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Nodulation, Yield and Economics of Machine Planted Chickpea (*Cicer arietinum* L.) under Varied Spacing and Nutrient Management

M. Karthika[1], K. Bhanu Rekha[1], K.S. Sudhakar[1], P. Rajaiah[2], A. Madhavi[3], S. Triveni[4]

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ABSTRACT

Background: Among the agronomic practices, optimum plant population and balanced nutrient management are pivotal for enhanced pulse production besides ensuring soil health.

Methods: Present study was conducted during *rabi* 2020-21 and 2021-22 in split plot design with four main plots *viz*; seed rate (52, 70, 77 and 105 kg ha^{-1}) and seven sub-plot nutrient management practices *viz.,* N_1- absolute control , N_2- 75% RDF, N_3- 100% RDF (20:50:20 kg N, P_2O_5 and K_2O ha^{-1}), N_4 -125 % RDF, S_5- 75% RDF + soil application of microbial consortia (*Azotobacter* + Phosphorus solubilizing bacteria (PSB) + Potassium releasing bacteria (KRB)+ Zinc solubilizing bacteria (ZnSB) @ 5 kg ha^{-1}), N_6- 100 % RDF + MC and N_7- 125% RDF + MC.

Result: Higher nodulation, seed yield (25.8 q ha^{-1}) and economics (net returns ` 88807 ha$^{-1}$ and B-C ratio 2.92) were registered with seed rate of 105 kg ha$^{-1}$. However, protein content of chickpea was better with seed rate of 52 kg ha$^{-1}$. Among the nutrient management treatments, crop growth, nodulation, seed yield (25.8 q ha$^{-1}$) and economics (net returns ` 84388 ha^{-1} and B-C ratio 2.90) were found to be better with application of 125% RDF + Microbial consortia. Significant and positive correlation was found between the parameters at p<0.01.

Key words: Correlation, Economics, Machine planted chickpea, Nodulation, Yield.

INTRODUCTION

India plays crucial role as largest producer (25% of global production), consumer (27% of global consumption) and importer (14%) of pulses in the world (John *et al.,* 2021). Under the current context to reduce the pulse imports, efforts must be concentrated towards increasing cultivation and inclusion of pulse crops in crop rotation as it ensures higher yields and improves soil biodiversity and soil health (Moring *et al.,* 2021).

Pulses play a crucial role on nitrogen cycling by the symbiotic nitrogen fixation. Nodulation and resultant symbiotic N fixation vary significantly with the agronomic practices (plant population, nutrient management and soil nitrogen availability). Among the pulses, chickpea (*Cicer arietinum* L.), is drought tolerant, suitable for rainfed conditions in marginal areas and remained an important source of vegetarian protein (20-22%) and superior to other pulses (Jukanti *et al.*, 2012). Apart from protein, it is a good source of minerals, calcium, essential amino acids and several bio-active compounds (phytates, lectins and enzyme inhibitors) that help in reducing the risk of chronic diseases like cardiovascular diseases, cancer, leukoderma *etc*., (Wallace *et al.,* 2016) and considered as "functional food" (Yegrem, 2021). Chickpea is cultivated in over 50 countries and India has the largest production and accounts for over 65% of total world production (Merga *et al.,* 2019). In India, chickpea is cultivated in an area of about 10 M ha with a total production of 11.9 M t and productivity of about 1192 kg ha^{-1} during 2021-22 (Anonymous, 2022). Inspite of the pivotal role played by India towards pulse production, there has been a continuous demand-supply gap resulting in a steep increase in prices and import of pulses. Pulse production has been caught in the vicious cycle of unstable and low yields owing to farmer's preference to cultivate them

[1]Department of Agronomy, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar-500 030, Hyderabad, Telangana, India.
[2]All India Coordinated Research Project on Farm Implements and Machinery Scheme, Professor Jayashankar Telangana State Agricultural University, Rajendranagar-500 030, Hyderabad, Telangana, India.
[3]All India Coordinated Research Project on Soil Test Crop Response Scheme, Professor Jayashankar Telangana State Agricultural University, Rajendranagar-500 030, Hyderabad, Telangana, India.
[4]Department of Bio-energy and Microbiology, Professor Jayashankar Telangana State Agricultural University, Rajendranagar-500 030, Hyderabad, Telangana, India.

Corresponding Author: Karthika, M., Department of Agronomy, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar-500 030, Hyderabad, Telangana, India. Email: karthika15895@gmail.com

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on marginal lands. Thus, there is still a need of second green revolution for technological progress in pulse crops (Ahlawat *et al.,* 2016).

In the recent past with the scarcity of labor and hike in wages, farm mechanization paves the way to relieve labor shortages and to enhance work efficiency (Shivam and Animesh, 2020). Sowing window particularly for *rabi* chickpea is very small and mechanization ensures timely sowing and other field operations (Dimate *et al.*, 2018), reduces drudgery and post- harvest losses (Shilpa *et al.*, 2017). Planters provide desired plant population with uniform spacing and depth of operation (Singh *et al.*, 2012), thereby reduce cost of cultivation due to elimination of thinning and gap filling operations as well as saving of seed and fertilizer cost (Dubey, 2011).

To meet the present and future requirement of pulse production, mechanization of pre and post-harvest operations along with varietal improvement and optimization of agronomic practices are the need of the hour (Anonymous, 2050). Optimum plant population along with balanced nutrient management sustains pulse production besides soil health (Pathak *et al.,* 2017). The present study is therefore aimed to have interlinked picture of nodulation, chlorophyll and protein content, yield and economics of machine planted chickpea under varied spacing and nutrient management practices.

MATERIALS AND METHODS

The field investigation was carried out at Agricultural Research Institute (ARI), Professor Jayashankar Telangana State Agricultural University (PJTSAU), Rajendranagar, Hyderabad during the *rabi* seasons of 2020-21 and 2021-22 (November - February). The climate of the experimental site was classified as dry tropical and semi-arid and comes under Semi-Arid Tropical region (SAT) according to Troll's climatic classification.

Textual class of the soil was sandy clay loam and the reaction of the soil was slightly alkaline in nature (pH-8.31), non-saline (EC-0.191 dsm^{-1}), low in organic carbon (0.37%), low in available nitrogen (176 kg ha^{-1}), high in available phosphorus (73 kg ha^{1}), high in available potassium (524 kg ha^{-1}). The pH, EC and available K were analyzed using standard procedure given by Jackson (1973) while that of organic carbon by Walkley and Black (1934), available N by Subbiah and Asija (1956) and available P by Olsen *et al.* (1954).

The experiment was laid out in split plot design consisting of four main plots *viz*; seed rate (52, 70, 77 and 105 kg ha^{-1}) with corresponding planting densities of P_1 - 2.22 lakh ha^{-1}, P_2 5- 2.96 lakh ha^{-1}, P_3 -3.33 lakh ha^{-1} and P_4 -4.44 lakh ha^{-1} sown at 45 cm × 10 cm, 45 cm × 7.5 cm, 30 cm × 10 cm and 30 cm × 7.5 cm spacings, respectively. The CIAE planter (Manufactured by Central Institute of Agricultural Engineering, Bhopal) was calibrated in the Engineering workshop, AICRP on Farm implements and Machinery, PJTSAU to obtain desired seed rate for four planting densities consisting of 2 inter row spacings (45 cm and 30 cm) and 2 intra row spacing (7.5 and 10 cm) achieved by using seed metering plates of 18 and 16 cells. The seven sub-plot treatments consisted of nutrient management practices *viz.,* N_1- absolute control (0- N, P and K), N_2- 75% RDF, N_3- 100% RDF (20:50:20 kg N, P_2O_5 and K_2O ha^{-1}), N_4 -125% RDF, S_5- 75% RDF + soil application of Microbial consortia (MC - *Azotobacter* + Phosphorus solubilizing bacteria (PSB) + Potassium releasing bacteria (KRB) + Zinc solubilizing bacteria (ZnSB) @ 5 kg ha^{-1}), N_6- 100% RDF + MC and N_7- 125% RDF + MC. Entire dose of P (Single super phosphate) and K (Muriate of potash) and 50% dose of N (urea) were applied as basal while, remaining 50% dose of N was top dressed at 30 days after sowing (DAS). Microbial consortia (*Azotobacter* + PSB + KRB + ZnSB) was obtained by mixing all the bio-fertilizer strains in equal proportion and was applied @ 5 kg ha^{-1} along with 250 kg vermicompost to the soil as basal by spreading uniformly throughout the respective treatment plots (N_5, N_6 and N_7).

Basal application of vermicompost @ 200 kg ha^{-1} was applied uniformly to all experimental plots along with 750 g of *Rhizobium*, 750 g of *Trichoderma viridae* and 750 g of *Pseudomonas sp.* to ensure control against fungal diseases. Pre-emergence herbicide application with tank mixture of pendimethalin (Dhanutop) and imazethapyr (Cheetah) @ 1 kg a.i ha^{-1} was done at 2 days after sowing (DAS). In plots with row spacing of 45 cm, weeding was done with the help of power weeder while, in plots with row spacing of 30 cm, weeding was carried out using wheel hoe. Plant protection measures were taken up as per the recommendation to the crop. Harvesting was done using mechanical reaper.

Assessment of root nodules

The destructive plant samples taken at peak flowering stage and roots of the plants were carefully washed. All the nodules were removed and collected separately. All the collected nodules were counted and fresh weight was recorded. The nodules were oven-dried at 60°C for 24 hours and dry weight was recorded.

Soil plant analysis development (SPAD)

Chlorophyll content of the third leaf from the top was taken from five tagged plants using SPAD meter (Apogee MC-100 Chlorophyll concentration meter) at peak flowering stage. The chlorophyll concentration was measured from the corresponding SPAD values using the relationships developed by Ling *et al.* (2011). The total chlorophyll per unit area (n moles cm^{-2}) was worked out from the equation:

$$Y= 0.0419x^2 + 1.6475x + 1.5239. \; R^2=0.99$$

The chlorophyll concentration mg^{-1} fresh weight of leaf tissue was obtained from the relationship.

$$Y= 0.0007x^2 + 0.0230x+ 0.0544. \; R^2=0.9809$$

Protein content

Protein content was calculated from nitrogen content using the formula given by Merill and Watt (1973).

$$\text{Protein content (\%)} = N \times 6.25$$

Economics

The existing market price for the seed and haulm were taken for calculating the gross returns (` ha^{-1}) under different treatments.

Net returns (` ha^{-1})

Net returns (` ha^{-1}) was computed using the formula:

Net returns (` ha^{-1}) = Gross returns - Cost of cultivation

Benefit -cost ratio

Benefit cost ratio was worked out using the formula:

$$\text{Benefit -cost ratio} = \frac{\text{Gross returns}}{\text{Cost of cultivation}}$$

Statistical analysis

Data on nodulation, yield, protein content and economics were scrutinized using analysis of variance technique for split plot design suggested by Gomez and Gomez (1984). To test the significance, least significance difference was worked out using WINDOSTAT software. The means were separated by Duncan multiple range test (DMRT) for normally distributed data at 95% confidence level and correlation studies were conducted using SPSS software.

RESULTS AND DISCUSSION

Nodule number plant^{-1}, fresh and dry weight

Mean number of nodules recorded were 36.4, 34.9, 32.9 and 32.0 under the seed rate treatments of 105, 77, 70 and 52 kg ha^{-1} respectively. Among the seed rate, 52 kg ha^{-1} resulted in significantly lowest number of nodules (32.0) over 105 kg ha^{-1} (36.4). This might be attributed to a corresponding increase in number of plants per unit area that increased competition for nitrogen that activated higher nodulation as compared to lower seed rate wherein, higher available N per plant reduced the competition and reflected in lower number of nodules per plant at seed rate of 52 kg ha^{-1}. These results are in line with those of Wafula *et al.* (2021). Results were in contrary with those of Kumar *et al.* (2016) who found non-significant effects due to spacing on nodule number in mung bean. Highest nodule number registered in the present study with seed rate of 105 kg ha^{-1} might be attributed to higher plant population and nitrogen demand in contrast to lower plant population under low seed rate. These results find support from the findings of Waskle *et al.* (2019).

Among the nutrient management practices, significantly higher number of nodules were recorded under absolute control (37.3) and the lowest nodules were registered with application of 125% RDF alone (31.7). Nodule fresh and dry weight also followed a similar trend as nodule number plant^{-1}. Low nodulation associated with different nutrient management treatments over absolute control could be ascribed to the inhibitory effect of fertilizer application as reported by Namvar *et al.* (2011). Significantly higher nodule fresh and dry weights registered in control plots might be ascribed to the higher number of nodules and lowest nodule fresh and dry weight recorded in fertilized plots might be ascribed to the lower number of nodules. Higher dose of fertilization decreased nitrogenase activity of rhizobia bacteria, inhibiting root infection and nodule development. Similarly, Salvagiotti *et al.* (2008) also reported a negative exponential relationship between fertilizer rate and nodulation in soybean. In the presence of effective rhizobia in the soil, the legume crop will fix N, if there is less availability of mineral N in soil as in the case of absolute control (176.2 kg N ha^{-1}).

SPAD value and chlorophyll concentration

From Table 1, it can be inferred that seed rate of 52 kg ha^{-1} resulted in significantly higher SPAD value (47.8) while, the lowest value of 42.7 was recorded under seed rate of 105 kg ha^{-1}. Similarly, significantly higher chlorophyll concentration (3.37 n moles mg^{-1} and 214.3 n moles cm^{-2}) was recorded with the seed rate of 52 kg ha^{-1}, while the lowest was recorded under the seed rate of 105 kg ha^{-1} (2.76 n moles mg^{-1} and 176.3 n moles cm^{-2}). Less dense plant population from seed rate of 52 kg ha^{-1} provided better opportunity to the individual plants to utilize the resources like nutrients, moisture and light in a better way in contrast to the dense population under higher seed rate. With better supply of nutrients and moisture, nutrient uptake by the plant increases. Nitrogen is the chief constituent of chlorophyll, proteins and amino acids, the synthesis of which is accelerated through increased supply of nitrogen. This increased the chlorophyll concentration and hence the SPAD values in wider spacing. Similar results with respect to higher SPAD values with lower seed rate were earlier reported by Patil *et al.* (2020).

Among the nutrient management practices, 125% RDF + MC @ 5 kg ha^{-1} resulted in significantly higher SPAD value (49.2) over 75% RDF (41.8) and absolute control (40.8). Significantly higher chlorophyll concentration was recorded with application of 125% RDF + MC (3.66 n moles mg^{-1} and 232.4 n moles cm^{-2}) which remained statistically at par with 125% RDF alone (3.41 n moles mg^{-1} and 216.9 n moles cm^{-2}) and 100% RDF + MC (3.40 n moles mg^{-1} and 216.5 n moles cm^{-2}). Significantly lower chlorophyll concentration was found with absolute control (2.28 n moles mg^{-1} and 146.1 n moles cm^{-2}). Higher chlorophyll concentration could be ascribed to the adequate N from added fertilizers along with the microbial consortia though solubilization of native nutrient. Further, balanced supply of nutrients increased leaf chlorophyll concentration which in turn had resulted in higher SPAD values of the treatment. A similar increase in SPAD values with an increase in fertilizer dose and conjunctive application of inorganic fertilizers and bio-inoculants in pigeon pea crop was reported by Kumar and Singh (2012).

Protein content

Protein content differed significantly among the seed rate and nutrient management practices. However, their interaction remained insignificant (Table 1).

Table 1: Nodulation, SPAD, chlorophyll concentration and protein content of chickpea as influenced by seed rate and nutrient management (mean of 2 years; *rabi* 2020-21 and 2021-22).

Treatments	Nodule number plant^{-1}	Nodule fresh weight (mg plant^{-1})	Nodule dry weight (mg plant^{-1})	SPAD value	Chlorophyll concentration (n moles mg^{-1})	Chlorophyll concentration (n moles cm^{-2})	Protein (%)
Main plot-Seed rate (M)							
M_1- 52 kg ha^{-1}	32.0b	49.8b	20.9b	47.8a	3.37a	214.3a	20.19a
M_2- 70 kg ha^{-1}	32.9bc	51.1b	21.5b	45.1ab	3.14ab	200.3ab	20.03ab
M_3- 77 kg ha^{-1}	34.9ab	53.7a	23.2a	44.5ab	3.01bc	191.7bc	19.78bc
M_4- 105 kg ha^{-1}	36.4a	55.6a	24.7a	42.7b	2.76c	176.3c	19.63c
LSD (p=0.05)	1.83	3.02	1.62	3.05	0.10	6.1	0.23
Sub plot-Nutrient management (S)							
S_1- Absolute control	37.3a	56.2a	25.1a	40.8b	2.28d	146.1d	19.54c
S_2- 75% RDF	34.7abc	52.9bc	22.9abc	41.8b	2.69c	171.7c	19.67bc
S_3- 100% RDF	32.8bc	51.9bcd	21.9bc	44.9ab	3.07bc	196.1bc	19.87abc
S_4- 125% RDF	31.7c	49.8d	20.7c	48.1a	3.41ab	216.9ab	20.21a
S_5- 75% RDF + MC	36.0ab	53.9ab	23.8ab	44.3ab	2.98bc	189.9c	19.81abc
S_6- 100% RDF + MC	33.2bc	52.6bcd	22.6bc	46.0ab	3.40ab	216.5ab	20.02ab
S_7- 125% RDF + MC	32.6c	50.8cd	21.2c	49.2a	3.66a	232.4a	20.23a
LSD (p=0.05)	2.95	2.68	2.16	4.84	0.40	25.2	0.41
Interaction (M × S)							
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS
Interaction (S × M)							
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS

Note: In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT at same level; DMRT= Duncan's multiple range test; LSD= Least significant difference.

Significantly higher protein content was found with seed rate of 52 kg ha^{-1} (20.19%) and among the nutrient management practices it was highest with the application of 125 % RDF + MC (20.23%). On the other hand, across the seed rates lowest protein content was registered with 105 kg ha^{-1} (19.63%) and with absolute control (19.54%) among the nutrient management practices. Improved protein content with wider spacing (45 cm) resulted in less competition between individual plants for nutrients that improved the absorption thereby increasing the protein content. Kumar *et al.* (2020) also reported higher protein content under wider spacing. Ability of the crop to convert inorganic N into protein in the seed is more efficient with enhanced N application. Similar findings of high protein content with increase in dose of fertilizer conjunctively with microbial inoculants were reported by Sangma and Changade (2020).

Yield

Significantly higher seed (25.8 q ha^{-1}) and haulm (29.1 q ha^{-1}) yields were recorded with the seed rate of 105 kg ha^{-1}. Lower yields were recorded with the seed rate of 52 kg ha^{-1}. This might be attributed to optimum number of plants per unit area at the seed rate of 105 kg ha^{-1} which helped in better utilization of resources, hence more photosynthesis and assimilate translocation from source (leaf) to sink (seed). Patil *et al.* (2021) also reported significantly higher seed and haulm yield with higher seed rate in machine planted chickpea.

Among the nutrient management practices, application of 125% RDF + MC resulted in significantly higher seed (25.8 q ha^{-1}) and haulm yield (28.0 q ha^{-1}). Yield reduction in chickpea was observed in absolute control with respect to both seed (17.8 q ha^{-1}) and haulm (21.2 q ha^{-1}). This could be ascribed to the fact that 125 % and 100% RDF facilitated adequate amount of nutrients in available form to the crop that favored better growth and development of root system thereby higher nutrient uptake and yield. Nawange *et al.* (2018) and Sangma and Changde (2020) also reported similar results with respect to improved seed yield in chickpea.

Economics

Economic analysis of chickpea (Table 2) reported significantly higher net returns (` 88807 ha$^{-1}$) and B-C ratio (2.92) at the seed rate of 105 kg ha$^{-1}$ when compared to the seed rate at 52 kg ha$^{-1}$ (` 54079 ha^{-1} and 2.30). Higher proportion of increase in seed yield than seed cost might have resulted in higher net returns at higher seed rate. With increase in seed cost of ` 2033 ha$^{-1}$, additional net returns of ` 13,406 ha^{-1} were obtained at the seed rate of 105 kg ha^{-1} as compared to seed rate of 77 kg ha^{-1}. Sujathamma and Babu (2019) also reported similar increase in net returns with higher seed rate in machine planted chickpea.

Table 2: Yield and economics of chickpea as influenced by seed rate and nutrient management (mean of 2 years; *rabi* 2020-21 and 2021-22).

Treatments	Seed yield (q ha^{-1})	Haulm yield (q ha^{-1})	Gross returns (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net returns (Rs ha^{-1})	B-C ratio
Main Plot-Seed rate (M)						
M_1- 52 kg ha^{-1}	18.2d	21.6c	95265d	41011	54254c	2.31c
M_2- 70 kg ha^{-1}	21.6c	24.3b	112807c	42235	70573b	2.66b
M_3- 77 kg ha^{-1}	22.9b	26.1b	119371b	43970	75401b	2.71b
M_4- 105 kg ha^{-1}	25.8a	29.1a	134809a	46003	88807a	2.92a
LSD (p=0.05)	0.82	2.37	4194	-	4194	0.10
Sub plot-Nutrient management (S)						
S_1- Absolute control	17.8e	21.2d	92835e	39585	53250d	2.33d
S_2- 75% RDF	20.0d	23.7cd	104515d	42521	61994c	2.45cd
S_3- 100% RDF	21.7cd	25.7abc	113337c	43275	70062c	2.61bc
S_4- 125% RDF	24.6ab	27.5ab	128415ab	44027	84388ab	2.90a
S_5- 75% RDF + MC	21.2c	24.4bcd	110825c	43821	67004c	2.52cd
S_6- 100% RDF + MC	23.8b	26.4abc	124258b	44575	79683b	2.78ab
S_7- 125% RDF + MC	25.8a	28.0a	134756a	45327	89429a	2.97a
LSD (p=0.05)	1.54	2.96	7819	-	7819	0.19
Interaction (M × S)						
LSD (p=0.05)	NS	NS	NS	-	NS	NS
Interaction (S × M)						
LSD (p=0.05)	NS	NS	NS	-	NS	NS

Note: In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT at same level; DMRT= Duncan's multiple range test; LSD= Least significant difference.

Table 3: Correlation between nodulation, SPAD, chlorophyll concentration, protein content and seed yield of chickpea.

	Nodule number plant^{-1}	Nodule fresh weight (mg plant^{-1})	Nodule dry weight (mg plant^{-1})	SPAD value	Chlorophyll concentration (n moles cm^{-2})	Protein content (%)	Seed yield (q ha^{-1})
Nodule number plant^{-1}	1	0.580**	0.562**	-0.188	-0.321**	-0.304**	0.066
Nodule fresh weight (mg plant^{-1})		1	0.915**	-0.277*	-0.336**	-0.429**	0.056
Nodule dry weight (mg plant^{-1})			1	-0.229*	-0.274*	-0.430**	0.036
SPAD value				1	0.682**	0.296**	0.041
Chlorophyll concentration (n moles cm^{-2})					1	0.395**	0.208
Protein content (%)						1	0.041
Seed yield (g plant^{-1})							1

Note: **indicates correlation is significant at 0.01 level. *indicates correlation is significant at 0.05 level.

Among the nutrient management practices, application of 125% RDF + MC resulted in significantly higher net returns and B-C ratio (` 89429 ha$^{-1}$ and 2.97) which was closely followed by 125% RDF alone (` 84388 ha^{-1} and 2.90). Higher seed and haulm yield with increased fertilizer dose had resulted in higher net returns with 125% RDF + MC. Dewangan *et al.* (2017) also reported similar results with respect to improved haulm yield in chickpea with integrated nutrient management.

Correlation studies

Significant and positive correlation was observed among investigated traits of chickpea at p<0.005 and p<0.001 (Table 3). Nodulation parameters (nodule number, fresh and dry weight) were found to be inversely correlated with SPAD, chlorophyll concentration, protein content. While, positive correlation was observed with seed yield. This indicates that N mineral fertilizer rather than symbiotic nitrogen fixation had determinant effect on growth, yield and quality of chickpea. These findings find support from the results of Agraw and Tsigie (2015) who reported negative correlation between nodulation and yield of common bean. SPAD values exhibited highly significant correlation with chlorophyll concentration and protein content (p<0.001) and significant relationship with seed yield (p<0.005). SPAD values were significantly correlated to chlorophyll concentration indicating that it has direct influence on SPAD value. Similar relation between SPAD and chlorophyll was reported by Chugh and Sharma (2021). A significant and positive correlation was also observed between seed yield and nodulation/SPAD/chlorophyll concentration/protein content ($p<0.005$). SPAD and chlorophyll are positively correlated to seed yield and protein content. This might be ascribed to the fact that SPAD and chlorophyll are dependent on nitrogen fertilization and better growth of the crop. Similar correlations were reported by Ghimire *et al.* (2015) and Kendal, 2015. The results emanating from the present study emphasize towards research need for complete mechanization of chickpea cultivation (seed- seed) with suitable machinery to increase cultivated area under chickpea through timely operations and to enhance farm efficiency and income by reduction of input costs.

CONCLUSION

From the present study in machine planted chickpea, it can be concluded that seed rate of 105 kg ha^{-1} resulted in better yield and economics while, nodulation and quality of chickpea was better at the seed rate of 52 kg ha^{-1}. SPAD values exhibited highly significant correlation with chlorophyll concentration and protein content and seed yield. Chickpea crop was responsive and economical to the application of higher dose of fertilizer (125% RDF + soil application of Microbial consortia @ 5 kg ha^{-1}) due to lower soil nitrogen status.

Conflict of interest: None.

REFERENCES

Ahlawat, I.P.S., Sharma, P. and Singh, U. (2016). Production, demand and import of pulses in India. Indian Journal of Agronomy. 61(3): 33-41.

Anonymous, (2022). www.indiastat.com. Ministry of Agriculture and Farmers Welfare. Government of India.

Anonymous, (2050). Indian Institute of Pulses Research (Indian Council of Agricultural Research) Kanpur www.iipr.res.in.

Argaw, A. and Tsigie, A. (2015). Indigenous rhizobia population influences the effectiveness of Rhizobium inoculation and need of inorganic N for common bean (*Phaseolus vulgaris* L.) production in eastern Ethiopia. Chemical and Biological Technologies in Agriculture. 2(1): 1-13.

Chugh, P. and Sharma, P. (2021). Effect of Heat Stress on the relationship between SPAD and Chlorophyll Content in Indian Mustard Genotypes. Current Journal of Applied Sciences and Technology. 40 (15): 38-47.

Dewangan, S., Singh, R.P., Singh, M.K. and Singh, S. (2017). Effect of integrated nutrient management and drought mitigating practices on performance of rainfed chickpea (*Cicer arietinum*). Indian Journal of Agricultural Sciences. 87(3): 301-305.

Dimate, A. S. Dogra, B., Dogra, R. Reddy, S. Srinivas, I. and Adake, R.V. 2018. Mechanization Scenario and in Chickpea Cultivation-Current Scope. Agriculture Update. 42 (3):1-11.

Dubey, S.K., Sah, U. and Singh, S.K. (2011). Participatory impact assessment of technological interventions disseminated in Bundelkhand region of Uttar Pradesh. Journal of Food Legumes. 24: 36-40.

Ghimire, B., Timsina, D. and Nepal, J. (2015). Analysis of chlorophyll content and its correlation with yield attributing traits on early varieties of maize (*Zea mays* L.). Journal of Maize Research and Development. 1(1): 134-145.

Gomez, K.A. and Gomez, A.A. (1984). Statistical procedures for agricultural research. Second Edition. An International Rice Research Institute Book. A Wiley-Inter-science Publication, John Wiley and Sons, New York.

Jackson, M. L. (1973). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd. New Delhi, India.

John, A.T., Makkar, S., Swaminathan, S., Minocha, S., Webb, P., Kurpad, A.V. and Thomas, T. (2021). Factors influencing household pulse consumption: A multilevel model analysis. Global Food Security. 29. doi.org/10.1016/j.gfs.2021.100534.

Jukanti, A., Gaur, P., Gowda, C., Chibbar, R. (2012). Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.): A review. British Journal of Nutrition. 108 (S1): S11-26. doi:10.1017/S0007114512000797.

Kendal, E. (2015). Relationship between chlorophyll and other features in durum wheat [*Triticum turgidum* (L.) var. durum] using SPAD and biplot analyses. Journal of Agriculture, Science and Technology. 17: 1873-1886.

Kumar, M., Panwar, G.S. and Kushwaha, S. (2016). Effect of planting date, seed rate and row spacing on nodulation efficiency of bold seeded spring mung bean [*Vigna radiata* (L.) Wilczek] in Bundelkhand region of India. Legume Research-An International Journal. 39(2): 293-296.

Kumar, R., Kumar, M., Awasthi, U.D., Singh, A.K. and Kumar, D. (2020). Response of row spacing, bio-fertilizer and nitrogen levels on yield attributes and quality parameters of chickpea (*Cicer arietinum* L.). International Journal of Current Microbiology and Applied Sciences. 9(2): 452-459.

Kumar, S.A. and Singh, R.S. (2012). Effect of phosphorus levels and bio-inoculants on growth and yield of long duration pigeonpea (*Cajanus cajan* L.). Journal of Food Legumes. 25(1): 73-75.

Ling, Q., Huang, W. and Jarvis, P. (2011). Use of a SPAD-502 meter to measure leaf chlorophyll concentration in Arabidopsis thaliana. Photosynthesis Research. *107*(2): 209-214.

Merga, B., Haji, J. and Yildij, F. (2019). Economic importance of chickpea: Production, value, and world trade. Cojent Food and Agriculture. 5: 1. DOI: 10.1080/23311932.2019.1615718.

Merill, L.A and Watt, B.K. 1973. Energy Value of Food: Basis and Derivation. United States Department of Agriculture. Hand Book No. 74. Pp: 4.

Moring, A., Hooda, S., Raghuram, N., Adhya, T.K., Ahmad, A., Bandyopadhyay, S.K., Barsby, T., Beig, G., Bentley, A.R., Bhatia, A. and Dragosits, U. (2021). Nitrogen challenges and opportunities for agricultural and environmental science in India. Frontiers in Sustainable Food Systems. doi: 10.3389/fsufs.2021.505347.

Namvar, A., Sharifi, R.S. and Khandan, T. (2011). Growth analysis and yield of chickpea (*Cicer arietinum* L.) in relation to organic and inorganic nitrogen fertilization. Ekologija. 57(3): 97-108.

Nawange, D.D., Verma, H.D. and Hemlata, V. (2018). Growth and yield performance of *kabuli* chickpea (*Cicer arietinum* L.) genotypes under different planting geometry and fertility levels in vindhya plateau region. International Journal of Agriculture Sciences. 10(5): 5291-5293.

Olsen, S. R., Cole, C.V., Watanabe, Fs. and Dean, L.A. (1954). Estimation of available phosphorous in soil by extraction with sodium bi-carbonate. USDA. Circular 1939: 19- 23.

Pathak, J., Ambreesh, S., Yadav, S., Sharma, A. and Arora, S. (2017). Integrated Nutrient Management in Pulses for Nutritional Security and Rural Livelihood. In Book: Sustainable Farming and Soil Health Management. Soil Conservation Society of India, New Delhi, India.

Patil, S.B., Mansur, C.P., Gaur, P.M., Salankinkop, S.R. and Alagundagi, S.C. (2021). Planting density affected dry matter production, partitioning and yield in machine harvestable chickpea genotypes in the irrigated ecosystem. International Journal of Plant Production. 15: 29-43.

Patil, S.B., Mansur, C.P., Gaur, P.M., Salkinkop, S.R. and Alagundagi, S.C. (2020). Physiological and agrometeorology indices of machine harvestable chickpea genotypes in different planting density under rainfed ecosystem. Journal of Pharmacognosy and Phytochemistry. 9(5): 523-530.

Salvagoitti, F., Cassman, K.G., Specht, J.E., Walters, D.T., Weiss, A. and Dobermann, A. (2008). Nitrogen uptake, fixation and response to fertilizer N in soybeans: A review. Field Crop Research. doi: 10.1016/j.fcr.2008.03.001.

Sangma, A.S. and Changade, N.M. (2020). Different fertilizer dose and biofertilizer inoculation's effect on N, P and K content and uptake of chickpea (*Cicer arietinum* L.). European Journal of Molecular and Clinical Medicine. 7(7): 2340- 2348.

Shilpa, P.C., Mundinamani, S.M. and Rudrapur, S. (2017). Comparitive economic analysis of chickpea cultivation in mechanized and non-mechanized farms of India. Agriculture Update. 12(3): 770-776.

Shivam, R.N. and Animesh, S.G. (2020).Agricultural mechanization in India. International Journal of Creative Research Thoughts. 8(5): 2595-2605.

Singh, M.K., Kumar, N., Verma, P. and Gar, S.K. (2012). Performance evaluation of mechanical planters for planting of chickpea and Pigeonpea. Journal of Food Legumes. 25(2): 131-134.

Subbiah, B. V. and Asija, G.L. (1956). A rapid method for the estimation of nitrogen in soil. Current Science. 26: 259-260.

Sujathamma, P. and Babu, D.V. (2019). Standardization of seed rate for mechanical sowing of newly released varieties of chickpea. International Journal of Current Microbiology and Applied Sciences. 8(2): 1719-1724.

Wafula, J.K., Njoka, F.M., Nthakanio, P.N., Mosioma, J.O., Mukono, S.T. and Onyari, C.A.N. (2021). Nodulation and protein content of selected chickpea varieties as impacted by spacing and N-fertilizer rates in Eastern Kenya. African Journal of Agricultural Research. 17(6): 882-895.

Walkley, A.J. and Black, I.A. (1934). An experimentation of the method for determination of soil organic matter and a proposed modification of chromic acid titration method. Soil Science. 37: 29-39.

Wallace, T.C., Murray, R. and Zelman, Z.K. (2016). The nutritional value and health benefits of chickpeas and Hummus. Nutrients. 8: 766. doi: 10.3390/nu8120766.

Waskle, U., Singh, R.P., Ninama, A., Dwivedi, M. and Dwivedi, V. (2019). Impact of row spacing in chickpea genotypes (*Cicer arietinum* L.). Bulletin of Environment, Pharmacology and Life Sciences. 8(6): 04-10.

Yegrem, L. (2021). Nutritional composition, antinutritional factors and utilization trends of Ethiopia chickpea (*Cicer arietinum* L.). International Journal of Food Science. https://doi.org/10.1155/2021/5570753.