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EFFECT OF PHOSPHORUS, SULPHUR AND PLANTING METHODS ON GROWTH PARAMETERS AND TOTAL YIELD OF GROUNDNUT (*ARACHIS HYPOGAEA* L.) AND SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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SUMMARY

Results of field experiment conducted at I.A.R.I., New Delhi during *Kharif* seasons of 1999 and 2000 revealed that the growth parameters like leaf area index (LAI), net assmilation rate (NAR), total dry matter (TDM) accumulation and per plant productivity of groundnut were favoured by one month delay in planting of sunflower in groundnut-sunflower intecropping system in replacement series. The NAR of groundnut was decreased at early growth stage due to simultaneous sowing of both the crops, but at later stage, it was recovered and the TDM and productivity were compensated. Whereas, late planting resulted in low LAI, TDM and productivity of sunflower. Total productivity was not influenced by intercropping. In the intercropping system, LAI, TDM as well as pod/seed weight were increased due to application of phosphorus up to 40 and 80 kg P_2O_5 ha^{-1} in groundnut and sunflower respectively, while application of sulphur up to 30 kg S ha^{-1} increased these parameters in both the years. However, total productivity was significantly increased due to 40 kg P_2O_5 and 30 kg S ha^{-1}.

Key words: **Groundnut, growth, intercropping, phosphorus, sulphur, sunflower.**

INTRODUCTION

Intercropping is not only a potential system of crop production, but also offers greater stability to productivity and efficient utilization of available growth factors. Groundnut-sunflower intercropping system is such a promising system which maximizes the production of edible oil per unit area and time by proper canopy management. This system not only reduces the seed-cost but also improves production of oilseeds (Rao and Reddy 1991). However, the growth of groundnut is suppressed mainly due to reduced photosynthetic activity (Sterling *et al.* 1990). Talwar *et al.* (2002) suggested that crop growth rate of groundnut could be manipulated by modifying canopy architecture like narrow leaves. But they emphasized the need for separate approaches to improve partitioning ability along with overall crop growth rates. Delaying the sowing of sunflower by one month may provide a competition-free period of about two months to groundnut and thereby minimizing the adverse effects of sunflower on groundnut. Adoption of proper nutrient management may ensure better partitioning of photosynthates. Phosphorus is considered essential for development of root and kernel and nodulation in groundnut. Phosphorus deficiency in sunflower causes reduction in leaf area, leaf dry weight, shoot/root ratio, photosynthetic activity and stomatal conductance (Guidi *et al.* 1994). The rate of light saturated photosynthesis per unit of leaf area is reduced and leaf appearance is delayed due to deficiency of phosphorus in sunflower (Rodriguez *et al.* 1998). Application of phosphorus is also necessary for maintaining a balance among other plant nutrients and ensuring the normal growth of the crop. The nutrient sulphur is essential for the synthesis of oil in both groundnut and sunflower.

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Since both the crops, groundnut and sunflower in the system are oil-yielding and one of them is leguminous, a system based approach for management of the nutrients like phosphorus and sulphur needs due attention. In this context, an experiment was conducted to study the effect of phosporus, sulphur and planting method on leaf area index (LAI), net assimilation rate (NAR), total dry matter (TDM) and productivity of groundnut and sunflower in intercropping and total productivity from the system.

MATERIALS AND METHODS

The field experiment was laid out at research farm of Indian Agricultural Research Institute (IARI), New Delhi, during *kharif* seasons of 1999 and 2000 in split-plot design with three replications. The main-plot treatments comprised three cropping systems *i.e.* 1. sole groundnut (GN_{sole}), 2. groundnut intercropped with simultaneously sown sunflower ($GN + SF_{simul.}$) and 3. groundnut intercropped with sunflower sown one month later ($GN + SF_{stag.}$). In both the intercropping systems, groundnut and sunflower were sown in 2 : 1 row ratio in replacement series with 33.3 cm row spacing. Hence, every third row of groundnut was replaced by one row of sunflower intercrop. In this system sunflower rows were 100 cm apart whereas normal spacing is 50 cm. Thus 67 and 50 per cent population of sole stand of groundnut and sunflower, respectively was maintained. The sub-plot treatments consisted combinations of three levels each of phosphorus (0, 40 and 80 kg P_2O_5 ha^{-1}) and sulphur (0, 30 and 60 kg S ha^{-1}). The groundnut variety SG-84 (semi-spreading Spanish type) and sunflower hybrid MSFH-8 were used as test crops. Growth observations were recorded at 30 days interval from the date of sowing and at harvesting stage from five plants under each treatment. Leaf area was maeasured by Leaf Area Meter (LICOR model LI-3000). Leaf area index (LAI) was computed on the basis of ground area covered by individual crop. Growth analysis parameters were calculated based on formulae given by Evans (1972). The tables presented contain data pooled over observations of two years experiments.

RESULTS AND DISCUSSION

LAI of groundnuts increased gradually with succuessive growth stages till the harvest (Table 1), but in sunflowr the LAI reached maximum at 60 days after sowing (DAS) and thereafter it declined at maturity of the

Table 1. Leaf area index (LAI) and net assimilation rate (NAR) of groundnut as influenced by cropping systems and levels of P and S.

Treatment	LAI				NAR (mg $cm^{-2}d^{-1}$)		
	30 DAS	60 DAS	90 DAS	Harvest	30-60 DAS	60-90 DAS	90 DAS-Harvest
Cropping system							
GN (sole)	0.51	2.24	2.99	3.47	1.30	0.46	0.43
GN + SF (simul.)	0.38	1.19	2.09	2.25	1.07	0.65	0.42
GN + SF (stagg.)	0.41	2.06	2.60	2.88	1.21	0.50	0.39
SEm(±)	0.02	0.08	0.09	0.06	0.02	0.01	0.02
CD (0.05)	0.06	0.33	0.36	0.26	0.09	0.05	NS
P levels (kg P_2O_5 ha^{-1})							
0	0.38	1.52	2.10	2.35	1.16	0.52	0.41
40	0.49	2.01	2.98	3.25	1.17	0.59	0.36
80	0.41	1.98	2.60	3.02	1.27	0.48	0.48
SEm(±)	0.01	0.04	0.04	0.05	0.02	0.02	0.02
CD (0.05)	0.02	0.11	0.12	0.15	0.05	0.07	0.06
S levels (kg S ha^{-1})							
0	0.37	1.68	2.25	2.42	1.23	0.50	0.34
30	0.52	1.92	2.81	3.19	1.11	0.57	0.43
60	0.40	1.90	2.61	3.03	1.27	0.52	0.47
SEm (±)	0.01	0.04	0.04	0.05	0.02	0.02	0.02
CD (0.05)	0.02	0.11	0.12	0.15	0.05	0.06	0.06

Table 2. Effect of cropping systems and levels of P and S on leaf area index (LAI) and net assimilation rate (NAR) of sunflower.

Treatment	LAI			NAR (mg $cm^{-2}d^{-1}$)	
	30 DAS	60 DAS	Harvest	30-60 DAS	60 DAS-Harvest
Cropping system					
GN+SF (simul.)	0.20	0.84	0.47	0.88	1.62
GN+SF (simul.)	0.07	0.42	0.30	1.42	0.84
SEm(±)	0.01	0.03	0.01	0.05	0.05
CD (0.05)	0.03	0.19	0.09	0.30	0.29
P levels (kg P_2O_5 ha^{-1})					
0	0.11	0.52	0.33	1.16	1.29
40	0.15	0.66	0.39	1.08	1.18
80	0.15	0.71	0.44	1.16	1.24
SEm(±)	0.01	0.03	0.01	0.03	0.08
CD (0.05)	0.02	0.10	0.04	NS	NS
S levels (kg S ha^{-1})					
0	0.13	0.55	0.35	0.09	1.33
30	0.14	0.67	0.41	1.11	1.25
60	0.13	0.67	0.38	1.21	1.13
SEm (±)	0.01	0.03	0.01	0.03	0.08
CD (0.05)	NS	0.10	0.04	0.08	NS

crop (Table 2). Groundnut in intercroping recorded lower LAI than that of sole crop because intercropping system had only 2/3 population of sole stand. Amongst the intercropping systems, groundnut with staggered planting of sunflower showed higher LAI at all the stages. Whereas, sunflower sown simultaneous (GN + $SF_{simul.}$) to the groundnut registered higher LAI than the crop sown one month later (GN + $SF_{stagg.}$). The growth of late sown sunflower was suppressed by groundnut crop at all the stages. Groundnut in sole stand showed the highest net assimilation rate (NAR) during the period of 30-60 DAS, while groundnut with simultaneously sown sunflower intercrop recorded the lowest during the same period (Table 1). Since the net photosynthetic rate in groundnut remains high in upper first to fourth leaves (Nautiyal *et al.* 1999), shading caused by sunflower might be the reason for the lowest NAR in groundnut with simultaneously sown sunflower at early stage of growth. Advancement of sunflower crop towards maturity reduced the LAI and permitted more penetration of solar radiation to reach the groundnut crop as it was reflected with the highest NAR value of groundnut in simultaneously sown sunflower intercropping system during 60-90 DAS period. In case of sunflower, higher NAR was recorded by late sown crop during 30-60 DAS and by normal sown crop during 60 DAS to harvest stage (Table 2). These two growth periods coincided for both the sunflower crops. Higher NAR of sunflower intercrops during this period might be attributed to prevailing favourable ambient temperature regime. Daily mean temperature during this period ranged between 27.0°C to 29.4°C.

Groundnut in staggered sown intercropping system accumulated the highest TDM being 26 and 28 per cent higher than groundnut in sole stand and other intercropping system, respectively (Table 3). Delay in sowing of sunflower intercrop by one month allowed groundnut crop to grow in a competition free environment with more space resulting into higher accumulation of dry matter. Since total dry matter is positively correlated with yield (Kumar *et al.* 2003), this reflected in terms of per plant productivity too. However, it remained statistically at par for both the intercropping system. Though sole groundnut crop recorded the highest LAI, per plant pod and dry matter production remained statistically on par with groundnut in simultaneously sown sunflower intercrop. The greater conversion efficiency of shaded groundnut may be due to improved light use efficiency in intercrop as suggested by Stirling *et al.* (1990). This showed that high NAR during pod development stage may be more important for better paritioning of dry matter into pods since all the reserved pool of carbohydrates in groundnut is not utilized for seed formation as suggested by Zheng *et al.* (2001).

As regards the influence on sunflower, normal sown sunflower intercrop recorded significantly higher seed weight as well as total dry matter (Table 3). Poor performance of late sown sunflower could be attributed to falling NAR at later growth stage. This crop might have faced stiff competition for mineral nutrients since the groundnut crop was in full grown stage when the staggered crop of sunflower was sown. This might have retarded its growth since sunflower seedling remained to a large extent dependent on an adequate supply of mineral elements in the soil for its transition from heterotrophic to photosynthetic growth (Jucknischke and Kutschera 1998). Due to the competition between the two component crops, total productivity (groundnut equivalent) was not significantly enhanced by intercropping over sole groundnut crop (Table 3).

LAI of groundnut was encouraged by the application of 40 kg P_2O_5 ha^{-1} and 30 kg S ha^{-1} (Table 1) but it was decreased at higher level of their application. Similar was the trend in case of pod yield and dry matter production of groundnut (Table 3). Whereas, sunflower, seed weight and total dry matter significantly increased up to 80 kg P_2O_5 ha^{-1} and 30 kg S ha^{-1} (Table 3) which was in close agreement with the observations on LAI in relation to phosphorus as well as sulphur (Table 2). Increase in growth and yield of both groundnut and sunflower due to application of phosphorus may be attributed to its role in

Table 3. Pod/seed and dry matter weight of groundnut and sunflower and total productivity as influenced by cropping systems and levels of phosphorus and sulphur

Treatment	Groundnut		Sunflower		Total productivity
	Pod yield (g $plant^{-1}$)	Total dry matter (g $plant^{-1}$)	Seed yield (g $plant^{-1}$)	Total dry matter (g $plant^{-1}$)	(Groundnut eq.) (t ha^{-1})
Cropping system					
GN (sole)	19.51	61.37	-	-	3.01
GN + SF (simul.)	21.42	60.69	13.02	106.42	2.81
GN + SF (stagg.)	24.74	77.56	6.53	45.53	2.78
SEm(±)	0.98	1.18	0.32	2.18	0.08
CD (0.05)	3.86	4.61	1.94	13.24	NS
P levels (kg P_2O_5 ha^{-1})					
0	19.35	54.40	8.21	65.50	2.50
40	24.59	74.96	10.04	75.89	3.19
80	21.72	70.25	11.06	86.43	2.91
SEm(±)	0.65	1.25	0.34	2.37	0.06
CD (0.05)	1.84	3.54	0.99	6.82	0.18
S levels (kg S ha^{-1})					
0	19.19	55.97	8.90	71.20	2.51
30	24.37	73.77	10.29	81.17	3.17
60	22.10	69.87	10.13	75.57	2.91
SEm (±)	0.65	1.25	0.36	2.37	0.06
CD (0.05)	1.84	3.53	1.03	6.82	0.18

cell division and development of meristematic tissue and photosynthetic activities. In groundnut, decrease in growth and pod weight at 80 kg P_2O_5 ha^{-1} may be because of the inhibition of starch synthesis in plants at higher concentration of inorganic phosphorus as viewed by Marschner (1995). This is also evident from the lowest value of NAR at 80 kg P_2O_5 ha^{-1} (Table 1) during 60-90 Das period which is the peak growth period of the crop. The groundnut plants can make use of appreciable quantity of soil-phosphorus through contact reactios with its root cell wall components (Ae *et al.* 1996, Ae and Otani 1997). That is why groundnut did not respond to higher dose of phosphorus. In sunflower, phosphorus plays important role in determining sink size and supply of assimilates (Rodriguez 1998). Since, sunflower was grown in intercropping with groundnut, there might have been more competition between two crops at 40 kg P_2O_5 ha^{-1} because groundnut is considered more efficient in P utilization. This might be the reason for significant increase in seed weight of sunflowre up to 80 kg P_2O_5 ha^{-1}.

The role of sulphur in synthesis of protein and chlorophyll might be responsible for enhanced plant growth and yield due to sulphur application. Though the NAR of groundnut was significantly influenced by P as well as S rates (Table 1) throughout the growth period, but that of sunflower was found to be affected by S (Table 2) nutrition at early growth stage only. At early growth period (30-60 DAS) of groundnut as well as sunflower, the NAR was decreased or remain unchanged with the first increment in the level of both P and S. This apparent anomaly could be explained as function of the nutrients would have been concentrated in root development which had not been taken into account since growth observations were taken on above ground plant parts only. During pod development stage of groundnut (60-90 DAS), NAR values were increased with the application of 40 kg P_2O_5 ha^{-1} and 30 kg S ha^{-1} approving significant role of P and S in the process of pod development. Growth rate of sunflower in terms of NAR was increased at early growth stage with application of 60 kg S ha^{-1}, but remained unaffected at seed maturity stage (60 DAS to harvest). Reddy and Singh (1996) reported the highest crop growth rate and net assimilation rate during early growth of sunflower with the higher rate of sulphur. Total productivity (groundnut equivalent) was significantly increased by both phosphorus and sulphur application. Highest productivity was recorded when 40 kg P_2O_5 ha^{-1} and 30 kg S ha^{-1} was applied. This was significantly superior than higher doses of respective nutrients (Table 3).

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