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Research Paper

Performance of groundnut (*Arachis hypogaea*) under different levels of sulphur and irrigation

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ABSTRACT

A field experiment was conducted on rice (*Oryza sativa* L.)–groundnut (*Arachis hypogaea* L.) cropping system during 2009, 2010 and 2011 at Chiplima, Sambalpur, Odisha to study the interaction effect of irrigation and sulphur on growth and pod yield of groundnut 'Smruti'. The experiment was conducted in spilt plot design with three irrigation schedules *viz.* irrigation water : cumulative pan evaporation (IW:CPE) ratio of 0.6, 0.8 and 1.0, in the main plots and 4 levels of sulphur (0, 20, 40, 60 kg/ha) in the subplots. Phosphogypsum (18% S) was used as source of sulphur. Pooled mean pod yield of 3 years indicated that the highest pod yield of 1.80 t/ha was observed with application of 20 kg S/ha irrespective of irrigation schedules. From the response quadratic curve, the economic highest pod yield of 1.82 t/ha was calculated with 34 kg S/ha. The mean oil content increased with increased dose of sulphur and was highest (47.90%) with 60 kg S/ha. The highest mean sulphur use-efficiency was recorded with 20 kg S/ha and it was reduced with increased dose of sulphur. The highest pod yield of groundnut was observed with IW:CPE of 0.8, irrespective of sulphur doses, whereas the highest water-use efficiency of 4.32 kg/ha-mm was observed with IW:CPE of 0.6 and gradually decreased with higher irrigation schedule. The highest gross returns, net returns and benefit: cost ratio of ₹68,400, ₹42,500 and 2.64, respectively, were achieved with application of 20 kg S/ha.

Key words : Pulse production, Groundnut, Irrigation scheduling, Phosphogypsum, Sulphur

Groundnut is an important oilseed crop in India which is cultivated in 6.16 million ha with an average productivity of 1.27 t/ha. It is the leading oilseed crop of Odisha which occupies 30.5% of the total oilseed area and accounts for 64.4% of total oilseed production in the state with an average productivity of 1.68 t/ha. The intensification of agriculture, introduction of high-yielding variety (HYV) and multiple cropping coupled with use of high-analysis fertilizers along with restricted use of organic manures have resulted in depletion of sulphur from the soils of Odisha. Sulphur (S) is considered as one of the most vital plant nutrients for oilseed crops, as it is essential for protein synthesis. It is an important constituent of the amino acids like cystine, cysteine and methionine. It is also involved in the formation of glucosides and glucosinolates, which on hydrolysis increases the oil content (Ghosh *et al*., 2000; Mishra *et al*., 1990; Prasad, 2003) also reported. The positive response of S application to groundnut. Phosphogypsum has been found either superior or equal to other S-containing fertilizers in groundnut (Ghosh *et al*., 2000). Irrigation scheduling based on IW:CPE ratio have been found most appropriate approach to determine irrigation water use by the crop. Optimum scheduling of irrigation led to increase in pod yield and water-use efficiency (WUE) in case of groundnut (Taha and Gulati, 2001). Keeping these aspects in view, an experiment was conducted to study the effect of different levels of irrigation and sulphur on pod yield, sulphur-use efficiency and water-use efficiency of groundnut in rice–groundnut cropping system.

MATERIALS AND METHODS

A field experiment was conducted on rice–groundnut cropping system during the winter (*rabi*) seasons of 2009, 2010 and 2011 at Chiplima, Sambalpur, Odisha. The acidic (pH 5.45) soil of the experimental field was sandy loam, low in organic carbon (0.42%) and available N, P, K and S contents were 223, 9.0, 152 and 13.4 kg/ha respectively. The moisture content at field capacity and permanent wilting point was 19.6 and 8.6% respectively. The experiment was laid out in split-plot design with 3 replica-

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tions. Main plot treatments consisted of 3 irrigation scheduling, viz. irrigation water: cumulative pan evaporation (IW:CPE) ratio of 0.6, 0.8, and 1.0, with 50 mm of water in each irrigation and 4 levels of sulphur (0, 20, 40 and 60 kg/ha) in the subplots with phosphogypsum as source of sulphur along with recommended doses of N, P and K (20, 40, 40 kg/ha). Groundnut variety 'Smruti' was grown with different doses of sulphur as per treatment plan and irrigation was applied as per irrigation treatments by calculating CPE from the climatological data. Number of irrigations provided were 9, 12 and 15 for IW:CPE ratio of 0.6, 0.8, and 1.0 respectively. Phosphogypsum was applied 10 days prior to sowing, whereas full doses of N, P and K were applied basal to the groundnut crop. The rhizobium culture inoculated groundnut seeds were sown with a spacing of 30 cm × 10 cm. The dates of sowing were 28.1.09, 27.1.10 and 30.1.11. Plant-protection measures were taken as and when required. All other cultural operations were carried out as per recommendations. The crop was harvested on 6-6-09, 6-6-10 and 8-6-11 during the 3 years. The observations on yield and yield-attributing parameters were recorded. The total rainfall during the crop growth period were 7.2 mm, 27.8 mm and 65.5 mm received in 1, 3 and 9 rainy days during 2009, 2010 and 2011 respectively. Consumptive use (CU) of water was calculated on the basis of soil moisture depletion in the effective root zone depth (45 cm) of groundnut crop during each irrigation interval along with effective rainfall for that interval. Basing on these data, water use efficiency (WUE) and sulphur-use efficiency (SUE) were calculated.

The oil content of the kernels was determined by Soxhelt ether extraction method (Jackson, 1973). From the pooled data, economics was worked out on the basis of prevailing market price of the produce and inputs used in the experiment. The data were statistically analyzed Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

Yield attributes

The highest number of pods/plant was observed with sulphur @ 20 kg/ha, which was statistically at par with that obtained with 40 kg/ha application. The lowest value of 10.87 was observed with plot no-sulphur application (Table 1). Pooled mean value of 100-seed weight was statistically not significant due to application of graded dose of sulphur. Highest value of 49.57 g with respect to 100-seed weight was observed with sulphur @ 20 kg/ha, whereas lowest with no sulphur application. Highest, statistically significant shelling (%) was observed with 40 kg/ha. Pooled haulm yield of 3 years indicated that irrespective of irrigation schedule, significantly highest haulm yield was observed with application of 40 kg S/ha against the lowest value obtained with no sulphur treated plot. Haulm yield with of 20 kg, 40 kg and 60 kg S/ha was statistically at par, whereas only significantly less haulm yield was obtained with no sulphur-treated plot.

Effect of irrigation scheduling irrespective of sulphur application indicated that yield- attributing characters such as number of pods/plant was significantly highest with irrigation scheduling at IW:CPE of 0.8, whereas the lowest value was observed with IW:CPE of 0.6 ratio. Other characters such as 100-seed weight, shelling (%) and haulm yield were statistically at par. However, highest 100-seed weight was observed with IW:CPE of 1.0 and highest shelling (%) and highest haulm yield were observed with IW : CPE of 0.8.

Yield

Effect of sulphur application on the pod yield of groundnut irrespective of irrigation scheduling revealed that during 2009, application of 40 kg S/ha recorded the highest mean groundnut pod yield, which was at par with application of 20 kg S/ha (Table 1). But this yield was significantly superior to the yield obtained with 60 kg S/ha as well as no sulphur. During 2010, an application of 20 kg S/ha recorded the highest pod yield but it was at par with yield obtained with 40 kg S/ha and was significantly superior to that of pod yield obtained with 60 kg S/ha and no sulphur. In the third year (2011), application of 40 kg S/ha recorded highest pod yield, which was at par with the yield with 20 kg S/ha as well with 60 kg S/ha but significantly superior to no sulphur treatment. Irrespective of irrigation schedules, the pooled mean pod yield of 3 years was maximum with the application 20 kg S/ha, which was at par with the yield obtained with 40 kg S/ha and significantly superior to that obtained with 60 kg S/ha along with no sulphur. This might be due to improvement of yield attributes in addition to its multiple roles in metabolism as an essential constituent of amino acids. Reduction in pod yields at higher dose, i.e. 60 kg/ha than the yield obtained with application of 20 kg S/ha might be due to some antagonistic effect of sulphur interfering with availability of some beneficial cations and anions essential for different metabolic processes. This result is in close conformity with the findings of Prasad (2003) and Nayak *et al.* (2003).

During the first 2 years, the pod yields were not significantly influenced by the irrigation schedules but in the third year the pod yield with irrigation scheduled at IW:CPE of 0.8 recorded significantly highest pod yield compared with any other irrigation schedules (Table 1). From the pooled mean, it was observed that highest pod yield of 1.8 t/ha was obtained with irrigation schedule at IW:CPE of 0.8 which was significantly superior to that obtained to other irrigation schedule, i.e. IW:CPE of 0.6 (1. 58 t/ha) and 1.0 (1.71 t/ha). This might be due to availability of proper moisture condition in the rhizosphere which affects the nodulation as well as availability of different nutrients .These results are in agreement with the findings of Rathod *et al.* (2011) which indicated both higher and lower irrigation frequencies are harmful. Taha *et al.* (2001) and Raskar and Bhoi (2003) reported similar results earlier.

The interaction effect of both irrigation and sulphur dose for the 3 years was statistically analyzed (Table 2).It was observed that significantly higher pod yield was observed with IW:CPE of 0.8. Pod yield of 1.80 t/ha was obtained with application of 20 kg S/ha, which was significantly superior to that obtained with no sulphur applied plot. Application of irrigation at 0.8 IW:CPE along with 20 kg S/ha gave the highest pod yield of groundnut.

Response curve of groundnut to graded doses of sulphur is shown in Fig. 1. The quadratic equation was fitted (R^2=0.972) where economic highest pod yield of 1.82 t/ha was calculated with sulphur dose of 34 kg/ha.

Seed yield and oil content

Seed yield due to application of graded doses of sulphur followed similar trend with that of pod yield. Mean seed yield of 3 years varied from 1.08 to 1.31 t/ha (Table 3). The oil content of the seed showed an increasing trend with increase in sulphur doses from 20 to 60 kg/ha. The

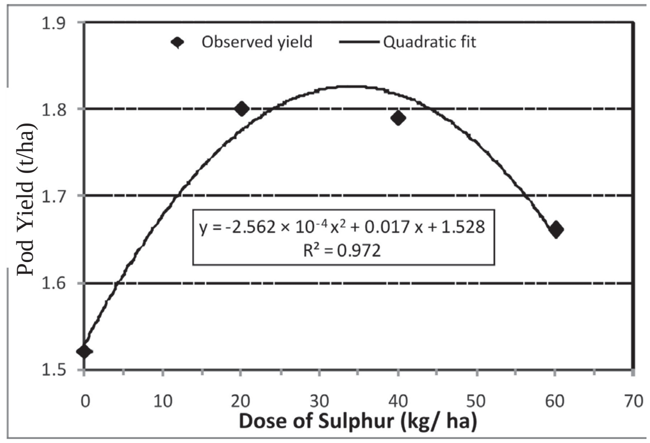

Fig. 1. Response curve of groundnut pod yield to graded doses of sulphur

Table 1. Effect of different levels of sulphur and irrigation on yield-attributing parameters and pod yield of groundnut (pooled mean)

Treatment	Mature pod/ plant	100-seed weight (g)	Shelling (%)	Haulm yield (t/ha)	Pod yield(t/ha)			
					2009	2010	2011	Pooled mean
Sulphur								
No sulphur	10.8	48.1	70.4	2.72	1.64	1.53	1.39	1.52
20 kg/ha	13.3	49.5	72.2	3.01	1.93	1.82	1.68	1.80
40 kg/ha	13.2	49.1	72.6	3.06	1.94	1.70	1.73	1.79
60 kg/ha	12.2	48.8	71.0	2.91	1.70	1.64	1.64	1.66
SEm±	0.4	0.8	0.5	0.03	0.07	0.05	0.04	0.03
CD (P=0.05)	1.3	NS	1.4	0.09	0.20	0.15	0.11	0.08
Irrigation schedules								
IW:CPE=0.6	11.4	48.6	70.9	2.85	1.66	1.58	1.50	1.58
IW:CPE=0.8	13.1	49.0	72.3	2.98	1.89	1.75	1.76	1.80
IW:CPE=1.0	12.7	49.1	71.6	2.94	1.86	1.69	1.57	1.71
SEm±	0.3	0.6	1.3	0.26	0.05	0.06	0.03	0.02
CD (P=0.05)	1.1	NS	NS	0. 08	NS	NS	0.10	0.07

IW, CPE; Irrigation water: cumulative pan evaporation

Table 2. Interaction effects of different levels of sulphur and irrigation on pod yield (t/ha) of groundnut (pooled mean)

Effect of irrigation schedules	Effect of sulphur				
	No sulphur	20 (kg/ha)	40 (kg/ha)	60 (kg/ha)	Mean
IW:CPE=0.6	1.48	1.69	1.66	1.49	1.58
IW:CPE=0.8	1.54	1.95	1.96	1.74	1.80
IW:CPE=1.0	1.53	1.78	1.75	1.76	1.70
Pooled mean	1.52	1.80	1.79	1.66	
	I	S	I within S	S within I	
SEm±	0.02	0.03	0.05	0.05	
CD (P=0.05)	0.07	0.08	0.13	0.14	

IW, CPE; Irrigation water: cumulative pan evaporation mean oil content of three years was the highest with 60 kg S/ha and the increase was 10.80% over the control. It might be due to availability of more sulphur for production of essential amino acids. This corroborates the results obtained by Giri and Saran (1989) and Ghosh *et al*. (2000). The increase in oil content was significantly higher over the control due to application of graded dose of sulphur. On the other hand, seed yield as well as oil content due to different levels of irrigation were statistically at par in all the 3 years.

Consumptive use of water and water-use efficiency

Consumptive use (CU) of water for sulphur-treated plot was the mean values of different irrigation treatment which was same for all the sulphur-treated plot (Table 4).Consumptive use of water of different irrigation scheduled plot varied from 367.6 to 479.0 mm. The highest CU (429.0 mm) observed with IW:CPE of 1.0, whereas the lowest value (367.6 mm) with IW:CPE of 0.6.

Irrespective of irrigation schedule, water-use efficiency (WUE) for different sulphur treatments varied from 3.62 to 4.24 kg/ha-mm. The mean WUE was highest with 20 kg S/ha, whereas, lowest value with no sulphur plot. Irrespective of sulphur doses, mean highest WUE was observed with IW:CPE of 0.6, whereas lowest value with IW:CPE of 1.0. Interaction effect indicated that the highest WUE was observed with 20 kg S/ha with IW:CPE of 0.6.

Sulphur-use efficiency

The pooled mean sulphur-use efficiency (SUE) only for sulphur treatments varied from 3.62 to 15.42 kg of pod per kg of sulphur applied. The highest response of 15.42 kg of pod/kg sulphur was observed with 20 kg S/ha and the lowest response at 60 kg S/ha (3.62 kg of pod/kg of sulphur). The SUE decreased with increasing dose of sulphur from 20 kg to 60 kg S/ha due to decrease in yield with higher dose of sulphur. Application of higher dose of sulphur to the soil resulted in high concentration of sulphur in the solution phase at the root zone which might have reduce the SUE due to its antagonistic effect.

Significantly highest pooled mean SUE kg pods/kg sulphur was observed with IW:CPE of 0.8, whereas the lowest with IW:CPE of 0.6.

Economics

The highest gross return, net return and benefit: cost ratio were observed (Table 5) with application of 20 kg S/ha, followed by 40 kg S/ha and 60 kg S/ha and the lowest value was recorded for no sulphur application.

Table 4. Effect of graded dose of sulphur and irrigation schedules on pod yield, water-use efficiency and sulphur-use efficiency.

Treatment	Consumptive use of water (mm) (3years average)	Water-use efficiency (kg/ha-mm) (pooled mean)	Sulphur-use efficiency (kg/kg) (pooled mean)
Sulphur			
No sulphur	426.8	3.62	-
20 kg/ha	426.8	4.30	15.42
40 kg/ha	426.8	4.24	6.67
60 kg/ha	426.8	3.95	3.62
SEm±	-	0.17	0.68
CD (P=0.05)	-	0.47	1.94
Irrigation schedules			
IW:CPE=0.6	367.6	4.32	5.13
IW:CPE=0.8	433.8	4.15	8.51
IW:CPE=1.0	479.0	3.60	5.64
SEm±	-	0.14	0.76
CD (P=0.05)	-	0.44	2.74

IW, CPE; Irrigation water: cumulative pan evaporation

Table 3. Effect of sulphur levels and irrigation schedules on kernel yield and oil content of groundnut crop (pooled mean)

Treatment	Seed yield (t/ha)				Oil content (%)			
	2009	2010	2011	Pooled mean	2009	2010	2011	Pooled mean
Sulphur								
No sulphur	1.19	1.08	0.98	1.08	42.0	43.8	43.9	43.23
20 kg/ha	1.39	1.32	1.21	1.31	47.0	46.8	46.0	46.60
40 kg/ha	1.41	1.24	1.26	1.31	47.8	47.9	47.6	47.77
60 kg/ha	1.21	1.17	1.16	1.18	47.8	48	47.9	47.90
SEm±	0.04	0.03	0.04	0.06	0.46	0.37	0.42	0.44
CD (P=0.05)	0.11	0.09	0.11	0.16	1.32	1.05	1.21	1.28
Irrigation schedules								
IW:CPE=0.6	1.21	1.12	1.06	1.12	45.3	43.2	44.6	44.6
IW:CPE=0.8	1.37	1.27	1.27	1.30	45.0	44.1	44.3	44.8
IW:CPE=1.0	1.33	1.21	1.13	1.22	45.5	44.0	45.0	44.9
SEm±	0.61	0.64	0.81	0.65	0.43	0.51	0.51	0.48
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

IW, CPE; Irrigation water: cumulative pan evaporation

Table 5. Economics of groundnut crop grown under different levels of irrigation as well as graded doses of sulphur (3 years average).

Treatment	Cost of cultivation (×10³ ₹/ha)	Gross returns (×10³ ₹/ha)	Net returns (×10³ ₹/ha)	Benefit: cost ratio
Sulphur				
No sulphur	25.6	57.6	32.0	2.25
20 kg/ha	25.9	68.4	42.5	2.64
40 kg/ha	26.2	68.0	41.8	2.59
60 kg/ha	27.0	63.1	36.1	2.34
Irrigation schedules				
IW:CPE=0.6	26.2	60.0	33.8	2.28
IW:CPE=0.8	27.5	68.4	40.9	2.48
IIW:CPE=1.0	29.0	64.6	35.6	2.23

Among the irrigation treatments, the highest gross return, net return and benefit: cost ratio were found at IW:CPE of 0.8. The lowest gross return and net return were found with IW:CPE of 0.6. The lowest benefit: cost ratio was found with IW:CPE of 1.0 closely followed by 0.6 IW:CPE.

It was concluded that application of 20 kg S/ha along with irrigation scheduling at IW:CPE of 0.8 can produce significantly higher pod yield in groundnut with highest gross return, net return and benefit: cost ratio. The highest SUE (15.42 kg of pod/kg of sulphur) was observed with 20 kg S/ha, whereas the highest mean WUE (4.32 kg/ha-mm) was observed with irrigation scheduling at IW:CPE of 0.6.

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