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Effect of Nano-Fertilizer on Growth and Yield of Green Gram (*Vigna radiata* L.)

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Abstract
The present investigation aimed to find out the "Effect of Nano-Fertilizer on Growth and Yield of Green Gram (*Vigna radiata* L.) was carried out at Agronomy Research Farm of Faculty of Agriculture and Veterinary Science, Mewar University, Gangrar, Chittorgarh, Rajasthan. Geographically Chittorgarh. The experiment was laid out in Randomized Block Design. Replicated thrice with 10 treatment combinations, comprising like T_1 Control, T_2 Foliar spray Nano Zinc @ 1 per cent, T_3 2 Foliar spray Nano Zinc @ 2 per cent, T_4 Foliar spray Nano DAP @ 1 per cent. T_5 Foliar spray Nano DAP @ 2 per cent, T_6 Foliar spray Nano Urea @ 1 per cent, T_7 Foliar spray Nano Urea @ 2 per cent, T_8 Foliar spray Nano Zinc+ DAP @ 1.5 per cent, T_9 Foliar spray Nano Zinc+ Urea @ 1.5 per cent and T_{10} Foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent. The results reveled that during experiment use of different nano-fertilizer on growth, yield and economics of green gram its effect among all treatments T_{10} (Foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent) was found to significantly increase growth, yield and economics of parameters, yield as well as economic of green gram. It was found that maximum value of growth parameters viz., the plant height was found to be the maximum plant height (35.12, 47.66 and 54.03 cm) at 30 DAS, 45 DAS and at harvest chlorophyll content (1.21) at 40 DAS, dry matter accumulation (4.86 and 7.65) at 25 DAS, 50 DAS, number of branches (6.36, 11.02 and 13.85) at 30 and, 45 DAS and at harvest. Yield attributes and yield *viz*., grain per pod was recorded significant maximum (6.50), pod length (6.36 cm), grain yield per plot (0.810 kg), higher seed yield (13.50 q/ha), higher biological yield in T_{10} (38.96 q/ha), maximum straw yield was (25.46 q/ha), maximum harvest index was (34.65 q/ha) economics viz., Maximum fetched value in term of net return (75250.00 ₹/ha) and B: C ratio (2.89) were recorded with foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent.

Keywords: Nano-fertilizer Green gram on growth, yield and economics

Introduction
Green gram (*Vigna radiata* (L.) Wilczek] also known as mung bean, is one of the important short duration pulse crop of India. It is the third most important pulse crop after chickpea and pigeon pea. It is grown in arid and semi-arid regions of the country. In Rajathan, green gram is mainly grown *kharif* season under inadequate and erratic rainfall. However, it is grown in large areas during summer season in many districts.

Growing of green gram in summer allows the farmers to utilize their land during the summer months which remains unused. Photo-insensitive short duration varieties of green gram (60-70 days) which could easily be placed before sowing of rainy season crops for catching the opportunity of summer rainfall are frequently available during this period (Kumar *et al.* 2013) [6].

Nano Zinc fertilizer is a specially blended liquid Zinc nutrient mix that is intended for use in animal feed additives and agricultural fertilization programs. It contains ionized Zinc particles embedded in a colloidal amino acid matrix. It is a crucial part of the several enzymes that are in charge regulating for initiating numerous metabolic processes in all crops. Its main purpose is to support the plant's many metabolic processes, such as the synthesis of chlorophyll and membrane integrity. Foliar nutrition of nano fertilizers 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.

Results and Discussion

Growth Parameters

The data pertaining to of growth as influenced by different treatments are presented in Table 1, 2 and 3. The significant differences in growth were recorded to different nano-fertilizer treatments. The maximum plant height (35.12, 47.66 and 54.03 cm) at 30 DAS, 45 DAS and at harvest, maximum chlorophyll content (1.21) at 40 DAS, maximum dry matter accumulation (4.86 and 7.65) at 25 DAS, 50 DAS, number of branch (6.36, 11.02 and 13.85) at 30 and, 45 DAS and at harvest were recorded, with T_{10} (Foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent).

The nano fertilizers have higher nutrient use efficiency as compared to the conventional fertilizers due to their nano size which enables the plants to quickly absorb them through the stomatal openings and pore openings. The nano fertilizers have high effective surface area which enables them to get involved in various biochemical and physiological processes in plants. The losses of nutrients when applied in the form of conventional fertilizers in soil results due to leaching, fixation, volatization (Mishra *et al*. 2020) [8].

The adequate supply of major nutrients, nitrogen and phosphorus, from foliar spray of nano fertilizers ensured sufficient nutrient availability for the treatment combinations foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent. This ample supply resulted in greater growth in terms of number of functional leaves and number of branches. As previously mentioned, nitrogen plays a crucial role in the vegetative growth of plants, while phosphorus supports efficient metabolic activities, root development, and nodulation in leguminous plants due to its role as a source of energy compounds.

The improved growth characters i.e. number of functional leaves and number of branches under the treatment led to better interception of solar energy and production of more photosynthates or source. The higher source available under the treatment combination foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent resulted in proportionally production of higher sink further leading to significantly higher weight of pods plant^{-1} and grain yield.

Similar results were obtained by Awasarmal *et al*. (2015), Somalraju *et al*. (2021) [2, 12] who reported that, the increased supply of nutrients led to a higher production of assimilates and proteins, enhancing metabolic processes and subsequently improving growth parameters

Yield attributes and yield

The significantly effect of nano- fertilizer on yield data presented in Table 4 and 5. The grain per pod maximum (6.50), The maximum pod length (6.36 cm), grain yield per plot (0.810 kg), higher seed yield (13.50 q/ha), higher biological yield in T_{10} (38.96 q/ha), maximum straw yield was (25.46 q/ha), maximum harvest index was (34.65 q/ha) respectively (Foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent), significantly higher than the other treatments. Might be due to the favorable effects of nutrient management and also due to the presence of beneficial microorganisms as reported by (Meena *et al*., 2016, Hadiyal *et al*., 2017 and Saini *et al*., 2017) [7, 3]. It was reported that the beneficial effects of nano-fertilizer, which attributed to huge quantity of microbial load and growth hormones which in turn might have enhanced the soil biomass, thereby sustaining the availability and uptake of applied as well as native soil nutrients which ultimately have resulted in better growth and yield of crops. These findings are in conformity with the results of Kumar and Singh (2019) [5].

Nano fertilizers, with their large surface area and smaller size, are easily absorbed by plants through stomatal and pore openings, enhancing their nutrient use efficiency. According to Razauddin *et al*. (2023) [10], once absorbed these nano fertilizers dissolve quickly in the plant's internal aqueous environment. As a result, even small quantities of nutrients in nano form are highly effective for the plants. Considering the major nutrients, nitrogen is a vital component of chlorophyll, protein, and nucleic acids, and it is crucial for cell division and enlargement. According to Srivastava and Singh (2023) [13], increased nitrogen availability improves the processes of protein synthesis and photosynthesis, causing cells to proliferate and lengthen quickly, ultimately leading to improved plant growth. Phosphorus significantly enhances root growth and is essential for the formation of nodules in leguminous plants, which increases nitrogen availability to the plants. Additionally, phosphorus is a key component of energy compounds such as ADP and ATP. This led to the plants under the treatments T_{10} becoming physiologically and metabolically more active resulting into superior growth characters under these treatments.

The improved growth attributes under the treatment foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent resulted in better translocation of photsynthates from source to sink leading to enhancement of yield character i.e. pods plant-1 and ultimately producing higher grain yield. This results are similar to those of Khemshetty *et al*. (2024), Yomso *et al*. (2023) and Prakash *et al*. (2023) [4, 14, 9] who stated that, the role of nano urea and nano phosphorus in plant metabolic activities facilitated effective translocation of assimilates from source to sink, leading to improved yield attributing traits

Economics

Significantly noted net return of green gram data showed in Table 6. Maximum fetched value in term of net return (75250.00 ₹/ha) and B:C ratio was recorded (2.89) with foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent. Though the cost of cultivation was higher under foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent, the amount of yield put forth by foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent was considerably higher as compared to the cost involved in its production, therefore the net returns and benefit-cost ratio were higher under foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent. Abd-El-Azeim *et al*. (2020) reported that, due to increase in yield the crop fetched more market price which resulted in increase in B:C ratio and other economic parameters

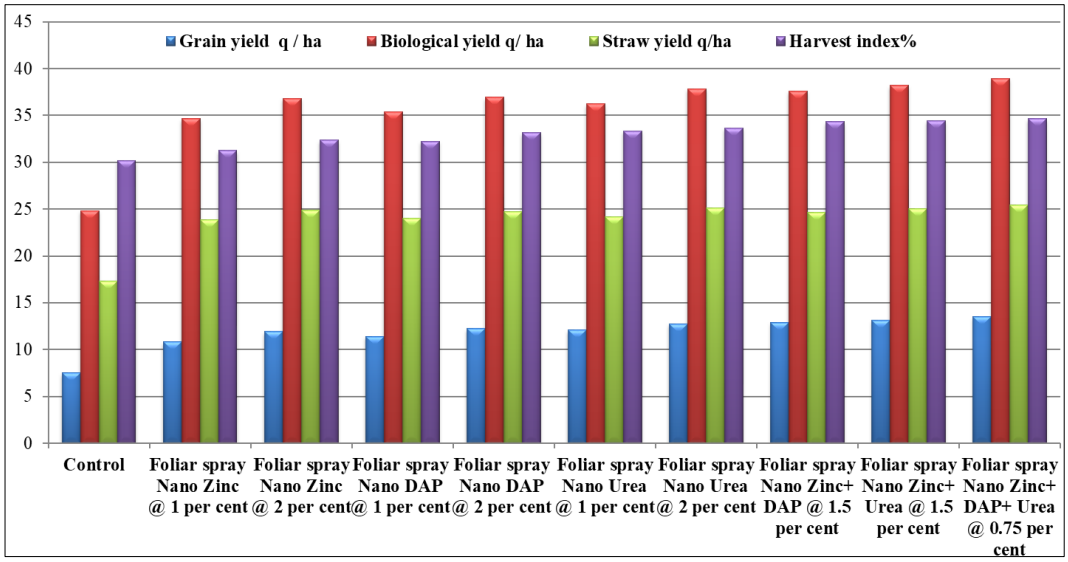

Fig 1: Effect of Nano-fertilizer on yield attributes of green gram

Table 1: Effect of Nano-fertilizer on plant height of green gram

Sr. No.	Treatments	Plant height (cm)		
		30 DAS	45 DAS	At harvest
T_1	Control	23.60	35.32	38.21
T_2	Foliar spray Nano Zinc @ 1 per cent	28.65	38.36	43.30
T_3	Foliar spray Nano Zinc @ 2 per cent	29.33	41.02	48.65
T_4	Foliar spray Nano DAP @ 1 per cent	28.98	39.36	48.06
T_5	Foliar spray Nano DAP @ 2 per cent	31.25	42.65	51.32
T_6	Foliar spray Nano Urea @ 1 per cent	30.02	42.36	50.12
T_7	Foliar spray Nano Urea @ 2 per cent	32.55	43.36	52.12
T_8	Foliar spray Nano Zinc+ DAP @ 1.5 per cent	33.26	44.30	53.32
T_9	Foliar spray Nano Zinc+ Urea @ 1.5 per cent	34.25	45.12	53.42
T_{10}	Foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent	35.12	47.66	54.03
	SEm ±	0.37	0.68	0.58
	CD @ 5 %	1.11	2.01	1.71
	CV %	8.32	8.36	9.11

Table 2: Effect of Nano-fertilizer on, chlorophyll and dry matter accumulation of green gram

Sr. No.	Treatments	Chlorophyll content at 40 DAS	Dry matter accumulation	
			25 DAS	50 DAS
T_1	Control	1.03	2.05	4.36
T_2	Foliar spray Nano Zinc @ 1 per cent	1.07	3.02	5.23
T_3	Foliar spray Nano Zinc @ 2 per cent	1.13	4.01	5.65
T_4	Foliar spray Nano DAP @ 1 per cent	1.10	3.45	5.35
T_5	Foliar spray Nano DAP @ 2 per cent	1.16	4.52	6.12
T_6	Foliar spray Nano Urea @ 1 per cent	1.15	4.15	5.85
T_7	Foliar spray Nano Urea @ 2 per cent	1.17	4.63	6.23
T_8	Foliar spray Nano Zinc+ DAP @ 1.5 per cent	1.18	4.75	6.35
T_9	Foliar spray Nano Zinc+ Urea @ 1.5 per cent	1.19	4.79	7.25
T_{10}	Foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent	1.21	4.86	7.65
	SEm ±	0.02	0.06	0.10
	CD @ 5 %	0.06	0.18	0.29
	CV %	9.35	8.45	8.05

Table 3: Effect of Nano-fertilizer on number of branch of green gram

Sr. No.	Treatments	Number of Branch		
		At 30 DAS	At 45 DAS	At harvest
T_1	Control	3.15	5.36	8.65
T_2	Foliar spray Nano Zinc @ 1 per cent	3.29	7.35	10.21
T_3	Foliar spray Nano Zinc @ 2 per cent	4.52	7.89	12.20
T_4	Foliar spray Nano DAP @ 1 per cent	4.35	7.45	10.25
T_5	Foliar spray Nano DAP @ 2 per cent	4.86	8.75	13.52
T_6	Foliar spray Nano Urea @ 1 per cent	4.65	8.65	12.56
T_7	Foliar spray Nano Urea @ 2 per cent	5.12	9.65	13.01
T_8	Foliar spray Nano Zinc+ DAP @ 1.5 per cent	5.23	10.12	13.06

T_9	Foliar spray Nano Zinc+ Urea @ 1.5 per cent	5.66	10.65	13.56
T_{10}	Foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent	6.36	11.02	13.85
	SEm ±	0.08	0.13	0.15
	CD @ 5 %	0.24	0.39	0.43
	CV %	8.36	8.01	9.14

Table 4: Effect of Nano-fertilizer on, Grain per pod, Pod length per plant and Grain yield per plot (kg) of green gram

Treatments	Treatments combination	Grain per pod	Pod length per plant (cm)	Grain yield per plot (kg)
T_1	Control	3.45	3.25	0.450
T_2	Foliar spray Nano Zinc @ 1 per cent	4.25	3.85	0.650
T_3	Foliar spray Nano Zinc @ 2 per cent	4.68	4.36	0.715
T_4	Foliar spray Nano DAP @ 1 per cent	4.65	4.02	0.685
T_5	Foliar spray Nano DAP @ 2 per cent	5.65	4.56	0.735
T_6	Foliar spray Nano Urea @ 1 per cent	5.00	4.32	0.725
T_7	Foliar spray Nano Urea @ 2 per cent	5.75	4.68	0.765
T_8	Foliar spray Nano Zinc+ DAP @ 1.5 per cent	5.86	5.66	0.775
T_9	Foliar spray Nano Zinc+ Urea @ 1.5 per cent	6.02	5.86	0.790
T_{10}	Foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent	6.50	6.36	0.810
	Sem	0.07	0.06	0.01
	CD at 5 %	0.20	0.17	0.04
	CV %	9.32	8.34	8.65

Table 5: Effect of Nano-fertilizer on yield attributes of green gram

Sr. No.	Treatments	Yield			
		Grain yield q / ha	Biological yield q/ ha	Straw yield q/ha	Harvest index%
T_1	Control	7.50	24.83	17.33	30.21
T_2	Foliar spray Nano Zinc @ 1 per cent	10.83	34.67	23.83	31.25
T_3	Foliar spray Nano Zinc @ 2 per cent	11.92	36.84	24.92	32.35
T_4	Foliar spray Nano DAP @ 1 per cent	11.42	35.42	24.01	32.23
T_5	Foliar spray Nano DAP @ 2 per cent	12.25	36.96	24.71	33.14
T_6	Foliar spray Nano Urea @ 1 per cent	12.08	36.23	24.15	33.35
T_7	Foliar spray Nano Urea @ 2 per cent	12.75	37.86	25.11	33.68
T_8	Foliar spray Nano Zinc+ DAP @ 1.5 per cent	12.92	37.60	24.69	34.35
T_9	Foliar spray Nano Zinc+ Urea @ 1.5 per cent	13.17	38.22	25.05	34.45
T_{10}	Foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent	13.50	38.96	25.46	34.65
	SEm ±	0.13	0.45	0.27	0.26
	CD @ 5 %	0.39	1.35	0.82	0.78
	CV %	8.23	9.15	8.65	8.47

Table 6: Effect of Nano-fertilizer on economics of green gram

Treatments	Treatments combination	Net return	B:C ratio
T_1	Control	38250.00	2.13
T_2	Foliar spray Nano Zinc @ 1 per cent	56250.00	2.25
T_3	Foliar spray Nano Zinc @ 2 per cent	62375.00	2.31
T_4	Foliar spray Nano DAP @ 1 per cent	59625.00	2.29
T_5	Foliar spray Nano DAP @ 2 per cent	66875.00	2.68
T_6	Foliar spray Nano Urea @ 1 per cent	63625.00	2.36
T_7	Foliar spray Nano Urea @ 2 per cent	69625.00	2.68
T_8	Foliar spray Nano Zinc+ DAP @ 1.5 per cent	71875.00	2.88
T_9	Foliar spray Nano Zinc+ Urea @ 1.5 per cent	73250.00	2.87
T_{10}	Foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent	75250.00	2.89
	Sem±	1070.53	0.03
	CD at 5 %	3180.70	0.09
	CV %	9.66	9.45

Conclusion

Thus, it can be concluded that to obtain higher growth, yield, net returns and benefit-cost ratio from the white green gram foliar spray Nano Zinc+ DAP+ Urea @ 0.75 per cent through two sprays at flowering and 15 DAF for green gram should be applied. The observations are based on one season data, to get more precise information, it is suggested that the experiment.

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