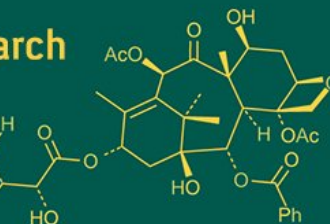
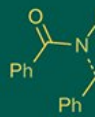


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Foliar application of nano diammonium phosphate enhances physiological performance, seed quality and productivity of field bean

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Abstract

A field experiment was conducted during the late *Kharif* season of 2024 at the College of Agriculture, Navile, Shivamogga, Karnataka, to evaluate foliar application of nano diammonium phosphate (nano DAP) on physiological, biochemical and seed quality attributes of field bean (*Lablab purpureus* (L.) Sweet). The experiment was laid out in a randomized complete block design with ten treatments and three replications comprising 100 and 75% recommended dose of fertilizers integrated with foliar nano DAP at 2 and 4 ml l⁻¹ applied at 30 DAS and/or 60 DAS, together with an absolute control. Foliar nano DAP significantly influenced chlorophyll content, total soluble solids, crude protein, crude fat, ash and crop yield. The treatment comprising 100% recommended dose of fertilizers with nano DAP @ 4 ml l⁻¹ at 30 and 60 DAS recorded the highest chlorophyll reading at 60 DAS (50.97), total soluble solids (8.40 °Brix), crude protein (24.92%) and ash content (5.47%). The same treatment recorded the highest seed yield (1234 kg ha⁻¹) and haulm yield (2035 kg ha⁻¹). Moisture and crude fibre were not significantly affected. The results indicated that repeated foliar application of nano DAP at 4 ml l⁻¹ with 100% recommended fertilizer dose improved physiological performance, selected seed quality traits and productivity of field bean under the conditions of the Southern Transitional Zone of Karnataka.

Keywords: Nano DAP; field bean; chlorophyll; seed quality; protein; productivity

Introduction

Field bean (*Lablab purpureus* (L.) Sweet), commonly known as hyacinth bean or dolichos bean, is one of the versatile legume crops cultivated in tropical and subtropical regions. The crop is valued for protein-rich seed, fodder and its contribution to soil fertility through biological nitrogen fixation. Its seed contains approximately 20–25% crude protein and also supplies carbohydrates, dietary fibre, vitamins and minerals [1]. The physiological performance and biochemical composition of field bean are closely related to nutrient availability. Phosphorus is central to energy transfer through adenosine triphosphate synthesis, photosynthetic efficiency, carbohydrate metabolism and transformation of sugars and starches. However, conventional fertilization can be associated with inefficient nutrient utilization because of fixation and other losses [2, 3]. Nanotechnology has introduced nano-fertilizers such as nano diammonium phosphate (nano DAP), which are intended to provide nutrients in readily available forms. Nano DAP contains nitrogen and phosphorus and its physicochemical properties may facilitate nutrient dispersion and foliar absorption [4]. Foliar application can provide nutrients directly to leaves and may improve nutrient assimilation, chlorophyll formation and crop physiological performance [5]. Chlorophyll measured as SPAD reading is a useful indicator of leaf physiological status. Total soluble solids provide an indication of soluble constituents in plant tissues, while seed protein, fat, fibre, ash and carbohydrate determine important aspects of nutritional quality [6]. The present study was therefore undertaken to evaluate different combinations of recommended fertilizer dose, nano DAP concentration and application frequency for their effects on chlorophyll content, total soluble solids, seed biochemical composition and productivity of field bean under the Southern Transitional Zone of Karnataka.

2. Materials and Methods

2.1 Experimental site and design

the field experiment was conducted during the late *Kharif* season of 2024 at the College of Agriculture, Navile, Shivamogga, and Karnataka. The experimental site lies in the Southern

Transitional Zone (Zone 7) of Karnataka at 13°56' N latitude, 75°34' E longitude and an altitude of 615 m above mean sea level. The region is characterized by a tropical climate. Total rainfall received during the cropping period was 644.2 mm and mean maximum and minimum temperatures were 29.7 °C and 20.5 °C, respectively. The soil of the experimental plot was sandy loam (Typic Haplustalf, *Alfisol*) with 0.45% organic carbon, 230.47 kg ha⁻¹ available nitrogen, 38.20 kg ha⁻¹ available phosphorus and 199.85 kg ha⁻¹ available potassium. Soil pH was 5.23 and electrical conductivity was 0.18 dS m⁻¹. The experiment was laid out in a randomized complete block design with ten treatments and three replications. Each gross plot measured 5.4 m × 2.7 m and the net plot measured 3.6 m × 2.1 m. Field bean variety Hebbal avare 5 (HA-5) was sown at 30 kg ha⁻¹ with spacing of 45 cm × 15 cm. The recommended dose of fertilizer was 25:50:25 kg N: P₂O₅:K₂O ha⁻¹. FYM at 7.5 t ha⁻¹ was applied uniformly except in the absolute control. Nano DAP containing 8% N and 16% P₂O₅ was applied at 2 or 4 ml l⁻¹ either once at 30 DAS or twice at 30 and 60 DAS using 500 l ha⁻¹ spray volume. Conventional fertilizers were applied basally according to treatment.

Table 1: Treatment details used in the field experiment.

Treatment	Treatment combination
T1	Absolute control
T2	100% RDF
T3	100% RDF + foliar spray of nano DAP @ 2 ml l ⁻¹ at 30 DAS
T4	100% RDF + foliar spray of nano DAP @ 4 ml l ⁻¹ at 30 DAS
T5	75% RDF + foliar spray of nano DAP @ 2 ml l ⁻¹ at 30 DAS
T6	75% RDF + foliar spray of nano DAP @ 4 ml l ⁻¹ at 30 DAS
T7	100% RDF + foliar spray of nano DAP @ 2 ml l ⁻¹ at 30 and 60 DAS
T8	100% RDF + foliar spray of nano DAP @ 4 ml l ⁻¹ at 30 and 60 DAS
T9	75% RDF + foliar spray of nano DAP @ 2 ml l ⁻¹ at 30 and 60 DAS
T10	75% RDF + foliar spray of nano DAP @ 4 ml l ⁻¹ at 30 and 60 DAS

RDF = recommended dose of fertilizers; DAS = days after sowing. FYM = farmyard manure.

2.2 Crop management

Field preparation was carried out by tractor ploughing followed by harrowing and levelling. Healthy seeds of field bean were sown manually in lines and thinned to maintain the required spacing. Standard agronomic practices for weed control, irrigation and plant protection were followed uniformly across treatments to ensure normal crop growth.

2.3 Observations and biochemical analysis

Chlorophyll readings were recorded at 30 and 60 DAS using a SPAD chlorophyll meter. Fully expanded trifoliate leaves were selected for measurement. Several readings were taken from leaves on the branch and averaged to provide an estimate of leaf chlorophyll status. Total soluble solids were determined to estimate soluble constituents in field bean seed. Seed extracts were prepared by homogenizing 5 g of seed in distilled water. TSS was measured using a hand refractometer at 25 °C and expressed in °Brix. Seed moisture content was determined using a Contech Moisture Analyzer based on the loss-on-drying method. One gram of finely ground seed was evenly spread on the sample pan.

The analyzer was preset to 105 °C and drying was continued until constant weight was achieved. Seed nitrogen was estimated by the micro-Kjeldahl method. Approximately 0.2 g of finely ground sample was used for analysis. Crude protein was calculated by multiplying nitrogen content by 6.25 and expressed as percentage. Crude fat was determined by Soxhlet extraction using petroleum ether. The dried sample was extracted at 60–80 °C with reflux for 6 h and fat percentage was calculated from the extracted material. Crude fibre was estimated by the acid-alkaline digestion method and expressed as percentage. Ash content was determined by combustion of the sample in a muffle furnace at 600 °C for 8 h. The sample was initially charred over a low flame and then heated in the muffle furnace. After cooling in a desiccator, the residue was weighed and the process was repeated until constant weight was obtained. Carbohydrate content was calculated by difference as: carbohydrate (%) = 100 – [moisture (%) + crude protein (%) + crude fat (%) + crude fibre (%) + ash (%)]. Pods harvested from the net plot were sun dried and threshed. Seed yield was recorded per plot and expressed as kg ha⁻¹. Haulm yield from the net plot was recorded and expressed on an area basis.

2.4 Statistical analysis

Data on physiological, biochemical, seed quality and yield attributes were subjected to analysis of variance following the procedure described by Gomez and Gomez.⁷ Treatment means were compared using the critical difference test at 5% probability. When the F-test was non-significant, critical difference was omitted and denoted as NS.

3. Results

3.1 Chlorophyll content

At 30 DAS, SPAD readings ranged from 29.21 in the absolute control (T₁) to 41.71 in T₄. The treatment differences at this stage were non-significant. At 60 DAS, treatment differences were significant. T₈ recorded the highest SPAD reading (50.97), followed by T₁₀ (50.44), T₇ (49.47) and T₉ (48.77), whereas T₁ recorded the lowest reading (38.02). The results are summarized in Table 2.

3.2 Total soluble solids

Total soluble solids differed significantly among treatments. T₈ recorded the highest TSS (8.40 °Brix), followed by T₇ (8.14 °Brix) and T₁₀ (8.10 °Brix). The lowest value was recorded in T₁ (6.50 °Brix). Complete values are presented in Table 2.

Table 2: Physiological and productivity response of field bean as influenced by nano DAP application

Treatment	SPAD 30 DAS	SPAD 60 DAS	TSS (°Brix)	Seed yield (kg ha ⁻¹)	Haulm yield (kg ha ⁻¹)
T1	29.21	38.02	6.50	459	1012
T2	40.50	42.13	7.01	987	1689
T3	40.81	44.47	7.44	1064	1809
T4	41.71	47.77	7.90	1078	1828
T5	35.38	43.81	7.20	1049	1769
T6	35.32	46.13	7.60	1070	1816
T7	40.66	49.47	8.14	1150	1912
T8	41.06	50.97	8.40	1234	2035
T9	35.84	48.77	7.54	1082	1860
T10	35.39	50.44	8.10	1178	1956
S.Em ±	2.61	1.43	0.23	30.17	52.50
C.D. (P=0.05)	NS	4.18	0.68	88.06	153.24

Values are means of three replications. DAS = days after sowing; TSS = total soluble solids; NS = non-significant.

3.3 Seed nutritional composition

Moisture content did not differ significantly and ranged from 11.10% in T₁ to 10.52% in T₁₀. Crude protein differed significantly, with the highest value in T₈ (24.92%), followed by T₁₀ (24.24%) and T₇ (24.00%), while T₁ recorded 21.11%. Crude fat differed significantly and

ranged from 1.35% in T₈ to 1.98% in T₁. Crude fibre did not differ significantly and ranged from 5.86% in T₈ to 6.55% in T₇. Ash content differed significantly and was highest in T₈ (5.47%) and lowest in T₁ (4.21%). Carbohydrate content was highest in T₁ (55.25%) and lowest in T₈ (51.75%). The complete values are presented in Table 3.

Table 3: Seed nutritional composition of field bean as influenced by nano DAP application

Treatment	Moisture (%)	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Carbohydrate (%)
T1	11.10	21.11	1.98	6.35	4.21	55.25
T2	11.02	22.37	1.80	6.13	4.48	54.20
T3	10.97	23.06	1.69	6.52	4.63	53.13
T4	10.91	23.52	1.59	6.01	4.80	53.17
T5	10.84	22.82	1.60	6.13	4.65	53.96
T6	10.77	23.34	1.52	5.93	4.88	53.56
T7	10.74	24.00	1.48	6.55	5.05	52.18
T8	10.65	24.92	1.35	5.86	5.47	51.75
T9	10.58	23.91	1.43	6.24	4.98	52.86
T10	10.52	24.24	1.38	6.06	5.17	52.63
S.Em ±	0.35	0.64	0.05	0.16	0.14	0.59
C.D. (P=0.05)	NS	1.87	0.15	NS	0.42	1.72

Values are means of three replications. NS = non-significant.

3.4 Seed and haulm yield

Seed and haulm yields were significantly influenced by the treatments. T₈ recorded the highest seed yield (1234 kg ha⁻¹), followed by T₁₀ (1178 kg ha⁻¹) and T₇ (1150 kg ha⁻¹).

The lowest seed yield was recorded in T₁ (459 kg ha⁻¹). Haulm yield was also highest in T₈ (2035 kg ha⁻¹) and lowest in T₁ (1012 kg ha⁻¹). The results are presented in Table 2 and Fig. 1.

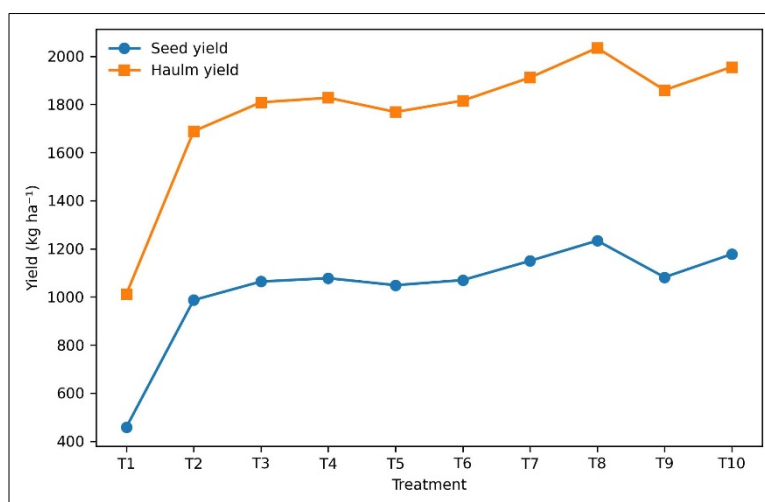


Fig 1: Seed and haulm yield of field bean under different nano DAP treatments

Table 4: Derived nutritional and productivity indices calculated from reported observations

Treatment	Protein yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)	Seed:haulm ratio
T1	96.89	1471	0.454
T2	220.79	2676	0.584
T3	245.36	2873	0.588
T4	253.55	2906	0.590
T5	239.38	2818	0.593
T6	249.74	2886	0.589
T7	276.00	3062	0.601
T8	307.51	3269	0.606
T9	258.71	2942	0.582
T10	285.55	3134	0.602

Protein yield = seed yield × protein concentration / 100. Biological yield = seed yield + haulm yield. Seed:haulm ratio = seed yield / haulm yield. These variables were not independently measured.

4. Discussion

The treatment response showed that foliar nano DAP was associated with improved physiological performance during the later crop stage. Although differences in SPAD reading

at 30 DAS were non-significant, significant treatment differences emerged at 60 DAS and the highest reading was recorded with two applications of nano DAP at 4 ml l⁻¹ combined with 100% RDF. The response is consistent with

the role of nitrogen and phosphorus in chlorophyll formation, energy transfer and nitrogen metabolism [5, 6].

The increase in TSS under nano DAP treatments indicates greater accumulation of soluble constituents in the seed. T₈ recorded the highest TSS and the response was accompanied by higher protein concentration and seed yield. Foliar nutrient supply can provide nutrients during active crop growth and may support nutrient assimilation and movement of assimilates towards reproductive sinks [8].

The biochemical response was selective rather than uniform. Moisture and crude fibre were not significantly affected, whereas protein, fat and ash showed significant treatment responses. T₈ recorded the highest protein and ash concentrations and the lowest crude fat. The higher protein concentration may be associated with improved nitrogen assimilation under combined basal fertilizer and foliar nutrient supply. Similar responses to nano-fertilizer application have been reported in legumes [9, 12].

Carbohydrate concentration showed the opposite pattern to protein concentration, with the highest value in the absolute control and the lowest value in T₈. Because carbohydrate was calculated by difference, changes in protein, fat, fibre,

ash and moisture contribute to the observed carbohydrate values. Therefore, the carbohydrate response should be interpreted as a change in relative seed composition rather than direct evidence of reduced carbohydrate synthesis.

The yield response was consistent with the physiological and biochemical response. T₈ recorded the highest seed and haulm yields. The improvement in yield under nano DAP treatments may be associated with improved nutrient availability, physiological performance and reproductive development. Similar yield responses to nano-fertilizer application have been reported in pulse and soybean crops [13, 16]. The derived nutritional-productivity indices provide an additional interpretation of the results. T₈ produced 307.51 kg protein ha⁻¹ compared with 220.79 kg ha⁻¹ under T₂, representing a 39.28% higher protein harvest per hectare (Fig. 2). This difference is important because nutritional output per unit area depends on both seed yield and protein concentration rather than protein percentage alone. The calculated biological yield and seed:haulm ratio further describe the partitioning of harvested biomass, although these indices should be regarded as derived measures.

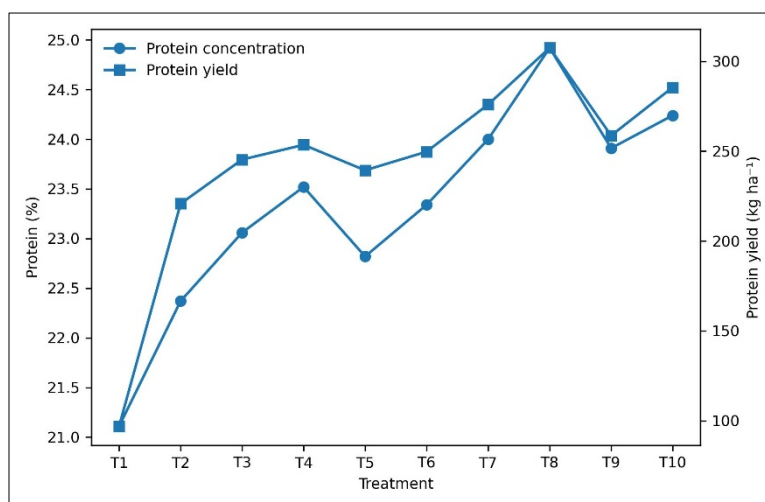


Fig 2: Protein concentration and derived protein yield of field bean under different nano DAP treatments.

The overall treatment pattern indicated that the combination of 100% RDF with nano DAP @ 4 ml l⁻¹ applied twice at 30 and 60 DAS provided the most consistent response across the principal variables evaluated. T₈ ranked highest for

SPAD at 60 DAS, TSS, protein concentration, ash concentration, seed yield and haulm yield. The integrated response is visualized in Fig. 3 using standardized treatment means.

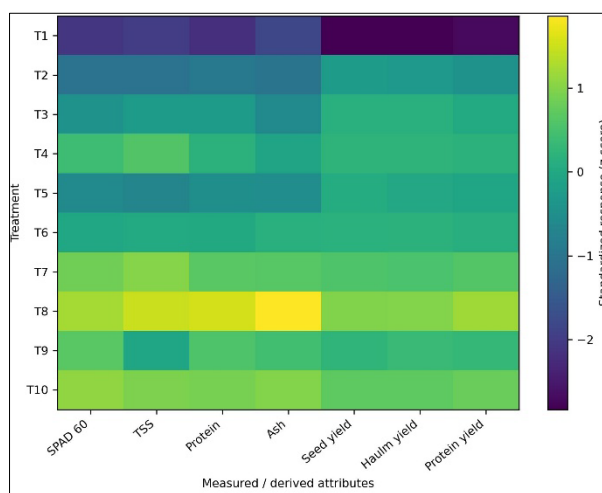


Fig 3: Integrated standardized response of selected physiological, quality and productivity attributes across treatments. The heatmap is based on the reported treatment means; z-scores are used only for visual comparison.

The treatment structure also shows a response to application frequency. Treatments receiving nano DAP at both 30 and 60 DAS generally performed better for the major response variables than corresponding single-application treatments. However, the experiment was designed as a set of ten

treatments rather than a formal factorial analysis and therefore the present interpretation is restricted to treatment comparisons rather than unreported interaction effects. Fig. 4 additionally shows the relative response of selected traits to the 100% RDF.

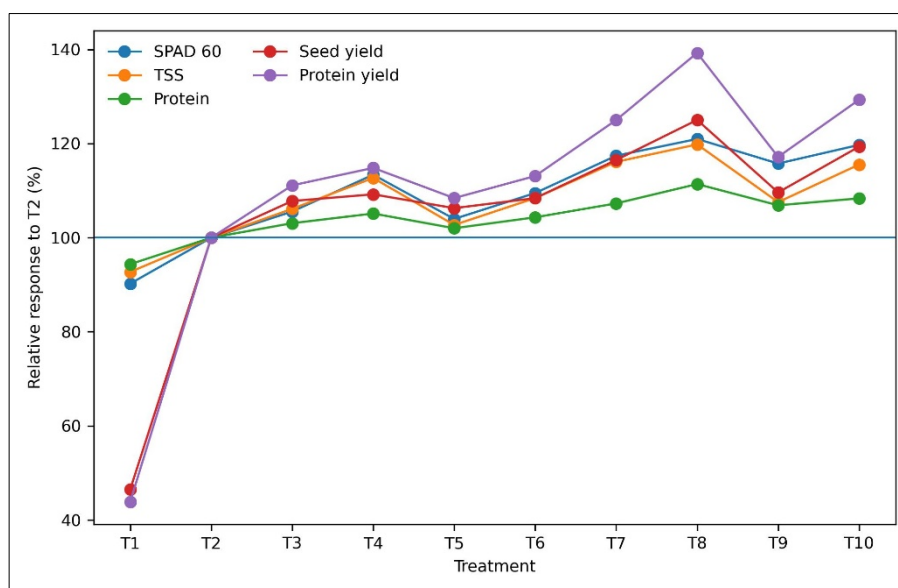


Fig 4: Relative response of selected traits to the 100% RDF treatment (T2 = 100%)

5. Conclusion

Under the conditions of the Southern Transitional Zone of Karnataka, foliar application of nano DAP influenced physiological performance, selected seed biochemical traits and productivity of field bean. The treatment comprising 100% RDF with nano DAP @ 4 ml l⁻¹ at 30 and 60 DAS (T₈) recorded the highest SPAD reading at 60 DAS, TSS, crude protein, ash, seed yield and haulm yield. The derived protein yield was also highest under T₈. The results indicate that repeated foliar nano DAP application in combination with the recommended fertilizer dose provided the most consistent performance among the treatments evaluated.

6. Acknowledgments

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7. Conflict of interest

The authors declare no conflict of interest related to this study.

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