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Effect of ammonium sulphate and spacings on growth, yield and economics of groundnut (A*rachis hypogeae* L.)

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ABSTRACT

Optimization of the mineral nutrition is the key to optimize groundnut production as it has very high nutrient requirement. Ammonium supply stimulates root branching with localized NH_4-N+P enhancing root growth and its distribution, due to intensive rhizosphere acidification. A field experiment was conducted at Agriculture College Farm, Bapatla, Andhra Pradesh on sandy upland soils to study the performance of groundnut (A*rachis hypogeae* L.) under varying levels of ammonium sulphate and spacings. Application of 60 kg N ha^{-1} resulted in 24.4%, 8.6% and 1.7% more plant height than 0, 30 and 90 kg N ha^{-1}. Plant spacing of 15 x 10 cm resulted in 21.1%, 18.2% and 7.2% taller plants than other spacing levels. Application of 90 kg N ha^{-1} was noticed to produce higher dry matter over other levels; however, it was at par with 60 kg N ha^{-1}. Plant geometry at spacing recorded higher dry matter. Higher pod yield and haulm yield was exhibited at 60 kg N ha^{-1} and 15 x 10 cm. Similarly, among the four levels of nitrogen, application of 60 kg N ha^{-1}, recorded in highest number of nodules plant^{-1}, nodule dry weight plant^{-1} and harvest index. Among the crop geometries, 30 x 10 cm spacing resulted in higher nodule count and nodule dry weight as compared to closer spacings. Likewise, graded increment in levels of nitrogen also recorded higher net returns, gross return and return per rupee investment. The maximum net returns and returns per rupee invested were obtained with 15 x 10 cm spacing.

1. Introduction

Groundnut (*Arachis hypogeae* L.) is the most important oilseed crop that serves dual purpose of demand of food for direct human sustenance and restoring soil fertility. Optimization of the mineral nutrition is the key to optimize the production of groundnut, as it has very high nutrient requirement. Further, the establishments of sole groundnut in wide rows result in sub-optimum plant densities, often leading to lower yields per hectare. High density planting in groundnut is known to reduce weed competition, thus increasing the potential for higher yields. In addition, rhizosphere processes such as root-induced changes in pH and root exudates release play a key role in nutrient acquisition (Marschner *et al*., 2007). Ammonium supply plays an important role in stimulating root branching, higher root proliferation in the fertilizer zone with localized NH_4-N + P might contribute to increased root growth (elongation and branching) and distribution in the soil profile, being associated with "acid-growth theory" due to intensive rhizosphere acidification in the localized area (Qinghua *et al*, 2013). The decrease in rhizosphere pH with ammonium fertilization can increase root length and the number of root tips, (Rosolem *et al*., 2020) which can increase nodule number per unit length of root. Moreover, increasing nitrogen levels are also reported in certain cases (Amba *et al*., 2013; Meena *et al.*, 2011) to increase number of nodules per plant in groundnut due to increase in carbohydrates and energy supply to root as well as to the nodulating bacteria in groundnut which resulted in higher nitrogen fixation. Enhanced nodulation thereby increases crop productivity and soil health. In addition, increased availability and acquisition of Zn with localized ammoniacal nitrogen and phosphorus (Ji *et al*., 2022) could likely help maintain the stability of root cell membranes because lack of Zn supply causes ion leakage from the roots (Rudani and Prajapati, 2018; Hassan et al., 2020). Recent studies showed that ammonium supply could play an important role in stimulating root branching (Bangkele *et al*., 2019; Jing *et al*., 2012).

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Thus, increasing levels of nitrogen in the form of acid forming ammonium sulphate as source along with high density planting can be an effective strategy in increasing the productivity potential of groundnut to meet the demand of ever increasing population of the country. With these ideas in view, an experiment was carried out to find out the effect of ammonium sulphate and spacing on growth, yield and economics of groundnut.

2. Material and Methods

The field experiment was conducted at 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 on *post-monsoon,* 2018 on effect of ammonium sulphate and spacing on growth, yield and economics of groundnut (A*rachis hypogeae* L.). The total rainfall received during the crop growth period was 191.21 mm. The weekly mean maximum and minimum temperatures during the growth period ranged from 26.6 °C to 34.8 °C and 17.7 °C to 26.6 °C, respectively. Similarly, the weekly mean relative humidity ranged from 83.92 to 73.00 %. The soil of research site was sandy sandy in texture with 85.60 % sand, 5.70 % silt and 8.70 % clay, near neutral in reaction (pH 6.83), low in EC (0.06 dS m^{-1}), low in organic carbon (0.15 %), low in available nitrogen (120 kg ha^{-1}) and medium in available phosphorus (29.20 kg ha^{-1}) and potassium (168 kg ha^{-1}). (Table 1).

The field was ploughed with tractor drawn rotovator. After through levelling the area was divided into required number of plots. The experiment was laid out in a randomized block design with factorial concept and replicated thrice, consisting sixteen treatments with 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} given in three splits i.e., $1/3^{rd}$ basal, $1/3^{rd}$ @ 30 DAS and $1/3^{rd}$ @ 60 DAS and four levels of spacings *viz*., 30 x 10 cm, 25 x 10 cm, 20 x 10 cm and 15 x 10 cm. Clean and bold seeds were selected and treated with Dithane M-45 at the rate of 3g kg^{-1} to prevent from seed borne diseases. The TAG 24 variety of groundnut was sown on 15^{th} September, 2018. The recommended dose of phosphorous and potassium were applied at the rate of 40 kg ha^{-1} and 50 kg ha^{-1}, respectively as basal dose through band placement to all the treatments uniformly. Gypsum was applied at early flowering stage @ 500 kg ha^{-1}.

Five plants in second row from the border row from each plot were sampled. The samples were dried in shade and then oven dried till a constant weight was obtained and was used for growth attribute estimation. The crop was harvested manually on 16^{th} December, 2018. After harvest, the produce was thoroughly sun-dried and weighed for biological yield (kg ha^{-1}). After threshing, separated pods were measured in kg ha^{-1} and subtracted from biological yield to calculate haulm yield (kg ha^{-1}). Harvest index was calculated by multiplying pod yield with 100 and dividing it with biological yield. (Donald, 1962). To estimate the profitability of the treatments gross returns, net returns and returns per rupee investment was calculated.

The data on growth, yield and economics were recorded and subjected to statistical analysis. Statistical significance was tested by applying F-test at 0.05 level of probability.

3. Results and Discussion

Effect of Ammonium Sulphate and Spacings on Growth Attributes

Plant Height (cm)

Plant height responded significantly to levels of nitrogen and spacings. The significantly taller plants (29.1 cm) was observed with 60 kg N ha^{-1} which was on par with 30 kg N ha^{-1} and 90 kg N ha^{-1} (Table 2). Application of 60 kg N ha^{-1} resulted in 24.4%, 8.6% and 1.7% taller plant over 0, 30 and 90 kg N ha^{-1}. The higher levels of nitrogen application might have accelerated the synthesis of more chlorophyll and amino acids Gohari and Niyaki, 2010) and it enhances vegetative growth through cell division and cell elongation (Souri and Hatamian, 2019). However, increase in height due to too much nitrogen resulted in shading of lower leaves which would in turn lead to auxin production and eventually, stopping plant growth (Gohari and Niyaki, 2010). Similar results have been reported by Chaudhary *et al.* (2015) and Souri *et al*., 2019). Significantly taller plants were observed with the closer spacing of 15 x 10 cm than with wider spacing. Plant spacing of 15 x 10 cm resulted in 21.1%, 18.2% and 7.2% taller plants than other spacing levels. Competition for sunlight, nutrients and space might have resulted in taller plants with narrow spacings (Chaudhari *et al.* 2018). The interaction between nitrogen levels and population densities did not influence the plant height at all stages of observation.

Dry matter accumulation (kg ha^{-1})

Increase in nitrogen levels from 0 kg N ha^{-1} to 90 kg N ha^{-1} resulted in higher dry matter production (Table 2). Application of 90 kg N ha^{-1} resulted in significantly higher dry matter accumulation but was on par with 60 kg N ha^{-1}. Application of 60 kg N ha^{-1} was noticed to produce 3073 kg and 1271 kg higher dry matter over 0 and 30 kg N ha^{-1}. It was probably because of the enhanced crop growth with higher levels of nutrients, which enhanced photosynthesis and hence resulted in accumulation of higher quantity of dry matter (Sengupta *et al.* 2016). Leaves are the critical organs that act as the main photosynthetic structures of plants and convert various resources to biomass (Marschner, 2012). Therefore, localized ammoniacal nitrogen along with phosphorous supply not only increased leaf expansion but also enhanced the photosynthetic rate, which greatly contributed to the production of shoot biomass. (Quighua *et al*., 2014).

Population density with 15 x 10 cm spacing resulted in significantly superior dry matter accumulation (10543 kg ha^{-1}). The lowest dry matter accumulation was found with 30 x 10 cm spacing (7061 kg ha^{-1}). Dry matter accumulation differed significantly with population densities and increased with increase in population density, this might be due to increase in plant population per unit area (Magagula et al., 2019; Priya *et al.,* 2016).

Initial and final plant population

Perusal of data presented in table 2 reveals that initial and final plant population was significantly influenced by spacings. The difference in plant stand was significant with varying population densities as closer spacing resulted into higher plant population as compared to wider spacings as higher seed was used in such treatment. Similar information was reported by Brar *et al.* (2004) and Maboko (2009).

Number of nodules per plant

The data on number of nodules per plant showed significant difference with levels of nitrogen and spacings whereas, their interactions did not produce significant result. (Table 2). The results revealed that significantly more number of root nodules was noticed at 90 kg N ha^{-1} and was on par with 60 kg N ha^{-1}. The lowest number of nodules was recorded with no nitrogen. Increasing nitrogen level might have increased number of nodules per plant due to increase in carbohydrates and energy supply to root as well as to the nodulating bacteria in groundnut which resulted in higher nitrogen fixation as reported by Meena *et al.* (2011). Further, root growth had increased with increasing nitrogen levels which could have contributed to more number of nodules over control. Increase in number of nodules with increase in nitrogen levels was also reported by Amba *et al*. (2013) and Anteneh Argaw (2018). The significantly higher numbers of nodules were recorded at population density with 30 x 10 cm spacing as compared to other density levels. The increase in nodule numbers with low planting rate as compared to high planting rate was due to limited growth due to competition (Chaudhari *et al*., 2018; Raju *et al*., 2022).

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

Nodule dry weight responded similarly to that of number of nodules per plant with nitrogen levels. Nodule dry weight was noticed to be significantly higher at 90 kg N ha^{-1} and was on par with 60 kg N ha^{-1}. Application of nitrogenous fertilizers might have stimulated microbes flush and improved root growth and better source–sink relationship lead to better nodulation (Anteneh Argaw 2018; Kamath *et al.* 2013). Significantly higher nodule dry weight was registered with wider spacing of 30 x 10 cm as compared to narrower density levels and was on par with 25 x 10 cm. Increase in number of nodules per plant increased the dry weight of nodules per plant with wider spacing (Meena *et al*. 2011).

Effect of ammonium sulphate and spacings on yields (kg ha^{-1})

With the increase in levels of nitrogen, yield increased significantly (Table 2). Nitrogen application @ 90 kg N ha^{-1} produced significantly superior pod yield and haulm yield over 30 and 0 kg N ha^{-1} and was on par with 60 kg N ha^{-1}. Ammonium sulphate @ 60 kg N ha^{-1} exhibited 51.0% and 18.0% higher pod yield and 39.4% and 11.8% more haulm yield over 0 and 30 kg N ha^{-1}, respectively. The lowest pod yield and haulm yield was recorded in control plot. N plays a critical role in plant growth leading to higher photosynthetic activity and translocation of photosynthates to the sink and pods, thereby increasing seed haulm yield (Tekulu *et al*., 2020). Further, ammonium sulphate along with phosphorus fertilization, resulted in rhizosphere acidification, enhancing root proliferation contributing to nutrient uptake and biomass accumulation, thereby increasing haulm yield and pod yield (Quinghua *et al*. 2014).

Pod and haulm yield differed significantly with population densities. Higher yields were obtained with the closest spacing of 15 x 10 cm and decreased gradually decreased with decrease in population and lowest pod yield was observed with 30 x 10 cm. Closer spacing of 15 x 10 cm out yielded 1125 kg, 878 kg and 475 kg of pods ha^{-1} and 2592 kg, 2005 kg and 1203 kg haulm ha^{-1}, over 30 x 10 cm, 25 x 10 cm and 20 x 10 cm, respectively. The increase in pods yield might be due to increased sink capacity and better availability of growth factors under narrow row spacing (Choudhari *et al*. 2018; Magagula *et al*., 2019). Though number of pods per plant was higher with wider spacing of 30 x 10 cm but it was not exhibited on yield per unit area. The increase in haulm yield is due to more number of plants per unit area (Waghmode *et al*. 2017).

The harvest index of groundnut varied with nitrogen levels and population densities. The data indicated gradual increase of harvest index with increasing nitrogen fertilization and highest harvest index (37 %) was recorded with application of 90 kg N ha^{-1} and lowest at control plot with 35 %. However, the results were non- significant with levels of nitrogen, population densities and their interaction as well. This was also reported by Waghmode *et al.* (2017).

Effect of ammonium sulphate and spacings on economics

Economics of groundnut crop as influenced by nitrogen levels and spacings are worked out and presented in table 3. The highest gross return, net return and returns per rupee investment was obtained with nitrogen fertilization of 90 kg N ha^{-1} which is significantly superior over other levels of nitrogen and was on par with 60 kg N ha^{-1}. The lowest return of was obtained from control plot (0 kg N ha^{-1}). Among the population densities, closer spacing with 15 x 10 cm recorded higher significant returns as compared to other spacing levels. The lower returns was obtained from wider spacing with 30 x 10 cm. The interaction between nitrogen levels and spacings was however non – significant.

4. Conclusion

The result of the experiment revealed that application of 60 kg N ha^{-1} recorded better growth attributing characters and higher returns during the post- monsoon season for groundnut. Among the spacing levels, 15 x 10 cm responded significantly to growth attributes and economics thus, resulting in taller plants, higher population and more profit. However, on per plant basis, more number of nodules and higher nodule dry weight was obtained with wider spacing of 30 x 10 cm.

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Table 1. Physico- chemical characteristics of soil (0-30 cm) before initiation of experiment

Method	Soil Physical Properties				Soil Chemical Properties					
	Sand	Silt	Clay	Soil texture	pH	EC (dS m^{-1})	Organic C (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
	Bouyoucos Hydrometer method				Glass electrode method	Digital electrical conductivity meter	Walkley and Black's modified method	Alkaline Potassium permanganate method	Modified Olsen's extractant method	Neutral normal ammonium acetate method
	85.6	5.7	8.7	Sandy	6.83	0.06	0.15	120	29.2	168

Table 2. Growth attributes and yield of groundnut as influenced by nitrogen levels and population densities

Treatments	Plant height (cm)	Dry matter accumulation (kg ha^{-1})	Initial plant population	Final plant population	Number of nodules per plant	Nodule dry weight (g $plant^{-1}$)	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest Index (%)
Nitrogen levels (N)									
N1: 0 kg N ha^{-1}	23.4	6374	4.745	4.368	65.3	0.059	2404	4487	35.0
N2: 30 kg N ha^{-1}	26.8	8176	4.748	4.349	81.6	0.072	3065	5597	35.6
N3: 60 kg N ha^{-1}	29.1	9447	4.748	4.375	91.6	0.078	3631	6257	36.8
N4: 90 kg N ha^{-1}	28.6	10166	4.758	4.386	99.1	0.083	3850	6597	37.0
SEm±	0.8	258	0.002	0.019	2.9	0.002	103	120	0.8
CD (P=0.05)	2.3	746	NS	NS	8.5	0.007	297	340	NS
Spacings (S)									
S1: 30 x 10 cm	24.7	7061	3.330	3.072	98.5	0.083	2732	4588	37.3
S2: 25 x 10 cm	25.3	7766	3.998	3.687	88.2	0.076	2979	5175	36.4
S3: 20 x 10 cm	27.9	8793	4.998	4.600	80.4	0.070	3382	5977	35.9
S4: 15 x 10 cm	29.9	10543	6.663	6.121	70.4	0.064	3857	7180	34.8
SEm±	0.8	258	0.002	0.019	2.9	0.002	103	120	0.8
CD (P=0.05)	2.3	746	0.005	0.054	8.5	0.007	297	340	NS
Interaction (N x S)									
SEm±	1.6	517	0.003	0.038	5.9	0.005	206	241	1.6
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	10.4	10.5	0.1	1.5	12.1	11.4	11.0	7.3	7.6

Table 3. Gross returns (Rs. ha^{-1}), Net returns (Rs. ha^{-1}) and Returns per rupee investment (Rs.) of groundnut as influenced by nitrogen levels and population densities

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	Returns per rupee investment (Rs.)
Nitrogen levels (N)				
N1: 0 kg N ha^{-1}	46430	124599	78169	1.67
N2: 30 kg N ha^{-1}	48760	154726	105966	2.15
N3: 60 kg N ha^{-1}	51090	174675	123585	2.40
N4: 90 kg N ha^{-1}	53420	187998	134578	2.50
SEm±	-	4908	4908	0.10
CD (P=0.05)	-	14174	14174	0.28
Spacings (S)				
S1: 30 x 10 cm	46125	133142	87017	1.87
S2: 25 x 10 cm	47725	144973	97248	2.02
S3: 20 x 10 cm	50925	165534	114609	2.23
S4: 15 x 10 cm	54925	198349	143424	2.60
SEm±	-	4908	4908	0.10
CD (P=0.05)	-	14174	14174	0.28
Interaction (N x S)				
SEm±	-	9815	9815	0.19
CD (P=0.05)	-	NS	NS	NS
CV (%)	-	10.59	15.37	15.14