Root Characters of high oleic and normal groundnut varieties as influenced by nutrient management under well water and water stress environments.

ABSTRACT

Aims: To find out the influence of moisture stress and nutrient managemnt on root parameters of high oleic and normal groundnut varieties

Background: A field experiment was conducted at ICRISAT, Patancheru, Hyderabad, during *rabi* 2022-23 and 2023-24 to evaluate the performance of high oleic and normal Groundnut varieties with nutrient management practices under well watered and water stress conditions.

Methodology: During the year 2022-23 and 2023-24 experiment was performed insplit plot design over the environments. Under well watered conditions irrigation is given at 1.0 cumulative Epan, whereas in water stress irrigation is scheduled at 0.5 cumulative Epan.Girnar 4 (ICGV 15083) and Girnar 5 (ICGV 15090) are the high oleic varieties and Kadiri Lepakshi (K1812) is the normal oleic variety, which were used in the study.

Results: The root parameters of high oleic and normal groundnut varieties were differed significantly between well watered and water stress conditions. The root dry weight and root volume was significantly higher in well wateredcondition(E I) over water stress(E II). There was no significant variation in nutrient management treatments with respect to all the root parameters studied. Among varieties V_2- Girnar 5 (ICGV 15090) registered the higher values for the root parameters and those were at par with V_1-Girnar 4 (ICGV 15083). Whereas, KadiriLepakshi variety (V_3) has recorded the lower values for the root parameters studied.

Key words:*Well water and water Stress, Root dry weight, Root Volume, High oleic varieties, Nutrient management*

1. INTRODUCTION

Groundnut ismajor oilseed crop of the country and It is considered as a king of oilseeds. It is cultivated in more than 82 countries in tropical, sub-tropical and warm temperate regions of the world (1).Globally, around 30.54 million hectares of area was cultivated, resulting in a production of 54.24 million metric tons (2). In India, Groundnutis grown in an area of about 44.31 lakh acres with production of 86.54 lakh tonnes and productivity of 1953 kg ha^{-1}(3).In India, groundnut cultivation primarily occurs under rainfed conditions, making it vulnerable to intermittent droughts that significantly affect final yields. To mitigate this, enhancing drought-adaptive traits in plants is crucial. Among these traits, root parameters are considered the most effective for improving drought tolerance (4),(5). An enhanced root system under moisture stress conditions allows plants to access water from deeper soil layers, offering a distinct advantage during droughts (6). Increased root mass is often indicative of a plant's greater ability to maintain water status(4), (7). Santos et al., (8)reported that increased root dry weight under moisture stress conditions may be associated with drought tolerance in plants. These root parameters can be further enhanced through improved agronomic practices,

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such as nutrient management and the selection of appropriate cultivars. Balanced nutrition enhances the nutrient availability in soil and improves soil conditionsfor root growth in plants (9).Selecting cultivars with larger root systems can improve water uptake, potentially leading to higher water use efficiency (WUE) under drought stress (10). In India, most cultivated Groundnuts are of normal oleic lines, but there is a growing trend towards the cultivation of high oleic Groundnuts. Groundnuts containing at least 72% oleate, or an oleate/linoleate ratio (O/L) of 9, are generally considered high-oleic (11). To date, the agronomic performance of normal oleic lines concerning root parameters has been well-documented. This study was therefore conducted to evaluate the performance of high oleic and normal groundnuts with respect to root parameters under moisture stress and nutrient management.

2. Material and Methods

A field experiment was carried out in a red sandy loam soil at RP 7c field, ICRISAT, Patancheru, Hyderabad, during *rabi* 2022-23 and 2023-24. The experimental soil was slightly alkaline with pH of 7.54 and EC 0.31 dS m^{-1}.The soil was low in organic carbon (0.44%), and available N (210.6 kg ha^{-1}), medium in available P_2O_5 (22.4 kg ha^{-1}) and high in available K_2O (314.3 kg ha^{-1}), medium in exchangeable Calcium (3.18 C mole kg^{-1}) and available sulphur (14.2 ppm). The experiment was laid out in split plot design in two environments. Environment I: Well water (Irrigation scheduled at 1.0 Epan) and Environment II: Water stress (Irrigation scheduled at 0.5 Epan). In water stress environment, stress was imposed after 50% of flowering of groundnut varieties in all the treatments. The Main plot treatments were four viz., N_1= RDF (30:40:50 kg NPK ha^{-1}), N_2= RDF (30:40:50 kg NPK ha^{-1}) + Gypsum@ 500 kg ha^{-1}, N_3= RDF (30:40:50 kg NPK ha^{-1}) + Gypsum@ 500 kg ha^{-1} + Vermicompost @ 5t ha^{-1}, N_4= RDF (30:40:50 kg NPK ha^{-1}) + Gypsum@ 500 kg ha^{-1} + Vermicompost @ 5t ha^{-1} + PGPR @ 9 g kg^{-1} seed and the sub plot treatments include three varieties viz., V_1- Girnar 4, V_2- Girnar 5, V_3- Kadiri Lepakshi. Girnar 4 and Girnar 5 are high oleic varieties; KadiriLepakshi is a normal oleic variety. The root portion from every plant that was chosen was removed. The roots that are removed from the plants that are collected for the dry matter production was cleaned labelled and then dried in an oven at 65 ± 2°C until they reached constant weights. At 30, 60, and 90 days after sowing (DAS) the root dry weight (g $palnt^{-1}$) was measured. The root volume was taken through water displacement method (12) at 30, 60 and 90 DAS.

3. Results

3.1 Root dry weight (g $plant^{-1}$)

The data presented in the table 1 and 2 represents the root dry weight of high oleic and normal groundnut varieties as influenced by nutrient management under well watered and water stress condition from 30 DAS to harvest during 2022-23 and 2023-24. The influence of nutrient management on root dry weight was non-significant in all growth stages in well water and water stress environments during 2022-23 and 2023-24, respectively. In case of varieties under well watered condition Girnar 5 recorded the higher root dry weight of 0.85, 1.89, 2.08 g $plant^{-1}$at 60, 90 DAS and harvest, in that order and it was statistically on par with Girnar 4 (0.82, 1.83 and 2.0 g $plant^{-1}$, at 60, 90

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DAS and harvest, in order)during 2022-23. Whereas the lowest values of root dry weight (0.76, 1.68 is from Kadiri Lepakshi variety in all growth stages during 2022-23. Similarly, during the second year of the experimentation at 60, 90 DAS and harvest, Girnar 5 (0.90, 1.93, 2.09 g plant^{-1}, respectively) registered significantly higher root dry weight which was on par with Girnar 4 (0.87, 1.90, 2.05 g plant^{-1}, respectively). Among all varieties Kadiri Lepakshi (V_3) showed significantly less root dry weight (0.74, 1.77, 1.89 g plant^{-1}, at 60, 90 DAS and harvest, respectively) in 2023-24. On the other hand, the root dry weight of varieties tested under water stress conditions was less in comparison with well watered conditions. Under water stress conditions, Girnar 5 exhibited a higher root dry weight of0.58, 1.14, and 1.24 g plant^{-1} at 60, 90 DAS and harvest in 2022-23, respectively, which were comparable to Girnar 4 (0.55,1.10 and 1.20 g palnt^{-1}, at 60, 90DAS and harvest, respectively) and superior to Kadiri Lepakshi (0.50,0.99 and 1.12 g palnt^{-1}, at 60, 90 DAS and harvest, respectively) during 2022-23 and in second year also similar trend was observed wherein, Girnar 5 (0.70,1.18 and 1.22 g plant^{-1}, at 60, 90DAS and harvest, respectively) produced significantly higher root dry weight again comparable to Girnar 4(0.65, 1.06 and 1.10 g plant^{-1} at 60, 90 DAS and harvest, respectively), and KadiriLepakshi showing lessvalues of 0.59, 1.06 and 1.10 g palnt^{-1}, at 60, 90 DAS and harvest, respectively . However, the interaction effect was found to be non-significant between nutrient management and varieties under well watered and water stress conditions during 2022-23 and 2023-24.

When the data of root dry weight compared over the environments, it is found that there was a significant influence of moisture stress on root dry weight at all growth stages except at 30 DAS during 2022-23 and 2023-24 (Table 3 and 4). The root dry weight recorded under well-watered conditions was significantly higher compared to that under stress conditions. In the 2022-23 season, the root dry weights under well-watered conditions were 0.81 g, 1.80 g, and 2.0 g per plant at 60 days after sowing (DAS), 90 DAS, and at harvest, respectively. For the 2023-24, these values were 0.83 g, 1.87 g, and 2.01 g plant^{-1} at the same intervals. On the other hand, under stress conditions, the root dry weights were 0.54 g, 1.08 g, and 1.19 g plant^{-1} at 60 DAS, 90 DAS, and harvest during the 2022-23 season, and 0.65 g, 1.13 g, and 1.16 g plant^{-1} during the 2023-24.Increased root dry weight under high moisture conditions is primarily due to the availability of sufficient water, which promotes optimal plant physiological processes. In a well-watered environment, roots can absorb water and nutrients more efficiently, leading to the proliferation of lateral roots and overall root system expansion. Additionally, the absence of water stress allows plants to allocate more energy toward root development rather than activating stress responses, further contributing to increased root dry weight. Similar findings were reported by Songsri et al., (10), Ding et al., (13)The influence of nutrient management was non-significant during all the growth stages during two years of study. Girnar 5 recorded higher root dry weights of 0.72 g, 1.52 g, and 1.7 g per plant during the 2022-23 season, and 0.80 g, 1.56 g, and 1.65 g per plant in the 2023-24 season at 60 days after sowing (DAS), 90 DAS, and harvest, respectively. These values were statistically on par with Girnar 4, which had root dry weights of 0.68 g, 1.46 g, and 1.60 g per plant in the 2022-23 year, and 0.76 g, 1.52 g, and 1.61 g per plant in the 2023-24 at the same intervals. Kadiri Lepakshi recorded the lowest root dry weights, with values of 0.63 g, 1.33 g, and 1.48 g plant^{-1} during the 2022-23 season, and 0.67 g, 1.41 g, and 1.50 g plant^{-1} in the 2023-24, which were lower than those of the other varieties.Groundnut varieties that recorded the higher root dry weight under well watered and water stress conditions might be due to their inherent capacity to develop robust and extensive root system. Similar findings were reported by Songsri et al., (10), Ding et al., (13). All the possible interactions among moisture stress, nutrient management and varieties were non-significant during both the years of study.

3.2 Root volume (cm^3 plant $^{-1}$)

Data presented in the table 5 and 6 shows the root volume of high oleic and normal groundnut varieties as influenced by nutrient management under well watered and water stress conditions from 30 days after sowing to 90 days after sowing. There was no significant variation in root volume under nutrient management treatments at all stages during both the years of the study in well watered and water stress conditions. Among varieties under well watered situations there was significant difference in root volume in all growth stages except at 30 days after sowing. Significantly higher root volumes were observed with Girnar 5, recording 4.05 cm³ plant^{-1}at 60 DAS and 4.40 cm³plant^{-1} at 90 DAS during the 2022-23 season. This was statistically comparable to Girnar 4, which recorded 3.87 cm³ plant^{-1} at 60 DAS and 4.35 cm³ plant^{-1} at 90 DAS. In contrast, Kadiri Lepakshi showed lower root volumes at both 60 and 90 DAS, respectivelyduring the same year. Similarly, in the second year of the study (2023-24), Girnar 5 again exhibited significantly higher root volumes under well-watered conditions, with 3.95 cm³ plant^{-1} at 60 DAS and 4.48 cm³ plant^{-1} at 90 DAS. These values were on par with Girnar 4, which recorded 3.87 cm³ plant^{-1}at 60 DAS and 4.41 cm³ plant^{-1} at 90 DAS. Kadiri Lepakshi continued to show lower root volumes during the second year as well, with 3.62 cm³ plant^{-1} at 60 DAS and 4.12 cm^3 plant^{-1} at 90 DAS. Under water stress conditions also Girnar 5 produced higher root volume of 3.50,3.88 cc plant^{-1}, at 60 and 90 DAS, during 2022-23, respectively and it was on par with Girnar 4 variety (3.45 and 4.35 cm^3 plant^{-1} at 60 and 90 DAS, respectively). Whereas Kadiri Lepakshi (V_3) has reported the less root volume of 3.18, 3.68 cm^3 plant^{-1} at 60 and 90 DAS during 2022-23, respectively. Similar trend of results were observed during 2023-24, wherein Girnar 5 (3.54 and 3.89 cm^3 plant^{-1} at 60 and 90 DAS) recorded the higher root volume under water stress and it was on par with Girnar 4 (3.48 and 3.78 cm^3 plant^{-1}). Kadiri Lepakshi again showed the lowest root volume among the varieties, with 3.25 cm³ per plant at 60 DAS and 3.56 cm³ per plant at 90 DAS.

Root volume when compared over the environments table 7, It was noted that the effect of environment on root volume at 30 DAS is non-significant during 2022-23 and 2023-34. While at 60 DAS and 90 DAS, Well watered environment (3.82 and 4.28 cc plant $^{-1}$, at 60 and 90 DAS, respectively) recorded the greater root volume than the stress environment during 2022-23. Similar results were noticed with respect to root volume in 2023-24, whereas well watered conditions (3.81 and 4.34 cm^3 plant $^{-1}$, at 60 and 90 DAS, respectively) lead to greater root volume than water stress, 3.42 and 3.74 cc plant $^{-1}$ at 60 and 90 DAS, respectively. Well watered conditions provides an ideal environment for roots to expand and proliferate by producing more lateral and thicker roots which results in increased root volume over water stress conditions. Similar findings were reported by Ding et al., (13). Effect of nutrient management on root volume when pooled over two environments was found to be non-significant in two years of the study. At 60 and 90 DAS, among the varieties root

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volume of Girnar 5 (3.78,4.14 cc plant $^{-1}$, respectively) was higher and it was on par with the root volume of Girnar 4 during 2022-23. Alike results were noticed in 2023-24, that Girnar 5 (V_2) registered significantly higher root volume of3.74 and 4.19 cm^3 plant $^{-1}$ at 60 and 90 DAS, respectively and it was on par with Girnar 4 (3.67 and 4.09 cm^3 plant $^{-1}$, respectively).This might be due to production of thick and robust roots which led to increased root volume. Similar findings were noticed by Tangthong et al., (14). The root volume of KadiriLepakshi was low in 2022-23 (3.37 and 3.89 cm^3 plant $^{-1}$) and 2023-24 (3.43 and 3.67 cm^3 plant $^{-1}$) at 60 and 90 DAS, respectively.

Interaction between the environment and nutrient management and varieties was found to be non-significant with respect to root volume at all growth stages during the two years of study.

4. CONCLUSION

From the above results it is concluded that root dry weight and root volume were significantly higher under well watered environmentover waters stress. The effect of the nutrient management was not significant on the root parameters studied.Among varieties V_2-Girnar 5 (ICGV 15090) registered significantly higher values for the root parameters and those were at par with V_1-Girnar 4 (ICGV 15083).

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Table 1. Root dry weight (g palnt^{-1}) of high oleic and normal groundnut varieties as influenced by nutrient management under well watered and water stress environments at 30 and 60 DAS.

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Treatment	Environment 1: Well water (1.0 E pan)						Environment 2: Water Stress (0.5 E pan)					
	30 DAS			60 DAS			30 DAS			60 DAS		
	2022 -2023	2023 -2024	Mean	2022 -2023	2023 -2024	Mean	2022 -2023	2023 -2024	Mean	2022 -2023	2023 -2024	Mean
Nutrient Management (N)												
N_1: RDF	0.34	0.31	0.33	0.76	0.80	0.78	0.35	0.30	0.33	0.53	0.61	0.57
N_2:RDF + Gypsum @ 500 kg ha^{-1}	0.38	0.32	0.35	0.79	0.82	0.81	0.35	0.32	0.34	0.53	0.63	0.58
N_3: RDF + Gypsum @ 500 kg ha^{-1}+Vermicompost @ 5 t ha^{-1}	0.36	0.33	0.35	0.82	0.84	0.83	0.36	0.35	0.36	0.54	0.66	0.60
N_4: RDF + Gypsum + Vermicompost @ 5 t ha^{-1} + PGPR (Seed treatment) @ 9 g kg^{-1} seed	0.39	0.34	0.37	0.85	0.87	0.86	0.38	0.33	0.36	0.56	0.69	0.63
SEm ±	0.01	0.01		0.03	0.03		0.01	0.01		0.02	0.03	
CD (P=0.05)	NS	NS		NS	NS		NS	NS		NS	NS	
Varieties (V)												
V1-Girnar 4 (ICGV 15083)	0.37	0.32	0.35	0.81	0.87	0.85	0.36	0.33	0.35	0.55	0.65	0.60
V2-Girnar 5 (ICGV 15090)	0.38	0.33	0.35	0.85	0.90	0.88	0.37	0.33	0.35	0.58	0.70	0.64
V3- Kadiri Lepakshi (K 1812)	0.35	0.32	0.36	0.76	0.74	0.75	0.34	0.31	0.33	0.50	0.59	0.55
SEm ±	0.01	0.01		0.02	0.02		0.01	0.01		0.01	0.01	
CD (P=0.05)	0.04	0.03		0.05	0.06		0.04	0.02		0.04	0.04	
Interaction (N ×V)												
Sub plot treatment at same level of main treatment												
SEm ±	0.03	0.02		0.04	0.04		0.03	0.02		0.03	0.03	
CD (P=0.05)	NS	NS		NS	NS		NS	NS		NS	NS	
Main plot treatment at same level of sub plot treatment												
SEm ±	0.02	0.02		0.04	0.04		0.02	0.02		0.03	0.04	
CD (P=0.05)	NS	NS		NS	NS		NS	NS		NS	NS	

*DAS (Days after sowing)

Table 2. Root dry weight (g palnt^{-1}) of high oleic and normal groundnut varieties as influenced by nutrient management under well watered and water stress environments at 90 DAS and harvest.

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Treatment	Environment 1: Well water (1.0 E pan)						Environment 2: Water Stress (0.5 E pan)					
	90 DAS			At Harvest			90 DAS			At Harvest		
	2022 -2023	2023 -2024	Mean	2022 -2023	2023 -2024	Mean	2022 -2023	2023 -2024	Mean	2022 -2023	2023 -2024	Mean
Nutrient Management (N)												
N_1: RDF	1.76	1.82	1.79	1.90	1.94	1.92	1.02	1.03	1.03	1.11	1.10	1.11
N_2:RDF + Gypsum @ 500 kg ha^{-1}	1.78	1.85	1.82	1.94	1.97	1.96	1.07	1.11	1.09	1.17	1.15	1.16
N_3: RDF + Gypsum @ 500 kg ha^{-1}+Vermicompost @ 5 t ha^{-1}	1.82	1.88	1.85	2.01	2.04	2.03	1.08	1.17	1.13	1.21	1.19	1.20
N_4: RDF + Gypsum + Vermicompost @ 5 t ha^{-1} + PGPR (Seed treatment) @ 9 g kg^{-1} seed	1.84	1.90	1.87	2.04	2.08	2.06	1.14	1.20	1.17	1.25	1.21	1.23
SEm ±	0.04	0.05		0.06	0.06		0.03	0.05		0.03	0.03	
CD (P=0.05)	NS	NS		NS	NS		NS	NS		NS	NS	
Varieties (V)												
V1-Girnar 4 (ICGV 15083)	1.83	1.90	1.86	2.00	2.05	2.03	1.10	1.14	1.12	1.20	1.17	1.19
V2-Girnar 5 (ICGV 15090)	1.89	1.93	1.91	2.08	2.09	2.09	1.14	1.18	1.16	1.24	1.22	1.23
V3- Kadiri Lepakshi (K 1812)	1.68	1.77	1.72	1.84	1.89	1.87	0.99	1.06	1.02	1.12	1.10	1.11
SEm ±	0.04	0.03		0.04	0.04		0.02	0.02		0.02	0.02	
CD (P=0.05)	0.13	0.08		0.12	0.12		0.07	0.06		0.06	0.07	
Interaction (N ×V)												
Sub plot treatment at same level of main treatment												
SEm ±	0.09	0.06		0.08	0.08		0.05	0.04		0.04	0.05	
CD (P=0.05)	NS	NS		NS	NS		NS	NS		NS	NS	
Main plot treatment at same level of sub plot treatment												
SEm ±	0.08	0.07		0.09	0.09		0.05	0.06		0.05	0.05	
CD (P=0.05)	NS	NS		NS	NS		NS	NS		NS	NS	

*DAS (Days after sowing)

Table 3. Root dry weight (g palnt^{-1}) of high oleic and normal groundnut varieties pooled over the environments.

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Treatment	30 DAS			60 DAS		
	2022-23	2023-24	**Mean**	2022-23	2023-24	**Mean**
Environment (E)						
Environment I: Non Stress (1.0 Epan)	0.37	0.32	0.35	0.81	0.83	0.82
Environment II: Stress (0.5 Epan)	0.36	0.33	0.35	0.54	0.65	0.60
SEm ±	0.01	0.01		0.01	0.02	
CD(P=0.05)	NS	NS		0.03	0.05	
Nutrient Management (N)						
N_1: RDF	0.34	0.30	0.32	0.65	0.70	0.68
N_2:RDF + Gypsum @ 500 kg ha^{-1}	0.36	0.32	0.34	0.66	0.73	0.70
N_3: RDF + Gypsum @ 500 kg ha^{-1}+Vermicompost	0.36	0.34	0.35	0.68	0.75	0.72
N_4: RDF + Gypsum + Vermicompost+ PGPR (Seed treatment) @ 9 g kg^{-1} seed	0.38	0.34	0.36	0.71	0.78	0.75
SEm ±	**0.01**	**0.01**		**0.02**	**0.02**	
CD (P=0.05)	NS	NS		NS	NS	
Varieties (V)						
V1-Girnar 4 (ICGV 15083)	0.37	0.33	0.35	0.68	0.76	0.72
V2-Girnar 5 (ICGV 15090)	0.38	0.33	0.36	0.72	0.80	0.76
V3- Kadiri Lepakshi (K 1812)	0.35	0.32	0.34	0.63	0.67	0.65
SEm ±	**0.01**	**0.01**		**0.01**	**0.01**	
CD(P=0.05)	NS	NS		**0.03**	**0.03**	
All two way and three way interactions are non-significant.						

***DAS (Days after sowing)

Table 4. Root dry weight (g palnt^{-1}) of high oleic and normal groundnut varieties pooled over the environments at 90 DAS and harvest

Comment [MF54]: plant $^{-1}$

Treatment	90 DAS			At harvest		
	2022-23	2023-24	**Mean**	2022-23	2023-24	**Mean**
Environment (E)						
Environment I: Non Stress (1.0 Epan)	1.80	1.87	1.84	2.0	2.01	1.99
Environment II: Stress (0.5 Epan)	1.08	1.13	1.11	1.2	1.16	1.18
SEm ±	0.02	0.03		0.02	0.02	
CD(P=0.05)	0.05	0.08		0.07	0.07	
Nutrient Management (N)						
N_1: RDF	1.39	1.43	1.41	1.5	1.52	1.51
N_2:RDF + Gypsum @ 500 kg ha^{-1}	1.42	1.48	1.45	1.6	1.56	1.56
N_3: RDF + Gypsum @ 500 kg ha^{-1}+Vermicompost	1.45	1.53	1.49	1.6	1.62	1.62
N_4: RDF + Gypsum + Vermicompost+ PGPR (Seed treatment) @ 9 g kg^{-1} seed	1.49	1.55	1.52	1.6	1.65	1.65
SEm ±	0.02	0.04		0.03	0.03	
CD (P=0.05)	NS	NS		NS	NS	
Varieties (V)						
V1-Girnar 4 (ICGV 15083)	1.46	1.52	1.49	1.6	1.61	1.61
V2-Girnar 5 (ICGV 15090)	1.52	1.56	1.54	1.7	1.65	1.66
V3- Kadiri Lepakshi (K 1812)	1.33	1.41	1.37	1.5	1.50	1.49
SEm ±	0.02	0.02		0.02	0.02	
CD(P=0.05)	0.07	0.05		0.07	0.07	
All two way and three way interactions are non-significant.						

***DAS (Days after sowing)**

Table 5. Root volume (cm^3 $plant^{-1}$)of high oleic and normal groundnut varieties as influenced by nutrient management under well watered and water stress environments at 30 and 60 DAS

Treatment	Environment 1: Well water (1.0 E pan)						Environment 2: Water Stress (0.5 E pan)					
	30 DAS			60 DAS			30 DAS			60 DAS		
	2022 -2023	2023 -2024	Mean	2022 -2023	2023 -2024	Mean	2022 -2023	2023 -2024	Mean	2022 -2023	2023 -2024	Mean
Nutrient Management (N)												
N_1: RDF	1.40	1.36	1.38	3.77	3.71	3.74	1.43	1.44	1.44	3.30	3.33	3.32
N_2:RDF + Gypsum @ 500 kg ha^{-1}	1.43	1.36	1.40	3.83	3.80	3.82	1.43	1.44	1.44	3.37	3.39	3.39
N_3: RDF + Gypsum @ 500 kg ha^{-1}+Vermicompost @ 5 t ha^{-1}	1.45	1.40	1.43	3.76	3.84	3.80	1.39	1.43	1.41	3.47	3.45	3.46
N_4: RDF + Gypsum + Vermicompost @ 5 t ha^{-1} + PGPR (Seed treatment) @ 9 g kg^{-1} seed	1.47	1.40	1.44	3.93	3.89	3.91	1.44	1.48	1.46	3.37	3.50	3.44
SEm ±	0.04	0.04		0.10	0.14		0.03	0.05		0.09	0.06	
CD (P=0.05)	NS	NS		0.34	0.49		NS	NS		0.33	0.21	
Varieties (V)												
V1-Girnar 4 (ICGV 15083)	1.46	1.39	1.43	3.87	3.87	3.87	1.46	1.44	1.45	3.45	3.48	3.47
V2-Girnar 5 (ICGV 15090)	1.46	1.41	1.44	4.05	3.95	4.00	1.45	1.48	1.47	3.50	3.54	3.52
V3- Kadiri Lepakshi (K 1812)	1.40	1.35	1.38	3.56	3.62	3.59	1.36	1.42	1.39	3.18	3.25	3.22
SEm ±	0.03	0.03		0.07	0.07		0.04	0.03		0.06	0.05	
CD (P=0.05)	NS	NS		NS	NS		NS	NS		NS	NS	
Interaction (N ×V)												
Sub plot treatment at same level of main treatment												
SEm ±	0.06	0.06		0.13	0.14		0.09	0.06		0.12	0.10	
CD (P=0.05)	NS	NS		NS	NS		NS	NS		NS	NS	
Main plot treatment at same level of sub plot treatment												
SEm ±	0.06	0.06		0.15	0.18		0.08	0.07		0.14	0.10	
CD (P=0.05)	NS	NS		NS	NS		NS	NS		NS	NS	

***DAS (Days after sowing)

Table 6. Root volume (cm^{3}plant^{-1})of high oleic and normal groundnut varieties as influenced by nutrient management under well watered and water stress environments at 90 DAS

Comment [MF55]: plant^{-1}

Treatment	Environment 1: Well water (1.0 E pan)			Environment 1: Well water (0.5 E pan)		
	90 DAS			90 DAS		
	2022 -2023	2023 -2024	Mean	2022 -2023	2023 -2024	Mean
Nutrient Management (N)						
N_1: RDF	4.17	4.24	4.21	3.75	3.67	3.75
N_2:RDF + Gypsum @ 500 kg ha^{-1}	4.20	4.31	4.26	3.78	3.72	3.75
N_3: RDF + Gypsum @ 500 kg ha^{-1}+Vermicompost @ 5 t ha^{-1}	4.37	4.36	4.37	3.79	3.76	3.78
N_4: RDF + Gypsum + Vermicompost @ 5 t ha^{-1} + PGPR (Seed treatment) @ 9 g kg^{-1} seed	4.40	4.43	4.42	3.81	3.82	3.81
SEm ±	**0.07**	**0.08**		**0.10**	**0.11**	
CD (P=0.05)	NS	NS		NS	NS	
Varieties (V)						
V1-Girnar 4 (ICGV 15083)	4.35	4.41	4.38	3.85	3.78	3.82
V2-Girnar 5 (ICGV 15090)	4.40	4.48	4.44	3.88	3.89	3.89
V3- Kadiri Lepakshi (K 1812)	4.10	4.12	4.11	3.61	3.56	3.62
SEm ±	**0.06**	**0.07**		**0.06**	**0.07**	
CD (P=0.05)	**0.17**	**0.22**		**0.19**	**0.22**	
Interaction (N ×V)						
Sub plot treatment at same level of main treatment						
SEm ±	0.11	0.15		0.13	0.14	
CD (P=0.05)	NS	NS		NS	NS	
Main plot at same level of sub plot treatment						
SEm ±	0.11	0.14		0.14	0.16	
CD (P=0.05)	NS	NS		NS	NS	

***DAS (Days after sowing)

Table 7. Root Volume (cm^3 plant^{-1}) of high oleic and normal groundnut varieties pooled over the environments at 30, 60 and 90 DAS

Treatment	30 DAS			60 DAS			90 DAS		
	2022-23	2023-24	**Mean**	2022-23	2023-24	**Mean**	2022-23	2023-24	**Mean**
Environment (E)									
Environment I: Non Stress (1.0 Epan)	1.44	1.38	1.41	3.82	3.81	3.82	4.28	4.34	4.31
Environment II: Stress (0.5 Epan)	1.42	1.45	1.44	3.38	3.42	3.40	3.80	3.74	3.77
SEm ±	0.02	0.02		0.05	0.05		0.04	0.05	
CD(P=0.05)	NS	NS		0.15	0.17		0.13	0.15	
Nutrient Management (N)									
N_1: RDF	1.41	1.40	1.41	3.54	3.52	3.53	4.00	3.96	3.98
N_2:RDF + Gypsum @ 500 kg ha^{-1}	1.43	1.40	1.42	3.60	3.60	3.60	3.98	4.01	4.00
N_3: RDF + Gypsum @ 500 kg ha^{-1}+Vermicompost	1.42	1.42	1.42	3.62	3.65	3.64	4.08	4.06	4.07
N_4: RDF + Gypsum + Vermicompost+ PGPR (Seed treatment) @ 9 g kg^{-1} seed	1.45	1.44	1.45	3.65	3.70	3.68	4.10	4.13	4.12
SEm ±	0.03	0.03		0.07	0.08		0.06	0.07	
CD (P=0.05)	NS	NS		NS	NS		NS	NS	
Varieties (V)									
V1-Girnar 4 (ICGV 15083)	1.46	1.41	1.44	3.66	3.67	3.67	4.10	4.09	4.10
V2-Girnar 5 (ICGV 15090)	1.45	1.45	1.45	3.78	3.74	3.76	4.14	4.19	4.17
V3- Kadiri Lepakshi (K 1812)	1.38	1.39	1.39	3.37	3.43	3.40	3.89	3.84	3.87
SEm ±	0.03	0.02		0.04	0.04		0.04	0.05	
CD(P=0.05)	NS	NS		0.13	0.12		0.12	0.15	
All two way and three way interactions are non-significant.									

***DAS (Days after sowing)**

Comment [MF56]: v

5. References

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