Effect of different levels of phosphorus and sulphur on yield and quality of green gram (*Vigna radiata* L) under teak (*Tectona grandis* L)-based agroforestry system

JAIVEER SINGH DHEWA, SAMEER DANIEL and SULOCHANA*

Department of Agroforestry, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad 211007 Uttar Pradesh, India
***Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology Udaipur 313001 Rajasthan, India**
Email for correspondence: jaiveerd01@gmail.com

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ABSTRACT

Application of phosphorus and elemental sulphur is an important tool to obtain high yield of green gram (*Vigna radiata* L) under teak-based agroforestry system in Kharif season. The overall goal of the present experiment was to assess the impact of phosphorus and elemental sulphur application on green gram yield under teak-based agroforestry system in eastern Uttar Pradesh. Green gram was grown in an alley cropping system which integrated trees with grain crop. Application of phosphorus at 65 kg/ha gave the best results in terms of green gram yield attributes like pod length, number of pods per plant, number of grains per pod, test weight, grain yield, haulm yield, biological yield, harvest index and protein content in grain and haulm, protein yield in grain and haulm and total protein yield as compared to the phosphorus at 45 and 25 kg/ha under both conditions of open and teak-based agroforestry system. Application of sulphur (50 kg/ha) also gave higher yield like pod length, number of pods per plant, number of grains per pod, test weight, grain yield, haulm yield, biological yield, harvest index and protein content in grain and haulm, protein yield by grain and haulm and total protein yield as compared to sulphur applied @ 35 and 20 kg/ha in open and teak-based agroforestry system.

Keywords: Phosphorus; sulphur; teak; agroforestry system; yield,; quality; green gram

INTRODUCTION

India is the largest producer (25% of global production), consumer (27% of world consumption) and importer (14%) of pulses in the world. Pulses account for around 20 per cent of the area under food grains and contribute around 7-10 per cent of the total food grain production in the country (Mohanty and Satyasai 2015).

Green gram (*Vigna radiata* L) is cultivated in tropical and subtropical regions of India as a summer (Kharif) rainfed crop (Anila Kumar et al 2010). It contains 24.3 per cent protein and is fairly rich in carbohydrates and also contains small amount of riboflavin and thiamine. It is also rich in phosphorus and iron (Patel et al 2013). It also contains high quality of lysine (4600 mg/g N) and tryptophan (60 mg/g N). The sprouted seeds of mung bean are rich in ascorbic acid (vitamin C), riboflavin and thiamine (Choudhary 2010)

Alley cropping is a type of agroforestry system in which seasonal crops are grown in between the rows of trees. There are several types of alley cropping systems depending upon different associations of trees and crops (Torquebiau 2000). Teak (*Tectona grandis* L) is the most important timber tree in India especially for furniture making. It can be grown in all parts of the country except dry western zone. Mostly it prefers a deep, fertile and well-drained deep alluvial soil. The sandy soil is considered to be the best soil texture for this tree. It fails to grow in the soil with pH below 6.5.

The phosphorus requirements of plants vary depending upon the nutrient content of the soil (Bose

and Som 1986). Phosphorus shortage restricts the plant growth and plant remains immature. Common diagnostic properties of phosphorus deficiency are a darker green leaf colour due to higher chlorophyll content (often with red pigments from anthocyanins), reduced leaf extension and a higher root-shoot ratio since root growth is much less affected by phosphorus deficiency than shoot growth (Wild 1988, Marschner 1995). A high phosphorus supply is needed for nodulation of legumes and hence phosphorus deficiency can also seriously reduce biological nitrogen fixation (Marschner 1995). Agroforestry techniques can help to overcome some of these constraints (Buresh 1999).

The deficiency of S, one of the foremost important nutrients after N, P and K (McGrath et al 1996, Walker and Dawson 2003) is a major constraint to sustainable production of oilseed crops in many parts of the world including India (Saha et al 2001, Biswas et al 2003, Grant et al 2003, Malhi and Gill 2007). About 41 per cent of soils in India are deficient in S and yield of oilseed crops is adversely affected (Lakkineni and Abrol 1992). Deficiency of S adversely affects flowering, fruiting and cupping of leaves, causes reddening of stems, petioles and stunted growth of oilseed crops (Salwa et al 2010, Saha et al 2001). The requirement of S is higher in oilseed crops due to its critical role in synthesis of oil and production of bold grains (Havlin et al 1999, Malhi and Gill 2007). Therefore the sustainable production of oilseed crops (ie sesame) in acidic soils requires knowledge of the site-specific rates of liming and S fertilization (Tiwari et al 2000, Singh et al 2011).

Research information on the conjunctive rate of P and S application under site-specific conditions of growing green gram are not widely available especially in an alley cropping system where pulse crops are grown in between the rows of fruit trees. Yet this information is necessary to effectively sustain the productivity of the green gram while also alleviating S deficiency. Therefore the present studies were conducted to assess the impact of application of P and S on yield and quality of green gram under teak (*Tectona grandis* L)-based agroforestry system and open condition of Allahabad, Uttar Pradesh.

MATERIAL and METHODS

Experimental site

The field experiment was conducted during Kharif season of 2014 and 2015 at the forest nursery of School of Forestry and Environment, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad, Uttar Pradesh.

Soil analysis

Soil samples were collected randomly from 0-30 cm depth within each 10 m interval at the three physiographic positions of the experimental field prior to sowing and after harvest of the crop. Soil samples were air-dried, gently ground and passed through 2 mm sieve. The plow layer contained 245.08 kg/ha alkaline permanganate oxidizable N (Subbiah and Asija 1956), 25.30 kg/ha of available P extracted by 0.5 M $NaHCO_3$ at pH 8.5 (Olsen and Sommers 1982), 128.60 kg/ha of available K as determined by the flame photometer method with 1N KCl and titrating sued 0.05N NaOH (McLean 1982), 13 kg/ha of S as determined by the turbidity method (Chesnin and Yein 1950), soil organic carbon (SOC) concentration of 0.31 per cent and converted to SOC stock (Anon 2000), soil pH (7.45) as determined in 1:2 (soil: water) extract of the soil using deionized water and electrical conductivity (EC) 0.034 dS/m at 25°C in 1:2 (soil:water) suspension using 0.01M potassium chloride solution (van Reeuwijk 2002).

Treatment details and field layout

The field experiment was laid out in factorial randomized block design with three replications. The experiment comprised 9 treatment combinations consisting of three levels of phosphorus (25, 45 and 65 kg/ha) and S (20, 35 and 50 kg/ha). Green gram variety Samrat was grown within the alleys of 12 year old teak (*Tectona graindis* L) plantation. The teak trees were planted at a spacing of 9 x 3 m. Green gram was sown at 30 cm between the rows and 10 cm spacing within the plants between the teak trees. There were a total of 10 rows of green gram within the alley of two rows of teak. The gross and net plot size was 3 x 4 m and 2.10 x 3 m respectively. The distance between the teak and green gram row was 1 m on both sides. The crop was also grown in open condition with same spacing and gross or net plot size.

Cultural practices and observations

Phosphorus and elemental sulphur were applied as per treatments 30 and 15 days before sowing respectively. Phosphorus (25, 45 and 65 kg/ha) and S (20, 35 and 50 kg/ha) were drilled at a depth of 5 cm as single super phosphate and elemental sulphur respectively. The fertilizer was drilled in furrows at 5 cm below the seedling depth before sowing. Green

gram was seeded at the recommended seed rate of 15 kg /ha and at 2.5 cm soil depth. The seeds were covered with the soil from the other side of furrow. Fifteen days after sowing (DAS) thinning was done to maintain the desired plant population. Periodic hand weeding was done as and when needed. Green gram was harvested from each plot when 80 per cent of pods turned brownish-yellow and started drying. The border rows were harvested first and kept aside and the yield was measured by manually harvesting the net plot area. Grain and stalk yields were recorded after proper sun-drying and tagged in bundles. Each bundle was weighed, threshed and cleaned separately and seed yield per plot was calculated from net plot. Grain and stock yields were recorded separately. Moisture in the seed was 18 per cent at the time of harvesting. Randomly selected ten plants were taken from each plot for agronomic observations of yield and yield parameters. Test weight of 1000 seeds from each plot was recorded. Protein content in seed was estimated by multiplying the N content (Nelson and Sommers 1980) in seed with the factor 6.25 as suggested by (Anon 1990). Protein yield was calculated by multiplying the estimated protein with the seed yield.

The Microsoft Excel was used as a statistical software package for analyzing the data for the analysis of variance and other statistical parameters (McCullough and Wilson 2005). Critical difference (CD) values at 5 per cent level of significance were used to determine the significance of differences between mean values of treatments. The standard level of significance used to justify a claim of a statistically significant effect was 0.05 (Draper and smith 1998).

RESULTS and DISCUSSION

Effect of phosphorus

Significantly higher pooled values of yield and quality parameters in 2014 and 2015 under shade (teak) were obtained with the phosphorus application of 65 kg/ha in comparison to 45 and 25 kg/ha. In three levels of P the pod length was 7.81, 6.70 and 5.13 cm, number of pods/plant 22.39, 19.22 and 14.69, number of grains/pod 6.47, 5.57 and 4.26, test weight 26.10, 22.34 and 17.09 g, grain yield 606.6, 495.2 and 369.1 kg/ha, haulm yield 1630.57, 1409.07 and 1111.99 kg/ha, biological yield 2237.23, 1904.23 and 1481.16 kg/ha and harvest index 27.28, 26.12 and 24.64 per cent respectively (Table1). Under quality parameters (Table 2) protein content in grains was 14.92, 12.49 and 9.54 per cent, protein content in haulm 8.68, 7.41 and 5.66 per cent, total protein content 23.56, 19.91 and 15.22 per cent, protein yield by grain 104.9, 80.66 and 46.64 kg/ha, protein yield by haulm 143.0, 107.2 and 65.2 kg/ha and total protein yield 234.23, 170.24 and 101.49 kg/ha in 65, 45 and 25 kg/ha P respectively.

The data show that significantly higher pooled values of yield and quality under open condition were obtained with the phosphorus application @ 65 kg/ha in comparison to 45 kg/ha and 25 kg/ha where the pod length was 10.39, 8.89 and 6.78 cm, number of pods/plant 27.43, 23.48 and 17.94, number of grains/pod 11.03, 9.42 and 7.20, test weight (39.06, 33.36 and 25.53 g, grain yield 1124.4, 956.28 and 731.09 kg/ha, haulm yield 3587.22, 3087.66 and 2394.31 kg/ha, biological yield 4711.68, 4043.93 and 3125.42 kg/ha and harvest index 23.91, 23.70 and 23.42 per cent respectively (Table 1). Under quality parameters (Table 2) the protein content in grains was 23.09, 19.73 and 15.10 per cent, protein content in haulm 10.13, 8.66 and 6.63 per cent, total protein content 33.22, 28.40 and 21.73 per cent, protein yield by grain 262.59, 193.39 and 113.49 kg/ha, protein yield by haulm 368.5, 275.3 and 163.6 kg/ha and total protein yield of green gram 631.1, 468.8 and 277.1 kg/ha in 65, 45 and 25 kg/ha P respectively. Similar results were found by Prasad et al (2014), Patil et al (2011), Parvez et al (2013), Dhewa et al (2015) and Dhewa et al (2017). In general the overall increase in growth of summer mung bean with P application can be ascribed to its pivotal role in several physiological and biochemical processes necessary for crop growth and development. Among nutrients P is the most important for exploiting genetic potentials of the crop/variety (Havlin et al 2008). Reduced plant height in agroforestry system compared to sole crop could be attributed to reduction in cell turgidity as a result of stress imposed due to competition for water which led to decrease in cell elongation and decreased plant height. The observations of the present studies are in line with those of Kramer (1959) who observed reduced cell elongation due to reduced cell turgidity which decreased not only the size of the plants but also the yield.

Effect of sulphur

Significantly higher pooled values of yield and quality parameters in 2014 and 2015 under shade (teak) were obtained with the sulphur application of 50 kg/ha in comparison to sulphur 35 and 20 kg/ha as the pod length was 6.93, 6.49and 6.22 cm, number of pods/plant 19.89, 18.58 and 17.83, number of grains/pod 5.77, 5.37 and 5.16, test weight 23.16, 21.62 and 20.76, grain

Table 1. Effect of phosphorus (P) and sulphur (S) levels on yield and yield attributes of Kharif green gram (pooled data of 2014 and 2015)

Treatment	Yield and yield attributes of green gram															
	Under shade			Under open			Under shade			Under open			Under shade		Under open	
	PL	NP	NG	PL	NP	NG	TW	GY	HY	TW	GY	HY	BY	HI	BY	HI
P (kg/ha)																
25	5.13	14.69	4.26	6.78	17.94	7.20	17.09	369.1	1111.99	25.53	731.09	2394.31	1481.16	24.64	3125.42	23.42
45	6.70	19.22	5.57	8.89	23.48	9.42	22.34	495.2	1409.07	33.36	956.28	3087.66	1904.23	26.12	4043.93	23.70
65	7.81	22.39	6.47	10.39	27.43	11.03	26.10	606.6	1630.57	39.06	1124.4	3587.22	2,237.23	27.28	4711.68	23.91
SEm±	0.107	0.319	0.089	0.15	0.38	0.16	0.37	6.22	44.61	0.54	13.85	50.32	48.15	0.558	63.46	0.099
$CD_{0.05}$	0.325	0.965	0.268	0.44	1.16	0.47	1.11	18.81	134.89	1.63	41.89	152.14	145.60	1.69	191.88	0.301
S (kg/ha)																
20	6.22	17.83	5.16	8.24	21.80	8.76	20.76	446.3	1309.16	31.00	887.9	2900.48	1755.49	25.26	3788.40	21.42
35	6.49	18.58	5.37	8.60	22.72	9.13	21.62	483.6	1382.60	32.33	925.3	2987.10	1866.21	26.09	3912.42	22.70
50	6.93	19.89	5.77	9.21	24.33	9.77	23.16	541.1	1459.87	34.61	998.6	3181.61	2000.92	26.69	4180.21	23.20
SEm±	0.107	0.319	0.089	0.15	0.38	0.16	0.37	6.22	44.61	0.54	13.85	50.32	48.15	0.558	63.46	0.099
$CD_{0.05}$	0.325	0.965	0.268	0.44	1.16	0.47	1.11	18.81	NS	1.63	41.89	152.14	145.60	NS	191.88	0.301

PL= Pod length (cm), NP= Number of pods/plant, NG= Number of grains/pod, TW= Test weight (g), GY= Grain yield (kg/ha), HY= Haulm yield (kg/ha), BY= Biological yield (kg/ha), HI= Harvest index, NS= Non-significant

Table 2. Effect of phosphorus (P) and sulphur (S) levels on protein content (%) and protein yield (kg/ha) of Kharif green gram (pooled data 2014 and 2015)

Treatment	Protein content (%)				Protein yield (kg/ha)				Total protein content (%) and yield (kg/ha)			
	Under shade		Under open		Under shade		Under open		Under shade		Under open	
	Grain	Haulm	Grain	Haulm	Grain	Haulm	Grain	Haulm	Content	Yield	Content	Yield
P (kg/ha)												
25	9.54	5.66	15.10	6.63	46.64	65.2	113.49	163.6	15.22	101.49	21.73	277.1
45	12.49	7.41	19.73	8.66	80.66	107.2	193.39	275.3	19.91	170.24	28.40	468.8
65	14.92	8.68	23.09	10.13	104.9	143.0	262.59	368.5	23.56	234.23	33.22	631.1
SEm±	0.207	0.124	0.32	0.141	3.73	4.87	6.679	10.10	0.288	6.02	0.46	16.73
$CD_{0.05}$	0.627	5.07	0.967	0.426	11.28	14.73	20.195	30.542	0.871	18.19	1.392	50.59
S (kg/ha)												
20	11.61	6.88	18.33	8.06	70.03	95.24	172.65	247.8	18.48	150.2	26.39	420.4
35	12.08	7.17	19.11	8.39	74.7	104.2	184.21	261.8	19.24	164.7	27.51	446.0
50	13.27	7.70	20.48	8.98	87.43	116.0	212.61	297.9	20.97	191.0	29.46	510.5
SEm±	0.207	0.124	0.32	0.141	3.73	4.87	6.679	10.10	0.288	6.02	0.46	16.73
$CD_{0.05}$	0.627	5.07	0.967	0.426	11.28	14.73	20.195	30.542	0.871	18.19	1.392	50.59

yield 541.1, 483.6 and 446.3 kg/ha, haulm yield 1459.87, 1382.60 and 1309.16 kg/ha, biological yield 2000.92, 1866.21 and 1755.49 kg/ha and harvest index 26.69, 26.09 and 25.26 per cent respectively (Table 1). Under quality parameters (Table 2) protein content in grains was 14.92, 12.49 and 9.54 per cent, protein content in haulm 8.68, 7.41 and 5.66 per cent, total protein content 23.56, 19.91 and 15.22 per cent, protein yield by grain 104.9, 80.66 and 46.64 kg/ha, protein yield by haulm 143.0, 107.2 and 65.2 kg/ha and total protein yield of green gram 234.23, 170.24 and 101.49 kg/ha respectively in three levels of S.

The data show that significantly higher pooled values of yield and quality under open condition were obtained with the sulphur application @ 50 kg/ha in comparison to 35 and 20 kg/ha where pod length was 9.21, 8.60 and 8.24 cm, number of pods/plant 24.33, 22.72 and 21.80, number of grains/pod 9.77, 9.13 and 8.76, test weight 34.61, 32.33 and 31.00, grain yield 998.6, 925.3 and 887.9 kg/ha, haulm yield 3181.61, 2987.10 and 2900.48 kg/ha, biological yield 4180.21, 3912.42 and 3788.40 kg/ha and harvest index 23.20 vs 22.70 and 21.42 per cent respectively (Table 1). Under quality parameters (Table 2) protein content in grain was 23.09, 19.73 and 15.10 per cent, protein content in haulm 10.13, 8.66 and 6.63 per cent, total protein content 33.22, 28.40 and 21.73 per cent, protein yield by grain 262.59, 193.39 and 113.49 kg/ha, protein yield by haulm 368.5, 275.3 and 163.6 kg/ha and total protein yield of green gram 631.1, 468.8 and 277.1 kg/ha respectively. The positive role of S is in formation of sulphalhydral group helping in building disulfide bond between the cysteine residues via oxidation and thus maintaining the protein structure (Leustek and Saito 1999).

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