

**RESEARCH ARTICLE :**

Effect of conventional and nano micronutrient fertilizers on yield and economics of pigeonpea [*Cajanus cajan* (L.) Millsp.]

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SUMMARY : The field experiment was carried out with different grade foliar spray solutions and soil application of nano and conventional multi micronutrient fertilizers to study their effect on yield and economics of pigeonpea [*Cajanus cajan* (L.) Millsp.] during *Kharif* season, 2015 at Main Agriculture Research Station, Raichur. The results revealed that foliar spray of either conventional or nano multi micronutrients along with RDF have shown higher grain yields of pigeonpea when compared with the RDF alone (941.8 kg ha⁻¹). Among conventional and nano multi micronutrient foliar sprays, the conventional multi micronutrient mixtures showed comparatively higher yield over the nano. In the case of soil applications, the applications of nano and conventional sodium molybdate to the soil have given comparatively higher yields (951.5 and 984.7 kg ha⁻¹) than the RDF alone (941.8 kg ha⁻¹) but the differences in yields were non-significant. The cost economic analysis of various treatments has given the highest B:C ratio of 2.32 to the treatment conventional multi micronutrients along with RDF while B:C ratio was lowest (0.85) for nano multi micronutrient sowing to high input costs of nano micronutrients.

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BACKGROUND AND OBJECTIVES

Pigeonpea [*Cajanus cajan* (L.) Millsp.] the second most important pulse crop of India after chickpea being cultivated in a multitude of production systems for a diversity of uses *viz.*, grain as dhal, green seed as a vegetable and stalk as fuel wood. Pigeonpea is commonly known in India as redgram or *Arhar* or *Tur*. It is grown throughout the tropical and sub-tropical regions of the world,

between 30° N and 35° S latitudes. However, major area under pigeonpea in India is lying between 14° S and 28° N latitudes. Pigeonpea is predominantly grown in India during *Kharif* season both as a sole crop and as intercrop, and found in wide range of agro-ecological situations. Its deep rooting and drought tolerating character make it a successful crop in areas of low and uncertain rainfall.

In India, pigeonpea is grown in an area

of 36.3 lakh hectares with a production of 27.6 lakh tonnes and productivity being 760.33 kg ha⁻¹. In Karnataka, among the pulses, pigeonpea stands first in both area and production. The crop is grown in an area of 6.81 lakh hectares with a production of 4.85 lakh tonnes and productivity of 712.19 kg ha⁻¹ (Anonymous, 2014). The low productivity of pigeonpea in India may be attributed to vagaries of climate and poor soil nutrient management practices more particularly micronutrients.

Micronutrients play a significant role in plant growth and metabolic processes associated with photosynthesis, chlorophyll formation, cell wall development and respiration, water absorption, xylem permeability, resistance to plant diseases, enzyme activities involved in the synthesis of primary and secondary metabolites, and nitrogen fixation and reduction (Adhikary *et al.*, 2010 and Vitti *et al.*, 2014). However, as most of the nutrients are taken up into the plant in the forms of soluble inorganic ions by plant root system; therefore, water stress reduces nutrient absorbability and nutrient uptake of the plant in drought situations even when the crop is facilitated with balanced nutrition through soil application, a most common scenario that prevail in rainfed agriculture.

Foliar spraying have advantages of low application rates, uniform distribution of fertilizer materials and quick response to applied nutrients. Although there is still some speculation about the benefits and correct implementation of this practice, foliar application of specific nutrients is considered a better approach to improve the efficiency of fertilizer use and increase crop yields.

In recent years the use of nano sized fertilizer mixtures in agriculture is gaining momentum to enhance nutrient use efficiency and overcome the chronic problems associated with the high use of conventional fertilizers. Therefore, efforts have been made to assess the feasibility of nano micronutrient fertilizer in comparison to the conventional fertilizers on the yield and economics of pigeonpea.

RESOURCES AND METHODS

The field experiment was conducted during *Kharif*, 2015 at MARS farm, Raichur, situated in the North Eastern Dry Zone (Zone-2) of Karnataka between 16°15' N latitude and 77° 20' E longitude with an altitude of 389 m above the mean sea level. The treatment combinations were laid out in Randomized Block Design with nine treatments and three replications. The soil was medium

black with clay texture. It had slightly alkaline pH (8.13) and low EC (0.23 dS m⁻¹). The CEC of soil was medium (38.7 c mol(p⁺)kg⁻¹) while the soil organic carbon content was low (4.10 g kg⁻¹).

The soil was low in available nitrogen (139.4 kg ha⁻¹) and high in available phosphorous (58.62 kg ha⁻¹) and potassium (462.5 kg ha⁻¹). The concentrations of DTPA extractable micronutrients *viz.*, iron, manganese and zinc were 5.35, 7.61 and 0.51 mg kg⁻¹, respectively. The hot water soluble boron and ammonium acetate extractable molybdenum were 0.40 and 0.02 mg kg⁻¹, respectively.

The variety TS-3R used in the study is a short duration, red and bold seeded variety which matures in 145 to 150 days. It is resistant to both wilt and sterility mosaic and it issuitable for *Kharif* season.

The equivalent quantity of NPK and zinc sulphate required for each treatment plot was calculated and applied two days after the sowing of pigeonpea. The fertilizers were placed in furrows opened at 5 cm away from the seed line (crop row) and covered with soil. Full dose of P and zinc sulphate along with 50%N was applied as basal and the remaining 50% N was placed at 30 days after sowing. All other cultural and plant protection measures were followed as recommended.

The multi micronutrient mixture (Grade I) was prepared as per Karnataka State Department of Agriculture recommendations *i.e.*, Fe: 2.0%, Mn: 1.0%, Zn: 3.0 % and B: 0.5%. This mixture was prepared in the laboratory by using iron sulfate, manganese sulfate, zinc sulfate and boric acid. The nano micronutrients like FeO and ZnO were procured from Sisco Research Laboratory Pvt. Ltd., Mumbai, India. The particle size of the FeO and ZnO were observed to be around 87 nm and 134 nm, respectively (Plate 1). These sizes were confirmed by analyzing the samples in Scanning Electron Microscope (Evo-18, Zeiss Smart, Switzerland). On the other hand, nano micronutrients of manganese and boron were prepared from reagent grade MnO₂ and Boric acid by using high-speed cryo ball mill (Retsch, CryoMill) at Nano Technology Laboratory, UAS, Raichur. The particle size of the powdered MnO₂ and boric acid were analyzed by using Zetasizer (Malvern Zetasizer, Nano-ZS, Malvern Instruments, UK) at NTL, UAS Raichur and the particle sizes were found to be around 789 nm for MnO₂ and 10 nm for that of boric acid particles. The multi micronutrient mixture of nanoparticles containing Fe (0.2%), Zn(0.3%), Mn (0.1%) and B (0.05%) was

prepared by using the respective nanoparticles. The so prepared mixture solution was preserved by adding a pinch of citric acid powder with 109 nm size particles. The foliar application of above prepared conventional and nano multi micronutrient mixture solutions in respective treatment plots were taken at 70 DAS and 100 DAS by using the above stock solutions @ 10 ml per liter concentrations. Approximately, a spray volume of 500 litres per ha at 70 DAS and 750 litres per ha at 100 DAS was required to apply uniformly. The soil application of nano and conventional sodium molybdate was done @ 0.5 and 1.5 kg ha⁻¹, respectively. The application was carried out by mixing the required quantity of respective sodium molybdate with approximately 1.0 kg of soil from the respective treatment plot in a plastic tray and was applied along the seed line in respective treatment plots on the day of sowing.

Five tagged plants from the net plot area which were used for recording growth parameters were harvested separately at physiological maturity and were used for recording various yield components and grain yield.

Treatment details	
T ₁	: 100% RDF
T ₂	: T ₁ + Soil application of conventional sodium molybdate
T ₃	: T ₁ + Soil application of nano sodium molybdate
T ₄	: T ₁ + Foliar spray of conventional multi micronutrients
T ₅	: T ₁ + Foliar spray of nano multi micronutrients
T ₆	: T ₂ + Foliar spray of conventional multi micronutrients
T ₇	: T ₃ + Foliar spray of conventional multi micronutrients
T ₈	: T ₂ + Foliar spray of nano multi micronutrients
T ₉	: T ₃ + Foliar spray of nano multi micronutrients

Note: RDF of pigeonpea: 25:50:0:15 N, P₂O₅, K₂O, ZnSO₄ in kg ha⁻¹
 Multi micronutrient mixtures of Grade I as per KSDA (Fe: 2%, Mn: 1%, Zn: 3%, B: 0.5%) @ 10 ml per liter of water;
 Soil application of conventional sodium molybdate is @ 1.5 kg ha⁻¹ while nano sodium molybdate @ 0.5 kg ha⁻¹
 Nano micronutrients are foliar sprayed @10% of the conventional fertilizer doses *i.e.* Fe:0.2%; Mn:0.1%, Zn: 0.3% and B: 0.05%
 All the treatments received FYM @ 6.0 t ha⁻¹ as common application

OBSERVATIONS AND ANALYSIS

The present investigation was undertaken to study the effect of foliar application of nano and conventional micronutrients on yield and economy of pigeonpea cultivation. In general, the application of RDF along with either nano or conventional micronutrients either through

soil or foliar spray has resulted comparatively better yields than the soil application of RDF alone (948 kg ha⁻¹). In treatments that are supplemented with foliar sprays along with RDF, the treatment with foliar spray of conventional micronutrients gave higher yielded (1424 kg ha⁻¹) than the foliar spray of nano multi micronutrients (1281 kg ha⁻¹). On the other hand, the treatment with foliar spray of nano multi micronutrients along with soil application of conventional sodium molybdate recorded higher yield (1358 kg ha⁻¹) compared to the treatment with foliar spray of conventional micronutrients along with soil application of either nano or conventional sodium molybdate (Table 1).

From the study, as a whole it was observed that the highest grain yield of pigeonpea was from treatment plots that have received the RDF and foliar spray of conventional micronutrient mixture (1424 kg ha⁻¹) which is significantly higher over all other treatments. Thus, indicating that foliar spray of conventional micronutrient mixture is better than the nano products. However, it should be noted that the respective concentration of each of nano micronutrients used in the foliar spray solutions were lower *i.e.*, one tenth of the conventional micronutrient concentrations. Moreover, conventional multi micronutrient mixtures also carried sulphur along with them, an important secondary nutrient. These facts might have given added advantages to the treatments of foliar applications of conventional multi micronutrients over the nano multi micronutrients.

The improvement in yield is achieved through improvement in yield attributing characters like grain yield per plant and test weight of 100 grains. Moreover, the grain yield per plant is greatly influenced by dry matter accumulation in reproductive parts like pods. The highest dry matter production of reproductive parts was found in the treatment T₄ *i.e.* 18.50 g plant⁻¹ and 32.29 g plant⁻¹ at 100 DAS and at harvest, respectively when compared to all other treatment combinations. The differences in various yield components which led to significant yield differences among different multi micronutrients could be attributed to differences in dry matter production and its distribution into different plant parts. The total dry matter per plant was significantly higher with the application of RDF along with foliar spray of conventional multi micronutrients at 100 DAS (99.29 g plant⁻¹) and at harvest (136.5 g plant⁻¹) and was followed by RDF with foliar spray of nano micronutrients at 100 DAS (95.62 g plant⁻¹) and at harvest (130.7 g plant⁻¹) in the study. The

observation on dry matter accumulation of pigeonpea at 70 DAS has shown no clear trends and visible differences. This may be due to fact that the first foliar spray of either nano or conventional micronutrients was taken up at 71st day after sowing and the second was followed at 101st day after sowing. Therefore, impact of these foliar sprays could be reflected possibly at 100 DAS and at harvest of crop only.

In the present study, grain yield per plant (36.61 g) and test weight of 100 grains (13.53 g) were significantly higher in the treatment which received RDF with foliar spray of conventional multi micronutrient mixture to an extent of 29.8 and 25.3 per cent, respectively over the treatment that had RDF alone. The increase in yield can be attributed to the higher availability of assimilates with foliar spray of multi micronutrients. Further, significant differences in the seed yield of pigeonpea with foliar spray of micronutrients might be attributed to improved growth and yield components *viz.*, total dry matter production and its distribution into different plant parts, number of branches per plant, number of pods per plant, seed yield per plant and test weight of 100 grains. This

can be validated by the observed significant positive correlations among the above yield parameters with grain yield in the present study (Table 2). Similar findings and observations were also reported by Tekale *et al.* (2009); El-Seifi *et al.* (2013); Mukund *et al.* (2013) and Gowthami and Rama Rao (2014).

The higher grain yield of pigeonpea due to foliar spray of multi micronutrient mixtures can also be supported by the facts that these treatments have positive effect on growth and development of pigeonpea which is evidenced by higher plant height, number of branches, number of leaves and dry matter accumulation in leaves over RDF alone. Similarly, Ali *et al.* (2014) have also observed increase in plant growth parameters of mungbean with foliar spray of micronutrients.

Effect of soil application of both conventional and nano sodium molybdate were also assessed during the study. It is known that molybdenum has a key role in the development of root nodules and in symbiotic nitrogen fixation and thus beneficial for crop growth and development. However, in the present investigation, we failed to record and monitor the observations on number

Table 1 : Average crop yield parameters of pigeonpea as influenced by various treatments

Treatments	Number of pods plants ⁻¹	Number of grains pod ⁻¹	Test weight (g)	Grain yield (g plant ⁻¹)	Grain yield (kg ha ⁻¹)	Stalk yield (kg ha ⁻¹)	Husk yield (kg ha ⁻¹)
T ₁	136.7	2.13	10.11	25.68	942	2192	922
T ₂	139.3	2.16	10.31	26.32	952	2491	1143
T ₃	140.4	2.12	10.65	27.12	985	2310	1115
T ₄	159.2	2.34	13.53	36.61	1424	3275	1325
T ₅	156.3	2.40	11.97	31.90	1281	2916	1244
T ₆	147.1	2.59	12.21	31.35	1264	2677	1239
T ₇	155.2	2.29	12.16	32.10	1300	2730	1286
T ₈	157.3	2.46	12.49	35.01	1358	3124	1306
T ₉	148.5	2.31	11.95	30.24	1192	2612	1204
S.E. ±	3.428	0.073	0.463	1.590	47.69	183.1	27.01
C.D. (P=0.05)	10.29	NS	1.391	4.772	143.1	549.5	81.10

Note : T₁ – RDF (25:50:0 NPK kg ha⁻¹ + ZnSO₄ @ 15 kg ha⁻¹); T₂ – T₁ + Soil application of sodium molybdate (1.5 kg ha⁻¹); T₃–T₁ + Soil application of nano sodium molybdate (0.5 kg ha⁻¹); T₄ – T₁ + Foliar spray of multi micronutrients (Fe, Mn, Zn, B); T₅ – T₁ + Foliar spray of nano multi micronutrients (Fe, Mn, Zn, B); T₆ – T₂ + T₄; T₇ – T₃ – T₄; T₈ – T₂ + T₅; T₉ – T₃ + T₅

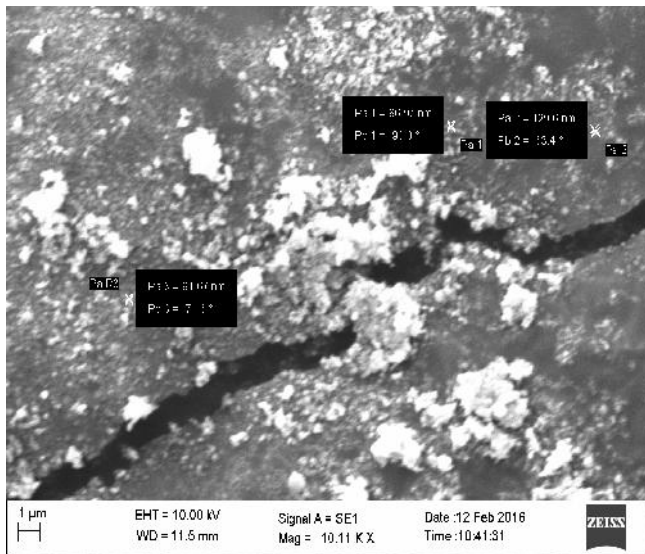
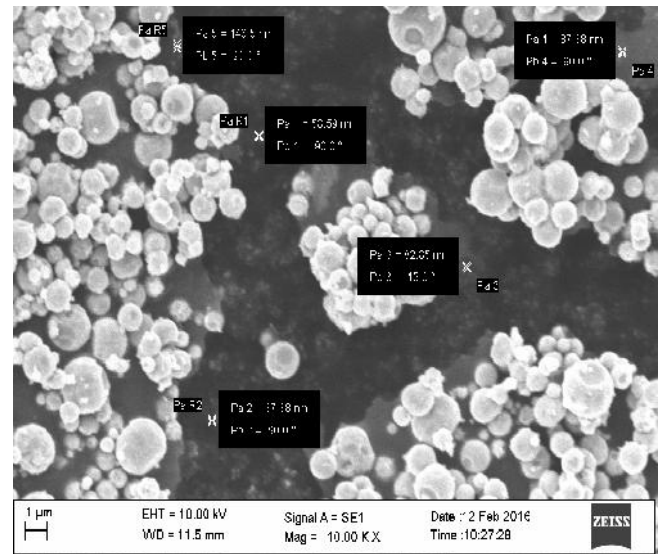
Table 2 : Simple correlation co-efficients between yield parameters of pigeonpea

Factor	1	2	3	4	5	6
Number of pods plant ⁻¹	1					
Number of grains pod ⁻¹	0.64	1				
Test weight (g)	0.92	0.72	1			
Grain yield (g plant ⁻¹)	0.95	0.70	0.97	1		
Grain yield (kg ha ⁻¹)	0.96	0.77	0.98	0.98	1	
Stalk yield (kg ha ⁻¹)	0.93	0.65	0.91	0.96	0.92	1

Table 3 : The economic analysis and benefit cost ratio of pigeonpea

Treatments	Cost of cultivation (Rs. ha ⁻¹)	Gross returns (Rs. ha ⁻¹)	Net returns (Rs. ha ⁻¹)	Benefit cost ratio
T ₁	31869	51799	19930	1.63
T ₂	34569	52335	17766	1.51
T ₃	34667	54161	19494	1.56
T ₄	33685	78309	44624	2.32
T ₅	85828	70439	-15390	0.82
T ₆	34885	69509	34624	1.99
T ₇	34982	71495	36512	2.04
T ₈	87028	74697	-12331	0.86
T ₉	87125	65566	-21560	0.75
S.E.±	-	-	1753	0.04
C.D. (P=0.05)	-	-	5254	0.13

Note : T₁ - RDF (25:50:0 NPK kg ha⁻¹ + ZnSO₄ @ 15 kg ha⁻¹); T₂ - T₁ + Soil application of sodium molybdate @ 1.5kg ha⁻¹; T₃ - T₁ + Soil application of nano sodium molybdate @ 0.5 kg ha⁻¹; T₄ - T₁ + Foliar spray of multi micronutrients (Fe, Mn, Zn, B); T₅ - T₁ + Foliar spray of nano multi micronutrients (Fe, Mn, Zn, B); T₆- T₂ + T₄; T₇- T₃ + T₄; T₈ - T₂ + T₅; T₉- T₃ + T₅

**Plate 1 (a) : SEM image of iron oxide (FeO) nano particles****Plate 1 (b) : SEM image of zinc oxide (ZnO) nano particles**

of root nodules, effective root nodules etc. owing to certain practical difficulties. Complete uprooting of roots was not practically possible after 70 DAS onwards. Leaving this aside, the observations on growth and yield of pigeonpea showed no added advantages due to application of these treatments when compared to the treatment RDF alone. On the other hand, a study by Karpagam and Rajesh (2014) have reported that soil application of sodium molybdate have given higher yield in greengram while Singh *et al.* (2014) observed improved crop growth and yield in mungbean with soil application of B and Mo.

The treatment which received RDF with foliar spray

of conventional multi micronutrient fertilizers recorded significantly higher gross returns (Rs.78,309), net returns (Rs. 44,624) and BC ratio (2.32) compared to rest of the treatments (Table 3). This is due to low input cost and high crop yield were obtained. On the other hand, treatments which received nano multi micronutrients (T₉, T₈, T₅) application had higher cost of cultivation (Rs. 87125, Rs. 87028, Rs. 85828, respectively) owing to high price of nanoparticles micronutrients and thus the net returns of these treatments were in negative and BC ratio is less than one *i.e.*, 0.75, 0.86, 0.82, respectively. Considering the above facts, the use of conventional multi micronutrients along with RDF has been found to be more

beneficial than other treatments.

Conclusion :

Based on the experimental results, one can conclude that foliar application of conventional multi micronutrients of Grade-I along with the recommended dose of fertilizer in pigeonpea at flower initiation and pod bearing stages can be more beneficial in terms of higher grain yield and higher net returns than the foliar application of nano multi micronutrients and soil application of either conventional or nano sodium molybdate.

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