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# Nutrient management for enhancing growth and forage productivity of fodder cowpea (*Vigna unguiculata* L.)

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**Abstract**
A field experiment was conducted during *rabi*, 2024-25 at the dryland farm of S.V. Agricultural College, Tirupati, to study the nutrient management for enhancing growth and forage productivity of fodder cowpea (*Vigna unguiculata* L.). The treatments consisted of four phosphorus levels (0, 20, 40 and 60 kg $P_2O_5$ ha$^{-1}$) and three zinc levels (0, 25 and 50 kg $ZnSO_4$ ha$^{-1}$), arranged in a factorial randomized block design. Results revealed that phosphorus and zinc application significantly improved growth attributes such as plant height, number of branches, leaf area index and dry matter accumulation, which in turn enhanced green fodder yield. The highest growth and yield were obtained with 60 kg $P_2O_5$ ha$^{-1}$ combined with 25 kg $ZnSO_4$ ha$^{-1}$ which also proved more economical compared to other treatments. Thus, balanced application of phosphorus and zinc is essential for improving growth, productivity and profitability of fodder cowpea under dryland conditions.

**Keywords:** Factorial randomized block design, forage, fodder, productivity and profitability

## Introduction

Fodder cowpea (*Vigna unguiculata* L.) is a widely cultivated, drought-tolerant leguminous forage crop known for its rapid growth, high green biomass production and rich protein content. It plays a crucial role in supporting livestock nutrition, particularly in arid and semi-arid regions, due to its adaptability to dryland farming systems and its ability to fix atmospheric nitrogen, thereby improving soil health.

Among the essential nutrients required for optimal fodder cowpea growth, phosphorus (P) and zinc (Zn) stand out due to their key physiological roles. Phosphorus is vital for energy metabolism (ATP formation), root proliferation, nodulation and early plant vigor, all of which directly influence forage yield. On the other hand, zinc, though required in smaller quantities, is indispensable for the activation of various enzymes, synthesis of auxins (plant hormones), regulation of photosynthesis and enhancement of plant stress resistance mechanisms.

## Materials and Methods

A field experiment was conducted during *rabi*, 2024-25 at dryland farm of S.V. Agricultural College, Tirupati. The experimental soil was sandy loam in texture, neutral in soil reaction (pH 7.0), low in organic carbon (0.4 per cent) and available nitrogen (230 kg ha$^{-1}$), medium in available phosphorus (22.7 kg ha$^{-1}$), available potassium (235 kg ha$^{-1}$) and available zinc (3.0 kg ha$^{-1}$). The experiment was laid out in randomized block design with factorial concept with four levels of factor-I and three levels of factor-II and replicated thrice. The treatments comprise of four phosphors levels *viz.*, 0 kg $P_2O_5$ ha$^{-1}$ ($P_0$), 20 kg $P_2O_5$ ha$^{-1}$ ($P_1$), 40 kg $P_2O_5$ ha$^{-1}$ ($P_2$) and 60 kg $P_2O_5$ ha$^{-1}$ ($P_3$) were allotted to Factor-I and three zinc levels *viz.*, 0 kg $ZnSO_4$ ha$^{-1}$ ($Z_0$), 25 kg $ZnSO_4$ ha$^{-1}$ ($Z_1$) and 50 kg $ZnSO_4$ ha$^{-1}$ ($Z_2$) were allotted to Factor-II. The test variety of fodder cowpea used in the present experiment was MFC-09, released from Mandya Research Station, Karnataka. The recommended basal dose of 25 kg N ha$^{-1}$ and 20 kg $K_2O$ ha$^{-1}$ was applied uniformly as common dose to all the treatments and $P_2O_5$ was applied as per the treatments. Fertilizer nitrogen was applied in two equal splits *i.e.*, 50% as basal and 50% at 30 DAS. Entire dose of phosphorus and potassium were applied as basal at the time of sowing. Soil application of zinc sulphate at 20 kg ha$^{-1}$ was done at 10 DAS as per the treatments. The crop was harvested for green fodder purpose by cutting the plants close to the ground at 50 per cent flowering stage.

### Statistical Analysis

The data recorded on various growth and yield parameters during the course of investigation were statistically analysed following the analysis of variance procedure suggested by Panse and Sukhatme (1985) [20]. Statistical significance was tested by 'F' value at 5 per cent level of probability and wherever the 'F' value was found significant, critical difference (CD) was worked out at 5 per cent level of probability and the values were furnished. The treatment differences which were non-significant were denoted by "NS".

## Results and Discussion

### Growth Parameters

The biometric observations with regard to plant height, number of branches plant$^{-1}$, number of leavesplant$^{-1}$, leaf area, dry matter production, leaf to stem ratio were recorded at periodic intervals *viz*., 15, 30, 45 DAS and at harvest. All the growth parameters were significantly influenced by phosphorus and zinc application (Table 1).

### Plant height

With regard to phosphorus levels tried, the higher plant height of fodder cowpea plants was observed with the application of 60 kg $P_2O_5$ ha$^{-1}$ ($P_3$) which was followed by 40 kg $P_2O_5$ ha$^{-1}$ ($P_2$) and 20 kg $P_2O_5$ ha$^{-1}$ ($P_1$). The shorter plants were recorded with control ($P_0$). At all stages of crop growth (15, 30, 45 DAS and at harvest), application of 60 kg $P_2O_5$ ha$^{-1}$ consistently resulted in significantly taller plants compared to the lower phosphorus levels. The progressive increase in plant height with higher phosphorus doses can be attributed to its vital role in promoting active cell division and elongation, particularly in the shoot and root meristematic regions where metabolic activity is high. Phosphorus is essential for the synthesis of nucleic acids, ATP and phospholipids, which support vigorous vegetative growth and elongation. These physiological functions collectively contribute to enhanced plant stature. Similar observations were reported by Meena and Chand (2014) [12] and Neeraj *et al*. (2022) [18], who also documented a positive response in plant height with increased phosphorus application in cowpea and other leguminous crops.

Application of 50 kg $ZnSO_4$ ha$^{-1}$ ($Z_2$) recorded significantly taller plants followed by application of 25 kg $ZnSO_4$ ($Z_1$) which was in partity with $ZnSO_4$ 50 kg ha$^{-1}$ ($Z_2$). The smaller plant has recorded in control ($Z_0$). At all the stages of crop growth, taller plants were recorded with the application of higher $ZnSO_4$ level of 50 kg ha$^{-1}$ relative to the lower doses. Zinc plays a vital role in the synthesis of tryptophan, metabolism of tryptamine, protein formation and nucleic acid production. It also enhances the absorption and efficient utilization of nitrogen and phosphorus in plants (Ram and Katiyar, 2013) [22]. Additionally, zinc promotes nodulation and nitrogen fixation in leguminous crops (Demeterio *et al*., 1972) [6]. Maximum plant height associated with $ZnSO_4$50 kg ($Z_2$) may be attributed to the role of these nutrients in a variety of physiological and biochemical processes that contribute to the growth of the meristematic region (Cakmak *et al*., 1989) [4]. Similar findings were observed with Meena and Chand (2014) [12] and Mohammad (2019) [15].

### Number of branches plant$^{-1}$

Significantly higher number of branches plant$^{-1}$ of fodder cowpea was noticed with application of 60 kg $P_2O_5$ ha$^{-1}$ ($P_3$). The next best treatment was 40 kg $P_2O_5$ ha$^{-1}$($P_2$) which was followed by application of 20 kg $P_2O_5$ ha$^{-1}$ ($P_1$), however significantly lower number of branches were noticed in control ($P_0$). Application of 60 kg $P_2O_5$ ha$^{-1}$ resulted in significantly higher number of branches plant$^{-1}$ compared with that of lower doses of phosphorus tested. The probable reason might be due to the fact that increase in phosphorus levels resulted in greater accumulation of carbohydrates, proteins and their translocation to the different parts of the plant which inturn promoted high number of branches. These results were in conformity with the findings of Neeraj *et al*. (2022) [18] and Nadeem *et al*. (2017) [16].

Significantly maximum number of branches plant$^{-1}$ were observed by application of 50 kg $ZnSO_4$ ha$^{-1}$ ($Z_2$). The next best treatment was 25 kg ha$^{-1}$ ($Z_1$) and it was on par with ($Z_2$). Minimum number of branches plant$^{-1}$ were recorded with control. Maximum number of branches plant$^{-1}$ in fodder cowpea was observed with the application of 50 kg $ZnSO_4$ ha$^{-1}$ ($Z_2$). This could be due to the beneficial role of zinc in enhancing metabolic activities and promoting the synthesis of photosynthetic pigments and enzymes, which in turn support increased branching (Michail *et al*., 2004) [13]. Application of zinc enhances branching in pulses which can be mainly attributed to promotion of bud and branch development by the auxin whereas, Zn application ultimately increased the availability of other nutrients and accelerated the translocation of photo assimilates. The results were found to be similar with Mohammad (2019) [15] and Debnath *et al*. (2018) [5].

### Number of leaves plant$^{-1}$

The higher number of leaves plant$^{-1}$ were recorded with application of 60 kg $P_2O_5$ ha$^{-1}$ ($P_3$) which was followed by application of 40 kg $P_2O_5$ ha$^{-1}$ ($P_2$) and significantly superior to 20 kg $P_2O_5$ ha$^{-1}$ ($P_1$). The number of leaves plant$^{-1}$ was lower with 0 kg $P_2O_5$ ha$^{-1}$ ($P_0$). Application of phosphorus 60 kg $P_2O_5$ ha$^{-1}$ significantly increased the number of leaves plant$^{-1}$. This might be due to availability and efficient utilization of nutrients through extensive and deep root system developed by virtue of rapid cell division, cell elongation in meristematic region of the plant which have increased the growth behaviour during the vegetative phase of the crop and reflected on number of leaves plant$^{-1}$. Similar findings were reported by Magani and Kuchinda (2009) [9].

Application of 50 kg $ZnSO_4$ ha$^{-1}$ ($Z_2$) resulted in significantly higher number of leaves plant$^{-1}$, but was on par with 25 kg $ZnSO_4$ ha$^{-1}$($Z_1$). The lower number of leaves plant$^{-1}$ was significantly recorded with control ($Z_0$). Zinc is an essential cofactor for a number of enzymes involved in hormone control and protein synthesis, including auxin metabolism, which affects cell differentiation and elongation. Carbonic anhydrase, an enzyme essential to photosynthetic $CO_2$ fixation is one of the major enzymes. Zinc increases photosynthetic efficiency and chlorophyll synthesis, which produces more energy and metabolites needed for the growth of new leaves. These results were consistent with previous findings by Manisha (2021) [10] in cowpea and Pandey *et al*. (2019) [19] in cluster bean.

### Leaf to stem ratio

Increasing the level of phosphorus, with the application of 60 kg $P_2O_5$ ha$^{-1}$ ($P_3$) has resulted significantly higher leaf to stem ratio when compared to control, which is followed by application of 40 kg $P_2O_5$ ha$^{-1}$ and 20 kg $P_2O_5$ ha$^{-1}$. The lower leaf to stem ratio was recorded under control (0 kg $P_2O_5$ ha$^{-1}$). Application of 60 kg $P_2O_5$ $ha^{-1}$ ($P_3$) resulted in the highest leaf to stem ratio in fodder cowpea. This enhancement can be attributed to the key role of phosphorus in promoting photosynthesis, which improves the photosynthetic efficiency of leaves and increases the production of assimilates. As a result, plant height, leaf area, dry matter accumulation and overall plant succulence are improved, ultimately leading to a higher leaf to stem ratio. These findings are supported by the observations of Kundu *et al*. (2015) [8] and Nanda *et al*. (2023) [17].

Application of 50 kg $ZnSO_4$ $ha^{-1}$ ($Z_2$) recorded significantly higher leaf to stem ratio compared to 25 kg $ZnSO_4$ $ha^{-1}$ however they were statically similar. Minimum leaf to stem ratio was recorded with control ($Z_0$). Zinc application, particularly at 50 kg $ZnSO_4$ $ha^{-1}$ ($Z_2$), significantly improved the leaf-to-stem ratio of fodder cowpea. The increase in leaf to stem may be due to the involvement of zinc as a precursor of tryptophan, which led to auxin metabolism, higher hormonal growth and metabolic activity. Improved nutrient uptake and metabolic activity also contributed to increased leaf biomass relative to stem growth, resulting in better forage quality. These findings align with earlier research highlighting the positive impact of zinc on vegetative growth and biomass distribution in fodder crops and in turn leaf to stem ratio. The results are in confirmity with Pandey *et al*. (2019) [19] and Ramakrishna *et al*. (2022) [23].

**Leaf area index**

The higher leaf area index was recorded with application of 60 kg $P_2O_5$ $ha^{-1}$($P_3$) was significantly higher than 40 kg $P_2O_5$ $ha^{-1}$($P_2$), which was followed by 20 kg $P_2O_5$ $ha^{-1}$($P_1$). Significantly lower leaf area index has recorded under control. At all growth stages of fodder cowpea, leaf area index was higher with the application of phosphorus 60 kg $P_2O_5$ $ha^{-1}$, can be attributed to enhanced leaf expansion resulting from efficient nutrient utilization. Phosphorus is essential for energy transfer (ATP), nucleic acid synthesis and cell division, all of which promote rapid cell elongation and expansion in leaves. The adequate supply of phosphorus during the vegetative phase ensured uninterrupted metabolic activity, leading to better leaf growth and canopy development. Similar results were reported by the findings of Amruth *et al*. (2017) [1] and Mobeena *et al*. (2020) [14].

Maximum leaf area index was registered with application of 50 kg $ZnSO_4$ $ha^{-1}$ ($Z_2$), which was significantly superior over the application of 25 kg $ZnSO_4$ $ha^{-1}$ ($Z_1$). While, lower leaf area index was recorded with control ($Z_0$). The increase in leaf area index with the application of 50 kg $ZnSO_4$ $ha^{-1}$ ($Z_2$) could be due to its key role in the production of IAA and acts as a cofactor for important enzymes like carbonic anhydrase and alcohol dehydrogenase, which support chlorophyll formation, photosynthesis and overall plant metabolism. In addition, zinc increases tryptophan and IAA levels, both of which promote leaf growth and expansion (Seifinadergholi *et al*., 2011) [24]. Similar results were reported by Mohammad (2019) [15] and Arvind *et al*. (2020) [2].

**Dry matter production**

With regard to phosphorus levels, higher dry matter accumulation was observed with the crop receiving higher dose of phosphorus *i.e.*, 60 kg $P_2O_5$ $ha^{-1}$ ($P_3$) which was significantly higher with 40 kg $P_2O_5$ $ha^{-1}$($P_2$). The next best treatment was 20 kg $P_2O_5$ $ha^{-1}$ ($P_1$). Significantly lower dry matter production was recorded with control ($P_0$). At all the stages of observation dry matter production was maximum with the application of 60 kg $P_2O_5$ $ha^{-1}$. This might be due to improvement in growth parameters like plant height, leaf area index, number of leaves $plant^{-1}$, number of branches $plant^{-1}$ and better nodulation of crop owing to better availability of phosphorus. The improvement in nodulation might have resulted in higher amount of nitrogen fixation and there by better vegetative growth and dry matter production. Enhanced dry matter production with increased phosphorus level was also reported by Umesha and Purushotham (1996) [26] and Bhagat *et al*. (2018) [3].

Significantly higher dry matter production was recorded with the application of 50 kg $ZnSO_4$ $ha^{-1}$($Z_2$) and it was on par with 25 kg $ZnSO_4$ $ha^{-1}$($Z_1$). Significantly lower dry matter production was recorded with control ($Z_0$). Higher dry matter production associated with application of 50 kg $ZnSO_4$ $ha^{-1}$ might be due to the fact that zinc is an essential component of several enzymes and plays an important role in nitrogen metabolism and higher uptake of nitrogen in plants, resulting in increased aminoacid and protein synthesis. It is directly involved in biosynthesis of growth substances such as auxin thereby producing more plant cells and enhanced dry matter. Similar results were also reported by Puniya *et al*. (2013) [21] and Teja *et al*. (2018) [25].

**Yield**

Green and dry fodder yields of cowpea was significantly influenced by different levels of phosphorus and zinc. The application of phosphorus significantly influenced the green and dry fodder yield. Higher green (14991 kg $ha^{-1}$) and dry fodder (6291 kg $ha^{-1}$) yields were observed with the application of 60 kg $P_2O_5$ $ha^{-1}$ ($P_3$), which was followed by 40 kg $P_2O_5$ $ha^{-1}$ ($P_2$) and it was on par with 20 kg $P_2O_5$ $ha^{-1}$ ($P_1$). Lower green (10728 kg $ha^{-1}$) and dry fodder (3155 kg $ha^{-1}$) yields were observed in control ($P_0$) (Table 2 and Fig 1). The improvement in green and dry fodder yields with increasing levels of phosphorus can be attributed to enhanced nutrient availability and better root development, leading to improved uptake and utilization of nutrients. Phosphorus plays a crucial role in root growth, energy transfer and overall plant vigour, which likely contributed to increased plant height, leaf area, number of leaves $plant^{-1}$ and number of branches $plant^{-1}$. These findings were in accordance with the results reported by Kumawat and khinchi (2017) [7], Mobeena *et al*. (2020) [14] and Nanda *et al*. (2023) [17].

Application of 50 kg $ZnSO_4$ $ha^{-1}$ ($Z_2$) significantly increased the green (14448 kg $ha^{-1}$) and dry fodder (5304 kg $ha^{-1}$) yields of cowpea compared to control ($Z_0$) and green and dry fodder yields were recorded at 25 kg $ZnSO_4$ $ha^{-1}$ which was statistically on par with 50 kg $ZnSO_4$ $ha^{-1}$ ($Z_2$). Significantly lower green (11143 kg $ha^{-1}$) and dry fodder (4066 kg $ha^{-1}$) yields were recorded in control ($Z_0$) (Table 2 and Fig 1). This enhancement in green and dry fodder yields with application of zinc can be attributed to several physiological and biochemical roles of zinc in plant growth and development.

**Table 1:** Effect of graded levels of phosphorus and zinc on growth parameters of fodder cowpea

| Treatments | Plant height (cm) | | Number of branches plant$^{-1}$ | | Number of leaves plant$^{-1}$ | | Leaf to stem ratio | | Leaf area index | | Dry matter production (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | At harvest | 30 DAS | At harvest | 30 DAS | At harvest | 30 DAS | At harvest | 30 DAS | At harvest | 30 DAS | At harvest |
| **Phosphorus levels** | | | | | | | | | | | | |
| $P_0$ - 0 kg ha$^{-1}$ | 31.9 | 72 | 4.4 | 8.0 | 20.8 | 30.1 | 0.87 | 0.50 | 1.33 | 3.14 | 1574 | 3101 |
| $P_1$ - 20 kg ha$^{-1}$ | 34.6 | 78 | 5.3 | 8.9 | 22.5 | 34.3 | 1.01 | 0.56 | 1.49 | 3.49 | 1900 | 4140 |
| $P_2$ - 40 kg ha$^{-1}$ | 37.0 | 85 | 5.9 | 9.8 | 24.6 | 38.4 | 1.13 | 0.60 | 1.61 | 3.70 | 2187 | 4741 |
| $P_3$ - 60 kg ha$^{-1}$ | 39.7 | 92 | 6.5 | 10.6 | 26.7 | 42.6 | 1.27 | 0.67 | 1.78 | 4.06 | 2439 | 5428 |
| S.Em± | 0.82 | 1.7 | 0.18 | 0.23 | 0.67 | 1.15 | 0.043 | 0.017 | 0.038 | 0.085 | 71 | 117 |
| CD (P=0.05) | 2.4 | 5 | 0.5 | 0.7 | 2.0 | 3.4 | 0.12 | 0.05 | 0.11 | 0.25 | 210 | 346 |
| **Zinc levels** | | | | | | | | | | | | |
| $Z_0$ - 0 kg ha$^{-1}$ | 34.1 | 77 | 5.1 | 8.8 | 21.4 | 33.9 | 0.96 | 0.54 | 1.46 | 3.26 | 1799 | 3762 |
| $Z_1$ - 25 kg ha$^{-1}$ | 36.7 | 87 | 5.6 | 9.8 | 24.5 | 36.3 | 1.11 | 0.60 | 1.58 | 3.68 | 2066 | 4533 |
| $Z_2$ - 50 kg ha$^{-1}$ | 38.2 | 85 | 6.0 | 10.1 | 25.5 | 38.8 | 1.17 | 0.61 | 1.62 | 3.83 | 2209 | 4761 |
| S.Em± | 0.71 | 1.5 | 0.15 | 0.19 | 0.58 | 0.99 | 0.039 | 0.015 | 0.038 | 0.073 | 62 | 102 |
| CD (P=0.05) | 2.1 | 4 | 0.4 | 0.6 | 1.8 | 2.9 | 0.11 | 0.04 | 0.11 | 0.22 | 181 | 299 |

Zinc function as a cofactor for enzymes and proteins involved in essential processes such as cell division, nucleic acid metabolism and protein synthesis (Marschner, 1986) [11]. It also plays a critical role in carbohydrate metabolism and is essential for the biosynthesis of tryptophan, a precursor to the plant hormone indole-3-acetic acid (IAA), which regulates plant growth and development. Positive responses of cowpea yield to zinc application have also been reported by Pandey *et al.* (2019) [19], Arvind (2020) [2] and Manisha (2021) [10].

**Table 2:** Effect of graded levels of phosphorus and zinc on yield (kg ha$^{-1}$) of fodder cowpea

| Treatments | Green fodder yield | Dry fodder yield |
|---|---|---|
| **Phosphorus levels** | | |
| $P_0$ - 0 kg ha$^{-1}$ | 10728 | 3155 |
| $P_1$ - 20 kg ha$^{-1}$ | 13033 | 4707 |
| $P_2$ - 40 kg ha$^{-1}$ | 13681 | 5179 |
| $P_3$ - 60 kg ha$^{-1}$ | 14991 | 6291 |
| S.Em± | 316 | 151 |
| CD (P=0.05) | 932 | 447 |
| **Zinc levels** | | |
| $Z_0$ - 0 kg ha$^{-1}$ | 11143 | 4066 |
| $Z_1$ - 25 kg ha$^{-1}$ | 13734 | 5129 |
| $Z_2$ - 50 kg ha$^{-1}$ | 14448 | 5304 |
| S.Em± | 273 | 131 |
| CD (P=0.05) | 807 | 387 |

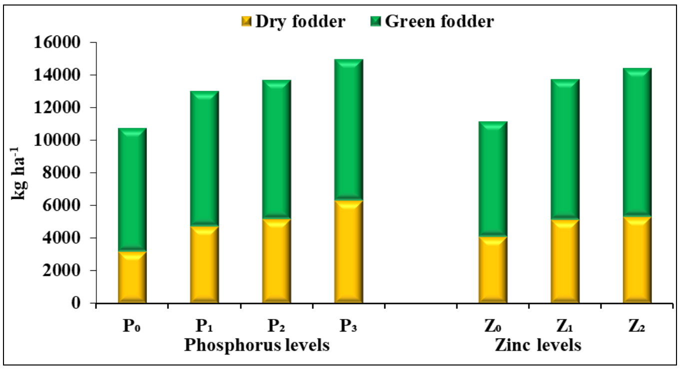


**Fig 1:** Yield (kg ha$^{-1}$) of fodder cowpea as influenced by phosphorus and zinc levels.

## Conclusion

From the present study, it can be concluded that application of 60 kg $P_2O_5$ ha$^{-1}$ along with 25 kg $ZnSO_4$ ha$^{-1}$ resulted in higher growth and yield of fodder cowpea during *rabi* on sandy loam soils of southern Agro-Climatic Zone of Andhra Pradesh.

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