

EFFECT OF PARTIAL AND COMPLETE REPLACEMENT OF THE FIRST UREA APPLICATION USING LOCAL GYPSUM COATING AND NANO-NITROGEN ON SORGHUM SEED EMERGENCE

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ABSTRACT

A field experiment was conducted in the experimental field of the Field Crops Department, College of Agriculture, University of Baghdad, during the spring season of 2025. Treatments were applied in a randomized complete block design (RCBD), with four replicates and three factors: the first factor seed coating (without or with gypsum), second factor suspension at Nano-nitrogen concentrations (0, 20, 40, and 60 mg L⁻¹), third factor was the Urea replacement levels (0, 50, 100%). The results showed that the coating treatment had a significant effect on all studied traits. The local gypsum coating treatment was superior in increasing the field emergence percentage in the final count, seedling height, and dry weight, which was reflected in an increase in the seedling vigor index. Meanwhile, the uncoated treatment was superior in the first field emergence count and provided the shortest time to complete field emergence. As for the effect of nitrogen addition, Nano nitrogen showed a significant effect on all studied traits. Seed treatment at a concentration of 40 mg L⁻¹ yielded the highest percentage of field emergence in the first and final counts. Nano nitrogen at a concentration of 60 mg L⁻¹ yielded the shortest number of days to complete field emergence and the highest average seedling height, seedling dry weight, and seedling vigor index. Regarding the effect of partial and total replacement rates for the first batch of urea fertilizer, the results showed that total replacement yielded the highest average for the first field count, while partial replacement at a rate of 50% yielded the highest average for final count, seedling dry weight, and vigor index. We can conclude that the presence of nano nitrogen combined with a seed coating treatment with local gypsum is superior to direct seed treatment with this fertilizer. It is also noted that nano fertilizer can replace the ground application of the first batch of urea fertilizer by up to 50%.

KEYWORDS: *Sorghum bicolor* (L.), fertilizer sources Nitrogen, field emergence, urea toxicity.

INTRODUCTION

Sorghum bicolor (L.) Moench is a versatile cereal crop. Its grains are used for human consumption or animal feed, and the green parts are used as green fodder or palatable silage for livestock and poultry, due to their high protein and carbohydrate content (Al-Beiruty *et al.*, 2020). It is also a crop with high tolerance to drought and salinity conditions, and it has a high capacity for post-harvest growth and branching (ratooning), providing a greater number of branches (El-Fahdawi *et al.*, 2019 and 2020; Al-Beiruty *et al.*, 2022). However, this vigorous growth necessitates the provision of fertilizers and plant nutrients, most importantly nitrogen fertilizer (Cheyed and Saleh, 2018). Nitrogen is one of the most essential nutrients required for plant growth.

Iraqi soils and surface and groundwater bodies suffer from numerous forms of pollution due to improper practices by farmers, including the excessive use of chemical fertilizers. The scarcity of applied scientific studies on sustainable farming methods and the limited communication of applied research findings to farmers are among the most significant obstacles contributing to the exacerbation of environmental pollution. One of the most prevalent of these practices is the overuse of chemical fertilizers, particularly urea, which is one of the most widely used fertilizers. Studies have shown that Iraqi fields and irrigation waters are experiencing increasing levels of urea residues, including nitrates and ammonia. The danger of urea use is compounded by the fact that some of it is released into the atmosphere, exacerbating the problem of global warming. Furthermore, successful crop production requires the use of high-quality seeds to ensure optimal field establishment and achieve the plant density necessary for maximum yield. This leads to increased economic returns for farmers, as confirmed by the results of several studies that demonstrated that seeds producing vigorous seedlings ultimately produce vigorous plants, and that the increase in grain yield is proportional to the percentage of vigorous seedlings obtained 96 hours after planting (Elsahookie and Jannu, 2010 and Cheyed and

Elsahokie, 2011). Several studies have indicated that direct fertilization with urea fertilizer can negatively affect seed emergence and field emergence, including in sorghum. This effect is mainly attributed to the formation of ammonia resulting from the decomposition of urea by the urease enzyme present in the soil, leading to ammonia accumulation around the seeds and hindering their emergence (Bremner and Krogmeier, 1989). The negative effect of urea on seed emergence may be due to the accumulation of ammonia in the soil, and not due to the urea itself or the impurities present in it (Krogmeier *et al.*, 1989). Some studies have shown that adding urea directly to the seeds leads to a decrease in the emergence rate and field emergence and inhibition of root hair formation in six wheat varieties. They attributed this to the volatilization of ammonia and its toxic effect on root growth (Zhang *et al.*, 2017).

To eliminate the harmful reaction resulting from urea use, alternative fertilizers can be used that require less urea and have limited or no toxicity. One such fertilizer is nano-nitrogen. This type of fertilizer has the ability to improve its properties, providing nutrients to plants and thus enhancing their growth and productivity (Duhana *et al.*, 2017). It is characterized by its nanoscale dimensions, ranging from 1 to 100 nanometers, and its rapid diffusion and absorption by plant tissues (Al-Rawi *et al.*, 2024). El-Sawah *et al.* (2021) indicated that the use of nano-nitrogen fertilizer improved emergence and dry weight indicators in wheat seedlings compared to conventional fertilizers, due to reduced ion stress and enhanced nutrient uptake in highly saline or alkaline soils. Using seed coating techniques to incorporate micronutrients or nano-fertilizers into the seed surface provides a direct nutrient source for seedlings in the rhizosphere, improving emergence efficiency and early growth. One of the cheapest coatings available for this purpose, which improves emergence conditions and increases seedling activity and emergence, is local plaster coating (Chayed *et al.*, 2019). Coating maize seeds with nitrogen nano-fertilizers was found to improve emergence rates and early seedling emergence (Ghasemi *et al.*, 2020). Al-Saady *et al.* (2019) found that seedlings coated with polymers containing nitrogen nanoparticles exhibited better emergence and stronger growth compared to seeds treated with conventional fertilizers. Musa *et al.* (2023) found that nitrogen stimulation of wheat seeds, whether nanoparticles alone or coated with local gypsum, improved emergence and field emergence indicators, and even crop growth and yield. The amount of fertilizer applied, especially the first application, affects seedling vigor and activity, and is also related to seedling growth rate. Moderate and carefully measured amounts promote the synthesis of proteins and enzymes necessary for growth, but high amounts inhibit primary root growth and delay the emergence of the embryonic stalk, due to a disturbance in internal ionic balance and an increase in nitrate accumulation to toxic levels in moist or poorly aerated soils (Singh *et al.*, 2019). Therefore, this study aims to achieve several objectives, most importantly reducing environmental pollution resulting from the excessive use of urea fertilizer by partially or completely regulating its use in the first application of sorghum seeds using local gypsum and nano-nitrogen.

MATERIALS AND METHODS:

A field experiment was conducted at the experimental field of the Field Crops Department, College of Agriculture, University of Baghdad, during the spring growing season of 2025. The treatments were implemented using a Randomized Complete Block Design (RCBD) with four replications and three factors. The first factor was the local gypsum coating treatment (the control treatment without coating and the seeds coated with a local gypsum suspension at nano-nitrogen concentrations of 0, 20, 40, and 60 mg L⁻¹) (second factor). The third factor was the application of the first dose of urea fertilizer as follows: full recommended (replacement= full urea 0%), half recommended (replacement= full urea 50%), and the control without application (replacement= full urea 100%) (Table 1). Sorghum seeds (Rescue variety) were used. The seeds were treated with the gypsum suspension for all treatments and their combinations, then allowed to air dry, taking care to prevent the seeds from sticking together. A suitable plot of land was selected and divided into 1m² sections. Two hundred seeds were planted in four rows, with 50 seeds planted in each row. The seeds were planted on April 2, 2025, and the experimental area was covered with netting to prevent birds from attacking and affecting the results of the experiment.

Table 1. The three study coefficients

First factor			
Without coating		Coating with local gypsum	
Second factor	Third factor	Second factor	Third factor
Nano-nitrogen	Urea fertilizer	Nano-nitrogen	Urea fertilizer
(mg L⁻¹)	(%)	(mg L⁻¹)	(%)
0	100	0	100
	50		50
	0		0
20	100	20	100
	50		50
	0		0
	100		100

40	50	40	50
	0		0
	100		100
60	50	60	50
	0		0

After field emergence was complete, the following characteristics were recorded:

1- First field emergence count (%): percentage of seedling emergence at first count day.

2- Final field emergence count (%): This characteristic was calculated 10 days after planting using the following equation, after determining the number of seeds in each hole (ISTA, 2013):

Field emergence percentage = (Number of seedlings emerging after 10 days ÷ Total number of seeds) × 100

3- Days to field emergence (days): This is the time between the first and last emergence or emergence of a quantity of seeds. The highest values indicate the greatest difference in emergence rate between fast and slow emergence of a quantity of seeds.

4- Seedling height (cm): The seedling height was measured from the soil surface to the tip of the top leaf of ten randomly selected seedlings using a ruler. The average height of a single seedling was calculated by dividing the sum of the heights of the ten seedlings by the number of seedlings (Cheyed, 2020).

5- Seedling Dry Weight (g seedling⁻¹): Ten normal seedlings were harvested after the 10-day field emergence period, placed in perforated paper bags, and oven-dried at 80°C for 24 hours. They were then weighed using a sensitive scale, and the average dry weight of each seedling was calculated.

6- Seedling Vigor Index (SV): This was calculated using the equation by Murti et al. (2004): Seedling Vigor Index = Field Emergence (%) × Seedling Length (radicle length + plumule length).

Statistical Analysis: After data collection and tabulation, statistical analysis was performed using Genestat software at a probability level of 0.05. The least significant difference (LSD) test was used to compare the arithmetic means of the studied traits (Steel *et al.*, 1997).

RESULTS:

1- First emergence count (%)

Table 2 shows significant differences in the first field count due to seed coating. The uncoated seed treatment (control treatment) gave the highest first field count at 38.51%, a slight difference (3.75%) compared to the plaster coating treatment, which gave the lowest first field count at 37.04%. Significant differences were found in the treatment with nano-nitrogen. The concentration of 40 mg L⁻¹ resulted in the highest rate of the trait at 40.05%, compared to the control treatment, which yielded the lowest rate at 32.34%. The percentage of urea fertilizer replacement also significantly affected this trait. The treatment with complete replacement (100%) resulted in the highest rate at 40.36%, while the control treatment (adding the full recommended amount) resulted in the lowest rate at 35.97%.

The results showed that the two-factor interactions (covering with local gypsum + nano-nitrogen), (covering with local gypsum + partial and complete urea fertilizer replacement), and the three-factor interaction did not produce significant differences in the first field count. While the dual interaction (nano nitrogen + partial and total urea fertilizer replacement) resulted in significant differences in the first field emergence count, the control treatment for both nitrogen and urea showed the highest dual interaction at 42.56%. Conversely, the control treatment for nitrogen with 100% urea fertilizer showed the lowest dual interaction at 30.34%.

Table 2. Partial and total replacement of the first batch of urea fertilizer using local gypsum coating and nano nitrogen in the first field emergence count.

Coating (A)	Nano-nitrogen (mg L ⁻¹) N	Partial and Complete Replacement of Urea Fertilizer (%) U			A × N
		100	50	0	
Without Coating A1	0	31.85	32.56	35.64	33.35
	20	37.02	38.33	42.93	39.43
	40	41.56	38.90	42.84	41.10
	60	37.69	40.31	42.50	40.17
Coating with local gypsum A2	0	28.83	30.79	34.37	31.33
	20	36.01	37.25	41.21	38.16
	40	38.20	38.04	40.77	39.00
	60	36.60	39.84	42.62	39.68
LSD α 0.05		NS			NS
		U			A × U
A		100	50	0	

A1	37.03	37.53	40.98	38.51
A2	34.91	36.48	39.74	37.04
LSD α 0.05	NS			1.14
	U			N×U
N	100	50	0	
0	30.34	31.68	35.01	32.34
20	36.51	37.79	42.07	38.79
40	39.88	38.47	41.81	40.05
60	37.14	40.08	42.56	39.93
LSD α 0.05	1.77			0.87
Mean U	35.97	37.00	40.36	
LSD α 0.05	0.97			

2- Final Field Emergence Count (%)

The results show significant differences in the final field emergence count for the treatment using local gypsum. The gypsum treatment yielded the highest rate at 65.52%, compared to the control treatment at 62.92% (Table 3).

The results also indicate significant differences in the nano-nitrogen treatment. A concentration of 40 mg L⁻¹ of nano-nitrogen achieved the highest rate of 69.8%, compared to the control treatment, which yielded the lowest final field emergence count at 53.03%. Regarding the effect of partial and full urea fertilizer replacement, significant differences were found between the replacement percentages. The 50% replacement treatment yielded the highest final field emergence count at 65.21%, while the 100% treatment yielded the lowest at 62.84%.

Regarding the effect of the dual interaction between local gypsum coating and nano nitrogen, with significant differences in the final field emergence count, the treatment with gypsum coating and nitrogen at a concentration of 60 mg L⁻¹ resulted in the highest final field emergence count, reaching 71.77%. In contrast, the control treatment (without gypsum coating) and distilled water resulted in the lowest rate, at 50.39%. Similarly, the dual interaction between local gypsum coating and the partial and total replacement of urea fertilizer did not produce a significant effect on the final field emergence count. The interaction between nano-nitrogen and partial and full urea fertilizer resulted in significant differences in the final field emergence count.

Table 3. Partial and total replacement of the first batch of urea fertilizer using local gypsum coating and nano-nitrogen in the final field emergence count

Coating (A)	Nano-nitrogen (mg L⁻¹) N	Partial and Complete Replacement of Urea Fertilizer (%) U			A×N
		100	50	0	
Without Coating A1	0	52.62	54.02	44.52	50.39
	20	59.43	64.46	70.37	64.75
	40	69.23	66.31	69.57	68.37
	60	64.24	68.57	71.68	68.16
Coating with local gypsum A2	0	56.95	59.17	50.88	55.67
	20	61.37	65.08	63.70	63.38
	40	69.08	72.22	72.42	71.24
	60	69.78	71.89	73.65	71.77
LSD α 0.05		3.02			1.38
		U			A×U
A		100	50	0	
A1		61.38	63.34	64.04	62.92
A2		64.30	67.09	65.16	65.52
LSD α 0.05		NS			1.29
		U			N×U
N		100	50	0	
0		54.79	56.60	47.70	53.03
20		60.4	64.77	67.04	64.07
40		69.15	69.26	71.00	69.80
60		67.01	70.23	72.66	69.97
LSD α 0.05		2.14			1.01
Mean U		62.84	65.21	64.6	
LSD α 0.05		1.19			

The 60 mg L⁻¹ nano-nitrogen concentration combined with the urea control treatment yielded the highest interaction at 72.66%, while the control treatment combining nano-nitrogen and urea resulted in the lowest final field emergence rate at 47.7%. Similarly, the interaction between local gypsum covering, nano-nitrogen, and partial urea fertilizer also showed significant differences in the final field emergence count. The gypsum covering treatment, the 60 mg L⁻¹ nano-nitrogen concentration combined with the 0% urea control treatment (full application of the recommended fertilizer) resulted in the highest rate at 73.65%. The control treatment combining covering, nitrogen, and urea resulted in the lowest rate at 44.52%.

3- Time to Field Emergence (days):

The results in Table (4) show significant differences in the effect of local gypsum coating and nano-nitrogen levels. However, partial and total urea fertilizer replacement treatments did not show any significant effect on the time to field emergence.

The treatment without coating resulted in the shortest number of days for field emergence, at 4.611 days, while the gypsum coating treatment took longer (6.083 days). The treatment with nano-nitrogen at a concentration of 60 mg L⁻¹ also achieved the shortest time to field emergence, at 4.444 days, significantly different from the other treatments. The control treatment showed the highest average number of days for field emergence, at 6.556 days. The statistical analysis (Table 4) also showed significant differences in the two-way interactions (coating with local gypsum + nano-nitrogen) and (nano-nitrogen + partial and total urea fertilizer replacement). The remaining two-way and three-way interactions did not show any significant effect on the time to field emergence. The interaction with seeds not coated with gypsum and treated with nano-nitrogen at concentrations of 40 and 60 mg L⁻¹ resulted in the shortest time to field emergence, at 4.222 days, while the coated seeds stimulated by water only resulted in the longest time to field emergence, at 7.667 days. Regarding the effect of the interaction (nano nitrogen + partial and total urea fertilizer replacement), the stimulation treatment with nano nitrogen at 40 and 60 mg L⁻¹ with a 0% replacement rate resulted in the shortest field emergence time of 4.167 days. The stimulation treatment with water only, applying the full recommended fertilizer (0% replacement rate), resulted in the longest field emergence time of 7.000 days.

Table 4. Partial and total replacement of the first application of urea fertilizer using local gypsum coating and nano nitrogen on field emergence time

Coating (A)	Nano-nitrogen (mg L ⁻¹) N	Partial and Complete Replacement of Urea Fertilizer (%) U			A × N
		100	50	0	
Without Coating A1	0	5.333	5.333	5.667	5.444
	20	4.333	5.000	4.333	4.556
	40	5.000	4.000	3.667	4.222
	60	4.333	4.333	4.000	4.222
Coating with local gypsum A2	0	7.000	7.667	8.333	7.667
	20	6.667	6.667	6.333	6.556
	40	5.667	6.000	4.667	5.444
	60	5.000	4.667	4.333	4.667
LSD α 0.05		NS			0.742
		U			A × U
A		100	50	0	
A1		4.750	4.667	4.417	4.611
A2		6.083	6.250	5.917	6.083
LSD α 0.05		NS			0.83
		U			N × U
N		100	50	0	
0		6.167	6.500	7.000	6.556
20		5.500	5.833	5.333	5.556
40		5.333	5.000	4.167	4.833
60		4.667	4.500	4.167	4.444
LSD α 0.05		0.659			0.489
Mean U		5.417	5.458	5.167	
LSD α 0.05		NS			

4- Seedling Height (cm):

Significant differences were observed in seed height resulting from the treatment of gypsum coating and fertilization with nano-nitrogen. No significant differences were observed in seedling height resulting from the partial and total replacement percentages of urea fertilizer.

The gypsum coating treatment resulted in the highest average seedling height of 15.838 cm, while the control treatment resulted in the lowest average seedling height of 13.854 cm. The nano-nitrogen treatment at a concentration of 60 mg L⁻¹ resulted in the highest average seedling height of 16.507 cm, compared to the control treatment which resulted in the lowest average seedling height of 11.969 cm.

The dual treatment (local gypsum coating + nano-nitrogen), the (local gypsum coating + partial and total replacement percentages of urea fertilizer), and the triple treatment did not show significant differences in seedling height. The combination of nano-nitrogen and partial urea fertilizer application showed significant differences in seedling height. Treating seeds with nano-nitrogen at a concentration of 60 mg L⁻¹ + complete urea fertilizer application (100% replacement) resulted in the highest combined effect of 16.826 cm, while the control treatment of nano-nitrogen and the application of the full dose of urea (0% replacement) resulted in the lowest average seedling height of 10.963 cm.

Table 5. Effects of Partial and Complete Urea Fertilizer Application on Seedling Height Using Local Gypsum Coating and Nano-Nitrogen

Coating (A)	Nano-nitrogen (mg L ⁻¹) N	Partial and Complete Replacement of Urea Fertilizer (%) U			A × N
		100	50	0	
Without Coating	0	11.177	12.257	9.967	11.133
A1	20	13.823	14.157	14.363	14.114
	40	14.687	14.817	14.870	14.791
	60	14.890	15.56	15.677	15.376
Coating with local gypsum	0	12.612	13.841	11.960	12.804
A2	20	15.844	16.221	15.677	15.914
	40	17.624	16.38	16.983	16.996
	60	17.091	17.847	17.976	17.638
LSD α 0.05		NS			NS
		U			A × U
A		100	50	0	
A1		13.644	14.198	13.719	13.854
A2		15.793	16.072	15.649	15.838
LSD α 0.05		NS			0.335
		U			N × U
N		100	50	0	
0		11.894	13.049	10.963	11.969
20		14.834	15.189	15.020	15.014
40		16.155	15.598	15.926	15.893
60		15.990	16.703	16.826	16.507
LSD α 0.05		1.15			0.885
Mean U		14.718	15.135	14.684	
LSD α 0.05		NS			

5- Seedling Dry Weight (g seedling⁻¹):

The results in Table (6) indicate significant differences in seedling dry weight due to the influence of all study factors and their two-way and three-way interactions. The treatment with local gypsum coating gave the highest average dry weight of the trait, reaching 1.5214 g seedling⁻¹, compared to the treatment with uncoated seeds, which gave the lowest average, reaching 1.1281 g seedling⁻¹. The treatment with nano-nitrogen at a concentration of 60 mg L⁻¹ gave the highest average dry weight of the seedling, reaching 1.5595 g seedling⁻¹, compared to the control treatment, which gave the lowest average dry weight of the trait, reaching 1.0442 g seedling⁻¹. The 50% urea fertilizer replacement treatment resulted in the highest average seedling dry weight (GFW) of 1.3559 g seedling⁻¹, while the 100% urea replacement treatment yielded the lowest GFW of 1.2825 g seedling⁻¹.

The dual treatment of plaster coating and nano-nitrogen at a concentration of 60 mg L⁻¹ resulted in the highest average seedling dry weight (GFW) of 1.7733 g seedling⁻¹, while the no-plaster treatment and the control treatment with nano-nitrogen resulted in the lowest average seedling dry weight (GFW) of 0.985 g seedling⁻¹. The combined treatment of covering and 50% urea fertilizer replacement also resulted in the highest average seedling dry weight of 1.6108 g seedling⁻¹. The combined treatment of no covering and urea replacement was also shown.

The seedlings were treated with gypsum and partially replaced with urea fertilizer (50%), resulting in the lowest average seedling dry weight of 1.101 g seedling⁻¹. However, the dual treatment of fertilization with nano-nitrogen at a concentration of 60 mg L⁻¹ and total replacement with urea (100%) resulted in the highest average seedling dry

weight of 1.5233 g seedling⁻¹, while the control treatment of nano-nitrogen and total replacement with urea (100%) yielded the lowest average seedling dry weight of 0.9342 g seedling⁻¹. The seeds were then treated with gypsum and partially replaced with urea fertilizer (50%). The triple interaction treatment of plaster coating, 60 mg L⁻¹ nano-nitrogen, and 50% urea partial replacement yielded the highest average yield of 1.81 g seedlings per 100°C, while the control treatment of coating, nitrogen, and 100% urea partial replacement yielded the lowest average yield of 0.895 g seedlings per 100°C.

Table 6. Partial and complete replacement of the first batch of urea fertilizer using local covering and nano-nitrogen on seedling dry weight

Coating (A)	Nano-nitrogen (mg L ⁻¹) N	Partial and Complete Replacement of Urea Fertilizer (%) U			A × N
		100	50	0	
Without Coating	0	0.895	0.950	1.110	0.985
A1	20	1.025	0.940	1.033	0.9994
	40	1.170	1.174	1.203	1.1824
	60	1.327	1.340	1.370	1.3456
Coating with local gypsum	0	0.973	1.373	0.963	1.1033
A2	20	1.397	1.577	1.623	1.5322
	40	1.753	1.683	1.593	1.6767
	60	1.720	1.810	1.790	1.7733
LSD α 0.05		0.1373			0.0967
		U			A × U
A		100	50	0	
A1		1.1042	1.101	1.1792	1.1281
A2		1.4608	1.6108	1.4925	1.5214
LSD α 0.05		0.0809			0.1044
		U			N × U
N		100	50	0	
0		0.9342	1.1617	1.0367	1.0442
20		1.2108	1.2583	1.3283	1.2658
40		1.4617	1.4287	1.3983	1.4296
60		1.5233	1.575	1.580	1.5594
LSD α 0.05		0.09556			0.0658
Mean U		1.2825	1.3559	1.3358	
LSD α 0.05		0.0453			

6- Seedling Vigor Index (SV) (%).

The results in Table (7) indicate significant differences for all individual study factors and their paired interactions. The triple interaction did not show any significant effect on the seedling vigor index.

The plaster coating treatment yielded the highest average yield of 101.46, while the control treatment yielded the lowest yield of 71.69. The treatment with nano-nitrogen at a concentration of 60 mg L⁻¹ resulted in the highest seedling strength index (SEI) of 109.58, compared to the control treatment which yielded the lowest SEI of 55.57. Regarding the partial and full urea fertilizer replacement treatments, the 50% partial replacement resulted in the highest SEI of 89.72, while the 100% full replacement treatment resulted in the lowest SEI of 82.08.

As for the effect of the dual interactions, the treatment combining plaster covering with nano-nitrogen at a concentration of 60 mg L⁻¹ resulted in the highest SEI of 127.37, while the control treatment combining plaster covering with nano-nitrogen resulted in the lowest SEI of 49.26. The interaction between local plaster coating and partial urea fertilizer application also yielded the highest score of 108.94 when local plaster coating and 50% urea replacement were applied. In contrast, the control treatment of local plaster coating and 100% urea replacement resulted in the lowest score of 49.26. Similarly, the interaction between 60 mg L⁻¹ nano-nitrogen and the full recommended urea application resulted in the highest interaction score of 114.97, while the control treatment of nano-nitrogen and urea resulted in the lowest seedling strength index score of 49.19.

Table 7. Partial and full urea replacement of the first application using local plaster coating and nano-nitrogen on seedling strength index

Coating (A)	Nano-nitrogen	Partial and Complete Replacement of Urea Fertilizer (%) U			A × N
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	(mg L ⁻¹) N	100	50	0	
Without	0	47.13	51.23	49.43	49.26
Coating	20	60.93	60.72	72.65	64.77
A1	40	81.06	78.02	83.77	80.95
	60	85.28	91.99	98.09	91.79
Coating with	0	55.41	81.25	48.95	61.87
local gypsum	20	85.71	102.65	103.45	97.27
A2	40	121.16	121.62	115.19	119.32
	60	120.01	130.25	131.84	127.37
LSD α 0.05		NS			7.479
		U			A×U
A		100	50	0	
A1		68.6	70.49	75.99	71.69
A2		95.57	108.94	99.86	101.46
LSD α 0.05		6.566			8.537
		U			N×U
N		100	50	0	
0		51.27	66.24	49.19	55.57
20		73.32	81.69	88.05	81.02
40		101.11	99.82	99.48	100.14
60		102.64	111.12	114.97	109.58
LSD α 0.05		7.331			4.864
Mean U		82.08	89.72	87.92	
LSD α 0.05		3.573			

DISCUSSION

Numerous studies have demonstrated that sorghum suffers from poor field emergence, with a significant discrepancy between seed viability and performance in the laboratory and actual field emergence. This necessitates extensive research to understand and overcome this problem (Mustafa and Cheyed, 2018; Alrawi and Cheyed, 2018). Among the most important methods for protecting seeds from various soil stresses is seed coating, which provides additional protection. One such material is local gypsum, which has proven effective as an inert material that protects seeds and acts as a carrier medium for fertilizers and pesticides (Cheyed *et al.*, 2019). This was demonstrated by the effect of local gypsum coating on increasing the field emergence percentage in the final count, seedling height, and dry weight, which was reflected in an increased seedling strength index (Tables 3, 5, 6, and 7). The reason for the superiority of the non-coating treatment in the field emergence percentage in the first count (Table 2) may be due to the presence of gypsum, which increases the thickness of the seed coat, thus delaying the emergence rate and increasing the time required for complete field emergence (Table 4). These results are consistent with those of Shehadeh and Giyad (2018) and Cheyed *et al.* (2019).

Regarding the effect of adding nano-nitrogen, we observe that the initial stages of field emergence and final count (Tables 2 and 3) responded significantly to the application of nano-nitrogen at a concentration of 40 mg L⁻¹. The response increased with nano-nitrogen at a concentration of 60 mg L⁻¹, shortening the number of days required for field emergence and increasing seedling height, dry weight, and vigor index. This improvement is attributed to the direct effect of nitrogen on enhancing emergence, field emergence, and seedling growth characteristics, particularly in its nano-form. One such fertilizer is nano-nitrogen, which can lead to increased yield (Duhana *et al.*, 2017).

The results of this study also reveal a negative impact of applying the full recommended amount. The initial count was optimal when the recommended amount was completely replaced with urea fertilizer (Table 2), while a partial replacement of 50% yielded the best results for final count, dry weight, and vigor index (Tables 3, 6, and 7). This is because direct fertilization with urea fertilizer can negatively affect seed emergence and field emergence, including in sorghum. This effect is mainly attributed to the formation of ammonia resulting from the decomposition of urea by the urease enzyme present in the soil. This leads to ammonia accumulation around the seeds, hindering emergence (Krogmeier *et al.*, 1989), or to ammonia volatilization and its toxic effect on root growth (Zhang *et al.*, 2017).

It is worth noting that the presence of nano-nitrogen combined with seed coating treatment using local gypsum is preferable to direct application of this fertilizer to the seeds. Furthermore, it has been observed that nano-fertilizer can replace the initial soil application of urea fertilizer, or even up to 50% of it.

CONCLUSIONS

This study concludes that coating seeds with local gypsum and treating them with nano-nitrogen combines the efficiency of direct fertilization with overcoming the physical constraints of the soil. Although emergence was delayed

in the initial application of the coating treatments, the final result was improved seedling emergence, increased emergence rates, and enhanced seedling activity and vigor in sorghum. This approach represents a promising strategy for improving productivity in challenging soil conditions. These treatments are a suitable alternative to the first application of urea fertilizer, which can be applied partially (50%) or fully (100%).

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