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Nitrogen and Sulphur Nutrition in Groundnut (*Arachis hypogaea* L.) for Northern Coastal Plains of Kerala

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Abstract

A field experiment was carried out at College of Agriculture, Padannakkad, Kerala Agricultural University during *rabi* season of 2022-2023 with an objective of optimising nitrogen : sulphur ratio for groundnut cultivated in northern coastal plains of Kerala. The experiment was laid out in Factorial Randomized Block Design with N levels in main plots (10, 20, 30 kg ha^{-1}) and S levels in subplots which was replicated thrice. The treatments which received the highest dose (30 kg ha^{-1}) of N or S or their combination were superior in terms of growth attributes such as plant height, number of branches per plant, total leaf area and drymatter per plant at all the growth stages. The trend was different with respect to the yield attributes, yield of the crop and economics of cultivation as these parameters were not significantly influenced by the treatments. Thus, the N:S @ 10 kg ha^{-1} each can be considered as the optimum dose of nitrogen and sulphur for groundnut cultivated in northern coastal plains of Kerala.

Keywords : Groundnut, Nitrogen, Sulphur, Nutrition in groundnut

India ranks first in area and second in production of groundnut with 4.94 million hectares (17.32%) with a production of 6.70 million tons (14.55%) of the total production (GoI, 2022). In Kerala groundnut is cultivated under an area of 111 hectares and with a production of 141 tonnes in that 4.6 hectares of area comes under northern coastal plains of Kerala (GoK, 2023). Groundnut kernel contains 43-55 per cent oil, 24-26 per cent protein, 45-48 per cent fat, 15-18 per cent carbohydrates and 3 per cent fiber. The nutrients present in the kernel, including calcium, magnesium, iron, zinc, phosphorus and B and E vitamins, largely contribute to human nutrition. Nitrogen being an essential component of proteins via amino acids, chlorophyll, nucleotides, alkaloids and enzymes, nitrogen is essential for photosynthesis, vigorous vegetative growth, dry matter production and assimilate synthesis for pod filling in groundnut (Sagvekar *et al*., 2017).

However, sulphur is very essential for oilseed crops along with N for protein, enzyme and oil syntheses (Walker & Booth, 2003; Abdin *et al*., 2003 and Pasricha & Abrol, 2003). The shortage in S supply to crops reduces the N use efficiency of crops (Ceccoti, 1996). Consequently, the poor efficiency of N utilization caused by insufficient S may increase N losses from cultivated soils (Schnug *et al*., 1993). Fazli *et al*. (2008) reported that lack of S limits the efficiency of added N and thus, S addition becomes necessary to achieve maximum efficiency of applied nitrogenous fertilizers.

A high N:S ratio (produced by addition of N) may result in a decrease in mineralization of S in the soil.

Janzen and Bettany (1984) indicated the optimum ratio of available N to available S in soil to be 7:1. Ratios below seven gave reduced seed yield in groundnut. It has been established that for every 15 parts of N in protein there is one part of S which implies that the N:S ratio is fixed within a narrow range of 15:1. The N:S ratio in the whole plant in general is 20:1 (Cram, 1990).

Several field studies have been conducted separately on S and N fertilization in groundnut (Chandini, 1992; Lakkineni & Abrol, 1992; Singh & Chudhari, 1995 and Chaubey *et al.*, 2000), but these data were insufficient to provide an optimum N:S ratio. Keeping these points in view, the present study was proposed to derive an optimum N:S ratio for groundnut cultivated in northern coastal plains of Kerala.

Material and Methods

The field experiment was conducted at College of Agriculture, Padannakkad, Kerala Agricultural University during *rabi* season of 2022-2023 (October, 2022 to January, 2023). The field is located at 12°20' 30" N latitude and 75° 04' 15" E longitude at an altitude of 20 m above the mean sea level. This area enjoys a typical warm humid tropical climate. The experimental field was left fallow prior to the layout of the experiment.

The soil of the experimental site was sandy, which belongs to the taxonomical order entisol, neutral in reaction (pH 6.89), low in organic carbon (0.35%), low in N (165 kg ha^{-1}), high in available P (45.3 kg ha^{-1}), medium in available K (141.7 kg ha^{-1}) and deficient in available S (3.5 mg kg^{-1}).

The experiment was laid out in Factorial Randomized Block Design (FRBD), comprising treatment combinations of three graded levels (10, 20 and 30 kg ha^{-1}) of each N and S. In two fertilizer treatments include T_1: 10 kg N and 10 kg S, T_2: 10 kg N and 20 kg S, T_3: 10 kg N and 30 kg S, T_4: 20 kg N and 10 kg S, T_5: 20 kg N and 20 kg S, T_6:20 kg N and 30 kg S, T_7: 30 kg N and 10 kg S, T_8: 30 kg N and 20 kg S, T_9: 30 kg N and 30 kg S. Recommended fertilizer dose of 75 kg ha^{-1} each of K_2O and P_2O_5 were applied to all the plots along with treaments as basal dose.

The variety used was CO 7. The experimental plot size was 2.25 m x 1.5 m. From each plot, six plants were selected randomly and tagged for recording observations periodically. Weeding operations were carried out manually at different stages of growth after germination to flowering stage (30 DAS). Irrigation was done using a hose on alternate days throughout the growing period. Irrigation was completely stopped two weeks before harvest. Groundnut blight disease was observed in the field and it was controlled by one spray of saaf (mancozeb+carbendazim) at 2 g l^{-1} and second spray with amistar (azoxystrobin) at 1 ml l^{-1}. Leaf rust and Tikka leaf spot infections were also observed late in the season which was controlled by spraying amistar (azoxystrobin) at 1 ml l^{-1}. The groundnut crop was uprooted at its full maturity, the pods were separated and dried in the sun for few days. Average dry weight of the haulm and kernel after shelling were converted into kg ha^{-1}.

Results and Discussion

Plant Height

The plant height was significantly influenced by an increase in levels of N at all growth stages (Table 1). Application of N @ 30 kg ha^{-1} (N_3) recorded significantly higher plant heights at 20 DAS (8.42 cm), 40 DAS (22.41 cm), 60 DAS (27.87 cm) and 80 DAS (35.14 cm) and it was on par with N @ 20 kg ha^{-1} (N_2)

Table 1

Plant height (cm) of groundnut as influenced by graded levels of N and S

Treatment	20 DAS	40 DAS	60 DAS	80 DAS
Nitrogen (N)				
N_1 (10 kg)	7.42 ^{b}	19.5 ^{c}	25.02 ^{c}	31.92 ^{b}
N_2 (20 kg)	7.84 ^{ab}	21.18 ^{b}	26.37 ^{b}	32.97 ^{b}
N_3 (30 kg)	8.42 ^{a}	22.41 ^{a}	27.87 ^{a}	35.14 ^{a}
S.Em (±)	0.23	0.28	0.19	0.48
CD (0.05)	0.69	0.85	0.59	1.46
Sulphur (S)				
S_1 (10 kg)	7.59	20.92 ^{b}	26.28	33.9
S_2 (20 kg)	8.1	20.03 ^{c}	26.49	33.3
S_3 (30 kg)	7.96	22.14 ^{a}	26.92	32.8

Continued....

TABLE 1 Continued....

Treatment	20 DAS	40 DAS	60 DAS	80 DAS
S.Em (±)	0.23	0.28	0.19	0.48
CD (0.05)	NS	0.857	NS	NS
Interaction (N x S)				
N_1S_1	7.25	19.1	25.6 c	32.6
N_1S_2	7.79	18.76	24.3 d	31.2
N_1S_3	7.21	20.63	25.16 c	31.9
N_2S_1	7.25	21.63	26.1 cd	33.7
N_2S_2	8.06	20.6	27.63 b	34
N_2S_3	8.16	21.86	25.36 c	31.2
N_3S_1	7.95	22.6	27.13 b	35.3
N_3S_2	8.44	20.73	27.53 b	34.6
N_3S_3	8.66	23.9	28.93 a	35.5
S.Em (±)	0.4	0.495	0.343	0.846
CD (0.05)	NS	NS	1.028	NS

at 20 DAS (7.84 cm). Application of S @ 30 kg ha^{-1} (S_3) has been found to increase the plant height significantly at 40 DAS (22.41 cm). The N x S interaction was significant only at 60 DAS. The combination, N_3S_3 (T_9: $N_{30}S_{30}$) recorded the highest plant height (28.93 cm) which was significantly superior to all other combinations.

The use of various levels of N may have accelerated plant tallness because N at higher levels could have sped up photosynthetic processes by increasing source

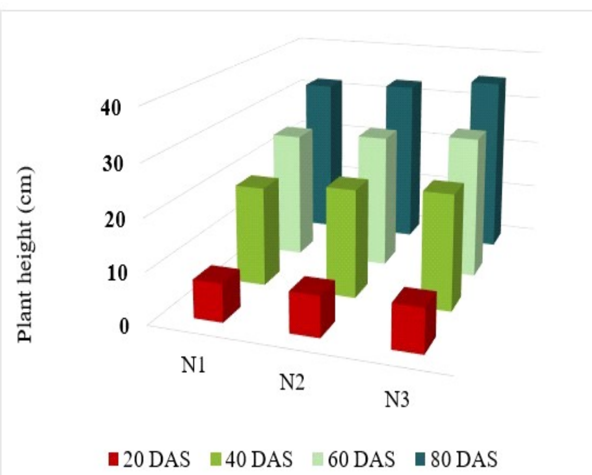

Fig. 1 : Effect of graded levels of N on plant height (cm)

size (plant stature and branches), thus providing the emerging bud with more photosynthates, which could have resulted in increased crop stature (Palsande *et al.*, 2019). Similar findings were reported by Devi *et al.* (2022), Bekele *et al.* (2019) and Tekulu *et al.* (2020).

A similar increase in plant height was observed with the combined application of highest levels (30 kg ha^{-1} each) of N and S (N_3S_3) at 60 DAS. This may be due to growth promotion via rapid meristematic activities induced by the application of N and S together in a nutrient deficient soil. Balanced fertiliser application can promote plant cell division and cell elongation, resulting in improved vegetative growth.

TABLE 2

Number of primary branches per plant as influenced by graded levels of N and S

Treatment	20 DAS	40 DAS	60 DAS	80 DAS
Nitrogen (N)				
N_1 (10 kg)	2.17	5.13 b	5.91 c	6.24 b
N_2 (20 kg)	2.52 a	5.73 b	6.21b	6.31 b
N_3 (30 kg)	2.7 a	6.52 a	6.56a	6.61 a
S.Em (±)	0.06	0.90	0.09	0.07
CD (0.05)	0.20	0.27	0.25	0.21
Sulphur (S)				
S_1 (10 kg)	2.33	5.6 b	6.17	6.23 b
S_2 (20 kg)	2.53	6.18 a	6.44	6.58 a
S_3 (30 kg)	2.52	5.61 b	6.17	6.36 b
S.Em (±)	0.06	0.90	0.09	0.07
CD (0.05)	NS	0.27	NS	0.21
Interaction (N x S)				
N_1S_1	2.1	5.16 b	5.8 b	6.03 c
N_1S_2	2.17	5.23 b	5.9 b	6.13 bc
N_1S_3	2.23	5.0 b	6.03 b	6.56 a
N_2S_1	2.36	5.26 b	6.1 b	6.16 bc
N_2S_2	2.57	6.67 a	6.73 a	6.83 a
N_2S_3	2.63	5.26 b	5.8 b	5.93 c
N_3S_1	2.55	6.36 a	6.55 a	6.51 ab
N_3S_2	2.86	6.63 a	6.7 a	6.76 a
N_3S_3	2.7	6.56 a	6.6 a	6.56 a
S.Em (±)	0.11	0.15	0.14	0.12
CD (0.05)	NS	0.46	0.44	0.36

Number of Primary Branches Per Plant

Increase in levels of N significantly increased the number of primary branches per plant at all growth stages (Table 2). Application of N @ 30 kg ha^{-1} (N_3) recorded the higher number of branches per plant at all the growth stages 20 (2.7), 40 (6.52), 60 (6.56) and 80 (6.61) DAS, respectively and it was on par with N @ 20 kg ha^{-1} (N_2) at 20 DAS (2.52). Application of S @ 20 kg ha^{-1} (S_2) has been found to increase the number of branches per plant significantly at 40 DAS (6.18) and 80 DAS (6.58). The N x S interaction was significant at all growth stages except at 20 DAS. The treatment combination of N and S each @ 20 kg ha^{-1} (N_2S_2) recorded the highest number of branches per plant which was significantly superior to all other combinations. According to Ahmad *et al.* (2018) higher N and S levels could improve the nutrient uptake, metabolic and meristematic activities of the plant, which resulted in more branches per plant. These results are line with the findings of Bais and Singh (2022).

Total Leaf Area Per Plant

Data presented in Table 3 shows that the total leaf area per plant was significantly influenced by an increase in levels of N at all growth stages. Application of N @ 30 kg ha^{-1} (N_3) recorded the highest leaf area at 20 DAS (164.67 cm^2), 40 DAS (708.44 cm^2), 60 DAS (1666.6 cm^2) and 80 DAS (1680.22 cm^2). Application of S @ 30 kg ha^{-1} (S_3) has been found to increase the plant leaf area significantly at 20 DAS (158.78 cm^2) and it was on par with S_2 (156.04 cm^2). The interaction effect was not significant at any growth stages. Increased supply of N might have prompted increased production and translocation of photosynthates that might have resulted in higher cell division and cell enlargement reflected as higher values of leaf area as reported by Hasan *et al.* (2021).

Dry Matter Per Plant

The dry matter produced by groundnut plant was significantly influenced by graded levels of nitrogen at all growth stages except at 20 DAS (Table 4). The treatment, N_3 (N @ 30 kg ha^{-1}) was significantly superior to all other treatments and it recorded 8.61 g, 12.43 g and 23.39 g of dry matter per plant, respectively at 40, 60 and 80 DAS. The effects of graded levels of S and N x S interaction were not significant at all growth stages. Dry matter build-up rose as nitrogen levels increased. This might be attributed to increased cell division and cell enlargement, as well as greater expansion of photosynthetic area, which resulted in higher dry matter production (Anil, 2017). Similar results were reported by Almaliki *et al.* (2019).

TABLE 3

Total leaf area (cm^2) per plant as influenced by graded levels of N and S

Treatment	20 DAS	40 DAS	60 DAS	80 DAS
Nitrogen (N)				
N_1 (10 kg)	145.93 ^{c}	626.89 ^{c}	1428.72 ^{c}	1406.44 ^{c}
N_2 (20 kg)	155.19 ^{b}	652.54 ^{b}	1536.11 ^{b}	1581.1 ^{b}
N_3 (30 kg)	164.67 ^{a}	708.44 ^{a}	1666.6 ^{a}	1680.22 ^{a}
S.Em (±)	1.741	3.960	27.337	25.704
CD (0.05)	5.221	11.871	81.956	77.060
Sulphur (S)				
S_1 (10 kg)	150.97 ^{b}	662.6	1523.89	1550.22
S_2 (20 kg)	156.04 ^{ab}	660.26	1567.39	1553.11
S_3 (30 kg)	158.78 ^{a}	665.1	1540.2	1564.44
S.Em (±)	1.741	3.960	27.337	29.241
CD (0.05)	5.221	NS	NS	NS
Interaction (N x S)				
N_1S_1	140.33	627.67	1437.60	1417.00
N_1S_2	145.47	629.00	1453.16	1388.30
N_1S_3	152.00	624.00	1395.30	1414.00
N_2S_1	152.23	648.00	153.00	1583.00
N_2S_2	156.00	657.00	1557.00	1577.00
N_2S_3	157.30	652.00	1521.30	1583.00
N_3S_1	160.30	712.20	1604.00	1650.60
N_3S_2	166.67	694.60	1692.00	1693.70
N_3S_3	167.00	718.30	1704.00	1696.30
S.Em (±)	3.016	6.858	47.349	44.52
CD (0.05)	NS	NS	NS	NS

Yield Attributes and Yield

Data presented in Table 4 reveals that the treatment which received N @ 10 kg ha^{-1} (N_1) recorded the highest number of pods per plant (12.00) and it was on par with N_2 (11.86). Varying levels of sulphur

TABLE 4

Dry matter production per plant (g) as influenced by graded levels of N and S

Treatment	20 DAS	40 DAS	60 DAS	80 DAS
Nitrogen (N)				
N_1 (10 kg)	0.614	6.57 [c]	10.8 [c]	19.96 [c]
N_2 (20 kg)	0.627	7.78 [b]	11.65 [b]	21.76 [b]
N_3 (30 kg)	0.656	8.61 [a]	12.43 [a]	23.39 [a]
S.Em (±)	0.037	0.199	0.160	0.270
CD (0.05)	NS	0.596	0.479	0.810
Sulphur (S)				
S_1 (10 kg)	0.593	7.5	11.52	21.66
S_2 (20 kg)	0.653	7.6	11.63	21.87
S_3 (30 kg)	0.651	7.86	11.73	21.57
S.Em (±)	0.037	0.199	0.160	0.270
CD (0.05)	NS	NS	NS	NS
Interaction (N x S)				
N_1S_1	0.530	6.33	10.80	19.93
N_1S_2	0.645	6.50	11.10	19.87
N_1S_3	0.643	6.87	10.50	20.10
N_2S_1	0.610	7.60	11.43	21.13
N_2S_2	0.640	7.90	11.57	22.00
N_2S_3	0.630	7.83	11.97	22.13
N_3S_1	0.650	8.57	12.30	23.90
N_3S_2	0.676	8.40	12.23	23.73
N_3S_3	0.675	8.67	12.73	22.52
S.Em (±)	0.065	0.344	0.277	0.468
CD (0.05)	NS	NS	NS	NS

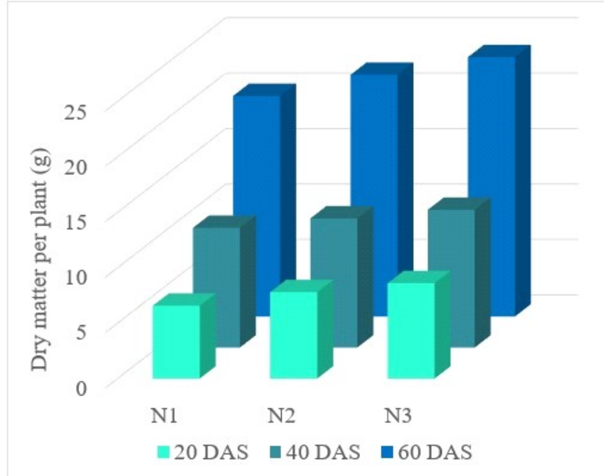

Fig. 2. Effect of graded levels of N on dry matter per plant (g)

couldn't make any significant influence on number of pods per plant of groundnut. Interaction effect was significant and the treatment combination, N_2S_2 (N and S each @ 20 kg ha^{-1}) recorded the highest number of pods per plant (13.17) and it was on par with N_1S_3 (12.67), N_1S_1 (12.33) and N_2S_1 (12.1). Whereas, number of seeds per pod, hundred kernel weight, kernel yield and haulm yield of groundnut were not varied with the treatments and their interaction. Groundnut's low yield response in terms of pod yield at the greatest N level can be linked to the crop's inability to utilize accumulated dry matter for yield production (Meena *et al*., 2011). According to Oriji *et al*. (2022) excessive inorganic fertilizer,

TABLE 5

Yield attributes and yield of groundnut as influenced by graded levels of N and S

Treatment	Pods per plant	Seeds per pod	100 kernel weight (g)	Kernel yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
Nitrogen (N)					
N_1 (10 kg)	12.00 [a]	1.67	40.08	1538.04	4339.70
N_2 (20 kg)	11.86 [a]	1.77	40.26	1552.70	4581.90
N_3 (30 kg)	10.97 [b]	1.71	39.49	1509.70	4626.50
SEm (±)	0.251	0.054	0.391	127.374	242.298
CD (0.05)	0.752	NS	NS	NS	NS

Continued....

TABLE 5 Continued....

Treatment	Pods per plant	Seeds per pod	100 kernel weight (g)	Kernel yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
Sulphur (S)					
S_1 (10 kg)	11.83	1.77	39.56	1504.1	4419.7
S_2 (20 kg)	11.47	1.68	40.66	1582.6	4570.1
S_3 (30 kg)	11.52	1.71	39.61	1513.7	4558.4
S.Em (±)	0.268	0.054	0.391	127.374	242.298
CD (0.05)	NS	NS	NS	NS	NS
Interaction (N x S)					
N_1S_1	12.33 ^{abc}	1.68	40.47	1504.2	4144.67
N_1S_2	11.10 ^{cde}	1.67	41.07	1490.6	4304.3
N_1S_3	12.67 ^{ab}	1.67	38.70	1618.4	4570
N_2S_1	12.10 ^{abc}	1.82	39.23	1491.1	4400.7
N_2S_2	13.17 ^{a}	1.75	40.56	1723.3	4750.9
N_2S_3	10.30 ^{de}	1.73	40.96	1384.9	4593.3
N_3S_1	11.17 ^{cde}	1.79	38.96	1516.4	4713.7
N_3S_2	10.13 ^{e}	1.62	40.33	1474.8	4653.9
N_3S_3	11.60 ^{bcd}	1.71	39.17	1538.0	4512
S.Em (±)	0.465	0.093	0.391	220.619	419.672
CD (0.05)	1.393	NS	NS	NS	NS

particularly nitrogen, may boost biomass production, but it may also create excessive shadowing of the canopy cover, reducing the light intensity required for adequate photosynthesis in the above biomass for seed formation. With increased plant height, peg penetration into the soil may be difficult, resulting in embryo abortion and yield decrease was found by Luz *et al*. (2011) who reported the correlation between plant height and pod yield of groundnut.

Nutrient Uptake and Soil Nutrient Status

Data presented in Table 6 shows that the total N uptake was significantly superior (128.73 kg ha^{-1}) with the application of N @ 30 kg ha^{-1} (N_3). The treatments, S_2 and S_3 were on par with respect to total N uptake and recorded the values of 117.13 kg ha^{-1} and 121.08 kg ha^{-1}, respectively. Combined application of N and S @ 30 kg ha^{-1} each (N_3S_3) resulted in highest N uptake (132.6 kg ha^{-1}) and it was on par with N_3S_2 (129.5 kg ha^{-1}). Similar results were reported by Mahmowd *et al*. (2014). The uptake of P and K was not affected significantly by the application of graded levels of

TABLE 6

Nutrient (N, P, K, S) uptake of groundnut at harvest as influenced by graded levels of N and S, kg ha^{-1}

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})
Nitrogen (N)				
N_1 (10 kg)	103.46 ^{c}	21.32	72.20	9.34 ^{b}
N_2 (20 kg)	111.80 ^{b}	22.86	73.46	11.00 ^{a}
N_3 (30 kg)	128.73 ^{a}	23.33	74.96	10.60 ^{a}
SEm (±)	1.859	0.794	2.941	0.221
CD (0.05)	5.574	NS	NS	0.663
Sulphur (S)				
S_1 (10 kg)	105.78^{b}	22.67	72.44	9.30 ^{b}
S_2 (20 kg)	117.13^{a}	21.83	72.97	10.72 ^{a}
S_3 (30 kg)	121.08^{a}	23.01	75.20	10.70 ^{a}
SEm (±)	1.859	0.794	2.941	0.221
CD (0.05)	5.574	NS	NS	0.663
Interaction (N x S)				
N_1S_1	95.5 ^{e}	22.10	71.40	9.40 ^{def}
N_1S_2	101.3 ^{e}	20.21	73.60	9.80 ^{def}
N_1S_3	113.6 ^{d}	21.60	71.61	8.80 ^{f}

Continued....

TABLE 6 Continued....

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})
N_2S_1	97.8 ^{e}	21.62	72.31	10.20 ^{cde}
N_2S_2	120.6 ^{bcd}	23.50	74.40	11.80 ^{ab}
N_2S_3	117.0 ^{d}	23.41	76.91	11.70 ^{bc}
N_3S_1	124.0 ^{bc}	24.30	76.40	9.10 ^{ef}
N_3S_2	129.5 ^{ab}	21.70	70.91	10.50 ^{cd}
N_3S_3	132.6 ^{a}	23.90	77.10	2.20 ^{a}
S.Em (±)	2.49	1.376	5.093	0.383
CD (0.05)	7.49	NS	NS	1.148

N, S and their combinations. The S uptake (11.0 kg ha^{-1}) was significantly highest for N_2 and it was on par with N_3 (10.6 kg ha^{-1}). Application of S @ 20 kg ha^{-1} (S_2) recorded the highest S uptake (10.72 kg ha^{-1}) and it was comparable with S_3 (10.70 kg ha^{-1}). Integrated application of N and S @ 30 kg ha^{-1} each (N_3S_3) recorded the highest S uptake by the crop (12.2 kg ha^{-1}) and it was on par with N_2S_2 (11.8 kg ha^{-1}) and N_2S_3 (11.7 kg ha^{-1}). S fertilization resulted in enhanced nutrient availability in the root zone, which, together with increased metabolic activity at the cellular level, may have increased nutrient uptake and accumulation in various plant parts as reported by Ravikumar *et al.* (2020).

The available N, P and K status of the soil was improved after the treatment, as per the data presented in Table 7. However, the graded doses of N, S and their combinations did not impart any significant difference on available N and P status of the soil. Available K and S contents varied significantly with the application of N and the treatment N_3 recorded the highest values of 190.33 kg ha^{-1} and 6.88 kg ha^{-1}, respectively. For available K, N_3 was on par with N_2, recording the value of 185.89 kg ha^{-1}. The ammonium ions released from the decomposition of urea might have replaced K^+ ions which is liberated from exchangeable layer to available layer in the soil and this is consistent with what was found by Jawad (2002). Available S content in the soil after the experiment varied with the application of S also and the treatment S_3 recorded the highest value of 6.46 kg ha^{-1}. Higher N doses *via* urea produce soil

TABLE 7

Available N, P, K and S status of soil after the experiment as influenced by graded levels of N and S, kg ha^{-1}

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})
Nitrogen (N)				
N_1 (10 kg)	188.00	62.61	169.91 ^{b}	5.59 ^{b}
N_2 (20 kg)	197.60	64.89	185.89 ^{a}	5.26 ^{b}
N_3 (30 kg)	210.11	68.08	190.33 ^{a}	6.88 ^{a}
S.Em (±)	11.276	2.641	3.845	0.241
CD (0.05)	NS	NS	11.527	0.722
Sulphur (S)				
S_1 (10 kg)	201.00	66.58	181.13	5.73 ^{b}
S_2 (20 kg)	195.71	66.00	177.78	5.52 ^{b}
S_3 (30 kg)	199.00	63.00	187.22	6.46 ^{a}
S.Em (±)	11.276	2.641	3.845	0.241
CD (0.05)	NS	NS	NS	0.722
Interaction (N x S)				
N_1S_1	188.31	69.21	157.73	5.51
N_1S_2	180.70	66.00	164.61	4.90
N_1S_3	195.00	52.61	187.30	6.31
N_2S_1	204.71	61.30	195.00	5.20
N_2S_2	198.70	65.60	183.00	4.72
N_2S_3	189.32	67.61	179.61	5.81
N_3S_1	210.11	69.21	190.61	6.53
N_3S_2	207.61	66.30	185.62	6.86
N_3S_3	212.70	68.60	194.60	7.21
S.Em (±)	19.530	4.754	6.66	0.417
CD (0.05)	NS	NS	NS	NS

acidification, which allows sulphate ions to be adsorbed on to the exchange sites and become resistant to leaching and thereby improving the S availability after the experiment (Scherer, 2009). Interaction effect of treatment on N, P, K and S was not significant.

Economic Analysis

The data on the effect of varying levels of N and S on gross income, net income and benefit cost ratio are presented in Table 8. The perusal of the results revealed that the treatments and their interaction had no significant effect on gross returns, net income and benefit cost ratio.

TABLE 8

Gross returns (Rs.ha^{-1}), net returns (Rs.ha^{-1}) and benefit-cost ratio of groundnut as influenced by graded levels of N and S

Treatment	Gross return (Rs.ha^{-1})	Net return (Rs.ha^{-1})	BCR
Nitrogen (N)			
N_1 (10 kg)	123000.7	55579.6	1.83
N_2 (20 kg)	124205.3	56624.3	1.85
N_3 (30 kg)	120774.2	52879.8	1.79
S.Em (±)	10191.96	10191.9	0.146
CD (0.05)	NS	NS	NS
Sulphur (S)			
S_1 (10 kg)	120303.3	59396.3	1.98
S_2 (20 kg)	126581.7	58220.7	1.85
S_3 (30 kg)	121095.1	47466.6	1.65
S.Em (±)	10191.96	10191.9	0.146
CD (0.05)	NS	NS	NS
Interaction (N x S)			
N_1S_1	120320.7	59673.7	1.98
N_1S_2	119209.3	51008.3	1.75
N_1S_3	129472.0	56056.8	1.76
N_2S_1	119282.7	58475.7	1.96
N_2S_2	142560.0	74199.0	2.09
N_2S_3	110773.0	37198.1	1.51
N_3S_1	121306.7	60039.7	1.98
N_3S_2	117976.0	49455.0	1.72
N_3S_3	123040.0	49144.1	1.67
S.Em (±)	17653.1	17653.1	0.254
CD (0.05)	NS	NS	NS

The study revealed that there was no significant variation in yield attributes, kernel yield, haulm yield and economics of cultivation of groundnut due to varying levels of N and S even though the influence of N and S levels on growth attributes were significant. Taking all these findings into account, N:S @ 10 kg ha^{-1} each can be considered as the optimum dose for groundnut cultivated in northern coastal plains of Kerala.

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