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National Academy of Agricultural Science (NAAS) Rating : 3.03

Effect of Phosphorus and Sulphur Fertilization on Growth, Yield, Nutrient Uptake, their Recovery and use Efficiency by Pigeonpea [*Cajanus cajan* (L.) Millsp.] genotypes

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ABSTRACT: *A field experiment was conducted during* kharif *season of 2010,2011 and 2012 to study the effect of phosphorus and sulphur fertilization on growth, yield, nutrient uptake, recovery, use efficiency and their economic feasibility on different pigeonpea genotypes. Three genotypes (UPAS 120, Pusa 992 and Pusa 855) four levels of P (0, 30, 60 and 90 kg* P_2O_5*/ha) and three levels of S (0, 20 and 40 kg S/ha) were tested in Split-Split Plot Design under three replications. Pusa 855 found significantly superior in respect of growth, yield and most of yield attributes as compared to other genotypes and produced 16.71 and 20.14% higher seed yield over UPAS 120 and Pusa 992, respectively. Application of phosphorus up to 90 kg* P_2O_5*/ha and 40 kg S/ha increased plant height, number of branches, dry weight/plant, pods/plant, 1000-seed weight, seed and straw/stalk yields. Application of 90 kg* P_2O_5*/ha resulted 46.78% higher seed yield over no phosphorus. However, application of 40 kg sulphur resulted, a net yield gain of 21.34% over no sulphur application. With application of 90 kg* P_2O_5*+40 kg S, Pusa 855 had 8.55 and 11.01 per cent higher P and S uptake than UPAS 120, respectively. Phosphorus recovery as well as P use efficiency decreased with increasing levels of P but increased with increasing sulphur levels. Highest P recovery (12.84 %) was noticed under Pusa 855 with application of 30 kg* P_2O_5*/ha +40 kg S/ha. Whereas, maximum S recovery (23.65 %) was observed with Pusa 992 under 90 kg* P_2O_5*/ha applied along with 20 kg s/ha. Similarly, higher P use efficiency (14.3 kg/kg P applied) was recorded under UPAS 120 fertilized by 30 kg* P_2O_5 *+40 kg S/ha. Analogously, highest S use efficiency (52.30 kg/kg S applied) was received in Pusa 855 with application of 90 kg* P_2O_5 *+20 kg S/ha. Among different treatment combinations genotype Pusa 855 gave maximum net return (₹ 39391) with 90 kg* P_2O_5*/ha + 40 kg S/ha whereas, Pusa 992 gave its maximum net return (₹ 29265) with 60 kg* P_2O_5*/ha + 40 kg S/ha. UPAS 120 gave its highest net return (₹ 30199) with 90 kg* P_2O_5*/ha + 40 kg S/ha.. The net return incurred with Pusa 855 stood 30.44 percent higher than UPAS 120.*

Keywords: *Growth, Nutrient recovery, Nutrient uptake, Nutrient use efficiency, Pigeonpea genotype, Phosphorus levels, Sulphur levels, Yield*

INTRODUCTION

Among *kharif* grain legumes pigeonpea, occupies first position and is the second most important pulse crop next to chickpea as a whole. Pigeonpea due to its extensive tap root and dense canopy, adds considerable amount of organic matter in the soil in the form of roots and leaves which, in turn, improves the physical condition of soil. The evoluation of short duration pigeonpea varieties of about 130-160 days duration have provided the opportunity for pigeonpea based multiple cropping in irrigated as well as rainfed areas. Besides having high yield potential (20-30 q/ha), they are harvested by the end of November. Thus, fit well under double cropping system with wheat. Adequate supply of phosphorus to legume is more important than that of nitrogen, as it has beneficial effect on nodulation, cell division, plays an important role in energy transfer reactions and required essentially as a constituent of RNA and DNA.

Pigeonpea shows special response to phosphatic fertilizers, because of their additional need for the multiplication of *Rhizobia* in the nodules. Phosphorus also improves the crop quality and make the crop resistant to diseases. Phosphorus application to pulses not only benefit the particular crop by increased nodulation, but also favorably affects the soil nitrogen content for the succeeding non legume crop thus reduces over all demand for inorganic nitrogen application.

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Although sulphur is an important secondary essential plant nutrient, but importance of sulphur in Indian agriculture is being increasingly emphasized and has been considered 4th important nutrient after NPK. Sulphur has a great impact on production of legumes as most of Indian soils are reported sulphur deficient. Sulphur plays important role in many physiological process in plant *viz*; synthesis of sulphur containing amino acids (Cysteine, Cystine and Methionine), synthesis of certain vitamins (Biotine and Thiomine), synthesis of co-enzyme A and in the metabolism of carbohydrates, proteins and fats. Sulphur also promotes nodulation in legumes and is also required as a constituent for the synthesis of chlorophyll. By virtue of disulfide linkage, sulphur application increases drought and cold tolerance in plants. It also helps in the control of diseases and pests. The sulphur deficiency has been recognized as a factor in limiting the yield and quality of grain legumes as around 70% of the S is found in the chloroplast and thus plays vital role in carbon assimilation (Deshbhratar *et al*. 2010).

Therefore, the present investigation was carried out to evaluate the effect of phosphorus and sulphur fertilization on growth, yield, nutrient uptake, recovery, use efficiency and their economic feasibility to different pigeonpea genotypes.

MATERIALS AND METHODS

The experiment was conducted during the *kharif* seasons of 2010, 2011 and 2012 at Agricultural Research Farm of R. K. (P.G.) College, Shamli, (20.6° N Latitude and 77.15° E Longitude, 230.6 m above mean sea level). The maximum and minimum atmospheric temperatures during crop period were 30.8 to 48.6 and 9.8 to 27.5° C, respectively. Rainfall received during 2010, 2011 and 2012was 536.3, 554.2 and 630 mm, respectively. The three genotypes (UPAS 120, Pusa 992 and Pusa 855) treated as main plots, four levels of phosphorus (0, 30, 60 and 90 kg P_2O_5/ha) as sub plot and three levels of sulphur (0, 20 and 40 kg S/ha) as sub-sub plots were, tested in split-split plot design under three replications.

The soil was sandy loam, having 7.4 pH, EC 1.76 dS/M, organic carbon 0.34% and available N, P, K and S status of 182.0, 29.50, 253.0 and 15.0 kg/ha, respectively. A uniform dose of nitrogen @ 20 kg N/ha and potassium @ 40 kg K_2O/ha were applied as basal. Extraction of sulphur in seed was done by procedure developed by Williams and Steinbergs (1959) and was analyzed as per methodology of Chesnin and Yien (1951). The nutrient recovery and nutrient use efficiency were calculated with following formula;

$$Nutrient\ recovery\ (\%) = \frac{Nutrient\ uptake\ in\ treated\ plot - Nutrient\ uptake\ in\ control\ plot}{Quantity\ of\ nutrient\ applied\ (kg/ha)} \times 100$$

$$\begin{array}{l} Nutrient\ use\ efficiency = \\ (kg\ yield / kg\ nutrient\ applied) \end{array} \frac{Yield\ in\ treated\ plot - Yield\ in\ control\ plot}{Quantity\ of\ nutrient\ applied\ (kg/ha)}$$

RESULTS AND DISCUSSION

Growth

The genotypes exhibited significant variation in respect of growth parameters. Pusa 855 grew taller (200.52 cm) than UPAS 120 (195.45 cm) and Pusa 992 (191.24 cm). Similarly, Pusa 855 produced significantly higher number of branches/plant (25.74) as compared to UPAS 120 (24.73 branches) and Pusa 992 (23.57 branches) and exhibited relatively superior morphological expression under iso-nutritional conditions. Dry matter accumulation also varied significantly from genotype to genotype and recorded highest with Pusa 855 (228.82 g/plant), which was significantly higher than Pusa 992 (217.02 g/plant) and UPAS 120 (212.60 g/plant). Pusa 855 grew 2.60% taller and produced 12.33% higher dry matter over UPAS 120. This might be attributed to superior genetic make up of the genotype. The higher dry matter accumulation was attributed to higher number of branches per plant. The result endorses the finding of Govil *et al.* (2000).

Growth parameters, *viz*. plant height, dry matter accumulation and branches/plant increased significantly with increasing levels of phosphorus up to 90 kg P_2O_5/ha. Plants fertilized with 90 kg P_2O_5/ha had 24.94, 13.89 and 5.61% taller plants as compared 0, 30 and 60 kg P_2O_5/ha, respectively. The favorable effects of phosphorus application on plant height have also been reported by Parihar *et al.* (2005). Dry matter production is resultant effect of growth parameters *viz*. plant height and number of branches per plant. Dry matter increased with increasing doses of phosphorus and monitored highest with 90 kg P_2O_5/ha (232.98 g/plant)which was significantly higher than 60 kg (224.63 g/plant), 30 kg P_2O_5/ha (209.54g /plant) and no phosphorus (185.06 g/plant). Every increase in level of phosphorus brought about a significant increase in the number of branches per plant. Maximum number of branches per plant (26.19 branches) was recorded with 90 kg P_2O_5/ha (Table 1), which was significantly higher than no phosphorus (20.69 branches) and 30 kg P_2O_5 (33.90 branches) and was statistically on par to 60 kg P_2O_5 (25.87 branches/plant). Application of 90 kg P_2O_5/ha

Table 1
Effect of Phosphorus and Sulphur Fertilization on Growth, Yield Parameters, Yield and Harvest Index of Different Pigeonpea Genotypes (Pooled Data of three Years)

Treatment	*Plant height (cm)*	*Dry matter (g/plant)*	*Branches/ plant*	*Pods / plant*	*Pod weight (g/plant)*	*Grain weight (g/plant)*	*1000-seed weight (g)*	*Biological yield (kg/ha)*	*Seed yield (kg/ha)*	*Stalk yield (kg/ha)*	*Harvest index*
Genotypes											
UPAS 120	195.45	212.60	24.73	192.31	29.23	24.71	73.40	6437	1365	5072	0.213
Pusa 992	191.24	217.02	23.57	180.22	27.83	23.97	70.95	5818	1326	4492	0.229
Pusa 855	200.52	228.82	25.74	197.14	31.15	26.64	78.80	7154	1593	5561	0.226
CD (P=0.05)	6.15	6.46	0.98	6.70	1.32	1.12	2.78	185	52	179	0.007
P levels (kg P_2O_5/ha)											
0	168.45	185.06	20.69	158.73	23.38	20.71	70.53	5570	1103	4468	0.198
30	184.78	209.54	23.90	175.83	28.56	24.85	74.66	6447	1403	5044	0.218
60	199.28	224.63	25.87	191.66	32.54	26.73	76.05	6901	1583	5318	0.230
90	210.45	232.98	26.19	194.32	33.12	27.70	76.29	6994	1619	5375	0.232
CD (P=0.05)	7.10	6.99	1.13	7.25	1.52	1.01	3.21	213	60	207	0.009
S levels (kg S/ha)											
0	171.50	191.78	20.81	158.26	23.56	23.89	72.44	6058	1265	4793	0.209
20	197.38	220.91	24.98	180.42	31.05	25.50	75.13	6657	1488	5170	0.224
40	206.34	229.75	25.21	189.86	32.60	28.94	75.57	6739	1535	5205	0.228
CD (P=0.05)	4.99	5.64	0.76	5.57	1.02	1.28	2.15	171	90	129	0.006

resulted 25.89, 12.19 and 3.71% higher dry matter yield, 26.58, 9.58 and 1.24% higher number of branches over 0, 30 and 60 kg P_2O_5/ha, respectively. The higher value of different growth parameters with 90 kg P_2O_5/ha might was due to increased rate of energy metabolism and accelerating effect of P on the synthesis of protoplasm. The result corroborates the finding of Deshbhratar *et al*. (2010).

Sulphur application also had significant influence on different growth parameters. Highest value of Plant height, number of branches as well as dry matter production was recorded with 40 kg S/ha. Highest plant height was noticed with 40 kg S/ha (206.34 cm), which was significantly higher than 0 kg S (171.5 cm) and 20 kg S/ha (197.38 cm). Similarly highest number of branches/plant (25.21 branches) was noticed with 40 kg S/ha, which was statistically on par to 20 kg S/ha (24.98 branches/plant) and was significantly higher than no sulphur application (20.81 branches/plant). Dry matter accumulation increased with successive increase in level of sulphur. Significantly higher dry matter produced with 40 kg S (229.75 g/plant) in comparison to 0 kg (191.78 g/plant) and 20 kg S/ha (220.91 g/plant). The increase in dry matter accumulation due to sulphur application was primarily due to increase in number of branches/plant thus plants might maintained higher number of leaves and higher pace of carbon assimilation. The plants receiving 40 kg S/ha grew 20.34 % taller, maintained 21.15 higher number of branches and produced 19.77 % higher dry matter yield over no sulphur application.

Yield Attributes, Yield and Harvest Index

Genotypes recorded significant variation in respect of different yield attributing characters *viz*; number of pods per plant, pod weight per plant, seed weight per plant and 1000-seed weight. Among genotypes Pusa 855 recorded highest pods/plant (197.14 pods) pod weight/ plant (31.15 g/plant) seed weight/ plant (16.64 g/plant) which stood 2.52, 6.57 and 13.12% higher over UPAS 120, respectively. Pusa 855 scored significantly highest biological yield (7154 kg/ha), seed yield (1593 kg/ha) as well as stalk yield (5561 kg/ha). The seed and stalk yield obtained with cv. Pusa 855 was significantly higher than same noticed with Pusa 992 and UPAS 120, which produced 16.71% and 9.64% higher seed and stalk yield over UPAS 120, respectively. The higher, yielding ability of Pusa 855 might was due to its relatively longer duration and was also attributed to relatively higher value of different yield attributing characters. Results corroborate the finding of Govil *et al.* (2000).

Phosphorus application reflected significant impact on number of pods per plant, pod weight/ plant, seed weight per plant and 1000-seed weight. Phosphorus at 90 kg P_2O_5/ha was found to be superior to other levels except 60 kg P_2O_5/ha. The plants enjoying 90 kg P_2O_5/ha had 22.42, 29.40 and 3.95%

higher pods/pant, pod weight/ plant and seed yield/ plant over no phosphorus application, respectively. Albeit, Biological (6994 kg/ ha), seed (1619 kg /ha) as well as stalk yields (5375 kg/ ha) were noticed maximum with application of 90 kg P_2O_5/ha which was significantly higher than 0 and 30 kg P_2O_5/ha and was on par to 60 kg P_2O_5/ha (Table 1). Application of 90 kg P_2O_5/ha resulted 46.78% higher seed yield over control. The higher yields with 90 kg P_2O_5/ha was due to favorable effect of phosphorus application on different yield attributes. Application of 60 kg P_2O_5/ha resulted 43.52 and 12.84% higher seed yield and 19.04 and 5.43% higher stalk yield over 0 and 30 kg P_2O_5/ha, respectively. Results endorses the finding of Prasad *et al*. (2007), Singh and Ahlawat (2006) and Ansari *et al.* (2011). The maximum stalk yield was observed with 90 kg P_2O_5/ha followed by 60 kg P_2O_5/ha. The greater value of stalk yield at highest dose of P was due to higher pace of growth in the plots enjoying surplus phosphorus. Where as, the higher seed yield was result of favorable effect of phosphorus on different yield contributing characters.

Sulphur fertilization brought about significant improvement in the production of seed and stalk both. Although the yield increase with the increase in level of sulphur was significant up to 20 kg S/ha. Application of 40 kg sulphur had no significant increase over 20 kg S/ha with regard to seed and straw/stalk yield, but the advantageous effects of various doses of sulphur over control was equally significant. Plots receiving 20 kg S/ha (1488 kg seed/ ha) and 40 kg S/ha (1535 kg seed/ha) yielded 17.63 and 21.35% higher seed yield over no sulphur application. Whereas application of 20 kg S/ha increased 7.87% straw yield over control.

The effect of sulphur application on yield contributing characters *viz*. number of pods per plant, weight of pods per plant and grain weight per plant was also influenced significantly. The beneficial effect of sulphur application on the yield of seed and straw/ stalk obtained in the present investigation, endorses the findings of Siag and Yadav (2003) and Deshbhratar *et al.* (2010).

Phosphorus and Sulphur Uptake

In general, cultivar Pusa 855 had higher uptake for phosphorus as well as sulphur followed by UPAS 120. Application of 90 kg P_2O_5+40 kg S resulted 13.96 kg Pand 16.43 kg S uptake/ha by Pusa 855, 12.43 kg P and 13.13 kg S by Pusa 992 and 12.86 kg P and 14.80 kg S/ha by UPAS 120. Results reveal that, with 90 kg P_2O_5+40 kg S, Pusa 855 had 8.55 and 11.01 per cent higher P and S uptake than UPAS 120, respectively (Table 2).

A magnificent difference in phosphorus uptake was realized with and without S application. Application of 90 kg P_2O_5+40 kg S had 12.86, 12.43 and 13.96 kg P uptke by UPAS 120, Pusa 992 and Pusa 855, respectively as compared to 10.61, 10.69 and 11.94 kg P uptake as against 90 kg P_2O_5+0 kg S, respectively. Similarly, Sulphur uptake also varied measurably with and without P application. Application of 90 kg P_2O_5+40 kg S had 14.80, 13.13 and 16.43 kg S uptake as compared to a uptake of only 12.49, 10.09 and 13.63 kg S/ha against 0 kg P_2O_5+40 kg S By UPAS 120, Pusa 992 and Pusa 855, respectively. Higher uptake of both P and S under their combined application was due to their involvement as a essential constituent in amino acids and synthesis of certain enzymes (Biotin and Thiamin), enabling them to respond in synergistic manner. The finding also corroborate with the results of Gupta *et al.* (2006), Sharma and Abrol (2007) and Ansari *et al.* (2011).

Recovery and Use Efficiency of Phosphorus and Sulphur

Nutrient recovery and their use efficiency also were influenced with phosphorus and sulphur applications. Amongst different pigeon pea cultivars, in general higher recovery for phosphorus was noticed with 30 kg P_2O_5+40 kg under Pusa 855 (12.84%) followed by UPAS 120 (12.20%) and Pusa 992 (11.67%). Where as, highest sulphur recovery was recorded under 90 kg P_2O_5+20 kg S with Pusa 992 (23.65%) followed by Pusa 855 (19.80%) and UPAS 120 (19.35 %). The cultivar Pusa 855 had 5.25 per cent higher P recovery at 30 kg P_2O_5+40 kg level and 2.33 per cent higher S recovery at 90 kg P_2O_5+20 kg S level as compared to UPAS 120. Higher phosphorus recovery with increasing S levels might was due to enhanced solublisation and mobilization effect of applied sulphur from soil immobile phosphorus pool.

Likewise P uptake, the P recovery also was influenced due to Phosphorus and sulphur application. The recovery of phosphorus declined with increasing rate of P applications and increased with increased rate of sulphur. The P recovery noticed with 30 kg P_2O_5+40 kg S (12.20, 11.67 and 12.84%) was relatively higher than the same obtained with 90 kg P_2O_5+40 kg S (6.24, 6.18 and 5.96 percent) under UPAS 120, Pusa 992 and Pusa 855, respectively. Similarly, sulphur recovery was also influenced noticeably with and without P application. The S recovery decreased with increasing S levels but increased with increase

Table 2
Effect of Phosphorus and Sulphur Fertilization on Seed Yield, Nutrient Uptake, Nutrient Recovery and Nutrient use Efficiency of Applied Nutrients by Different Pigeon Pea genotypes (Pooled data of three years)

Treatment combination	*Seed yield (kg/ha)*	*Nutient uptake (kg/ha)*		*Nutrient recovery (%)*		*Nutrient use efficiency (kg seed /kg nutrient applied)*	
		P	*S*	*P*	*S*	*P*	*S*
UPAS 120 + 0 kg P_2O_5 + 0 kg S/ha	834	7.24	10.09	_	_	_	_
UPAS 120 + 0 kg P_2O_5 + 20 kg S/ha	920	8.49	11.12	_	5.15	_	4.30
UPAS 120 + 0 kg P_2O_5 + 40 kg S/ha	1010	8.98	12.49	_	6.0	_	4.40
UPAS 120 + 30 kg P_2O_5 + 0 kg S/ha	1100	9.26	11.36	6.73	_	8.87	
UPAS 120 + 30 kg P_2O_5 + 20 kg S/ha	1163	10.55	12.68	11.03	12.95	10.96	16.45
UPAS 120 + 30 kg P_2O_5 + 40 kg S/ha	1263	10.90	13.04	12.20	7.37	14.30	10.72
UPAS 120 + 60 kg P_2O_5 + 0 kg S/ha	1321	10.44	12.11	5.33	_	8.11	
UPAS 120 + 60 kg P_2O_5 + 20 kg S/ha	1396	11.77	13.72	7.55	18.15	9.37	28.10
UPAS 120+ 60 kg P_2O_5 + 40 kg S/ha	1508	12.28	14.06	8.40	9.93	11.23	16.85
UPAS 120 + 90 kg P_2O_5 + 0 kg S/ha	1610	10.61	12.34	3.74	_	8.62	
UPAS 120 + 90 kg P_2O_5 + 20 kg S/ha	1668	12.47	13.96	5.81	19.35	9.26	41.70
UPAS 120 + 90 kg P_2O_5 + 40 kg S/ha	1743	12.86	14.80	6.24	11.77	10.10	22.73
Pusa 992 + 0 kg P_2O_5 + 0 kg S/ha	782	6.87	8.15	_	_	_	
Pusa 992 + 0 kg P_2O_5 + 20 kg S/ha	863	8.15	9.47	_	6.60	_	4.05
Pusa 992 + 0 kg P_2O_5 + 40 kg S/ha	921	8.58	10.09	_	4.85	_	3.48
Pusa 992 + 30 kg P_2O_5 + 0 kg S/ha	1008	8.91	10.17	6.83	_	7.54	
Pusa 992 + 30 kg P_2O_5 + 20 kg S/ha	1097	10.12	11.67	10.86	17.60	10.50	15.75
Pusa 992 + 30 kg P_2O_5 + 40 kg S/ha	1149	10.36	12.76	11.67	11.48	12.24	9.18
Pusa 992 + 60 kg P_2O_5 + 0 kg S/ha	1235	10.89	10.99	6.73		7.55	
Pusa 992 + 60 kg P_2O_5 + 20 kg S/ha	1313	11.13	12.15	7.12	20.00	8.85	22.65
Pusa 992 + 60 kg P_2O_5 + 40 kg S/ha	1378	11.45	13.50	7.64	13.38	9.94	13.28
Pusa 992 + 90 kg P_2O_5 + 0 kg S/ha	1460	10.69	11.40	4.25	_	7.58	
Pusa 992 + 90 kg P_2O_5 + 20 kg S/ha	1530	12.03	12.88	5.74	23.65	8.32	37.40
Pusa 992 + 90 kg P_2O_5 + 40 kg S/ha	1629	12.43	13.13	6.18	12.45	9.42	21.18
Pusa 855 + 0 kg P_2O_5 + 0 kg S/ha	1044	8.60	11.62	_	_	_	
Pusa 855 + 0 kg P_2O_5 + 20 kg S/ha	1164	10.02	12.99	_	6.85	_	6.00
Pusa 855 + 0 kg P_2O_5 + 40 kg S/ha	1238	10.52	13.63	_	5.03	_	4.85
Pusa 855 + 30 kg P_2O_5 + 0 kg S/ha	1303	10.76	13.71	7.20	_	8.64	
Pusa 855 + 30 kg P_2O_5 + 20 kg S/ha	1376	11.95	14.94	11.17	16.60	10.07	16.60
Pusa 855 + 30 kg P_2O_5 + 40 kg S/ha	1461	12.45	15.34	12.84	9.30	13.90	10.43
Pusa 855 + 60 kg P_2O_5 + 0 kg S/ha	1550	11.44	14.27	4.74	_	8.44	
Pusa 855 + 60 kg P_2O_5 + 20 kg S/ha	1635	11.93	15.58	5.55	17.25	9.85	29.55
Pusa 855 + 60 kg P_2O_5 + 40 kg S/ha	1821	13.31	16.03	7.85	11.03	12.95	19.43
Pusa 855 + 90 kg P_2O_5 + 0 kg S/ha	1901	11.94	14.71	3.72	_	9.53	
Pusa 855 + 90 kg P_2O_5 + 20 kg S/ha	2089	13.37	15.07	5.30	19.80	11.63	52.30
Pusa 855 + 90 kg P_2O_5 + 40 kg S/ha	2194	13.96	16.43	5.96	12.03	12.78	28.75

in P. Highest sulphur recovery of 19.35, 23.65 and 19.80 per cent under UPAS 120, Pusa 992 and Pusa 885 observed with 90 kg P_2O_5+20 kg S as compared to 11.77, 12.45 and 12.03 per cent with 90 kg P_2O_5+40 kg S, respectively. The increase in S recovery with increased P levels was due to improved rooting and nodulation, thus the plants met their most of sulphur demands from soil sulphur pool. The finding corroborate with the result of Kumar and Singh (2006).

Phosphorus and sulphur use efficiencies also differed for different cultivars. Application of 30 kg P_2O_5+40 kg S had P use efficiency of (14.3kg /kg P) with UPAS 120 followed by Pusa 855 (13.90 kg / kg P) and Pusa 992 (12.24 kg /kg P). Where as, application of 90 kg P_2O_5+20 kg S resulted highest sulphur use efficiency of 52.30 kg / kg S with Pusa 855 followed by UPAS 120 (41.70 kg/kgS) and Pusa 992 (37.40kg/kg S).

Application of phosphorus greatly influenced the P use efficiency. In general the P use efficiency decreased with increasing application of phosphorus and increased with increasing levels of sulphur (Table 2). The highest P use efficiency of 14.3, 13.90 and 12.78 kg/kg P was observed with 30 kg P_2O_5+40 kg S against an use efficiency of 10.10, 9.42 and 12.78 kg /kg P obtained under the application of 90 kg

P_2O_5+40 kg S by UPAS 120, Pusa 855 and Pusa 992, respectively.

Similarly S use efficiency also decreased with increasing S but increased with increasing levels of P fertilization. Highest S use efficiency of 52.32, 41.70 and 37.40 kg/kgS was observed with 90 kg P_2O_5+20 kg S as compared to 28.75, 22.73 and 21.18 kg/ kg S with application of 90 kg P_2O_5 +40 kg S under cultivars Pusa 855, UPAS 120 and Pusa 992, respectively. Decrease in P use efficiency with increasing P levels was attributed to operation of law of diminishing marginal production. Where as, increased P use efficiency with successive increase in S level was due to substantially enhanced solublization and mobilization of native phosphorus. The result endorses the finding of Tripathi and Verma (2007.

Economics

Gross return is a function of production per unit area and price of the produce. Highest gross return (₹ 69712/ha) was found with $V_3P_3S_2$ (Pusa 855 with 90 kg P_2O_5 and 40 kg S/ha) treatment combination followed by (₹ 67596/ha) with (Pusa 855 with 90 kg P_2O_5 and 20 kg S/ha). Similarly highest net return also (₹ 39391/ha) was received with $V_3P_3S_2$ (Pusa 855 with 90 kg P_2O_5 and 40 kg S/ha) followed by (₹ 38495/ha) with (Pusa 855 with 90 kg P_2O_5 and 20 kg S/ha).Where as, highest B:C ratio of 1.323 was obtained with Pusa 855 fertilized with 90 kg P_2O_5 and 20 kg S/ha. Higher gross return with Pusa 855 with 90 kg P_2O_5 and 40 kg S/ha was due to its respective higher seed and stalk yield. Whereas, higher net return was due to relatively higher level of gross return (Table 3). The net return

Table 3
Economics of Different Treatment Combinations (Mean of Three Years)

Treatment combination	*Cost of cultivation (₹/ha)*	*Gross return (₹/ha)*	*Net return (₹/ha)*	*B:C ratio*
UPAS 120 + 0 kg P_2O_5 + 0 kg S/ha	23960	34794	10834	0.459
UPAS 120 + 0 kg P_2O_5 + 20 kg S/ha	25159	39762	14633	0.582
UPAS 120 + 0 kg P_2O_5 + 40 kg S/ha	26359	42966	16607	0.630
UPAS 120 + 30 kg P_2O_5 + 0 kg S/ha	25726	44474	18748	0.729
UPAS 120 + 30 kg P_2O_5 + 20 kg S/ha	26925	51258	24333	0.904
UPAS 120 + 30 kg P_2O_5 + 40 kg S/ha	28127	53112	24985	0.888
UPAS 120 + 60 kg P_2O_5 + 0 kg S/ha	26759	49456	22697	0.848
UPAS 120 + 60 kg P_2O_5 + 20 kg S/ha	27960	56458	28498	1.019
UPAS 120+ 60 kg P_2O_5 + 40 kg S/ha	29161	58422	29261	1.003
UPAS 120 + 90 kg P_2O_5 + 0 kg S/ha	27921	50740	22819	0.817
UPAS 120 + 90 kg P_2O_5 + 20 kg S/ha	29101	58634	29533	1.014
UPAS 120 + 90 kg P_2O_5 + 40 kg S/ha	30321	60520	30199	0.996
Pusa 992 + 0 kg P_2O_5 + 0 kg S/ha	23960	31560	7600	0.317
Pusa 992 + 0 kg P_2O_5 + 20 kg S/ha	25159	38426	13267	0.527
Pusa 992 + 0 kg P_2O_5 + 40 kg S/ha	26359	40384	14025	0.532
Pusa 992 + 30 kg P_2O_5 + 0 kg S/ha	25726	42212	16486	0.641
Pusa 992 + 30 kg P_2O_5 + 20 kg S/ha	26925	49849	22924	0.851
Pusa 992 + 30 kg P_2O_5 + 40 kg S/ha	28127	50994	22867	0.813
Pusa 992 + 60 kg P_2O_5 + 0 kg S/ha	26759	46978	20219	0.756
Pusa 992 + 60 kg P_2O_5 + 20 kg S/ha	27960	53832	25872	0.925
Pusa 992 + 60 kg P_2O_5 + 40 kg S/ha	29161	55426	29265	0.901
Pusa 992 + 90 kg P_2O_5 + 0 kg S/ha	27921	50880	22959	0.822
Pusa 992 + 90 kg P_2O_5 + 20 kg S/ha	29101	41490	12389	0.426
Pusa 992 + 90 kg P_2O_5 + 40 kg S/ha	30321	58752	28431	0.937
Pusa 855 + 0 kg P_2O_5 + 0 kg S/ha	23960	39848	15888	0.663
Pusa 855 + 0 kg P_2O_5 + 20 kg S/ha	25159	49034	23875	0.949
Pusa 855 + 0 kg P_2O_5 + 40 kg S/ha	26359	50848	24489	0.929
Pusa 855 + 30 kg P_2O_5 + 0 kg S/ha	25726	51736	26010	1.011
Pusa 855 + 30 kg P_2O_5 + 20 kg S/ha	26925	58610	31685	1.177
Pusa 855 + 30 kg P_2O_5 + 40 kg S/ha	28127	60246	32119	1.142
Pusa 855 + 60 kg P_2O_5 + 0 kg S/ha	26759	57986	31227	1.167
Pusa 855 + 60 kg P_2O_5 + 20 kg S/ha	27960	63492	35532	1.271
Pusa 855 + 60 kg P_2O_5 + 40 kg S/ha	29161	65124	35963	1.233
Pusa 855 + 90 kg P_2O_5 + 0 kg S/ha	27921	59348	31427	1.126
Pusa 855 + 90 kg P_2O_5 + 20 kg S/ha	29101	67596	38495	1.323
Pusa 855 + 90 kg P_2O_5 + 40 kg S/ha	30321	69712	39391	1.299

incurred with Pusa 855 stood 30.44 percent higher than UPAS 120.

On the basis of three years experimental results, it was concluded that the pigeonpea genotype Pusa 855 out performed to UPAS 120 and Pusa 992 in respect of plant growth, yield attributes, seed yield, nutrient uptake nutrient recovery and use efficiency. To harness the existing agro-resources and to produce the crop in their higher quantity and quality and to explore maximum net return pigeon pea should be fertilized with 90 kg P_2O_5 and 40 kg S/ha.

REFERENCES

Ansari, M. A.; Rana, K. S.; Rana, D. S. and Kumar, P. (2011), Effect of nutrient management and antitranspirants on rainfed sole and intercropped pearlmillet (*Penisetum glaucum*) and pigeonpea (*Cajanus cajan*). *Indian J. Agron*. 56 (3): 209-216.

Deshbhratar, P. B.; Singh, P. K.; Jambhulkar, A. P. and Ramteke, D. S. (2010), Effect of sulphur and phosphorus on yield, quality and nutrient status of pigeonpea (*Cajanus cajan*). *J. of Environmental biology*. 31 (6): 933-937.

Govil, J. N.; Ram, H.; Singh, A. K. and Singh, S. P. (2000), Pusa 855, an improved early variety of pigeonpea. *Indian Farming*. 10: 35-36.

Gupta, Ajay; Vinod Kumar Sharma; Sharma, G. D. and Pankaj, Chopra. (2006), Effect of biofertilizer and phosphorus level on yield attributes, yield and quality of urdbean. *Indian J. Agron*. 51(2): 142-144.

Kumar, Avanesh and Singh, B. P. (2006), Effect of row ratio and phosphorus level on performance of chickpea-Indian mustard inter cropping. *Indian J. Agron*. 51(2): 100-102.

Prasad, Angad; Ghanshyam, Singh and Rai, O. P. (2007), Effect of irrigation and phosphorus levels on the productivity of chickpea. National Symposium on Legumes for Ecological Sustainability: Emerging Challenges and Opportunities held on November 3-5 at I I P R, Kanpur. pp. 59.

Parihar, C. M.; M. M. Kaushik and D. R. Palsaniya (2005), Effect of varieties, plant density and phosphorus levels on growth and yield of clusterbean [*Cyamopsis* texagonoloba (L.) taub]. *Ann. Agric. Res. New Series*. 26(1): 5-7.

Sharma, Vikas and Vikas, Abrol. (2007), Effect of phosphorus and zinc application on yield and uptake of P and Zn by chickpea under rainfed conditions. *J. Food Legumes*. 20(1): 49-51.

Singh, Ummed and IPS, Ahlawat. (2006), Productivity, nutrient uptake and soil fertility as influenced by phosphorus management in pigeonpea-wheat cropping system. *Indian. J. Ag. Sci*. 76 (9).

Siag, R. K. and B. S. Yadav (2003), Effect of levels and methods of sulphur application on growth and yield of mungbean. *Indian J. Pulses Res*. 16(2): 159-160.

Tripathi, S. K. and Verma, C. B. (2007), Studies on effect of different levels of sulphur on growth, yield and metabolic traits in pea genotypes of semi arid zone. National Symposium on Legumes for Ecological Sustainability: Emerging Challenges and Opportunities held on November 3-5 at I I P R, Kanpur. pp. 73.