



Productivity of soybean (*Glycine max*) varieties under different levels of integrated nutrient management

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ABSTRACT

The present experiment was conducted during the rainy (*kharif*) seasons of 2019 and 2020 at Bidhan Chandra Krishi Viswavidyalaya, West Bengal to study the performance of various soybean [*Glycine max* (L.) Merr.] varieties under different levels of integrated nutrient management. A three-time repeated factorial randomized block design (F-RBD) was used for the experiment having 3 varieties (Factor 1), viz. PS-1225; YEZIN-15; and PS-24 and 5 nutrient management treatments (Factor 2), viz. 100% recommended dose of fertilizer (RDF); 75% RDF+3 t/ha farmyard manure (FYM); 75% RDF+1.5 t/ha vermicompost; 75% RDF+3 t/ha FYM+25 kg/ha ZnSO₄; and 75% RDF+1.5 t/ha vermicompost+25 kg/ha ZnSO₄. Findings explored that 75% RDF+1.5 t/ha vermicompost+25 kg/ha ZnSO₄ supply in PS-24 variety ensured highest seed yield (2601 kg/ha), stover yield (5241 kg/ha) and harvest index (33.17%) owing from high nutrient uptakes. Further, production economics stated that PS-24 cultivated with 75% RDF+1.5 t/ha vermicompost+25 kg/ha ZnSO₄ supply registered maximum net return (₹42994/ha) and benefit cost (B:C) ratio (2.32) indicating its suitability in eastern Indian condition.

Keywords: Economics, Integrated nutrient management, Soybean, Variety, Yield

Soybean [*Glycine max* (L.) Merr.] is well appreciated for high protein and oil contents. Although India comprises 10% of global soybean area, soybean production is only 2.75% of world's average due to low productivity (USDA 2020). Currently, country is facing shortage of oilseed supply. Low production, oilseed import, high demand-supply gap are making oilseeds a costly market commodity. Increasing the productivity of oilseeds like soybean is therefore a major challenge for researchers and farmers (Sharma *et al.* 2016). Selection of appropriate variety is one of the fundamental approaches towards achieving high crop productivity. Suitable adaptation of variety to a region and its adequate growth depends on interaction between its genetic characters and environment. Response of soybean to agronomic management and environmental conditions varies markedly with varieties (Madanzi *et al.* 2012).

Cultivation of improved soybean varieties requires optimum and balanced nutrient management to manifest potential yield. Among the legumes, soybean is a nutrient-

exhaustive crop that needs an adequate supply of nutrients to grow. Overuse of chemical fertilizers results in pollution of the environment and deterioration of soil health, which ultimately makes crop yield unsustainable. As an alternative, organic manure although can restore the soil fertility and sustain crop productivity in eco-friendly way, inadequate availability in bulk quantities, initial low yield and lack of awareness are some of the constraints associated with it (Biswas *et al.* 2020). Thus, maintaining productivity and generating significant financial gain can be achieved by the balanced utilization of nutrients through combining bio-organic and inorganic sources of nutrition (Maheshbabu *et al.* 2008). Better yield of soybean is the result of integrated interactions of varieties and nutrients under specific soil and climatic conditions and it can be achieved by scientific and sustainable management of this complex interaction. However, information regarding interaction effects of improved varieties and integrated nutrient use in soybean is very scanty in eastern India and therefore, to elucidate it, the present experiment was planned to study the performance of various soybean varieties under different levels of integrated nutrient management.

MATERIALS AND METHODS

The present experiment was conducted during the summer (*kharif*) seasons of 2019 and 2020 at Bidhan Chandra Krishi Viswavidyalaya, Nadia (22°N, 89°E and

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9.75 m msl), West Bengal. A factorial randomized block design (F-RBD) with 3 repetitions comprising 3 soybean varieties as factor 1 (V_1 , PS-1225; V_2 , YEZIN-15; V_3 , PS-24) and 5 nutrient management options as factor 2 (N_1 , 100% RDF i.e. N: P_2O_5 : K_2O -20:60:40 kg/ha; N_2 , 75% RDF+3 t/ha FYM; N_3 , 75% RDF+1.5 t/ha vermicompost; N_4 , N_2 +25 kg/ha $ZnSO_4$; N_5 , N_3 +25 kg/ha $ZnSO_4$) was used. High temperature was observed during March-April, while lowest was found in January. The crop received monthly rainfall of 0–90.3 mm in 2018–19 and 0–147.4 mm in 2019–20. With a texture of sandy loam and an Entisol classification in West Bengal's new Alluvial zone, the experimental soil had a pH of 7.20, 0.61% soil organic carbon (SOC), 191.8 kg/ha of available nitrogen, 27.1 kg/ha of available phosphorus, 171.5 kg/ha of available potassium, and 0.50 ppm of zinc. One deep ploughing through tractor drawn disc plough and two cross-harrowing and planking were done. Manures were applied and mixed with soil during land preparation as per the treatments. Soybean @75 kg/ha was sown into 5 cm soil depth on 28th June, 2019 and 25th June, 2020 at 45 cm × 10 cm spacing in a 4.5 m × 3 m sized plot and thinning/gap filling were done 1 week after emergence. In both the years, excess water was drained. During land preparation, fertilization included urea, single super phosphate (SSP), muriate of potash (MOP), and zinc sulphate. In all plots, one hand weeding was done 35 days after sowing (DAS) after using PE pretilachlor 50% EC @0.75 kg a.i./ha at 3 DAS. To suppress stem fly and girdle beetle, phorate 10 G @1 kg a.i./ha at the time of sowing and two spraying of quinalphos 25 EC @1.5 litre/ha at 35 and 50 DAS to control Bihar hairy caterpillar and leaf roller were done. Yellow mosaic virus infected plants were uprooted and burnt when noticed. YEZIN-15 was introduced from Myanmar, while other two were Indian varieties. The crop was harvested at around 110–115 DAS. After harvest of 1st year crop, mustard and jute were grown in *rabi* and *pre-kharif* seasons in the same fields without application of nutrients to exhaust the left-over nutrients.

Observations included seed yield, stover yield, harvest index of soybean varieties as well as their total uptakes of nutrients (N, P_2O_5 , K_2O and Zn) and residual soil fertility status (SOC, N, P_2O_5 , K_2O and Zn) under varying levels of INM. For yield estimation, 3 m × 2 m area from each plot was selected excluding border rows and plants growing in that area were cut from 6–8 cm above ground, followed by sun drying for 3 days and threshing through seed beating. A weighing scale was used to weigh the stover and threshed seeds individually, and the results were expressed in kg/ha. Harvest index was calculated as (Donald 1962):

$$\text{Harvest index (\%)} = \frac{\text{Seed yield}}{\text{Total Biomass (seed + stover)}} \times 100$$

The calculation of nutrient absorption involved multiplying the concentration of nutrients by the biomass of soybean. The techniques proposed by Walkley and Black (1934), Olsen *et al.* (1954), Jackson (1973), Jackson (1973), and Lindsay and Norvell (1978) were used to analyse SOC,

N, P_2O_5 , K_2O , and Zn, respectively. Finally, production economics was chalked out as follows:

$$\text{Cultivation cost (₹/ha)} = \text{Cost of input purchases and agricultural operations}$$

$$\text{Gross return (₹/ha)} = \text{Yield} \times \text{Market price}$$

$$\text{Net return (₹/ha)} = \text{Gross return (₹/ha)} - \text{Cultivation cost (₹/ha)}$$

$$\text{Benefit:Cost ratio (B:C)} = \frac{\text{Gross return (₹/ha)}}{\text{Cultivation cost (₹/ha)}}$$

The analysis of variance approach was used to statistically analyze the data from both the field and the laboratory. The critical difference was taken to compare treatment means at $P=0.05$ significance level (Panse and Sukhatme 1985).

RESULTS AND DISCUSSION

Seed yield, stover yield and harvest index: Data (Table 1) showed that soybean seed yield, stover yield and consequently, harvest index significantly varied among varieties and nutrients. Treatment V_3 registered highest seed yield (2421, 2287 and 2354 kg/ha), stover yield (5063, 4859 and 4961 kg/ha) and harvest index (32.30, 31.94 and 32.12%) while, V_2 showed lowest values in 2019, 2020 and pooled result, respectively. Luxuriant vegetative growth owing from greater uptake and assimilation of nutrients might favour PS-24 to achieve higher yield and harvest index. YEZIN-15 was introduced from Myanmar and it performed worst due to its poor adaptation to agro-climatic conditions. The outcome supported the conclusions made by Nath *et al.* (2017).

The best seed yield (2380, 2259 and 2320 kg/ha), stover yield (4924, 4616 and 4770 kg/ha) and harvest index (32.51, 32.81 and 32.66%) were recorded from N_5 in both the years and pooled data, respectively, and N_1 recorded lowest values. Interaction effect revealed that V_3N_5 showed highest seed yield (2656, 2545 and 2601 kg/ha), stover yield (5340, 5141 and 5241 kg/ha) and harvest index (33.22, 33.11 and 33.17%) in both the years and pooled data, respectively (Table 1). Increased dry-matter production through photosynthesis and efficient partitioning of photo-assimilates towards reproductive development under V_3N_5 might resulted in improvement of soybean yield. Under that INM option, the harvest index might have further represented increased sink activity and effective photosynthate translocation from source to sink. Vermicompost improved soil health and thereby, positively impacted nutrient uptakes and sink development. Addition of Zn further helped in pollen viability and seed setting (Morya *et al.* 2018).

Uptake of nutrients: Significant variations in nutrient uptake existed among varieties and nutrients (Table 1). Treatment V_3 showed maximum uptakes of N (180.20, 167.95 and 174.07 kg/ha), P_2O_5 (20.60, 19.54 and 20.07 kg/ha), K_2O (125.80, 119.32 and 122.56 kg/ha) and Zn (192.35, 185.35 and 188.85 g/ha) in each year and the pooled value, correspondingly. Treatment V_2 recorded the lowest

Table 1 Effect of integrated nutrient management on yield, harvest index and total nutrients uptake of soybean varieties

Treatment	Seed yield (kg/ha)			Stover yield (kg/ha)			Harvest index (%)			N (kg/ha)			P ₂ O ₅ (kg/ha)			K ₂ O (kg/ha)			Zn (g/ha)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Variety (V)																					
V ₁	2101	1974	2038	4641	4301	4471	31.03	31.34	31.18	158.85	145.88	152.36	18.36	17.34	17.85	110.2	103.63	106.91	187.70	175.88	181.79
V ₂	1734	1635	1685	4096	3701	3898	29.65	30.52	30.09	137.49	123.82	130.65	16.12	14.10	15.11	97.25	89.03	93.14	163.71	160.78	162.24
V ₃	2421	2287	2354	5063	4859	4961	32.30	31.94	32.12	180.20	167.95	174.07	20.60	19.54	20.07	125.80	119.32	122.56	192.35	185.35	188.85
SEm (±)	35.28	30.34	32.97	51.79	45.83	48.81	0.18	0.15	0.16	2.62	1.75	2.18	0.28	0.26	0.27	1.65	1.33	1.49	3.16	3.06	3.11
CD	103.12	88.68	86.37	151.40	134.38	142.69	0.53	0.44	0.47	7.67	5.12	6.39	0.82	0.76	0.79	5.23	3.89	4.56	9.26	8.96	9.11
(P= 0.05)																					
Nutrient management (N)																					
N ₁	1780	1658	1719	4216	3908	4062	29.51	29.66	29.59	142.32	131.07	136.69	16.49	14.68	15.58	100.79	92.46	96.62	150.38	141.68	146.03
N ₂	1921	1795	1858	4467	4150	4308	29.87	30.06	29.97	151.32	137.60	144.46	17.47	15.97	16.72	106.45	98.50	102.47	159.97	154.07	157.02
N ₃	2208	2103	2156	4741	4428	4585	31.72	32.16	31.94	165.12	152.09	158.60	19.14	18.12	18.63	115.23	109.31	112.27	175.48	172.65	174.06
N ₄	2136	2013	2075	4651	4333	4492	31.35	31.63	31.49	159.71	148.23	153.97	18.48	17.39	17.93	111.67	105.89	108.78	206.67	196.50	201.58
N ₅	2380	2259	2320	4924	4616	4770	32.51	32.81	32.66	175.69	160.41	168.05	20.22	19.01	19.61	121.28	113.55	117.41	213.75	205.10	209.42
SEm (±)	41.76	37.13	39.45	61.93	56.71	59.32	0.25	0.23	0.24	2.80	2.36	2.58	0.33	0.30	0.31	2.09	1.40	1.74	3.46	3.27	3.36
CD	122.06	108.53	115.31	180.05	165.75	173.41	0.72	0.67	0.70	8.19	6.89	7.54	0.98	0.89	0.93	6.10	4.10	5.10	10.13	9.57	9.85
(P= 0.05)																					
Interaction (V × N)																					
V ₁ N ₁	1737	1595	1666	4166	3830	3998	29.42	29.40	29.41	135.23	125.89	130.56	16.21	14.97	15.59	95.13	89.91	92.52	157.19	144.34	150.76
V ₁ N ₂	1866	1755	1811	4552	4206	4379	29.07	29.44	29.26	151.46	136.96	144.21	17.52	16.55	17.03	104.57	98.37	101.47	168.87	158.82	163.84
V ₁ N ₃	2204	2087	2145	4778	4437	4607	31.59	31.98	31.79	165.17	152.13	158.65	18.83	18.09	18.46	114.92	108.51	111.71	184.46	172.87	178.66
V ₁ N ₄	2212	2115	2164	4706	4360	4533	31.90	32.68	32.29	162.39	150.72	156.55	18.51	17.98	18.24	111.73	106.27	109.00	210.18	197.40	203.79
V ₁ N ₅	2484	2320	2402	5007	4671	4839	33.16	33.18	33.17	180.02	153.69	166.85	20.73	19.13	19.93	124.65	115.11	119.88	217.80	205.96	211.88
V ₂ N ₁	1432	1330	1381	3668	3279	3474	28.01	28.86	28.58	121.56	110.41	115.98	14.23	10.89	12.56	88.51	78.76	83.63	129.59	120.36	124.97
V ₂ N ₂	1545	1452	1498	3913	3514	3713	28.30	29.24	28.77	128.83	115.27	122.05	15.16	12.93	14.04	92.46	84.83	88.64	139.82	131.40	135.61
V ₂ N ₃	1925	1820	1873	4288	3894	4091	30.98	31.85	31.42	144.29	130.83	137.56	16.98	15.46	16.22	81.29	93.51	87.40	153.21	164.71	158.96
V ₂ N ₄	1777	1662	1720	4180	3781	3981	29.82	30.52	30.17	138.41	126.21	132.31	16.42	15.02	15.72	97.17	90.62	93.89	194.82	189.41	192.11
V ₂ N ₅	2001	1912	1957	4424	4035	4229	31.14	32.15	31.65	154.37	136.38	144.23	17.83	16.21	17.02	106.83	97.43	102.13	201.10	198.03	199.56
V ₃ N ₁	2181	2048	2114	4814	4615	4713	31.10	30.73	30.91	170.17	156.91	164.54	19.02	18.18	18.60	118.72	109.46	114.09	164.38	160.34	162.36
V ₃ N ₂	2351	2177	2264	4938	4729	4833	32.25	31.52	31.89	173.72	150.58	162.15	19.72	18.43	19.07	122.32	112.32	117.32	171.23	172.01	171.62
V ₃ N ₃	2495	2402	2449	5159	4955	5057	32.59	32.64	32.61	185.91	173.32	179.61	21.62	20.80	21.21	129.48	125.92	127.70	188.79	180.38	184.58
V ₃ N ₄	2420	2262	2341	5066	4857	4962	32.33	31.70	32.02	178.53	167.76	173.14	20.53	19.17	19.85	126.11	120.78	123.44	215.01	202.71	208.86
V ₃ N ₅	2656	2545	2601	5340	5141	5241	33.22	33.11	33.17	192.68	181.18	186.93	22.11	21.70	21.90	132.37	128.11	130.24	222.36	211.32	216.84
SEm (±)	53.86	50.07	52.31	70.25	65.60	67.93	0.32	0.28	0.30	3.43	2.92	3.175	0.38	0.36	0.37	2.43	1.97	2.20	3.79	3.65	3.72
CD	157.42	146.37	152.89	205.34	191.76	198.55	0.93	0.83	0.88	10.03	8.53	9.28	1.13	1.04	1.08	7.12	5.76	6.44	11.10	10.66	10.88
(P= 0.05)																					

V₁, PS-1225; V₂, YEZIN-15; V₃, PS-24; N₁, 100% RDF; N₂, 75% RDF+3 t/ha FYM; N₃, 75% RDF+1.5 t/ha vermicompost; N₄, N₂+25 kg/ha ZnSO₄; N₅, N₃+25 kg/ha ZnSO₄.

uptakes of those nutrients. The requirement of nutrients for PS-24 was higher than others due to more production of biomass, which perhaps led to greater nutrient uptake and translocation in this variety (Bortolon *et al.* 2018). Among nutrient management, N_5 noted maximum uptakes of N (175.69, 160.41 and 168.05 kg/ha), P_2O_5 (20.22, 19.01 and 19.61 kg/ha), K_2O (121.28, 113.55 and 117.41 kg/ha) and Zn (213.75, 205.10 and 209.42 g/ha), while N_1 registered lowest uptakes of nutrients. Specifically, V_3N_5 recorded maximum uptakes of N (192.68, 181.18 and 186.93 kg/ha), P_2O_5 (22.11, 21.70 and 21.90 kg/ha), K_2O (132.37, 128.11 and 130.24 kg/ha) and Zn (222.36, 211.32 and 216.84 g/ha) in 2019, 2020 and pooled analysis, respectively. V_2N_1 recorded lowest nutrient uptakes. Soil incorporation of vermicompost and fertilizers might have facilitated nutrient availability in crop root zone, followed by allocation and transfer of nutrients to seeds and stover of soybean. Yadav (2001) reported increased efficiency of fertilizers under combined uses with organic manures. Further, soil application of $ZnSO_4$ in vermicompost treated plots might form the Zn-organic chelate which in turn increased Zn availability and uptake due to its steady release from chelating compounds synchronizing with crop demand. Morya *et al.* (2018) reported nearly identical results.

Residual soil fertility status: Significant variation existed in residual soil fertility among varieties except soil organic carbon (SOC) and Zn contents (Table 2). The highest SOC (0.64%), available N (210.11 kg/ha), P_2O_5 (27.43 kg/ha), K_2O (169.35 kg/ha) and Zn (0.54 ppm) were observed from soil where V_2 was grown. Low residual soil fertility status was observed from V_3 grown plots. The amount of nutrients available in soil after crop harvest depended on nutrient uptakes by the variety. YEZIN-15 had lowest nutrient uptakes due to its non-suitability to the agro-climatic condition and thereby, residual soil nutrients were more from YEZIN-15 grown plots. These results are in line with the finding of Vyas and Kushwah (2015). Among nutrient management, the highest residual SOC (0.65%), available N (209.50 kg/ha), P_2O_5 (27.90 kg/ha) and K_2O (169.31 kg/ha) were observed from application of N_2 and it was followed by N_4 which additionally recorded highest residual Zn (0.55 ppm) (Table 2). SOC (0.66%), available N (213.01 kg/ha), P_2O_5 (28.86 kg/ha) and K_2O (171.29 kg/ha) were highest from post-harvest soil under V_2N_2 , while post-harvest soil of V_2N_4 had the highest available Zn (0.57 ppm) (Table 2). Lowest residual soil fertility was observed from soil under V_1N_1 . Utilizing vermicompost in conjunction with NPK and Zn fertilizers caused the nutrients in organic manures to release gradually, allowing the nutrients to be kept in the soil for longer and ensuring a long-lasting impact. Better carbon sequestration as a result of the addition of vermicompost was shown by the soil's enhanced organic carbon content from its starting point. The increased growth of soil microbes brought about by the addition of vermicompost, which progressively converted organically bound N into inorganic form, may be responsible for the increase in the N pool. Similarly, Zn fertilization in

Table 2 Effect of integrated nutrient management on residual soil fertility status after harvest of soybean varieties (Pooled of 2 years)

Treatment	Soil organic C (%)	Available nutrient			
		N (kg/ha)	P ₂ O ₅ (kg/ha)	K ₂ O (kg/ha)	Zn (ppm)
Variety (V)					
V ₁	0.63	206.63	26.64	165.19	0.52
V ₂	0.64	210.11	27.43	169.35	0.54
V ₃	0.63	203.85	25.89	162.92	0.53
SEm (±)	0.01	1.64	0.22	1.21	0.01
CD (P= 0.05)	NS	4.82	0.65	3.54	NS
Nutrient management (N)					
N ₁	0.62	202.60	24.51	159.95	0.51
N ₂	0.65	209.50	27.90	169.31	0.52
N ₃	0.63	207.23	26.49	166.90	0.53
N ₄	0.65	208.42	27.65	167.78	0.55
N ₅	0.63	206.50	26.71	165.20	0.54
SEm (±)	0.01	1.93	0.32	1.39	0.01
CD (P= 0.05)	0.02	5.64	0.91	4.08	0.02
Interaction (V × N)					
V ₁ N ₁	0.61	202.51	24.54	159.53	0.50
V ₁ N ₂	0.65	209.26	27.92	168.59	0.52
V ₁ N ₃	0.63	206.99	26.04	166.12	0.53
V ₁ N ₄	0.65	208.12	27.82	167.73	0.55
V ₁ N ₅	0.63	206.29	26.87	163.99	0.54
V ₂ N ₁	0.62	204.08	25.24	162.69	0.53
V ₂ N ₂	0.66	213.01	28.86	171.29	0.52
V ₂ N ₃	0.65	211.46	27.54	170.98	0.54
V ₂ N ₄	0.66	211.82	28.43	172.27	0.57
V ₂ N ₅	0.64	210.21	27.09	169.53	0.56
V ₃ N ₁	0.62	201.22	23.76	157.64	0.51
V ₃ N ₂	0.64	206.46	26.94	166.96	0.53
V ₃ N ₃	0.63	203.26	25.89	163.62	0.52
V ₃ N ₄	0.64	205.32	26.72	164.34	0.55
V ₃ N ₅	0.63	203.01	26.18	162.07	0.54
SEm (±)	0.01	2.04	0.37	1.60	0.01
CD (P= 0.05)	0.02	5.96	1.10	4.67	0.03

V_1 , PS-1225; V_2 , YEZIN-15; V_3 , PS-24; N_1 , 100% RDF; N_2 , 75% RDF+3 t/ha FYM; N_3 , 75% RDF+1.5 t/ha vermicompost; N_4 , N_2 +25 kg/ha $ZnSO_4$; N_5 , N_3 +25 kg/ha $ZnSO_4$.

Table 3 Effect of integrated nutrient management on production economics of soybean varieties

Treatment	Cultivation cost (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	Benefit-cost ratio
<i>Variety (V)</i>				
V ₁	30822	59288	28466	1.92
V ₂	30072	49151	19079	1.63
V ₃	29724	68386	38662	2.30
<i>Nutrient management (N)</i>				
N ₁	27087	50200	23113	1.85
N ₂	29036	54167	25131	1.86
N ₃	32036	62650	30614	1.95
N ₄	29936	60345	30409	2.01
N ₅	32936	67344	34408	2.04
<i>Interaction (V × N)</i>				
V ₁ N ₁	27703	48647	20944	1.75
V ₁ N ₂	29652	52897	23245	1.78
V ₁ N ₃	32652	62363	29711	1.90
V ₁ N ₄	30552	62858	32306	2.05
V ₁ N ₅	33552	69675	36123	2.07
V ₂ N ₁	26953	40405	13452	1.49
V ₂ N ₂	28902	43800	14898	1.51
V ₂ N ₃	31902	54489	22587	1.70
V ₂ N ₄	29802	50150	20348	1.68
V ₂ N ₅	32802	56910	24108	1.73
V ₃ N ₁	26605	61548	34943	2.31
V ₃ N ₂	28554	65808	37254	2.30
V ₃ N ₃	31554	71100	39546	2.25
V ₃ N ₄	29454	68029	38575	2.30
V ₃ N ₅	32454	75448	42994	2.32

V₁, PS-1225; V₂, YEZIN-15; V₃, PS-24; N₁, 100% RDF; N₂, 75% RDF+3 t/ha FYM; N₃, 75% RDF+1.5 t/ha vermicompost; N₄, N₂+25 kg/ha ZnSO₄; N₅, N₃+25 kg/ha ZnSO₄.

two consecutive years led to an increase in the residual Zn level. However, the increased loss of these nutrients by the legume crop was the cause of the little drop in the P₂O₅ and K₂O balance. This outcome was consistent with what Reimer *et al.* (2020) found.

Economics: Production economics of soybean cultivation is given in Table 3. Pooled data revealed that V₁ required maximum cultivation cost (₹30822/ha) while, V₃ ensured best gross return (₹68386/ha), net return (₹38662/ha) and B:C (2.30) ratio. Higher returns were the result of highest seed and stover yields, and relatively lower cultivation cost (₹29724/ha) as the seed cost of PS-24 was

little bit less than remaining varieties. Lowest gross return (₹49151/ha), net return (₹19079/ha) and B:C (1.63) were recorded by V₂. The variation in economic returns among varieties was earlier mentioned by Meena *et al.* (2016). Among nutrient management, N₅ required maximum cultivation cost (₹32936/ha), but provided maximum gross return (₹67344/ha), net return (₹34408/ha) and B:C (2.04) too, while lowest cultivation cost (₹27087/ha), gross return (₹50200/ha), net return (₹23113/ha) and B:C (1.85) were observed from N₁. INM option N₅ fetched maximum cultivation cost due to requirement of bulk quantity of vermicompost for cultivation. However, beneficial impact of this treatment on crop yield directly reflected on higher economic return. Similar results were observed by Jat and Praharaj (2018). Interaction effect revealed that V₁N₅ fetched maximum cultivation cost (₹33552/ha), while V₃N₅ ensured best gross return (₹75448/ha), net return (₹42994/ha) and B:C (2.32). Lowest economic return was recorded by V₂N₁.

Drawing from the aforementioned research, it can be inferred that the soybean variety PS-24 was well-suited to the agro-climatic conditions of eastern India when cultivated with a combination of 75% RDF+1.5 t/ha vermicompost+25 kg/ha ZnSO₄. Consequently, it is recommended to cultivate this variety with a combination of 75% RDF+1.5 t/ha vermicompost+25 kg/ha ZnSO₄ to achieve increased nutrient uptake, yield, residual soil fertility, and financial profitability in the conditions of eastern India.

REFERENCES

- Biswas S, Jana K, Agrawal R K and Puste A. 2020. Impact of integrated nutrient management on performance of oat-grasspea cropping systems, competition indices and residual soil fertility. *International Research Journal of Pure and Applied Chemistry* **21**(24): 358–71.
- Bortolon L, Solange E, Bortolon O, Camargo F P, Seraglio N A, Lima A O, Rocha P H F, Souza J P, Sousa W C, Tomazzi M, Lago B C, Nicolodi M and Gianello C. 2018. Yield and nutrient uptake of soybean cultivars under intensive cropping system. *Journal of Agricultural Science* **10**(12): 344–57.
- Donald C M. 1962. In search of yield. *The Journal of Australian Institute of Agricultural Science* **238**: 171–78.
- Jackson M L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt., Ltd., New Delhi.
- Jat R L and Praharaj C S. 2018. Impact of zinc and molybdenum with manure in soybean-chickpea system in Vertisols of central India. *Journal of Food Legumes* **31**(3): 147–53.
- Lindsay W L and Norvell W A. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal* **42**: 421–28.
- Madanzi T, Chiduza C, Richardson, Kageler S J and Muziri T. 2012. Effects of different plant populations on yield of different soybean [*Glycine max* (L.) Merrill] varieties in a smallholder sector of Zimbabwe. *Journal of Agronomy* **11**: 9–16.
- Maheshbabu H M, Hunje R, Biradar N K and Babalad H B. 2008. Effect of organic manures on plant growth, seed yield and quality of soybean. *Karnataka Journal of Agricultural Sciences* **21**(2): 219–21.
- Meena D S, Ram B and Jadone C. 2016. Effect of integrated nutrient management on productivity, profitability, nutrient

- uptake and soil fertility in soybean [*Glycine max* (L.) Merrill]. *Soybean Research* **14** (1): 21–33.
- Morya J, Tripathi R K, Kumawat N, Singh M, Yadav R K, Tomar I S and Sahu Y K. 2018. Influence of organic and inorganic fertilizers on growth, yields and nutrient uptake of soybean [*Glycine max* (L.) Merrill] under Jhabua Hills. *International Journal of Current Microbiology and Applied Sciences* **7**(2): 725–30.
- Nath A, Karunakar A P, Kumar A and Nagar R K. 2017. Effect of sowing dates and varieties on soybean performance in Vidarbha region of Maharashtra, India. *Journal of Applied and Natural Science* **9**(1): 544–50.
- Olsen S R, Cole C V, Watanabe F S and Dean L A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA, Circular No. 939.
- Panse V G and Sukhatme P V. 1985. *Statistical Methods for Agricultural Workers*, pp. 87–89. Indian Council of Agricultural Research Publication. New Delhi.
- Reimer M, Hartmann T E, Oelofse M, Magid J, Else K B and Moller K. 2020. Reliance on biological nitrogen fixation depletes soil phosphorus and potassium reserves. *Nutrient Cycling in Agroecosystems* **118**: 273–91.
- Sharma P, Dupare B U and Patel R M. 2016. Soybean improvement through research in India and socio-economic changes. *Legume Research-An International Journal* **39**: 935–45.
- USDA. 2020. World Agricultural Production, pp. 30. Circular series WAP 7–20, July 2020. <https://ipad.fas.usda.gov>
- Vyas M D and Kushwah S S. 2015. Response of soybean [*Glycine max* (L.) Merrill] varieties to fertility levels in Vertisols of Vindhyan Plateau of Madhya Pradesh. *Soybean Research* **13**(2): 09–18.
- Walkley A and Black I A. 1934. An examination of Degtjareff methods for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29–38.
- Yadav R L. 2001. On farm experiments on integrated nutrient management in rice-wheat cropping system. *Experimental Agriculture* **37**: 99–113.