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The Influence of Nano-fertilizers Priming on Augmenting Groundnut (*Arachis hypogaea* L.) Growth, Yield and Quality

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ABSTRACT

Background: Groundnut is one of the most important oilseed crops and also a good source of proteins, carbohydrates and fibre. Conventionally, groundnut cultivation also need good amount of commercial nitrogen fertilizers which are found to be not efficiently and effectively utilized by the plants, also lost due to leaching and so, causing severe ecological damage. However, our study of priming groundnut seeds with nanofertilizers have reduced the dosage of fertilizers as well as increased the yields.

Methods: A two-year field experiment (2020-2021) was carried out to evaluate the effect of nano fertilizers (NF) (phosphorus, zinc, and iron) seed priming and NF foliar spray on the growth, yield, and seed quality characteristics of groundnut var TG-37 A. Groundnut was chosen as the testcrop and seeds were primed with nanofertilizers as well as standing crop is foliar sprayed with nanofertilizer at pre-flowering stage. The effect of nanofertilizers on test crop was evaluated on seed germination, seedling vigor, plant growth, flowering, chlorophyll content, pod yield, oil content and protein content.

Result: The results indicated that in both the years, NF seed primingandfoliar sprays treatments showed higher seed germination and seedling vigor aided in early establishment in soil, which manifested by higher plant height, early flowering, higher leaf chlorophyll content, 100-seed weight and shelling percentage. Pod yield per plant was 30.1% and 33.0% higher in 2020 and 2021, respectively, as compared to the control. In both years, the application of nano fertilizers considerably boosted the oil and protein content compared to the control (31.5% and 28.9% for oil, 33.1% and 30.0% for protein). Thus, it is concluded that nano-fertilizers considerably improved growth, yield and quality of groundnut.

Keywords: *Arachis hypogea*, Groundnut, Nanofertilizers, Seed quality, Seedling Vigour.

INTRODUCTION

The groundnut (*Arachis hypogea* L.) is one of the most important and cost-effective oleaginous crops cultivated in the world's tropical and subtropical climates, owing to its oil, protein and carbohydrates (Panhwar, 2005). Groundnut seeds contains oil (45%), protein (26-28%), carbohydrates (20%) and fiber (5%), showing their outstanding nutritional value for both humans as well as animal consumption (Fageria *et al*., 2010). Thus, groundnuts are known for their nutritional benefits and their ability to grow under rainfed areas.

Across the world, agriculture is facing many challenges *viz*., crop yield stagnation, decrease in arable land due to land degradation and urbanization, low nutrient use efficiency, nutrient deficiencies, declining soil organic matter and water scarcity, *etc*. It will be difficult to produce enough food to feed the teeming population, which is expected to cross 9 billion by 2050 (UNDESA, 2022). Hence, there is a need to increase crop productivity through the development of new input-responsive cultivars and adoption of intensive cropping systems. However, the injudicious use of agrichemicals more than recommended doses leads to several problems like environmental pollution, higher cost of production, reduction in input use efficiency, contaminations and residues affecting quality of agricultural produce, development of resistance and pest resurgence, reduction in income and net-profits, soil degradation, deficiency of soil micronutrient, toxicity to different beneficial living organism present above and below the soil surface, *etc*. For solving these problems in crop production, nano-formulations are assumed to be very effective in agriculture for pest and nutrient management. Various research findings elucidated that because these nano-materials have more penetration capacity, enhance surface area and use efficiency thus they are eco-friendly as they reduce environmental pollution. In order to reduce the dosages and simplify applications, scientists have been looking out for new technologies.

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Nanotechnology research assumes importance in agriculture, which reduces fertilizer quantities and enhances fertilizer efficiency to a tune of 20 to 50% (nitrogen), 10-25% (phosphorus) and 70-80% (potassium) (Shaviv, 2000; Guru *et al*., 2015). In nanotechnology, the active ingredients of agrichemicals like nano-fertilizers are encapsulated/ coated with nanomaterials for a controlled and slow delivery of one or more nutrients in order to satisfy the imperative nutrient requirements of plants.

To assess the efficacy of nano-fertilizers in producing good seed crops of groundnut, various combinations of fertilizer doses were compared. Considering the importance of nanofertilizers, this research was conducted to investigate the individual and combined effects of seed priming and foliar spray of nanofertilizers on the growth metrics, yield components and quality of groundnut.

MATERIALS AND METHODS

The site and crop management

The present experiment was conducted in the 2020 and 2021 cropping seasons in a randomized block design with four replications at Seed Production Farm, Seed Research and Technology Centre (SRTC), Professor Jayashankar Telangana State Agricultural University, Hyderabad, India.

The groundnut variety TG-37 A developed by The Energy and Resource Institute (TERI) by crossing TG 24 and TG 26 was chosen as test crop and was characterized by semi-dwarf in height, Spanish bunch habit, smooth pod surface and compact pod setting.

The spacing of planting rows was 30 cm and plant spacing within the row was 10 cm in a plot of 5 m $\times$ 2.25 m, in which we could establish a crop stand of approximately 370 plants per plot. Four treatments were chosen for both the experiments *i.e.,* Hydro priming + No fertilizers: control (C), Hydro priming + recommended dose of fertilizers (RDF) - (35:40:45 N:P:K kg ha^{-1}) and 500 kg ha^{-1} of gypsum, Seed priming with Nano P, Nano Zn and Nano Fe (SP), Seed priming with Nano P, Nano Zn and Nano Fe + Foliar Spray with Nano P, Nano Zn and Nano Fe at pre-flowering stage (SP+FS) (Table 1). The major source of nitrogen is given as Urea (46% N), Phosphorus as Single Superphosphate (16% P_2O_5), Potassium as Muriate of Potash (60% K_2O) and Zinc as Zinc Sulphate (Zinc 21%). Full dosage of phosphorus, potassium and half the dosage of nitrogen were given as basal fertilizers, while the recommended gypsum and the remaining nitrogen are given during flowering stage. Weeds were controlled by hand at the initial flowering and pod formation stages. The homogenized nano formulation were used for seed priming prior to sowing, shade dried and used for sowing. To assess the efficacy of various treatments, we recorded various growth, yield and quality metrics in both the experiments.

Observations recorded

Shoot length (cm)

The shoot length was measured from the ground level to the tip of the growing point and expressed as cm.

Dry matter production (mg per seedlings)

The seedlings selected for measuring shoot length was placed in a paper cover, shade dried for 24 hours and dried them at 80°C for 16±1 hours in a hot air oven. Then they were cooled in a desiccator, weighed and expressed as milligrams per seedlings.

Seedling vigour index I

The seedling vigour index was computed using the following formula and expressed the mean values as a whole number (Abdul-Baki and Anderson, 1973; ISTA, 2023).

Seedling vigour index I =

$$\text{Germination (\%)} \times \text{Total seedling length (cm)}$$

Seedling vigour index II

Seedling Vigour index II =

$$\text{Germination (\%)} \times \text{Seedling dry weight}$$

(Abdul-Baki and Anderson, 1973; ISTA, 2023).

Table 1: Details of various fertilizers treatments used in the conduct of the experiment.

Treatment	Details of fertilizer application
T1	No fertilizer (Control).
T2	The recommended dose of fertilizers (RDF) for Telangana state by PJTSAU.
T3	100 % RDF + Seed priming with Nano P, Nano Zn and Nano Fe.
T4	100 % RDF + Seed priming with Nano P, Nano Zn and Nano Fe + Foliar Spray with Nano P, Nano Zn and Nano Fe at flowering stage.

T1: Cultivation of groundnut var TG-37A by following all recommended agronomical practices except the application of fertilizers.

T2: Cultivation of groundnut var TG-37A by following all recommended agronomical practices including the application of fertilizers (20 N : 40 P : 50 K kg/ha as basal and gypsum at flowering stage) by PJTSAU groundnut production manual.

T3: Cultivation of groundnut var TG-37A by following all recommended agronomical practices as in T2 while nanofertilizers are applied as seed priming before sowing.

T4: Cultivation of groundnut var TG-37A by following all recommended agronomical practices as in T2 while nanofertilizers are applied as seed priming before sowing as well top dressing at flowering stage.

Kernel nitrogen, oil and protein content

The kernels were taken from each treatment and the nitrogen percentage was determined. The kernels were dried in a drying chamber at 75°C for 72 hours and then milled and stored for further analysis. A weight of 0.5 grams of the seed powder was wet-digested with sulfuric acid (H_2SO_4) and perchloric acid ($HClO_4$) mixture. Total nitrogen was determined in Micro-Kjeldahl method (Humphries, 1956).

The protein content in the groundnut seeds was calculated by using Equation (Mariotti *et al*., 2008) as total crude protein= Nitrogen content (%) × 6.25.

The seed oil content was determined by using the Soxhlet method (Heldrich, 1990).

Yield and yield parameters

The yield was recorded at maturity, including the shelling percentage (%), number of pods per plant, 100-seed weight and pod yield. All the yield component observations were taken by mean values of five randomly selected plants during harvesting. The kernels were separated from the pods and air-dried to calculate the yield per plot, which was then converted to into yield per hectare.

The shelling percentage was determined as the total weight of groundnut seed (Ws) divided by the total weight of pods (Wp) (Konlan *et al*., 2013)

$$\text{Shelling percentage (\%)} = \frac{Ws}{Wp} \times 100$$

Statistical analysis

The experimental data were statistically analyzed using SPSS (ver.23.0) software and data means compared by the least significant difference test (LSD) at *p*= 0.05.

RESULTS AND DISCUSSION

Effect on seedling emergence

Due to priming of seeds, germination percentage was significantly increased. Among the seed priming treatments, nanofertilizer priming for 24 hours along with FS at pre-flowering stage (T4) gave significantly higher percentage of germination (84.6% and 84.2%) in both the years, respectively, followed by seed priming (T3-82.1% and 83.0%), respectively (Table 2). Seeds with hydro priming treatment (Control- T1) gave the lowest germination in both the years. Nanopriming treatments resulted in slight increase in seedling length from 12.3 cm to 16.2 cm during 2020 and from 12.9 to 16.8 in 2021 with the application of treatment *viz.,* SP+FS (T4). Irrespective of the years, the mean seedling dry weight showed significant increase with the application of nano priming treatments (T3 and T4). Among the priming treatments, highest Seed Vigour Index-I value of 1371 and 1415 in 2020 and 2021, respectively was recorded in SP+FS (T4), followed by SP (T3- 1223 and 1212, respectively). The increase in Seed Vigour Index-I was due to increase in seed germination and seedling length. Among the treatments, highest Seedling vigour index (20,981 and 21,134) was found with NP+FS (T6) during 2020 and 2021, respectively, which might be due to beneficial effect of nano priming and foliar application of nanofertilizers treatment in strengthening the cell membrane integrity of the groundnut seeds.

Seed priming is an efficient approach for promoting fast and uniform emergence as well as high vigor, resulting in improved stand establishment and yield (Rehman *et al*., 2011). This is similar to the present observations regarding better seed quality, namely increased seedling vigour and better field stand establishment (Mahmoodzadeh *et al*., 2013; Prasad *et al*., 2012; Prasad *et al*., 2014). According to Aamir Iqbal (2019) and Pijls *et al*. (2009) nano-fertilizers have a significant impact on seed germination, seed vigour and seedling growth because they penetrate easily into the seed and increase the availability of nutrients to the growing seedling needed for the development of more robust seedlings.

Growth parameters

The findings showed that the treatment which received SP+FS along with RDF had a significant effect ($p \leq 0.05$) on all growth parameters in both years of the study. The performance of growth parameters under different treatments is presented in Table 3. The highest plant height of 45.5 cm and 47.6 cm was recorded by the application of SP+FS treatment (T4) in both the years of the experiment,

Table 2: Characteristics of groundnut genotypes treated after nanofertilizer seed priming and foliar spray.

Treatments	Germination (%)		Seedling length (cm)		Seed Vigour index-I		Seedling dry weight (mg)		Seed vigour index-II	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
C	69.3	69.0	12.3	12.9	852	890	212	209	14692	14421
RDF	70.4	70.9	13.5	14.0	950	993	219	223	15418	15811
SP	82.1	83.0	14.9	14.6	1223	1212	234	240	19211	19920
SP+FS	84.6	84.2	16.2	16.8	1371	1415	248	251	20981	21134
Mean	76.6	76.8	14.2	14.6	1099.0	1127.5	228.3	230.8	17575.5	17821.5
CD (P=0.05)	0.39	0.39	5.42	5.53	194.88	195.21	12.05	11.98	182.63	183.2

C: Control; RDF: Recommended dose of fertilizers; SP: Seed priming with nanofertilizers; SP+FS: Seed priming with nanofertilizers and top dressing/foliar sprays of Nanofertilizers.

respectively. While the control treatment, which received hydro priming with no added fertilizers recorded minimum plant height in both the years. Seed priming of groundnut seeds with nanofertilizers and foliar spraying resulted in the highest chlorophyll content (39.3 and 38.6) in both the years, respectively followed by SP (T3) with the values as 36.5 and 37.8. Though the number of days to 50% flowering difference was statistically non-significant, the treatment, SP+FS showed minimum number of days (25.1 and 25.9) in 2020 and 2021, respectively, while the control treatment, it was 30.1 days and 31.2 days to reach its 50% flowering. Our findings are in coherence with the research findings of Al-Juthery *et al.* (2019) and Singh *et al.* (2017) that nanofertilizers enhance growth parameters *viz*., plant height, leaf area, number of leaves per plant, dry matter production, chlorophyll production, rate of the photosynthesis which result in more production and translocation of photosynthesis to different parts of the plant as compare to traditional fertilizers. Gözde and Ebru (2023) reported that nanofertilizers can have a significant effect on the growth and development (total chlorophyll, total phenolic total antioxidant, ascorbic acid peroxidase activity *etc*) of corn plants. Abdel Aziz *et al.* (2016) observed that the foliar feeding combination of N, P and K nano-fertilizer improves the growth and yield of wheat. Abdel Aziz *et al.* (2018) reported that the nano-fertilizers are easily absorbed by the epidermis of leaves and translocated to stems which facilitated the uptake of active molecules and enhanced growth and productivity of wheat. Our observations and excerpts from relevant literature support the logical understanding that due to very less particle size, nano-fertilizers possess maximum surface area which provides more sites to facilitate different metabolic processes in the plant system, thus resulting in maximum photosynthesis and production of more biomass. Due to their higher surface area and very small size nano-fertilizers have high reactivity with other compounds. Since they are highly soluble in water, they penetrate well into the plant from applied surfaces such as soil or leaves. Thus, they enhance the uptake and nutrient use efficiency as reported by Lin and Xing, 2007. Devi *et al.* (2022) suggested that the IFFCO nanofertilizers especially nano urea helps in reducing the consumption of urea, significantly increases crop yields in castor, chickpea, coriander, cumin, maize, mustard, wheat because of increasing plant growth and metabolic process *viz*., photosynthesis which enhances accumulation and translocation of photosynthates to the economic plant parts.

Yield and yield attributes

The data collected from the two seasons (2020 and 2021) exemplified that the seed priming with nano-fertilizers + nano-fertilizers foliar spray at pre-flowering stage (T4) produced more number of pods and 100 pods weight (test weight) (Table 4). Similar to the above observations on vegetative traits, the number of pods per plant has been

Table 3: Effects of nanofertilizer seed priming and foliar spray on groundnut growth parameters across two successive seasons (2020 and 2021).

Treatments	Days to 50% flowering (DAS)		Chlorophyll content (SPAD value)		Plant height at harvest (cm)	
	2020	2021	2020	2021	2020	2021
C	30.1	31.2	31.5	31.0	30.2	31.9
RDF	28.9	28.0	34.0	35.1	32.5	34.2
SP	26.8	27.1	36.5	37.8	42.6	42.0
SP+FS	25.1	25.9	39.3	38.6	45.5	47.6
Mean	0.48	0.44	0.56	0.61	1.56	1.77
CD (P=0.05)	0.48	0.44	0.56	0.61	1.56	1.77

C: Control; RDF: Recommended dose of fertilizers; SP: Seed priming with nanofertilizers; SP+FS: Seed priming with nanofertilizers and top dressing/foliar sprays of Nanofertilizers.

Table 4: Effects of nanofertilizer seed priming and foliar spray on yield attributes across two successive seasons (2020 and 2021).

Treatments	No. of pods/plant		Test weight (100 pods) (g)		Shelling (%)	
	2020	2021	2020	2021	2020	2021
C	23.4	21.6	38.9	36.8	72.1	73.2
RDF	27.6	28.1	44.8	45.9	73.2	72.6
SP	29.2	29.9	53.8	50.6	71.9	73.2
SP+FS	34.0	33.4	65.7	66.2	72.6	72.9
Mean	28.55	28.25	50.8	49.875	72.45	72.975
CD (P=0.05)	1.65	1.57	1.67	1.73	2.92	2.89

C: Control; RDF: Recommended dose of fertilizers; SP: Seed priming with Nanofertilizers; SP+FS: Seed priming with nanofertilizers and top dressing/foliar sprays of nanofertilizers.

Table 5: Effects of nanofertilizer seed priming and foliar spray on yield and quality indices across two successive seasons (2020 and 2021).

Treatments	Pod yield (kg/ha)		Protein content (%)		Oil content (%)	
	2020	2021	2020	2021	2020	2021
C	2379	2348	21.0	22.3	40.8	39.9
RDF	2531	2510	22.3	22.5	39.9	40.8
SP	2972	2906	22.8	22.7	40.4	41.3
SP+FS	3096	3124	23.1	22.9	41.1	41.8
Mean	2744.5	2722	22.3	22.6	40.55	40.95
CD (P=0.05)	9.22	8.99	1.88	1.68	1.66	1.72

C: Control; RDF: Recommended dose of fertilizers; SP: Seed priming with nanofertilizers; SP+FS: Seed priming with nanofertilizers and top dressing/foliar sprays of nanofertilizers.

significantly affected by the treatments with a maximum number of pods being recorded in T4 (34.0 and 3304) followed by T3 (29.2 and 29.9) in 2020 and 2021, respectively. In the same way, test weight showed significant response to nanopriming and foliar spray with nanofertilizers. The maximum test weight was registered with T4 (35.7 and 66.2) and minimum was found to be with control (38.9 and 36.8) in 2020 and 2021 respectively. Since the number of pods per plant and test weight has significantly increased, the seed yield per plant also showed a similar trend. It was observed that nanofertilizers seed priming along with foliar spray of nanofertilizers enhanced seed yields i.e., maximum in case of T4 (3096 kg ha^{-1} and 3124 kg ha^{-1}) followed by T3 (2972 kg ha^{-1} and 2906 kg ha^{-1}) and the minimum was recorded in control (2379 kg ha^{-1} and 2348 kg ha^{-1}) during 2020 and 2021, respectively. However, no significant difference with the applied treatments on shelling percentage was noticed.

The findings are in line with the reports of Sugunan and Dutta (2008) that nanotechnology increases the production potential of agricultural crops as the harvest yields increase significantly in an eco-friendly way even in challenging environments. Zinc (Zn) and zinc oxide (ZnO) are two of the metal and metal oxide-engineered nanomaterials that are frequently used on plants. Zinc insufficiency is one of the many common micronutrient deficiencies in the soil (Sauvik Raha and Md. Ahmaruzzaman, 2022). Our findings regarding increased seed yields are consistent with those of Stella *et al*. (2010) who claimed that zinc is the nutrient most responsible for yield limitations after nitrogen, phosphorus and potassium; Mahmoodzadeh *et al*. (2013) also claimed that Nano-Fe_2O_3 promotes peanut plant growth and photosynthesis. Dinesha and Gayan. (2021) also reported that the chemical fertilizers lead to the loss of nutrients from agricultural fields in the form of leaching and gaseous emissions which significantly contribute to that environmental pollution and climate change whereas advanced nanotechnology would help in boosting sustainable crop production and protecting the environment. Nikita *et al*. (2023) expressed their concern about applications, utilization and commercialization of nanotechnology are still comparably marginal in agricultural sector and research on a larger scale despite tremendous advantages. Prashant *et al.* (2023) reviewed Nanotechnology applications are increasingly recognized as potential tools in animal sciences, veterinary medicine, drug delivery and disease diagnosis and vaccine development.

Biochemical indices

The findings showed that the combination of conventional fertilizers along with nanofertilizers as seed priming and foliar spray had a significant effect on oil content and seed protein content of groundnut in both the years of the study. The difference in the biochemical composition of groundnut seed under various treatments are shown in Table 5.

Seed priming with nanofertilizers combined with foliar spraying of nanofertilizers recorded the highest oil content (41.1% and 41.8%) in the first and second years, respectively, while priming the seeds with water with no foliar spray registered minimum oil content as 40.8% and 39.9%, respectively. In the case of protein content, the highest levels (23.1% and 22.9%) were obtained by treating plants with nanofertilizer priming + foliar spray (T4) in both the years, respectively. Kouchebagh *et al*. 2014 also reported that oil content of sunflower was enhanced as a result of various priming treatments. Das and Mohanty (2018) also reported seed priming helped for oil content and protein quality groundnut seeds.

CONCLUSION

The study conducted during 2020-2021 with nano P, nano Zn and nano Fe developed by TERI as a seed priming and foliar applications has highly beneficial in the production of quality seed of groundnut which was manifested in the form of enhanced seed germination percentage, test weight (100 seed weight) and plant height establishment. And, one of our major inferences is that nano-fertilizers enhanced the plant surface area that enhanced photosynthesis rate, increase oil content and protein content, besides improved the crop yield. Hence, seed priming prior to sowing with nano Zn, nano Fe and nano P along with foliar spray before flowering stage was screened as an efficient treatment and it can be used for improving seed quality in groundnut for getting better seedling quality.

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Conflict of interest

All authors declare that they have no conflicts of interest.

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