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Agronomic manipulations to increase nutrient content in groundnut (*Arachis hypogeae* L.)

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ABSTRACT

Ammonical fertilizers reduce rhizosphere pH through release of proton and activates wall loosening processes and root cell elongation thereby, improves the nutrient uptake. Thus, a field experiment was conducted on the sandy soil of Agricultural College Farm, Bapatla, Andhra Pradesh, during *kharif* 2018 to increase nutrient availability in groundnut through agronomic manipulations. Sixteen treatments comprised of four levels of nitrogen (ammonium sulphate as source) *viz.*, 0 kg ha^{-1}, 30 kg ha^{-1}, 60 kg ha^{-1} and 90 kg ha^{-1} with 60 kg ha^{-1} and 90 kg ha^{-1} which were applied in three splits i.e., 1/3rd basal, 1/3rd @ 30 DAS and 1/3rd @ 60 days after sowing (DAS) and four planting geometry *viz.*, 30 x 10 cm, 25 x 10 cm, 20 x 10 cm and 15 x 10 cm. Application of 60 kg N ha^{-1}, produced highest root dry weight at 30 and 60 DAS, whereas, 90 kg N ha $^{-1}$ recorded the highest root dry weight at harvest. N, P and Zn uptake was higher at 90 kg N ha^{-1}, whereas, 60 kg N ha $^{-1}$ gave greater K and Fe uptake over other nitrogen levels. Significant acidification of rhizosphere pH was observed with 90 kg N ha^{-1} which was on par with 60 kg N ha $^{-1}$, however, soil bulk pH did not influence significantly to levels of ammonium sulphate. Root dry weight and nutrient uptake were highest and rhizosphere pH lowest under 15 x 10 cm spacing. The results thus revealed that agronomic manipulation through application of 60 kg N ha^{-1} and adoption of closer spacing (15 X 10 cm) can significantly influence rhizosphere chemistry thereby increasing nutrient availability in the groundnut crop.

1. Introduction

Groundnut, is a unique legume cum oilseed crop of India and is an essential source of edible oil. Its importance lies in high oil (45%) and protein (26%) content and minerals like iron, calcium and phosphorus (Chakraborty and Luther, 2020). However, the productivity of groundnut in India (1210 kg ha^{-1}) is much lesser than the leading countries like United States (4650 kg ha^{-1}) and China (3810 kg ha^{-1}) and the global average (1700 kg ha^{-1}) as well (Anonymous, 2022). The reasons for low yields could be attributed to several constraints, nutrient deficiency being one major factor. Fertilizer management is thus a key factor in improving groundnut production (Somasundaram *et al.,* 2010). Yield is a function of plant population and hence, it is highly associated with yield potential and optimum density per unit area is an important non-monetary input to decide the maximum productivity of the crop. (Waghmode *et al.,* 2017). Optimum plant population and nutrient dose are necessary factors recognized to derive yield potential of a cultivar.

Rhizosphere is the region of soil in the vicinity of plant roots in which the chemistry and microbiology is influenced by their growth, respiration and nutrient exchange (Chakraborty and Luther, 2020). The key biological functions of plant roots such as respiration, absorption and exudation can significantly amend many chemical properties in the rhizospheric region, such as: nutrients concentrations, concentrations of chelating compounds, redox potential, pH, etc. Rhizosphere processes such as root-induced changes in pH and root exudates release play a key role in nutrient acquisition. Rhizosphere chemistry can be significantly changed according to the form of N taken up: ammonium supply may reduce rhizosphere pH through promoting proton release and activation of wall-loosening processes, leading to root cell elongation and thus improving the nutrient uptake. (Hinsinger *et al.,* 2003). The possible explanations for stimulation of root growth by ammonium when localized with P could involve: (i) rhizosphere acidification might loosen the cell wall matrix and thus stimulate root growth ii)

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*Corresponding author: Chakrabortymandakranta@gmail.com ammonium may be the preferred form of nitrogen for protein synthesis in the root apical meristems because of the lower energy requirement for ammonium assimilation in comparison with nitrate (iii) ammonium may accelerate cell divisions and (iv) root absorption and assimilation of ammonium may cause a moderate decrease in root redox potentials and membrane-associated redox activities, favouring cell proliferation and extension and thus, root growth. (Jing *et al.*, 2010). Moreover, ammonium localization together with P caused rhizosphere acidification and increase nutrient availability.

In the light of the above knowledge, the present experiment was conducted to study the effect of agronomic manipulations to increase nutrient availability of groundnut

2. Material and Methods

The experimental trial was conducted in the sandy (85.6% sand, 5.7% silt and 8.7% clay) soil of Agricultural College Farm, Bapatla, Andhra Pradesh situated at an altitude of 5.49 m above mean sea level, 15° 54′N latitude, 80° 30′E longitude. During *kharif,* 2018 the study was conducted to increase nutrient availability in groundnut through agronomic manipulations. During the crop growth period, a total of 191.21 mm rainfall was received. The weekly mean maximum ranged between 26.6 ºC and 34.8 ºC and and minimum temperatures between 17.7 ºC and 26.6 ºC, respectively. The weekly mean relative humidity was 83.92 to 73.0%. The soil was near neutral in reaction (pH 6.83) and low in EC (0.06 dS m^{-1}), organic carbon (0.15%), available nitrogen (120 kg ha^{-1}) and medium in available phosphorus (29.2 kg ha^{-1}) and potassium (168 kg ha^{-1}).

The tractor drawn rotovator was used to plough the land followed by thorough levelling. The experimental design was randomized block design with factorial concept and was replicated three times. Sixteen treatments comprised of four levels of nitrogen (ammonium sulphate as source) *viz.*, 0 kg ha^{-1}, 30 kg ha^{-1}, 60 kg ha^{-1} and 90 kg ha^{-1} with 60 kg ha^{-1} and 90 kg ha^{-1} which were applied in three splits i.e., 1/3rd basal, 1/3rd @ 30 DAS and 1/3rd @ 60 DAS and four planting geometry *viz.*, 30 x 10 cm, 25 x 10 cm, 20 x 10 cm and 15 x 10 cm. Clean, bold seeds were selected and treated with Dithane M-45 @3g kg^{-1} to prevent from seed borne diseases. The TAG 24 variety of groundnut was sown on 15th September, 2018. The recommended dose of phosphorous and potassium were applied at 40 kg ha^{-1} and 50 kg ha^{-1}, respectively, through band placement to all the treatments uniformly. Gypsum was applied at early flowering stage @ 500 kg ha^{-1}.

Roots of five sampled plants were separated, oven dried to a constant weight and the root dry weight was recorded separately and expressed as g plant^{-1}. The pH of the rhizosphere was measured at 10 days interval and it was compared to the soil bulk pH. Soil adhering root surface was taken for measuring rhizosphere pH and the top soils in the surface around the plants were measured as soil bulk pH. Measurement was done immediately in the field using pH meter with a highly sensitive probe. The probe has a cut-out tip design, allowing a small amount of soil to be placed directly onto the sensor surface. One drop of distilled water was added to keep soil wet. (Jing *et al.*, 2010). N, P, K, Zn and Fe content in haulm and seed were determined according to the standard method described by Jackson (1973) as mentioned below:

Nutrient	Method
Nitrogen	Modified Micro-Kjeldahl method
Phosphorus	Vanado-molybdo-phosphoric acid method
Potassium	Flame-photometer method
Zinc	Atomic Absorption Spectrophotometer method
Iron	Atomic Absorption Spectrophotometer method

The nutrient uptake was recorded using formula:

Nutrient uptake (kg ha^{-1})

$$= \frac{\text{Nutrient concentration (\%) x Weight of drymatter (kg ha}^{-1}\text{)}}{100}$$

The data recorded were subjected to statistical analysis Statistical significance was tested by applying F-test at 0.05 level of probability.

3. Results and Discussion

Root Dry Weight

Root dry weight was found to respond significantly to the levels of nitrogen and increased with increasing nitrogen levels (Table 1). Significantly higher dry weight was observed at 90 kg N ha^{-1} as compared to lower levels on nitrogen at harvest stage (8.9%, 19.5% and 68.7%, respectively, over 60, 30 and 0 kg N ha^{-1}); however it was on par with 60 kg N ha^{-1} at 30 DAS and 60 DAS (5.3% and 25.0% and 7.7% and 50.0%, respectively, over 30 and 0 kg N ha^{-1}). Increasing population densities, root dry weight was observed to decrease, highest weight was noticed from 30 x 10 cm spacing, however it did not differ significantly to other spacings. The lowest root dry weight was observed 15 x 10 cm. The nutrient enrichment with fertilizer application might have stimulated root proliferation. Besides, localized application of P plus ammonium fertilizer induced growth of large amounts of fine roots, which can efficiently acquire soil nutrients not only through expanding root absorption surface, but also by accessing nutrients to the places where coarse roots cannot enter (Jing *et al,* 2010, Schachtman and Shin 2007). Such responses may account for the increased biomass of roots Further, increased zinc accumulation in shoot with ammonium sulphate might have increased auxin synthesis, leading to root proliferation, thus producing more dry weight (Quinghua *et al.* 2014, Jing *et al*, 2010).

Soil Bulk pH and Rhizosphere pH

The soil bulk pH was insignificant irrespective of nitrogen levels and population density (Table 2). Whereas, a gradual decrease in rhizospheric pH was observed with increasing nitrogen levels. Rhizosphere pH was significantly influenced by nitrogen level after 30 days of sowing and with population densities from 50 DAS. With the advancement of crop growth, gradual acidification was produced till harvest. The changes in rhizosphere chemistry might be due to the form of N applied, i.e., ammoniacal nitrogen supply reduced rhizosphere pH through promoting release of proton. Ammonium is the only form of N which tends to raise H^+ extrusion from roots. Ammonium ions get oxidised to form nitrate ions which release H^+ ions, resulting in soil acidification. Barber *et al.* (1995) stressed that root-induced processes occurring in the rhizosphere, such as pH changes, could have a dramatic effect on the acquisition of nutrients. Extracellular enzymes such as phosphatases, proteases and arylsulfatases exhibit more activity in the rhizosphere relative to the bulk soil, and may have a dramatic effect on the cycling of nutrients such as phosphorus, nitrogen and sulfur (Pinton *et al.*, 2001).

Nutrient Uptake

Nitrogen Uptake

Nitrogen uptake was maximum at 90 kg N ha^{-1} and minimum at control. Application of 90 kg N ha^{-1} recorded 68.4, 158.9 and 280.7 kg ha^{-1} higher uptake over 60, 30 and 0 kg N ha^{-1}, respectively. Among the population densities, significantly higher uptake of nitrogen was noticed with the closer spacing of 15 x 10 cm (14.7%, 25.1% and 32.7% more than 20 x 10 cm, 25 x 10 cm and 30 x 10 cm). Moreover, the data revealed that the uptake of nitrogen was more in seeds than that of haulms. The nutrient uptake is a function of yields and nutrient concentrations in plants, thus significant uptake might have resulted in higher yields. Localised placement of phosphorus and ammonium fertilizer might have modified the rhizosphere processes by stimulating root proliferation and by ammonium induced rhizosphere acidification, thereby increasing N acquisition by plants as reported by Jing *et al.* (2010).

Phosphorus Uptake

An increasing trend in uptake of phosphorus was observed with increasing nitrogen levels. Thus, the higher phosphorus uptake was observed significantly at 90 kg N ha^{-1}, which was recorded to be 8.1, 19.5 and 30.3 kg ha^{-1}, higher over 60, 30 and 0 kg N ha^{-1}. Maximum uptake was recorded with the higher density of 15 x 10 cm which was on par with 20 x 10 cm. The uptake of phosphorus was higher in seeds than haulms. Steady supply of nutrients throughout the crop growth period increased the nutrient availability for uptake and better utilization by the crop, thereby, producing more photosynthates and better partitioning of dry matter from source to sink (Chavan *et al.* 2014). Further, better root growth helped in greater extraction of nutrients which might have increased the availability of phosphorus (Jing *et al.* 2010).

Potassium Uptake (kg ha^{-1})

There was an increasing response observed in uptake of potassium with increasing nitrogen levels (Table 4). Thus, the higher potassium uptake was observed significantly with 90 kg N ha^{-1} which was on par with 60 kg N ha^{-1}. Application of 60 kg N ha^{-1}, recorded 51.8 and 123.kg higher total uptake over 30 and 0 kg N ha^{-1}. Population densities responded significantly to potassium uptake in groundnut. Closest spacing of 15 x 10 cm recorded 16.4%, 28.8% and 35.4%, higher total uptake over other spacings (20 x 10 cm, 25 x 10 cm and 30 x 10 cm, respectively). The interaction between nitrogen levels and population densities did not differ significantly. Moreover, the uptake of potassium was less in seeds than that of haulms. Higher yields and nutrient concentrations in plants might have resulted in significantly higher uptake of potassium (Chavan *et al.* 2014). Further, improved root growth and its functional activity also helped in greater extraction of potassium (El- Habbasha *et al.* 2013).

Zinc Uptake

An increasing trend was observed in uptake of zinc with increase in nitrogen levels. That is how, zinc uptake was observed significantly higher at 90 kg N ha^{-1}, which was 103.4, 214.7 and 396 g ha^{-1} over other nitrogen levels (60, 30 and 0 kg N ha^{-1}). Maximum uptake was recorded significantly with higher density of 15 x 10 cm, which was on par with 20 x 10 cm, which was 9.0% and 14.5%, higher over 25 x 10 cm and 30 x 10 cm. Ma *et al.* (2013) reported that ammonium-induced rhizosphere acidification in the localized fertilizer zone significantly enhanced Zn availability and acquisition, resulting in improved growth and Zn uptake.

Iron Uptake

Higher iron uptake in haulms was observed at 90 kg N ha^{-1} and it was on par with 60 kg N ha^{-1} whereas, for seed 90 kg N ha^{-1} resulted in significantly superior uptake (Table 5). Maximum uptake was recorded with higher density of 15 x 10 cm and it was on par with 20 x 10 cm for both haulm and seed. Least uptake was observed with wider spacing of 30 x 10 cm. Moreover, the uptake of iron was more in haulms than in seeds. Increased iron availability might have increased nodulating bacteria as iron is a constituent of ferridoxin and leghaemoglobin which might have increased the yield of groundnut with higher uptake of iron. Non-graminaceous plants increase iron availability by releasing protons that lower the soil pH and organic acid anions (Chakraborty and Luther, 2020). Organic acid anions can complex Fe^{3+} and hold it in a soluble form that can diffuse to the root surface. Further, plant can include changes in root morphology and histology. (Marschner *et al.*, 2011).

Accordingly, it can be accomplished that localized placement of ammonium sulphate (NH_4-N) is responsible for significant acidification in the rhizosphere. Althrough, the growing period, pH of rhizosphere was found to decrease which valued between 6.55-6.60 during harvest as compared to soil bulk pH which was nearly 6.90. This rhizospheric acidification can thus be believed to result in greater root proliferation and hence better uptake of macro nutrients (N, P and K) and micro nutrients (Zn and Fe) in the crop. Thereby, to optimize the quality and quantity of groundnut production ammonium fertilization (60 kg N ha^{-1}) at 15 x 10 cm spacing could be a suitable practice.

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Table 1. Root dry weight (g plant^{-1}) of groundnut as influenced by nitrogen levels and population densities at 30 DAS, 60 DAS and at harvest

Treatments	**Days after sowing**		
	30	**60**	**At Harvest**
Nitrogen levels (N)			
N1: 0 kg N ha^{-1}	0.16	0.28	0.29
N2: 30 kg N ha^{-1}	0.19	0.39	0.41
N3: 60 kg N ha^{-1}	0.20	0.42	0.45
N4: 90 kg N ha^{-1}	0.22	0.45	0.49
SEm±	0.01	0.01	0.01
CD (P=0.05)	0.02	0.04	0.03
Population densities (D)			
D1: 30 x 10 cm	0.21	0.41	0.45
D2: 25 x 10 cm	0.20	0.40	0.42
D3: 20 x 10 cm	0.19	0.38	0.40
D4: 15 x 10 cm	0.17	0.35	0.38
SEm±	0.01	0.01	0.01
CD (P=0.05)	0.02	NS	NS
Interaction (N x D)			
SEm±	0.02	0.02	0.02
CD (P=0.05)	NS	NS	NS
CV (%)	15.08	12.03	10.76

Table 2. Soil bulk pH under groundnut as influenced by nitrogen levels and population densities at 10 days interval

Treatments	**Days after sowing**								
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
Nitrogen levels (N)									
N1: 0 kg N ha^{-1}	7.00	6.99	6.94	6.93	6.92	6.91	6.94	6.89	6.88
N2: 30 kg N ha^{-1}	6.99	6.93	6.93	6.93	6.93	6.93	6.92	6.92	6.91
N3: 60 kg N ha^{-1}	6.97	6.94	6.95	6.95	6.94	6.94	6.94	6.94	6.93
N4: 90 kg N ha^{-1}	7.01	6.98	6.98	6.97	6.97	6.96	6.96	6.96	6.95
SEm±	0.03	0.03	0.02	0.03	0.02	0.03	0.03	0.03	0.03
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Population densities (D)									
D1: 30 x 10 cm	6.99	6.92	6.95	6.95	6.94	6.93	6.94	6.94	6.92
D2: 25 x 10 cm	7.03	6.97	6.99	6.92	6.94	6.91	6.93	6.91	6.92
D3: 20 x10 cm	6.99	6.98	6.90	6.93	6.95	6.93	6.93	6.91	6.91
D4: 15 x 10 cm	6.96	6.99	6.96	6.97	6.93	6.97	6.96	6.95	6.91
SEm±	0.03	0.03	0.02	0.03	0.02	0.03	0.03	0.03	0.03
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (N x D)									
SEm±	0.06	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.05
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	1.47	1.3	1.2	1.4	1.05	1.27	1.28	1.32	1.31

Table 3. Rhizosphere soil pH under groundnut as influenced by nitrogen levels and population densities at 10 days interval

Treatments	**Days after sowing**								
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
Nitrogen levels (N)									
N1: 0 kg N ha^{-1}	7.00	6.98	6.93	6.92	6.91	6.91	6.90	6.89	6.88
N2: 30 kg N ha^{-1}	6.92	6.93	6.83	6.81	6.78	6.76	6.74	6.72	6.71
N3: 60 kg N ha^{-1}	6.93	6.88	6.78	6.79	6.75	6.72	6.69	6.65	6.60
N4: 90 kg N ha^{-1}	6.94	6.93	6.78	6.78	6.71	6.68	6.63	6.58	6.55
SEm±	0.03	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.02
CD (P=0.05)	NS	NS	0.05	0.06	0.07	0.07	0.09	0.08	0.07
Population densities (D)									
D1: 30 x 10 cm	6.93	6.94	6.85	6.84	6.84	6.84	6.83	6.81	6.78
D2: 25 x 10 cm	6.93	6.89	6.83	6.83	6.80	6.81	6.76	6.74	6.70
D3: 20 x 10 cm	6.99	6.94	6.79	6.82	6.76	6.72	6.70	6.67	6.67
D4: 15 x10 cm	6.94	6.94	6.84	6.80	6.73	6.70	6.66	6.62	6.59
SEm±	0.03	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.02
CD (P=0.05)	NS	NS	NS	NS	0.07	0.07	0.09	0.08	0.07
Interaction (N x D)									
SEm±	0.06	0.06	0.04	0.04	0.05	0.05	0.07	0.06	0.05
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	1.46	1.59	0.96	1.08	1.18	1.30	1.70	1.49	1.20

Table 4. N, P, K uptake of groundnut as influenced by nitrogen levels and population densities.

Treatments	**Nutrient Uptake (kg ha^{-1})**								
	N			**P**			**K**		
	Haulm	**Seed**	**Total**	**Haulm**	**Seed**	**Total**	**Haulm**	**Seed**	**Total**
Nitrogen levels (N)									
N1: 0 kg N ha^{-1}	114.9	211.5	326.4	7.7	13.2	20.9	91.5	70.3	161.8
N2: 30 kg N ha^{-1}	170.2	278.0	448.2	12.5	19.2	31.7	124.8	104.2	229.0
N3: 60 kg N ha^{-1}	203.3	335.4	538.7	17.3	25.8	43.1	147.7	137.1	284.8
N4: 90 kg N ha^{-1}	230.5	376.6	607.1	19.4	31.8	51.2	161.7	159.1	320.8
SEm±	7.9	8.4	-	0.6	1.1	-	4.9	6.4	-
CD (P=0.05)	22.7	24.3	-	1.8	3.1	-	14.1	18.6	-
Population densities (D)									
D1: 30 x 10 cm	159.1	263.4	422.5	13.0	18.3	31.3	112.5	105.6	218.1
D2: 25 x 10 cm	168.2	280.1	448.3	13.6	21.9	35.5	118.3	111.0	229.3
D3: 20 x 10 cm	182.3	306.6	488.9	14.7	23.4	38.1	129.9	123.8	253.7
D4: 15 x 10 cm	209.2	351.5	560.7	15.7	26.4	42.1	165.1	130.3	295.4
SEm±	7.9	8.4	-	0.6	1.1	-	4.9	6.4	-
CD (P=0.05)	22.7	24.3	-	1.8	3.1	-	14.1	18.6	-
Interaction (N x D)									
SEm±	15.7	16.8	-	3.5	2.2	-	9.8	6.4	-
CD (P=0.05)	NS	NS	-	NS	NS	-	NS	NS	-
CV (%)	15.1	9.7	-	14.8	16.7	-	12.9	18.9	-

Table 5. Zn and Fe uptake of groundnut as influenced by nitrogen levels and population densities.

Treatments	**Nutrient Uptake (g ha^{-1})**					
	Zn			**Fe**		
	Haulm	**Seed**	**Total**	**Haulm**	**Seed**	**Total**
Nitrogen levels (N)						
N1: 0 kg N ha^{-1}	212.7	68.3	281.0	961.7	312.8	1274.5
N2: 30 kg N ha^{-1}	341.2	121.1	462.3	1541.8	500.3	2042.1
N3: 60 kg N ha^{-1}	423.6	150.5	573.6	1941.6	630.3	2571.9
N4: 90 kg N ha^{-1}	505.6	171.4	677.0	2214.9	738.5	2953.4
SEm±	21.4	6.5	-	85.5	20.4	-
CD (P=0.05)	61.8	18.7	-	246.9	58.8	-
Population densities (D)						
D1: 30 x 10 cm	333.6	113.0	446.6	1502.9	488.8	1991.7
D2: 25 x 10 cm	346.4	122.4	468.8	1589.1	513.3	2102.4
D3: 20 x 10 cm	380.7	130.8	511.5	1714.9	570.5	2285.4
D4: 15 x 10 cm	419.3	145.1	564.4	1853.0	609.2	2462.2
SEm±	21.4	6.5	-	85.5	20.4	-
CD (P=0.05)	61.8	18.7	-	246.9	58.8	-
Interaction (N x D)						
SEm±	42.8	13.0	-	171.0	40.7	-
CD (P=0.05)	NS	NS	-	NS	NS	-
CV (%)	20.0	17.6	-	17.8	12.9	-