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Effect of organic manure and sulphur fertilization in pigeonpea (*Cajanus cajan*) + groundnut (*Arachis hypogaea*) intercropping system

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ABSTRACT

There is large number of sulphur(S) sources available in the country and their efficiency need to be evaluated. In view of the meager information available on sulphur nutrition in a popular intercropping system of pigeonpea + groundnut. A field experiment was conducted during *kharif* 2003 and 2004 to evaluate the response of pigeonpea [*Cajanus cajan* (L.) Millsp.] + groundnut (*Arachis hypogaea* L.) intercropping system to FYM and S fertilization. Application of FYM at 5.0 t/ha significantly increased the yield and yield attributes, nutrient (NPK) uptake in pigeonpea and groundnut, system productivity (1.71 t/ha), net returns (Rs 18,287) and available S in soil after harvest (15.72 kg/ha). However, B: C ratio was higher with crop receiving no FYM. Intercropping failed to influence the yield attributes, yield and nutrient uptake in pigeonpea, however, system productivity, net income and B: C ratio was higher in pigeonpea + groundnut system. The available soil S after harvest of crop(s) was lower in pigeonpea + groundnut system (13.11 kg/ha) when compared with sole pigeonpea (17.06 kg/ha). Application of sulphur at 35 and 70 kg/ ha, being on par, recorded significant increase in yield and nutrient uptake in pigeonpea and groundnut, system productivity and total net income over no S. The available soil S after harvest of crop (s) was higher with 70 kg S/ha. The S use efficiency indices were higher at lower i.e. 35 kg S/ha. Among the sources of sulphur, cosavet recorded higher yield and yield attributes, nutrient uptake and S use efficiency. However, the highest soil available S at harvest (19.34 kg/ha) was recorded with elemental S applied at 70 kg/ ha, while the highest net income (Rs 20,431) and B: C ratio (2.0) were achieved with gypsum at 35 kg S/ha.

***Key words**:* Farmyard manure, Groundnut, Intercropping, Pigeonpea, Sulphur

Grain legumes are important source of protein in the diets of a large section of vegetarian population in the developing countries in general and India in particular. Even though India has the largest area under pulses in the world, the average productivity is low, and the production is not sufficient to meet the per caput requirement. Organic manures play vital role in improving fertility and productivity of soils, their use has been continuously declining in Indian agriculture due to number of reasons. Intercropping is an intensive land use system with an objective to utilize the space between the rows of main or base crop and to produce more produce/unit area. Pigeonpea [*Cajanus cajan* (L.) Millsp.], a deep rooted crop with slow initial growth rate between 45 and 60 days after sowing is well suited for intercropping. The space between the rows could be effectively utilized by growing a short duration crop, which may generate an additional income without adversely affecting the yield of pigeonpea. Groundnut (*Arachis hypogaea* L.) being an efficient cover crop fits well in this system.

The development of modern agricultural technology has attracted the attention to sulphur nutrition owing to adoption of high-yielding varieties, intensive cropping systems, use of high analysis fertilizers, shifting of cropping patterns to S loving crops including oilseeds, legumes and vegetables, and decreased use of organic manures (Jaggi, 2004). Sulphur plays important role in the formation of S containing amino acids. There is large number of sulphur sources available in the country and their efficiency need to be evaluated. In view of the meager information available on sulphur nutrition in a popular intercropping system of pigeonpea + groundnut, the present study was undertaken to evaluate the effect of sources and rates of sulphur in this cropping system.

MATERIALS AND METHODS

A field experiment was conducted at Indian Agricultural Research Institute, New Delhi (28°38'N latitude,

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77°11'E longitude and 228.16 m above MSL) on a sandy loam soil during *kharif* of 2003 and 2004. The soil of the experimental site had a pH of 8.1, containing 0.37% organic carbon, 864.5 kg/ha total N, 8.30 kg/ha available P and 176.0 kg/ha available K and 12.0 kg/ha available S. The total rainfall received during the crop season was 440.1 and 320.8 mm during 2003 and 2004, respectively. The treatments comprised two rates of FYM (0 and 5 t FYM/ha) and two cropping systems (sole pigeonpea and pigeonpea + groundnut) as main plots and seven S treatments (control, elemental sulphur at 35 and 70 kg S/ha, gypsum at 35 kg and 70 kg S/ha, cosavet at 35 and S 70 kg/ha) as sub-plots replicated thrice in a split plot design. Pigeonpea 'Pusa 855' was grown in additive series intercropping with groundnut 'M 522' keeping the seed rates of 15 and 100 kg/ha, respectively. A spacing of 75 cm x 25 cm was adopted for pigeonpea and between two rows of pigeonpea; two rows of groundnut were sown. Sowing of the crops was done on 18 June in 2003 and 23 June in 2004. Groundnut was harvested in October whereas pigeonpea was harvested in December in both the years. The recommended dose of N (20 kg/ha) and P (17.2 kg/ha) through di-ammonium phosphate and urea was drilled in bands 8 to 10 cm below the surface before sowing of crops. Sulphur was applied as per treatments two weeks before sowing and incorporated in the soil. Cosavet, gypsum and elemental sulphur contained 80%, 18.6%, and 85% sulphur, respectively. The sulphur content in soil and plant was determined by turbidimetric method (Tabatabai and Bremner, 1970). The net return was computed using the prevailing market price of produce and cost of cultivation. Various S use efficiencies viz., agronomic S use efficiency, ASUE (kg grain/kg S applied), physiological S use efficiency, PSUE (kg grain/kg S uptake), apparent S recovery, ASR (%), and S harvest index, SHI (%) were workedout using standard procedures.

RESULTS AND DISCUSSION

Yield attributes and yield

Application of 5 t FYM/ha markedly improved the yield and yield attributes of both pigeonpea and groundnut over no FYM (Table 1). The yield of pigeonpea increased by FYM application to the tune 5.95 and 7.11 %, while the corresponding values for groundnut were 25.00 and 27.28 % in 2003 and 2004, respectively. The improvement in the development of yield attributes in both the crops with FYM was finally reflected in the yield. The intercropping of pigeonpea with groundnut, however, did not affect the yield attributes and yield of pigeonpea. This might be ascribed to differential growth habits of pigeonpea and groundnut, and both the crops could grow in a non-competitive environment. Gupta and Rai (1999) also observed that pigeonpea growth and development was not affected by groundnut intercropping. Over the 3 sources, application of 35 and 70 kg S/ha both being on par significantly increased the yield attributes and yield of pigeonpea and groundnut over no sulphur. The yield increment in pigeonpea due to application of 35 and 70 kg S/ha being 14.11 and 15.64% in 2003 and 16.11 and 19.02 % in 2004, respectively when compared with no sulphur. The corresponding values in groundnut were 38.25 and 38.79% in 2003 and 41.94 and 44.68% in 2004, respectively. Improvement in yield might have resulted from favourable influence of S on the growth attributes viz., plant height, branching and LAI and efficient and greater partitioning of metabolites and adequate translocation of nutrients to developing reproductive structures (Singh and Ali, 1994). Among the sources, cosavet markedly improved the yield attributes (pods/plant and grains/pod) and yield of both pigeonpea and groundnut when compared with elemental S and gypsum. This might be attributed to better growth and development of plant owing to higher biological availability of S with cosavet having smaller particle size leading to faster conversion of S to SO_4^{-2}, which is available form of S to plants.

The total system productivity in terms of pigeonpea yield equivalent significantly increased with application of 5 t FYM/ha (Table 2). Pigeonpea intercropped with groundnut recorded 14.86% higher system productivity over sole pigeonpea. Higher productivity in intercropping could be achieved because of additional groundnut yield without any effect of intercropping on yield of Pigeonpea. All the three sources of S at both the rates had higher productivity over no S. The differences between 35 and 70 kg S/ha were not marked among the various sources of S. Cosavet at 70 kg S/ha recorded the highest productivity among S treatments, except cosavet at 35 kg S/ha.

Nutrient uptake

Application of FYM at 5 t/ha significantly increased the total uptake (grain + non-grain) of N, P and S in both pigeonpea and groundnut (Table 3). The increase in nutrient uptake by FYM could be attributed to higher yield coupled with slight improvement in nutrient content (data not reported here) in grain and straw. The organic acids produced from decomposition of organic matter might partly be responsible for quick release of nutrients from native pool, resulting greater availability of nutrients to growing plants. Cropping system did not exhibit marked variation in total N, P and S uptake in pigeonpea. This could be attributed to similar conditions available to pigeonpea for growth and development in both the cropping systems. Further, since the nutrient uptake is a function of yield and its nutrient content, almost similar yields

Table 1. Effect of FYM, cropping system, source and levels of sulphur on yield attributes and yield of pigeonpea and groundnut (Pooled data of 2 years)

Treatment	Pigeonpea								Groundnut							
	Pods/plant		Grains/pod		Grain yield (t/ha)		Stalk yield (t/ha)		Pods/plant		Kernels/pod		Pod yield (t/ha)		Haulm yield (t/ha)	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
FYM (t/ha)																
0	157.4	152.3	3.50	3.45	1.46	1.38	8.59	7.87	9.92	7.77	1.47	1.36	0.43	0.40	1.96	1.74
5	161.1	156.0	3.63	3.58	1.55	1.48	9.00	8.27	10.13	9.98	1.55	1.44	0.54	0.51	2.20	2.03
SEm ±	0.7	1.0	0.02	0.01	0.02	0.01	0.05	0.04	0.04	0.03	0.01	0.008	0.002	0.002	0.02	0.02
CD (P=0.05)	2.2	3.1	0.66	0.04	0.07	0.02	0.16	0.12	0.13	0.09	0.03	0.02	0.006	0.006	0.07	0.05
Cropping system																
Sole pigeonpea	159.9	154.8	3.57	3.51	1.51	1.43	8.73	8.07								
Pigeonpea + groundnut	158.6	153.5	3.55	3.51	1.50	1.42	8.76	8.05								
SEm ±	0.7	1.0	0.02	0.01	0.02	0.01	0.05	0.04								
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS								
Source and level of S (kg/ha)																
0	141.0	135.9	3.10	3.05	1.33	1.24	7.27	6.55	6.33	5.68	1.40	1.34	0.37	0.33	1.62	1.40
Elemental sulphur @ 35	156.9	150.8	3.57	3.47	1.44	1.33	8.60	7.86	8.51	8.06	1.51	1.44	0.47	0.43	2.03	1.82
Elemental sulphur @ 70	161.9	156.8	3.60	3.57	1.46	1.35	9.88	8.25	9.06	8.40	1.52	1.45	0.47	0.44	2.12	1.89
Gypsum @ 35	158.8	152.7	3.60	3.54	1.46	1.38	8.79	8.07	8.81	8.21	1.51	1.44	0.47	0.43	2.06	1.83
Gypsum @ 70	163.2	159.1	3.66	3.63	1.48	1.42	9.18	8.45	9.13	8.54	1.53	1.46	0.47	0.44	2.13	1.91
Cosavet @ 35	165.4	162.4	3.70	3.66	1.66	1.60	9.27	8.55	12.31	11.66	1.55	1.51	0.58	0.54	2.40	2.17
Cosavet @ 70	167.5	164.4	3.70	3.66	1.68	1.65	9.48	8.76	12.35	11.70	1.56	1.53	0.58	0.55	2.41	2.21
SEm ±	2.9	2.9	0.04	0.04	0.03	0.03	0.18	0.17	0.22	0.20	0.03	0.03	0.11	0.12	0.05	0.04
CD (P=0.05)	8.4	8.3	0.12	0.14	0.09	0.09	0.52	0.48	0.63	0.57	0.10	0.09	0.31	0.35	0.15	0.13

and nutrient content in pigeonpea in both the cropping systems led to identical values of N, P and S uptake (Giri, 1990). Application of 35 and 70 kg S/ha through all the sources significantly increased total uptake of N, P and S in pigeonpea and groundnut over no sulphur. This increase in nutrient uptake could be attributed to increased availability of S to plants, which in turn might have resulted in profuse shoot and root growth thereby activating greater absorption of N, P and S from the soil. The uptake of N, P and S in plant was also significantly affected by different S sources. Cosavet recorded significantly higher N, P and S uptake over elemental S and gypsum. The superiority of cosavet was mainly due to higher yield of both the crops in this treatment.

Sulphur use efficiencies

Over the sources, application of 35 kg S/ha recorded higher agronomic and physiological S use efficiency (ASUE and PSUE) and apparent S recovery (ASR) compared to its next dose of 70 kg S/ha in pigeonpea (Table 5). The declining rate of yield increases with 70 kg S/ha compared to 35 kg S/ha was responsible for lower ASUE at higher rates of S application. Similarly, decline in PSUE at 70 kg S/ha might be ascribed to greater increase in S uptake than increase in yield. Further, higher uptake of applied S at 35 kg/ha than at 70 kg/ha was responsible for higher values of ASR at 35 kg/ha. Among the sources of S, cosavet registered higher ASUE, PSUE and ASR followed by gypsum and elemental sulphur. This may be due to higher yield (in ASUE, PSUE) and better uptake (in ASR) of applied S through cosavet.

Application of FYM @ 5 t/ha recorded higher SHI in pigeonpea when compared with no FYM application (Table 5). Sole pigeonpea registered more SHI than pigeonpea + groundnut intercropping system. Highest SHI was recorded with no S and declined with successive higher rates of S application. Among the sources of S, cosavet recorded the highest SHI. Similar results were reported by Barman (2004) and Palsaniya and Ahlawat (2009).

Response studies

The response to applied S in sole pigeonpea was quadratic in nature with all the sources of

Table 2. Effect of FYM, cropping system, source and levels of sulphur on system productivity and economics of pigeonpea

Treatment	Pigeonpea equivalent yield (t/ha)		Cost of cultivation (Rs/ha)		Net return (Rs/ha)		B: C ratio (Rs)	
	2003	2004	2003	2004	2003	2004	2003	2004
FYM (t/ha)								
0	1.52	1.41	11,794	12,204	19,068	16,719	1.62	1.40
5	1.74	1.67	13,684	13,789	19,177	17,396	1.40	1.26
SEm ±	0.01	0.01						
CD (P=0.05)	0.03	0.03						
Cropping system								
Sole pigeonpea	1.51	1.44	12,249	12,634	14,939	12,736	1.22	1.01
Pigeonpea + groundnut	1.76	1.64	13,229	13,359	23,148	21,379	1.75	1.60
SEm ±	0.01	0.01						
CD (P=0.05)	0.03	0.03						
Source and level of S (kg/ha)								
0	1.50	1.39	9,072	9,177	15,620	15,139	1.72	1.65
Elemental sulphur @ 35	1.65	1.54	10,289	10,393	20,808	18,575	2.02	1.79
Elemental sulphur @ 70	1.72	1.59	11,279	11,858	20,464	18,099	1.81	1.53
Gypsum @ 35	1.67	1.57	10,077	10,356	21,365	19,498	2.12	1.88
Gypsum @ 70	1.81	1.64	10,855	11,378	21,229	18,519	1.96	1.63
Cosavet @ 35	1.89	1.77	15,634	15,739	19,447	18,232	1.24	1.16
Cosavet @ 70	1.96	1.81	21,970	22,074	14,225	12,484	0.65	0.56
SEm ±	0.03	0.03						
CD (P=0.05)	0.08	0.08						

in both the seasons (Table 4). The economic optimum dose of S was the lowest (32.07 and 29.76 kg/ha) in cosavet followed by elemental sulphur (32.87 and 39.62 kg/ha) and gypsum (40.66 and 41.73 kg/ha) in 2003 and 2004, respectively. The response at optimum dose of sulphur was greater with gypsum when compared with other two sources. However, the response/kg of applied S was the maximum with cosavet. The lower economic optimum dose and higher response with each unit of applied S through cosavet could be attributed to its greater availability to crop plants as described earlier. Based on pigeonpea equivalent in pigeonpea + groundnut intercropping system, there was quadratic response in case of elemental sulphur and cosavet, whereas it was linear with gypsum. The economic optimum dose of S applied through elemental sulphur and cosavet in intercropping was higher than those of sole pigeonpea. It is obvious that both the crops in intercropping system required more S for their growth and development. The response and the response/kg of applied S were also higher in intercropping system than those of sole pigeonpea. This behavior could be described due to higher productivity/unit of area in intercropping system.

Available sulphur in soil

Availability of S in soil was significantly increased with the application of FYM. This might be ascribed to adsorption of part of applied S on organic matter and thereby reducing the leaching losses of sulphur. The pigeonpea + groundnut intercropping system resulted in significantly lower available S in soil over sole pigeonpea after the harvest of crops (Table 3). This is obvious that both the crops removed more of S from the soil than pigeonpea alone. The increasing level of S fertilization up to 70 kg/ha significantly improved available S content in soil after the harvest of crops. The increase in available S content in soil after harvest of crops might be attributed to the fact that only a small fraction of the applied S was utilized by the crops.

Application of S through cosavet recorded significantly lower available S content in soil as compared with gypsum and elemental sulphur. This might be attributed to the fact that cosavet produced relatively more dry matter production leading to removal of higher amount of S from the soil in comparison to other sources of sulphur.

Economics

Application of FYM at 5 t/ha gave higher net return than no FYM owing to increased yield of both the crops (Table 2). On the contrary, crop without FYM recorded higher B:C ratio. The value of increased yield not only nullified the increased cost of FYM application, but also gave additional monetary returns. The higher cost of production in case of FYM application was responsible for lower B: C ratio in this treatment. Pigeonpea + groundnut intercropping recorded higher net return and B: C ratio

Table 3. Effect of FYM, cropping system, source and levels of S application on nutrient uptake (kg/ha), economics and change in soil S content

Treatment	Pigeonpea						Groundnut						Soil S content after harvest (kg/ha)	
	N		P		S		N		P		S			
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
FYM (t/ha)														
0	161.3	143.5	14.69	13.23	17.43	15.22	39.50	35.32	4.57	3.90	3.38	2.96	13.44	15.48
5	172.8	154.6	15.80	14.30	18.58	16.39	50.65	46.31	6.00	5.32	4.20	3.76	14.61	16.82
SEm ±	1.1	0.8	0.10	0.10	0.11	0.08	0.32	0.30	0.06	0.03	0.03	0.03	0.09	0.15
CD (P=0.05)	3.3	2.9	0.32	0.30	0.33	0.26	0.97	0.89	0.18	0.10	0.10	0.09	0.28	0.45
Cropping system														
Sole pigeonpea	165.5	147.9	15.10	13.67	17.88	15.75							16.04	18.08
Pigeonpea + groundnut	168.5	150.1	15.40	13.91	18.13	15.84	45.07	40.81	5.28	4.61	3.79	3.36	12.01	14.22
SEm ±	1.1	0.8	0.10	0.10	0.11	0.08							0.09	0.15
CD (P=0.05)	NS	NS	NS	NS	NS	NS							0.28	0.45
Source and level of S (kg/ha)														
0	127.1	112.4	12.12	10.82	14.48	12.44	30.30	26.57	3.67	3.11	2.67	2.26	10.20	12.17
Elemental sulphur @ 35	166.2	143.1	14.55	13.02	17.33	15.21	43.99	37.34	5.12	4.48	3.68	3.22	13.27	15.63
Elemental sulphur @ 70	168.7	150.6	15.33	13.89	18.18	16.07	44.02	39.72	5.18	4.54	3.78	3.34	18.34	20.40
Gypsum @ 35	166.1	149.7	15.28	13.81	18.31	15.78	43.69	39.75	5.14	4.49	3.70	3.28	11.74	13.80
Gypsum @ 70	171.2	153.9	15.63	14.10	18.43	16.47	45.20	40.86	5.27	4.62	3.82	3.38	16.69	18.70
Cosavet @ 35	181.0	164.4	16.52	14.98	19.31	16.99	53.73	49.48	6.27	5.59	4.41	3.98	11.42	13.61
Cosavet @ 70	183.4	169.0	17.76	15.75	20.00	17.57	54.43	49.97	6.33	5.65	4.50	4.08	16.54	18.44
SEm ±	3.4	2.9	0.27	0.29	0.37	0.31	0.94	0.88	0.14	0.09	0.09	0.08	0.40	0.44
CD (P=0.05)	9.8	8.3	0.80	0.83	1.07	0.91	2.68	2.50	0.39	0.27	0.25	0.24	1.16	1.28

Initial S content in soil (kg/ha): 12.00 in both the years

Table 4. Response and optimum dose of sulphur for the sole pigeonpea and its intercropping system

Cropping system	Source	Response equation		Economic optimum dose of S (kg/ha)		Response at optimum dose of S (t/ha)		Response/kg of S (kg)	
		2003	2004	2003	2004	2003	2004	2003	2004
Sole pigeonpea	(a) Elemental S	$13.34+0.0463x-0.0004x^2$	$13.09+0.0668x-0.0006x^2$	32.87	39.62	0.56	0. 54	17.06	13.52
	(b) Gypsum	$13.34+0.0476x-0.0004x^2$	$12.95+0.0649x-0.0006x^2$	40.66	41.73	0.58	0. 58	14.14	13.80
	(c) Cosavet	$13.34+0.0778x-0.0007x^2$	$12.85+0.0790x-0.0007x^2$	32.07	29.76	0. 56	0. 56	17.43	18.64
Pigeonpea + groundnut	(a) Elemental S	$15.01+0.0464x-0.0002x^2$	$14.74+0.0425x-0.0002x^2$	67.05	58.53	1.26	1.16	18.74	19.75
	(b) Gypsum	$13.5117+0.0216x$	$12.55+0.0257x$						
	(c) Cosavet	$15.01+0.0979x-0.0003x^2$	$14.47+0.0940x-0.0004x^2$	41.35	33.33	0.90	0.76	21.86	22.71

Table 5. Effect of FYM, cropping system and S fertilization on S-use efficiencies in pigeonpea (mean of 2003 and 2004)

Treatment	ASUE	PSUE	ASR	SHI
FYM (t/ha)				
0				17.7
5				18.1
Cropping system				
Sole pigeonpea				17.9
Pigeonpea + groundnut				17.9
Source and level of S (kg/ha)				
0				18.7
Elemental sulphur @ 35	2.8	35.2	8.7	17.4
Elemental sulphur @ 70	1.7	33.4	5.7	17.2
Gypsum @ 35	3.9	38.3	11.2	17.2
Gypsum @ 70	2.4	41.6	5.7	17.4
Cosavet @ 35	9.4	74.1	14.6	18.9
Cosavet @ 70	5.4	70.5	7.7	18.6

ASUE, Agronomic S use efficiency (kg grain/kg S applied); PSUE, physiological S use efficiency (kg grain/kg S uptake); ASR, Apparent S recovery (%); SHI, sulphur harvest index (%).

over sole pigeonpea (Table 2). The additional yield of groundnut with similar yields of pigeonpea in sole and intercropping resulted in higher net return in pigeonpea + groundnut cropping system when compared with sole pigeonpea. The net return and B: C ratio increased with application of sulphur through elemental sulphur and gypsum at both the rates (35 and 70 kg/ha). However, the net return and B:C ratio showed decreasing trend with higher rate of S (70 kg/ha) because of higher cost of S without proportionate increase in economic yield. Cosavet at 35 kg S/ha though recorded higher net returns than no sulphur, but its higher rate (70 kg S/ha) fetched lower net returns than no sulphur because of its higher cost.

The present study revealed that pigeonpea could be successfully intercropped with groundnut for higher total productivity. In soils analyzing low or even medium in S status, application of 35 kg S/ha through gypsum could enhance the system productivity substantially. Application of FYM though increased the yield of crops and the system productivity, but its cost nullified the increase in productivity resulting marginally higher net return and lower B:C ratio.

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