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Influence of Increased Plant Density and Fertilizer Levels on Physiological Parameters and Yield of Greengram (*Vigna radiata* (L.) Wilczek)

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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 physiological parameters 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 transpiration rate increased with decrease in plant population. Nutrient management practices did not influence the transpiration rate. SDR was the highest with the higher population of 5.0 lakh plants ha^{-1}. Application of 150 or 125 per cent NP along with foliar sprays had the lowest SDR. Canopy bottom light quantum increased with reduction in population from 5.0 to 3.33 lakh plants ha^{-1}, but the differential light quantum showed reversing trend. Canopy bottom light quantum was the lowest and differential light quantum was the highest with 150 per cent recommended NP along with foliar sprays and comparable with 125 per cent NP along with foliar sprays. Grain and bhusa yield were higher at higher plant density. Application of 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 recorded higher grain and bhusa yield.

Key words: Greengram, increased plant density, fertilizer levels, physiological parameters, 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[6]. 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[5]. 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[12].

To exploit the full genetic potentiality of any greengram variety, development of management technology would become utmost 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

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spacing of 30 x 10 cm significantly produced the highest seed yield. Sekhon *et al.*[20] reported that the summer greengram raised in loamy sand at 20 cm row spacing recorded 15 per cent higher yield over 30 cm row spacing. Khan *et al*.[7] reported that Phosphorus application significantly increased the yield of mungbean. Similarly, Chovatia *et al.*[3] reported that application of Phosphorus increased the seed yield upto 40 kg $P_2 O_5$ ha^{-1}. Muhammad Ather Nadeem *et al.*[11] reported that higher seed yield of greengram was obtained at a fertilizer level of 30-60 kg N, $P_2 O_5$ ha^{-1}. Pulses are among the crops which have relatively high requirement of S and are particularly sensitive to S deficiency[23].

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 find out the effect of increased plant population and nutrient levels on the physiological parameters and yield of greengram.

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 on the physiological parameters 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 i.e. 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.

Transpiration rate was measured in the third leaf from top with the help of "steady State Porometer" (Model Li-1600 Li-Cor Inc., Nebraska, USA) as described by O'Toole and Tomer[13] and expressed in $\mu g\ cm^{-2}\ s^{-1}$. Stomatal diffusive resistance was measured with pre-calibrated "Steady State Porometer" (Model Li-1600, Li-Cor Inc., Nebraska, USA) as described by O'Toole and Tomer[13] and expressed in $s\ cm^{-1}$. The rate of CO_2 depletion in the closed system was measured in the third leaf from the top with an Infra Red Gas Analyzer as per the procedure suggested by Poskuta and Nelson[15] and the photosynthetic rate was calculated as per the method adopted by Phogat *et al.*[14] at 30 DAS and expressed in $\mu g\ CO_2\ m^{-2}\ s^{-1}$. Light interception was measured with the help of "Steady State Porometer" (Model Li-1600.) as described by O' Toole and Tomer (13) and expressed in μ mol s^{-1} m^{-2}. The quantum received at the top of the canopy was measured at fully opened top leaf and the bottom canopy quantum was measured at fully active lower leaf. The differential quantum was worked out as given below.

- Differential light quantum = Canopy top light quantum – Canopy bottom light quantum

Pods harvested from the net plot were dried and thrashed and the grain yield was expressed in kg ha-1. The bhusa yield after threshing the pods from the plants from net plot was recorded and expressed in kg ha^{-1}.

RESULTS AND DISCUSSION

Transpiration Rate: Transpiration rate (TR) was higher during summer 2003 followed by *kharif 2002* and *rabi 2002* (Table 1). The maximum TR was recorded at 30 DAS during all the three seasons. Greengram raised at a spacing of 30 x 10 cm (S_3) accommodating 3.33 lakh plants ha^{-1} registered higher TR than the other spacings. It was followed by closer spacing of 20 x 10 cm with 5 lakh plants ha^{-1}. The trend was similar at both the stages.

Transpiration rate did not vary with the nutrient management practices at both stages during all the three seasons.

Stomatal Diffusive Resistance: SDR was higher during *rabi* 2002 than in other two seasons (Table 2).

Greengram raised at 20 x 10 cm spacing (S_1) registered higher SDR at 30 DAS and 50 DAS during all the three seasons. Application of 150 per cent NP combined with foliar spraying of two per cent DAP and one per SOP at 25 and 45 DAS (N_5) resulted in the least SDR at both the growth stages during all the three seasons. On the other hand N_6 had resulted in higher SDR and was followed by N_3 and N_2 in all the seasons at both the stages of crop growth.

Stomatal diffusive resistance (SDR) tended to decrease with increase in fertilization. The foliar applied K and S in addition to the increased dose of N and P through soil might have produced synergetic effect in regulating the water content in the plant cell. Increased leaf water potential in black gram by application of K through foliage was recorded by Velu and Srinivasan[24].

Canopy Top Light Quantum: The quantum of sunlight received at the top of the canopy recorded at 30 and 50 DAS did not vary with the spacing or with nutrient management practices during all the three seasons.

Canopy Bottom Light Quantum: Quantum of light recorded at bottom canopy was higher during summer 2003 followed by *kharif 2002* (Table 4). The bottom canopy quantum measured at 30 and 50 DAS were higher in greengram raised in normal spacing of 30 x 10 cm (S_3) than in closer spacings. Similar trend was noticed during all the seasons.

Application of 150 per cent NP coupled with foliar spraying of DAP and SOP twice (N_5) resulted in the least sunlight quantum at bottom of the crop canopy of greengram during all the three seasons. However, this was comparable with N_4 and N_1 in all the seasons and stages of observation. The treatment N_6 registered the highest quantum at the bottom of the canopy and was closely followed by N_3 and N_2 during all the three seasons. The trend was similar at both stages of observation.

Differential Light Quantum: Differential quantum was significantly higher in greengram raised in closer spacing of 20 x 10 cm (S_1) than in normal spacing of 30 x 10 cm, but was comparable with that of the spacing of 25 x 10 (S_2) (Table 5). The same observation was evident during all the three seasons both at 30 and 50 DAS. Differential quantum was higher in greengram raised with the application of 150 per cent NP (N_5) along with foliar spraying and was comparable with that of N_4 at both the growth stages during all the three seasons.

Differential light quantum was the highest with the application of higher dose of nutrients. The LAI was higher in these treatments due to increased aerial growth and hence the light received at the bottom of the canopy was the lowest. Similar inferences have been drawn earlier by Venkataraman and Krishnan [25].

Canopy bottom light quantum is a measure which gives an indication of interception of light by the crop canopy. Light quantum at the bottom of the canopy received increased with increase in row spacing from 20 to 30 cm. Though the leaf area $plant^{-1}$ was higher under wider spacing, the coverage of leaf canopy for the given land area was less as it was observed with LAI. Hence, more quantum of light passed though the canopy to the bottom. Under narrow row spacing of 20 cm, the LAI was higher intercepting more light and reducing the quantum of light reaching the bottom. This had resulted in wide difference between the quantum of light received at the top and bottom of the canopy (Differential light quantum). Bashandi and Poehlman[2] have reported earlier that the practice of growing greengram at different population densities normally resulted in varying amounts light interception.

Photosynthetic Rate: The photosynthetic rate (PR) was higher during summer 2003 and was followed by *kharif 2002* and *rabi 2002* (Table 6).

The photosynthetic rate was higher in plants under normal spacing of 30 x 10 cm. Higher PR was registered with the application of 125 per cent NP along with foliar spraying of DAP and SOP twice (N_4)

Table 1: Transpiration rate (µg cm^{-2} S^{-1}) as influenced by spacing and nutrient management

Treatment	*kharif* 2002		*rabi* 2002		Summer 2003	
	30 DAS	50 DAS	30 DAS	50 DAS	30 DAS	50 DAS
			Spacing (S)			
S_1	18.51	17.18	16.94	15.62	19.80	18.47
S_2	18.48	17.14	16.86	15.58	19.80	18.47
S_3	19.23	17.89	17.67	16.36	20.52	19.16
SE_d	0.17	0.15	0.14	0.13	0.20	0.17
CD	0.48	0.43	0.41	0.36	0.54	0.47
			Nutrient management (N)			
N_1	18.87	17.53	17.30	15.96	20.16	18.82
N_2	18.89	17.54	17.31	15.97	20.17	18.83
N_3	18.62	17.28	17.06	15.72	19.91	18.57
N_4	18.71	17.36	17.14	15.79	20.00	18.65
N_5	18.77	17.42	17.19	15.85	20.05	18.71
N_6	18.64	17.30	17.07	15.75	19.93	18.63
SE_d	0.30	0.27	0.25	0.23	0.36	0.30
CD	NS	NS	NS	NS	NS	NS

Table 2: Stomal diffusive resistance (s cm^{-1}) as influenced by spacing and nutrient management

Treatment	*kharif* 2002		*rabi* 2002		Summer 2003	
	30 DAS	50 DAS	30 DAS	50 DAS	30 DAS	50 DAS
			Spacing (S)			
S_1	5.93	7.10	6.26	7.30	5.30	6.23
S_2	5.17	6.21	5.50	6.41	4.54	5.34
S_3	4.95	6.12	5.24	6.29	4.32	5.25
SE_d	0.19	0.28	0.19	0.26	0.17	0.25
CD	0.54	0.78	0.52	0.73	0.48	0.69
			Nutrient management (N)			
N_1	5.34	6.39	5.67	6.59	4.71	5.52
N_2	5.44	6.54	5.78	6.74	4.81	5.67
N_3	5.65	6.79	5.98	6.98	5.02	5.92
N_4	5.04	6.37	5.32	6.46	4.40	5.50
N_5	4.90	5.89	5.21	6.09	4.27	5.02
N_6	5.73	6.89	6.06	7.10	5.10	6.02
SE_d	0.24	0.29	0.33	0.31	0.20	0.24
CD	0.49	0.58	0.67	0.63	0.41	0.49

than in other nutrient management practices and was followed by N_5. The PR was lesser in N_1 and N_6 during all the seasons.

Photosynthetic rate of the leaves was higher in plants under wider spacing. The plants grown under wider spacing with low plant density are endowed with more moisture from a wider area which could easily be absorbed and transpired. Because of the availability of water, the stomatal diffusive resistance had been decreased due to turgor pressure which would have permitted more gas exchange favouring high photosynthetic rate. Further, the limited plant canopy over the land surface could intercept more light which also might

Table 3: Canopy top light quantum (μ mol sec^{-1} m^{-2}) as influenced by spacing and nutrient management

Treatment	*kharif* 2002		*rabi* 2002		summer 2003	
	30 DAS	50 DAS	30 DAS	50 DAS	30 DAS	50 DAS
Spacing (S)						
S_1	1348	1287	1051	990	1471	1413
S_2	1343	1289	1050	992	1473	1413
S_3	1404	1341	1104	1044	1527	1469
SE_d	26	21	25	22	30	27
CD	NS	NS	NS	NS	NS	NS
Nutrient management (N)						
N_1	1374	1316	1077	1019	1500	1442
N_2	1376	1321	1074	1024	1500	1447
N_3	1358	1291	1054	994	1482	1417
N_4	1362	1304	1065	1007	1488	1430
N_5	1364	1302	1063	1005	1488	1428
N_6	1360	1301	1070	1004	1490	1427
SE_d	46	37	44	39	53	48
CD	NS	NS	NS	NS	NS	NS

Table 4: Canopy bottom light quantum (μ mol sec-1 m-2) as influenced by spacing and nutrient management

Treatment	*kharif* 2002		*rabi* 2002		summer 2003	
	30 DAS	50 DAS	30 DAS	50 DAS	30 DAS	50 DAS
Spacing (S)						
S_1	724	665	424	366	809	751
S_2	733	673	433	372	818	757
S_3	797	738	497	438	882	823
SE_d	15	17	12	10	16	13
CD	41	48	33	27	43	36
Nutrient management (N)						
N_1	750	686	450	386	835	771
N_2	765	705	465	405	850	790
N_3	780	723	480	423	865	808
N_4	723	664	423	364	808	749
N_5	706	647	406	347	791	732
N_6	784	727	484	427	869	812
SE_d	24	26	19	16	23	20
CD	49	53	39	33	47	41

have contributed to increased photosynthetic rate. These results are in accordance with Liyanage *et al.*[8] who have recorded increased photosynthetic rate due to higher water potential and lesser diffusive resistance in greengram provided with more spacing.

Photosynthetic rate increased with 125 per cent NP along with foliar sprays. Optimum dose of applied N and P along with K and S though foliage might have favoured the chlorophyll formation[9] which in turn affected the photosynthetic rate. Sadasivam *et al.*[19]

Table 5: Differential light quantum (µ mol sec^{-1} m^{-2}) as influenced by spacing and nutrient management

Treatment	*kharif* 2002		*rabi* 2002		summer 2003	
	30 DAS	50 DAS	30 DAS	50 DAS	30 DAS	50 DAS
Spacing (S)						
S_1	624	622	627	624	665	662
S_2	610	616	617	620	655	656
S_3	607	603	607	606	645	646
SE_d	5	6	7	4	7	5
CD	15	17	18	14	18	15
Nutrient management (N)						
N_1	624	636	627	633	665	671
N_2	611	616	613	619	650	657
N_3	578	568	574	571	617	609
N_4	639	640	642	646	680	681
N_5	658	655	657	658	697	696
N_6	584	574	586	577	621	615
SE_d	10	11	12	7	12	9
CD	20	22	24	14	24	18

Table 6: Photosynthetic rate (µg CO_2 m^{-2} s^{-1}) of greengram as influenced by spacing and nutrient management

Treatment	*kharif* 2002			*rabi* 2002			summer 2003		
	30 DAS	50 DAS	Harvest	30 DAS	50 DAS	Harvest	30 DAS	50 DAS	Harvest
Spacing (S)									
S_1	539	714	635	489	676	638	562	746	688
S_2	562	842	654	516	797	760	576	848	780
S_3	571	972	682	544	923	886	590	997	918
SE_d	3.8	5.9	4.8	5.9	8.5	10.2	3.8	12.2	7.8
CD	10.4	16.5	13.3	16.3	23.5	28.4	10.6	33.9	21.6
Nutrient management (N)									
N_1	531	747	600	478	712	693	555	786	724
N_2	552	810	641	503	769	740	590	880	812
N_3	520	812	628	505	771	735	558	816	752
N_4	618	985	756	580	954	874	601	946	871
N_5	597	943	723	556	895	833	604	944	868
N_6	528	740	598	476	697	687	557	807	743
SE_d	8.1	10.6	8.7	10.7	15.3	18.4	6.9	21.2	14.0
CD	16.5	21.5	17.7	21.7	31.2	37.4	14.0	43.1	28.4

also observed higher photosynthetic rate due to foliar spraying of SOP in greengram.

Grain Yield: The grain yield obtained during summer 2003 was the highest and the grain yield obtained in *rabi 2002* was the least (Table 7). 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 7: 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

Table 8: 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

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 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 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.* (20) 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} (21) 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[16]. 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[19]. 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.*[18] 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[10], Singh *et al.*[22] and Rao and Ghildiyal[17] 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 8). 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 experiment revealed that transpiration rate increased with decrease in plant population from 5.0 to 3.33 lakh plants ha^{-1}. Nutritional management practices did not influence the transpiration rate. Stomatal diffusive resistance (SDR) was the highest with the higher population of 5.0 lakh plants ha^{-1} than other two population levels. Application of 150 or 125 per cent NP along with, foliar sprays had the lowest SDR and comparable with recommended nutrient management practice but superior to other management practices. Canopy bottom light quantum increased with reduction in population from 5.0 to 3.33 lakh plants ha^{-1}, but the differential light quantum showed reversing trend. Canopy bottom light quantum was the lowest and differential light quantum was the highest with 150 per cent recommended NP along with foliar sprays and comparable with 125 per cent recommended NP along with foliar sprays. Grain and bhusa yield were higher at higher plant density. Application of 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 recorded higher grain and stover yield.

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