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Growth and Yield of Grain Cowpea (*Vigna unguiculata* sub sp. *cylindrica*) in Response to Foliar Nutrition and Graded Levels of Phosphorus and Potassium

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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).

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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.

Keywords: 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 production in India [1]. 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 [2] 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 [3], folic acid content and lower fat content (less than 1%) [4]. The study conducted by Nhamo et al [5] revealed that cowpea enhanced the fertility of soil through nitrogen fixation and produced high yield and possess a quick growing habit due to legume effect.

Phosphorus (P) plays a key role in stimulating nodulation, improving growth and yield of legumes [6]. The role of P in promoting root growth and proliferation, better nutrient uptake [7] and is necessary for metabolic processes like photosynthesis, respiration, synthesis of carbohydrate and protein and enzyme activation [8]. Grain cowpea being a leguminous crop respond actively towards P supply rather than N and K [9]. Potassium (K) plays a prominent part in promoting flowering and pod setting [10] and enhanced seed germination, development of emerged seedling, nutrient balance and protein synthesis in legumes [11]. Potassium stimulates early crop growth, protein synthesis, improving water use efficiency, enhanced drought tolerance and contributing to resistance against disease and pest [12]. 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 [13]. 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 [14]. 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 [15].

2. MATERIALS AND METHODS

The study was carried out at the Integrated Farming System Research Station, Karamana, geographically located at $8^o28^{'}43.896^{''}$ N latitude and $76^o57^{'}46.6812^{''}$ 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 data generated from the field experiment were statistically analysed using analysis of variance technique (ANOVA).

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 (p_1-100 % RDP, p_2-50 % RDP), three levels of K (k_1 - 100 % RDK k_2 - 150 % RDK, k_3 - 200 % RDK) and foliar application at 20 DAS and 40 DAS (f_1 - nano DAP @ 0.4%, f_2 - 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 (6.40), high in organic carbon (1.74 %) and available soil P (32.48 kg ha^{-1}), and medium in available N (388.86 kg ha^{-1}) and K (199.36 kg ha^{-1}). 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}. Irrigation was given at weekly intervals upto 20 DAS and thereafter at bi-weekly intervals. Weeding was done at 20 DAS. Decapitation was done at 42 DAS, when the crop began to exhibit trailing tendency. 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, p_1 (100 % RDP) (5.49 at 45 DAS; 6.35 at 60 DAS) and k_3 (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) (f_1) recorded more number of primary branches per plant (6.46) at 60 DAS. The treatment combinations, p_1k_3 (100 % RDP + 200 % RDK) and p_1k_1 (100 % RDP + 100 % RDK) resulted in more number of branches per plant (6.54 each) at 60 DAS. The second order interaction, $p_1k_3f_2$ (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) [16] 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 [17], [18]. Potassium is a key macronutrient that generates a greater number of primary branches, increasing plant vigour. It was reported by Kumar et al [19] that primary branches were influenced by synergistic interaction of K with N and P. Similar results were recorded by Deolankar [20] and Tak [21]. 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 Poudel [22]. 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 [23].

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.

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

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

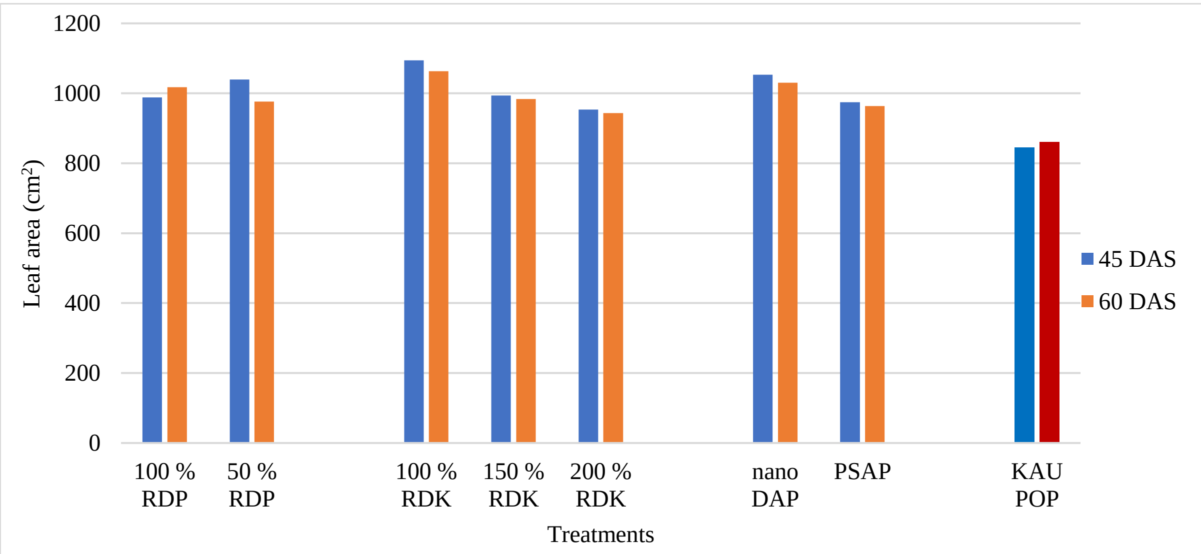

Fig. 1. Effect of levels of P, K and foliar application (F) on leaf area per plant of cowpea, cm^2

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

Treatment	Primary branches			
	15 DAS	30 DAS	45 DAS	60 DAS
P x K				
p_1k_1	0	3.38	5.08	6.54
p_1k_2	0	3.29	5.58	5.96
p_1k_3	0	3.72	5.82	6.54
p_2k_1	0	3.27	4.72	5.77
p_2k_2	0	3.36	4.81	6.17
p_2k_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_1f_1	0	3.27	4.87	6.62
k_1f_2	0	3.38	4.92	5.68
k_2f_1	0	3.27	5.17	6.29
k_2f_2	0	3.38	5.22	5.84
k_3f_1	0	3.38	5.45	6.46
k_3f_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_1f_1	0	3.34	5.46	6.58
p_1f_2	0	3.59	5.53	6.11
p_2f_1	0	3.27	4.88	6.33
p_2f_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				
$p_1k_1f_1$	0	3.43	5.03	7.08
$p_1k_1f_2$	0	3.33	5.13	6.00
$p_1k_2f_1$	0	3.25	5.47	6.00
$p_1k_2f_2$	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 (±)	-	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

3.1.3 Leaf Area Index (LAI)

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 [24]. 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 [25]. The interactions between P and K might have increased the leaf area and LAI as observed by Devi and Luikham [26] 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 Manikandan and Subramanian [27] 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 Rashmi and Prakash [28].

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 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 [29]. Phosphorus exhibits stimulating effect on crop growth contributing to higher accumulation of dry matter, complimenting the overall total DMP of cowpea [30] Similar finding was reported by Jat [31]. Study conducted by Motaghi and Nejad [32] 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

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 (±)	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 (±)	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 (±)	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_1k_1	0.115	1.699	2.98	2.76
p_1k_2	0.120	1.690	2.51	2.75
p_1k_3	0.119	1.694	2.41	2.63
p_2k_1	0.116	1.692	2.85	2.91
p_2k_2	0.116	1.689	2.79	2.50
p_2k_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_1f_1	0.118	1.696	3.01	2.90
k_1f_2	0.113	1.694	2.82	2.77
k_2f_1	0.119	1.688	2.62	2.63
k_2f_2	0.117	1.691	2.68	2.62
k_3f_1	0.119	1.687	2.78	2.71
k_3f_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_1f_1	0.118	1.693	2.76	2.78
p_1f_2	0.117	1.695	2.51	2.64
p_2f_1	0.119	1.687	2.85	2.71
p_2f_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				
$p_1k_1f_1$	0.116	1.700	3.05	2.86
$p_1k_1f_2$	0.115	1.697	2.91	2.67
$p_1k_2f_1$	0.120	1.690	2.39	2.83
$p_1k_2f_2$	0.119	1.690	2.63	2.67
$p_1k_3f_1$	0.120	1.690	2.85	2.67
$p_1k_3f_2$	0.117	1.699	1.98	2.59
$p_2k_1f_1$	0.121	1.693	2.97	2.94
$p_2k_1f_2$	0.111	1.691	2.73	2.87
$p_2k_2f_1$	0.118	1.686	2.86	2.44
$p_2k_2f_2$	0.115	1.692	2.72	2.56
$p_2k_3f_1$	0.118	1.684	2.72	2.75
$p_2k_3f_2$	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

and thus improves DMP [33]. Foliar application of nano P was closely linked with DMP in groundnut [34]. 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 [35].

3.1.5 Yield Parameters

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

3.2 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.

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_1k_1	4684
p_1k_2	4911
p_1k_3	4961
p_2k_1	4462
p_2k_2	4777
p_2k_3	4873
SEm (±)	35
CD (0.05)	NS
K x F	
k_1f_1	4958
k_1f_2	4188
k_2f_1	4862
k_2f_2	4826
k_3f_1	4955
k_3f_2	4880
SEm (±)	35
CD (0.05)	102.7

Treatment	Total dry matter production
P x K	
P x F	
p_1f_1	5113
p_1f_2	4591
p_2f_1	4737
p_2f_2	4671
SEm (±)	28
CD (0.05)	83.8
P x K x F	
$p_1k_1f_1$	5287
$p_1k_1f_2$	4081
$p_1k_2f_1$	4802
$p_1k_2f_2$	5020
$p_1k_3f_1$	5250
$p_1k_3f_2$	4673
$p_2k_1f_1$	4630
$p_2k_1f_2$	4295
$p_2k_2f_1$	4922
$p_2k_2f_2$	4632
$p_2k_3f_1$	4659
$p_2k_3f_2$	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

Phosphorus promotes carbohydrate accumulation and its translocation leading to better flowering and pod formation and grain filling [36]. Study conducted by Sharma et al [37] observed that P had a crucial part in facilitating photosynthesis, root growth and development, and improved nutrient uptake and store energy as ATP and leaded to higher yield. This result is in agreement with the findings of [38]. Application of K can lead to increased metabolic activities and better root proliferation in legumes ultimately resulting in enhanced seed setting and pod formation [39]. These findings are in conformity with study reported by Hussain et al [40-42]. 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 [42]. 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 [43]. 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 [44]. Significantly higher seed yield of soybean was observed with foliar application of PSAP [45].

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_1k_1	1313	4161
p_1k_2	1148	4661
p_1k_3	1237	4531
p_2k_1	1554	3444
p_2k_2	1387	3711
p_2k_3	1510.333	3940
SEm (±)	13	39
CD (0.05)	NS	115.4
K x F		
k_1f_1	1375	3854
k_1f_2	1492	3750
k_2f_1	1250	4366
k_2f_2	1285	4006
k_3f_1	1340	4332
k_3f_2	1408	4139
SEm (±)	13	39
CD (0.05)	38.5	115.4
P x F		
p_1f_1	1206	4589
p_1f_2	1260	4313
p_2f_1	1437	3779
p_2f_2	1530	3618
SEm (±)	10	32
CD (0.05)	31.4	NS
P x K x F		
$p_1k_1f_1$	1286	4200
$p_1k_1f_2$	1341	4122
$p_1k_2f_1$	1126	4927
$p_1k_2f_2$	1170	4395
$p_1k_3f_1$	1206	4641
$p_1k_3f_2$	1268	4421
$p_2k_1f_1$	1465	3509
$p_2k_1f_2$	1642	3379
$p_2k_2f_1$	1374	3805
$p_2k_2f_2$	1400	3617
$p_2k_3f_1$	1474	4023
$p_2k_3f_2$	1547	3857
SEm (±)	18	55
CD (0.05)	54.4	NS
Control (KAU POP)	898	3839
Treatment *vs* Control	S	NS

3.3 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 Abraham et al [46] revealed that haulm yield of black gram was significantly enhanced with combined application of P and K. Similar findings reported by Yadav et al [47]. 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 [48]. Similar observed were made by Wakudkar et al [49].

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.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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