Int.J.Curr.Microbiol.App.Sci **(2020) Special Issue-11: 956-965**

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Special Issue-11 pp. 956-965**
Journal homepage: http://www.ijcmas.com

Original Research Article

Effect of Row Spacing and Nutrient Management on Yield and Quality of Soybean [*Glycine max* (L.) Merrill]

C. Mahapatra* and S. N. Shah

Department of Agronomy, B. A. College of Agriculture, Anand Agricultural University, Anand-388 110, Gujarat, India

**Corresponding author*

Keywords

Nutrient management, Row spacing, Soybean

A B S T R A C T

A field experiment was conducted during *kharif*, 2019 at Agronomy farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat to study the effect of row spacing and nutrient management levels on yield and quality parameters of soybean. The soil of the experimental plot was loamy sand in texture locally called "Goradu" soil, low in organic carbon and available nitrogen, medium in available phosphorus and low in available potassium. The experiment was laid out in Split plot design comprising two factors *viz*., row spacing of 30 and 45 cm and nutrient management with five levels *i.e*., 1) 100 % RDF [(100% RDF (45:60:00 N-P_2O_5-K_2O kg ha^{-1})], 2) 100% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching, 3) 75% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment, 4) 75% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching, 5) Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching. Total 10 treatment combinations were replicated four times. At 30 cm row spacing, significant increase in plant height, no. of root nodules, seed yield and stover yield were recorded, whereas maximum pods per plant was reported at wider spacing (45 cm). Similarly, tested nutrient management practice *viz.*, 100 % RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching exhibited better performance with respect to growth and yield attributes *i.e.*, plant height, branches $plant^{-1}$, no. of root nodules $plant^{-1}$, dry weight of nodules $plant^{-1}$, microbial count (cfu per g soil), no. of pods $plant^{-1}$, seed index, seed yield and stover yield ; however, found at par with [(100% RDF (45:60:00 N-P_2O_5-K_2O kg ha^{-1})]. Henceforth, crop sown at 30 cm row spacing and fertilized with 100% recommended dose of fertilizer (45:60:00 N-P_2O_5-K_2O kg ha^{-1}) + Bio NP (*Rhizobium* + PSB) as seed treatment @ 5 ml kg^{-1} seed + Bio NP as soil drenching @ 1 litre ha^{-1} at 25-30 DAS can be acknowledged as a bumper yielding and remunerative operation.

Introduction

Soybean *(Glycine max* (L.) Merrill) is known as soja bean, soya bean, chinese pea and manchurian bean which belongs to family *Fabaceae* and has Eastern Asian origin. Soybean is considered as a wonder crop due to its dual qualities *viz*., high protein (40-43 per cent) and oil content (20 per cent). In addition to this, soybean protein has 5 per cent lysine, which is deficit in most of the cereals and enriching cereal flour with soybean improves the nutritive quality (Narayana *et al*., 2009). It is gaining rapid recognition as a highly desirable pulse and oil seed crop. It is the third most vital oilseed crop next to groundnut and rapeseed-mustard. India stands next only to China with respect to global area and production of soybean, while USA, Brazil and Argentina are the leading producers. In India, the total acerage of soybean cultivation is 11.2 million ha with the production and the productivity of 10.5 million metric tons and 937 kg ha^{-1}, respectively (Anon., 2019-20). Among the states, Madhya Pradesh and Maharashtra are solely contributing 89% of total production, where rest 11% shared by Rajasthan, Andhra Pradesh, Karnataka, Chhattisgarh and Gujarat. In Gujarat, 1.342 million ha of cultivated area is indulged in production of 1.241 million metric tons yielding about 673 kg ha^{-1} (Anon., 2019-20).

Among various factors influencing growth and yield of soybean, row spacing is considered important. Establishment of an optimum plant density per unit area through adjusting plant geometry is a non-monetary input factor for getting higher soybean production. Planting soybean in rows ensures easy intercultural operations as well as modulates the microclimatic factors related to growth and development of the crop. Mostly when planted in narrow rows, "thin-line" varieties usually yield more than "fat-line" varieties at wider spacing. Although, higher yield can be assured at narrow row spacing with high population, lodging becomes the main problem. Besides it, low light availability to the lower canopy may affect nodulation followed by nitrogen fixation. More scientific efforts needed to increase the productivity of soybean per unit area and per unit time with optimum row spacing. With response to spatial differentiation, soybean shows high phenotypic plasticity. In order to compensate low population at wider spacing, it produces more no. of branches along with high pod weight per plant (Procopio *et al.*, 2013).

Besides it, nutrient availability factor has been shown to play vital role in boosting soybean productivity (Mishra *et al.*, 1990). Oilseeds and legumes have relatively higher P requirements over other crops as it is a constituent of phospholipids, which are important in formation of cell membrane and its permeability. In addition to P, soybean also has a relatively high nitrogen requirement especially at later growth stages (Wantanabe *et al.*, 1983). Average recommended dose of fertilizer for soybean is 45:60:00:20 (N-P_2O_5–K_2O-S in kg ha^{-1}). Fertilizer plays an important role in substantial increase in crop production as its rate of nutrient dissemination is higher than organic sources.

However, fertilizer production costs high exhaustion of fossil energy source and moreover, being a costly input, declines the income value of farmers. Another situation is further compounded by the fact that almost 75-90% of such chemical fertilizers with high P content is precipitated by metal cation complexes present in the soil, which reduces the availability of P content to plant. *Rhizobium* and Phosphate Solubilizing Bacteria (PSB) have capability in augmenting the productivity of pulses considerably through N and P needs. Hence, it is imperative to explore the diverse soil and agroclimatic condition through organisms with phosphate solubilizing abilities, so that they increase the availability of soluble phosphate and can enhance plant growth by increasing the efficiency of biological nitrogen fixation or enhancing the availability of other trace elements such as Fe, Zn *etc*. and by production of plant growth promoting regulators (Sattar and Gaur, 1987; Ponmorugan and Gopi, 2006).

Nodules contain millions of bacteria (*Rhizobium japonicum*). The bacteria enter the soybean root hairs and work with the plant through a process called symbiosis. Bacteria in nodules convert nitrogen from the air into a form usable by plants. In time, the plant supplies Carbon rich photosynthates to the bacteria for multiplication and tissue building. Well nodulated soybeans generally do not need nitrogen fertilization. Nodulation and nitrogen fixation are decreased by high soil nitrogen. When soybeans are grown regularly in a rotation, they may not need to be inoculated each time. It may be possible to increase symbiotic N fixation further with more competitive and effective strains of nodulating bacteria, together with improved inoculation techniques. These essential plant nutrients can be supplied from different sources *viz*., organic manures, crop residues, agro wastes, bio-fertilizers *i.e.* inoculation with *Bradyrhizobium japonicum* for facilitating N_2 fixation (ranging from 49-150 kg N ha^{-1} of fixation capacity), *Bacillus* and *Pseudomonas sp*. *etc*. for P solubilization in soil. Now on behalf of Dept. of Microbiology in AAU, Anand there is a new liquid biofertilizer product called "Anubhav Bio NP consortia" through co-inoculation of *Azotobacter / Azospirillum / Rhizobium* and PSB) in specified proportion supplied to all departmental plant nutrient management researches.

Materials and Methods

A field experiment was conducted during *kharif* 2019 at the Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat which is geographically situated at 22^0-35' N latitude and 72^0-55' E longitude with an elevation of 45.1 m above mean sea level in a semi-arid and sub-tropical climate. The soil of the experimental site was loamy sand in texture with fine friability and moisture retentive capacity. In relation to chemical properties, the soil was neutral in reaction (pH 7.11) and less saline (EC 0.22 dS m^{-1}). It was low in both organic carbon (0.47%) and available nitrogen (223.56 kg ha^{-1}), whereas, medium in available phosphorus (34.20 kg ha^{-1}) and available potassium (208.69 kg ha^{-1}). The experiment was laid out by NRC 37 variety (Ahilya 4) in split plot design with four replications. The treatment consisted of two row spacing *viz.*, 30 cm (S_1) and 45 cm (S_2) in main plot and five nutrient management practices *viz.*, N_1 : 100% RDF (45:60:00 N-P_2O_5-K_2O kg ha^{-1}), N_2 : 100% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching, N_3 : 75% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment, N_4 : 75% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching, N_5 : Bio NP (*Rhizobium* + PSB) comprising ten treatment combinations.

Soybean was sown on 2^{nd} July, 2019 using seed rate of 60 kg ha^{-1} at two row spacings (30 and 45 cm) as per the treatment maintaining 10 cm plant to plant spacing in each plot. Prior to sowing, Bio NP (*Rhizobium* + PSB) was applied @ 5 ml kg^{-1} seed as seed treatment. During layout preparation, FYM @ 5 t ha^{-1} was incorporated in the soil as a common application in all treatments. As per the treatments, nitrogen and phosphorus were supplied as urea and DAP, respectively with recommended dose of 45:60:00 N-P_2O_5-K_2O kg ha^{-1}) as basal dose at the time of sowing. In response to lower seedling emergence, at 14 DAS gap filling was done. Further, at 7 DAS thining operation was carried out manually to attain an optimum crop stand. At 25 DAS, as per the treatments, Bio NP (*Rhizobium* + PSB) was applied @ 1 litre ha^{-1} as soil drenching at 25-30 DAS. Afterwards as per crop growth behavior, different agricultural operations *viz.*, irrigation, hoeing, hand weeding, herbicide and pesticide application. Finally, at 108 DAS on 18^{th} October, 2019 the crop was harvested, winnowed and threshed.

Prior to sowing, five representative soil samples from each plot were collected to estimate physical and chemical properties as initial soil test value. Similarly, five plants were selected at random from net plot area and labeled with tags for measuring the plant height from ground level to the base of fully unfolded top leaf at 30 and 60 DAS. The average number of branches from five random plants were counted.

Five random plants were uprooted as representative from each plot. The root portion was carefully cleaned with tap water to count the effective number of nodules. Thereafter, the counted nodules were kept in hot air oven at 60-65^0 C for 24 hrs and nodule dry weight was calculated in mg plant^{-1}. During uprooting of above plants, soil from 15 cm depth was collected, from which 10 g soil was weighed. To 10 gm soil, 90 ml sterile saline water was added and then, it is serially diluted to 10^{-7}. From that, 0.1 ml sample was taken in agar plate media following spread plate technique and then, it was incubated at 37^0 C for 48 hr. The number of colony forming units were counted.

Colony forming units (cfu) per g soil sample =

$$\frac{\text{No. of colonies} \times \text{dilution factor}}{\text{Dry weight of soil sample taken}}$$

At harvesting, those 5 plants were sampled from the net plot of each plot to observe the yield attributes like number of pods plant^{-1}, number of seeds pod^{-1}, seed index, seed yield and stover yield. Seed yield was worked out by deducting stover yield from the total above ground biological yield (bundle weight before threshing) for each treatment. Collected seeds from the treatments were counted up to 100 seeds in a seed counter followed by weighing in a weighing machine. Harvest index was calculated by dividing the economical yield from total biological yield.

Harvest index (HI %) =

$$\frac{\text{Seed yield} \times 100}{\text{Seed yield + Stover yield}}$$

After harvest, from each plot five representative soil samples were collected to estimate the physio-chemical properties of soil. Soil samples were oven dried in hot air oven at 105^0 C for 48 hrs to a constant weight. Then, by quartering method 500 g soil was extracted.

Following Micro-Kjeldahl's method, nitrogen content was estimated by taking 20 g soil from each treatment followed by mixing with water and digestion mixture of 0.32% $KMnO_4$ and 2.5% NaOH. This prepared solution along with some glass beads were heated in a distillation flask and under the distillation receiver tube 4% Boric acid containing mixed indicator was kept to collect Ammonium borate. This solution was then titrated against 0.1N H_2SO_4.

Available phosphorus content in ground soil sample was determined through Olsen's meter method using 0.5 M $NaHCO_3$ extractant followed by taking absorbance reading in spectrophotometer at 660 nm wave length.

Similarly, to estimate available potassium content 5 g soil sample was digested in Neutral N ammonium acetate solution and the filtered solution was fed in to flame photometer.

The data were statistically analyzed with standard method outlined for split plot design as described by Cochran and Cox (1957). Statistically significance was tested by F-value at 0.05 % level of probability and critical difference was worked out where ever the effect was significant.

Results and Discussions

Growth attributes

With respect to different growth attributes (Table 1) *viz.,* plant height, number of branches, dry weight and number of nodules at 45 DAS displayed substantially significant treatment effect with respect to both row spacing and nutrient management treatments.

At 30 cm row spacing, plants exhibited inter-competition for sunlight owing to high plant population, which attributed towards more stem elongation and higher plant height. But, at 45 cm row spacing, less population density might have encouraged intra-row competition for moisture and nutrition followed by better vegetative growth, which leads to more no. of branches. Number of root nodules were found high at narrow spacing due to inter-competitional effect, whereas maximum dry weight of nodules recorded due to intra-competition. These results were also supported by Halvankar *et al.,* (1999), Ibrahim and Kandil (2007), Cox *et al.,* (2011) and Verma *et al.,* (2020).

With respect to nutrient management treatments, N_2 treatment [100% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching] exhibited significantly maximum estimates of above growth parameters. However, it was found at par with N_1 [(100% RDF (45:60:00 N-P_2O_5-K_2O kg ha^{-1})] in relation to plant height, no. of branches and dry weight of nodules. It can be attributed to the fact that nitrogen and phosphorus supply from chemical fertilizers and organic resources had stimulating effect on vegetative growth as well as upon nodulation, which might have added more biomass to the root nodules. There was non-significant interaction effect reported with respect to above parameters except no. of branches. These findings were in agreement with Argaw (2012), Abbasi *et al.,* (2008), Devi *et al.,* (2012), Solomon *et al.,* (2012) and Ezekiel–Adewoyin *et al.,* (2017).

The results as depicted in figure 1 indicated the significant estimate of microbial count in terms of cfu per g soil sample obtained from serial dilution technique with respect to nutrient management treatments, whereas significant influence owing to row spacing was nullified. With application of N_2 treatment [100% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching] there was significantly higher count of microbes reported (159.88 × 10^{-7} cfu/g soil). Contrarily, whereas the least count of 70.50 × 10^{-7} CFU g^{-1} soil was recorded with N_1 treatment [100% RDF (45:60:00 N-P_2O_5-K_2O kg ha^{-1})].

Yield attributes

Among different crop geometries, at 45 cm row spacing significantly maximum no. of pods per plant was observed, which may be due to vigorous growth of plant that attributed towards maximum translocation followed by efficient assimilation of photosynthates. However, no. of seeds per plant as rather a genetic character, did not claim any significant influence. In relation to seed index, significantly higher estimate was recorded at wider row spacing of 45 cm, which may be accredited with stockpiling of high dry matter in the beans due to less competitive interruption during translocation of photosynthates (Table 2).

Among the nutrient management treatments, with application of N_2 treatment [100% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching] maximum no. of pods, no. of seeds per pod and higher seed index were recorded, however was found at par with N_1 treatment [100% RDF (45:60:00 N-P_2O_5-K_2O kg ha^{-1})].

These parameters failed to display any significant interaction effect. . This is in accordance with the results reported by Devi *et al.*, (2012), Sarawgi *et al.*, (2012) and Rana *et al.*, (2013).

Table.1 Growth attributes of soybean influenced by row spacing and nutrient management treatments

Treatments	Plant height (cm)	Branches plant^{-1}	No. of root nodules plant^{-1}	Dry weight of root nodules plant^{-1} (mg)
Row spacing (S)				
S_1 : 30 cm	68.55	3.50	29.90	123.20
S_2 : 45 cm	64.83	4.15	27.80	126.96
S.Em ±	0.80	0.09	0.46	0.82
C.D. (P = 0.05)	3.61	0.40	2.09	3.71
C.V.%	5.38	10.40	7.19	2.95
Nutrient management (N)				
N_1 : 100% RDF (45:60:00 N-P_2O_5-K_2O kg ha^{-1})	69.24	4.38	29.25	127.33
N_2 : 100% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching	71.95	4.50	32.00	132.92
N_3 : 75% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment	65.68	3.50	27.88	122.64
N_4 : 75% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching	67.39	3.75	29.38	124.96
N_5 : Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching	59.18	3.00	25.75	117.54
S.Em.±	1.11	0.14	0.59	1.93
C.D. (P = 0.05)	3.23	0.41	1.73	5.63
Interaction (S X N)				
S.Em.±	1.57	0.20	0.84	2.73
C.D. (P = 0.05)	NS	0.58	NS	NS
C.V.%	4.70	10.40	5.80	4.37

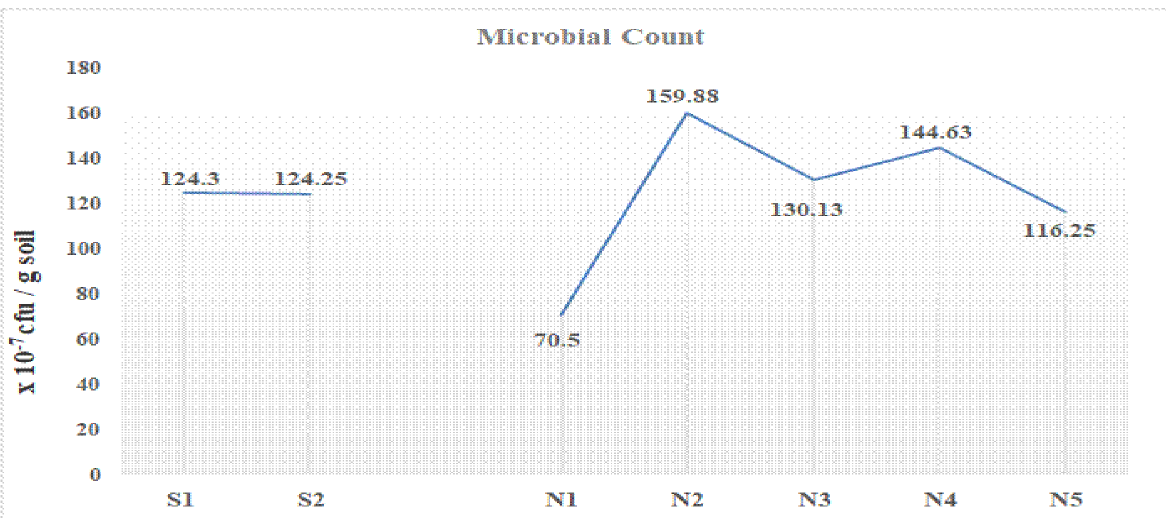
Table.2 Yield attributes and yield estimates of soybean as influenced by row spacing and nutrient management

Treatments	**No. of pods plant^{-1}**	**Seeds per pod**	**Seed Index (g)**	**Grain yield (kg ha^{-1})**	**Straw yield (kg ha^{-1})**	**Harvest Index (%)**
Row spacing (S)						
S_1 : 30 cm	49.60	2.35	9.62	2118	2660	44.32
S_2 : 45 cm	54.50	2.40	10.18	1929	2447	44.08
S.Em ±	0.98	0.04	0.12	41	45	-
C.D.	4.41	NS	0.55	186	204	-
C.V.%	8.43	6.66	5.47	9.15	7.92	-
Nutrient management (N)						
N_1 : 100% RDF (45:60:00 N-P_2O_5-K_2O kg ha^{-1})	55.13	3.00	10.06	2033	2556	44.29
N_2 : 100% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching	56.13	3.00	10.14	2226	2795	44.33
N_3 : 75% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment	51.13	2.25	9.91	2017	2538	44.28
N_4 : 75% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching	51.50	2.25	9.98	2090	2626	44.31
N_5 : Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching	46.38	1.38	9.40	1753	2254	43.74
S.Em.±	1.23	0.11	0.17	53	64	-
C.D. (P = 0.05)	3.60	0.31	0.50	154	188	-
S×N Interaction						
S.Em.±	1.74	0.15	0.24	75	91	-
C.D. (P = 0.05)	NS	NS	NS	NS	NS	-
C.V.%	6.70	12.75	4.91	7.37	7.12	-

Table.3 Economic analysis of soybean as influenced by row spacing and nutrient management

Treatments	Total cost of cultivation (₹ . ha^{-1})	Gross realization (₹ . ha^{-1})	Net realization (₹ . ha^{-1})	B:C Ratio
Row spacing (S)				
S_1 : 30 cm	25556	2.35	9.62	3.36
S_2 : 45 cm	23564	2.40	10.18	3.32
Nutrient management (N)				
N_1 : 100% RDF (45:60:00 N-P_2O_5-K_2O kg ha^{-1})	55.13	3.00	10.06	3.53
N_2 : 100% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching0	56.13	3.00	10.14	3.83
N_3 : 75% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment	51.13	2.25	9.91	3.63
N_4 : 75% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching	51.50	2.25	9.98	3.74
N_5 : Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching	46.38	1.38	9.40	3.57

Fig.1 Microbial count in soil at 15 cm depth as influenced by row spacing and nutrient management treatments



Yield

At narrow crop geometry (30 cm) there was significantly higher grain and stover yield recorded, which can be attributed to the fact that owing to maximum population density, high estimates of yield parameters were recorded. Similarly, with application of N_2 treatment [100% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching] maximum grain yield and stover yield were reported. However, there was no any significant interaction effect observed. This is in line agreement with Board *et al.*, (1992), Halvankar *et al.,* (1999), Pederson *et al.*, (2003), Devani *et al.*, (2003), Ibrahim and Kandil (2007) and Bruin and Pederson (2008).

Economy

Maximum gross and net realization with higher BCR value were fetched at narrow row spacing of 30 cm (S_1), whereas among the nutrient management treatments, N_2 treatment **[**100% RDF + Bio NP (*Rhizobium* + PSB) as seed treatment + Bio NP as soil drenching**]** accrued the highest estimate (Table 3).

Based on foregoing discussion, it can be concluded that for obtaining higher yield, net return and benefit cost ratio of soybean, crop should be sown at 30 cm row spacing and fertilized with 100% recommended dose of fertilizer (45:60:00 N-P_2O_5-K_2O kg ha^{-1}) + Bio NP (*Rhizobium* + PSB) as seed treatment @ 5 ml kg^{-1} seed + Bio NP as soil drenching @ 1 litre ha^{-1} at 25-30 DAS.

Acknowledgement

Author would like to express their gratefulness to Principal and Dean, B.A. College of Agriculture and Professor and Head, Department of Agronomy for their proficient guidance and providing all types of facilities during the term of candidature work, without their cherished assistant this work would not completed.

References

Abbasi, M. K., Majeed, A., Sadiq, A. and Khan, S. R. (2008). Application of *Bradyrhizobium japonicum* and Phosphorus Fertilization Improved Growth, Yield and Nodulation of Soybean in the Sub-humid Hilly Region of Azad Jammu and Kashmir, Pakistan. *Plant Production Science*, 11(3): 368-376.

Anonymous (2019-20). Soybean Production by State. Soybean Processors Associations of India (2019-20).

Argaw, A. (2012). Evaluation of Co-inoculation of *Bradyrhizobium japonicum* and Phosphate Solubilizing *Pseudomonas spp.* effect on Soybean (*Glycine max* L. (Merr.)) in Assossa Area. *J. Agr. Sci. Tech*., 14: 213-224.

Board, J. E., Kamal, M. and Harville, B. G. (1992). Temporal importance of greater light interception to increased yield in narrow-row soybean. *Agronomy Journal*, 84(4): 575-579.

Bruin, J. L. D. and Pederson, P. (2008). Effect of row spacing and seeding rate on soybean yield. *Agronomy Journal*, 100(3): 704-710.

Cochran, W. G. and Cox, G. M. (1957).Experimental design.2nd ed. Wiley, New York.

Cox, W. J. and Cherney, J. H. (2011). Growth and yield responses of soybean to row spacing and seeding rate. *Agronomy Journal*, 103(1): 123-128.

Devani, Lenis, M. R., J. M., Ledesma, F., Gandur, M. A. and Gratia, M. B. (2003). Response of soybean cultivars of maturity group III, IV, V to row spacing reduction in spring planting in Tucuman and its area of influence. *Revista Industrial Y Agricola De Tucuman*, 80(1-2): 37-43.

Devi, K. N., Singh, L. N. K., Devi, T. S., Devi, H. N., Singh, T. B., Singh, K. K. and Singh, W. M. (2012). Response of soybean [*Glycine max* (L.) Merrill] to sources levels of phosphorus. *Journal of Agricultural Sciences*, 4(6): 44-53.

Ezekiel–Adewoyin, D. T., Ewusi-Mensah, N., Oluwafemi, O. A., Ogunleti, D., Adekunle, A. and Kayode, C. (2017). Nodulation, growth and yield response of soybean [(*Glycine max* L. (Merrill)] to inoculum (*Bradyrhizobium japonicum*) under phosphorus levels and compost amendment in Northern Ghana. *Net Journal of Agricultural Science*, 5(4): 141-150.

Halvankar, G. B., Verghese, P., Taware, S. P. and Raut, V. M. (1999). Influence of planting geometry and variety on seed yield and related parameters in soybean. *Indian Journal of Agronomy*, 44(3): 601-604.

Ibrahim, S. A. and Kandil, H. (2007). Growth, yield and chemical constituents of soybean (*Glycine max* L.) plants as affected by plant spacing under different irrigation intervals. *Research Journal of Agriculture and Biological Sciences*, 3(6): 657-663.

Mishra, R. C., Sahu, P. K. and Uttaray, S. K. (1990). Response of soybean to nitrogen and phosphorus. *J. Oilseed Res*., 7: 6-9.

Narayana, L., Gurumurthy, K. T. and Prakasha, H. C. (2009). Influence of integrated nutrient management on growth and yield of soybean [*Glycine max* (L.) Merrill]. *Karnatak J. Agric. Sci*., 22(2): 435-437.

Pedersen, P. and Lauer, J. G. (2003). Corn and soybean response to rotation sequence, row spacing, and tillage system. *Agron. J.*, 95: 965–971.

Ponmurugan, P. and Gopi, C. (2006). In-vitro production of growth regulators and phosphatase activity by phosphate solubilizing bacteria. *African J. Biotechnol.*, 5, 348-350.

Procópio, S. O., Balbinot Junior, A. A., Debiasi, H., Franchini, J. C. and Panison, F. (2013). Plantio cruzado na cultura da soja utilizando uma cultivar de hábito de crescimento indeterminado. *Revista de Ciências Agrárias*, 56: 319-325.

Rana, M., Pathania, P. and Khaswan, S. L. (2013). Effect of biofertilizers and phosphorus on productivity and nutrient uptake of soybean [*Glycine max* (L.) Merrill]. *Annals Agric. Res*., 34(3): 245-247.

Sarawgi, S. K., Chitale, S., Tiwari, A. and Bhoi, S. (2012). Effect of Phosphorus application along with PSB, *Rhizobium* and VAM on P fractionation and productivity of soybean (*Glycine max*). *Indian J. Agron*., 57(1): 55-60.

Sattar, M. A. and Gaur, A. C. (1987). Production of auxins and gibberellins by phosphate dissolving micro-organisms. *Zbi. Mikrabiol*., 142 : 393-395.

Solomon, T., Pant, L. M. and Angaw, T. (2012). Effects of inoculation by *Bradyrhizobium japonicum* strains on nodulation, nitrogen fixation, and yield of soybean (*Glycine max* L. Merrill) varieties on nitisols of Bako, Western Ethiopia. *International Scholarly Research Network (ISRN) Agronomy*. Article ID 261475.

Verma, C., Tripathi, V. K. and Singh, I. (2020). Response of newly released varieties of soybean [*Glycine max* (L.) Merrill] to crop geometry planted on ridge and furrow system. *Journal of Pharmacognosy and Phytochemistry*, 9(1): 216-221.

Wantanabe, I., Tabuchi, K. and Nakano, H. (1983). Response of soybean to supplemental nitrogen after flowering. In producing of symposium soybean in tropical and sub-tropical cropping systems, held at Tsaukaba, Japan during 24th September- 1st October 1983. Pp. 301-308.