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Influence of Increased Plant Density and Fertilizer Application on the Nutrient Uptake and Yield of Greengram (*Vigna radiata* (L.) Wilczek)

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Abstract: Field experiments were conducted during *kharif and rabi* 2002 and *summer* 2003 at the College of Agricultural Engineering, Kumulur, Tiruchirappalli district of Tamil Nadu to study the effect of greengram to increased plant density and nutrient management on the nutrient uptake 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 experiment revealed that N, P, K and S uptake increased with increase in plant population from 3.33 to 5.0 lakh plants ha^{-1} in all the three seasons. Among the nutrient management practices, N, K and S uptake was higher with 125 per cent or 150 per cent NP along with foliar spraying of DAP and SOP. Regarding P, 150 per cent NP along with foliar sprays resulted in higher uptake. Post harvest soil available N was more under recommended population (3.33 lakh plants ha^{-1}). Application of 125 per cent or 150 per cent NP along with foliar sprays recorded higher and comparable soil available N. The availability of P and K was neither influenced by spacing nor by nutrient management practices. Higher plant density favoured the grain and bhusa yield. Similarly higher yield was observed when applied with 125 per cent NP along with foliar sprays during *kharif* 2002 and summer 2003 and with 150 per cent NP with foliar sprays during *rabi* 2002.

Keywords: Greengram, row spacing, fertilizer levels, nutrient uptake, 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[11]. The area under pulses in the country 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[12]. 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[17].

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.,*[26] reported that the

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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.*,[13] reported that Phosphorus application significantly increased the yield of mungbean. Similarly, Chovatia *et al.,*[5] reported that application of Phosphorus increased the seed yield upto 40 kg P_2O_5 ha^{-1}. Muhammad Ather Nadeem *et al.*,[16] 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[36].

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, nutrient uptake and yield may be reduced due to one or more limiting factors even through efforts are made to overcome resource limitations. With these ideas in view, an attempt was made to study the effect of increased plant population and nutrient levels on the nutrient uptake and yield of greengram and also the post harvest soil nutrient status.

MATERIAL 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 fertilizer application on the nutrient uptake 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.

Total nitrogen, phosphorus, potassium and sulphur contents in the plant sample were analyzed by the following methods and the uptake was expressed in kg ha^{-1}.

Nutrient	Method	Author
Total nitrogen	Microkjeldhal	Humphries (9)
Total phosphorus	Vanadomolybdate method (Triple acid extract)	Jackson (10)
Total potassium	Flame photometer (Triple acid extract)	Jackson (10)
Total sulphur	Barium sulphate turbidimetry method	Bhargava and Raghupathi (4)

Pre sowing and post harvest soil samples were taken from the experimental plots from a depth of 30 cm. The samples were analyzed for textural properties. pH, EC, organic carbon and available nitrogen, phosphorus and potassium by the following methods.

Property	Method	Author
Available nitrogen	Potassium permanganate-N	Subbiah and Asija (34)
Available phosphorus	0.5 M Na HCO_3 extraction	Olsen *et al.* (19)
Available potassium	Flame photometry	Stanford and English (33)
Organic carbon	Chromic acid wet digestion	Walkly and Black (39)

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 DISCUSSIONS

Nutrient Uptake: Nitrogen uptake: Nitrogen uptake by greengram was higher during *rabi 2002* and was followed by summer 2003.

Nitrogen uptake was higher in greengram raised at 20 x 10 cm spacing (S_1) and was comparable with that of S_2. The trend was similar at all the growth stages except at harvest where in uptake in S_1 was significantly higher than other two spacings in *kharif 2002*. During *rabi 2002* and summer 2003, the trend in N uptake was almost similar to that of *kharif 2002*, but there was significant decrease in N uptake for every decrease in population (S_2 and S_3). Similar trend was observed at all the growth stages during both the seasons.

Application of 125 per cent NP along with foliar spraying of two per cent DAP and one per cent SOP twice at 25 and 45 DAS (N_4) registered higher N uptake which was comparable with 150 per cent NP combined with foliar spraying (N_5) during *kharif 2002*. During *rabi 2002* and summer 2003, the N uptake was higher in N_5 which was comparable with N_4.

Phosphorus Uptake: Phosphorus uptake was higher in *rabi 2002* and was followed by summer 2003 and *kharif 2002*. Significantly higher P uptake was recorded in greengram raised at a closer spacing of 20 x 10 cm (S_1) than in other two spacings (S_2 and S_3) at all growth stages in all the three seasons.

Phosphorus uptake by greengram was significantly higher with the application of 150 per cent NP in combination with foliar spraying (N_5) at all growth stages and seasons. It was followed by N_4 and N_2 in the descending order of P uptake.

Potassium Uptake: Similar to that of other nutrients, potassium uptake was higher during *rabi 2002* and was followed by summer 2003 and then *kharif 2002*.

As in P uptake, K uptake was significantly higher in greengram raised at closer spacing of 20 x 10 cm (S_1) than in other two spacings (S_2 and S3). The trend was similar during *rabi 2002* and summer 2003. Consistently, application of 125 per cent NP along with foliar spraying (N_4) registered the highest K uptake but was comparable with that of 150 per cent NP with foliar spraying (N_5) in all the growth stages during all the three seasons. The least K uptake was with N_6 at all stages in the all the seasons.

Sulphur Uptake: Greengram raised in *rabi 2002* recorded higher S uptake than in summer 2003 and *kharif 2002*.

Adopting a spacing of 20 x 10 cm (S_1) to accommodate 5 lakh plants ha^{-1} registered significantly higher S uptake than the other two spacings (S_2 and S_3) in all the three stages of observation during all the three seasons. During *kharif 2002* alone the S uptake was comparable between these two treatments (S_2 and S_3). Higher S uptake was registered in greengram with the application of 125 per cent NP along with foliar spraying (N_4) and was on par with that of 150 per cent NP combined with foliar spraying (N_5) in all the three stages during all the season.

As legumes are bestowed with the capacity of fixing the elemental N from the atmosphere N nutrition is not a major problem. However, N supplement is essential for the initial growth of roots and formation of nodules which takes about two weeks time[6].

Phosphorus promotes the formation of lateral and fibrous roots[20,14]. It is also needed by nodule bacteria which ultimately affects the N fixation in leguminous crops[3].

Potassium is the third major nutrient required in adequate amount for healthy growth, high yields, and superior quality of pulses. Application of K fertilizers is restricted to pulses in Tamil Nadu owing to their non response in soils with high K. However, in certain isolated pockets the response is reported where this nutrient is deficient[2, 38].

Sulphur is now recognized as the fourth major nutrient in addition to NPK. It is essential for protein production. Field scale deficiencies of S in soils and plants are becoming increasingly important. Legumes are among the crops which have a relatively high requirement of S and are particularly sensitive to S deficiency[35].

Application of mineral nutrients through foliage makes the nutrients readily available to plants without any loss. The chief advantage of foliar fertilization over soil application lies in the increased fertilizer use efficiency[27]. Pulses being invariably indeterminate flowering plants, demand heavy for nutrients during flowering and pod formation stage or if the source and sink develop simultaneously, plant may not be able to absorb all the required soil nutrients at that time. Hence, foliar application will benefit these crops very much.

Response of pulses to the balanced fertilization was reported earlier by Singh *et al.*[32], Singh and Sharma[31] and Pasricha[21]. The effect was not observed during *rabi 2002* season because of high rainfall and it might have moved the nutrients to deeper soil layers and lowered the availability at the root zone.

Post harvest soil available NPK: Post harvest soil available N, P and K results were highly varying. The post harvest available P and K status was not significantly altered both by spacing and nutrient management practices during all the three seasons. But, significant variation was observed in available N in the post harvest soil sample during *kharif 2002* and summer 2003.

Higher soil available N was registered after the harvest of greengram raised at a spacing of 30 x 10 cm (S_3) which was comparable with that of 25 x 10 cm spacing (S_2) during *kharif 2002* and summer 2003. The post harvest N status did not vary significantly with the spacings during *rabi 2002*. Application of 125 per cent NP in combination with foliar spacing of two per cent DAP and one per cent SOP at 25 and 45 DAS to greengram (N_4) had resulted in higher post harvest soil available N during all the three seasons. It was closely followed by 150 per cent recommended NP with foliar spraying (N_5). Post harvest available N was the least with N_6. Generally, growing of legumes helped in nodulation and ultimately enriched the soil available N status[7,40,18].

Higher amount of post harvest available soil N recorded after greengram raised in 30 x 10 cm could primarily be attributed to the effect of higher number of functional root nodules which could have absorbed more N from atmosphere and supplied to the plant. Further, disintegration of root nodules at later stage might have also added more N to the soil. Increase of root nodules in greengram with wider inter row spacing was earlier observed by Singh and Singh (30) consequently resulting in higher post harvest soil available nitrogen. Similarly, higher number of root nodules observed in greengram raised with application of either 125 per cent or 150 per cent of NP along with foliar spraying of DAP and SOP might have contributed more to the soil available N status. Disintegration of root nodules enhanced the post harvest soils available N[37].

Yield:

Grain Yield: The grain yield obtained during summer' 2003 was the highest and the grain yield obtained in *rabi 2002* was the least. 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 (Table 1). Grain yield of greengram raised in normal spacing of 30 x 10 cm (S_3) was significantly lower 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 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 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.*[8] and Sekhon *et al.*[26] in greengram under irrigated condition.

The advantage of recording higher grain productivity with 125 per cent recommended 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

Table 1: Nitrogen uptake (kg ha^{-1}) 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	40.46	37.95	40.51	62.89	52.03	53.40	46.06	43.90	46.87
S_2	37.23	35.87	38.91	54.62	44.18	46.34	43.14	41.61	45.02
S_3	34.38	33.09	37.62	47.85	48.84	40.75	40.22	39.77	43.54
SE_d	1.02	0.95	1.06	1.36	1.58	1.50	0.83	0.75	0.98
CD	2.84	2.63	3.925	3.78	4.39	4.16	0.31	2.07	2.73
				Nutrient management (N)					
N_1	29.97	30.39	33.89	48.39	38.92	40.87	34.44	35.17	39.21
N_2	35.95	35.33	39.98	58.13	47.82	50.62	41.60	41.66	46.27
N_3	30.27	29.13	33.57	45.93	38.55	39.82	35.03	35.90	38.86
N_4	50.31	46.31	49.38	63.23	53.21	56.93	56.95	53.57	57.13
N_5	49.88	45.28	47.17	66.76	55.27	55.20	57.73	52.40	54.58
N_6	27.76	27.35	30.08	48.26	36.31	37.52	33.08	31.87	34.81
SE_d	1.81	1.69	1.88	2.42	2.81	2.66	1.48	1.34	1.74
CD	3.68	3.43	3.82	4.92	5.72	5.40	3.01	2.72	3.53

Table 2: Phosphorus uptake (kg ha^{-1}) 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	5.57	6.49	5.51	8.64	8.82	7.42	6.43	7.50	6.38
S_2	5.17	6.19	5.33	7.40	7.50	6.35	5.99	7.16	6.36
S_3	4.79	5.85	5.09	6.45	6.57	5.55	5.54	6.78	5.89
SE_d	0.13	0.14	0.09	0.17	0.19	0.21	0.14	0.09	0.08
CD	0.36	0.39	0.26	0.48	0.53	0.59	0.38	0.27	0.22
				Nutrient management (N)					
N_1	3.43	4.14	3.57	5.53	5.31	4.30	3.94	4.80	4.13
N_2	4.87	6.00	5.72	7.86	7.93	7.23	5.62	6.95	6.61
N_3	3.78	4.43	3.73	5.74	5.51	4.47	4.38	5.13	4.32
N_4	7.94	9.26	6.74	9.98	10.64	7.79	9.19	10.72	7.79
N_5	8.52	10.45	8.58	11.63	12.75	10.35	9.86	12.09	9.92
N_6	2.51	2.76	3.54	4.26	3.64	4.43	2.93	3.20	4.09
SE_d	0.23	0.25	0.14	0.30	0.33	0.37	0.26	0.16	0.14
CD	0.47	0.51	0.32	0.61	0.67	0.75	0.53	0.32	0.28

with increase in levels of P indicating that the highest yield obtained with 60 kg P_2O_5 ha^{-1}[28] 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[22]. 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

Table 3: Potassium uptake (kg ha^{-1}) 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	28.29	28.33	30.95	44.55	38.74	41.54	32.65	31.63	36.23
S_2	25.94	26.76	29.70	38.21	32.97	35.40	30.06	314.05	34.36
S_3	24.39	25.68	28.76	33.36	28.99	31.13	28.22	29.72	33.29
SE_d	0.83	0.71	0.35	1.31	1.09	1.46	0.5	0.37	0.67
CD	2.31	1.96	0.98	3.63	3.04	4.06	1.38	1.02	1.87
Nutrient management (N)									
N_1	21.41	23.48	26.76	34.57	30.11	32.28	24.60	27.18	30.96
N_2	25.26	27.00	30.46	40.85	35.68	35.57	29.23	31.25	35.25
N_3	22.70	23.63	26.11	34.45	29.37	31.26	26.27	27.35	30.22
N_4	35.75	38.18	38.16	44.93	40.44	43.99	41.37	38.41	44.15
N_5	32.85	33.09	34.31	44.84	40.39	41.36	38.02	38.29	40.54
N_6	19.23	19.14	23.01	32.63	25.42	28.69	22.38	28.31	26.63
SE_d	1.46	1.25	0.63	2.30	1.91	2.57	0.89	0.65	1.18
CD	2.96	2.53	1.27	4.65	3.87	5.20	1.80	1.32	2.39

Table 4: Sulphur uptake (kg ha^{-1}) 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	4.51	6.95	7.61	7.06	9.50	10.24	5.19	8.03	8.81
S_2	4.13	6.56	7.30	6.06	8.08	8.72	4.78	7.62	8.45
S_3	3.84	6.12	7.08	5.29	7.11	7.67	4.44	7.24	8.19
SE_d	3.13	0.14	0.09	0.17	0.33	0.38	0.39	0.14	0.13
CD	0.36	0.40	0.26	0.48	0.92	1.06	0.53	0.38	0.36
Nutrient management (N)									
N_1	2.67	4.42	6.42	4.28	5.66	7.74	3.05	5.11	7.41
N_2	4.18	6.75	7.23	6.76	8.92	9.36	4.83	7.81	8.38
N_3	2.84	4.73	6.53	4.31	5.88	7.81	3.29	5.47	7.56
N_4	5.96	8.71	8.75	7.49	10.00	10.09	6.89	10.07	10.12
N_5	5.35	8.36	8.15	7.31	10.20	9.82	6.20	9.67	9.43
N_6	3.94	6.57	6.90	6.67	8.71	8.61	4.57	7.65	7.98
SE_d	0.23	0.24	0.16	0.30	0.56	0.67	0.32	0.24	0.21
CD	0.47	0.49	0.32	0.61	1.13	1.36	0.67	0.49	0.21

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[25]. 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.*[24] that sulphur increased the yield of greengram.

Table 5: Post harvest soil available NPK (kg ha^{-1}) 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	220.3	14.80	221.0	199.8	15.17	221.2	222.1	14.33	218.3
S_2	222.5	15.12	218.8	204.5	15.31	223.5	225.4	14.49	224.1
S_3	227.1	15.12	219.6	204.5	15.31	223.5	225.4	14.49	224.1
SE_d	2.1	0.41	3.8	3.2	0.51	4.0	1.9	0.39	4.3
CD	5.8	NS	NS	NS	NS	NS	5.3	NS	NS
				Nutrient management (N)					
N_1	218.8	14.69	217.2	197.5	15.02	220.9	222.9	13.98	221.0
N_2	222.3	14.98	219.1	201.9	15.49	224.4	224.3	14.32	223.0
N_3	217.8	14.54	218.4	197.6	15.06	221.7	219.6	14.34	222.9
N_4	233.6	15.87	224.3	213.5	15.65	229.6	235.5	15.36	229.3
N_5	229.7	15.59	222.8	208.2	15.68	229.1	232.0	15.04	227.4
N_6	217.7	14.65	216.9	198.4	15.04	223.3	219.3	13.95	220.7
SE_d	3.7	0.72	5.9	5.2	0.89	6.9	3.2	0.71	7.3
CD	7.5	NS	NS	11.6	NS	NS	6.5	NS	NS

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	

	kharif 2002 SE_d	*kharif* 2002 CD	*rabi* 2002 SE_d	*rabi* 2002 CD	summer 2003 SE_d	summer 2003 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

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[15], Singh *et al.*[29] and Rao and Ghildiyal[23] who also 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 2). 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

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

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 N, P, K and S uptake increased with increase in plant population from 3.33 to 5.0 lakh plants ha^{-1} in all the three seasons. Among the nutrient management practices, N, K and S uptake was higher with 125 per cent or 150 per cent NP along with foliar spraying of DAP and SOP. Regarding P, 150 per cent NP along with foliar sprays resulted in higher uptake. Post harvest soil available N was more under recommended population (3.33 lakh plants ha^{-1}). Application of 125 per cent or 150 per cent NP along with foliar sprays recorded higher and comparable soil available N. The availability of P and K was neither influenced by spacing nor by nutrient management practices. Higher plant density favoured the grain and bhusa yield. Similarly higher yield was observed when applied with 125 per cent NP along with foliar sprays during *kharif* 2002 and summer 2003 and with 150 per cent NP with foliar sprays during *rabi* 2002.

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