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# Effect of Nano fertilizer on growth, yield attributes and yield of Cowpea (*Vigna unguiculata* L.)

**Yuvraj Singh Choudhary [*], Harish Kumar Bijarnia[1], Chayan Singh Saini[*], Mukesh Kumar Jat[2], Vaishali Chaturvedi[1], Sushila Choudhary[2], Manisha Katariya[*], Savita Choudhary[*]**

[*] Research Scholar, Department of Agronomy, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan-302017
[1]Assistant Professor, Department of Agronomy, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan-302017
[1]Assistant Professor, Department of Plant Pathology, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan-302017

Corresponding author: Yuvraj Singh Choudhary E-mail ID: choudharyuvraj132@gmail.com

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**Abstract:** A field experiment was conducted during *kharif* season of 2023 at Research Farm, School of Agriculture, Suresh Gyan Vihar University Jaipur, to study the **"Effect of Nano fertilizer on Productivity and Profitability of Cowpea (*Vigna unguiculata* L.)"**. The experiment was laid out in randomized block design with three replications. The experiment was consisting eight treatments *viz*., Control, 50, 75, 100% RDN, 75% RDN + one foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering initiation, 50% RDN + one foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering initiation, 75% RDN + two foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation and 50% RDN + two foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation. The cowpea variety used for study was CPD-119. The experimental results showed that application of 75% RDN + two foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation produced significantly higher plant height and dry matter accumulation at 50 DAS and at harvest, number of branches plant$^{-1}$ at harvest, number of total and effective nodules plant$^{-1}$ at 40 DAS, number of pods plant$^{-1}$, number of seeds pod$^{-1}$, seed yield, straw yield and biological yield over rest of treatments but it was remained at par with application of 50% RDN + two foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation. However, application of 100% RDN significantly increased plant height at 30 DAS over control and application of 50% RDF, remained at par with rest of treatments. Application of 75% RDN + two foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation recorded significantly higher dry matter accumulation at 30 DAS and test weight of cowpea seed as compared to control and application of 50% RDF, remained at par with rest of treatments

## Introduction

Pulses popularly known as "poor man's meat", constitute the major source of dietary protein of the large section of vegetarian population of the world. On an average, pulses contain 20 to 30 per cent protein. Infect, there has been stagnation in the production and productivity of pulses over the past two decades. There has been a diversion of acreage from pulses to cereals as a result of "Green

Revolution" brought by the high yielding varieties of cereals. This is mainly due to the low yield potential of pulses and their instability. The important pulse crops grown in India are chickpea, pigeonpea, greengram, blackgram, cowpea, lentil and pea. In India, total pulses grown on an area of 29.36 lakh ha with 23.02 million tons of production (Anonymous, 2019-20).

Among the pulses, cowpea (*Vigna unguiculata* L.) belongs to the family *Fabaceae* (*leguminosae*). It is an important multipurpose grain legume extensively cultivated in arid and semiarid tropics as catch crop, mulch crop, intercrop, mixed crop and green manure crop. The cowpea cultivation is gaining popularity among growers due to its short duration, quick growing nature, soil enriching habit, higher productivity and profitability thus, gradually replacing the other traditional summer legume crops. Cowpea has been intercropped for long time with various other crops such as maize, sorghum and millets. It is good source of protein (20-25 %) and can be utilized in various ways ranging from the use of young green seedling as vegetables and also forage for livestock and the green pods are used as vegetables for human consumption. Cowpea also contributes to the improvement of soil fertility by fixation of the nitrogen in the soil (60-70 kg N per ha) in association with symbiotic bacteria under the favorable condition for N fixation, it need a starter dose of nitrogen for early growth and establishment (Russell, 1961). In Rajasthan, the area under cowpea is 0.50 lakh ha with the annual production of 0.33 lakh tonnes and an average productivity of 653 kg $ha^{-1}$ (Anonymous, 2020).

Fertilizers have a significant role in today's crop production and productivity. Many factors including genotype, ambient conditions, soil fertility and cultural practices, influence seed yield and its components (Golzarfar *et al.*, 2012). The residualminerals may seep to deeper layer causing irreversible damage to the soil structure, mineral cycles, soil microbial flora and plants (Solanki *et al.*, 2015). Plants require phosphorus as a macronutrient. As a result of activating the symbiotic bacteria, it is engaged in numerous processes for plant growth including cell division, the development of a healthy root system, chlorophyll production, pod setting, seedcreation, protein synthesis and increased N-fixation by root nodules. Phosphorus is alsoimportant in nearly every plant process that involves energy transfer. As a result of thephosphorus deficiency, the rate of leaf expansion and photosynthesis decreased, resulting a reduction in yield (Kumar *et al.*, 2016).

Microelements are essential for crop development and quality. They playimportant role in plant growth and metabolic processes related with photosynthesis, chlorophyll formation, cell wall development and respiration, water absorption, xylempermeability, disease resistance and enzyme activities. They are also involved in the synthesis of primary and secondary metabolites, nitrogen fixation and reduction (Adhikary *et al.*, 2010). Micronutrients are required in extremely minute amounts for plant growth and development and their absence can disrupt the plant physiological and metabolic pathway (Nadi *et al.*, 2013). Using micronutrient fertilizers in combination with conventional chemical fertilizers may not be effective in terms of crop growth and productivity. Zinc is the second most common transition metal and is necessary for membrane integrity and phytochrome action (Prasad *et al.*, 2012). Enzyme activation and regulation, protein building, photosynthesis, glucose assimilation, fertility and seed generation are only some of the roles it performs in plants.

The use of traditional fertilizers, whether chemical or organic can cause a number of issues, including soil and ground water pollution, micronutrient deficiencies and soil deterioration, all of which can lead to a deterioration in quality (Meena, 2017). As a result, each form of fertilizer has a favorable or unfavorable effect on crop development and soil fertility. Excess use of pesticides and chemical fertilizers has been one of the most important challenges for food and health security in most regions of the world in the recent decade of environmental pollution, especially water and soil. Nanotechnology has promise in overcoming all of these limitations and nano-fertilizers can help ensure long-term soil health and agricultural output. Nano fertilizer, as a novel technology are a potential replacement for traditional chemical fertilizer in agricultural practice, can reduce soil and water pollution by releasing nutrients gradually and controllably into the soil and then onto the plant (Naderi and Abedi, 2012; Sekhon, 2014).

Nano-fertilizers are called smart delivery systems because of their large surface area, sorption capacity and controlled-release kinetics to specified areas. Nanotechnology in agricultural systems can boost crop growth while saving energy, resulting in better and more cost-effective food production (Rameshaiah *et al.*, 2015). Nano-fertilizers require less spraying and are less expensive than chemical fertilizers. Nanoparticle entrance via cell walls is determined by the cell wall's pore diameter 5 to 20 nm (Fleischer *et al.*, 1999). As a result, nanoparticle aggregates with a diameter smaller than the plant cell wall pore size can easily pass through the cell wall and reach the plasma membrane. When reduced to the nanoscale, these nutrient exhibit properties that differ from their macroscale counterparts, allowing for novel applications (Naderi and Shahraki, 2013). When fertilizer is applied in nanoform, the nutrients are released at a slower pace and over a longer period of time, minimising nutrient loss from the soiland lowering soil-groundwater contamination (Liu and Lal, 2015). Nano-fertilizers are contained inside nano porous materials, coated with thin polymer films or administered as nanoscale particles or emulsions (Rai *et al.*, 2012). Nano-fertilizers, which contain nutrients and growth promoters contained in nano scale polymers, deliver the major nutrients to the crop as needed in a phased manner. These nanoscale polymers ensure a modest and targeted release of nutrients to the crop in a sustained way throughout its life cycle, resulting in higher nutrient use efficiency. These could also more accuratelyrelease their active ingredients in response to environmental cues and biologicaldemands, enhancing soil health by increasing carbon uptake, improving soil aggregation and increasing water holding capacity. Encapsulating nano-fertilizers in nano-particles improves nutrient uptake (Tarafdar *et al.*, 2014).

## Material and method

The experiment was laid out at Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur (Rajasthan) which is situated at an altitude of 432 metre above mean sea level with 26°48'35" N latitude and 75°51'44" E longitude. This region falls under agro-climatic zone IIIa (Semi-Arid Eastern Plain Zone) of Rajasthan. The average annual rainfall of this tract ranges between 400-500 mm, most of which is contributed by the south-west monsoon during July and August. There is hardly any rain during winter months. The maximum and minimum temperatures during the crop season ranged between 30.2°C to 35.2°C and 9.9°C to 23.0°C, respectively. A total of 365.5 mm rainfall was recorded during the crop season.

The sandy loam texture of the experimental field soil had a pH of 8.5, which was slightly alkaline in reaction, very low amount of organic carbon (0.42%), very low in available nitrogen (135.66 kg $ha^{-1}$), medium in available phosphorus (20.93 kg $ha^{-1}$) and high in available potassium (234.23 kg $ha^{-1}$) and low in available sulphur (16.35 kg $ha^{-1}$). On July 25, 2023, the crop was sown with variety of CPD-119. There were three replications and eight treatments *viz*., control ($T_1$), 50%

RDN ($T_2$), 75% RDN ($T_3$), 100% RDN ($T_4$), 75% RDN + one foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering initiation ($T_5$), 50% RDN + one foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering initiation ($T_6$), 75% RDN + two foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation ($T_7$) and 50% RDN + two foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation ($T_8$), which were laid out in randomized block design.

Five plants were selected randomly from each plot and tagged permanently. Height of these five plants was measured at 30, 60 DAS and at harvest from the base of the plant to the top of the main shoot by metre scale and their mean was expressed as plant height (cm). Dry matter accumulation (g $plant^{-1}$) was recorded at 30, 60 DAS and at harvest and plants were uprooted randomly from sample rows of each plot. After removal of the root portion, the samples were first air-dried for some days and finally dried in an electric oven at 68 °C till a constant weight was achieved. The weight was recorded and expressed as g $plant^{-1}$. The number of total nodules $plant^{-1}$ was counted at 40 and 45 DAS. Five plants were selected randomly in sample rows of each plot and uprooted carefully. The soil mass embodying the roots of the plants was washed off with water and total nodules were counted. The mean value was recorded as total number of nodules $plant^{-1}$. Number of effective nodules was counted from same plants as taken for total number of nodules. Healthy pink colored nodules were counted and mean value was recorded as effective number of nodules $plant^{-1}$. The root nodules obtained from the selected five plants from each plot and after dry under oven at 68 °C till a constant weight were obtained in mg $plant^{-1}$ and then average was worked out. The pods of five plants randomly selected from each plot were counted at harvest and average number of pods $plant^{-1}$ was worked out. Number of seeds $pod^{-1}$ was recorded at harvest by counting the seeds of the five randomly collected pods from each plot and the average value was estimated. Samples were drawn randomly from produce of each plot and one thousand seeds were counted from each sample and weighed to record test weight (g). After threshing and winnowing of the seeds from each net plot were weighed in kg $plot^{-1}$ and converted in kg $ha^{-1}$ for seed yield. Haulm yield was obtained by subtracting the seed yield (kg $ha^{-1}$) from biological yield (kg $ha^{-1}$). At maturity completely, dried biomass *i.e*. pods and straw from each net plot harvested were weighed and computed for biological yield as kg $ha^{-1}$. The harvest index was calculated by using following formula and expressed as percentage (Singh and Stoskoff, 1971).

$$\text{HI (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

Experimental data recorded in various parameters were statistically analyzed with the help of Fisher's analysis of variance technique (Fisher, 1950).

## Results and Discussion

### Growth parameters

Application of different source of nutrients significantly increased various growth parameters, *viz.*, plant height, dry matter accumulation, number and weight of nodules $plant^{-1}$ at successive growth stages of cowpea (Table 1 to 4). The cumulative effect of these increases ultimately led to the production of higher biomass by plants at harvest. The relationship between nutrient released and plant demand is very vital to achieve higher pace of growth and accumulation of dry matter per unit time. Under present investigation the improved effect of application of different nutrients on various growth parameters of cowpea appears to be on account of enrichment of soil with primary, secondary and micronutrients to the stable proportion and to the level of sufficiency.

The highest plant height was recorded with 100% RDF, which was 25.29 cm at 30 DAS. However, highest dry matter accumulation was recorded with the application of 75% RDN + two foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation, which was 13.79 g $plant^{-1}$ at 30 DAS. These components appear to have increased due to an increase in growth hormones and naturally occurring phytohormones along with an increase in nitrogen supply. The increase in biomass and dry matter accumulation was likely caused by an increase in auxin supply along with higher nitrogen levels. Since, nitrogen is one of the major essential plant nutrients needed for growth, the observed expansion might be due to an early and abundant availability of nitrogen leading to a better nutritional environment in the root zone for growth and development. Therefore, greater availability of nitrogen on otherwise poor soil might have resulted in an increased cell number and cell size, which in turn lead to better growth in terms of height and dry matter accumulation. Nitrogen accelerates photosynthetic rate and increasing the supply of carbohydrates to plant. Thus, nitrogen application increased dry matter production. Similarly, increased supply of available phosphorus has long been considered as a necessary constituent of all living organisms and is crucial for conservation and transfer of energy in the metabolic reactions of living cells including biological energy transformations.

Phosphorus plays a significant role in root development and proliferation by supplying assimilates to the roots. Increased availability of phosphorus owing to its application in the soil low in phosphorus content (Table 2) might have improved the availability of nutrients, resulting into more uptake. The energy gained from photosynthesis and metabolism of carbohydrates stored in storage compounds (ATP and ADP) for subsequent use might have resulted in vigorous growth of plants. As a result, application of recommended dose of fertilizers at optimum level improved plant height and dry matter accumulation $plant^{-1}$ in the present investigation over their lower doses.

The findings demonstration that conventional fertilizer as well as foliar spray of nano DAP and nano zinc significantly influenced the crop growth. The growth of cowpea is leading by plant height, dry matter accumulation, number and weight of nodules $plant^{-1}$ which was significantly influenced by foliar spray of nano DAP and nano zinc presented in preceding chapters (Table 1 to 3). The data presented that highest plant height, dry matter accumulation, number and weight of nodules $plant^{-1}$ at 40 DAS was recorded with application of 75% RDF + two spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation. Since, nutrients are crucial play an important role in root development and proliferation, nodule formation and nitrogen fixation by supplying assimilates to the roots and the sufficient supply of this nutrient might have increased the utilization of nitrogen application. The findings closely match those of Saha *et al.* (2022). The combination of the most effective application technique, foliar application and the supply of nutrients by nanofertilizers with the most effective nutrient delivery systems have led to an increase in the growth of the cowpea. Nano nutrients applied topically to leaves permit nutrients to enter mainly through the stomata and cuticles. Nanoparticles that are larger travel along the stomatal pathway while smaller than 5 nm travel along the cuticular pathway (Eichert and Goldbach, 2008). They subsequently go to the conducting system, which due to rapid and simple uptake of nutrients by leaves because they are complete solubility (Fernandez and Eichert, 2009). Pandey *et al.* (2010) also reported that improve growth of lentil under combined application of soil and foliar nutrients may be attributed to the efficient use of nutrients by leaves for improved vegetative and reproductive growth of lentil by foliar application, which occurs at the emergence stage.

Nanoparticles have high specific surface area and high reactivity due to their tiny size, which increased the reactivity of the density of reactive areas or the reactivity of the increase of growth. Giraldo *et al.* (2014) and Choudhary and Khandelwal (2020) have also reported ability of nano-particles to enter into plants cells and leaves which accelerate growth and development.

Zinc is a cofactor of the carbonic anhydrase enzyme, which is situated in chloroplasts and increases $CO_2$ content to assist the ability of the Rubisco enzyme to fix $CO_2$ photosynthetically (Salama *et al.*, 2006). Increased internodal length contributed to the rise in plant height and may have been caused by the high activity of nano zinc in the synthesis of auxins, particularly IAA. The increased activity of nano zinc in the synthesis of auxins, particularly IAA, may have led to the increase in internodal length, which in turn contributed to the increase in plant height. A zinc deficit made it harder for tryptophan to become IAA. This outcome was consistent with Snehalbhai (2016), Abdel-Aziz *et al.* (2016) and Aghahei *et al.* (2022).

**Yield attributes and yield**

Data (Table 5 and 6) reveal that pods plant$^{-1}$, seeds pod$^{-1}$, test weight, seed yield, haulm yield and biological yield increased significantly. The highest pods plant$^{-1}$, seeds pod$^{-1}$, test weight, seed, haulm and biological yield were observed under application of 75% RDF + two spray of each 2 ml l$^{-1}$ nano DAP and nano Zn at flowering and pod initiation. The enormous potential of nano fertilizers, which ensure high nutrient availability to plants in a controlled manner for the duration of the crop growth period, stimulated various metabolic processes that in turn produced more shoot and root biomass, high photosynthetic activity resulted in translocation of assimilate products in seed resulting in a higher pods plant$^{-1}$, seeds pod$^{-1}$, test weight, increased the yield attributes and yield of cowpea. These metabolic processes were stimulated by the great potentialities of nano fertilisers, which guarantee the high availability of nutrients to plants in a controlled manner throughout the entire crop growth period.

The overall improvement in vigour and crop growth as explained in preceding paragraphs due to adequate supply of nitrogen early in the life of a plant is considered important in promoting rapid vegetative growth and biomass. Thus, N fertilization stimulated seed setting and increased yield attributes. At later stage in reproductive phase when the current photosynthesis is not able to furnish the increased assimilate demand of the plant sinks, the storage compounds probably remobilize and move to active sinks (pods and seeds) which ultimately increased pods plant$^{-1}$ and seeds pod$^{-1}$ in cowpea. During leaf senescence also, carbohydrates, nitrogenous compounds, phosphorus and other mobile nutrients are remobilized and translocated to current plant sinks *i.e.*, seeds which are very close to the source resulting into higher test weight due to bold seed formation. The increased supply of NPK and their higher uptake by plants might have stimulated the rate of various physiological processes in plant and led to increased growth and yield parameters and ultimately resulted in higher seed and haulm yield. The biological yield is a function of seed and stalk yield. Thus, significant increase in biological yield with the application of nutrients could be ascribed due to increased seed and haulm yield. The results of present investigation are in line with those of Tului *et al.* (2021), Saha *et al.* (2022) and Prasad *et al.* (2012).

On application of nano-P there was 30% more nutrient mobilizations noticed in the rhizosphere. This might be due to easy availability of phosphorus for proper root development, nodulation, photosynthesis and energy transfer processes. Rhizobium (bio-fertilizers) inoculation in legume with foliar spray of nano-P resulted in greater nodulation and increased availability of fixed as well as applied nitrogen and phosphorus to the plants, which in turn encouraged cell formation, division and multiplication. The use of zinc may have increased grain yield by enhancing pollen and seed production, which would have improved plant reproduction. The current study's findings are comparable to those of Elshayb *et al.* (2021), Drostkar *et al.* (2016), Du *et al.* 2019, Tarafdar *et al.* (2014), Kumar *et al.* (2022a), Deo *et al.* (2022) and Abdel-Aziz *et al.* (2016).

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**Table 4.1 Effect of nano fertilizer on growth parameters (plant population and plant height) of cowpea**

| Treatments | Plant population ($m^{-1}$ row length) | | Plant height (cm) | | |
|---|---|---|---|---|---|
| | 30 DAS | Harvest | 30 DAS | 60 DAS | Harvest |
| Control | 7.85 | 6.47 | 17.55 | 24.11 | 37.41 |
| 50% RDN | 7.89 | 6.48 | 20.86 | 28.92 | 44.72 |
| 75% RDN | 8.25 | 6.81 | 24.24 | 33.82 | 52.19 |
| 100% RDN | 8.60 | 7.25 | 25.29 | 35.80 | 54.54 |
| 75% RDN + one foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering initiation | 8.58 | 7.24 | 24.39 | 40.42 | 61.94 |
| 50% RDN + one foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering initiation | 8.59 | 7.25 | 23.35 | 38.83 | 59.63 |
| 75% RDN + two foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation | 8.60 | 7.20 | 24.79 | 46.93 | 69.46 |
| 50% RDN + two foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation | 8.75 | 7.25 | 23.98 | 45.85 | 69.15 |
| SEm± | 0.34 | 0.39 | 1.07 | 1.53 | 2.37 |
| CD (p=0.05) | NS | NS | 3.24 | 4.63 | 7.20 |
| CV | 6.96 | 9.63 | 8.03 | 7.18 | 7.32 |

**Table 4.2 Effect of nano fertilizer on growth parameters (dry matter accumulation, number and weight of nodules) of cowpea**

| Treatments | Dry matter accumulation (g $plant^{-1}$) | | | Number of nodules $plant^{-1}$ | | Weight of nodules (mg $plant^{-1}$) | |
|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | At harvest | 30 DAS | 45 DAS | 30 DAS | 45 DAS |
| Control | 9.02 | 20.62 | 29.22 | 36.22 | 47.52 | 475.19 | 570.22 |
| 50% RDN | 10.99 | 22.99 | 32.99 | 42.59 | 55.19 | 561.89 | 683.27 |
| 75% RDN | 13.14 | 25.54 | 36.94 | 49.14 | 62.14 | 641.36 | 787.63 |
| 100% RDN | 13.59 | 25.99 | 37.39 | 51.19 | 64.59 | 665.89 | 817.07 |
| 75% RDN + one foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering initiation | 13.66 | 28.36 | 41.16 | 51.46 | 64.86 | 672.57 | 834.08 |
| 50% RDN + one foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering initiation | 12.65 | 27.35 | 39.82 | 51.62 | 65.02 | 678.15 | 840.78 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 75% RDN + two foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation | 13.79 | 30.79 | 44.59 | 52.39 | 65.72 | 681.23 | 850.15 |
| 50% RDN + two foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation | 13.68 | 30.74 | 45.21 | 52.18 | 65.18 | 675.77 | 845.25 |
| SEm± | 0.64 | 0.77 | 1.12 | 1.68 | 2.28 | 25.61 | 33.31 |
| CD (p=0.05) | 1.93 | 2.34 | 3.40 | 5.10 | 6.91 | 77.68 | 101.04 |
| CV | 8.76 | 5.03 | 5.06 | 6.03 | 6.44 | 7.02 | 7.41 |

**Table 4.3 Effect of nano fertilizer on yield attributes and yield of cowpea**

| **Treatments** | **Yield attributes** | | | **Yield (kg $ha^{-1}$)** | | | **Harvest index (%)** |
|---|---|---|---|---|---|---|---|
| | **Number of pods $plant^{-1}$** | **Number of seeds $pod^{-1}$** | **Test weight (g)** | **Seed** | **Haulm** | **Biological** | |
| Control | 7.62 | 7.62 | 65.52 | 728 | 1238 | 1966 | 37.04 |
| 50% RDN | 9.49 | 9.19 | 73.19 | 850 | 1426 | 2276 | 37.33 |
| 75% RDN | 11.04 | 9.56 | 73.64 | 966 | 1614 | 2581 | 37.47 |
| 100% RDN | 11.49 | 9.65 | 73.39 | 985 | 1636 | 2621 | 37.58 |
| 75% RDN + one foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering initiation | 13.11 | 9.97 | 73.66 | 1096 | 1829 | 2926 | 37.48 |
| 50% RDN + one foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering initiation | 12.10 | 9.86 | 73.82 | 1059 | 1765 | 2824 | 37.49 |
| 75% RDN + two foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation | 14.79 | 9.99 | 74.02 | 1243 | 2061 | 3303 | 37.62 |
| 50% RDN + two foliar spray of each 2 ml $l^{-1}$ nano DAP and nano Zn at flowering and pod initiation | 14.74 | 9.94 | 73.98 | 1216 | 2022 | 3238 | 37.55 |
| SEm± | 0.51 | 0.36 | 2.34 | 33 | 61 | 93 | 0.16 |
| CD (p=0.05) | 1.53 | 1.10 | 7.11 | 99 | 184 | 282 | NS |
| CV | 7.42 | 6.63 | 5.59 | 5.55 | 6.18 | 5.92 | 0.72 |