Growth, yield and phosphorus use efficiency of vegetable cowpea (*Vigna unguiculata*) varieties as influenced by phosphorus levels under rainfed conditions of semi-arid environment

ABSTRACT

Selection of a suitable variety and use of optimum level of phosphorous can significantly increase the productivity and profitability of vegetable cowpea under rainfed conditions in semi-arid tropics. However, application of appropriate level of phosphorus is of prime importance to realize higher yield, economics and phosphorus use efficiency. Hence, a field study was conducted at the Research Farm of Indian Agricultural Research Institute, New Delhi, India to find out the effect of different varieties and phosphorus levels on the growth, yield, economics and phosphorus use efficiency in two consecutive rainy seasons of 2018 and 2019 under semi-arid conditions. Three varieties of cowpea (Pusa Dharni, Pusa Komal and Kashi Kanchan) and four levels of phosphorus (0, 20, 40 and 60 kg P_2O_5 ha^{-1}) were laid out in split plot design with three replications. The results revealed that variety Pusa Dharani recorded significantly higher green pod yield (5.12 t ha^{-1}) with net returns of Rs. 40454 ha^{-1} and net B:C ratio of 1.27. The maximum nodules per plant, nodule weight per plant and nutrient uptake were also recorded with variety Pusa Dharni. Maximum increase in agronomic phosphorus use efficiency (33.73 kg pod yield per kg P applied) and P recovery (18.19%) were noted with Pusa Dharni. Phosphorus levels showed significant variation on all the growth and yield attributing parameters, and yield. Application of 60 kg P_2O_5 ha^{-1} resulted in highest green pod yield (5.38 t ha^{-1}) but remained statistically comparable with 40 kg P_2O_5 ha^{-1}. However, maximum net returns (Rs.41320 ha^{-1}) and net B:C ratio (1.28) were obtained with 40 kg P_2O_5 ha^{-1}, whereas 60 kg P_2O_5 ha^{-1} could fetched net returns of Rs. 41120 ha^{-1} and net B:C ratio of 1.22. Highest nodules per plant, nodules weight and N, P and K uptake were registered with 60 kg P_2O_5 ha^{-1} and was closely followed by 40 kg P_2O_5 ha^{-1}. Application of 20 kg P_2O_5 ha^{-1} noted highest agronomic P use efficiency (39.72 kg pod yield per kg P applied) and P recovery (15.05%) followed by 40 kg P_2O_5 ha^{-1}. The highest net returns (Rs. 41345 ha^{-}1), net B:C ratio (1.28), economic efficiency (Rs. 516.81 per day per ha) and production efficiency (66.25 kg per day per ha) were obtained due to the application of 40 kg P_2O_5 ha^{-1}. Increasing P levels showed positive correlation with nodules per plant, dry weight of nodules, nutrient uptake and pod yield. Hence, the results indicated that growing of cowpea variety Pusa Dharni ~~alongwith~~along with the application of 40 kg P_2O_5 ha^{-1} registered to be most suitable to obtain higher net returns and net B:C ratio under rainfed condition of semi-arid regions.

INTRODUCTION

Cowpea (*Vigna unguiculata* L. Wasp) is one of the most important multipurpose legume crops extensively grown under rainfed conditions in arid and semi-arid ecosystems. It is grown for several purposes like vegetable, pulse, fodder, green manure and as cover crop (Kyei-Boahen *et al*., 2017 ; Mfeka *et al*., 2019). Besides many uses of cowpea, it has the ability to improve soil fertility through fixing atmospheric nitrogen and thus can provide around 60-70 kg ha^{-1} nitrogen to the succeeding crops (Aikins and Afuakwa, 2008). Growing of cowpea for vegetable purposes is gaining popularity in the semi-arid regions.

Several characteristics of cowpea such as its low moisture and nutrient requirements, deep and tap root system, and fast-growing nature make it suitable for growing in rainfed conditions (Chatterjee and Bandyopadhyay, 2017). In addition, its nutritious and delicious vegetables and green fodder quality, enrichment of soil fertility, high potentiality of green pod and fodder yield as well more profit attracts the farmers to grow it for different purposes. Besides, it is one of the important legume crops to diversify the traditional low-profit crops and can be adapted very well to various cropping systems in arid and semi-arid regions of rainfed conditions. Cowpea being a leguminous crop is rich in various nutrients and is an important source of providing more nutrients especially in vegetarian diet. One hundred gram of cowpea matured seeds contain 24.8 grams protein, 63.6 grams carbohydrates, 1.9 grams fat, 6.3 grams fibre, 0.74 mg thiamine, 0.42 mg riboflavin, and 2.281 mg niacin as well as it is rich in calcium and iron (Shaw M, 2007). Green pods of cowpea also contain 3.55 proteins, 2.0% fibre, 8.1% carbohydrates, 0.09% mineral content and 0.50% niacin (Patel and Kumari, 2018). It is also known as one of the important sources of soluble and insoluble dietary fibres, phenolic compounds and B group vitamins (Liyanage *et al*., 2012). Therefore, the versatile characteristics of cowpea make it an important component of subsistence agriculture, especially in water-scarce areas (Singh *et al.*, 2003).

In India, cowpea is grown in several states including Rajasthan, Karnataka, Kerala, Tamil Nadu, Maharashtra, Gujarat, Punjab, Haryana, Delhi and Uttar Pradesh, with an average productivity of 567 kg ha^{-1}. It is cultivated in an area of 3.9 million hectares with a total production of about 2.21 million tonnes (Giridhar *et al*., 2020). But the low yield of cowpea grown for vegetable and grain purposes is a major concern for the growers of semi-arid regions. Among several biotic and abiotic factors, use of non-descript low yielding varieties and inadequate supply of nutrients have been reported by many workers as important reasons for low yield of cowpea in semi-arid regions (Kan'ankuk'a, 1999; Boukar, *et.al.* 2016 ; Patel *et.al.*, 2018).

Soils of semi-arid regions suffer from macro and micronutrient deficiencies in general and major nutrients (nitrogen and phosphorus) in particular (Saharawat *et al*., 2007; Saharawat and Wani, 2013). Most of the soils in arid and semi-arid regions are inherently deficient in phosphorus. Out of total 135 pulses growing districts in India, soils of 68 and 62 districts are low and medium in phosphorus, respectively (Sweta and Malik, 2014; Hosmani, *et al*., 2017). Phosphorus has been recognized as one of the most important elements of plant nutrition involved in various functions of growth and metabolism activities of pulses (Sweta and Malik, 2014). It is involved in many physiological and bio-chemical activities of plant like stimulating root growth and development, root hairs, nodulation, symbiotic nitrogen fixation, transfer of energy, sugar, and starch formation and essential for cell division and photosynthesis (Udvardi and Poole, 2013; Haruna, 2011; Nziguheba *et al.,* 2016; Singh *et al.*, 2011). Enhanced nodulation and plant growth provide energy for nitrogen fixation process that directly affects the nitrogenase activity in nodules and photosynthesis (Hogh-Jensen *et al.*, 2002). Apart from this, phosphorus pronounced the flower initiation, seed and fruit development (Ndakemi and Dakora, 2007). Furthermore, growing suitable varieties with optimum supply of nutrients leads to optimum use of soil and environmental factors that produce higher yield components and yields (Khourgamy and Farnia, 2009). Keeping in view the above facts, an attempt was made to study the effect of varieties and phosphorus levels on the growth, productivity, profitability and nutrient use efficiency of cowpea under rainfed conditions of semi-arid region.

MATERIALS AND METHODS

A field experiment was conducted at the Indian Agricultural Research Institute, New Delhi during rainy seasons of 2018 and 2019 to study the effect of different phosphorus levels on the growth, yield and nutrient uptake of cowpea varieties under rainfed conditions of semi-arid regions. The experimental site is situated at 28^0 38' N latitude and 77^0 18' E longitude at the altitude of 228.6 m above the mean sea-level having semi-arid and sub-tropical type of climate. The total rainfall received during the entire crop growth period (July, August, September and October months) was 854 mm in 2018 and 560 mm in 2019. The experimental soil was sandy loam in texture containing 64.8% sand, 12.4% silt and 22.8% clay. The bulk density of the soil was 1.54 mg/m^3 with pH 7.4 and EC 0.48 dS m^{-1}. The soil had 0.41% organic carbon, 154 kg ~~ha~~/ha available nitrogen, 12.8 kg/ ha available phosphorus and 176 kg/ha available potassium. Three varieties of cowpea (Pusa Dharani, Pusa Sukomal and Kashi Kanchan) and four levels of phosphorus (0, 20, 40 and 60 kg ha) were tested in a split plot design with three replications. Varieties were placed in main and phosphorus levels in sub-plots. Pusa Dharani and Pusa Sukomal varieties were developed by Indian Agricultural Research Institute, New Delhi in 2019 and 2005, respectively for the purpose of vegetables and grain under rainfed conditions. The Plant of variety Pusa Dharani is semi-erect and bears yellow flowers. Its seeds are kidney shaped, bi-coloured white hilum and black speckled. Pusa Sukomal variety plant is semi-dwarf with creamy coloured flowers. The pods are round, less fibrous, straight, light green in colour, while the seeds are black in colour. Variety Kashi Kanchan was developed by Indian Vegetable Research Institute, Varanasi, India during 2007 for vegetable and seed purposes. The plant of this variety is branched, with tendrils and photo-insensitive properties. It has white-purple flowers and soft, fleshy, less fibrous pods with red and kidney-shaped seeds, which are free of parchment. All three varieties are resistant to golden yellow mosaic virus disease.

The crop was sown in the second week of July during both ~~the~~ years using 20 kg seed per hectare after obtaining sufficient moisture in the soil profile through rainfall. Seeds were sown in rows at a row-to-row and plant to plant spacing of 45 and 15cm, respectively. Recommended dose of 20 kg N and 40 kg K_2O ha^{-1} was applied uniformly in all the plots, whereas different levels of phosphorus (20, 40 and 60 kg P_2O_5 ha^{-1}) were applied as per treatment schedule. Full amount of all nutrients was applied as basal dose at the time of sowing of the crop. N, P and K nutrients were supplied through urea, single super phosphate and muriate of potash, respectively. The first picking of marketable green pods was done at 54 days after sowing and a total of four picking were done up to 80 days after sowing the crop. Observations on plant height and yield traits (number of pods per plant, fresh weight of green pods per plant, pod length, fodder yield) were recorded from the selected tagged plants. The yields of green pods of all four pickings were summed up according to the treatments to obtain the yield of green pods per plot and per hectare as well. Observations on nodules per plant were recorded at 60 days after sowing. Determination of N content in pod and stover of cowpea was made by using modified Kjeldahl method (Jackson, 1973), phosphorus by ammonium vanado-molybdate yellow colour method with spectrophotometer (Jackson,1973). Potassium content in pod and stover were determined following flame photometer method (Jackson, 1973). Economics of different treatments were worked out considering the prevailing market prices of inputs and outputs. Statistical analysis of data was performed following standard procedures of ANOVA at 5% level using F-test (Gomez and Gomez, 1984). The agronomic phosphorus use efficiency, phosphorus recovery efficiency, economic efficiency and production efficiency were worked out by using formulas as given below (Ahmad *et al*., 2016)

- Agronomic P use Efficiency (kg ha^{-1} P applied) $= \dfrac{\text{Pod yield in P applied plot- Pod yield in control plot (kg ha}^{-1})}{\text{P applied in fertilized plot (kg ha}^{-1})}$

- Phosphorus recovery efficiency (%) $= \dfrac{\text{P uptake in treated plot (kg ha}^{-1}) - \text{P uptake in control plot (kg ha}^{-1})}{\text{Phosphorus applied to the test treatment (kg ha}^{-1})}$

- Production Efficiency (kg pod yield day^{-1} ha^{-1}) $= \dfrac{\text{Green pod yield (kg ha}^{-1})}{\text{Total duration taken by crop (days)}}$

Net return (Rs.day^{-1} ha^{-1})

- Economic efficiency (Rs.day^{-1} ha^{-1}) = --
  Total duration taken crop (days)

RESULTS AND DISCUSSION

Effect of varieties

Perusal of data presented in Table 1 indicated that varieties significantly influenced all the growth and yield attributing parameters. Among all three varieties, Pusa Dharni recorded tallest plant (68.17 cm) followed by Kashi Kanchan (64.83 cm) and registered significantly superior over Pusa Sukomal (39.75 cm). Significantly higher pods per plant (31.08) were also recorded with Pusa Dharni, which were 91.26 and 18.81% higher than Pusa Sukomal and Kashi Kanchan, respectively. However, pod length and weight per pod were recorded ~~maximum~~ with Kashi Kanchan, but remained statistically at par with Pusa Dharni and significantly higher over Pusa Sukomal. Significant variation in the plant height and yield attributing parameters could be attributed to the genetic makeup of the individual varieties and differences in their performance due to environmental adaptability (Shilpa *et al*., 2015; Das *et al*., 2019; Samant, 2014).

Among the different cowpea varieties, Pusa Dharni recorded significantly higher green pod yield (5.12 t ha^{-1}) increasing by 7.34 and 6.22% over Pusa Sukomal and Kashi Kanchan, respectively. Variety Kashi Kanchan produced statistically higher green pod yield (4.82 t ha^{-1}) than Pusa Sukomal; thus, lowest green pod yield (4.77 t ha^{-1}) obtained with Pusa Sukomal. The increased pod yield indicates superiority of Pusa Dharni owing to genetic characteristics and adaptability to moisture deficient conditions compared to rest of the varieties. Srinivas *et al*. (2017) also reported significant variability for yields and yield attributing parameters in cowpea due to genetic makeup of the genotypes and climate diversity. The results further revealed that Pusa Dharni variety yielded significantly higher green fodder yield (21.03 t ha^{-1}) than Pusa Sukomal (16.87 t ha^{-1}) and Kashi Kanchan (19.48 t ha^{-1}).

Maximum N, P and K uptake was observed by Pusa Dharni variety which was 32.98, 36.79 and 38.78 and 12.61, 17.0 and 11.33% higher than Pusa Sukomal and Kashi Kanchan respectively (Table 2). This might be attributed to the higher pod and fodder yield, root growth, and root hair formation in Pusa Dharni variety than rest of the varieties. Sathyaseelan *et al.* (2014) reported that increased uptake of NPK largely depends on yield potentiality of a variety. Highest agronomical P use efficiency (33.73 kg pod yield per kg P applied) was registered in variety Pusa Dharni, which was 21.37 and 15.83% higher over Pusa Sukomal and Kashi Kanchan, respectively. However, lowest agronomical P use efficiency (27.79 kg pod yield per kg P applied) was noted in case of variety Pusa Sukomal. Variety Pusa Dharni also recorded highest phosphorus recovery (18.19%) followed by Kashi Kanchan (13.23%). The lowest phosphorus recovery (9.70%) was registered with variety Pusa Sukomal. Nodules per plant and nodule weight were recorded maximum variety Pusa Dharni.

Variety Pusa Dharni fetched highest net returns (Rs. 40454 ha^{-1}) with net B:C ratio of 1.27 and economic efficiency of Rs.505.67 per day per hectare (Table 3). The variety also resulted in maximum production efficiency (63.9 kg per day per ha). The lowest net returns, net B: C ratio, economic efficiency and production efficiency were registered with variety Pusa Sukomal. The higher net returns, net B: C ratio, economic efficiency and production efficiency might be attributed to the production of higher green pod and fodder yield by variety Pusa Dharni compared to Kashi Kanchan and Pusa Sukomal.

Effect of phosphorus levels

Various growth and yield attributing parameters viz. plant height, pod length, pod weight and pods per plant of cowpea were significantly influenced by the application of different phosphorus levels compared to control (Table 1). Highest plant height (63.44 cm), pods per plant (27.89), pod length (26.91 cm) and weight per pod (7.22 g) were recorded with 60 kg P_2O_5 ha^{-1} and found significantly superior over control and 20 kg P_2O_5 ha^{-1}. However, no significant difference was observed between the growth and yield attributing parameters obtained with of that 60 kg P_2O_5 ha^{-1} and 40 kg P_2O_5 ha^{-1}. The lowest plant height, pods per plant, pod length and pod weight were recorded in control. The green pod and fodder yield increased significantly with the application of all the phosphorus levels over control. The highest green pod yield (5.38 t ha^{-1}) and green fodder yield (21.02 t ha^{-1}) were recorded with the application of 60 kg P_2O_5 ha^{-1} closely followed by 40 kg P_2O_5 ha^{-1} (5.30 t ha^{-1} and 20.75 t ha^{-1}). Thus, the lowest green pod yield (4.11 t ha^{-1}) and green fodder yield (16.82 t ha^{-1}) were obtained under control. This might be owing to the fact that phosphorus application significantly influenced root development and stimulation of several biochemical activities such as photosynthesis, respiration, cell division and other processes, leading to better sink translocation. As a result, increased growth, yield attributing parameters and yields over control (Nkaa *et al.*, 2014; Kumar *et al.*, 2012). The increase in phosphorous level from control to 20 kg ha^{-1} resulted in an increase of 19.22% in green pod yield, whereas the difference between the yield obtained with 40 kg and 60 kg P_2O_5 ha^{-1} was not significant, indicating good performance of cowpea crop under rainfed conditions using 40 kg P2O5 ha^{-1}. Magani and Kuchinda (2009) also reported 40 kg P_2O_5 ha^{-1} as optimum phosphorus dose for cowpea.

Increased phosphorus levels significantly increased N, P and K uptake by cowpea crop over control (Table 2). Application of 60 kg P_2O_5 ha^{-1} showed maximum N (94.84 kg ha^{-1}), P (16.42 kg ha^{-1}) and K (60.65 kg ha^{-1}) uptake followed by 40 kg P_2O_5 ha^{-1} (91.71, 15.93 and 59.09 kg ha^{-1} uptake of NPK). However, lowest uptake of N (63.91 kg ha^{-1}), P (9.93 kg ha^{-1}) and K (39.58 kg ha^{-1}) was registered under control. Higher N, P and K uptake by cowpea might be attributed to the availability of phosphorus due to higher doses of phosphorus (40 kg and 60 kg ha^{-1}) that caused better root development and root hairs growth, nodulation and nutrient translocation in plants. This leads to higher biological activities for N_2 fixation, P-solubilization and mineralization, resulting in increased NPK uptake by the crop plants (Vikrant *et al.*, 2005; Singh *et al.*, 2016; Singh and Prasad, 2008; Rudreshappa and Halikatti, 2002). The highest agronomical phosphorus use efficiency (39.75 kg pod yield per kg P applied) and phosphorus recovery (15.05%) were observed with lowest level of phosphorus (20 kg ha^{-1}). Further, application of 40 kg P_2O_5 ha^{-1} found superior for providing higher agronomical phosphorus use efficiency (29.67 Kg pod yield per kg P applied) and phosphorus recovery (14.86%) compared to 60 kg P_2O_5 ha^{-1} (21.24 kg pod yield per kg P applied and 11.22%). Increased values of agronomical phosphorus use efficiency and phosphorus recovery with lower doses of phosphorus showed an inverse relationship between agronomical phosphorus use efficiency, phosphorus recovery, and phosphorus levels (Devi *et al.*, 2012; Ahirwar *et al.*, 2016). The number of nodules per plant and dry weight of nodules per plant increased significantly with increased phosphorus levels compared to control. The maximum number of nodules per plant (16.67) and dry weight of nodules per plant (251.67 mg) were recorded with the application of 60 kg P_2O_5 ha^{-1}, which was at par with 40 kg P_2O_5 ha^{-1}. However, the lowest nodules per plant (11.20) and nodules dry weight (153 mg plant^{-1}) were recorded in control. The increase in nodules and their dry weight might be attributed to enhanced root growth and root hairs due to phosphorus nutrition (Nziguheba *et al.*, 2016).

Economic analysis revealed that the highest net returns (Rs.41345 ha^{-1}) and net B: C ratio (1.28) was realized with the application of 40 kg P_2O_5 ha^{-1} (Table 3). Application of 60 kg P_2O_5 ha^{-1} fetched lower net return by Rs.225 ha^{-1} compared to 40 kg P_2O_5 ha^{-1}, which was owing to involvement of higher cost of cultivation with 60 kg P_2O_5 ha^{-1} than 40 kg P_2O_5 ha^{-1}. Further, application of 40 kg P_2O_5 ha^{-1} showed 47.42 and 11.07 % higher net returns over control and 20 kg P_2O_5 ha^{-1}, respectively which indicates the importance of optimum supply of phosphorus for realizing higher net returns. Jat *et al*. (2013) also reported higher net returns and B: C ratio with the application of 40 P_2O_5 ha^{-1} by cowpea crop under rainfed conditions.

Conclusion

~~On the basis of~~ Based on the results obtained from the study, it is concluded that productivity and profitability of cowpea can be enhanced by growing newly evolved variety Pusa Dharni ~~alongwith~~ along with the application of 40 kg P_2O_5 ha^{-1} under rainfed conditions of semi-arid regions.

Table 1: Yield and yield attributes of cowpea varieties as influenced by phosphorus levels

Treatments	Plant height (cm)	Pods per plant	Pod length (cm)	Weight of per pod (g)	Green Pod yield (t ha^{-1})	Green fodder yield (t ha^{-1})	Harvest index (%)
Variety							
Pusa Dharni	68.17	31.08	25.40	6.74	5.12	21.03	19.58
Pusa Sukomal	39.75	16.25	23.10	6.14	4.77	16.87	22.04
Kashi Kanchan	64.83	26.16	26.71	7.07	4.82	19.48	19.00
SEm±	1.61	0.81	0.62	0.07	0.04	0.42	0.58
CD (P=0.05)	4.52	2.20	1.82	0.62	0.13	1.26	1.73
Phosphorus levels (kg ha^{-1})							
0	49.78	19.67	23.10	5.77	4.11	16.82	19.64
20	56.00	23.33	24.52	6.58	4.90	19.35	20.21
40	61.10	27.11	25.70	7.05	5.30	20.75	20.34
60	63.44	27.89	26.91	7.22	5.38	21.02	20.38
SEm±	0.89	0.62	0.43	0.05	0.06	0.22	0.64
CD (P=0.05)	2.76	1.19	1.26	0.17	0.17	0.64	1.94

Table 2: Effect of varieties and phosphorus levels on NPK uptake, nodulation, P use efficiency and P recovery

Treatments	Nutrient uptake (kg ha^{-1})			Nodules per Plant	Nodule weight (mg $plant^{-1}$)	Agronomical P use efficiency (Kg pod yield per kg P applied)	Phosphorus recovery (%)
	N	P	K				
Variety							
Pusa Dharni	92.42	16.10	60.54	15.50	221.90	33.73	18.19
Pusa Sukomal	69.50	11.77	43.75	13.00	208.62	27.79	9.70
Kashi Kanchan	82.07	13.76	53.68	14.75	194.51	29.12	13.23
SEm±	2.69	0.43	1.71	0.52	5.34	0.82	0.33

CD (P=0.05)	8.01	1.26	5.28	1.51	16.48	2.49	1.01
Phosphorus levels (kg/ha)							
0	63.91	9.93	39.58	11.20	153.32	0	0
20	77.21	12.93	52.73	13.48	173.40	39.72	15.05
40	91.71	15.93	59.09	16.33	245.00	29.67	14.86
60	94.84	16.42	60.65	16.67	251.61	21.24	11.22
SEm±	2.39	0.34	1.41	0.43	6.19	0.91	0.43
CD (P=0.05)	7.15	1.09	4.28	1.23	18.61	2.71	1.24

Table 3: Effect of varieties and phosphorus levels on economics and production efficiency

Treatments	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	Net B:C ratio	Economic efficiency (Rs./day/ha)	Production efficiency (kg/day/ha)
Variety						
Pusa Dharni	31776	72230	40454	1.27	505.67	63.9
Pusa Sukomal	31776	64570	32794	1.03	409.92	59.62
Kashi Kanchan	31776	68740	36964	1.16	462.05	60.25
Phosphorus levels (kg ha^{-1})						
0	29875	57920	28045	0.94	350.56	51.37
20	31125	68350	37225	1.20	465.31	61.25
40	32405	73750	41345	1.28	516.81	66.25
60	33700	74820	41120	1.22	514.00	67.25

REFERENCES

Ahirwar, R.P., Mishra, U.S., Mitra, N.G. and Sirothia, P. 2016. Effect of phosphorus and biofertilizers on phosphorus use efficiency, biological N-Fixation and yield of pigeonpea (*Cajanus cajan* L.). *International Journal of Agriculture, Environment and Biotechnology* **9**(6): 1039-1043.

Ahmed, S., Humphreys, E., Salim, M., and Chauhan, B.S. 2016. Growth, yield and nitrogen use efficiency of dry-seeded rice as influenced by nitrogen and seed rates in Bangladesh. *Field Crops Research* **186**:18-31.

Aikins, S. H. M. and Afuakwa, J. J. 2008. Growth and dry matter yield responses of cowpea to different sowing depths. *ARPN Journal of Agricultural and Biological Science* ***3***(5-6): 50-54.

Boukar, O., Fatokun, C. A., Huynh, B. L., Roberts, P. A. and Close, T. J. 2016. Genomic tools in cowpea breeding programs: Status and Perspectives. *Front. Plant Science* **7,** https://doi.org/10.3389/fpls.2016.00757

Chatterjee Ranjit and Subhendu Bandyopadhyay. 2017. Effect of boron, molybdenum and biofertilizers on growth and yield of cowpea (*Vigna unguiculata* L. Walp.) in acid soil of eastern Himalayan region. *Journal of the Saudi Society of Agricultural Sciences* **16**(4): 332–336.

Das Reshmi Rani, Das Goutam, Talukdar Pranab and Neog Seuji Bora. 2019. Genetic Analysis for Yield and Yield Attributing Traits in Cowpea (*Vigna unguiculata* L. Walp). *Legume Research*, Online ISSN: 0976-0571.

Giridhar Karukonda, Pakalpati Satyanarayana Raju, Ganesh Pushpalatha and Patra Chinmayee . 2020. Effects of plant density on yield parameters of cowpea (*Vigna unguiculata* L.). *International Journal of Chemical Studies* **8**(4): 344-347.

Gomez, K.A. and Gomez, A.A. 1984. Statistical Procedures for Agriculture Research. 2nd Edn. John Willey and Sons, New York. pp:1-680.

Hogh-Jensen, H., Schjoerring, Jan K. and Soussana, Jean-Francois. 2002. The Influence of Phosphorus Deficiency on Growth and Nitrogen Fixation of White Clover Plants. *Annals of Botany* **90**(6):745-753.

Haruna, I. M. and Aliyu, L. 2011. Yield and economic returns of sesame (*Sesamum indicum* L.) as influenced by poultry manure, nitrogen and phosphorus at Samaru. *Nigeria. Elixir Agric* **39**: 4884-4887.

Hosamani Vinayak, Chittapur, B. M., Hosamani Venkatesh and Hiremath Rajanand . 2017. Sustained Nutrient Management Practice for Pulse Production: A Review. *Int.J. Curr.Microbiol.App.Sci* **6**(11): 3773-3786.

Jackson, M.L.1973. Soil chemical analysis. Prentice Hall of India Pvt., New Delhi **15**: 13–22.

Jat , S.R., Patel, B.J., Shivran, A.C., Kuri, B.R. and Jat, G. 2013. Effect of P and S levels on growth and yield of cowpea under rainfed conditions. *Annals of Plant and Soil Research* **15**: 114-117.

Kan'ankuk'a, C.N. 1999. Effect of lime, N and P on growth, yield and yield components of cowpea (*V. unguiculata* (L.) Walp.). Thesis submitted to the Postgraduate school, Ahmadu Bello University, Zaria.pp:110.

Khourgamy A. and Farnia A. 2009 - Effect of phosphorus and zinc fertilization on yield components of chickpea cultivars. African Crop Sci. Conference Proc. **9**:205-208.

Kumar, A., Yadav, P.K., Yadav, R.K., Singh, R. and Yadav, H.K. 2012. Growth biomass production and quality characters of cowpea as influenced by Phosphorus and sulphur fertilization on loamy sands of semi-arid sub tropics. *Asian Journal of Soil Science* **7**: 80-83.

Kyei-Boahen S., Savala C.E.N., Chikoye, D. and Abaidoo, R. 2017. Growth and Yield Responses of Cowpea to Inoculation and Phosphorus Fertilization in Different Environments. Front. Plant Sci. 8:646. doi: 10.3389/fpls.2017.0064.

Liyanage, R., Perera. O.S., Wethasinghe, P., Jayawardana, B.C., Vidanaarachchi, J.K. and Sivaganesan, R. 2014. Nutritional properties and antioxidant content of commonly consumed cowpea cultivars in Sri Lanka. *J Food Legume Indian J Pulses Res*. **27**(3):215-217.

Magani, I. E. and Kuchinda, C. 2009. Effect of phosphorus fertilizer on growth, yield and crude protein content of cowpea (*Vigna unguiculata* L.) in Nigeria. *J. Appl. Biosci*. **23**: 1387 -1393.

Mfeka, N., Mulidzi, R.A. and Lewu, F.B. 2019. Growth and yield parameters of three cowpea (*Vigna unguiculata* L. Walp) lines as affected by planting date and zinc application rate. *S Afr J Sci*. **115**(1/2), https://doi.org/10.17159/sajs.2019/4474.

Devi Nandini, K., Singh, L. Nongdren Khomba., Sunanda, Toijam, Nanita Heisnam, Basanta Singh, Singh, K. Khamba, and Singh, Mohendro Wakambam. 2012. Response of Soybean [*Glycine max* (L.) Merrill] to Sources and Levels of Phosphorus. *Journal of Agricultural Science* **4**(6): 44-53.

Ndakidemi, P. A. and Dakora, F. D. 2007. Yield components of nodulated cowpea (*Vigna unguiculata* (L.) Walp) and maize (*Zea mays*) plants grown with exogenous phosphorus in different cropping systems. *Aust. J. Exp. Agric*. **47**: 587-590.

Sathyaseelan Neenu, Ramesh Kulasekaran, Ramana Sivakoti and Biswas Ashis Kumar.2014. Growth and yield of different varieties of chickpea (*Cicer arietinum* L.) as influenced by the phosphorus nutrition under rainfed conditions on Vertisols. *International Journal of Bio-resource and Stress Management* **5**(1): 053-057.

Nkaa, F.A., Nwokeocha, O.W. and Ihuoma, O. 2014. Effect of phosphorus fertilizer on growth and yield of cowpea (*Vigna unguiculata*). *IOSR J. Pharm. Biol. Sci* 9: 74-82.

Nziguheba, G., Zingore, S., Kihara, J., Merckx, R., Njoroge, S., Otinga, A., Vandamme, E. and Vanlauwe, B. 2016. Phosphorus in smallholder farming systems of sub-Saharan Africa: Implications for agricultural intensification. *Nutr. Cycl. Agroecosyst* **104:** 321–340.

Patel Dipikaben, M. and Kumari Shilpa. 2018. Varietal evaluation of vegetable cowpea (*Vigna unguiculata* (L.) Walp) with respect to yield under North Gujarat condition. *Journal of Pharmacognosy and Phytochemistry* **7**(4): 424-427.

Rudreshappa, T.S. and Halikatti, S.I. 2002. Response of green gram to nitrogen and phosphorus levels in paddy fallow. *Karnataka J. Agric. Sci* **15**(1): 4-7.

Sahrawat Kanwar Lal, Wani Suhas, P., Rego, T. J., Pardhasaradh Gazulai and Murthy, K. V. S. 2007. Widespread deficiencies of sulphur, boron and zinc in dryland soils of the Indian semi-arid tropics. *Current science* **93**(10):1428-1432.

Sahrawat, K. L. and Wani, S. P. 2013. Nutrient Deficiencies and their Management in Soils of the Semi-Arid Tropical Regions. In: Climate Change and Agriculture. Stadium Press (India) Pvt. Ltd., New Delhi. Pp:73-89.

Samant, T.K. 2014. Evaluation of Growth and Yield parameters of Greengram (*Vigna radiata* L). *Agriculture Update* **9**(3):427-430.

Shaw, M. 2007. 100 Most Protein Rich Vegetarian Foods. Smarter Fitter Blog. Http://smarterfitter.com/blog/2007/10/28/100-most-protein-rich-vegetarian foods.

Shilpa, H. D., Wali, S. Y., Hanamant Halli, M. and Amrutha, T.G. 2015. Response of cowpea (*Vigna unguiculata*) genotypes to different levels of phosphorus during summer under Northern dry zone of Karnataka. *International Journal of Technical Research and Applications* **3**(5): 224-226.

Shweta and Malik Manu. 2014. Response of pulse production to phosphorus-A Review. *Agriculture Review* **35**(4): 295 - 298.

Singh, A., Baoule, A.L., Ahmed, H.G., Dikko, A.U., Aliyu, U., Sokoto, M. B., Alhassan, J., Musa, M. and Haliru B. 2011. Influence of phosphorus on the performance of cowpea (*Vigna unguiculata* (L.) Walp.) varieties in the Sudan Savanna of Nigeria. *Agricultural Sciences* **2**(3): 313-317.

Singh, B.B., Aajeigbe, H., Atarawali S., Sfernandez-Rivera and Abubakar Musa . 2003. Improving the production and utilization of cowpea as food and fodder. *Field Crops Research* **84**(1-2):169–177.

Singh, R. and Prasad, K. 2008. Effect of vermin-compost, Rhizobium and DAP on growth, yield and nutrient uptake by chickpea. *J. Food legumes* **21**(2):112-114.

Singh, V., Ali, J., Singh, H. and Singh, J.P. 2016. Effect of sources of phosphorus and bio-fertilizers on yield, nutrient uptake and quality of lentil. *Annals of Plant and Soil Research* **18**(1): 14-17.

Srinivas Jogdhande, Vijay S. Kale and Nagre, P. K. 2017. Evaluation of Different Cowpea Varieties and Genotypes. *Int J Pure App Biosci* **5**(3): 329-334.

Udvardi, M. and Poole, P.S. 2013. Transport and metabolism in legume-rhizobia symbioses. *Annu. Rev. Plant Biol* **64**:781–805.

Vikrant Singh H., Malik, C.V.S. and Singh B.P. 2005. Grain yield and protein content of cowpea as influenced by farm yard manure and phosphorus application. *Indian Journal of Pulses Research* **18**(2):250-251.