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MACRONUTRIENT REQUIREMENT OF GROUNDNUT : EFFECTS ON GROWTH AND YIELD COMPONENTS

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SUMMARY

A series of sand culture pot experiments were conducted to find out the optimum concentration of N, P, K, Ca, and S, in the nutrient solution, for growing groundnut with maximum growth and yield by taking each macronutrient in the range of 2-200 ppm. The observations on plant height, dry matter production, and podding at 20, 40, 60 days after emergence (DAE) and at harvest, chlorophyll content and transpiration at 40 and 70 DAE, flowering from 25-70 DAE and finally pod and haulm yields, at harvest showed that increasing the macronutrients levels, in the nutrients solution, increased these parameters significantly up to a certain level only which was optimum dose for that parameter. The number of flowers produced during the first two weeks (25-40 DAE) of its flowering increased significantly up to 10 ppm of N, P, K, and S and 20 ppm of Ca, but the number of pods at harvest increased up to 50 ppm of N and 20 ppm of P, K, Ca and S. The pod yield and dry matter, chlorophyll, flowering, podding and transpiration at either of the stages, however, increased up to 20 ppm of P and S and 50 ppm of N, K, and Ca and further increase in the levels of these macro-nutrients did not increase these parameters any more significantly. The macronutrient levels of 50 ppm of N, K, and Ca, and 20 ppm of P and S, in nutrient solution, are being recommended for growing groundnut in nutrient culture.

Key words: **Dry matter, groundnut, optimum macronutrients, pod yield, sand culture**

INTRODUCTION

The groundnut is a major oilseed crop of India and many other Asian countries. Though, the groundnut cultivation has been extended in almost all soils throughout the world, its nutrient requirement is high and like other crops it also requires all the macro- and micro-nutrients for its growth and development (Dwivedi 1988, Singh *et al*. 1990, Adams and Hartzog 1991, Adams *et al*. 1993, Singh 1999). The fertilizer requirement of groundnut crop has been worked out by many workers by conducting field experiments in U.S.A. (Cox *et al.* 1982, Hartzog and Adams 1988) India (Kanwar *et al*. 1983, Dwivedi 1988, 1989, Singh 1999, 2004, Singh and Chaudhari 1995) and Australia (Bell 1985), but the information on the nutrient composition of solution required for growing groundnut is scarce. In few studies conducted on nutrient solution culture of groundnut, the composition of nutrients are adopted directly from the one being used for other crop (Fageria 1974, Bell *et al.* 1989, Singh and Chaudhari 1992).

As the nutrients requirements vary from crop to crop, it was felt necessary to study the concentration of macronutrients needed for solution culture of groundnut in tropical environments prevailing during the groundnut growing seasons in India and Asia (Dwivedi 1988, Singh 1999). Therefore, sand culture pot experiments were

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conducted to find out the optimal concentrations of N, P, K, Ca, and S in nutrient solution for growing groundnut crop with an adequate supply of all these nutrients at a concentration as low as are compatible with adequate rate of absorption and growth. This paper describes the effects of various levels of macronutrient on the growth and dry matter production, chlorophyll contents, transpiration, nodulation, flowering, pegging, podding and the cumulative effects of all these on pod and haulm yields of groundnut.

MATERIALS AND METHODS

Sand culture pot experiments were conducted, during wet and dry seasons, at the experimental site of the National Research Centre for Groundnut, Junagadh, India. Five macronutrients namely N, P, K, Ca, and S each with their 8 levels (2, 5, 10, 20, 50, 100, 150, and 200 ppm) in the nutrient solution were studied separately. Fifteen kg of sand was filled in a number of ceramic pots of 25 cm diameter with a bottom hole plugged with glass wool. The healthy seeds of groundnut variety JL 24 were sown at a rate of four seeds per pot in 10 replicates (4 for final harvest and 2 each for three samplings at 20, 40, and 60 DAE) for each treatment. During wet season, the groundnut was sown in July which germinated within 6 days and from the day of emergence the crop took 95 days to mature. While during dry season, the sowing was done in February which germinated in 8 days and took 103 days to mature. The date of sowing, emergence and harvest of the crop were July 21 (6^{th} day of 29^{th} week), July 26 (4^{th} day of 30^{th} week) and October 30 (2^{nd} day of 44^{th} week), respectively during wet season and Feb. 6 (2^{nd} day of 6^{th} week), Feb. 14 (3^{rd} day of 7^{th} week) and May 26 (6^{th} day of 21^{st} week) during dry season, respectively. The temperature, relative humidity, sunshine hours and evaporation prevailing during the wet and dry seasons are depicted in the Fig. 1.

The nutrient solutions used in this study were based on Hoagland and Arnon (1938), with slight modification (Table 1). As the groundnut requires more iron and is sensitive to iron-deficiency chlorosis, its concentration in the nutrient solution was kept 5 ppm. The iron recipe was prepared separately as Fe-EDTA as per Steiner and Von Winden (1970) and was added in the nutrient solution just

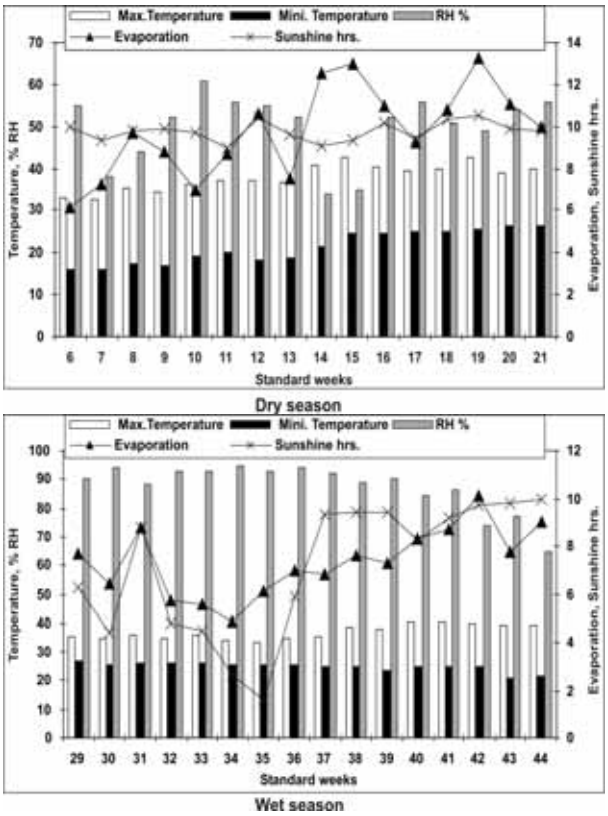

Fig. 1.Weekly mean minimum and maximum temperature (°C), RH (%), evaporation (mm) and sunshine hours (h) during the experimentation period. The date of sowing and harvest of the crop was July 21 (6^{th} day of 29^{th} week), and October 30 (2^{nd} day of 44^{th} week), respectively during wet season and February 6 (2^{nd} day of 6^{th} week) and May 26 (6^{th} day of 21^{st} week) during dry season, respectively.

before application. For complete solution, the complete composition of nutrients listed in Table 1 was followed which contained 210, 32, 235, 200, 64, and 48 ppm of N, P, K, Ca, S, and Mg, respectively and 5, 0.5, 0.05, 0.02, 0.05 and 0.01 ppm of Fe, Mn, Zn, Cu, B, and Mo, respectively. For different levels of macronutrients the minus solution of that particular nutrient was taken as base solution and from a 1000 ppm stock solutions of NH_4NO_3 for N, Na_2HPO_4 for P, KCl for K, $CaCl_2.2H_2O$ for Ca and Na_2SO_4 for S, the 2, 5, 10, 20, 50, 100, 150, and 200 ml l^{-1} was added for the preparing the nutrient solution of 2, 5, 10, 20, 50, 100, 150, and 200 ppm concentration, respectively. The pots were initially irrigated with 2 litres of complete solution in each pot on

Table 1. Composition of the nutrient solution used in the experiment

Chemicals	Concentration (milli moles) of mineral nutrients chemicals					
	Complete	-N	-P	-K	-Ca	-S
KNO_3	5	-	5	-	5	5
$Ca(NO_3)2.4H_2O$	5	-	5	5	-	5
KH_2PO_4	1	1	-	-	1	1
$MgSO_4.7H_2O$	2	2	2	2	2	-
$NaNO_3$	-	-	-	5	10	-
$MgCl_2.6H_2O$	-	-	-	-	-	2
$NaH_2PO_4.2H_2O$	-	-	-	1	-	-
$CaCl_2.2H_2O$	-	5	-	-	-	-
KCl	-	5	-	-	-	-

The micronutrients formulation used in the study was common for all. The composition of the micronutrient was H_3BO_3, 2.86 mg l^{-1}; $MnCl_2.4H_2O$, 1.81 mg l^{-1}; $ZnCl_2$, 0.11 mg l^{-1}; $CuCl_2.2H_2O$, 0.05 mg l^{-1}; MoO_3, 0.015 mg l^{-1} and Fe-EDTA at 5 mg Fe l^{-1}which contained 5, 0.5, 0.5, 0.05, 0.02 and 0.01 ppm (mg l^{-1}) of Fe, B, Mn, Zn, Cu, and Mo, respectively. The pH of the nutrient solution was maintained at 6.0.

the day it was sown, and at 250 ml pot^{-1} day^{-1} till 7 days after emergence (DAE). The solution was inoculated with *Bradyrhizobium* NC 92 to provide an initial concentration of 10^6 - 10^9 cells ml^{-1}. After 7 DAE the pots were flushed with water and the treatment of different levels of macronutrient was started by providing 500 ml of nutrients solution pot^{-1} day^{-1} from 7-30 DAE, 750 ml pot^{-1} day^{-1} from 31-50 DAE and at a rate of 1 L pot^{-1} day^{-1} thereafter. The nutrient solution was stopped 5 days before harvest. The pots were flushed with water at weekly interval. Proper care was taken to protect the crop from other physical factors and insects pests during the cropping season.

Out of the ten pots, from each treatments, four pots (replications) were maintained till maturity, in which the number of flowers day^{-1} from 25 - 70 DAE, chlorophyll content, transpiration rate and diffusion resistance at 40 and 70 DAE, and number of pods and pegs, pod and haulm yields at harvest were recorded. The remaining 6 pots were used in three samplings at 20, 40, and 60 DAE each with two replications. The plants from each treatment were uprooted, washed, and observations on plant height, nodule number, peg and pod numbers were recorded. The plants, after these observations, were separated into leaf, stem, pod and peg, dried in oven at 60°C for about a week and weighed separately. The flowers appearing in plants were counted daily from the day it started and continued till 6 weeks. These were summed to weekly numbers of flowers per pot. The first fully opened mature leaf was subjected to the measurement of diffusion resistance and transpiration rate using LI-COR steady state porometer (LI-1600) between 10-11A.M. and later on sampled for estimating chlorophyll contents (Arnon 1949).

At maturity the plants from each pot were harvested washed, separated into pegs, pods, stem and leaves, and observations on the plant height and the peg and pod numbers recorded. The plant materials were dried and weighed and pod and haulm yields were determined. All these data were analyzed statistically by analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Growth and dry matter production: The dry matter and plant height observed at 20, 40, 60 DAE and at harvest, showed increasing trends with increase in N, P, K, Ca, and S levels linearly and significantly up to a certain level, and thereafter there was no increase (Fig. 2). The plant height and dry matter at 20 DAE did not show any difference due to various levels of macronutrients indicating that the plant growth was slow during the initial stages, but as the growth increased after 40 DAE these parameters showed marked differences due to various levels of macronutrients. From the observations, recorded at various growth stages, it is evident that the nutrient requirement of groundnut varies with growth stages, which was low up to 40 DAE and increased thereafter. Hence, the lower levels of macronutrients also performed well during early growth stages, but with advancement of growth stages these were not enough to meet the plant's requirement and thus the plant with adequate supply of macronutrients only showed healthy and good growth (Fig. 2).

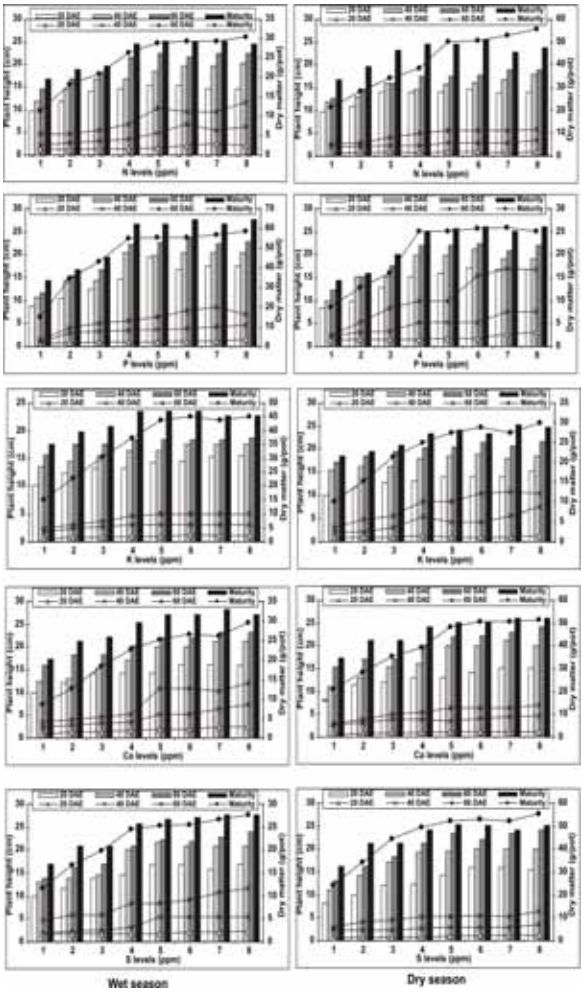

Fig. 2. Effects of N, P, K, Ca and S levels (1, 2, 3, 4, 5, 6, 7 and 8 are respective 2, 5, 10, 20, 50, 100, 150 and 200 ppm levels of macro-nutrients) in the nutrient solution on the plant heights (bars) and dry matter production (lines) in groundnut at 20, 40, and 60 days after emergence (DAE) and at maturity during wet and dry seasons.

The trends of dry matter production, though varied slightly at various growth stages, the overall optimum dry matter in groundnut plant was observed at 50 ppm of N, 20 ppm of P, 50 ppm of K, 50 ppm of Ca, and 20 ppm of S, and further increase in the levels of these macro-nutrients did not increase the dry matter any more significantly. Bell *et al*. (1989) in their study on flowing solution culture experiments used a nutrient solution containing 500, 1.1, 250, 150, and 153-2626 µM (7, 0.034, 9.75, 3.6, and 4.9-84 ppm, respectively) of N, P, K, Mg and S, respectively, a low level of macronutrients, for studying the calcium levels in different legumes including groundnut. However, the minus N solution containing 16, 55, 48, 38, and 12 ppm of P, K, Ca, S and Mg, respectively used by Bond and Hewitt (1962) for growing *Alnus* and *Casurina* was similar to that of our finding in groundnut. In our study the lower levels of P, Ca, and S, caused slow growth resulting in stunted plant structure and under low N and K supply the plants became thin with elongated stem. The dry season crop produced more dry matter than of wet season crop, but the trends of the effect of different macronutrients levels on the growth and dry matter production was similar during both the seasons. More dry matter production during the dry season was probably due to the longer duration of crop and more sunshine hours and evaporation rate prevailed during the cropping season (Fig. 1). These observations were also demonstrated in our earlier report (Singh and Joshi 1993, Singh *et al*. 1995).

Chlorophyll content and transpiration in leaves: At 40 and 70 DAE the total chlorophyll content, in the first fully expanded leaves, showed an increasing trend with increasing macronutrients levels up to 200 ppm N, 20 ppm P, 50 ppm K, 50 ppm Ca, and 20 ppm S (Table 2). This indicated that the macronutrient requirements of groundnut are fixed and the P, K, Ca, and S increased the chlorophyll up to their optimal level. Further increasing the levels after that it was an extra amount and others, than that particular macronutrient, were the limiting factor. The nitrogen, however, was luxuriantly absorbed by the plant and increased chlorophyll even at 200 ppm of N (Table 2). Though the chlorophyll content was affected due to poor nutrition of almost all the macronutrients, 2 ppm of N showed lowest chlorophyll at 40 DAE due to severe N-deficiency chlorosis during the initial stages. The nodulation started about 15 DAE and there was some recovery of the N-deficiency in terms of increase in chlorophyll content due to nitrogen-fixation by *Bradyrhizobium* in root nodule, in case of low levels of N. At 70 DAE, the lowest chlorophyll was with 2 ppm of Ca and S, indicating that these nutrients also show chlorosis as their deficiency symptoms. The deficiencies of Ca and S are more prominent in groundnut when grown in field causing considerable yield losses (Singh and Chaudhari 1995, Singh *et al*. 1995, Singh 2004). In soil with high Ca, the calcium-induced iron-

Table 2. Chlorophyll content (mg g^{-1} dw of leaves), at different crop growth stages, in groundnut grown under various levels of macronutrients in the nutrients solution.

Nutrient levels	40 DAE					70 DAE				
(ppm)	N	P	K	Ca	S	N	P	K	Ca	S
2	3.1	3.6	5.2	4.2	3.7	4.0	3.8	3.3	3.0	3.0
5	4.5	4.8	5.2	5.4	4.7	4.7	4.5	4.4	5.2	4.2
10	4.5	4.9	5.4	6.6	5.7	5.2	5.0	5.2	5.7	5.2
20	4.6	6.7	5.8	7.0	5.9	5.3	6.6	5.9	6.4	6.2
50	5.4	6.9	6.6	6.7	5.6	5.9	6.3	6.4	7.0	6.4
100	5.7	7.4	7.7	6.4	7.1	6.0	7.1	6.7	6.8	7.9
150	6.0	7.2	7.6	7.3	6.1	6.6	7.3	6.5	6.9	6.9
200	7.7	6.1	7.4	6.3	5.5	7.2	6.7	6.8	7.1	7.0
LSD 0.05	0.8	1.1	0.8	1.0	0.9	0.6	1.1	0.6	0.4	1.0

chloriosis is the main problem (Singh and Dayal 1992) affecting yields.

Among the macronutrients, lowest transpiration was observed in 2 ppm S at 40 DAE, but it increased thereafter (Table 3). Both the lower and higher levels of P, Ca, and S showed higher transpiration than their normal dose at 40 DAE due to low concentration of these elements at their low level and probably due to low concentration of other macronutrients at high levels of these elements. The transpiration rate, at 40 DAE, increased with increasing up to 100 ppm of N, P, and K, 50 ppm of S and 150 ppm of Ca. At 70 DAE, it increased only up to 20 ppm of K and 50 ppm of Ca but N and P did not show any definite trend.

Flowering and podding: Under normal condition flowering initiated 25 DAE and pegging 40 DAE, but these processes were delayed by 2-3 and 5-10 days, respectively in the treatment with less than 20 ppm of all the macronutrients. The weekly number of flowers for first two weeks showed that increasing the levels of macronutrients increased the numbers of flowers up to 10 ppm (Table 4). Though the flowering in groundnut occurred till 6 weeks, more than 60% of the total flowers appeared in first two weeks of flower initiation.

The pod number at maturity increased only upto 50 ppm of N, 10 ppm of P and 20 ppm of K, Ca and S (Table 5). The pegging in groundnut starts 10-15 days after flowering and the podding starts once the peg reaches soil. As a result there were sufficient pegs and pods at 60 DAE in the treatment with sufficient level of macronutrients only, as most of the flowers appeared up to 2-3 weeks of initiation of flowering, were able to produce pegs and pods by that time. But the low levels of macronutrients delayed flowering, pegging and hence pod formation.

In general there is good correlation between the flowers produced and pod yield in groundnut. In this study the number of pods at harvest were positively correlated with the number of flowers during the first two weeks of flowering (Table 4). Significant increase in flowering was noticed by increasing the macronutrient levels, only up to 10 ppm of N, P, K, and S and 20 ppm of Ca. The pod numbers, however, increased up to 50 ppm N and 20 ppm of rest of the macronutrients. This clearly indicated that the fruit setting and kernel development was poor at the lower levels of macronutrients as a result pod weight observed at harvest were not proportional to their numbers.

Table 3. Effect of macronutrient levels in the nutrient solution, on the transpiration rate (μg cm^{-2} s^{-1}) in groundnut leaves, at different crop growth stages.

Nutrient levels	40 DAE					70 DAE				
(ppm)	N	P	K	Ca	S	N	P	K	Ca	S
2	12.0	17.3	16.5	17.6	8.4	10.2	16.3	13.8	13.6	17.2
5	14.2	15.9	16.6	15.0	14.9	13.8	12.9	10.5	14.0	21.9
10	15.8	15.1	18.0	14.4	13.5	11.8	12.1	16.2	18.0	21.5
20	13.5	14.0	21.4	15.3	12.5	10.0	14.0	15.3	21.3	19.5
50	15.0	18.1	20.6	14.2	13.1	15.0	13.1	16.6	22.2	19.1
100	18.8	19.9	20.7	16.0	11.8	10.8	12.9	17.7	23.0	20.1
150	18.3	17.8	20.9	19.0	11.2	12.9	14.8	17.9	21.0	20.2
200	19.4	15.0	20.5	20.5	13.0	12.1	14.7	16.5	22.1	20.5
LSD 0.05	1.5	1.8	1.6	2.1	1.0	0.8	1.0	1.3	3.2	2.0

Table 4. Effect of macronutrients levels in the nutrient solution, on the flower production during the first two weeks of flowering, and number of pods at maturity in groundnut.

Nutrient levels	Flowers pot^{-1} during first two weeks					Pods pot^{-1} at harvest				
(ppm)	N	P	K	Ca	S	N	P	K	Ca	S
2	22	10	21	19	25	11	10	13	9	12
5	28	41	36	34	36	15	18	17	14	15
10	39	48	37	35	43	18	23	21	21	20
20	37	44	35	43	38	21	24	25	25	24
50	36	46	40	41	45	25	25	26	24	24
100	42	46	50	45	39	25	26	28	25	23
150	38	45	46	48	42	26	28	28	25	28
200	51	53	56	50	52	34	29	32	28	33
LSD 0.05	6	7	9	6	7	4	5	4	3	3

Pod and haulm yields : The pod and haulm yields in groundnut increased with increasing macronutrient levels up to 20 ppm of P and S, and 50 ppm of N, K, Ca during both the seasons except that of haulm yield in P which increased up to 50 ppm (Table 5 and 6). Higher levels of these macronutrients showed more or less similar pod and haulm yields as no significant differences were observed except in one or two cases where the higher yields were due to luxuriant absorption of these macronutrients (Singh and Chaudhuri, unpublished). The

Table 5. Pod yields (g pot^{-1}) of groundnut under different levels of macronutrients in the nutrient solution.

Nutrient levels	Wet season					Dry season				
(ppm)	N	P	K	Ca	S	N	P	K	Ca	S
2	3.5	2.5	2.3	2.1	3.5	3.0	2.1	3.2	3.1	4.1
5	4.0	4.4	5.6	4.9	4.9	5.4	5.3	5.2	6.2	6.6
10	4.3	5.6	6.5	5.2	6.9	6.6	8.2	8.4	7.0	9.2
20	6.1	10.2	8.3	8.1	9.6	8.8	12.8	12.0	8.6	13.0
50	9.8	10.0	9.6	9.8	9.8	12.5	13.0	12.9	13.0	13.2
100	10.4	10.2	9.7	9.7	9.9	11.9	13.5	13.4	13.2	13.4
150	10.6	9.8	9.2	10.1	10.1	12.4	13.6	13.5	13.4	13.6
200	10.4	10.7	12.0	11.5	11.3	12.7	14.0	14.0	13.2	13.6
LSD 0.05	0.8	0.9	0.6	1.0	0.5	1.1	0.8	0.7	0.5	0.7

Table 6. Haulm yields (g pot^{-1}) of groundnut obtained under different levels of macronutrients in the nutrient solution.

Nutrient levels	Wet season					Dry season				
(ppm)	N	P	K	Ca	S	N	P	K	Ca	S
2	8.1	6.8	8.5	7.1	8.8	18.1	12.0	12.4	18.0	20.1
5	15.6	8.7	10.1	8.2	12.1	22.4	27.5	17.5	22.0	27.5
10	18.4	10.7	14.5	12.1	13.3	27.5	33.5	21.2	28.0	34.2
20	22.1	14.6	17.2	13.1	15.2	31.0	35.0	25.3	30.4	36.5
50	27.5	13.8	18.4	16.2	15.9	38.0	39.5	30.4	35.2	38.0
100	22.2	14.4	18.5	16.8	15.8	39.0	38.8	31.0	36.0	37.1
50	21.0	15.4	18.1	17.6	15.6	41.0	39.8	28.6	39.0	38.2
200	21.7	14.7	18.3	19.4	16.8	43.0	41.0	30.2	38.1	42.0
LSD 0.05	2.4	2.1	1.2	3.0	1.5	4.9	4.1	5.0	4.5	2.2

2 ppm, lowest dose of these macronutrient was more detrimental to growth and reduced pod and haulm yields. The dry season crop produced more pod and haulm yields than wet season but the ratio of pod to total dry matter was more during wet season. This was due to more sunshine hours, evaporation, and a wide gap between maximum and minimum daily temperature prevailed during the dry season than that during wet season (Fig. 1). During wet season the sunshine hour and evaporation was quite low from 10-45 DAE which is an active stage of crop growth and most crucial for flowering and pegging (Fig. 1).

Hewitt (1966) compiled the nutrient solutions used by various laboratories for a variety of crops and observed a wide range of variation in concentration of macronutrients but mostly the normal solution referred contained 70-210, 20-40, 39-312, 20-200, 16-64, and 12-48 ppm of N, P, K, Ca, S, and Mg, respectively. In the present study, all the macronutrients were tested in the range from 2-200 ppm in the nutrient solution, of these 50, 20, 50, 50, and 20 ppm of N, P, K, Ca, and S, respectively, was best for pod yield of groundnut. These all are well within the range of tested solutions except N which was less due to intensive nodulation and nitrogen fixation by the crop. This concentration was similar to the solution of Bond and Hewitt (1962) as referred earlier. The composition of the nutrient solution which were found best for groundnut in our study, was almost similar to the two other studies cited by Hewitt (1966) the one containing 50, 50, 40, 20, and 15 ppm of N, K, Ca, S, and Mg, respectively for growing pine, spruce and birch and the other containing 47, 4, 65, 50, and 72 ppm of N, P, K, Ca and Mg, respectively, for growing tomatoes. The rate of renewal of nutrient solution is also an important factor while deciding the nutrient concentrations in the nutrient culture experiment. The frequent renewal requires comparatively lower concentration of nutrients in the solution. Bell *et al.* (1989) in there flowing solution culture experiment used comparatively low levels of macronutrients for growing groundnut. In the present study, the solution was replenished daily with adequate amount to meet the water requirement of groundnut and the concentration mentioned were found to be best.

It is therefore concluded that to provide an adequate supply of macronutrients for optimum growth and yield of groundnut, a nutrient solution containing 20 ppm of P and S and 50 ppm of N, K, and Ca along with other macro- and micronutrient is essential and need to be replenished daily with adequate amount for growing groundnut successfully in sand culture experiment.

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