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Nano NPK and designer seeds for enhancing growth and yield of cowpea

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Abstract
A research experiment was conducted at the Instructional Farm of the College of Agriculture, Kerala Agricultural University (KAU), Vellanikkara, Thrissur from October to December 2021. The primary objective of the study was to evaluate the effect of nano fertilizer and designer seeds on the growth and yield of cowpea (*Vigna unguiculata* (L.) Walp). The experimental design employed was Completely Randomized Design (Factorial), comprising three replications. The experimental treatments encompassed application of various concentrations of nano NPK fertilizer at different rates (2/3, 1/2, 1/3, 1/4) of the recommended dose of NPK as per package of practices (POP) of KAU, NPK as per POP (20:30:10 kg/ha), and absolute control. Three levels of seed treatments were also applied; designer seeds, rhizobium treated seeds and untreated seeds. The findings of the study revealed that both nano fertilizers and designer seeds exerted a significant positive influence on the biometric and yield parameters of cowpea. Among the nano fertilizers, nano NPK (2/3) as per POP demonstrated the highest chlorophyll content at harvest (5.01 mg/g) compared to the absolute control (2.11 mg/g). Moreover, the synergistic application of nano NPK (2/3) as per POP in conjunction with designer seeds demonstrated remarkable efficacy, yielding the highest recorded grain yield at 838.47 kg/ha.

Keywords: Nano NPK fertilizer, designer seeds, biometric parameters, chlorophyll content, grain yield

Introduction
The world's population is growing rapidly and is expected to reach 9 billion by 2050 (UN, 2015) [21]. This surge in the global population is driving an increased need for food, resulting in the widespread and extensive use of fertilizers. While these fertilizers offer advantages, their overuse can have various negative consequences. Hence it is high time to shift fertilizer use efficient technologies.

Cowpea (*Vigna unguiculata* L. Walp) plays a crucial role as a primary provider of dietary protein in the cropping systems of semi-arid tropics and subtropics. It contributes significantly to the nutritional security of the country. Even though, cowpea yield remains low (less than 1 t/ha) in most areas of India **(**Justin, *et al*., 2015) [8]. It is highly essential to increase the yield of cowpea.

Nano fertilizers, serving as an alternative to traditional fertilizers, release nutrients gradually and in a controlled manner within the soil (Naderi and Danesh-Shahraki, 2013) [14]. The urgent challenges linked to the suboptimal efficiency of traditional fertilizers (around 30-50%) and the insufficient measures for their improvement emphasize the necessity for incorporating nano fertilizers in crop production (Derosa *et al*., 2010) [4]. The rapid absorption rate of nano-fertilizers not only enhances efficiency and the quality of food resources but also leads to significant reductions in soil pollution, preservation of water reserves, and minimising loss of fertilizers through leaching. This approach ensures the complete absorption of fertilizers by plants and releases nutrients optimally throughout the growing season (Liu and Lal, 2015) [11].

Utilizing designer seed technology for seed fortification proves to be a beneficial approach to enhance both seed production and quality. Designer seed technology constitutes a comprehensive presowing seed treatment method, incorporating the addition of nutrients, plant protectants, and bioinoculants.

The goal is to improve seed quality, field emergence, and various parameters contributing to overall yield (Sujatha and Ambika, 2018) [20].

Recognizing the necessity to boost cowpea productivity within constrained resources to ensure nutrient security amid a growing population, there is a notable absence of resource conservation technologies. Specifically, the application of nano fertilizers and designer seeds, aimed at enhancing growth and yield, has been lacking. Against this backdrop, the current study was initiated to investigate the impact of nano fertilizers and designer seed technology on cowpea, to optimize its growth and yield.

Materials and Methods

The study was conducted at Instructional Farm, College of Agriculture, Kerala Agricultural University (KAU), Vellanikkara, Thrissur (India) from October to December, 2021. The experiment was laid out in a Completely Randomized Design (Factorial), with 3 replications. Cowpea variety Anaswara was used for the study. The treatments comprised of two factors *viz*., fertilizer applications (6 levels) and seed treatments (3 levels). The various fertilizer applications consists of nano NPK fertilizer at different rates (2/3, 1/2, 1/3, 1/4) of the recommended dose of NPK as per package of practices (POP) of KAU, NPK as per POP (20:30:10 kg/ha), and absolute control. Three levels of seed treatments were designer seeds, rhizobium treated seeds and untreated seeds. Designer seeds were prepared by soaking seeds in a micronutrient solution (KAU sampoorna micronutrient mix) of 100ppm for 3 hours and drying back to original moisture content and then treating the seeds with polymer @ 3ml/kg of seed, imidacloprid @ 2ml/kg of seed, PGPR (plant growth promoting rhizobacteria) mix I @ 4g/kg of seed and rhizobium @ 20g/kg of seed. Rhizobium treated seeds were prepared by mixing rhizobium culture @ 20g/kg of seed along with rice gruel and shade dried for a few hours. Nano NPK 19:19:19 (Geolife) were applied based on K equivalent and the remaining N and P were supplied as urea and SSP respectively. The applied amount of fertilizer in each treatment was detailed below (Table 1). The growth parameters *viz*., plant height, number of branches and dry matter content per plant were recorded at 20 days interval. Yield parameters *viz*., pod weight per plant (g) and grain yield (kg/ha) were recorded at harvest. The experimental data on various growth and yield parameters of cowpea were subjected to analysis of variance using statistical package 'GRAPES (General R based Analysis Platform Empowered by Statistics)' developed by Gopinath *et al*. (2020) [6]. This platform is based on R software.

Table 1: Fertilizer application details

Fertilizer application levels	Geolife (kg/ha)	Urea (kg/ha)	SSP (kg/ha)	MOP (kg/ha)
Nano NPK (2/3) as per POP	27.41	17.78	47.40	-
Nano NPK (1/2) as per POP	23.70	11.85	29.63	-
Nano NPK (1/3) as per POP	15.56	8.15	22.46	-
Nano NPK (1/4) as per POP	9.63	7.33	15.56	-
NPK as per POP		20.00	30.00	10.00
Absolute control	-	-	-	-

Results and Discussion

The application of nano NPK (2/3) as per POP resulted in significant improvement in various growth parameters, including increased plant height (52.87 cm), a higher number of branches (6.00), and higher dry matter content per plant (25.40g). Importantly, these outcomes were comparable to the performance observed with nano NPK (1/4) as per POP, as detailed in Table 2. These findings align with the study by Kahlel *et al*. (2021) [9], where nano fertilizers (K, Cu, Zn, Mn, Fe) demonstrated significant enhancements in various growth parameters such as plant height, number of leaves per plant, stem diameter, chlorophyll content, fresh weight, and dry weight during the vegetative growth phase of senna plant cultivation, outperforming the control group. The use of nano iron oxide, in contrast to conventional iron oxide, resulted in a marked improvement in various growth parameters in wheat. This improvement was evident in spike length, plant height, grain weight per spike, and dry weight of straw and stubble (Mazaherinia *et al.* 2010) [12].

Among the various seed treatments, designer seeds performed superior in terms of plant height (60.22 cm), number of branches (7.00), and dry matter content per plant (30.47g) respectively (Table 2). This better performance was attributed to the presence of pelleting materials in designer seeds, providing early micro and macronutrient supplements during the initial stages of plant establishment. This innovative approach had the potential to stimulate improved root and shoot growth, facilitating enhanced water and nutrient absorption by the plants, thereby promoting overall vigor (Sujatha and Ambika, 2018) [20]. Furthermore, polymer coating in the designer seeds may resulted in the better growth parameters. A study conducted by Prashanth *et al*. (2018) [15] reported the effects of polymer seed coating and seed treatment on the seed quality and growth parameters of hybrid maize. Their findings revealed that seeds coated with polymer, in conjunction with fungicides and insecticides, exhibited superior performance. Specifically, these treated seeds demonstrated the highest germination percentage (92.75%), seedling root length (11.28 cm), seedling shoot length (3.19 cm), overall seedling length (14.47 cm), seedling fresh weight (1.47 g), and seedling dry weight (0.40 g) compared to untreated seeds. The heightened vigour observed in the germinated seedlings suggests potential benefits for overall crop growth during the vegetative stage. These results emphasize the promising role of designer seeds with polymer coatings in enhancing crop performance and seedling development.

The highest chlorophyll content at harvest was observed in plants applied with nano NPK (2/3), recording a value of 5.01 mg/g, whereas the absolute control exhibited a chlorophyll content of 2.11 mg/g. According to Alzreejawi and Al-Juthery (2020) [2], treatment with nano NPK (12:12:36) led to a notable elevation in chlorophyll content of maize, reaching 54.63 SPAD units compared to 51.08 SPAD units in control plants. Mirji *et al*. (2023) [13] demonstrated that the chlorophyll content of sapota leaves was significantly increased under treatment with 50% recommended dose fertilizer (RDF) combined with a 0.2% nano NPK foliar spray (2.30 mg/g) as compared to 100 % RDF (1.98 mg/g). Higher chlorophyll content could be attributed to the activation of enzymes associated with chlorophyll formation by nitrogen fertilizer, ultimately leading to an increase in chlorophyll accumulation within the leaves. This increase in chlorophyll content might be attributed to the stimulatory effect of nano NPK on porphyrin molecules, which are vital constituents of metabolic compounds such as chlorophyll pigments and cytochrome. These molecules play essential roles in photosynthesis and respiration processes, thereby contributing to enhanced vegetative growth and yield of crops (Rop *et al*., 2019) [16]. Among seed treatments, designer seeds exhibited the highest chlorophyll content (5.74 mg/g). This could be attributed to the inclusion of Plant Growth-Promoting Rhizobacteria

(PGPR) in the designer seed treatment. PGPR has been shown to enhance chlorophyll content and photosynthetic activity in rice (Hafez *et al.*, 2020) [7] and potato (Batool *et al.*, 2020) [3].

Table 2: Effect of treatments on plant height, number of branches, dry matter content per plant and chlorophyll content at harvest of cowpea

Treatments	Plant height (cm)	Number of branches	Dry matter content per plant(g)	Chlorophyll content (mg/g)
Nano fertilizers				
2/3 NPK as per POP	52.87	6.00	25.40	5.01
1/2 NPK as per POP	46.27	4.77	17.20	4.26
1/3 NPK as per POP	46.57	5.00	20.61	4.55
1/4 NPK as per POP	51.50	5.33	24.43	4.62
NPK as per POP	46.29	5.02	20.89	4.46
Absolute control	33.83	3.11	12.33	2.11
CD (0.05)	2.61	0.97	1.77	0.25
SE(m)±	0.91	0.34	0.62	0.09
Seed treatments				
Designer seeds	60.22	7.00	30.47	5.74
Rhizobium treated seeds	45.29	4.28	17.74	3.87
Untreated seeds	33.16	3.39	12.17	2.89
CD (0.05)	1.84	0.69	1.25	0.17
SE(m)±	0.64	0.24	0.44	0.06

The highest pod weight per plant was observed in plants treated with nano NPK (2/3) as per POP, recorded at 33.80g, which was comparable to the performance with nano NPK (1/4) as per POP at 32.29 g (Table 3). Furthermore, the highest grain yield was obtained from plants treated with nano NPK (2/3) as per POP, yielding 611.87 kg/ha, in contrast to the absolute control which yielded 258.25 kg/ha. A study conducted by Sruthi *et al.* (2022) [19] reported a notable increase in grain yield (712.50 kg/ha) through the soil application of organic nano NPK at 50 kg/ha combined with FYM at 5 t/ha, compared to the control group (499 kg/ha). The enhanced performance of nano fertilizers might be attributed to their efficient absorption and permeability into plant tissues, facilitated by their smaller ion sizes. Additionally, nanoparticles possess a high specific surface area and energy, which facilitates their interaction with plant tissues. Moreover, nano-fertilizers provide essential nutrients such as nitrogen, crucial for amino acid and protein formation, cell division, and elongation, phosphorus, vital for energy compound formation, thereby promoting root development, vegetative growth, and potassium, essential for enzyme formation, growth, and ultimately, enhancing yield. These combined factors contribute to the positive impact of nano-fertilizers on crop productivity.

Among seed treatments, designer seeds showed the highest pod weight per plant (37.95g) and grain yield (714.04 kg/ha). The enhanced yield could be attributed to the incorporation of inoculants, protectants, nutrients, and polymers in the coating treatment. Additionally, bioinoculants applied during seed treatment played a role in promoting plant growth through the solubilization and sequestration of diverse plant nutrients, subsequently facilitating their delivery to the plants (Dinesh *et al.*, 2018) [5].

Table 3: Effect of treatments on pod weight per plant and grain yield at harvest

Treatments	Pod weight per plant (g)	Grain yield (kg/ha)
Nano fertilizers		
2/3 NPK as per POP	33.80	611.87
1/2 NPK as per POP	27.98	548.70
1/3 NPK as per POP	24.74	509.23
1/4 NPK as per POP	32.29	594.32
NPK as per POP	31.01	536.49
Absolute control	20.34	258.25
CD (0.05)	1.52	14.09
SE(m)±	0.53	4.91
Seed treatments		
Designer seeds	37.95	714.04
Rhizobium treated seeds	26.47	535.05
Untreated seeds	21.22	284.00
CD (0.05)	1.07	9.67
SE(m)±	0.37	3.48

The results of the experiment revealed that the treatment combination of nano NPK (2/3) as per POP with designer seeds resulted in significant positive effects on various growth parameters, plant height (72.27 cm), number of branches (9.00), and dry matter content per plant (40.30g). These outcomes were closely comparable to those observed with the combination of nano NPK (1/4) with designer seeds (Table 4). The observed increase in plant height and overall productivity might be associated with the combined effect of nano fertilizers and designer seeds. Nano fertilizers could be attributed to their distinctive properties, characterized by a larger surface area and higher absorption capacity. This facilitates improved nutrient uptake by plants, subsequently stimulating photosynthesis and promoting increased leaf area. As reported by Sekhon (2014) [18], these combined effects likely contribute to the observed enhancements in overall plant growth. Moreover, designer seeds of rice have been shown to increase plant height (12.2%), and overall improved vigour when compared to untreated control, as highlighted by Sujatha and Ambika (2018) [20]. Higher growth parameters may be due to the potential synergistic effects of combining nano fertilizers and designer seeds to optimize crop growth at the vegetative stage.

The treatment combination of nano NPK (2/3) with designer seeds recorded a higher chlorophyll content (7.04 mg/g) at harvest, which was comparable to the combination of nano NPK (1/4) with designer seeds (6.95 mg/g) as indicated in Table 4. This increase in chlorophyll content might be due to the effect of nano NPK applied and designer seed treatment. Nitrogen and potassium had crucial roles in photosynthesis and the growth of meristematic tissues. The augmentation of chlorophyll levels can be attributed to the role of nanoparticles in enhancing leaf photosynthesis while simultaneously reducing the rate of respiration (Abdel *et al*., 2019) [1]. Kavitha *et al*. (2013) [10] highlighted that seeds treated with KH_2PO_4, imidacloprid, a micronutrient mixture, and film coating with carbendazim and Azospirillum exhibited a significant increase in total seedling chlorophyll content. Combined beneficial effects of nano NPK and designer seed treatments may resulted in higher chlorophyll levels in this study.

The treatment combination of nano NPK (2/3) as per POP with designer seed treatment exhibited higher yield parameters, including pod weight per plant (48.62g) and grain yield (838.47kg/ha), which were comparable to those of the treatment combination of nano NPK (1/4) as per POP with designer seeds (45.98g and 826.17 kg/ha respectively) (Table 5). This enhanced yield may be attributed to the increased chlorophyll content, leading to enhanced photosynthesis and improved translocation of assimilates, thereby facilitating biomass accumulation by nano fertilizers (Sruthi *et al*., 2022) [19]. Additionally, the increase in yield attributed to designer seeds could be due to the presence of inoculants, protectants, nutrients and polymer in the coating treatment (Sujatha and Ambika, 2018) [20]. Similar results were reported for designer seeds in maize by Seema *et al*., (2023) [17]. Combined effect of nano fertilizer and designer seeds resulted in better yield and yield parameters of cowpea in this experiment

Table 4: Interaction effect of treatments on plant height, number of branches, dry matter content per plant, total chlorophyll content at harvest of cowpea

Treatments	Plant height (cm)			Number of branches			Dry matter content per plant (g)			Total chlorophyll content (mg/g)		
	Designer seeds	Rhizobium seeds	Untreated seeds	Designer seeds	Rhizobium seeds	Untreated seeds	Designer seeds	Rhizobium seeds	Untreated seeds	Designer seeds	Rhizobium seeds	Untreated seeds
Nano NPK (2/3) as per POP	72.27	50.77	35.57	9.00	5.00	4.00	40.30	22.77	13.13	7.04	4.80	3.20
Nano NPK (1/2) as per POP	64.60	42.20	32.00	7.00	3.00	3.00	35.67	14.83	12.17	5.14	4.40	3.23
Nano NPK (1/3) as per POP	61.43	45.60	32.67	7.00	4.00	4.00	34.07	16.23	11.53	5.75	4.32	3.60
Nano NPK (1/4) as per POP	68.63	53.87	32.00	8.00	5.00	3.00	37.83	23.27	12.20	6.95	3.83	3.07
NPK as per POP	55.53	47.03	36.30	6.00	5.67	4.00	21.40	16.70	13.50	6.53	3.77	3.07
Absolute control	38.83	32.27	30.40	4.00	3.00	2.33	13.57	12.63	10.50	3.00	2.13	1.20
CD (0.05)	4.51			1.69			3.07			0.43		
SE(m)±	1.57			0.59			1.07			0.15		

Table 5: Interaction effect of treatments on pod weight per plant and grain yield of cowpea at harvest

Treatments	Pod weight per plant (g)			Grain yield (kg/ha)		
	Designer seeds	Rhizobium seeds	Untreated seeds	Designer seeds	Rhizobium seeds	Untreated seeds
Nano NPK (2/3) as POP	48.62	30.14	22.64	838.47	658.63	338.50
Nano NPK (1/2) as POP	35.63	26.29	22.07	772.43	544.30	329.37
Nano NPK (1/3) as POP	31.59	22.12	18.47	736.60	335.70	241.07
Nano NPK (1/4) as POP	45.98	24.92	21.63	826.17	487.40	246.23
NPK as per POP	41.06	31.23	28.14	795.23	714.63	559.10
Absolute control	25.27	21.37	14.37	315.33	242.17	213.20
CD (0.05)	2.68			24.42		
SE(m) ±	0.92			8.51		

Conclusion

The study results indicated that the application of nano NPK (2/3) as per POP significantly increased cowpea yield by 14% and 137%, compared to NPK as per POP of KAU and absolute control, respectively. The use of designer seeds led to a 151% increase in cowpea yield compared to untreated seeds. The combination of nano NPK (2/3) as per POP with designer seeds and nano NPK (1/4) with designer seeds exhibited superior performance in both biometric and yield parameters. Application of nano NPK (2/3) as per POP along with designer seeds resulted in 50 % increase in yield followed by application of nano NPK (1/4) as per POP along with designer seeds resulted in 48 % increase in yield compared to the recommended dose of NPK as per POP of KAU with untreated seeds.

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