

Original Research Article

Growth and yield of grain cowpea (*Vigna unguiculata* sub sp. *Cylindrica*) in response to foliar nutrition and graded levels of phosphorus and potassium

ABSTRACT

Aim: To assess the growth and yield of grain cowpea in response to varied doses of phosphorus (P) and potassium (K) supplemented with foliar application of nano diammonium phosphate (DAP) and potassium salt of active phosphorus (PSAP).

Study Design: The field experiment was a factorial experiment, laid out in randomised block design with two levels of P, three levels of K and two sources of foliar nutrition, compared against a control, with three replications.

Place and Duration of Study: The study was conducted at the Integrated Farming System Research Station, Karamana, Nedumcaud, Thiruvananthapuram, Kerala, India, during the period from December 2022 to February 2023.

Methods: The study utilized PGCP-6 cowpea variety and adopted fertilizer recommendations as per KAU POP (Package of Practices Recommendations of the Kerala Agricultural University). The entire dose of FYM, P and K and half dose of nitrogen (N) were applied as basal dose. The remaining half dose of N was applied at 15 days after sowing (DAS). Additionally, foliar application of nano DAP and PSAP (each @ 0.4 %) was done at 20 DAS and 40 DAS.

Results: The results of the study revealed that the treatment combination, $p_2k_1f_2$ and $p_2k_1f_1$ had comparable leaf area per plant and leaf area index (LAI) (at 60 DAS). The highest seed yield (1642 kg ha^{-1}) was recorded with $p_2k_1f_2$. Higher dose of P and K along with foliar application of nano DAP (0.4 % at 20 DAS and 40 DAS) had significant effect on the total DMP and haulm yield.

Conclusion: Combined application full dose of N, half dose of P, full dose of K and foliar application of PSAP (0.4 %) at 20 DAS and 40 DAS could be recommended as the best treatment combination for yield enhancement in grain cowpea.

Key words: Cowpea, PSAP, nano DAP, leaf area, seed yield

1. INTRODUCTION

Internationally, there is a rising trend in utilization of grain legumes especially cowpea (*Vigna unguiculata*) as food, animal feed and as raw material for several industries. Cowpea belonging to the Fabaceae family is the prime pulse crop of Asia, Africa, South America and South Europe. Globally, India occupies a vital position as the largest consumer and importer of pulses. Cultivated in about 20 per cent of area it accounts for approximately 7 to 10 per cent of the total food grain area and production in India. Uttar Pradesh is the leading producer of cowpea in India. Grain cowpea (*Vigna unguiculata* sub sp. *cylindrica*) hold the distinction of being one of the earliest crops cultivated [1] and is a predominant legume cultivated in Kerala. Cowpea grains are rich in carbohydrates (50% - 60%), protein (23% - 32%), dietary fibre, minerals, vitamins and phytochemicals [2], folic acid content and lower fat content (less than 1%) [3]. The study conducted by [4] revealed that cowpea enhanced the fertility of soil and demonstrated a rapid growth habit with profound yield.

Phosphorus (P) plays a key role in stimulating nodulation, improving growth and yield of legumes [5]. The role of P in promoting root growth and proliferation, better nutrient uptake [6] and is necessary for metabolic processes like photosynthesis, respiration, synthesis of carbohydrate and protein and enzyme activation [7]. Grain cowpea being a leguminous crop respond actively towards P supply rather than N and K [8]. Potassium (K) plays a prominent part in promoting flowering and pod setting [9] and enhanced seed germination, development of emerged seedling, nutrient balance and protein synthesis in legumes [10]. Potassium stimulates early crop growth,

Comment [WU1]: Not leaf area it is growth.

Comment [WU2]: Add references.

Comment [WU3]:

Comment [WU4]: Add more justification in introduction section.

protein synthesis, improving water use efficiency, enhanced drought tolerance and contributing to resistance against disease and pest [11]. Potassium accelerates the transfer of newly synthesized photosynthates and had positive influence on movement of stored materials, reduced ovule abortion by increasing material availability to seeds [12]. Nano-fertilizers are a novel approach in plant nutrition ensuring greater nutrient use efficiency as these particles are absorbed as whole through the roots or stomata depending on the method of application adopted. Nano-fertilizers are more efficient than conventional fertilizers since they can regulate the release of nutrients in tune with the crop requirements [13]. Potassium salt of active phosphorus (PSAP) is a technical molecule manufactured by adopting catalytic technology which was reported to be 180 per cent water soluble and 100 per cent absorbed by foliage [14].

2. MATERIALS AND METHODS

The study was carried out at the Integrated Farming System Research Station, Karamana, geographically located at 8°28'43.896" N latitude and 76°57'46.6812" E longitude, at an altitude of 5 m above mean sea level, during 2022-2023 (December, 2022 to February, 2023). The main objective of the study was to assess the growth and yield of grain cowpea in response to varied doses of phosphorus and potassium nutrition supplemented with foliar application of nano diammonium phosphate (nano DAP) and potassium salt of active phosphorus (PSAP) at 0.4 per cent each, at 20 DAS and 40 DAS.

The experiment was laid out in randomised block design with (2 x 3 x 2) + 1 treatments, replicated thrice. The treatments comprised combinations of two levels of P (p₁-100 % RDP, p₂-50 % RDP), three levels of K (k₁- 100 % RDK, k₂- 150 % RDK, k₃- 200 % RDK) and foliar application at 20 DAS and 40 DAS (f₁ - nano DAP @ 0.4%, f₂ - PSAP @ 0.4 %), compared against a control (KAU POP) (Package of Practices Recommendations of the Kerala Agricultural University, 2016).

The soil of the experimental site was sandy clay loam, slightly acidic in reaction, high in organic carbon and available soil P, and medium in available N and K. Cowpea seeds treated with rhizobium were sown at a spacing of 25 cm x 15 cm. The variety used for the study was PGCP-6 and the fertilizer recommendation followed was 20:30:10 kg NPK ha⁻¹. Liming was done at the rate of 250 kg ha⁻¹ along with the last ploughing. The entire dose of FYM (20 t ha⁻¹), half the dose of N, and full dose of P and K were applied basally and the remaining N was applied at 15 DAS. Foliar application of nano DAP and PSAP, each at 0.4 per cent concentration were sprayed at 20 DAS and 40 DAS as per the treatments, along with an adjuvant (1 mL per 10 L of spray fluid) at a spray volume of 500 L ha⁻¹. Observations of growth parameters were taken at 15 days intervals.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

The growth parameters were recorded at 15 DAS, 30 DAS, 45 DAS and 60 DAS.

3.1.1 Primary branches per plant

The levels of P, K and foliar application at 20 DAS and 40 DAS had significant influence on the number of primary branches per plant. The treatments, p₁ (100 % RDP) (5.49 at 45 DAS; 6.35 at 60 DAS) and k₃ (200 % RDK) (5.45 at 45 DAS) had significant effect on the number of primary branches per plant. Foliar application of nano DAP (0.4 % at 20 DAS and 40 DAS) (f₁) recorded more number of primary branches per plant (6.46) at 60 DAS. The treatment combinations, p₁k₃ (100 % RDP + 200 % RDK) and p₁k₁ (100 % RDP + 100 % RDK) resulted in more number of branches per plant (6.54 each) at 60 DAS. The second order interaction, p₁k₃f₂ (100 % RDP + 200 % RDK + PSAP @ 0.4 % at 20 DAS and 40 DAS) resulted in more number of primary branches per plant at 30 DAS (4.10) as presented in Table 1a and Table 1b.

Aryal *et al.* (2021) [15] reported that P might have enhanced cell division and cell elongation leading to a greater number of lateral buds facilitating development of branches. Plants absorb P from vicinity of root zone at early growth stages, sufficient quantity of P supply might be the reason for a greater number of primary branches [16, 17]. Potassium is a key macronutrient that generates a greater number of primary branches, increasing plant vigour. It was reported by [18] that primary

Comment [WU5]: In which statistics technique you follow to analyse the data?? Mention in this section.

Comment [WU6]: The dose of RDP must be mentioned

Comment [WU7]: Add the dose of RDK in details.

Comment [WU8]: Soil Data should be included.

branches were influenced by synergistic interaction of K with N and P. Similar results were recorded by [19] and [20]. Nano fertilizers have been reported to possess higher penetration capacity and rapid translocation within the plants. This in turn might have ensured the availability of P for a longer duration as reported by [21]. However, the three-factor interactions revealed the superiority of foliar application of PSAP in combination with full dose of P and double dose of K. Optimum quantity of RDF (recommended dose of fertilizers) along with foliar application of P and K (PSAP) plays a pivotal role in improving plant growth achieved through photosynthesis, active metabolism and controlled stomatal opening and closing in soybean [22].

3.1.2 Leaf area per plant

Leaf area per plant responded significantly to the levels of P, K and foliar application as depicted in Fig.1. Application of 50 per cent RDP (p_2) recorded higher leaf area per plant (1038.96 cm^2) at 45 DAS. While 100 per RDK (k_1) resulted in more leaf area at 45 DAS (1093.92 cm^2) and 60 DAS (1063.16 cm^2). Foliar application of nano DAP (0.4%) at 20 DAS and 40 DAS (f_1) resulted in more leaf area per plant (1052.79 cm^2 at 45 DAS; 1030.14 cm^2 at 60 DAS). Among the two-factor interactions, p_1k_1 (100 % RDP + 100 % RDK) recorded more leaf area (1118.91 cm^2) at 45 DAS. However, the treatment combination, p_2k_1 (50 % RDP + 100 % RDK) resulted in more leaf area (1091.15 cm^2) at 60 DAS. Application of full dose of K along with foliar application of nano DAP (0.4 % at 45 DAS and 60 DAS) (k_1f_1) resulted in higher leaf area (1129.64 cm^2 and 1087.71 cm^2) at 45 DAS and 60 DAS respectively. The leaf area per plant was higher (1144.79 cm^2) with $p_1k_1f_1$ at 45 DAS. At 60 DAS the treatment combination, $p_2k_1f_1$ resulted in higher leaf area (1103.86 cm^2), comparable with $p_2k_1f_2$ (1078.45 cm^2). Comparing the treatment combination against KAU POP (control), $p_2k_1f_2$ recorded 25.20 per cent higher leaf area per plant.

3.1.3 Leaf area index

Levels of P had no significant effect on the LAI of grain cowpea. However, LAI was the highest with k_1 (100 % RDK) and f_1 (nano DAP @ 0.4% at 20 DAS and 40 DAS) (2.83 and 2.75 respectively) at 60 DAS. Among the two-factor interactions, p_2k_1 and k_1f_1 had significantly higher LAI (2.91 and 2.90 respectively) at 60 DAS. Among the P x K x F interactions, $p_2k_1f_1$ (50 % RDP + 100 % RDK + nano DAP @ 0.4 % at 20 DAS and 40 DAS) had significantly higher LAI (2.94) which was on par with $p_2k_1f_2$ (2.87) at 60 DAS as presented in Tables 2a and Table 2b. The LAI recorded 24.78 per cent higher value with the treatment combination, $p_2k_1f_2$ as compared against KAU POP (control).

Phosphorus activates cell division by accumulation at meristematic regions and increases leaf area and leaf number [23]. Potassium being a mobile element is essential in promoting leaf area by enhancing leaf expansion, promoting more number of leaves and enzyme activation leading to augmentation of leaf area and LAI supporting the overall plant growth [24]. The interactions between P and K might have increased the leaf area and LAI as observed by [25] in black aromatic rice. Foliar application of nano DAP (0.4%) at 20 DAS and 40 DAS might have concurred with the nutrient demand of the crop through faster absorption and assimilation as suggested by [26] in maize. Further, supplementing soil application of P with foliar application of nano P might also have resulted in quicker absorption of P in the nano form as it might have easily penetrated into the leaves resulted in more leaf area and LAI. Similar study was conducted by [27].

3.1.4 Total dry matter production

Higher doses of P and K had significant effect on total dry matter production (DMP) of grain cowpea recorded at harvest. The treatments, p_1 (100 % RDP) and k_3 (200 % RDK) resulted in significantly higher total DMP of 4852 kg ha^{-1} and 4917 kg ha^{-1} respectively. The total DMP recorded significantly higher value (4925 kg ha^{-1}) with foliar application of nano DAP (0.4%) at 20 DAS and 40 DAS (f_1). Among the P x F interactions, p_1f_1 (100 % RDP + nano DAP @ 0.4 %) recorded higher total DMP (5113 kg ha^{-1}).

The treatment combinations, k_1f_1 (100 % RDK + nano DAP at 0.4 % at 20 DAS and 40 DAS) (4958 kg ha^{-1}) was on par with k_3f_1 (4955 kg ha^{-1}), k_3f_2 (4880 kg ha^{-1}) and k_2f_1 (4862 kg ha^{-1}). Among

Comment [WU9]: Mention LAI within a bracket

the three-factor interactions, $p_1k_1f_1$ was observed to be significant with higher total DMP for (5287 kg ha⁻¹) and was comparable with $p_1k_3f_1$ (5250 kg ha⁻¹) as presented in Table 3a and Table 3b.

The accrual of dry matter is a direct outcome of capturing of incident solar radiation and subsequent conversion of solar energy into biomass through photosynthesis, achieved by ensuring optimum quantity of N, P and K [28]. Phosphorus exhibits stimulating effect on crop growth contributing to higher accumulation of dry matter, complimenting the overall total DMP of cowpea [29]. Similar finding was reported by [30]. Study conducted by [31] observed that enhanced augmentation of total dry matter through preserving leaves in conjunction with supply of K. Graded levels of K application could have increased N, P, K uptake and thus improves DMP [32]. Foliar application of nano P was closely linked with DMP in groundnut [33]. Foliar application of P as nano form along with adequate supply of RDF might be the reason for increased nutrient uptake, effective translocation of photosynthates eventually promoting DMP [34].

3.1 Yield Parameters

Cowpea was harvested in three pickings and seed yield and haulm yield were recorded.

3.2.1 Seed yield

Application of half dose of P (p_2), full dose of K (k_1) and foliar application of PSAP (0.4%) at 20 DAS and 40 DAS resulted in the highest seed yield (1484 kg ha⁻¹, 1433 kg ha⁻¹ and 1395 kg ha⁻¹ respectively) of cowpea. Among the K x F interactions, the treatment combination k_1f_2 (100 % RDP + PSAP @ 0.4 % at 20 DAS and 40 DAS) produced the highest seed yield (1492 kg ha⁻¹). The second order interactions, $p_2k_1f_2$ (50 % RDP + 100 % RDK + PSAP @ 0.4 % at 20 DAS and 40 DAS) resulted in the highest seed yield (1642 kg ha⁻¹) of grain cowpea as presented in Table 4a and Table 4b. The treatment combination, $p_2k_1f_2$ were 82.85 per cent superior against control (KAU POP) with respect to the seed yield of grain cowpea.

Phosphorus promotes carbohydrate accumulation and its translocation leading to better flowering and pod formation and grain filling [35]. Study conducted by, [36] observed that P had a crucial part in facilitating photosynthesis, root growth and development, and improved nutrient uptake and store energy as ATP and led to higher yield. This result is in agreement with the findings of [37]. Application of K can lead to increased metabolic activities and better root proliferation in legumes ultimately resulting in enhanced seed setting and pod formation [38]. These findings are in conformity with study reported by [39,40,41]. The K plays a crucial role in facilitating carbohydrate synthesis and translocation of photosynthates from source to sink might have linked with better productivity of cowpea [41]. Foliar application of water-soluble fertilizers resulted in enhanced plant growth, increased translocation of photosynthates from source to sink, and reduce flower and pod shedding [42]. Foliar application of PSAP supply both P and K nutrients which are quickly absorbed by foliage, translocated at a faster rate, regulated stomatal opening and enhanced metabolism improves the yield in soybean [43]. Significantly higher seed yield of soybean was observed with foliar application of PSAP [44].

3.2.2 Haulm yield

Higher dose of P (100 % RDP) and elevated dose of K (200 % RDK) contributed to higher haulm yield of cowpea (4451 kg ha⁻¹ and 4235 kg ha⁻¹ respectively). The treatment involving foliar application of nano DAP (0.4 %) at 20 DAS and 40 DAS resulted in significantly higher haulm yield (4184 kg ha⁻¹). Among the interactions, P x K and K x F had significant effect on haulm yield. The treatment combinations, p_1k_2 and k_2f_1 recorded higher haulm yield (4661 kg ha⁻¹ and 4366 kg ha⁻¹ respectively) as presented in Table 4a and Table 4b. The study conducted by [45] revealed that haulm yield of black gram was significantly enhanced with combined application of P and K. Similar findings reported by [46]. Haulm yield was observed to be higher with foliar application of DAP (2 %) as the photosynthetic efficiency of plants were improved with foliar application of nutrients which might have enhanced the haulm yield [47]. Similar observed were made by [48].

Table 1a. Effect of levels of phosphorus, levels of potassium and foliar application on primary branches per plant of cowpea, nos

Comment [WU10]: ???

Treatment	Primary branches			
	15 DAS	30 DAS	45 DAS	60 DAS
Levels of phosphorus (P)				
p ₁ : 100 % recommended dose of phosphorus	0	3.46	5.49	6.35
p ₂ : 50 % recommended dose of phosphorus	0	3.34	4.87	6.04
SEm (±)	-	0.07	0.05	0.09
CD (0.05)	-	NS	0.155	0.252
Levels of potassium (K)				
k ₁ : 100 % recommended dose of potassium	0	3.32	4.90	6.15
k ₂ : 150 % recommended dose of potassium	0	3.32	5.20	6.07
k ₃ : 200 % recommended dose of potassium	0	3.55	5.45	6.35
SEm (±)	-	0.08	0.06	0.10
CD (0.05)	-	NS	0.19	NS
Foliar application (F) at 20 DAS and 40 DAS				
f ₁ : nano DAP (0.4 %)	0	3.31	5.17	6.46
f ₂ : PSAP (0.4 %)	0	3.49	5.17	5.92
SEm (±)	-	0.07	0.05	0.09
CD (0.05)	-	NS	NS	0.252

Table 1b. Effect of P x K, K x F, P x F and P x K x F interactions on primary branches per plant of cowpea, nos

Comment [WU11]: ??

Treatment	Primary branches			
	15 DAS	30 DAS	45 DAS	60 DAS
P x K				
p ₁ k ₁	0	3.38	5.08	6.54
p ₁ k ₂	0	3.29	5.58	5.96
p ₁ k ₃	0	3.72	5.82	6.54
p ₂ k ₁	0	3.27	4.72	5.77
p ₂ k ₂	0	3.36	4.81	6.17
p ₂ k ₃	0	3.38	5.08	6.17
SEm (±)	-	0.12	0.09	0.15
CD (0.05)	-	NS	NS	0.437
K x F				
k ₁ f ₁	0	3.27	4.87	6.62
k ₁ f ₂	0	3.38	4.92	5.68
k ₂ f ₁	0	3.27	5.17	6.29
k ₂ f ₂	0	3.38	5.22	5.84
k ₃ f ₁	0	3.38	5.45	6.46
k ₃ f ₂	0	3.72	5.45	6.25
SEm (±)	-	0.12	0.09	0.15
CD (0.05)	-	NS	NS	NS
P x F				
p ₁ f ₁	0	3.34	5.46	6.58
p ₁ f ₂	0	3.59	5.53	6.11
p ₂ f ₁	0	3.27	4.88	6.33
p ₂ f ₂	0	3.40	4.86	5.74
SEm (±)	-	0.10	0.07	0.12
CD (0.05)	-	NS	NS	NS
P x K x F				
p ₁ k ₁ f ₁	0	3.43	5.03	7.08
p ₁ k ₁ f ₂	0	3.33	5.13	6.00
p ₁ k ₂ f ₁	0	3.25	5.47	6.00
p ₁ k ₂ f ₂	0	3.33	5.70	5.92

$p_1k_3f_1$	0	3.33	5.87	6.67
$p_1k_3f_2$	0	4.10	5.77	6.42
$p_2k_1f_1$	0	3.10	4.72	6.17
$p_2k_1f_2$	0	3.43	4.72	5.37
$p_2k_2f_1$	0	3.28	4.88	6.58
$p_2k_2f_2$	0	3.43	4.73	5.77
$p_2k_3f_1$	0	3.43	5.03	6.25
$p_2k_3f_2$	0	3.33	5.13	6.08
SEm (\pm)	-	0.17	0.13	0.21
CD (0.05)	-	0.493	NS	NS
Control (KAU POP)	0	4.17	4.50	5.17
Treatment vs Control	-	S	S	S

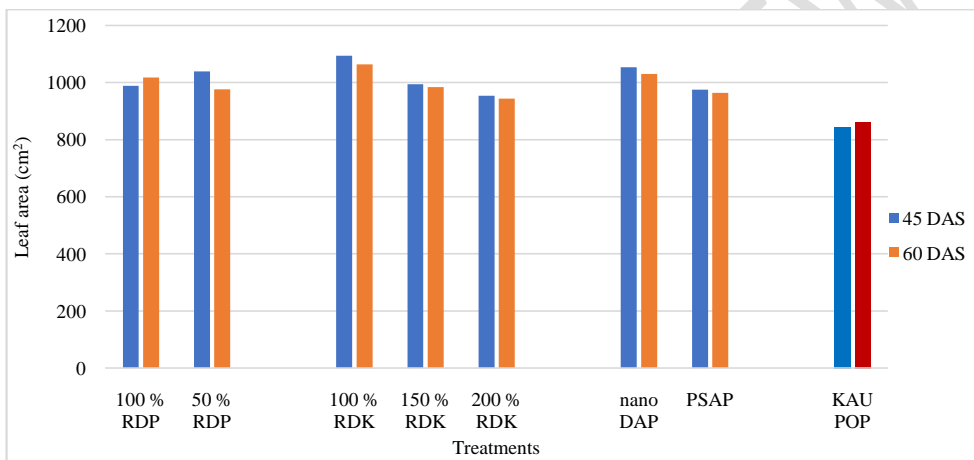


Fig.1. Effect of levels of P, K and foliar application (F) on leaf area per plant of cowpea, cm²

Table 2a. Effect of levels of phosphorus, levels of potassium and foliar application on leaf area index of cowpea

Treatment	Leaf area index			
	15 DAS	30 DAS	45 DAS	60 DAS
Levels of phosphorus (P)				
p_1 : 100 % recommended dose of phosphorus	0.118	1.694	2.64	2.71
p_2 : 50 % recommended dose of phosphorus	0.117	1.690	2.77	2.60
SEm (\pm)	0.002	0.016	0.13	0.04
CD (0.05)	NS	NS	NS	NS
Levels of potassium (K)				
k_1 : 100 % recommended dose of potassium	0.116	1.695	2.92	2.83
k_2 : 150 % recommended dose of potassium	0.118	1.689	2.65	2.62
k_3 : 200 % recommended dose of potassium	0.118	1.691	2.54	2.52
SEm (\pm)	0.002	0.02	0.16	0.05
CD (0.05)	NS	NS	NS	0.147
Foliar application (F) at 20 DAS and 40 DAS				
f_1 : nano DAP (0.4 %)	0.119	1.690	2.81	2.75
f_2 : PSAP (0.4 %)	0.116	1.694	2.60	2.57
SEm (\pm)	0.002	0.016	0.133	0.04
CD (0.05)	NS	NS	NS	0.120

Table 2b. Effect of P x K, K x F, P x F and P x K x F interactions on leaf area index of cowpea

Treatment	Leaf area index			
	15 DAS	30 DAS	45 DAS	60 DAS
P x K				
p ₁ k ₁	0.115	1.699	2.98	2.76
p ₁ k ₂	0.120	1.690	2.51	2.75
p ₁ k ₃	0.119	1.694	2.41	2.63
p ₂ k ₁	0.116	1.692	2.85	2.91
p ₂ k ₂	0.116	1.689	2.79	2.50
p ₂ k ₃	0.118	1.688	2.67	2.40
SEm (±)	0.003	0.028	0.23	0.07
CD (0.05)	NS	NS	NS	0.208
K x F				
k ₁ f ₁	0.118	1.696	3.01	2.90
k ₁ f ₂	0.113	1.694	2.82	2.77
k ₂ f ₁	0.119	1.688	2.62	2.63
k ₂ f ₂	0.117	1.691	2.68	2.62
k ₃ f ₁	0.119	1.687	2.78	2.71
k ₃ f ₂	0.118	1.696	2.30	2.32
SEm (±)	0.003	0.028	0.23	0.07
CD (0.05)	NS	NS	NS	0.208
P x F				
p ₁ f ₁	0.118	1.693	2.76	2.78
p ₁ f ₂	0.117	1.695	2.51	2.64
p ₂ f ₁	0.119	1.687	2.85	2.71
p ₂ f ₂	0.115	1.692	2.69	2.50
SEm (±)	0.003	0.023	0.188	0.06
CD (0.05)	NS	NS	NS	NS
P x K x F				
p ₁ k ₁ f ₁	0.116	1.700	3.05	2.86
p ₁ k ₁ f ₂	0.115	1.697	2.91	2.67
p ₁ k ₂ f ₁	0.120	1.690	2.39	2.83
p ₁ k ₂ f ₂	0.119	1.690	2.63	2.67
p ₁ k ₃ f ₁	0.120	1.690	2.85	2.67
p ₁ k ₃ f ₂	0.117	1.699	1.98	2.59
p ₂ k ₁ f ₁	0.121	1.693	2.97	2.94
p ₂ k ₁ f ₂	0.111	1.691	2.73	2.87
p ₂ k ₂ f ₁	0.118	1.686	2.86	2.44
p ₂ k ₂ f ₂	0.115	1.692	2.72	2.56
p ₂ k ₃ f ₁	0.118	1.684	2.72	2.75
p ₂ k ₃ f ₂	0.118	1.693	2.62	2.05
SEm (±)	0.005	0.040	0.326	0.10
CD (0.05)	NS	NS	NS	0.294
Control (KAU POP)	0.111	1.656	2.25	2.30
Treatment vs Control	NS	S	S	S

Table 3a. Effect of levels of phosphorus, levels of potassium and foliar application on total dry matter production of cowpea, kg ha⁻¹

Treatment	Total dry matter production
Levels of phosphorus (P)	
p ₁ : 100 % recommended dose of phosphorus	4852
p ₂ : 50 % recommended dose of phosphorus	4704
SEm (±)	20

CD (0.05)	59.3
Levels of potassium (K)	
k ₁ : 100 % recommended dose of potassium	4573
k ₂ : 150 % recommended dose of potassium	4844
k ₃ : 200 % recommended dose of potassium	4917
SEm (±)	24
CD (0.05)	72.6
Foliar application (F) at 20 DAS and 40 DAS	
f ₁ : nano DAP (0.4 %)	4925
f ₂ : PSAP (0.4 %)	4631
SEm (±)	20
CD (0.05)	59.3

Table 3b. Effect of P x K, K x F, P x F and P x K x F interactions on total dry matter production, kg ha⁻¹

Treatment	Total dry matter production
P x K	
p ₁ k ₁	4684
p ₁ k ₂	4911
p ₁ k ₃	4961
p ₂ k ₁	4462
p ₂ k ₂	4777
p ₂ k ₃	4873
SEm (±)	35
CD (0.05)	NS
K x F	
k ₁ f ₁	4958
k ₁ f ₂	4188
k ₂ f ₁	4862
k ₂ f ₂	4826
k ₃ f ₁	4955
k ₃ f ₂	4880
SEm (±)	35
CD (0.05)	102.7
P x F	
p ₁ f ₁	5113
p ₁ f ₂	4591
p ₂ f ₁	4737
p ₂ f ₂	4671
SEm (±)	28
CD (0.05)	83.8
P x K x F	
p ₁ k ₁ f ₁	5287
p ₁ k ₁ f ₂	4081
p ₁ k ₂ f ₁	4802
p ₁ k ₂ f ₂	5020
p ₁ k ₃ f ₁	5250
p ₁ k ₃ f ₂	4673
p ₂ k ₁ f ₁	4630
p ₂ k ₁ f ₂	4295
p ₂ k ₂ f ₁	4922
p ₂ k ₂ f ₂	4632
p ₂ k ₃ f ₁	4659
p ₂ k ₃ f ₂	5087
SEm (±)	49
CD (0.05)	145.2
Control (KAU POP)	4120

Treatment vs Control	S
----------------------	---

Table 4a. Effect of levels of phosphorus, levels of potassium and foliar application on yield of cowpea, kg ha⁻¹

Treatment	Seed yield (kg ha ⁻¹)	Haulm yield (kg ha ⁻¹)
Levels of phosphorus (P)		
p ₁ : 100 % recommended dose of phosphorus	1233	4451
p ₂ : 50 % recommended dose of phosphorus	1484	3698
SEm (±)	7	22
CD (0.05)	22.2	66.6
Levels of potassium (K)		
k ₁ : 100 % recommended dose of potassium	1433	3802
k ₂ : 150 % recommended dose of potassium	1267	4186
k ₃ : 200 % recommended dose of potassium	1374	4235
SEm (±)	9	27
CD (0.05)	27.2	81.6
Foliar application (F) at 20 DAS and 40 DAS		
f ₁ : nano DAP (0.4 %)	1322	4184
f ₂ : PSAP (0.4 %)	1395	3965
SEm (±)	7	22
CD (0.05)	22.2	66.6

Table 4b. Effect of P x K, K x F, P x F and P x K x F interactions on yield of cowpea, kg ha⁻¹

Treatment	Seed yield (kg ha ⁻¹)	Haulm yield (kg ha ⁻¹)
P x K		
p ₁ k ₁	1313	4161
p ₁ k ₂	1148	4661
p ₁ k ₃	1237	4531
p ₂ k ₁	1554	3444
p ₂ k ₂	1387	3711
p ₂ k ₃	1510.333	3940
SEm (±)	13	39
CD (0.05)	NS	115.4
K x F		
k ₁ f ₁	1375	3854
k ₁ f ₂	1492	3750
k ₂ f ₁	1250	4366
k ₂ f ₂	1285	4006
k ₃ f ₁	1340	4332
k ₃ f ₂	1408	4139
SEm (±)	13	39
CD (0.05)	38.5	115.4
P x F		
p ₁ f ₁	1206	4589
p ₁ f ₂	1260	4313
p ₂ f ₁	1437	3779
p ₂ f ₂	1530	3618
SEm (±)	10	32
CD (0.05)	31.4	NS
P x K x F		
p ₁ k ₁ f ₁	1286	4200
p ₁ k ₁ f ₂	1341	4122
p ₁ k ₂ f ₁	1126	4927
p ₁ k ₂ f ₂	1170	4395

P ₁ K ₃ f ₁	1206	4641
P ₁ K ₃ f ₂	1268	4421
P ₂ K ₁ f ₁	1465	3509
P ₂ K ₁ f ₂	1642	3379
P ₂ K ₂ f ₁	1374	3805
P ₂ K ₂ f ₂	1400	3617
P ₂ K ₃ f ₁	1474	4023
P ₂ K ₃ f ₂	1547	3857
SEm (±)	18	55
CD (0.05)	54.4	NS
Control (KAU POP)	898	3839
Treatment vs Control	S	NS

4. CONCLUSION

The results of the present study revealed that higher dose of P and K combined with foliar application of nano DAP (0.4 %) at 20 DAS and 40 DAS had significant effect on the total DMP and haulm yield. However, reducing the level of P by half (15 kg P ha⁻¹) along with application of full dose of K (10 kg ha⁻¹) supplemented with foliar application of PSAP (0.4 %) at 20 DAS and 40 DAS could be a viable option for higher leaf area, LAI and seed yield of grain cowpea in high P soils.

REFERENCES

- Ogunkanmi LA, Taiwo A, Mogaji OL, Awobodede A, Eziashi EE, Ogundipe OT. Assessment of genetic diversity among cultivated cowpea (*Vigna unguiculata* L. Walp.) cultivars from a range of localities across West Africa using agronomic traits. *Journal Scientific Research and Development*. 2006;10:111-118.
- Liyanage R, Perera OS, Weththasinghe P, Jayawardana BC, Vidanaarachchi JK, Sivakanesan R. Nutritional properties and antioxidant content of commonly consumed cowpea cultivars in Sri Lanka. *Journal of Food Legumes*. 2014;27(3):215-7.
- Gonçalves A, Goufo P, Barros A, Domínguez-Perles R, Trindade H, Rosa EA, Ferreira L, Rodrigues M. Cowpea (*Vigna unguiculata* L. Walp), a renewed multipurpose crop for a more sustainable agri-food system: nutritional advantages and constraints. *Journal of the Science of Food and Agriculture*. 2016;96(9):2941-2951.
- Nhamo NH, Mupangwa WA, Siziba S, Gatsi T, Chikazunga D. The role of cowpea (*Vigna unguiculata*) and other grain legumes in the management of soil fertility in the smallholder farming sector of Zimbabwe. *Grain legumes and green manures for soil fertility in southern Africa: taking stock of progress*. 2003:119-27.
- Haruna IM, Usman A. Agronomic efficiency of cowpea varieties (*Vigna unguiculata* L. Walp) under varying phosphorus rates in Lafia, Nasarawa State, Nigeria. *Asian Journal of Crop Science*. 2013;5(2):209-215.
- Niu YF, Chai RS, Jin GL, Wang H, Tang CX, Zhang YS. Responses of root architecture development to low phosphorus availability: a review. *Annals of botany*. 2013;112(2):391-408.
- Zhang Z, Liao H, Lucas WJ. Molecular mechanisms underlying phosphate sensing, signaling, and adaptation in plants. *Journal of integrative plant biology*. 2014;56(3):192-220.
- Bhagat SB, Jadhao YS, Dahiphale AV. Effect of different levels of phosphorus on nutrient uptake and quality parameter of fodder cowpea (*Vigna unguiculata* L. Walp) varieties under lateritic soil of Konkan region. *Journal of Pharmacognosy and Phytochemistry*. 2018;7(6):183-5.
- Zahran FA, Negm AY, Bassiem MM, Ismail KM. Foliar fertilization of lentil and lupine in sandy soils with the supernatant of superphosphate and potassium sulphate. *Egyptian Journal of Agricultural Research*. 1998;76(1):19-31.
- Marschner, H. *Marschner's Mineral Nutrition of Higher Plants*. 3rd Ed. Academic Press, London, UK. 2012;178-279.
- Ruhela A, Singh J, Singh HN. Impact assessment of 'Potash for life' project: Accelerating adoption of balanced use of fertilizers and enhancing farm income of farmers' in Chhattisgarh, India. *The Pharma Innovation Journal*. 2021;10 (10): 1453-1472.

12. Abed, R. D., 2017. Effects of genotypes and potassium rates on some of cowpea traits heritability. *Asian Journal of Crop Science*. 9(1):11-19.
13. Liu R, Lal R. Potentials of engineered nanoparticles as fertilizers for increasing agronomic productions. *Science of The Total Environment*. 2015;514: 131–139.
14. Bhatt R, Verma KK, Kumar R, Sanghera GS. Foliar application of potassium salt of active phosphorus (PSAP) mitigates insect pests and improves yield along with sugarcane quality in response to agroclimatic conditions of Punjab. *Sugar Tech*. 2023;25(3):660-669.
15. Aryal A, Devkota AK, Aryal K, Mahato M. Effect of different levels of phosphorus on growth and yield of cowpea varieties in Dang, Nepal. *Journal of Agriculture and Natural Resources*. 2021;4(1):62-78.
16. Nkaa F, Nwokeocha OW, Ihuoma O. Effect of phosphorus fertilizer on growth and yield of cowpea (*Vigna unguiculata*). *IOSR Journal of Pharmacy and Biological Sciences*. 2014;9(5):74-82.
17. Sandaña P, Pinochet D. Grain yield and phosphorus use efficiency of wheat and pea in a high yielding environment. *Journal of Soil Science and Plant Nutrition*. 2014;14(4):973-986.
18. Kumar H, Singh R, Yadav DD, Yadav R, Saquib M, Yadav RK. Effect of different levels of potassium on growth, yield attributes and yields of chickpea varieties. *Plant Archives*. 2017;17(2):1549-1553.
19. Deolankar KP. Effect of fertigation on growth and yield of chickpea (*Cicer arietinum* L.). *Journal of Maharashtra Agricultural Universities*. 2005;30(2): 170-172.
20. Tak HI, Babalola OO, Huyser MH, Inam A. Urban wastewater irrigation and its effect on growth, photosynthesis and yield of chickpea under different doses of potassium. *Soil science and plant nutrition*. 2013;59(2):156-167.
21. Poudel A, Singh SK, Jiménez-Ballesta R, Jatav SS, Patra A, Pandey A. Effect of nano-phosphorus formulation on growth, yield and nutritional quality of wheat under semi-arid climate. *Agronomy*. 2023;13(3):768.
22. Kumari S, Dixit AK, Kumar M, Patel N, Singh M, Bhargav KS. Effect of potassium salt of active phosphorus on growth, yield and quality contributing attributes of soybean. *Journal of Krishi Vigyan*. 2023;11(2):75-80.
23. Namakka A, Jibrin DM, Hamma IL, Bulus J. Effect of phosphorus levels on growth and yield of cowpea (*Vigna unguiculata* (L.) Walp.) in Zaria, Nigeria. *Journal of Dryland Agriculture*. 2017;3(1):85-93.
24. Al-Furtuse AK, Aldoghachi KA, Jabail WA. Response of three varieties of cowpea (*Vignasinensis* L.) to different levels of potassium fertilizer under southern region conditions of Iraq. *Basrah Journal of Agricultural Sciences*. 2019;32:25-34.
25. Devi NM, Luikham E. Influence of phosphorus and potassium on growth and yield of black aromatic rice (Chak-hao). *International Journal of Current Microbiology and Applied Science*. 2018;7(8):143-150.
26. Manikandan A, Subramanian K. Evaluation of zeolite based nitrogen nano-fertilizers on maize growth, yield and quality on inceptisols and alfisols. *International Journal of Plant & Soil Science*. 2016;9(4):1-9.
27. Rashmi C, Prakash S. Effect of nano phosphorus fertilizers on growth and yield of maize (*Zea mays* L.) in Central Dry Zone of Karnataka. *The Mysore Journal of Agricultural Science*. 2023;57(2):286-93.
28. Pyne S, Negi M.S, Shukla A, Malik N, Paul J. Effect of NPK nutrition on leaf area index and chlorophyll content of fibre flax (*Linum usitatissimum* L.). *The Pharma Innovation Journal*. 2022;11(7):2076-2078.
29. Jat SR, Patel BJ, Shivran AC, Kuri BR, Jat G. Effect of phosphorus and sulphur levels on growth and yield of cowpea under rainfed conditions. *Annals of Plant and Soil Research*. 2013;15(2):114-117.
30. Shekara BG, Sowmyalatha BS, Baratkumar C. Effect of phosphorus levels on forage yield of fodder cowpea. *Journal of Horticulture Letters*. 2012;2(1):325.
31. Motaghi S, Nejad TS. The effect of different levels of humic acid and potassium fertilizer on physiological indices of growth. *International Journal of Biosciences*. 2014;5(2):99-105.
32. Chavan AS, Khafi MR, Raj AD, Parmar RM. Effect of potassium and zinc on yield, protein content and uptake of micronutrients on cowpea [*Vigna Unguiculata* (L.) Walp.]. *Agricultural Science Digest-A Research Journal*. 2012;32(2):175-177.

33. Kumari MS, Rao PC, Padmaja G, Ramulu V, Saritha JD, Ramakrishna K. Effect of bio and nano phosphorus on yield, yield attributes and oil content of groundnut (*Arachis hypogaea* L.). Environment Conservation Journal. 2017 Dec 21;18(3):21-26.
34. Kumar GS, Mehera B, Kumar P, Kumar GS. Effect of nano phosphorus on growth and yield of groundnut varieties (*Arachis hypogaea* L.) and yield prediction over SPSS model. International Journal of Environment and Climate Change. 2023;13(10):590-595.
35. Ndakidemi PA, Dakora FD. Yield components of nodulated cowpea (*Vigna unguiculata*) and maize (*Zea mays*) plants grown with exogenous phosphorus in different cropping systems. Australian Journal of Experimental Agriculture. 2007;47(5):583-589.
36. Sharma K, Choudhary K, Bochalya RS. Effect of seed treatment and phosphorus levels on growth, yield and economics of cowpea (*Vigna unguiculata* L.). International Journal of Plant & Soil Science. 2023;35(21):156-160.
37. Singh SP, Kumar A, Bhasose R, Kumar S. Response of summer mungbean to phosphorus and biofertilizers in eastern Uttar Pradesh. Annals of Plant and Soil Research. 2015;17(1):64-5.
38. Gadi Y, Sharma YK, Sharma SK, Bordoloi J. Influence of phosphorus and potassium on performance of green gram (*Vigna radiata* L.) in Inceptisols of Nagaland. Annals of Plant and Soil Research. 2018;20(2):120-124.
39. Hussain F, Malik AU, Haji MA, Malghani AL. Growth and yield response of two cultivars of mungbean (*Vignaradiata* L.) to different potassium levels. Journal of Animal and Plant Science. 2011 Jan 1;21(3):622-625.
40. Kumar H, Singh R, Yadav DD, Yadav R, Saquib M, Yadav RK. Effect of different levels of potassium on growth, yield attributes and yields of chickpea varieties. Plant Archives. 2017;17(2):1549-1553.
41. Chaudhari AV, Mane SS, Chadar BR. Effect of graded levels of potassium on growth, yield and quality of black gram. International Journal of Current Microbiology and Applied Sciences. 2018;6:1607-1612.
42. Dey S, Prasad S, Tiwari P, Sharma P. Effect of urea, KCl, Zinc placement & spray on growth of cowpea. Journal of Pharmacognosy and Phytochemistry. 2017;6(6S):971-973.
43. Kumari S, Dixit AK, Kumar M, Patel N, Singh M, Bhargav KS. Effect of potassium salt of active phosphorus on growth, yield and quality contributing attributes of soybean. Journal of Krishi Vigyan. 2023;11(2):75-80.
44. Dixit AK, Kumari S, Kumar M. Field Evaluation Report on To Study a Bio- efficacy of Product PSAP, 'Potassium Salt of Active Phosphorus' on Soybean 2018-19. KrishiVigyan Kendra – Dewas, RajmataVijayarajeScindiaKrishiViswavidyalaya, Gwalior, Madhya Pradesh, India. 2019;12p.
45. Abraham YL, Umesha C, Sanodiya LK. Effect of levels of phosphorus and potassium on growth, yield and economics of black gram. The Pharma Innovation Journal. 2021;10(9):109-112.
46. Yadav T, Nisha KC, Chopra NK, Yadav MR, Kumar R, Rathore DK, Soni PG, Manarana G, Tamta A, Kushwah M, Ram H. Weed management in cowpea-A review. International Journal of Current Microbiology and Applied Sciences. 2017;6(2):1373-1385.
47. Choudhary GL, Yadav LR. Effect of fertility levels and foliar nutrition on cowpea productivity. Journal of food Legumes. 2011;24(1):67-68.
48. Wakudkar D, Swaroop N, Ravindra J, Thomas T. Effects of different level of phosphatic fertilizers on soil health and yield of cowpea (*Vigna unguiculata* L.). The Pharma Innovation Journal. 2022;11(5):2547-2549.