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Influence of Nano Urea on Growth, Yield and Nutrient use efficiency of Pigeonpea (*Cajanus cajana* L.) of Karnataka, India

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ABSTRACT: Nano urea particles has an average physical size of 20-50 nm and contains 4 % nitrogen by weight in its nano form. Further, application of nano urea (liquid) improves yield, biomass, soil health and nutritional quality of the produce due to higher absorption rate, utilization efficacy and minimum losses. The field experiment was conducted at ZARS, GKVK, Bangalore, Karnataka, India during *Kharif* 2021 on influence of nano urea on growth, yield and quality of pigeonpea. Results indicated that application of RDF (Nano Urea) + foliar application of $ZnSO_4$ @ 0.5 % + $FeSO_4$ @ 0.5 % resulted significantly higher number of pods plant^{-1} (116.2), pod yield (52.3 g plant^{-1}), pod bearing length plant^{-1} (64.7 cm) seed yield (1179 kg ha^{-1}) and stalk yield (4568 kg ha^{-1}) and higher uptake of nutrients (kg ha^{-1}) i.e., nitrogen (111.5), phosphorus (16.9) and potassium (82.3) hence higher nutrient use efficiency (kg grains kg^{-1} nutrient applied) i.e., nitrogen (93.0), phosphorus (23.58) and potassium use efficiency (47.16) and across the different phenophases of crop, from 120 DAS till harvest higher values of absolute growth rate(1.97g plant^{-1}day^{-1}), crop growth rate (14.57 g m^{-2} day^{-1}) and relative growth rate (0.012 g g^{-1} day^{-1}) were observed.

Keywords: Yield, stalk nitrogen phosphorus and potassium.

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is an important protein-rich pulse crop native to the Indian sub-continent. It is the sixth most important grain legume grown in the semi-arid tropics of Asia under wide cropping systems and the second most important grain legume in India after chickpea. The application of fertilizer ensures complete harmony between the vegetative and reproductive phases and helps in realizing the potential yield of the crop. To meet the pulse requirement for ever growing population, an annual growth rate of the pulse should be 4.2 per cent (IIPR, 2011). India is the largest producer of pigeonpea. In India, pigeonpea is cultivated on an area of 4.7 mha, with 4.31 mt annual production and 914 kg ha^{-1} productivity (INDIASTAT, 2021). India is the largest producer, importer and consumer of pulses in the world. Major problems with pulses production include low yield potential, unstable production levels due to biotic and abiotic stresses, climate change, loss of soil fertility and limited land resources. Pigeonpea is climate resilient crop and has potential to increase the income of small and marginal farmers. Also, it is a low nitrogen requirement crop as it fixes atmospheric nitrogen (40-50 kg N ha^{-1}). It has deep-root system and slow initial growth due to which it is best as intercrop. Apart from grains, its immature stems and leaves can be used as green manure. With these many benefits, there is a lot of scope for increasing pigeonpea production by proper management practices to overcome national and global food security challenges.

Nano-fertilizers are advantageous over conventional fertilizers by having large surface area and particle size which is less than the pore size of root and leaves of the plant which can increase penetration into the plant from the applied surface and improve uptake and nutrient use efficiency (Liu and Lal 2015). The usage of nano fertilizers in small quantities makes the soil not get loaded with salts that usually are prone to over-application using conventional fertilizers on a short- or long-term basis (Leon Silva *et al.*, 2018). Fertilizers in the nano form, improves the productivity of crops and efficiently regulate the delivery of nutrients to plants and targeted sites, guaranteeing the minimal usage of agrochemicals. Nano-fertilizers are synthesized to regulate the release of nutrients depending on the requirements of the crops and are more efficient than ordinary fertilizers (Liu and Lal 2015). Rameshaiah *et al*. (2015) reported that nano-fertilizers increase nutrient use efficiency (NUE) by 3 times. Spraying of nano nitrogen at the rate of 2-4 ml litre^{-1} of water at critical crop growth stages triggers crop response, fulfils its nutritional requirement and improves nutrient availability in the rhizosphere. When sprayed on leaves, nano N fertilizer easily gets absorbed and enters through stomata due to its nano size (Kumar *et al*., 2021). These nano fertilizers have many other advantages, suppress crop diseases by acting directly on phytopathogens, improve stress tolerance and improve soil health. These nanomaterials also enhance crop production indirectly by improving crop nutrition and boosting plant defence pathways. The present study entitled "Influence of nano urea on growth, yield and Nutrient Use Efficiency of pigeonpea" has been undertaken to evaluate the response of pigeonpea crop to foliar application of nano urea with comparison to normal urea, so that a viable and economically feasible option can be given to the farmers for maintaining sustainable crop production with improved quality and enhanced nutrient use efficiency in the pigeonpea.

MATERIALS AND METHODS

A field experiment was conducted at K Block, ZARS, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India during *Kharif* 2021. The experimental site belongs to Eastern Dry Zone (Agro-climatic Zone-V) of Karnataka and Located between 12º51'N Latitude and 77º35'E Longitude at an altitude of 930m above mean sea level (MSL). The experiment was laid out in Randomised Complete Block Design with 3 replications and 15 treatments. Treatment details given in following Table.1

Table 1: Treatment details.

T_1 =	RDF (NU)
T_2 =	RDF (nU)
T_3 =	RDF (NU) + Soil application of $ZnSO_4$ @ 25 kg ha^{-1}
T_4 =	RDF (NU) + Soil application of $FeSO_4$ @ 5 kg ha^{-1}
T_5 =	RDF (NU) + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Soil application ofFeSO$_4$ @ 5 kg ha^{-1}
T_6 =	RDF (NU) + Foliar application of $ZnSO_4$ @ 0.5 per cent
T_7 =	RDF (NU) + Foliar application of $FeSO_4$ @ 0.5 per cent
T_8 =	RDF (NU) + Foliar application of $ZnSO_4$ @ 0.5 per cent + Foliarapplication of $FeSO_4$ @ 0.5 per cent
T_9 =	RDF (nU) + Soil application of $ZnSO_4$ @ 25 kg ha^{-1}
T_{10} =	RDF (nU) + Soil application of $FeSO_4$ @ 5 kg ha^{-1}
T_{11} =	RDF (nU) + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Soil application of $FeSO_4$ @ 5 kg ha^{-1}
T_{12} =	RDF (nU) + Foliar application of $ZnSO_4$ @ 0.5 per cent
T_{13} =	RDF (nU) + Foliar application of $FeSO_4$ @ 0.5 per cent
T_{14} =	RDF (nU) + Foliar application of $ZnSO_4$ @ 0.5 per cent + Foliar application of $FeSO_4$ @ 0.5 per cent
T_{15} =	Water spray

The soil of the experimental site was red sandy loam in texture, classified under the order *Alfisols*. The composite soil samples from 0 to 30cm depth were collected randomly in experimental area before treatment imposition from each replication. Analysis was done for various physical and chemical properties of the soil. The values obtained along with methods followed for estimation are presented in Table 1. The textural class of the soil was red sandy loam consisting of 53.40 percent coarses and, 14.8 per cent fine sand, 16.6 per cent silt and 15.2 per cent of clay. The soil was acidic (5.3) in reaction with an electrical conductivity of 0.17 dSm^{-1}. The organic carbon content was 0.36 percent. The soil was medium in available nitrogen (318.5 kg ha^{-1}), available phosphorous (48.5 kgha^{-1}) and available potassium (280.5kgha^{-1}). The data on growth parameters of pigeonpea was recorded at 60, 90, 120 days after sowing (DAS) and at harvest. The experimental data recorded on the growth, yield and soil parameters were subjected to Fisher's method of "Analysis of Variance" (ANOVA). For comparison between the treatment means, an appropriate value of critical difference (CD) was worked out. All the data were analyzed and the results are presented and discussed at a probability level of 5 per cent.

In the experiment, treatments with RDF (Normal Urea) and water spray, 100 per cent of RDF (N, P and K) was applied as basal dose at the time of sowing. In the treatments with RDF (Nano Urea), 100 per cent of RDPK and 50 per cent of RDN through normal urea as basal dose at the time of sowing and foliar application of nano nitrogen (3 ml l^{-1}) in three sprays at 60, 90 and 120 DAS were given. In the water spray treatment, foliar application with only water during 60, 90 and 120 DAS was done. In the treatments with soil application of 25 kg zinc and 5 kg ferrous sulphate ha^{-1} were applied as basal dose during the time of sowing along with RDF (Normal Urea) or RDF (Nano Urea). In the treatments with foliar application of water-soluble zinc and iron fertilizers, these fertilizers @ 0.5% each were sprayed at flowering and pod development stages of pigeonpea along with RDF (Normal Urea) and RDF (Nano Urea).

Absolute growth rate (Radford, 1967), Crop growth rate (Watson, 1952) and Relative growth rate Radford (1967) was computed by following formula

$$\text{Absolute growth rate (g plant}^{-1}\text{ day}^{-1}) = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_1 and W_2 refer to the dry matter weight (g) at the time t_1 and t_2.

$$\text{Crop growth rate (gm}^{2}\text{ day}^{-1}) = \frac{W_2 - W_1}{t_2 - t_t} \times \frac{1}{P}$$

Where,

W_1 and W_2 =Dry matter production plant^{-1} in g at time t_1 and t_2, respectively.

P = Spacing (m^2)

$$\text{Relative growth rate } (gg^{-1}day^{-1}) = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where, W_1 and W_2 are dry weights of plant at time t_1 and t_2, respectively,

Nutrient use efficiency (NUE) was calculated by using following formula and expressed as kg grain yield per kg nutrient applied. It was separately calculated for each nutrient *viz.*, N, P and K.

$$\text{NUE} = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Nutrient applied (kg ha}^{-1})}$$

Nitrogen content in seeds was estimated by modified Micro-Kjeldhal's method as outlined by Jackson (1973) and expressed in percentage. Nitrogen uptake ($kgha^{-1}$) by crop was calculated for each treatment separately using the following formula

Climatic conditions. The normal as well as actual weather data on total rainfall, maximum and minimum temperature, relative humidity, sunshine hours, wind speed and pan evaporation prevailed during the crop period is represented in the Fig. 1.

$$\text{Nitrogen uptake}(kgha^{-1}) = \frac{\text{Nitrogen concentration}(\%)}{100} \times \text{Seed yield } (kgha^{-1})$$

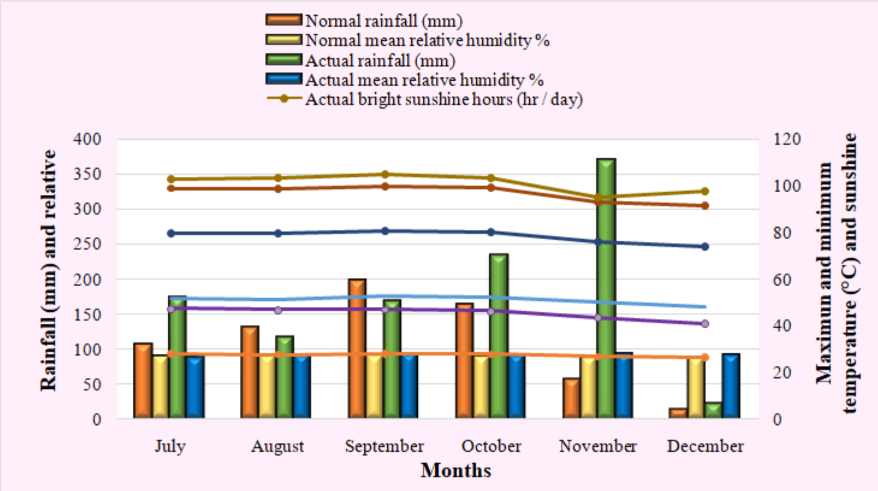

Fig. 1. Meteorological data of the experimental site during crop growth period at GKVK, UAS, Bangalore, Karnataka, India.

Table 2: Initial soil physical and chemical properties of the experimental site.

Particulars	Values	Status	Method followed
I. Physical properties			
1. Coarses and(%)	53.4	Red sandy loam	International pipette method (Piper,1966)
2. Fines and(%)	14.8		
3. Silt(%)	16.6		
4. Clay(%)	15.2		
II. Chemical properties			
1. pH(1:2.5)	5.4	Acidic	Potentiometric method (Jackson, 1973)
2. EC(1:2.5)(dSm^{-1})	0.16	Normal	Conductometric method (Jackson,1973)
3. Organic carbon(%)	0.43	Medium	Wet oxidation method (Walkley and Black, 1934)
4. Available N($kgha^{-1}$)	287	Medium	Alkaline potassium permanganate method (Subbaiah andAsija,1956)
5. Available P_2O_5($kgha^{-1}$)	36.5	Medium	Bray's method (Jackson,I973)
6.Available K_2O($kgha^{-1}$)	255.5	Medium	Flame photometry (Jackson, 1973)
7. Available Zinc (mg kg^{-1})	2.9	Medium	Diethylenetriamine pentaacetate (DTPA) method (Lindsay and Norvell, 1978) Atomic absorption spectrophotometry
8. Available Iron (mg kg^{-1})	7.6	Medium	

RESULTS AND DISCUSSION

At harvest, significantly higher plant height (242 cm), number of branches $plant^{-1}$ (23.7) and dry matter accumulation (254 g $plant^{-1}$) were recorded with application of RDF (Nano Urea) + foliar application of $ZnSO_4$ @ 0.5 per cent + $FeSO_4$ @ 0.5 per cent and lower plant height (172 cm), number of branches $plant^{-1}$ (17.2) and dry matter accumulation (165 g $plant^{-1}$) were observed with application of RDF (Normal Urea).Initial growth rate of pigeonpea was slow, which was reflected in plant height at 60 DAS which did not show any significant difference in the treatments. After that there was a significant increase in plant height was observed. This difference in increase in plant height of pigeonpea was recorded might be due to the application of nitrogen as basal dose with normal urea and by foliar spray with nano urea increased the availability of nutrients to the growing plant. Also, this nano fertilizer helped in quick absorption of nutrients through stomata of leaves viz. foliar application of nano urea and might have increased chlorophyll formation, photosynthetic rate, dry matter production and thus,enhanced the growth of the plant. The similar findings were reported by Rani *et al*. (2019). Nitrogen plays a vital role in plant growth and development. Application of nitrogen in nano form increases its availability at critical stages. Nitrogen enhances cell metabolism and cell divisional activities in shoot apical meristem which increases plant height (Kaur *et al*., 2015). Benzon *et al*. (2015) opined that plant height was increased when nano-fertilizer was applied in combination with conventional fertilizer because nano-fertilizer can either provide nutrients for the plant or help in the transport or absorption of available nutrients resulting in better crop growth. Also, the foliar application of $ZnSO_4$ and $FeSO_4$ at flowering and pod filling stage along with RDF increased the growth attributes due to balanced availability of micronutrients throughout growing period (Saakshi *et al*., 2020).

In yield attributes, significantly higher number of pods plant^{-1} (116.2), pod yield (52.3 g plant^{-1}), pod bearing length plant^{-1} (64.7 cm) seed yield (1179 kg ha^{-1}) and stalk yield (4568 kg ha^{-1}) were recorded with application of RDF (Nano Urea) + foliar application of $ZnSO_4$ @ 0.5 per cent + FeSO4 @ 0.5 per cent in pigeonpea. Significantly lower seed yield (874 kg $^{ha-1}$) and stalk yield (3688 kg ha^{-1}) were recorded with the application of RDF (Normal Urea).

The increase in seed yield might be due to the combined application of normal and nano urea along with micronutrients which ensured optimum and balanced nutrient availability throughout the crop period. Many research studies have showed the increase in yield due to application of fertilizers in nano form. Benzon *et al*. (2015) reported positive effect of the nano-fertilizers on the efficacy of conventional fertilizer for better nutrient absorption by plant cells resulting to optimal growth of plant parts and metabolic process such as photosynthesis leads to higher photosynthates accumulation and translocation to the economic parts of the plant, thus resulting higher yield. In this experiment, combined application of normal urea and nano urea ensured nutrient availability thought out the crop period specially during the critical stages which resulted in increased biomass, lower flower drop and increased the yield attributing characters and finally, amplified translocation of assimilates to seeds which increased over all pigeonpea yield compared to only RDF. Similar results were reported by Kumar *et al*. (2020). Foliar application of micronutrients ensured quick absorption of essential nutrients, at the time of reproductive stage where the nutrient demand is at the peak due to indeterminate growth habit of the crop. Hence, it reduced the flower drop and ultimately enhanced the pod setting and resulted in higher seed yield (Elumle Priyanka, 2019). Also, zinc and ferrous sulphate includes sulphur which is a secondary nutrient which might be advantageous in increasing the crop yields (Kailas *et al*., 2019). Foliar application of nutrients at flowering and pod development stage might have been easily absorbed and better trans located in the plant and maintained constant requirement of nutrients at the reproductive stage of the crop.

Application of RDF (Nano Urea) + foliar application of $ZnSO_4$ @ 0.5 per cent + FeSO4 @ 0.5 per cent recorded higher nutrient use efficiency (kg grains kg^{-1} nutrient applied) i.e., nitrogen use efficiency (93.0 kg grains kg^{-1} N applied), phosphorus use efficiency (23.58 kg grains kg^{-1} P applied) and potassium use efficiency (47.16 kg grains kg^{-1} K applied) in pigeonpea (Table 4). Higher nutrient use efficiency was recorded with foliar application of nano urea mainly due to the higher nutrient uptake which increased the yield and biomass of the pigeonpea. Below 100 nm nano-fertilizers makes plant use fertilizers more efficiently, reduces pollution, environmentally friendly, dissolve in water more effectively thus increase its metabolic activities (Joseph and Morrison 2006). Higher nutrient use efficiency of nitrogen, phosphorus and potassium was mainly due to increased availability and uptake of nutrients leading to higher growth and yield attributes in turn increased yield kg^{-1} nutrient applied.

Significantly higher uptake of nutrients i.e., nitrogen uptake (111.5 kg ha^{-1}), phosphorus uptake (16.9 kg ha^{-1}) and potassium uptake (82.3 kg ha^{-1}) was recorded with the application of RDF (Nano Urea) + foliar application of $ZnSO_4$ @ 0.5 per cent + $FeSO_4$ @ 0.5 per cent. The increase in nutrient uptake was due to the foliar application of nano urea with zinc and ferrous sulphate which increased physiological characters, dry matter production and its partitioning. Reduction of particle size results in increased specific surface area and number of particles per unit area of a fertilizer that provide more opportunity to contact of nano-fertilizer which leads to more penetration and uptake of the nutrient and thus results in high nutrient use efficiency (Liscano *et al.,* 2000). Marschner (1986) opined that generally the levels of nutrients in xylem sap and their flux into the shoot decline during the reproductive phase in monocarphic plants. The foliar application of nutrients might reduce the nutrient depletion in the foliage. This might help in increasing the photosynthesis while reduce flower, pod abscission, and improve nutrient concentration in pigeonpea.

Significantly higher AGR, CGR and RGR values (Table 5) of pigeonpea were recorded during 120 DAS till harvest due to the influence of nano urea as a foliar spray. RDF (Nano Urea) + foliar application of $ZnSO_4$@ 0.5per cent+ $FeSO_4$@ 0.5 per cent recorded significantly higher AGR values (1.97 g plant^{-1} day^{-1}), CGR (14.57 g m^{-2} day^{-1}), and RGR (0.012 g g^{-1} day^{-1}). Higher AGR values represents the enhanced vegetative growth and reduced leaf senescence due to application of nano urea along with foliar application of zinc and ferrous sulphate. Increase in CGR was mainly due to increase in the dry matter production of pigeonpea at periodic intervals. Interaction of phytohormones and nutrients on growth and development of crop plants cause positive responses on plant growth rate, relative growth rate, crop growth rate and net assimilation rate (Kaur *et al*., 2015). Foliar application of nano urea with ferrous and zinc sulphate increased the leaf area, photosynthetic efficiency and dry matter accumulation which was reflected in increase of CGR.RGR is the rate of accumulation of new dry matter per unit of existing dry matter. It is an indirect measurement of rate of resource acquisition (Lowry and Smith 2018). In this experiment, RGR was increased may be due to increased photosynthetic efficiency by retaining more chlorophyll content and efficient translocation. These results are supported by the findings of Gowthami and Rama Rao (2014) in soybean. Nano fertilizers gets quickly absorbed and translocated by the plant tissues. Unutilized nutrients get stored in plant vacuoles and are released based on crop requirement. This might also have helped to increase assimilates in plants and improved the dry matter accumulation at periodic intervals. These results were in corroboration with the findings of Mehta Swathi (2017).

Table 3: Yield and yield attributes of pigeonpea as influenced by foliar application of nano urea.

Treatments	**Number of pods plant^{-1}**	**Pod yield plant^{-1} (g)**	**Pod bearing length (cm)**	**Seed yield plant^{-1} (g)**	**Shelling percentage (%)**	**Test weight (g/100 seeds)**
T_1= RDF (NU)	89.6	42.9	54.4	16.8	55.98	13.9
T_2= RDF (nU)	95.2	44.7	56.0	17.9	57.06	14.9
T_3= RDF (NU) + SA $ZnSO_4$ @ 25 kgha^{-1}	103.7	45.7	56.4	18.5	57.05	14.7
T_4= RDF (NU) +SA $FeSO_4$ @ 5kgha^{-1}	103.6	45.2	54.3	18.1	55.97	14.9
T_5=RDF (NU) + SA $ZnSO_4$ @ 25 kgha^{-1} + SA $FeSO_4$ @ 5 kgha^{-1}	112.2	48.3	64.0	19.7	60.52	14.9
T_6= RDF (NU) + FA $ZnSO_4$ @ 0.5%	98.2	49.3	57.8	20.0	61.65	15.3
T_7 = RDF (NU) + FA $FeSO_4$ @ 0.5%	106.5	46.3	55.4	18.9	58.74	15.9
T_8= RDF (NU) + FA $ZnSO_4$ @ 0.5% + FA $FeSO_4$ @ 0.5%	111.2	51.4	63.9	20.7	57.53	15.4
T_9 = RDF (nU) + SA $ZnSO_4$ @ 25 kgha^{-1}	102.8	49.7	58.2	20.3	62.05	15.2
T_{10}= RDF (nU) + SA $FeSO_4$ @ 5kgha^{-1}	109.8	46.6	56.4	19.7	61.06	15.0
T_{11} = RDF (nU) + SA $ZnSO_4$ @ 25 kgha^{-1} + SA $FeSO_4$ @ 5 kgha^{-1}	113.2	51.8	63.6	20.8	60.56	15.5
T_{12}= RDF (nU) + FA $ZnSO_4$ @ 0.5%	108.1	50.6	56.1	20.5	61.49	15.1
T_{13}= RDF (nU) + FA $FeSO_4$ @ 0.5%	104.5	47.4	54.7	19.7	59.95	15.4
T_{14} = RDF (nU) + FA $ZnSO_4$ @ 0.5% + FA $FeSO_4$ @ 0.5%	116.2	52.3	64.7	21.0	62.40	15.9
T_{15} = Water spray	91.0	43.9	55.1	17.1	58.53	14.4
S.Em. ±	**3.99**	**1.79**	**2.43**	**0.85**	**3.22**	**0.54**
C.D @ 5%	**11.57**	**5.19**	**7.04**	**2.46**	**NS**	**NS**

NU: Normal Urea nU: Nano Urea
SA: Soil application FA: Foliar application

Table 4: Effect of foliar application of nano urea on uptake of total nitrogen, phosphorus, potassium and nutrient use efficiency of pigeonpea.

Treatments	**NUE (kg grains kg^{-1} of N fertilizer applied)**	**PUE (kg grains kg^{-1} of P fertilizer applied)**	**KUE (kg grains kg^{-1} of K fertilizer applied)**	**N (kg ha^{-1})**	**P (kg ha^{-1})**	**K (kg ha^{-1})**
T_1= RDF (NU)	35.0	17.48	35.84	80.3	13.9	64.9
T_2= RDF (nU)	75.6	19.16	38.32	87.1	14.1	66.8
T_3= RDF (NU) + SA $ZnSO_4$ @ 25 kgha^{-1}	40.0	19.98	39.96	98.2	14.7	69.4
T_4= RDF (NU) +SA $FeSO_4$ @ 5kgha^{-1}	38.7	19.34	38.68	90.9	14.3	68.9
T_5= RDF (NU) + SA $ZnSO_4$ @ 25 kgha^{-1} + SA $FeSO_4$ @ 5 kgha^{-1}	43.6	21.8	43.6	104.3	15.5	71.3
T_6= RDF (NU) + FA $ZnSO_4$ @ 0.5%	44.5	22.24	44.48	100.3	15.6	71.6
T_7 = RDF (NU) + FA $FeSO_4$ @ 0.5%	41.2	20.6	41.2	96.4	14.6	70.3
T_8= RDF (NU) + FA $ZnSO_4$ @ 0.5% + FA $FeSO_4$ @ 0.5%	46.5	23.26	46.52	106.4	16.4	75.0
T_9 = RDF (nU) + SA $ZnSO_4$ @ 25 kgha^{-1}	89.0	22.58	45.16	106.0	15.8	73.3
T_{10}= RDF (nU) + SA $FeSO_4$ @ 5kgha^{-1}	85.2	21.6	43.2	99.9	15.2	70.5
T_{11} = RDF (nU) + SA $ZnSO_4$ @ 25 kgha^{-1} + SA $FeSO_4$ @ 5 kgha^{-1}	92.0	23.32	46.64	108.4	16.2	77.0
T_{12}= RDF (nU) + FA $ZnSO_4$ @ 0.5%	89.7	22.76	45.52	107.6	16.2	73.6
T_{13}= RDF (nU) + FA $FeSO_4$ @ 0.5%	85.3	21.62	43.24	99.6	15.2	70.9
T_{14} = RDF (nU) + FA $ZnSO_4$ @ 0.5% + FA $FeSO_4$ @ 0.5%	93.0	23.58	47.16	111.5	16.9	82.3
T_{15} = Water spray	35.8	17.92	34.96	80.9	14.0	65.9
S.Em. ±	-	-	-	**2.12**	**0.53**	**2.87**
C.D @ 5%	-	-	-	**6.31**	**1.59**	**8.61**

Table 5: Absolute growth rate, Relative growth rate and Crop growth rate of pigeonpea as influenced by foliar application of nano urea at 120 to harvest.

Treatments	Absolute growth rate (g $plant^{-1}$ day^{-1})	Relative growth rate (g g^{-1} day^{-1})	Crop growth rate (g m^{-2} day^{-1})
T_1 = RDF (NU)	1.10	**120-At harvest**	7.89
T_2 = RDF (nU)	1.13	0.007	8.39
T_3 = RDF (NU) + SA $ZnSO_4$ @ 25 kg ha^{-1}	1.38	0.008	10.23
T_4 = RDF (NU) +SA $FeSO_4$ @ 5 kg ha^{-1}	1.30	0.008	9.62
T_5 = RDF (NU) + SA $ZnSO_4$ @ 25 kg ha^{-1} + SA $FeSO_4$ @ 5 kg ha^{-1}	1.42	0.008	10.48
T_6 = RDF (NU) + FA $ZnSO_4$ @ 0.5%	1.77	0.008	13.07
T_7 = RDF (NU) + FA $FeSO_4$ @ 0.5%	1.85	0.011	13.70
T_8 = RDF (NU) + FA $ZnSO_4$ @ 0.5% + FA $FeSO_4$ @ 0.5%	1.89	0.011	13.95
T_9 = RDF (nU) + SA $ZnSO_4$ @ 25 kg ha^{-1}	1.30	0.011	9.61
T_{10} = RDF (nU) + SA $FeSO_4$ @ 5 kg ha^{-1}	1.37	0.009	10.11
T_{11} = RDF (nU) + SA $ZnSO_4$ @ 25 kg ha^{-1} + SA $FeSO_4$ @ 5 kg ha^{-1}	1.55	0.008	11.47
T_{12} = RDF (nU) + FA $ZnSO_4$ @ 0.5%	1.92	0.008	14.22
T_{13} = RDF (nU) + FA $FeSO_4$ @ 0.5%	1.74	0.010	12.85
T_{14}= RDF (nU) + FA $ZnSO_4$ @ 0.5% + FA $FeSO_4$ @ 0.5%	1.97	0.010	14.57
T_{15} = Water spray	1.07	0.012	8.14
S.Em. ±	**0.08**	0.008	**0.57**
C.D. @ 5%	**0.22**	**0.0005**	**1.66**

CONCLUSIONS

Based on the results obtained from the present investigation, the following practices are beneficial in pigeonpea cultivation. Application of 100 per cent of RDPK and 50 per cent of RDN through normal urea as basal dose and foliar application of nano urea (3 ml l-1) in three sprays at 60, 90 and 120 DAS has improved the crop growth, yield, quality and B: C ratio in pigeonpea compared to only RDF through normal urea. Foliar application of water-soluble zinc and iron sulphate @ 5 per cent each, at flowering and pod development stages along with nano urea and RDF has produced higher growth, yield and improved quality of pigeonpea compared to the soil application of zinc and ferrous sulphate with nano urea. Foliar application of nano urea and water-soluble zinc and iron sulphate along with RDF in pigeonpea recorded 34.8 per cent higher yield compared to only RDF through normal urea. Application of RDF along with foliar application of nano urea and soil application of zinc and ferrous sulphate is more economical and recorded higher net returns (Rs. 39346 ha^{-1}) and B: C ratio (2.02) compared to only RDF.

FUTURE SCOPE

In depth study is required to know the impact of nano urea at different concentrations on biological nitrogen fixation in pigeonpea. Need to standardise the optimum dose of nano urea for field crops based on their nutrient requirement. Further, any potential risk or concerns due to the higher concentrations of nano urea should be critically analysed.

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