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Shahna S Salim
M.Sc. Scholar, Department of Agronomy, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram, Kerala, India

Dr. Shimi GJ
Assistant Professor, Department of Agronomy, College of agriculture, Vellayani, Kerala Agricultural University, Thiruvanathapuram, Kerala, India

Dr. Shalini Pillai P
Professor and Head, Department of Agronomy, College of agriculture, Vellayani, Kerala Agricultural University, Thiruvanathapuram, Kerala, India

Dr. Sheeja K Raj
Assistant Professor, Department of Agronomy, College of agriculture, Vellayani, Kerala Agricultural University, Thiruvanathapuram, Kerala, India

Shruthy ON
Assistant Professor, Department of Vegetable Science, College of agriculture, Vellayani, Kerala Agricultural University, Thiruvanathapuram, Kerala, India

Corresponding Author:
Shahna S Salim
M.Sc. Scholar, Department of Agronomy, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram, Kerala, India

Effect of foliar application of nano-N and nano-Zn on growth and yield attributes in bush type vegetable cowpea (*Vigna unguiculata* subsp. *unguiculata* (L.) Verdcourt)

Shahna S Salim, Dr. Shimi GJ, Dr. Shalini Pillai P, Dr. Sheeja K Raj and Shruthy ON

Abstract
An experiment entitled "Enhancing nutrient use efficiency through Nano fertilizers in bush type vegetable cowpea (*Vigna unguiculata* subsp. *unguiculata* (L.) Verdcourt)" was conducted at College of Agriculture, Vellayani to assess and evaluate the effectiveness of foliar applied nano-N and nano-Zn on growth and yield attributes of bush type vegetable cowpea. The experiment was conducted during January to March 2022 in randomized block design with ten treatments replicated thrice. The variety of bush cowpea used was Bhagyalakshmi. Nano-N and nano-Zn were applied at 15 DAS, 30 DAS and 45 DAS in different treatment combinations to find the best treatment. Treatment T_5 (50 percent RDN + nano-N at 30 DAS + nano-Zn at 30 DAS) was found to be the best treatment which exhibited better growth attributes such as plant height, number of branches, number of leaves and leaf area per plant. Better yield attributes such as pod weight, number of pods per plant, pod yield per plant, haulm yield per plant, pod yield per hectare and haulm yield per hectare were also seen in T_5.

Keywords: Nano fertilizers, nano-N, nano-Zn, bush cowpea, growth, yield

Introduction
Agriculture sector is one of the most important sectors which plays a major role in ensuring food and nutritional security around the world. Green revolution was a major leap in meeting the food requirements of the rising population around the globe through the intensive use of fertilizers, agrochemicals, high yielding varieties etc. which ultimately led to an increase in world food production. However the adverse impacts of green revolution became evident in the later years. Intensive use of chemical fertilizers led to the deterioration of soil health and the quality of underground water. Eutrophication, nutrient imbalances and other environmental hazards occurred as a result of improper and unscientific management of conventional fertilizers (Alshaal and El-Ramady, 2017) [1].

Majority of the nutrients in conventional fertilisers are lost through leaching, volatilization, and soil fixation, which causes poor uptake and low nutrient use efficiency, leaving the crop with little access to these nutrients. Moreover, increasing population and depleting resources demand implementation of newer agriculture technologies. Here lies the significance of sustainable agriculture which ensures efficient utilization of agricultural inputs that provide nutritional and food security along with minimal losses and ecological imbalance. Foliar nutrition of crops with nano fertilizers is such an alternative to improve nutrient use efficiency on account of minimal wastage of nutrients as well as minimal impairment to the ecosystem.

Bush type vegetable cowpea (*Vigna unguiculata* subsp. *unguiculata* (L.) Verdcourt) was selected for the study as it is one of the preferred pulse crops of Kerala. In comparison to trailing types of cowpea, bush cowpea has a higher production potential, cultivation practices are significantly simpler, more convenient and also suitable for terrace cultivation in urban households.

Materials and Methods
A research work was conducted in bush type vegetable cowpea (*Vigna unguiculata* subsp. *unguiculata* (L.) Verdcourt) during January to March 2022 at The Instructional Farm, College of Agriculture, Vellayani with the objective of evaluation of effect of foliar applied nano-N

and nano-Zn on growth and yield in bush type vegetable cowpea.

The experiment was laid out in Randomized Block Design with 10 treatments and three replications. In all the treatments half dose of N, full P and K were given as basal as per Package of practice recommendation by Kerala Agricultural University (20:30:10 kg NPK ha^{-1}). The remaining N was provided in the form of nano-N through foliar application. Additionally, nano- Zn was also given through foliar application. IFFCO Nano urea and Nano-Zn were used as the sources of nano-N and nano-Zn respectively at the rate of 2 mL L^{-1}. Farm yard manure (20 t ha^{-1}) and lime (250 kg ha^{-1}) were also incorporated in the field at the time of land preparation.

The treatments were T_1:50 percent RDN + nano-N at 15 DAS, 30 DAS; T_2:RDN + nano-Zn at 30 DAS, 45 DAS; T_3:50 percent RDN + nano-N at 15 DAS + nano-Zn at 30 DAS; T_4:50 percent RDN + nano-N at 15 DAS + nano-Zn at 45 DAS; T_5:50 percent RDN + nano-N at 30 DAS + nano-Zn at 30 DAS; T_6:50 percent RDN + nano-N at 30 DAS + nano-Zn at 45 DAS; T_7:50 percent RDN + nano-N at 15 DAS, 30 DAS + nano-Zn at 30 DAS; T_8:50 percent RDN + nano-N at 15 DAS, 30 DAS + nano-Zn at 45 DAS; T_9:50 percent RDN + nano-N at 15 DAS, 30 DAS + nano-Zn at 30 and 45 DAS; T10:POP (½ N, full P and K as basal and ½ N at 15 DAS).

Results and Discussion

Growth and growth attributes

The results revealed that foliar application of nano-N and nano-Zn had significant effect on plant height, number of branches, leaf area index and dry matter production. At 30 DAS, T_2 recorded the tallest plants (47.75 cm) whereas at 60 DAS and at harvest stage, T_7 produced the tallest plants (77.63 cm and 82.08 cm respectively). The treatment T10 resulted in the highest number of branches at 30 DAS (2.72). At 60 DAS and at harvest, T_5 and T_7 produced higher number of branches per plant (3.69 and 3.95 respectively). At 30 DAS, T_2 (1.02) recorded significantly the highest LAI (leaf area index) and it was on par with T_{10}. Whereas at 60 DAS and at final harvest stage, T_5 resulted in the highest leaf area index (1.57 and 0.90 respectively) and it was found to be on par with T_9, T_7 and T_2. At 30 DAS, the highest dry matter production was noticed in T10 (3.86 g per plant) and was comparable to T2. Whereas at 60 DAS and at final harvest, T5 produced considerably higher dry matter of 24.89 and 37.36 g per plant respectively which was on par with T_2, T_7, T_9 and T_{10}.

Foliar nutrition of nanofertilizers helps in the efficient absorption and translocation of nutrients to different plant parts due to their small particle size which aids in easy penetration through stomatal openings and effective distribution throughout the plant system. The superior growth characteristics observed with foliar application of nano-N and nano-Zn might be due to the better availability, efficient absorption and utilization of the foliar applied nanofertilizers.

The higher nutrient use efficiency and significantly lower nutrient losses of nano fertilizers also lead to higher growth and productivity in crops (Mishra *et al*., 2020) [5]. Taller plants observed in nanofertilizer applied treatments (T_5, T_7, T_9 and T_2) might be due to the role of N on meristematic activity, cell division and cell expansion. Auxin synthesis might have been enhanced by nano-Zn treatment which would have accelerated the vegetative growth by encouraging cell division as mentioned by El-Tohamy and El-Greadly (2007) [2]. An improvement in the number of branches was also obtained by the foliar application of nano-N and nano-Zn which could be due to the improvement in nutrient uptake and translocation. The increased leaf area index obtained in the treatments receiving foliar nutrition of nano-N and nano-Zn were attributed to the increased number of leaves and leaf area as a result of enhanced cell division and cell expansion caused by nano-N and nano-Zn. Similar results were reported by Sathyan (2022) [7]. Effective absorption of N might have enhanced the chlorophyll synthesis which contributed to higher photosynthesis resulting in higher dry matter production in nano fertilizer applied treatments (T_5, T_9, T_7, $T1_0$ and T_2).

Table 1: Effect of foliar nutrition of nano-N and nano-Zn on growth attributes in bush type vegetable cowpea

Treatments	Plant height(cm)			No of branches per plant			Leaf area index			Dry matter production (g per plant)		
	30 DAS	60 DAS	At final harvest	30 DAS	60 DAS	At final harvest	30 DAS	60 DAS	At final harvest	30 DAS	60 DAS	At final harvest
T1: 50 percent RDN + nano-N at 15 DAS, 30DAS	43.58	72.08	78.08	2.41	3.22	3.23	0.93	1.21	0.56	3.42	20.84	31.63
T2: RDN + nano-Zn at 30 D AS, 45 DAS	47.75	74.71	79.03	2.71	3.48	3.74	1.02	1.47	0.84	3.79	23.12	36.05
T3: 50 percent RDN + nano-N at 15 DAS + nano-Zn at 30 DAS	43.75	71.42	74.21	2.47	3.16	3.47	0.90	0.98	0.56	3.27	21.06	32.07
T4: 50 percent RDN + nano-N at 15 DAS + nano-Zn at 45 DAS	42.08	68.21	70.92	2.36	3.06	3.21	0.70	0.87	0.52	3.23	18.81	28.86
T5: 50 percent RDN + Nano-N at 30 DAS + nano-Zn at 30 DAS	42.50	76.92	80.23	2.17	3.69	3.94	0.72	1.57	0.90	3.24	24.89	37.36
T6: 50 percent RDN + nano-N at 30 DAS + nano-Zn at 45 DAS	41.67	73.46	75.79	2.12	3.31	3.48	0.70	1.46	0.73	3.24	20.77	32.45
T7: 50 percent RDN + nano-N at 15 DAS, 30DAS + nano-Zn at 30 DAS	43.08	77.63	82.08	2.37	3.61	3.95	0.81	1.49	0.81	3.16	23.79	35.82
T8: 50 percent RDN + nano-N at 15 DAS, 30DAS + nano-Zn at 45 DAS	43.08	71.38	76.50	2.39	3.21	3.21	0.76	1.19	0.56	3.35	21.18	32.81
T9: 50 percent RDN + nano-N at 15 DAS, 30DAS + nano-Zn at 30 and 45 DAS	41.42	75.31	81.33	2.39	3.55	3.85	0.88	1.49	0.84	3.23	24.40	35.68
T10: POP (½ N, full P and K basal and ½ N at 15 DAS)	47.00	74.63	78.96	2.72	3.44	3.47	0.97	1.45	0.74	3.86	23.18	35.07
S.Em (±)	1.69	1.55	1.82	0.10	0.14	0.13	0.04	0.05	0.04	0.20	0.84	1.25
CD (0.05)	3.551	3.267	3.823	0.228	0.294	0.276	0.086	0.113	0.096	0.429	1.771	2.630

Yield and yield attributes

Pod weight, number of pods per plant, pod yield per plant, haulm yield per plant, pod yield per hectare and haulm yield per hectare were found to be significantly influenced by the foliar application of nano-N and nano-Zn. However, foliar application of nano-N and nano-Zn had no significant impact on days to 50 percent flowering, pod length, pod girth and harvest index. The treatment T_7 resulted in the highest pod weight (4.77 g) which was on par with T_9, T_5, T_2 and T_{10}. The highest number of pods per plant and pod yield per plant were observed in T_5 (27.80 and 98.31 g, respectively) which was found to be on par with T_7, T_9, T_2 and T_{10}. The highest pod yield per hectare was observed in T5 (7076 kg ha^{-1}) and was comparable to T_7, T_9, T_2 and T_{10}. The treatment T_5 recorded a 3.14% increase in yield over POP. The treatment T_9 recorded the highest haulm yield per plant and haulm yield per hectare of 27.13 g and 4522 kg ha^{-1} respectively and it was on par with T_5, T_7 and T_2.

The superiority in the yield and yield attributes obtained as a result of nanofertilizer application might be due to increase in leaf area which rendered the leaf surface more conductive to absorption of nutrients through foliar nutrition. This might have improved the production of flowers as a result of increased synthesis of carbohydrates and transport of sugar from the source to sites where they were needed during reproductive phase. This might be the reason for increase in the number of pods per plant. According to Fageria (1992) [3], the number of pods per plant is the most crucial factor that determined the yield in pulses. In view of the aforementioned, an increase in the number of pods per plant due to the foliar application of nano-N might have contributed to the higher yield. The highest number of pods per plant was noted in T_5 which was on par with T_7, T_9, T_2 and T_{10}. Similar trend was observed in pod yield per plant and pod yield per hectare. An yield enhancement of 3.14% was obtained in the T5 treatment where nano-N and nano-Zn were applied at 30 DAS compared to the POP treatment.

The possible reason for increase in activity of photosynthetic system might be due to the involvement of Zn in improving metabolic processes inside the plant system which consequently improved flowering and yield attributes (Quary *et al*., 2006) [6]. It could be assumed that increased absorption of Zn due to foliar application of nano-Zn improved the leaf area and leaf area index. Higher leaf area contributed to more carbohydrate production and translocation to the economic parts of plant resulted in higher yield. Higher translocation of carbohydrates to the sink might have led to the higher pod weight in nanofertilizer applied treatments. Among the treatments, the highest pod weight was observed in T_7 (50% RDN + nano-N at 15 DAS, 30 DAS + nano-Zn at 30 DAS) and was comparable with T_9, T_5, T_2 and T_{10}. The treatment T9 recorded the highest haulm yield per plant which was on par with T5, T7 and T2. A similar trend was also noticed in haulm yield per hectare. This was due to the overall enhancement in the vegetative growth and yield parameters broughtout by nano-N and nano- Zn foliar application at the active growth stages of the crop. The lowest harvest index found in nanofertlizer applied plots might be due to the higher vegetative growth attained along with higher yield. Days to 50% flowering, pod length and pod girth was also not influenced as these characters were linked to the genetic makeup of the crop variety.

Table 2: Effect of foliar nutrition of nano-N and nano-Zn on yield attributes in bush type vegetable cowpea

Treatments	Days to 50% flowering	Pod length (cm)	Pod girth (cm)	Pod weight (g)	Number of pods per plant	Pod yield per plant (g)	Dry haulm yield per plant (g)	Green pod yield (kg ha^{-1})	Dry haulm yield (kg ha^{-1})	Harvest Index
T1: 50 percent RDN + nano-N at 15 DAS, 30DAS	47.33	16.25	1.96	4.37	21.80	87.91	23.35	6621	3892	0.417
T2: RDN + nano-Zn at 30 D AS, 45 DAS	47.33	16.84	1.98	4.61	26.47	95.96	25.43	6888	4239	0.406
T3: 50 percent RDN + nano-N at 15 DAS + nano-Zn at 30 DAS	46.67	16.13	1.95	4.48	20.50	76.87	20.84	5962	3473	0.419
T4: 50 percent RDN + nano-N at 15 DAS + nano-Zn at 45 DAS	48.00	15.69	1.95	4.34	19.80	76.51	19.09	5431	3282	0.410
T5: 50 percent RDN + Nano-N at 30 DAS + nano-Zn at 30 DAS	45.67	16.58	2.00	4.73	27.80	98.31	27.09	7076	4514	0.397
T6: 50 percent RDN + nano-N at 30 DAS + nano-Zn at 45 DAS	47.67	16.30	1.96	4.39	22.37	84.40	24.34	6470	4057	0.401
T7: 50 percent RDN + nano-N at 15 DAS, 30DAS + nano-Zn at 30 DAS	46.33	16.44	1.97	4.77	27.27	96.76	26.42	6915	4403	0.398
T8: 50 percent RDN + nano-N at 15 DAS, 30DAS + nano-Zn at 45 DAS	47.67	16.12	1.97	4.37	20.93	81.57	22.98	5903	3830	0.393
T9: 50 percent RDN + nano-N at 15 DAS, 30DAS + nano-Zn at 30 and 45 DAS	46.67	16.38	2.05	4.74	26.57	96.51	27.13	6890	4522	0.390
T10: POP (½ N, full P and K basal and ½ N at 15 DAS)	47.33	16.35	1.96	4.57	25.52	95.84	23.59	6859	3931	0.423
S.Em (±)	0.65	0.34	0.03	0.10	1.11	1.71	0.92	147.96	144.34	0.01
CD (0.05)	NS	NS	NS	0.210	2.345	3.612	1.953	310.878	303.270	NS

Conclusion

From the study it could be concluded that application of half the recommended dose of N (10 kg ha-1), full P (30 kg ha-1) and full K (10 kg ha-1) as basal dose followed by foliar application of N as nano urea and Zn as nano zinc each at the rate of 2 mL L-1 separately at 30 DAS could result in better growth and yield in bush type vegetable cowpea.

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