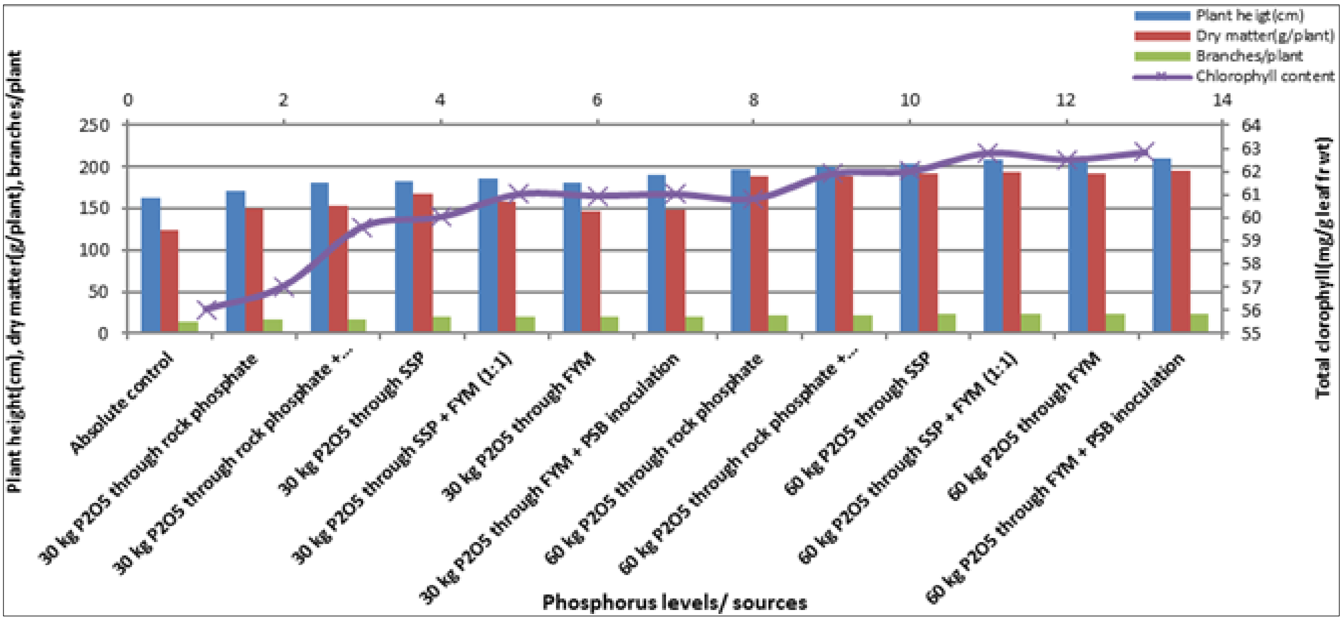

Fig 1: Effect of integrated phosphorus management practices on growth parameters and chlorophyll content

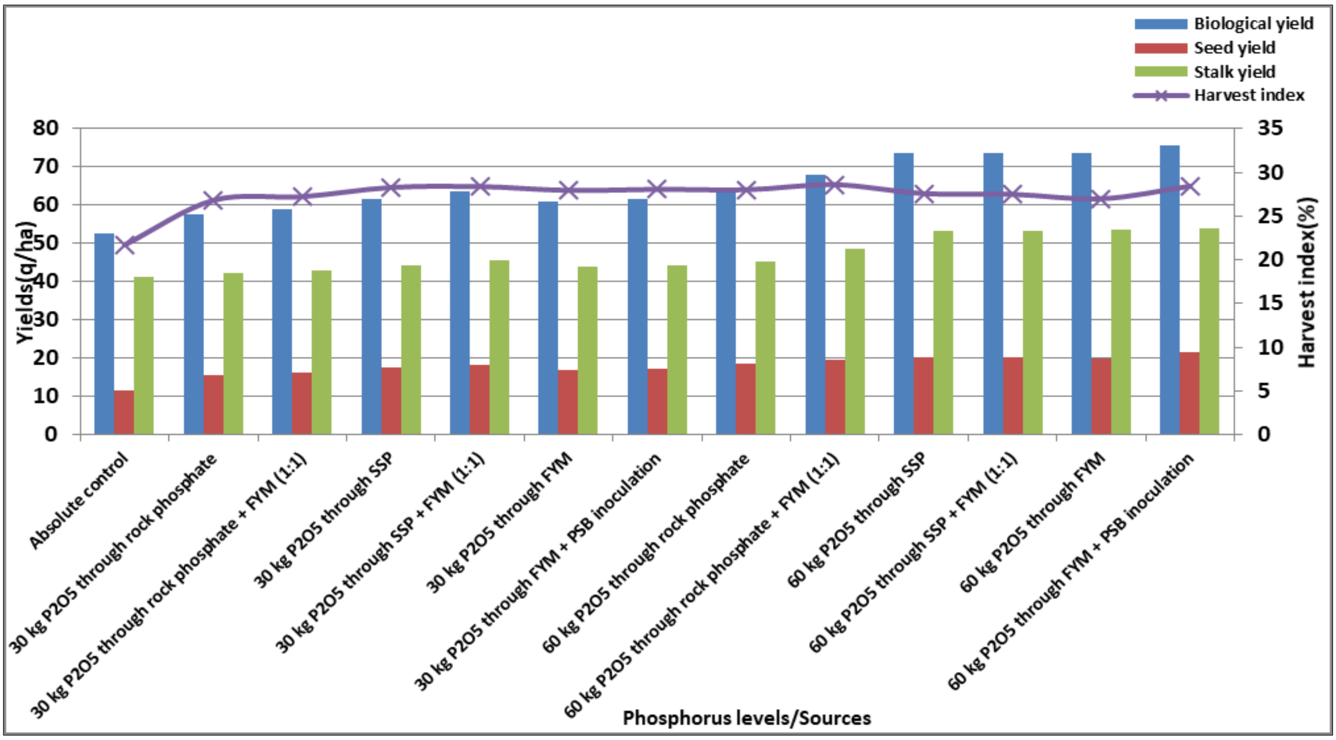

Fig 2: Effect of integrated phosphorus management practices on yields and harvest index

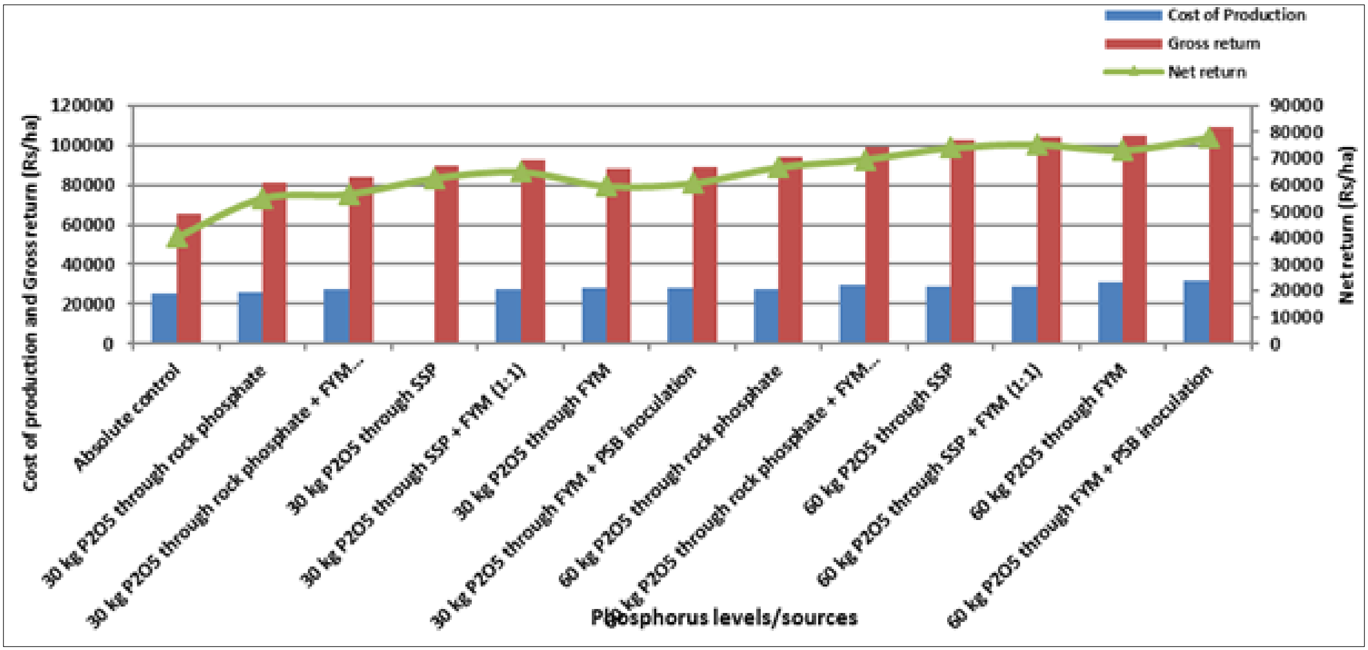

Fig 3: Economics of integrated phosphorus management practices on pigeon pea Cv. UPAS 120

4. Conclusion

Based on result of 5 years consecutive experimentation it is concluded that application of 60 Kg P_2O_5 through FYM along with PSB inoculation yielded even better than 60 kg P_2O_5 through SSP. Thus, the practice could be used as a boom to solve the present crisis and price hike of phosphatic fertilizers in the country. Besides, it would also be an environment conserving practice of food production of higher quality and quantity.

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