Res. Jr. of Agril. Sci. **11**(6): 1332-1342, Nov-Dec 2020

ISSN: 0976-1675

www.rjas.org

Research Journal of Agricultural Sciences

© Centre for Advanced Research in Agricultural Sciences

Research Paper

DI: 6291-2407-262

Applications of Organic and Synthetic Fertilizers for Sustainable Production of Soybean Crop (*Glycine max* L.) and Improvement in Soil Health

R R Lohar*[1], C P Hase[2] and J D Kapurkar[3]

[1]Postgraduate Research Center in Environmental Science,
Baburaoji Gholap College, Sangvi, Pune - 411 027, (RIT, Rajaramnagar, Sangli), Maharashtra, India
[2]Department of Botany, Baburaoji Gholap College, Sangvi, Pune - 411 027, Maharashtra
[3]Sushilanand Agro Polyclinic, Islampur, Kisannagar, Uran Islampur - 415 409, Maharashtra

Received: 24 July 2020; Revised accepted: 31 August 2020

A B S T R A C T

A field experiment was conducted on black cotton soil for two consecutive rabbi seasons (2018, 2019) to investigate the effects of organic and synthetic fertilizers on growth and yield as well as seed quality of soybean crop along with soil health parameters using cultivar *JS-335*. The results revealed that combined applications of organic manures and synthetic fertilizer improved the growth and seed yield as well as oil content, protein and carbohydrate contents as compared to control and other treatments. Similarly, the various soil health parameters were also greatly significantly improved. The sustainable use of both organic and inorganic fertilizers together enhanced economic yield, agronomic efficiency, physiological efficiency, partial factor productivity, apparent recovery efficiency, sustainable yield index etc. It is concluded from the above experiment that combined application of RDF (30:80:20:40) + FYM & RDF (30:80:20:40) + VCM emerged as promising method for sustainable cultivation of soybean in the region of Sangli district (Maharashtra).

Key words: Soybean, RDF, FYM, VCM, Growth parameters, Yield, Oil content, Nutrient quality, Soil health

Soybean (*Glycine max* L.) is one of the most economic and nutritious crop which is rich in protein, carbohydrate contents and oil contents (Anonymous 2014-15, Vijayalaxmi *et al*. 2017). Many food items like soy-milk, sauce, paste, cake, paneer, soy-flour, soy-namkeen and soy flakes are prepared from soybean at commercial scale. These food items are very popular among the consumers. It is also added to bread, cereals and meat products (Huang *et al*. 2014, SOPA 2015). Apart from its nutritious values it is highly useful in curing many health disorders such as heart diseases, malignancy, HIV etc. (Kumar 2007). Soybean protein is rich in lycin, different minerals, vitamins like thiamine and riboflavin (Singh *et al*. 2004, Dass *et al*. 2018). Because of these nutrient qualities in soybean it is known as 'vegetarian meat' and described as a 'miracle crop'. Soybean is placed at the top among oil seed crops, contributing about 25% to the world's oil production. The area under soybean cultivation at global level is 121.53 million hectares and production is 334.89 million tons. In India the area under soybean cultivation is 11.72 million hectares with a production of 10.5 million tons (ICAR 2018). Leading states in the cultivation of soybean are M. P., Rajasthan, Maharashtra, and AP. This crop improves soil fertility by fixing atmospheric nitrogen through its root nodules. The leaf fall also add to humus content in the soil and help to improve soil health and soil microflora.

It was reported that organic manures along with synthetic fertilizers improved the physico-chemical properties of soil and soil microflora (Deshmukh *et al*. 2005). It is accounted that application of FYM and Vermicompost to soybean caused sufficient increase in plant growth and seed yield in both seasons (Bandopadhyay *et al*. 2010, Ranjitha *et al*. 2016). Javed and Panwar (2013) reported that combination of organic and inorganic fertilizers cause greater increase in yield of soybean. To meet the global demand of soybean implementation of sustainable practice of its cultivation is need of time. Considering all these realities present investigation was

***Corresponding author:** R. R. Lohar, Senior Instructor, Sciences and Humanities Department, RIT, Rajaramnagar, Maharashtra

e-mail: rajaram.lohar@ritindia.edu | **Contact:** +91- 7709242092

under taken to evaluate the effects of sustainable agricultural practices through applications of different fertilizers on soil health, growth parameters, yield of crop and quality of seeds as well as oil content. The sustainability of agricultural practices was assessed on the basis of sustainable parameters like economic yield, agronomic efficiency, physiological efficiency, partial factor productivity, apparent recovery efficiency, sustainability yield index and quality of seeds containing oil %, protein % and carbohydrate %.

MATERIALS AND METHODS

The present investigation was conducted in the Walwa-tehsil, Sangli district, Maharashtra. Sangli district is located in the western part of Maharashtra having latitude and longitude coordinators are as 16.8676 and 74.5703 respectively. The average temperature is 25.4°C and total annual rainfall is 580 mm. The experimental design was randomized block design with 12 different treatments of organic and synthetic fertilizers for soybean variety JS-335. The seeds as well as FYM, VCM and RDF were procured from authentic and reliable sources. The whole experimental field was divided into three equal blocks and each block was again divided into twelve equal sized plots measuring 2.5 m × 2.5 m in order to accommodate the treatments and control. Total 36 plots were prepared and all the treatments were randomly designed. The treatments schedule was as follows: Recommended dose of fertilizer (RDF-30:80:20:40, N:P:K:S), Farmyard Manure (N-0.5%, P_2O_5-0.15%, K_2O_5-0.5%), Vermicompost (N-2.5%, P_2O_5-1.55%, K-1.85%).

Details of cultivation

The organic and inorganic fertilizer were applied to each plot according to the preplanned doses made specifically for each treatment. Organic manures were applied one month before sowing so that well decomposition of the organic manures would take place for the crop and thoroughly incorporated into soil. The growth parameters, seed yield and biochemical analysis and oil content in the seed was analyzed as and when required by using random collection method of the samples. The experimental plot was ploughed in the mid November after the monsoon rains were over. The field was then harrowed and levelled properly. All stubbles were removed and the layout was done according to experimental design. The seeds of soybean were treated with Rhizobium culture for the entire nutritional schedule as seed treatment before sowing the seeds except for absolute control plot. The required chemical fertilizers were purchased from fertilizer store and by calculating the quantity as per the recommended dose of fertilizer applied to each plot. The seeds were sown directly into the plots by maintaining 10 cm plant to plant and 45 cm row to row spacing. The seeds were sown on 15th November for both consecutive seasons. Irrigation schedule: Soybean requires around 15 inches to over 25 inches of water per year depending on planting date, maturity group, location and climatic conditions. The water demand of soybean is generally low during seedling stage and increment fundamentally during fast vegetative development. The crop was irrigated after 15 to 20 days of interval. Inter cultivation- Time to time inter cultivation for weeding and other operations was carried out regularly.

Application of organic and synthetic fertilizers: The second dose was given before the pod formation.

Harvesting of the pods: The pods were harvested after full maturity of the crop.

Analysis of growth parameters

Plant height- total plant height was measured at 30, 45, 60, and 75 DAS using randomly selected ten plants from each treatment and the average height was calculated.

Number of leaves- Total number of leaves per plant were measured at 30,45 and 60 DAS using randomly selected ten plants from each treatment.

Analysis of yield parameters

Yield parameters like number of immature pods per plant, number of mature pods per plant, number of seeds per pod, Seed index (100 seed weight), total seed yield (kg/ha), stover yield (kg/ha) were analyzed from each treatment using randomly selected ten plants and the average was recorded in tables.

Analysis of seed quality

Oil content- Seed samples of 5g each from all the treatments were taken for extraction of oil. The crushed samples were placed in a thimble and extracted with light petroleum ether for six hours in a soxhlet extraction unit as per the method described by AOAC (1960).

Protein content- The protein content in seed was estimated by the formula:

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

Carbohydrate content: The carbohydrate was determined by carbohydrate subtraction method. The gram of protein, fat, alcohol, water and ash were deducted from the absolute gram weight of the seed sample, and the amount left over is considered for the carbohydrate value.

Seed and stover analysis: The seed and stover samples were isolated after threshing and dried. The dried seed and Stover samples were then grounded in a Willy mill and kept in a polythene bag for chemical analysis.

Analysis of mineral elements: The seed and Stover samples were separately collected after threshing from each plot and dried in oven. The oven dried samples were ground to powder and analyzed for N, P, K and sulphur content. Nitrogen content in both seed and Stover was assessed by modified Kjeldhal method cited by Black (1965). Phosphorus was determined by vanadium-molybdate yellow color method as given by Jackson (1976). Potassium was determined by flame photometry method (Chapman and Pratt (1961). Sulphur content was estimated by "Turbidimetric Method" (Tabatabi and Bremer 1970). The plant samples both seed and Stover were taken separately

and digested completely in nitric acid and then in perchloric acid and the aliquots were mixed with barium gelatin reagents and then percent sulphur was determined by measuring the turbidity calorimetrically using blue filter. The percent sulphur content in both seed and Stover was calculated.

Sulphur uptake by Seed = S content (%) × seed yield (q/ha)
Sulphur uptake by Stover = S content (%) × Stover yield (q/ha)
Sulphur uptake by Crop = S uptake by seed + S uptake by Stover

Soil analysis: The soil samples (0-15cm depth) were collected from the experimental plots. The samples were oven dried after cleaning and grounded and then sieved through 2mm strainer and kept in polythene bag with labels.

Nutrient status of soil: Soil samples were analyzed pH, organic carbon, available nitrogen, phosphorus, potassium and sulphur contents. Available nitrogen was determined by antacid potassium permanganate method (Subbiah and Asija 1956) and the values were expressed in terms of percentage. Available phosphorus was determined by the method of Brays and Kurtz, 1945 using calorimeter. The available potassium was analyzed by flame photometer. Available sulphur was determined by turbidimetric method (Williams and Steinberg's 1969) using UV spectrophotometer at 440nm.

Analysis of sustainability parameters

Harvest index (%), economic yield, agronomic efficiency, physiological efficiency, partial factor productivity, apparent recovery efficiency, Sustainability yield index and quality of seeds containing Oil %, Protein % and Carbohydrate % by using following formulae:

i) Harvest index (%) = $\frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$

ii) Agronomic efficiency (AE) = $\frac{Y - Y_o}{F}$

iii) Physiological Efficiency = $\frac{Y - Y_o}{U - U_0}$

iv) Apparent recovery efficiency (RE) = $\frac{U - U_0}{F}$

v) Partial Factor Productivity (PFP) = $\frac{Y}{F}$

vi) Sustainable Yield Index = $\frac{Ym - SD}{Y_{max}}$

vii) Oil Content (%) = $\frac{W_2 - W1}{X}$

viii) Protein Content = 6.25 × N (%)

Where, *Y*- yield of harvested portion of crop with nutrient applied, Y_o- Yield with not nutrient applied, *F*- Amount of nutrient applied, *U*- Total nutrient uptake in above ground crop biomass with nutrient applied, U_0- Nutrient uptake in above ground crop biomass with no nutrient applied. *Ym*- Mean yield, SD- Standard Deviation, Y_{max}- Maximum yield, W_2- Weight of the empty flask (g), W_1-Weight of empty Flask + Weight of oil (g), *X*= Weight of sample taken for extraction

Statistical analysis

The data for the crop and soil, significance of treatment effect, least significance difference (LSD) at 5% probability level and coefficient of correlations were analyzed by analysis of variance (ANOVA) and using data analysis tool pack of MS Excel (2013).

RESULTS AND DISCUSSION

Growth attributes

Plant height: Improvement in various growth attributes such as plant height, number of leaves per plant, number of branches per plant, leaf area, dry weight etc. contribute directly or indirectly to the crop yield (Khutate *et al*. 2005). It was found that all these parameters were positively influenced by the treatment of different doses of organic fertilizers (FYM and VCM) and inorganic or synthetic fertilizer like RDF. Plant height was increased in soybean by all the treatments used (T_1 to T_{12}). The results recorded in (Table 1) clearly indicated that the application of RDF 125% + Farmyard manure 25% and RDF 125% + Vermicompost 25% had shown significant increase plant height as compare to all other treatments and control. The results are statistically significant. It was 28.30 cm and 28.65cm, 47.65cm and 48.33cm, 67.00 cm and 68.65cm, 69.80 cm and 69.67cm at 30 DAS, 45 DAS, 60 DAS and 75 DAS respectively (Table 1). The maximum plant height (Table 1) was recorded at 30, 45, 60 and 75 DAS in combined application of RDF + FYM and RDF + VCM. The plant height was increased with the advancement of age in all the stages of the crop growth because growth process is irreversible in nature (Patil *et al*. 2016). Increase in plant height causes positively to overall growth of soybean crop. As the plants are exposed to absorb maximum sunlight during photosynthesis, which contribute directly to the yield. Shirpurkar *et al*. (2005), Thakur *et al*. (2010), Saxena *et al*. (2013) also reported the values of the growth attributes like plant height, leaf number, leaf area, leaf area index, branch number etc. Ultimately increasing productivity of soybean.

Number of leaves per plant: The number of leaves per plant (Table 1) was significantly increased with the combined applications of 125% RDF + farmyard manure 25% and 125% RDF + Vermicompost 25%. It was 17.33 and 18.67, 36.67 and 37.00, 72.33 and 73.67 at 30 DAS and 60 DAS respectively. The above treatments of fertilizers cause highest increase in number of leaves per plant as compared to the remaining treatments and control. The combined application of synthetic and organic fertilizers has given best results causing sufficient increase in leaf number

per plant in soybean. Similar results were observed by Gupta and Sharma (2003). The leaves are main photosynthetic organ of every plant, hence increase in number of leaves increases the photosynthetic area and chlorophyll content. The increase in plant height and number of leaves per plant lead to increase in yield. Many researchers Vyas *et al*. (2007), Thakur *et al*. (2010), Devi *et al*. (2011), Kumar *et al*. (2016) reported similar results in different crop.

Table 1 Effect of fertilizer treatments on plant height and number of leaves per plant in Soybean

Season 2018/2019							
Treatments	Plant height DAS (cm)				No. of leaves per plant DAS		
	30	45	60	75	30	45	60
T_1	20.00	32.65	39.67	42.30	9.00	26.33	41.33
T_2	20.60	38.33	53.33	57.35	10.33	18.33	44.33
T_3	21.30	40.00	54.67	58.67	11.67	19.00	45.00
T_4	22.33	42.32	58.00	61.65	10.07	26.67	45.33
T_5	25.30	43.00	60.32	65.33	12.33	34.33	48.67
T_6	26.42	43.65	61.33	67.35	13.00	34.67	48.33
T_7	23.33	45.33	59.67	62.20	13.33	33.67	50.67
T_8	28.30	47.65	67.00	69.80	17.33	36.67	72.33
T_9	28.65	48.33	68.65	69.67	18.67	37.00	73.67
T_{10}	18.30	30.33	32.00	38.20	9.67	24.33	40.33
T_{11}	19.33	32.34	33.00	39.30	10.00	25.67	41.00
T_{12}	14.00	22.67	28.00	38.00	7.67	14.33	36.00
LSD (0.05)	8.06	13.95	28.67	26.69	7.04	15.19	26.31
SE±	1.09	1.88	3.87	3.60	0.95	2.05	3.55
CV%	15.66	15.50	24.06	20.84	25.66	23.66	23.55

LSD-Least Significant difference at p=0.05, SE±: Standard error of mean, CV%: Coefficient of variation

Table 2 Effect of fertilizer treatments on plant dry weight, nodule count per plant, nodule fresh weight, nodule dry weight, number of pods, number of filled pods per plant and number of seeds per pod in soybean

Season 2018/2019

Treatments	Plant dry weight (g)			Nodule count per plant		Nodule fresh weight (g)		Nodule dry weight (g)		No. of pods per plant	No. of filled pods per plant	No. of seeds per pod
	30	45	60	30	45	30	45	30	45			
T_1	2.45	8.50	16.57	8.83	18.50	0.25	0.38	0.072	0.35	50.73	40.00	2.57
T_2	2.48	11.00	17.35	11.35	38.15	0.26	0.40	0.072	0.36	52.27	44.33	2.56
T_3	2.55	11.82	17.62	11.65	31.65	0.27	0.41	0.073	0.37	53.00	44.87	2.62
T_4	2.58	13.52	18.30	10.35	31.33	0.27	0.41	0.081	0.38	51.85	45.33	2.60
T_5	2.80	14.67	18.80	11.80	26.85	0.28	0.42	0.079	0.54	55.10	70.83	2.62
T_6	2.85	14.83	19.00	12.00	27.30	0.30	0.43	0.080	0.55	55.87	70.87	2.67
T_7	2.80	16.50	21.20	16.32	43.10	0.29	0.41	0.093	0.47	56.85	47.87	2.58
T_8	3.15	17.83	23.35	19.33	35.90	0.32	0.42	0.099	0.48	64.80	55.33	2.83
T_9	3.25	18.00	23.45	20.10	36.00	0.33	0.43	0.098	0.48	65.27	56.00	2.90
T_{10}	2.45	7.45	17.90	9.82	34.00	0.23	0.39	0.058	0.34	48.30	39.67	2.25
T_{11}	2.50	7.90	18.00	10.00	34.50	0.24	0.41	0.060	0.34	48.83	40.33	2.30
T_{12}	2.12	6.57	13.15	8.34	20.67	0.22	0.33	0.051	0.25	40.58	33.34	2.34
LSD (0.05)	0.62	8.61	5.28	8.68	14.64	.07	0.034	0.030	0.18	12.76	25.58	0.42
SE±	0.085	1.16	0.71	1.17	2.05	0.009	0.007	0.0044	0.024	1.72	3.45	.057
CV%	10.39	29.93	12.33	30.27	20.22	11.47	3.7	17.51	19.31	10.44	22.72	7.35

LSD-Least Significant difference at p=0.05, SE±: Standard error of mean, CV%: Coefficient of variation

Plant dry weight: Increase in plant dry weight in soybean with different treatments is shown in (Table 2). From the results it was revealed that the combined treatments of RDF + FYM and RDF + VCM emerged as superior treatments causing increase in dry weight of plant as compared to other treatments used and control. The increase in dry weight of soybean was recorded at 30, 45, and 60 DAS. The increase was by 3.15g and 3.25 g, 17.83g and 18.00g, 23.35g and 23.45g at 30, 45 and 60 DAS respectively. All the results are statistically significant. Finding of the present investigation was supported by Khutate *et al*. (2005), Jagmeet *et al*. (2015).

Number of nodules per plant: In leguminous plants like soybean number of nodules on the roots of each plant is very important factor in growth attributes. The root nodules fix atmospheric nitrogen symbiotically and provide it to the host plant. The nitrogen supplied by root nodule bacteria contribute significantly and plays vital role in plant growth (Galeshi *et al*. 2004). In the present study all the treatments

of synthetic and organic fertilizers have significantly induced the increase in number of nodules per plant (Table 2). Due to application of 125% RDF + 25% FYM and 125% RDF + VCM 25%. The increase was by 19.33, 20.10, 35.90 and 36.00 respectively. Both the treatments mentioned above were highly beneficial to soybean plant for increasing the number of nodules per plant. This has directly influenced the various growth attributes like plant height, number of leaves per plant etc. The beneficial effect of farmyard manure, bio inoculants along with RDF provided increased availability of nutrients which considerably resulted in improved nodule development, energy transformation, metabolic processes and root growth, resulting in more dry matter production, number of branches/plant and nodule numbers (Suryawanshi *et al.* 2006, Chaturvedi *et al.* 2010).

Nodule fresh and dry weight

The results on these parameters shown in (Table 2) indicated that the fertilizer treatments of RDF 125% + FYM 25% and RDF 125% + VCM 25% had caused positively increase in fresh and dry weight of nodules in soybean. Nodule fresh weight was 0.32 g, 0.33 g, 0.42 g and 0.43 g at 30, 45, and 60 DAS. Which was much better than control and other treatments. Similar was the case regarding nodule dry weight due to above mentioned both the treatments. The nodule dry weight recorded was 0.099, 0.098, 0.48 and 0.48g at 30, 45 and DAS with both treatments. Similar results were reported by Gupta and Sharma (2003), Billore *et al*. (2009), Sigh *et al*. (2010). They claimed that the combined application of synthetic and organic fertilizers increases positively soil condition as well as enhanced the activity of nodulation resulting into improved vegetative growth of treated plant as compared to control. Further they reported that such type of fertilizer application to plants increases their metabolic activities and causes improvement in various growth parameters. In the present study sulphur present in the RDF is integral component of nitrogenase enzyme playing key role in nitrogen fixation. This may be the probable reason for increase in number of nodules per plant, fresh and dry weight of nodules in soybean treated with RDF + FYM and RDF + VCM (Najar *et al*. 2011). The additional probable reasons for improvement of growth attributes and nodule number, dry and fresh weight of nodule may be due to the different types of enzymes and growth promoting factors secreted by earth worms in vermicompost.

Yield and yield attributes

Number of total pods per plant: The results shown on this parameter in (Table 2) clearly indicated that maximum number of pods per plant were recorded in the treatments of combined applications of RDF + FYM and RDF + VCM as compared to all other treatments and control. The highest number of pods per plant observed in soybean was 64.80 and 65.27 respectively in both the treatments. Similar results were observed by Govidan and Thirumurugan (2005), Rana *et al*. (2018) with combined treatments of organic and synthetic fertilizers for the increase in growth of number of pods per plant.

Number of filled pods per plant: As recorded in (Table 2) highest number of filled pods also recorded in the treatments of combined applications of RDF + FYM and RDF + VCM. The maximum number of filled pods per plant recorded in both the treatments were in between 55 and 56. Both the parameters studied have greatly contributed to increase in economic yield over control and remaining treatments (Shirpurkar *et al*. 2005, Singh *et al*. 2011).

Number of seeds per pod: The results recorded in (Table 2) clearly showed that highest results on this parameter were recorded in the combined treatments T_8 and T_9 i.e. RDF + FYM and RDF + VCM. The significant values are 2.83 and 2.90 seeds per pod respectively. The increase in number of seeds per pod has direct relation with enhanced seed yield or economic yield. All the above parameters mentioned have direct relationship with economic yield in soybean (Surywanshi *et al*. 2006).

Table 3 Effects of fertilizer treatments on inorganic, organic content and oil content in soybean

Treatments	Season 2018/2019							
	N, P, K and S content in seed				Nitrogen uptake (%) by crop	Oil content	Protein	Carbohydrate
	N%	P %	K %	S %	(Stover + Seed)	(%)	content (%)	content (%)
T_1	5.72	0.38	1.72	0.25	124.30	17.10	35.75	13.84
T_2	6.10	0.41	1.92	0.29	134.13	18.02	38.12	16.20
T_3	6.12	0.42	1.94	0.30	135.08	18.10	38.25	16.80
T_4	6.14	0.41	2.21	0.30	173.6	18.30	38.37	16.70
T_5	6.18	0.44	2.32	0.32	182.35	18.38	38.62	18.20
T_6	6.21	0.45	2.34	0.33	182.64	18.42	38.81	18.25
T_7	6.34	0.44	2.47	0.32	205.10	18.55	39.62	17.80
T_8	6.41	0.47	2.52	0.35	209.03	18.75	40.06	25.40
T_9	6.42	0.48	2.57	0.35	210.05	18.88	40.12	25.50
T_{10}	5.28	0.39	1.40	0.26	98.40	17.25	33.00	13.20
T_{11}	5.32	0.40	1.42	0.27	98.46	17.38	33.25	1385
T_{12}	5.20	0.36	1.32	0.20	86.20	16.78	32.5	12.05
LSD (0.05)	0.9	0.07	0.94	0.076	95.37	1.36	5.63	9.31
SE±	0.12	0.009	0.12	0.01	12.89	0.18	0.76	1.25
CV%	6.7	7.5	20.44	11.24	26.83	3.36	6.7	23.48

Seed composition
Seed composition (Seed Quality)

NPK and S content in the seed: All the mineral elements like nitrogen, phosphorus, potassium and sulphur were analyzed on percent basis in the seed. The results shown in the (Table 3) on these parameters indicated that like all the previous parameters discussed the mineral composition of seed also followed the same trend of fertilizer treatment. It was constantly observed that the treatments of RDF + FYM and RDF + VCM have shown similar effects on N, P, K and S contents of the seed. The percent values for N were 6.41 and 6.42 respectively. The values for P were 0.47 and 0.48%. Similarly, the values for K were 2.52 and 2.57% for T_8 and T_9 respectively. While the values for S were 0.35% for both the treatments. Similar results were also reported by Patil *et al*. (2008), Chaturvedi and Chandel (2010).

Oil content: The results shown in (Table 3) on oil content in soybean seed revealed that highest oil content was found in the treatments of RDF + FYM (T_8) and RDF + VCM (T_9). The highest oil content was 18.75% and 18.88% respectively. The other treatments were at par with this. Oil content was increased due to application of various fertilizers as compared to control. The increased oil content in oil seeds may be due to S utilization present in RDF. Similar results were also earlier reported by Singh *et al.* (2004). Application of balanced fertilizers with FYM to soybean crop enhanced the oil content over control (Singh *et al*. 2007, Shivkumar and Ahlawat 2008).

Protein content: The results shown in (Table 3) indicated that protein content was enhanced by 40.06% and 40.12% due to the treatments like T_8 and T_9 respectively. The protein content in other treatments was also at par with the above treatments. Like oil content in soybean seeds it was noted that sulphur application caused enhancement in protein along with amino acid content. It may be due to presence of S in RDF used in the present study. Same trend was also noted regarding increase in both oil and protein contents by several workers like Kiyoko *et al*. (2004). Tanwar and Shaktawat (2003), Laltlanmawia *et al*. (2003) reported similar results with application of phosphorus fertilizer.

Carbohydrate contents: The carbohydrate contents of soybean seed also followed similar trend like protein content (Table 3). Increase in carbohydrate content was by 25.40 and 25.50% in both the treatments of RDF + FYM and RDF + VCM. The other treatments were at par. The carbohydrate content generally increased by the application of different fertilizers. FYM treatments are more effective than the other treatments to improve carbohydrates in the soybean seed. Similar results were also reported by Javed and Panwar (2013) in case of soybean with application of chemical fertilizers and vermicompost together as compared to chemical fertilizers alone. The results of Gupta *et al*. (2018) are inconformity with these results. They also recorded significant improvement in seed quality parameters such as protein, carbohydrates and oil contents of soybean due to combined application of chemical fertilizers and vermicompost as well as FYM during sustainable organic cultivation on black cotton soil. Improvement in yield along with seed quality, oil content and seed nutrient content is playing key role in soybean cultivation (sharma *et al*. 2014).

Nutrient uptake: Nutrient uptake in soybean was influenced due to the application of different fertilizers. The uptake of nutrients by the crop was positively influenced with the application of RDF + FYM (T_8) and RDF + VCM (T_9) as compared to other treatments and control. The uptake of N, P, and K was increased due to above treatments. The nutrient uptake in seed was highest by 6.41 and 6.42 for N while for P it was 0.47 and 0.48. The values of K were 2.52 and 2.57 while in case of S the values were 0.35 in both the treatments. The increase in N uptake can be attributed to the increase in number and size of root nodule in treated soybean plant. The increase in nitrogen fixation might be contributing to N enhancement. This might be helping for synthesis of protein which caused increase in these content Ganeshamurthy and Reddy (2000), Arancon *et al*. (2005). N, P and K uptake was the significant increase in N, P and K uptake with the increased application of different fertilizers (Reddy *et al*. 1990). Similarly, Najar *et al*. (2011) also reported increase in nutrient uptake with the application of chemical fertilizers with along with different types of organic manures like farmyard manures, vermicompost etc. The results of Jinghua (2004) showed that application of Nano composite consisting of N, P, K, micronutrients, mannose and amino acids showed higher increase in the uptake of different nutrients required by the various grain crops.

Yield attributes

Economic yield of soybean: The results on this parameter shown in (Table 4) revealed that economic yield was also significantly very high in the treatments of combined applications of RDF + FYM and RDF + VCM. The economic yield due to first treatment T_8 was 2485.17 kg/ha and in the second treatment (T_9) it was 2510.33 kg/ha. It was highest record of economic yield as compared to control and other treatments. The increase in economic yield has direct relation with cost benefit ratio of the crop. The treatment T_9 was slightly superior to T_8 (Deshmukh *et al*. 2005, Shirpurkar *et al*. 2005).

Stover yield: Similar to increase in economic yield stover yield was also very high in both the treatments T_8 (3184.47 kg/ha) and T_9 (3210.28 kg/ha). It is clearly seen that between these two-better treatment of combined fertilizers T_9 that is RDF + VCM was superior to T_8 (RDF + FYM). The slightly better over T_8 (Mandel *et al*. 2000, Khutate *et al*. 2005).

Biological yield: Biological yield is very important aspect in the cultivation of legume crop like soybean. The results recorded on this parameter in (Table 4) clearly indicated that the biological yield was also highest in the

treatments of T_8 and T_9 in which combined application of RDF + FYM and RDF + VCM was followed for soybean crop. The recorded values were 5669.64 kg/ha and 5720.61 kg/ha respectively. When the effect of both treatments on biological yield is compared the treatment T_9 (RDF + VCM) had shown better results than T_8 (Gupta *et al*. 2003).

Table 4 Effect of fertilizer treatments on economic yield, stover yield, biological yield, harvest index and seed index in soybean

Treatments	Season 2018/2019				
	Economic yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)	Seed index (%)
T_1	1420.55	2057.5	3478.05	40.8432	13.30
T_2	1630.1	2184.25	3814.35	42.7359	14.10
T_3	1645.04	2208.03	3853.07	42.6942	14.30
T_4	1710.07	2674.5	4384.57	39.0020	15.10
T_5	2078.25	2884.04	4962.29	41.8808	14.74
T_6	2110.08	2910.18	5020.26	42.0312	18.85
T_7	2190.04	3085.28	5275.32	41.5148	15.08
T_8	2485.17	3184.47	5669.64	43.8329	15.84
T_9	2510.33	3210.28	5720.61	43.8822	16.05
T_{10}	1508.1	2028.66	3536.76	42.6407	12.18
T_{11}	1510.08	2082.04	3592.12	42.0386	12.74
T_{12}	1210.58	1228.38	2438.96	49.6350	11.84
LSD (0.05)	887.36	1080.28	1948.98	3.05	4.06
SE±	119.97	146.06	263.51	0.41	0.55
CV%	21.04	18.69	19.49	3.25	12.36

LSD-Least Significant difference at p=0.05, SE±: Standard error of mean, CV%: Coefficient of variation

Harvest index

The results on harvest index showed the same trend like that of seed index. The treatments of RDF + FYM and RDF + VCM had shown almost similar values (43.83% and 43.88%). Amongst all the yield attributes harvest index is the most reliable indicator of crop profitability and economic returns in general. The profitability of any crop when it is cultivated is judged through values of harvest index. As it is the ratio of:

$$\frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

These results are in conformity with the findings of Devi *et al*. (2011), Shweta *et al*. (2014).

Seed index: The results on seed index revealed that the superior treatments T_8 and T_9 were almost at par (15.84% and 16.05%). Both the treatments were equally infuencive on results of seed index (Bandopadhyay *et al*. 2010).

Table 5 Effect of fertilizer treatments on economic yield, agronomic efficiency, physiological efficiency, partial factor productivity, apparent recovery efficiency, sustainable yield index in soybean

Treatments	Economic yield (kg/ha)	Agronomic efficiency (AE)	Physiological efficiency (PE)	Partial factor productivity (PFP)	Apparent recovery efficiency (RE)	Sustainable yield index (SYI)
T_1	1420.55	6.999	5.5110	47.3516	1.27	0.4073
T_2	1630.1	13.984	8.7527	54.3366	1.5976	0.4908
T_3	1645.04	14.482	8.8882	54.8346	1.6293	0.4967
T_4	1710.07	16.6496	5.7149	57.0023	2.9133	0.5227
T_5	2078.25	28.9223	9.0241	69.275	3.205	0.6693
T_6	2110.08	29.9833	9.3077	70.336	3.2213	0.6820
T_7	2190.04	32.6486	8.2376	73.0013	3.9633	0.7138
T_8	2485.17	42.4863	10.3768	82.839	4.0943	0.8314
T_9	2510.33	43.325	10.4945	83.6776	4.1283	0.8414
T_{10}	1508.1	9.9173	24.3868	50.27	0.4066	0.4422
T_{11}	1510.08	9.9833	24.4290	50.336	0.4086	0.4430
T_{12}	1210.58	-	-	-	-	0.3237
LSD (0.05)	887.36	36.31	14.8	29.57	3.17	0.3794
SE±	119.97	4.26	2.001	3.99	0.42	0.04
CV%	21.04	-	-	21.04	-	29.74

LSD-Least Significant difference at p=0.05, SE±: Standard error of mean, CV%: Coefficient of variation

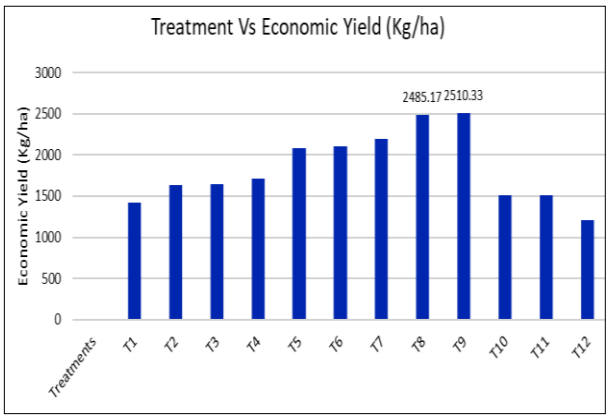

Fig 1 Effect of fertilizer treatments on treatment vs economic yield (kg/ha) in soybean

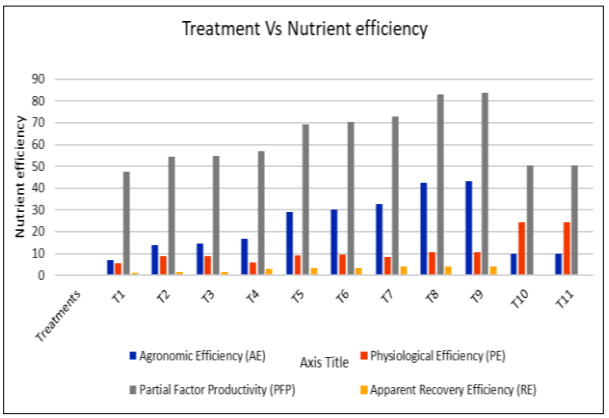

Fig 2 Effect of fertilizer treatment on treatment vs nutrient efficiency in soybean

Sustainability parameters

Parameters of application of sustainable fertilizers

The application of organic fertilizers along with chemical fertilizers is effective method for sustainable cultivation of different crops (Table 5, Fig 1-2). The organic fertilizers showed best effect on economic yield, agronomic efficiency, physiological efficiency, partial factor productivity, apparent recovery and sustainable yield index. All these sustainable parameters were highly improved due to the applications of synthetic fertilizers along with FYM and vermicompost. The nutrient combination treatments of 125% RDF + FYM and 125% RDF + VCM emerged as the best sustainable treatments for improvement of yield, yield parameters, growth parameters, seed composition, seed oil content along with improvement in soil health. According to Wanjari (2004), Bhattacharya *et al*. (2008) sustainable yield index is the best parameter to analyze the effect of sustainable application of fertilizers to various crops.

Statistical analysis of sustainable parameters

The applied nutrients (kg/ha) to the soil and accumulation of organic carbon (g/kg), and agronomic efficiency (ANUE) and economic yield (kg/ha) were significantly and positively correlated (r = 0.97 & r = 0.99) respectively and there is linear relationship between these variables. It all reflects immediate effect of applied compost and VCM which has direct influence on financial returns from the cultivation of soybean.

Table 6 Effects of fertilizer treatments organic carbon and available nutrients in soil before sowing and after harvesting in soybean (Pooled over 2 years)

Treatments	Before sowing					After harvest				
	N kg/ha	P_2O_5 kg/ha	K_2O	S	OC g/kg	N kg/ha	P_2O_5	K_2O	S	OC g/kg
T_1	182.72	13.35	164.20	16.88	4.10	214.30	17.80	165.33	17.34	4.16
T_2	198.40	17.42	179.32	15.93	4.38	221.61	21.32	182.21	16.72	4.47
T_3	200.82	17.85	180.80	16.82	4.41	223.42	21.80	183.05	17.03	4.51
T_4	215.14	22.62	176.65	23.87	4.80	220.70	27.78	178.10	24.08	4.85
T_5	230.43	18.30	181.20	24.80	5.16	232.33	22.10	183.78	25.68	5.42
T_6	232.31	18.85	181.80	25.76	5.22	234.15	22.33	184.15	26.04	5.44
T_7	255.16	21.20	182.73	26.73	5.41	258.92	23.30	186.52	27.63	5.48
T_8	262.14	22.80	190.83	31.08	5.53	266.72	24.40	193.33	31.85	5.63
T_9	265.04	23.02	190.88	30.35	5.61	267.42	24.73	194.03	31.83	5.67
T_{10}	204.33	17.15	152.33	16.82	3.95	218.34	19.30	155.18	17.07	4.00
T_{11}	205.38	17.35	152.83	16.80	4.02	219.22	19.65	156.07	17.13	4.07
T_{12}	172.34	10.07	109.04	13.06	3.85	175.05	12.35	109.28	13.20	3.90
LSD (0.05)	62.74	6.72	30.06	13.04	1.41	45.17	6.26	30.24	13.60	1.48
SE±	8.48	0.90	4.06	1.76	0.19	6.10	0.84	4.08	1.83	0.20
CV%	12.60	15.79	7.66	26.18	13.24	8.64	12.62	7.60	26.58	13.59

LSD-Least Significant difference at p=0.05, SE±: Standard error of mean, CV%: Coefficient of variation

Soil health

Soil health was significantly improved by the application of RDF + FYM and RDF + VCM (Table 6). The contents of different soil nutrients and organic carbon were increased due to the application of combination of fertilizers in T_8 and T_9 as compared to control and other treatments. The increase in organic carbon was very high in T_8 and T_9 treatment (5.63 g/kg and 5.67 g/kg) as compared to control (3.90 g/kg). Organic carbon plays a major role in improvement of soil fertility and soil health. It has direct

effect on increase in seed yield and seed quality in soybean. As soybean is a nodule crop fixing nitrogen symbiotically, effectively help in improvement of soil health and fertility. Similar results were recorded by several researchers Navale *et al*. (2000), Nimje (2003), Kundu *et al*. (2008), Muneshwar *et al*. (2008). They claimed that the application of FYM and vermicompost resulted in higher content of N, P, K, and seed yield as well as oil content in soybean. The chemical or synthetic fertilizer if applied alone cause soil pollution and desertification of soil but application of vermicompost and FYM as well as Nano-compost helps to improve soil fertility, physico-chemical properties of soil and biological properties such as soil enzymes, soil micro flora etc. are improved having with great effect on yield and yield quality of various crops (Naderi *et al*. 2013).

Statistical analysis of sustainable parameters

The applied nutrients (kg/ha) to the soil and accumulation of organic carbon (g/kg) and agronomic efficiency (ANUE) and economic yield (kg/ha) were significantly and positively correlated (r = 0.97 & r = 0.99) respectively and there is linear relationship between these variables. It all reflects immediate effect of applied compost and VCM which has direct influence on financial returns from the cultivation of soybean.

From the present investigation it may be concluded that application of synthetic fertilizers such as recommended dose of fertilizers (RDF) and organic manures like Farmyard manure (FYM) and vermicompost if applied in combination to soybean crop it has resulted into highly significant improvement in different attributes of growth, yield, oil content, soil health, nutrient uptake and almost all the sustainable parameters in soybean. These two treatments (T_8 and T_9) showed remarkable influence on various sustainability parameters such as harvest index, economic yield, sustainable yield index, agronomic efficiency, nutrient use efficiency, nitrogen use efficiency etc. The applications of Farmyard manure (FYM) and VCM were highly effective in combination with recommended dose of fertilizers (RDF). The present investigation proved that use of mixture of fertilizers like RDF + FYM and RDF + VCM will provide best sustainable production method for soybean cultivation. By following this method growers will get profitable yield along with maintaining or improving the fertility status of soil under soybean cultivation. Apart from the present method of using some chemical fertilizers with organic manures if practiced on large scale by farmers it will be a great contribution towards the protection of environment and soil health avoiding the different types of pollutions caused by chemical fertilizers. Henceforth, applications of synthetic fertilizer with farmyard manure and vermicompost can be recommended as a sustainable agricultural practice for crop the cultivation of crops like soybean.

Acknowledgements

The authors gratefully acknowledge the help rendered by Mr. Dipak A. Kapurkar, Lab. I/C Sushilanand Agro Polyclinic, Islampur district Sangli for various types of analyses. Similarly, the field facilities provided by the farmers for the cultivation of soybean is duly acknowledged. We are also thankful to our mentor Prof. Dr. K. N. Dhumal, Department of Botany, SPPU Pune. We duly thank Dr. Mrs. S. S. Kulkarni, Director, RIT, Rajaramnagar for providing the research opportunity.

LITERATURE CITED

Anonymous. 2014-15. Director's Report and Summary Tables of Experiments 201-15. All India coordinated research project on soybean, ICAR-Directorate of Soybean Research, Indore, India. pp 329.

Arancon N Q, Edwards C A, Bierman P, Metzger J D and Lucht C. 2005. Effects of vermicompost produced from cattle manure, food waste and paper waste on the growth and yield of peppers in the field. *Pedobiologia* **49**: 297-306.

Bandopadhyay K K, Misra A K, Ghosh P K and Hati K M. 2010. Effect of integrated use of farmyard manure and chemical fertilizers on soil physical properties and productivity of soybean. *Soil and Tillage Research* **110**: 115-125.

Billore S D, Vyas A K and Joshi O P. 2009. Effect of integrated nutrient management in soybean (*Glycine max* L.) and Pigeon Pea (*Cajanas cajan* L.) intercropping on productivity, energy budgeting and competition functions. *Journal of Food Legumes* **22**(2): 124-126.

Bobde G N, Deshpande R M, Khandalkar D M and Turankar V L. 1998. Nutrient management of Soybean. *Indian Journal Argon* **43**: 390-392.

Chandel A S, Pandey K N and Saxena S C. 1989. Symbiotic nitrogen benefits by nodulated soybean to interplanted crops in Northern India. *Tropical Agriculture* **66**(10): 73-77.

Chaturvedi S, Chandel A S, Dhyani A S and Singh A P. 2010. Productivity, profitability and quality of soybean (*Glycine max*) and residual soil fertility as influenced by integrated nutrient management. *Indian Journal of Agronomy* **55**(2): 133-137.

Chiezey U F and Odunze A C. 2009. Soybean response to application of poultry manure and phosphorus fertilizer in the sub-humid Savanna of Nigeria. *Journal of Ecology and National Environment* **1**(2): 25-31.

Cirak O M S, Kenseroglu K, Karaca E and Gulumser A. 2006. Response of soybean to soil and foliar applied boron at different rates. *Indian Journal of Agricultural Sciences* **76**(10): 603-606.

Dass A, Dey D, Lal S K and Ranjanna G A. 2018. Tank mix insecticide and herbicide application effects on weeds, insect-pest menace and soybean productivity in semi-arid northern plain of India. *Legume Research* **42**(3): 385-391.

Deshmukh K K, Sariya A B and Dubey D P. 2005. Effect of integrated nutrient management on productivity trends, economics and soil fertility in soybean-chickpea cropping system. *JNKVV Research Journal* **39**(2): 29-32.

Devi K N, Abhay K V, Maibam S S and Naorem G S. 2011. Effect of bioregulators on growth, yield and chemical constituents of soybean (*Glycine max*). *Journal of Agricultural Sciences* **3**(4): 151-159.

Galeshi S, Solanani A and Taheri A H. 2004. Effect of nitrate on growth and nodulation of soybean (*Glycine max*). *Agricultural Sciences and Technology* **18**(1): 139-150

Govidan K and Thirumurugan V. 2005. Synergistic association of Rhizobium with phosphate-solubilizing bacteria under different sources of nutrient supply on productivity and soil fertility in soybean (*Glycine max* L.). *Indian Journal of Agronomy* **50**(3): 214-217.

Gupta Anshita, Dwivedi A K, Nagwanshi A and Dwivedi B S. 2018. Effect of long term application of chemical fertilizers and organic manure application on crop quality parameters in soybean crop. Inter. *Journal of Current Microbiology and Applied Science* **7**: 1403-1407.

Gupta V, Sharma G L, Sonakiya V K and Tiwari G. 2003. Impact of different levels of FYM and Sulphur on morphological indices and productivity of soybean genotypes. *JNKV Research journal* **37**(2): 76-78.

Huang M, Wanga Q, Zhang M and Zhu Q. 2014. Prediction of color and moisture content for vegetable soybean during drying using hyper spectral imaging technology. *Journal of Food Engineering* **128**: 24-30.

Jagmeet K, Ram H, Gill B S and Jasdeep K. 2015. Agronomic performance and economic analysis of soybean (*Glycine max*) in relation to growth regulating substances in Punjab. *India Legume Research* **38**(5): 603-608.

Javed S and Panwar A. 2013. Effect of biofertilizer, vermicompost and chemical fertilizer on different biochemical parameters of *Glycine max* and *Vigna mungo. Recent Research in Science and Technology* **5**: 40-44.

Jinghua G. 2004. Synchrotron radiation, soft x-ray spectroscopy and nano-materials. *Journal of Nanotechnology* **1**: 193-225.

Khutate N G, Mendhe S N, Dongarkar K P, Dadhe N N and Gavande V H. 2005. Effect of nutrient management treatments on growth and yield of soybean. *Journal of Soils and Crops* **15**(2): 411-414.

Kumar A P and Kumar S B. 2006. Effect of boron and sulphur on performance of gram. *Indian Journal of Agronomy* **51**(1): 57-59.

Kumar T, Samaiya R K, Singh Y, Dwivedi S K and Meena K C. 2016. Effect of foliar parameters of soybean (*Glycine max* L.) Merill. *International Journal of Agricultural Sciences* **8**: 133-138.

Kumar. 2007. A study of consumer attitudes and acceptability of soy food in Ludhiana. MBA research project report, Department of business management. *Punjab Agricultural University, Ludhiana,* Punjab.

Kundu S, Bhattacharya R, Ved P and Gupta H S. 2008. Carbon sequestration potential of Inceptisols under long term soybean-wheat rotation in sub-temperate rain-fed agro-ecosystem of North-west Himalayas. *Journal of Indian Society of Soil Science* **56**(4): 423-429.

Laltlanmawia L, Singh A K and Sharma S K. 2003. Effect of phosphorus and molybdenum on yield, protein content and nutrient uptake by soybean on acid soil. *Journal of Indian Society Soil Science* **52**(2): 199-202.

Mandel K G, Mishr A K and Hati K M. 2000. Effect of combination of nitrogen, phosphorus, potassium and FYM on growth, yield and agronomic efficiency on soybean in vertisols. *Environment and Ecology* **18**(1): 207-209.

Muneshwar S M, Singh M and Kumrawat B. 2008. Influence of nutrient supply system on productivity of soybean-wheat and soil fertility of vertisols of Madhya Pradesh. *Journal of Indian Society of soil Science* **56**(4): 436-441.

Naderi M R and Danesh-Shahraki A. 2013. Nano fertilizers and their roles in sustainable agriculture. *International Journal of Agriculture and Crop Sciences* **5**(19): 2229-2232.

Najar G R, Singh S R, Akhtar F H and Hakeem S A. 2011. Influence of sulphur level on yield, uptake and quality of soybean (*Glycine max*) under temperate conditions of Kashmir. *Indian journal of Agricultural Science* **81**(4): 340-343.

Navale K B, Gaikwad C B and Tamboli B D. 2003. Effect of integrated nutrient management on yield, nutrient availability and uptake of nutrients by soybean. *Journal of Maharashtra Agricultural University* **25**(1): 105-107.

Nimje P M. 2003. Effect of phosphorus fertilization on soybean (*Glycine max*) based cropping sequences under rain fed conditions. *Indian Journal of Agricultural Sciences* **73**(4): 191-193.

Patil H M and Udmale K B. 2016, Response of different organic inputs on growth and yield of soybean on Inceptisol. *Scholarly Journal of Agricultural Science* **6**(5): 139-144.

Patil S J. 2008. Effect of organic and inorganic treatment on soil microbial biomass carbon and nitrogen under soybean. *M. Sc. Thesis,* Dr. PDKV, Akola, Maharashtra.

Patil V, Meti S, Mansur C P, Rajashekhara E, Itagi P and Hadimani H P. 2017. Nutritional studies on vegetable soybean (*Glycine max* Merrill). In Northern dry zone of Karnataka, India. *International Journal of Current Microbiology and Applied Science* **6**(12): 5364-5374.

Prasad R. 1996. Cropping systems and sustainability of agriculture. *Indian Farming* **46**: 39-45.

Ramaswamy M, Srinivisam K and Sakaran N. 2001. Effect of phosphorous mobilize and different levels of phosphorous on growth and yield of crop soybean. *Madras Agricultural Journal* **87**(10/12): 676-675.

Rana D S, Dass A, Rajanna G A and Choudhary A K. 2018/ Fertilizer phosphorus solubility effects on Indian mustard maize and wheat-soybean cropping systems productivity. *Agronomy Journal* **110**(6): 2608-2618.

Ranjan Bhattacharya, Kundu S, Ved P and Gupta H S. 2008. Sustainability under combined application of mineral and organic fertilizers in a rain-fed soybean-wheat system of the Indian Himalayas. *European Journal of Agronomy* **28**: 33-46.

Ranjitha B M. 2016. Effects of soil test based INM practices on the performance of chilli (*Capscium annuum* L.) *M. Sc. Thesis*, University of Horticultural Sciences, Bagalkot.

Reddy Ramkrishna T, Rao Mohan and Rao Rama K. 1990. Response of soybean (*Glycine max*) to nitrogen and phosphorus. *Indian Journal of Agronomy* **35**(3): 308-310.

Saxena S C and Chandel A S. 1992. Effect of nitrogen fertilization on different varieties of Soybean. *Indian Journal of Agricultural Sciences* **62**(10): 695-697.

Saxena S C, Nainwal R C and Joshi A. 2013. Optimization of nutritional levels for newly released soybean (*Glycine max* (L) merill) varieties in mollisols of uttarakhand. *Soybean Research* **11**(2): 43-54.

Sharma S, Kaur M, Goyal R and Gill B S. 2014. Physical characteristics and nutritional composition of some new soybean (*Glycine max* L.) genotypes. *Journal of Food Science and Technology* **51**(3): 551-557.

Shirpurkar G N, Kashid N V, Kamble M S and Gavhane V N. 2005. Effect of application of different micronutrient on growth attributing characters of soybean (*Glycine max*). *Research on Crops* **6**(2): 225-228.

Shivkumar B G and Ahlawat I P S. 2008. Integrated nutrient management in soybean (*Glycine max*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **53**(4): 273-278.

Shweta G, Jain M P and Atul G. 2014. Effect of nitrogen and plant growth regulators on soybean under sown conditions. *Soybean Research* **12**(Special issue): 184-187.

Singh G, Aggarwal N and Kumar V. 2010. Integrated nutrient management in lentil with organic manures, chemical fertilizers and biofertilizers. *Journal of Food Legumes* **23**(2): 149-151.

Singh R and Rai R K. 2004. Yield attributes, yield and quality of soybean (*Glycine max*) influenced by integrated nutrient management. *Indian Journal of Agronomy* **49**(4): 271-274.

Singh S R, Najar G R and Singh U. 2007. Productivity and nutrient uptake of soybean (*Glycine max*) as influenced by bio-inoculants and farmyard manure under rain-fed conditions. *Indian Journal of Agronomy* **52**(4): 325-329.

Suryawanshi S B, Lad N G, Suryawanshi V P, Shaikh A K and Adsul P B. 2006. Combined effect of organic and inorganic fertilization on yield attributes and yield of soybean (*Glycine max* L.). *Journal of Soils and Crops* **16**: 145-147.

Tanwar S P S and Shakatawat. 2003. Influence of phosphorus sources, levels and solubilizers on yield, quality and nutrient uptake of soybean (*Glycine max*)-wheat (*Tritium aestivum*) cropping system in southern Rajasthan. *Indian Journal of Agricultural Sciences* **73**(1): 3-7.

Thakur H S and Girothia O P. 2010. Response of soybean (*Glycine max* L.) and chickpea (*Cicer arietinum*) cropping sequence to phosphorus nutrition. *Soybean Research* **8**: 13-19.

Vyas A K, Billore S D, Joshi O P and Pachlania N K. 2007. Influence of balanced nutrition on productivity of soybean. *Soybean Research* **5**: 21-25.

Wanjari. 2004. Sustainable yield index: An approach to evaluate the sustainability of long-term intensive cropping systems in India. *Journal of Sustainable Agriculture* **24**: 4.