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Root Growth and Yield of Greengram (*Vigna radiata* (L.) Wilczek) as influenced by Increased Plant Density and Nutrient Management

[1]K. Sathyamoorthi, [2]M. Mohamed Amanullah, [1]E. Somasundaram, [2]S. Pazhanivelan and [2]K. Vaiyapuri

[1]Coconut Research Station, Aliyarnagar, 642 101 Tamil Nadu Agricultural University, India.
[2]Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore- 641 003, Tamil Nadu, India.

Abstract: Field experiments were conducted during *kharif 2002*, *rabi* 2002 and *summer* 2003 at the College of Agricultural Engineering, Kumulur, Tiruchirappalli district of Tamil Nadu to study the effect of increased plant density and nutrient management on the root growth and yield of greengram. Three inter row spacings of 20 cm (S_1), 25 cm (S_2) and 30 cm (S_3) with a constant intra row spacing of 10 cm accommodating 5.0, 4.0 and 3.33 lakh plants ha^{-1} were tried in the main plot. The treatments tried in sub plot were recommended N and P (N_1), N_1 with foliar spraying of one per cent sulphate of potash (SOP) (N_2), N_1 with soil application of 25 kg K_2O ha^{-1} as muriate of potash (MOP) (N_3), 125 per cent N and P with foliar spraying of one per cent SOP (N_4), 150 per cent N and P with foliar spraying of one per cent SOP (N_5) and 50 per cent N and P with foliar spraying of two per cent Diammonium phosphate (DAP) and one per cent SOP (N_6). The treatments were fitted in a split plot design replicated thrice. The results of the experiments revealed that root length increased with increase in population from recommended level of 3.33 to 5.0 lakh plants ha^{-1} at all stages and seasons. Root volume was more with lesser population and it decreased with higher population at all stages and seasons. Functional root nodules were higher with recommended plant population of 3.33 lakh plants ha^{-1}. Among the fertilizer levels, application of 125 per cent NP with foliar sprays recorded higher root length, root volume and functional root nodules and was followed by 150 per cent NP with foliar sprays. Higher plant density favoured the grain and bhusa yield. In general, yield were better when applied with 125 per cent NP along with foliar sprays during *kharif* 2002 and summer 2003 and 150 per cent NP with foliar sprays during *rabi* 2002.

Key words: Greengram, increased plant density, fertilize levels, root growth, yield

INTRODUCTION

Pulses are the major sources of dietary protein in the vegetarian diet in our country. Besides being a rich source of protein, they maintain soil fertility through biological nitrogen fixation in soil and thus play a vital role in furthering sustainable agriculture[5]. The area under pulses in India is around 24.38 million hectares with a production of 14.52 million tonnes. Nearly 8 per cent of this area is occupied by greengram (*Vigna radiata),* which is the third important pulse crop of India in terms of area cultivated and production next to gram and pigeon pea. In Tamil Nadu, greengram is cultivated in an area of 1.83 lakh hectares with an annual production of 0.696 lakh tonnes[6]. The productivity of the crop is only 333 kg ha^{-1}. This low yield is attributed to several reasons viz, cultivated as rainfed crops, as intercrops in marginal lands, poor management practices and low yield potential of varieties. Nutrient and weed management practices play a major role in realizing the potential of a given variety along with other contributing factors. Availability of short duration greengram varieties with high yield potential and the possibility of raising them all through the year, offers now immense scope to increase the productivity[11].

To exploit the full genetic potentiality of any greengram variety, development of management technology would become atmost important. Under the use of improved crop management practices, greengram responded markedly to plant population level and mineral nutrition especially, when applied in balanced amount and by appropriate methods. Abdur Rahman Sarkar *et al.*[1] reported that greengram planted at a spacing of 30 x 10 cm significantly produced the highest seed yield. Sekhon *et al.*[16] reported that the summer greengram raised in loamy sand at 20 cm row spacing recorded 15 per cent higher yield over 30 cm

Corresponding Author: K. Sathyamoorthi, Professor, Coconut Research Station, Aliyarnagar, 642 101, Tamil Nadu Agricultural University, India.

row spacing. Khan *et al.*[7] reported that Phosphorus application significantly increased the yield of mungbean. Similarly, Chovatia *et al.*[2] reported that application of Phosphorus increased the seed yield upto 40 kg P_2O_5 ha^{-1}. Muhammad Ather Nadeem *et al.*[10] reported that higher seed yield of greengram was obtained at a fertilizer level of 30-60 kg N, P_2O_5 ha^{-1}. Pulses are among the crops which have relatively high requirement of S and are particularly sensitive to S deficiency[20].

Yield is a product of individual plant yield and number of plants per unit area. The number of plants is determined experimentally which gives an indication of maximum utilization of available resources. If these resource limitations are overcome through agronomic manipulations, there will be scope for increasing the plants per unit area, thereby increasing the yield without drastic reduction in individual plant yield. But, this hypothesis may not be true always to give the desired result. With increase in the number of plants, growth and yield may be reduced due to one or more limiting factors even though efforts are made to overcome resource limitations. With these ideas in view, an attempt was made to increase the yield of greengram by increasing the plant population and nutrient levels.

MATERIALS AND METHODS

Field experiments were conducted during *kharif 2002*, *rabi* 2002 and summer 2003 at the College of Agricultural Engineering, Kumulur, Tiruchirappalli district of Tamil Nadu to find out the effect of increased plant density and nutrient management through soil and foliage on the root growth and yield of greengram. The treatments were fitted in a split plot design replicated thrice. Three inter row spacings of 20 cm (S_1), 25 cm (S_2) and 30 cm (S_3) with a constant intra row spacing of 10 cm accommodating 5.0, 4.0 and 3.33 lakh plants ha^{-1} were tried in the main plot. The treatments tried in sub plot were recommended NP (N_1), N_1 with foliar spraying of one per cent SOP at 25 and 45 DAS (N_2), N_1 with soil application of 25 kg K_2O ha^{-1} as MOP (N_3), 125 per cent NP with foliar spraying of one per cent SOP at 25 and 45 DAS (N_4), 150 per cent NP with foliar spraying of one per cent SOP at 25 and 45 DAS (N_5) and 50 per cent NP with foliar spraying of two per cent DAP and one per cent SOP four times at ten days interval from 15 to 45 DAS (N_6). The treatments from N_1 to N_5 had a common two per cent DAP foliar spraying at 25 and 45 DAS. The soil of the experimental field was well drained red sandy loam classified taxonomically as Paralithic Ustropepts. The soil of the experimental fields were low in available nitrogen (208, 205 and 218 kg ha^{-1} in *kharif* 2002, *rabi* 2002 and summer 2003, respectively), medium in available phosphorus (17.7, 15.1 and 16.9 and kg ha^{-1} in *kharif* 2002, *rabi* 2002 and summer 2003, respectively) and potassium (226, 207 and 233 kg ha^{-1} in *kharif* 2002, *rabi* 2002 and summer 2003, respectively).

The greengram variety 'Vamban 1' which is recommended for general cultivation in this zone was selected for the study. Vamban 1 is a hybrid derivate of the cross S-8 x PIMS-3 which matures in 65 days of duration. The recommended fertilizer schedule for the crop of 25 kg N + 50 kg P_2O_5 ha^{-1} was followed for fertilizer treatments. Farmyard manure was applied @ 12.5 t ha^{-1} just before last harrowing and incorporated by harrowing. Nitrogen in the form of urea, phosphorus as super phosphate and potassium as MOP were applied basally as per the treatment schedule. Two per cent DAP and one per cent SOP solutions were prepared by soaking the required quantity of fertilizer in known volume of water for 12 hours and sufficient quantity of supernatant solutions were used for foliar spraying as per the treatment schedule. Seeds were treated with carbendazim @ 2 g kg^{-1} of seed as a prophylactic measure. After 24 hours of fungicide treatment, seeds were bio-inoculated with multistrain *Rhizobium, Phosphobacteria* each @ 600 g ha^{-1} and *Trichoderma* @ 4 kg^{-1} of seed as well as soil application of phosphobacteria mixed with 25 kg FYM for all the treatments. Seeds were dibbled @ 2 per hill adopting specific spacing as per the main plot treatment.

Root length was estimated using direct measurement at 30 DAS, 50 DAS and at harvest and expressed in cm. Root volume was measured using water displacement technique as suggested by Misra and Ahmed [8] at 30 and 50 DAS and expressed in cc $plant^{-1}$. Functional root nodules were counted in five plants selected from the sample rows at 30 DAS, 50 DAS and at harvest and expressed in number $plant^{-1}$. Dry weight of root samples were recorded and expressed in g $plant^{-1}$.

RESULTS AND DISCUSSION

Root Length: Roots were longer in green gram raised during *rabi 2002* and were followed by summer 2003 (Table 1). Generally, the root length increased significantly with increase in population at all the stages in all the three seasons.

Application of 125 per cent NP in combination with foliar spraying of two per cent DAP and one per cent SOP at 25 and 45 DAS (N_4) resulted in longer roots than the other nutrient management practices. It was followed by 150 per cent NP and foliar spraying of DAP and SOP (N_5) foliar application of SOP (N_2) and soil application of MOP (N_3).

Table 1: Root length (cm) of green gram as influenced by spacing and nutrient management

Treatment	*kharif* 2002			*rabi* 2002			summer 2002		
	30 DAS	50 DAS	Harvest	30 DAS	50 DAS	Harvest	30 DAS	50 DAS	Harvest
Spacing (S)									
S_1	19.08	35.47	37.73	20.38	36.37	50.77	17.16	33.66	48.96
S_2	18.46	30.70	36.19	19.44	30.92	43.18	15.18	29.09	42.09
S_3	16.80	26.04	35.12	18.72	27.20	37.98	13.33	24.72	35.12
SE_d	0.31	0.48	0.60	0.10	0.17	0.28	0.05	0.48	0.66
CD	0.88	1.35	1.66	0.21	0.46	0.78	0.10	1.35	1.82
Nutrient management (N)									
N_1	16.23	27.24	33.20	17.94	28.68	40.04	12.55	25.96	38.33
N_2	17.73	29.55	35.46	20.38	32.12	44.88	14.31	28.05	40.91
N_3	15.45	29.64	34.72	18.15	29.77	41.57	14.41	28.12	40.63
N_4	22.35	36.67	41.79	21.21	34.49	48.17	19.70	34.80	48.35
N_5	20.90	34.38	39.91	21.36	34.45	48.14	18.04	32.64	46.16
N_6	16.02	26.98	32.95	18.04	29.42	41.09	12.39	25.43	38.00
SE_d	0.26	0.41	0.92	0.31	0.44	0.70	0.36	0.41	1.10
CD	0.62	0.83	1.90	0.67	0.92	1.43	0.73	0.83	2.26
N at S									
SE_d	0.57	0.70	1.61	0.57	0.76	1.22	0.62	0.70	1.92
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS
S at N									
SE_d	0.47	0.81	1.58	0.52	0.72	1.14	0.57	0.81	1.87
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Root volume (cc) of green gram as influenced by spacing and nutrient management

Treatment	*kharif* 2002			*rabi* 2002			summer 2002		
	30 DAS	50 DAS	Harvest	30 DAS	50 DAS	Harvest	30 DAS	50 DAS	Harvest
Spacing (S)									
S_1	1.44	2.04	2.02	1.62	2.06	2.29	1.14	1.92	2.12
S_2	1.74	2.36	2.13	1.80	2.36	2.44	1.43	2.23	2.38
S_3	1.87	2.61	2.19	2.00	2.53	2.76	1.68	2.48	2.69
SE_d	0.03	0.03	0.05	0.01	0.01	0.02	0.01	0.03	0.04
CD	0.06	0.11	0.11	0.03	0.04	0.05	0.03	0.11	0.12
Nutrient management (N)									
N_1	1.49	2.06	2.18	1.68	2.17	2.67	1.18	1.98	2.61
N_2	1.62	2.29	2.32	1.87	2.44	2.94	1.41	2.19	2.89
N_3	1.43	2.25	2.27	1.68	2.28	2.71	1.37	2.14	2.85
N_4	2.06	2.79	2.73	1.99	2.63	3.16	1.87	2.66	3.34
N_5	1.93	2.63	2.61	1.89	2.60	3.14	1.68	2.49	3.13
N_6	1.49	2.06	2.17	1.62	2.25	2.68	1.18	2.14	2.59
SE_d	0.03	0.03	0.06	0.03	0.03	0.05	0.04	0.03	0.09
CD	0.06	0.05	0.12	0.06	0.08	0.09	0.07	0.06	0.17
N at S									
SE_d	0.05	0.05	0.11	0.05	0.05	0.08	0.06	0.05	0.15
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS
S at N									
SE_d	0.04	0.05	0.09	0.04	0.05	0.08	0.06	0.06	0.14
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS

Root Volume: As the growth stages advanced from 30 DAS to harvest the root volume also increased. Root volume was higher in *rabi 2002* and was followed by summer 2003 (Table 2). Contrary to the root length increase in population decreased the root volume significantly in all the three seasons and at all the stages of crop growth. Application of 125 per cent NP along with foliar spraying of DAP and SOP twice (N_4) produced higher root volume than in other nutrient management treatments at all the growth stages.

Root Dry Matter: The dry matter accumulation in root increased form 30 DAS to till harvest in all the three seasons. Both the plant population and nutrient management practices significantly influenced the root dry matter accumulation.

The plant spacing, with a population of 3.33 lakh plants ha^{-1} (S_3) recorded higher root dry matter accumulation than higher population treatments (Table 3). Root dry matter accumulation was the least with the highest population (S_1). The trend was similar at all the growth stages during all the three seasons.

Application of 125 per cent NP with foliar spraying of two per cent DAP and one per cent SOP twice (N_4) recorded significantly higher root dry matter at all the growth stages in all the three seasons. It was followed by application of 150 per cent NP with foliar spraying of DAP and SOP (N_5) which was very close to N_4 during *rabi 2002*.

Functional Root Nodules: Functional root nodules were more during summer 2003 than the other two seasons at all the growth stages. Lesser number of root nodules were recorded during *rabi 2002* at all the stages. The functional root nodules were found to be higher at 50 DAS.

The plant population levels influenced the functional root nodules at all the growth stages during all the three seasons. Green gram raised at 30x10 cm spacing (S_3) permitting 3.33 lakh plants ha^{-1} recorded more number of functional root nodules than raised at other two closer spacing permitting 4.0 and 5.0 lakh plants ha^{-1} (S_2 and S_1) during *kharif 2002* and summer 2003 (Table 4 & 5). But, during *rabi 2002*, 4.0 lakh plants ha^{-1}(S_2) registered higher functional root nodules but was very closely followed by 3.33 lakh plants ha^{-1} (S_3). Similar trend was noticed at 50 DAS.

Application of 125 per cent NP with foliar spraying of two per cent DAP and one per cent SOP at 25 and 45 DAS (N_4) recorded significantly higher number of functional root nodules at all the stages of observation. It was followed by the application of 150 per cent recommended NP along with foliar spraying of DAP and SOP (N_5).

Functional root nodules were significantly influenced by the interaction effect of spacing (S) and nutrient management practices (N) at all stages during the three seasons of experimentation. More number of root nodules sere recorded in green gram raised at spacing of 30x10 cm with application of 125 per cent recommended NP with foliar spraying of two per cent DAP and one per cent SOP at 25 and 45 DAS (S_3N_4) at all growth stages during *kharif 2002* and summer 2003. The picture was entirely different during *rabi 2002*, where the higher population level of 4.0 lakh plants ha^{-1} with higher level of 150 per cent recommended NP along with foliar spraying of DAP and SOP twice (S_2N_5) resulted in significantly more functional root nodules than any other combination at all the growth stages.

Root growth measured in terms of root length, root volume and root weight was influenced due to variation in special arrangement of the plant and nutrient management practices. The root length increased with the narrowing of row spacing. As the foraging area decreased for individual plant roots horizontally, roots might have penetrated into deeper soil layers for moisture and nutrients extraction. As against root length, root volume and root dry weight decreased with the narrowing of row spacing. Though the roots were longer, their proliferation was limited as indicated by its lesser volume and weight. The limiting of proliferation of roots leading to reduced growth might have reflected on the decreased number of functional modules. The reduction in root nodules and root weight by increasing the plant population in soybean was earlier reported by Sprent and Bradford[19].

Application of 125 per cent NP with foliar spraying of two per cent DAP and one per cent SOP at 25 and 45 DAS (N_4) recorded significantly lengthier roots, higher root volume and root weight. This might be due to the additional N and P applied in the initial stages which might have helped in the formation and growth of roots in the initial stages. The usefulness of N supplement for initial growth of roots and formation of nodules has been enlightened by Das[3].

Grain Yield: The grain yield obtained during summer 2003 was the highest and the grain yield obtained in *rabi 2002* was the least (Table 6). The grain yield of greengram raised at 20 x 10 cm spacing (S_1) was higher and was comparable with that of the crop raised in 25 x 10 cm spacing (S_2) during *kharif 2002*, whereas, during *rabi 2002* and summer 2003, higher grain yield was registered with S_2 which was comparable with S_1. Grain yield of greengram raised in normal spacing of 30 x 10 cm (S_3) was significantly lesser in all the seasons.

Table 3: Root dry matter (g plant^{-1}) as influenced by spacing and nutrient management

Treatment	*kharif* 2002			*rabi* 2002			summer 2002		
	30 DAS	50 DAS	Harvest	30 DAS	50 DAS	Harvest	30 DAS	50 DAS	Harvest
				Spacing (S)					
S_1	0.24	0.71	0.99	0.27	0.72	1.07	0.19	0.67	0.99
S_2	0.27	0.88	1.29	0.29	0.88	1.54	0.23	0.83	1.50
S_3	0.29	1.01	2.45	0.31	0.98	3.26	0.26	0.96	3.18
SE_d	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.03
CD	0.02	0.04	0.07	0.02	0.02	0.03	0.02	0.04	0.08
				Nutrient management (N)					
N_1	0.24	0.76	1.43	0.27	0.80	1.72	0.19	0.73	1.71
N_2	0.26	0.83	1.52	0.30	0.90	1.93	0.22	0.79	1.83
N_3	0.23	0.83	1.49	0.27	0.84	1.78	0.22	0.79	1.89
N_4	0.33	1.03	1.79	0.32	0.97	2.07	0.30	0.98	2.19
N_5	0.31	0.97	1.71	0.32	0.96	2.06	0.27	0.92	2.05
N_6	0.24	0.76	1.42	0.26	0.83	1.76	0.19	0.71	1.70
SE_d	0.01	0.01	0.04	0.01	0.01	0.03	0.01	0.01	0.06
CD	0.02	0.02	0.08	0.02	0.03	0.06	0.02	0.02	0.12
				N at S					
SE_d	0.01	0.02	0.07	0.01	0.02	0.05	0.01	0.02	0.10
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS
				S at N					
SE_d	0.01	0.02	0.06	0.01	0.02	0.05	0.01	0.02	0.10
CD	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4: Functional root nodules (No. plant^{-1}) of greengram as influenced by spacing and nutrient management at 30 DAS

Treatment	*kharif* 2002				*rabi* 2002				summer 2003			
	S_1	S_2	S_3	mean	S_1	S_2	S_3	mean	S_1	S_2	S_3	mean
N_1	23.4	23.2	25.6	23.7	7.4	8.2	10.6	8.7	23.7	24.7	26.1	25.1
N_2	23.7	27.3	30.3	27.1	8.7	12.3	15.7	12.2	24.8	29.0	32.0	28.6
N_3	19.6	23.6	26.2	23.1	5.3	8.6	11.2	8.4	20.7	24.6	27.7	24.3
N_4	30.5	34.8	36.3	33.8	15.6	21.0	14.8	17.1	32.1	38.1	41.3	37.2
N_5	33.7	30.2	33.4	32.4	17.7	24.6	18.5	20.3	35.6	32.6	35.5	34.6
N_6	20.9	23.2	26.2	23.4	7.8	8.5	11.8	9.4	22.0	24.5	27.7	24.7
mean	25.1	27.1	29.6		10.4	13.9	13.8		26.5	28.9	31.9	

	SE_d	CD	SE_d	CD	SE_d	CD
S	0.50	1.39	0.20	0.55	0.59	1.65
N	0.93	1.91	0.30	0.62	0.93	1.91
N at S	1.62	3.30	0.53	1.07	1.62	3.30
S at N	1.56	3.30	0.52	1.11	1.59	3.41

Table 5: Functional root nodules (No. plant^{-1}) of greengram as influenced by spacing and nutrient management at 50 DAS

Treatment	*kharif* 2002				*rabi* 2002				summer 2003			
	S_1	S_2	S_3	mean	S_1	S_2	S_3	mean	S_1	S_2	S_3	mean
N_1	36.1	36.7	40.5	37.8	11.8	14.2	16.8	14.3	38.1	38.8	42.9	40.0
N_2	37.5	43.2	47.9	42.9	13.9	19.5	24.9	19.4	39.6	45.8	50.6	45.3
N_3	31.2	37.7	41.4	36.8	10.4	14.8	16.8	14.0	32.9	39.8	43.8	38.8
N_4	48.3	56.9	62.0	55.7	24.7	33.3	23.5	27.2	51.0	60.2	65.3	58.8
N_5	53.3	47.8	52.8	51.3	28.1	39.2	29.4	32.2	56.3	50.5	55.8	54.2
N_6	32.9	36.9	41.7	37.2	13.8	13.6	18.7	15.4	34.8	39.0	44.0	39.3
mean	39.9	43.2	47.7		17.0	22.4	21.9		42.1	45.7	50.4	

	SE_d	CD	SE_d	CD	SE_d	CD
S	0.52	1.44	0.24	0.66	0.57	1.58
N	0.96	1.96	0.42	0.86	1.04	2.13
N at S	1.66	3.39	0.73	1.49	1.80	3.68
S at N	1.60	3.40	0.71	1.50	1.74	3.69

Table 6: Grain yield (kg ha^{-1}) influenced spacing and nutrient management

Treatment	*kharif* 2002				*rabi* 2002				summer 2003			
	S_1	S_2	S_3	mean	S_1	S_2	S_3	mean	S_1	S_2	S_3	mean
N_1	925	878	841	881	696	739	672	702	1178	1234	1017	1143
N_2	1014	1075	892	994	853	850	752	818	1349	1345	1247	1314
N_3	915	943	807	888	792	730	693	738	1054	1059	958	1023
N_4	1178	1156	1030	1121	873	894	761	843	1369	1389	1256	1338
N_5	1085	1026	1095	1069	822	869	872	854	1317	1364	1367	1349
N_6	934	885	833	884	655	730	676	687	1050	1058	971	1027
Mean	1008	994	916		782	802	738		1220	1241	1136	

	SE_d	CD	SE_d	CD	SE_d	CD
S	14.3	39.7	8.3	23.1	8.7	24.0
N	27.5	56.1	12.7	25.9	13.2	26.9
N at S	39.8	81.3	21.9	44.8	22.9	46.5
S at N	39.1	83.6	21.7	46.6	22.5	48.5

Application of 125 per cent NP in combination with foliar spraying of two per cent DAP and one per cent SOP at 25 and 45 DAS (N_4) resulted in higher grain yield in *kharif 2002*. It was comparable with the grain yield recorded with the 150 per cent NP with foliar spraying of DAP and SOP twice (N_5). During *rabi 2002* and summer 2003, the grain yield obtained with 150 per cent NP (N_5) was higher, but was comparable with N_4.

Grain yield was significantly influenced by the interaction effect of spacing (S) and nutrient management (N). During *kharif 2002* greengram raised with the spacing of 20 x 10 cm along with application of 125 per cent recommended NP combined with foliar spraying of DAP and SOP (S_1N_4) produced the highest grain yield but was comparable with that of S_2N_4. During *rabi 2002* and summer 2003, S_2N_4 itself recorded higher grain yield and was comparable with that of S_1N_4. The higher grain yield of greengram with closer spacing could be attributed to the increase in the total productivity than the individual plant performance. Generally, closer spacings recorded higher grain yield than the recommended spacing of 30 x 10 cm (S_3). In case of closer spacings, eventhough the yield contributing variables were less when compared to the recommended spacing, the productivity was higher due

Table 7: Bhusa yield (kg ha^{-1}) as influenced spacing and nutrient management

Treatment	*kharif* 2002				*rabi* 2002				summer 2003			
	S_1	S_2	S_3	mean	S_1	S_2	S_3	mean	S_1	S_2	S_3	mean
N_1	1170	1170	1155	1164	1005	954	912	957	1275	1347	1275	1299
N_2	1431	1242	1269	1314	1155	1065	1119	1113	1554	1512	1428	1497
N_3	1255	1125	1140	1173	993	984	1038	1005	1338	1287	1278	1302
N_4	1533	1434	1467	1479	1215	1077	1143	1146	1692	1710	1626	1677
N_5	1389	1536	1350	1425	1179	1236	1077	1164	1737	1767	1695	1734
N_6	1170	1161	1167	1167	990	957	858	936	1287	1320	1320	1311
Mean	1326	1278	1257		1092	1047	1026		1482	1491	1437	

	SE_d	CD	SE_d	CD	SE_d	CD
S	20.3	56.4	11.2	30.3	18.9	51.2
N	31.8	65.1	17.4	35.4	29.2	59.6
N at S	55.2	110.8	30.0	61.5	38.4	77.8
S at N	54.3	116.4	29.7	63.3	36.0	81.3

to higher plant population ha^{-1} by 50 and 20 per cent in S_1 and S_2 respectively. Similar increase in grain productivity with closer row spacing of 20 cm as compared to wider row of 30 cm was recorded by Dewangan *et al.*[4] and Sekhon *et al.*[16] in greengram under irrigated condition.

The advantage of recording higher grain productivity with 125 per cent NP with foliar spraying of DAP and SOP (N_4) could be justified with better growth and yield attributes. In an earlier study also a linear increase in grain yield was recorded with increase in levels of P indicating that the highest yield obtained with 60 kg P_2O_5 ha^{-1}[17] and 15 per cent of additional yield could be obtained by additional application of 33.6 kg P_2O_5 ha^{-1} over recommended level[12]. The yield advantage due to foliar spraying of SOP in N_2 treatment was 14.6 per cent over the recommended package of nutrient management combined with foliar spraying of DAP alone (N_1). The productivity increase of 18 per cent was registered with the same treatment (N_2) over the treatment where K was applied through soil in the form of MOP (N_3). This might be attributed to foliar spraying of SOP alone. The role of S and K applied through foliage in the form of SOP in influencing the growth and yield attributes as discussed earlier might have contributed for higher grain yield. An increase in productivity of greengram with foliar spraying of 1 per cent SOP was earlier attributed to the influence of K (15). Since, the response for foliar application of SOP was more than soil applied K, the yield increase can be attributed to the effect of S also as indicated by Ravichandran *et al.*[14] that sulphur increased the yield of greengram.

Highest average productivity of 1199 kg of grain ha^{-1} was registered during summer 2003 which is 23.2 per cent and 54.9 per cent higher than the yield recorded during *kharif 2002* and *rabi 2002* respectively. Similarly, the increase in productivity during *kharif* 2002 was 25.70 per cent when compared to *rabi 2002*. The higher productivity might be attributed to the higher amount of cumulative solar radiation activating the photosynthesis and higher mean temperature hastening the flowering and low minimum temperature during maturity favouring accumulation of more synthates in the sink. This result is in accordance with those of Monteith (9), Singh *et al.* (18) and Rao and Ghildiyal (13) who also have reported higher productivity during summer with higher solar radiation than during rainy season with cloudy weather.

Bhusa Yield: Similar to that of grain yield, bhusa yield was also higher during summer 2003 and was followed by *kharif 2002* and *rabi 2002* (Table 7). Higher bhusa yield was recorded in greengram raised at 20 x 10 cm spacing (S_1) than other two spacings (S_2 and S_3). Application of 125 per cent NP with foliar spraying of DAP and SOP (N_4) produced higher bhusa yield and was comparable with that of N_5 during *kharif 2002*. During *rabi 2002*, higher bhusa yield was registered with N_5 which was on par with that of N_4. During summer 2003, the trend was similar, but application of 150 per cent NP with foliar spraying (N_5) produced higher bhusa yield but was comparable with N_4.

Among the treatment combinations, S_2N_5 combination registered the highest bhusa yield. The next best combination was S_1N_4 during *kharif 2002* and *rabi 2002* and S_3N_4 during summer 2003. Bhusa yield increased with increase in population from the recommended level of 3.33 to 5.0 lakh plants ha^{-1} in all the seasons. Though, the DMP plant^{-1} was low with higher population level, the increase in number of

plants per unit area would have overcome this reduction in DMP plant^{-1} and increased the TDMP ha^{-1} and thereby increasing the bhusa yield.

Application of both 125 per cent and 150 per cent of NP along with foliar spraying of two per cent DAP and one per cent SOP increased the bhusa yield and were comparable with each other during all the three seasons. The increase in DMP plant^{-1} resulting in more TDMP ha^{-1} would be the reason for such increase in bhusa yield

Conclusion: The results of the experiments revealed that root length increased with increase in population from recommended level of 3.33 to 5.0 lakh plants ha^{-1} at all stages and seasons. Root volume was more with lesser population and it decreased with higher population at all stages and seasons. Functional root nodules were higher with recommended plant population of 3.33 lakh plants ha^{-1}. Among the fertilizer levels, application of 125 per cent NP with foliar sprays recorded higher root length, root volume and functional root nodules and was followed by 150 per cent NP with foliar sprays. Higher plant density favoured the grain and bhusa yield. In general, yield were better when applied with 125 per cent r NP along with foliar sprays during *kharif* 2002 and summer 2003 and 150 per cent NP with foliar sprays during *rabi* 2002.

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