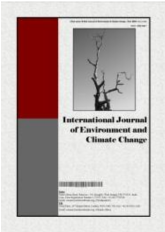

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Effect of Integrated Nutrient Management on Growth Characters of Soybean (*Glycine max* L.) Varieties

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Authors' contributions

This work was carried out in collaboration among all authors. Author LLN carried out the experiment. Authors SB and RD wrote the manuscript. Authors MM helped LLN in analysis. Author DD planned the experiment. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out at Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal during *kharif* season of 2019 and 2020, following three times replicated split plot design with 3 soybean varieties (V_1: PS 1225; V_2: YEZIN 15; V_3: PS 24) in main plot and 5 nutrient management options (N_1: 100% recommended dose of fertilizer (RDF) *i.e.* N: P_2O_5: K_2O-20:60:40 kg/ha; N_2: 75% RDF + 3 t/ha farm yard manure (FYM); N_3: 75% RDF+ 1.5 t/ha vermicompost; N_4: 75% RDF + 3 t/ha FYM + 25 kg/ha $ZnSO_4$; N_5: 75% RDF + 1.5 t/ha vermicompost + 25 kg/ha $ZnSO_4$) in subplot. Results revealed that soybean variety PS 24 grown under application of 75% RDF + 1.5 t/ha vermicompost + 25 kg/ha $ZnSO_4$ recorded highest plant height (73.81 cm at harvest), leaf area index (5.39 at 90 days after sowing *i.e*. DAS), number of branches/plant (11.40), dry matter accumulation (767.09 g/m^2) and crop growth rate (14.02 g/m^2/day). Application of 75% RDF+ 1.5 t/ha vermicompost also ensured high growth attributes soybean varieties specially in PS 24. Conversely, Myanmar variety YEZIN 24 grown under 100% RDF did not perform well due to its non-adaptability in West Bengal condition.

Keywords: Growth; nutrient management; soybean; varieties; vermicompost; zinc.

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1. INTRODUCTION

Soybean is a popular oilseed crop in India where it covers around 12 m ha area with 2.75% of the global soybean production and thereby, indicates low productivity (0.98 t/ha) [1]. Soybean has multipurpose uses as a source of edible oil, cooked dishes and raw materials for various processed products like soya chunk, soya milk, tofu etc. The demand of soybean oil due to its high quality is increasing, while the supply is less due to less productivity. Adequate attention and implementation of modern package of practices can reduce the high market price of soybean oil through addressing demand-supply gap. As a part of suitable package of practices for a crop, selection of right variety based on its adaptability can ensure high productivity as crop performance varies strongly with the interaction between variety and environment [2,3]. Selection of right variety and standardization of package of practice are highly needed to achieve high crop growth specially, under changing climate scenario. In India, the majority of the cultivated varieties of soybean are released more than 20 years back and the age-old varieties have gradually been losing their yield potentialities. Therefore, replacement of the old varieties by newly released improved ones suited to specific agro-climatic conditions is utmost essential for realizing higher crop performance.

As agricultural land is constricted due to heavy population pressure, intensive crop cultivation using chemicals has become a routine farmer's practice to increase crop productivity [4]. However, intensive crop cultivation using chemical fertilizer can not only degrade land productivity but also possess serious environmental hazards due to fertilizer's toxic nature. Under changing climate scenario, therefore, considering the safety of the environment, it is necessary to reduce the use of chemical fertilizers by substituting a part of it with organic manures which can ensure the good growth of soybean crop for achieving adequate productivity. Organic manures such as farm yard manure (FYM) and vermicompost can effectively supply various kinds of nutrients, plant growth promoting hormones, enzymes etc. and thereby, improve soybean growth. In addition, micronutrient Zn influences chlorophyll content and stomatal conductance [5], therefore, its deficiency decreases photosynthetic rate [6] in addition to reduction in protein biosynthesis [7]. Hence, Zn fertilization becomes an integral part of nutrient management to enhance yield and quality of soybean [8], particularly in Zn deficient soils. Experimental findings reveal that the integrated nutrient management (INM) practices sustain productivity and quality of crop as well as ensure economic profit and environment safety to a high extent [9].

Soybean is a nutrient exhaustive crop among the legumes and therefore, the crop does not yield high unless the sufficient quantity of nutrients is supplied during the growth period [10] (Singh et al., 2006). However, the standardization of agro-techniques specially, nutrient management for achieving adequate growth of soybean under the agro-climatic conditions of eastern India is still lacking. Therefore, the field experiment was planned to identify suitable nutrient management practice and variety for achieving high growth of soybean.

2. MATERIALS AND METHODS

The field experiment was conducted at Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal during monsoon season of 2019 and 2020 with the aim to observe growth properties of soybean varieties under various INM practices. The experiment followed three times replicated split plot design with 3 soybean varieties (V_1: PS 1225; V_2: YEZIN 15; V_3: PS 24) in main plot and 5 nutrient management options (N_1: 100% recommended dose of fertilizer (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: 75% RDF + 3 t/ha FYM + 25 kg/ha $ZnSO_4$; N_5: 75% RDF + 1.5 t/ha vermicompost + 25 kg/ha $ZnSO_4$) in subplot. Along with organic manures, chemical fertilizers such as urea (N), single super phosphate *i.e*. S.S.P. (P_2O_5) and muriate of potash *i.e*. M.O.P. (K_2O) and $ZnSO_4$, $7H_2O$ (Zn) were applied as basal dressing. Seed rate and spacing of soybean were 75 kg/ha and 45 cm ×10 cm, respectively. Soybean seeds were sown on 28th and 25th June in 2019 and 2020, respectively and crops were grown using standard package of practices suitable for the region. Size of individual plot was 4.5 m× 3 m.

Observations were taken on growth attributes such as plant height, leaf area index, dry matter accumulation, crop growth rate and number of branches/plant. Plant height, leaf area index and dry matter accumulation were taken at 30, 60, 90 days after sowing (DAS) and at harvest. Crop growth rate (CGR) were observed between the intervals of 30-60 DAS, 60-90 DAS, 90-120 DAS.

Number of branches/plant was counted during the time of harvesting. For observations of plant height and number of branches/plant, 10 random plants were selected leaving the border rows and tagged. For observations on leaf area index and dry matter accumulation, 5 random plants from net sown area were taken at each interval. Mean values were chalked out finally. Crop growth rate was computed using the following formula:

$$CGR\ (g/m^2/day) = (W_2\text{-}W_1)/(T_2\text{-}T_1) \times 1/A$$

Where, W_2 and W_1 were dry matter (g/m^2) produced at T_2 and T_1 times (days). A was the 1 m^2 area.

Data collected from the field were statistically analysed by ‘analysis of variance’ method [11] and treatment means were compared using critical difference values at 5% level of significance using OP-Stat online portal developed by Sheoran et al. [12].

3. RESULTS AND DISCUSSION

It was observed from the results (Tables 1, 2,3, 4, 5) that plant height, leaf area index, number of branches/plant, dry matter accumulation and crop growth rate at various intervals during crop growth period were significantly varied among varieties, nutrient management levels and their interactions. According to pooled analysis, maximum plant height (28.87, 60.74, 67.72 and 69.66 cm at 30, 60, 90 DAS and harvest), leaf area index (1.70, 4.81, 5.13 and 3.62 at 30, 60, 90 DAS and harvest), number of branches/plant (10.29), dry matter accumulation (58.05, 446.18, 659.01 and 705.48 g/m^2 at 30, 60, 90 DAS and harvest) and crop growth rate (12.94, 7.09 and 1.86 g/m^2/day at 30-60, 60-90 and 90-120 DAS) were shown by PS 24 (V_3), which was next followed by PS 1225 (V_2). It might be due to greater adaption potential of these Indian varieties over Myanmar variety YEZIN 15. High plant height under PS 24 was perhaps the result of greater cell division and elongation as well as increase in internode length. Maximum leaf area index under PS 24 might be due to high generation of leaves as well as expansion of leaf area. Increase in leaf area index and high solar radiation interception probably ensured high photosynthesis which reflected on high accumulation of dry matter as well as high number of branches/plant and thereby, ensured high growth rate of crop. The result was in line with the finding of Nath et al. [13].

Among various nutrient management levels, application of 75% RDF + 1.5 t/ha vermicompost + 25 kg/ha $ZnSO_4$ (N_5) ensured maximum plant height (28.03, 58.38, 64.59 and 66.82 cm at 30, 60, 90 DAS and harvest), leaf area index (1.67, 4.69, 5.01 and 3.51 at 30, 60, 90 DAS and harvest), number of branches/plant (9.71), dry matter accumulation (56.59, 438.17, 642.38 and 685.38 g/m^2 at 30, 60, 90 DAS and harvest) and crop growth rate (12.72, 6.80 and 1.81 g/m^2/day at 30-60, 60-90 and 90-120 DAS) of soybean. It was closely followed by application of 75% RDF+ 1.5 t/ha vermicompost (N_3). On a contrary, 100% RDF application (N_1) recorded relatively lowest plant height, leaf area index, number of branches/plant, dry matter accumulation and crop growth rate. Along with chemical fertilizer, beneficial impact of vermicompost as organic source of nutrients on soil physical, chemical and biological properties through increasing nutrient availability, water holding capacity, micro-organisms’ activity specially of rhizobium and supplying wide range of nutrients, plant growth promoting hormones, enzymes, vitamins etc. to the crop might favour soybean crop growth [14]. Additionally, zinc application from treatment N_5 perhaps helped soybean to attain high crop growth through its positive influence on enzymatic activities, nodulation, chlorophyll synthesis and thereby, photosynthesis activity. The results were in consonance with the findings of Shivakumar and Ahlawat [15]. With progress towards crop maturity, plant height and dry matter accumulation increased steadily. However, maximum increase of crop growth (CGR) was observed up to 60 DAS. Maximum leaf area index increased up to 90 DAS, thereby, declined with maturity. Results obtained from interactions between varieties and nutrient management options were mentioned hereunder.

Soybean variety PS 24 grown under application of 75% RDF + 1.5 t/ha vermicompost + 25 kg/ha $ZnSO_4$ (V_3N_5) recorded maximum plant height throughout the crop growth period. Plant height increased with progress of crop towards maturity. However, maximum increase in plant height was observed up to 60 DAS. It was perhaps due to active period of vegetative growth when there was no need of partitioning of dry matter to reproductive organs. According to the pooled data (Table 1), PS 24 grown under application of 75% RDF + 1.5 t/ha vermicompost + 25 kg/ha $ZnSO_4$ (V_3N_5) attained plant height of 32.35 cm, 64.44 cm, 71.61 cm and 73.81 cm at 30, 60, 90 DAS and at harvest, respectively, which was followed by PS 24 grown under application of

Table 1. Effect of integrated nutrient management on plant height (cm) of soybean varieties

Treatments	30 DAS			60 DAS			90 DAS			Harvest		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Varieties (V)												
V_1	25.13	22.42	23.78	56.08	52.92	54.50	62.18	57.87	60.03	64.60	59.66	62.13
V_2	19.15	16.88	18.02	45.69	42.46	44.08	52.97	48.63	50.80	55.56	50.48	53.02
V_3	30.59	27.15	28.87	62.76	58.71	60.74	70.34	65.10	67.72	72.47	66.84	69.66
S. Em. (±)	0.65	0.62	0.64	0.88	0.83	0.86	0.93	0.89	0.91	1.0	0.96	0.98
C. D. (P= 0.05)	1.90	1.82	1.86	2.58	2.44	2.51	2.72	2.59	2.65	2.92	2.81	2.86
Nutrient Management (N)												
N_1	18.42	17.43	17.93	47.70	45.73	46.72	55.23	51.30	53.27	57.46	53.09	55.28
N_2	22.98	20.25	21.62	51.28	48.81	50.05	58.93	54.98	56.96	60.95	56.57	58.76
N_3	27.16	23.57	25.37	57.99	54.07	56.03	64.90	60.41	62.66	67.12	62.27	64.70
N_4	26.31	23.32	24.82	56.72	51.95	54.34	63.34	56.90	60.12	65.98	58.94	62.46
N_5	29.89	26.17	28.03	60.51	56.25	58.38	66.75	62.42	64.59	69.53	64.10	66.82
S. Em. (±)	0.70	0.66	0.68	0.99	0.95	0.97	1.06	1.01	1.03	1.10	1.06	1.08
C. D. (P= 0.05)	2.05	1.94	1.99	2.91	2.79	2.85	3.09	2.95	3.02	3.21	3.11	3.16
Interaction (V × N)												
V_1N_1	16.29	15.16	15.73	46.72	45.32	46.02	54.16	50.67	52.42	55.21	52.34	53.78
V_1N_2	23.57	20.73	22.15	52.63	50.79	51.71	58.39	55.71	57.05	59.37	57.12	58.25
V_1N_3	26.14	23.09	24.62	59.54	56.86	58.20	65.28	61.45	63.37	68.68	63.23	66.00
V_1N_4	29.31	25.52	27.42	60.18	53.54	56.86	65.65	57.19	61.42	67.53	59.46	63.50
V_1N_5	30.32	27.61	28.97	61.32	58.08	59.70	67.41	64.34	65.88	71.19	66.17	68.68
V_2N_1	13.72	13.42	13.57	38.16	36.75	37.46	46.37	43.46	44.92	49.61	45.53	47.57
V_2N_2	15.56	14.37	14.97	40.42	38.32	39.37	48.92	45.72	47.32	51.23	47.29	49.26
V_2N_3	22.82	19.19	21.01	48.52	45.09	46.81	56.71	52.32	54.52	60.49	54.41	57.45
V_2N_4	18.91	16.57	17.74	47.81	43.63	45.72	53.56	48.42	50.99	56.61	50.13	53.37
V_2N_5	24.73	20.83	22.78	53.51	48.51	51.01	59.29	53.25	56.27	61.87	55.05	58.46
V_3N_1	25.25	23.72	24.49	58.23	55.12	56.68	65.17	59.77	62.47	67.56	61.42	64.49
V_3N_2	29.82	25.65	27.70	60.74	57.34	59.04	69.48	63.52	66.50	70.25	65.31	67.78
V_3N_3	32.53	28.44	30.40	65.92	60.25	63.08	72.72	67.47	70.09	74.19	69.18	71.68
V_3N_4	30.73	27.87	29.30	62.18	58.67	60.42	70.81	65.09	67.95	72.82	67.22	70.02
V_3N_5	34.64	30.07	32.35	66.72	62.17	64.44	73.56	69.67	71.61	76.53	71.09	73.81
S. Em. (±)	0.75	0.70	0.72	1.05	1.02	1.03	1.13	1.10	1.11	1.20	1.16	1.18
C. D. (P= 0.05)	2.18	2.06	2.12	3.08	2.97	3.02	3.30	3.21	3.25	3.51	3.39	3.45

Table 2. Effect of integrated nutrient management on leaf area index of soybean varieties

Treatments	30 DAS			60 DAS			90 DAS			Harvest		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Varieties (V)												
V_1	1.69	1.49	1.59	4.39	4.27	4.33	4.75	4.55	4.65	3.32	3.09	3.21
V_2	1.51	1.39	1.45	3.87	3.80	3.84	4.15	3.97	4.06	2.81	2.57	2.69
V_3	1.82	1.57	1.70	4.94	4.67	4.81	5.23	5.02	5.13	3.74	3.50	3.62
S. Em. (±)	0.02	0.01	0.02	0.06	0.05	0.06	0.07	0.06	0.07	0.05	0.04	0.04
C. D. (P= 0.05)	0.08	0.05	0.06	0.19	0.17	0.18	0.21	0.19	0.20	0.15	0.13	0.14
Nutrient Management (N)												
N_1	1.56	1.40	1.48	3.94	3.84	3.89	4.21	4.09	4.15	2.84	2.67	2.76
N_2	1.63	1.45	1.54	4.30	4.17	4.24	4.62	4.44	4.53	3.20	2.96	3.08
N_3	1.73	1.52	1.63	4.53	4.38	4.46	4.84	4.62	4.73	3.44	3.17	3.31
N_4	1.67	1.48	1.58	4.44	4.26	4.35	4.74	4.53	4.64	3.34	3.08	3.21
N_5	1.78	1.56	1.67	4.79	4.58	4.69	5.13	4.88	5.01	3.63	3.38	3.51
S. Em. (±)	0.03	0.02	0.03	0.07	0.06	0.07	0.08	0.07	0.08	0.06	0.05	0.05
C. D. (P= 0.05)	0.10	0.07	0.08	0.22	0.20	0.21	0.24	0.22	0.23	0.17	0.16	0.16
Interaction (V × N)												
V_1N_1	1.52	1.40	1.46	3.89	3.99	3.94	4.13	4.10	4.12	2.82	2.71	2.77
V_1N_2	1.64	1.46	1.55	4.32	4.22	4.27	4.75	4.54	4.65	3.30	3.08	3.19
V_1N_3	1.77	1.53	1.65	4.47	4.31	4.39	4.88	4.63	4.76	3.45	3.16	3.31
V_1N_4	1.70	1.49	1.60	4.39	4.26	4.33	4.79	4.60	4.70	3.38	3.12	3.25
V_1N_5	1.82	1.59	1.71	4.90	4.58	4.74	5.20	4.89	5.05	3.68	3.40	3.54
V_2N_1	1.43	1.32	1.38	3.26	3.18	3.22	3.50	3.42	3.46	2.15	2.01	2.08
V_2N_2	1.45	1.36	1.41	3.81	3.69	3.75	4.00	3.82	3.91	2.70	2.38	2.54
V_2N_3	1.55	1.43	1.49	4.05	4.07	4.06	4.35	4.15	4.25	3.05	2.80	2.93
V_2N_4	1.50	1.39	1.45	3.99	3.87	3.93	4.21	3.95	4.08	2.91	2.62	2.77
V_2N_5	1.62	1.46	1.54	4.27	4.20	4.24	4.67	4.50	4.59	3.23	3.05	3.14
V_3N_1	1.74	1.50	1.62	4.68	4.37	4.53	5.01	4.76	4.89	3.55	3.30	3.43
V_3N_2	1.80	1.55	1.68	4.77	4.60	4.69	5.12	4.98	5.05	3.62	3.43	3.53
V_3N_3	1.87	1.61	1.74	5.09	4.78	4.94	5.30	5.10	5.20	3.83	3.57	3.70
V_3N_4	1.82	1.57	1.70	4.95	4.66	4.81	5.24	5.03	5.13	3.75	3.50	3.63
V_3N_5	1.90	1.63	1.77	5.20	4.95	5.08	5.52	5.25	5.39	3.98	3.70	3.84
S. Em. (±)	0.04	0.03	0.04	0.08	0.07	0.08	0.09	0.08	0.09	0.06	0.06	0.06
C. D. (P= 0.05)	0.12	0.10	0.11	0.24	0.22	0.23	0.26	0.24	0.25	0.19	0.18	0.18

Table 3. Effect of integrated nutrient management on number of branches per plant of soybean varieties

Treatments	Number of branches per plant		
	2019	**2020**	**Pooled**
Varieties (V)			
V_1 (PS 1225)	9.13	7.90	8.51
V_2 (Yezin 15)	7.34	6.33	6.84
V_3 (PS 24)	10.79	9.79	10.29
S. Em. (±)	0.21	0.14	0.17
C. D. (P= 0.05)	0.63	0.41	0.52
Nutrient Management (N)			
N_1 (100% RDF)	7.73	6.79	7.26
N_2 (75% RDF + 3 t/ha FYM)	8.58	7.69	8.13
N_3 (75% RDF + 1.5 t/ha vermicompost)	9.58	8.46	9.02
N_4 (75% RDF + 3 t/ha FYM+ 25 kg/ha $ZnSO_4$)	9.21	8.02	8.61
N_5 (75% RDF +1.5 t/ha vermicompost +25 kg/ha $ZnSO_4$)	10.35	9.07	9.71
S. Em. (±)	0.26	0.19	0.23
C. D. (P= 0.05)	0.76	0.58	0.67
Interaction (V × N)			
V_1N_1	7.21	6.52	6.86
V_1N_2	8.89	7.77	8.33
V_1N_3	9.61	8.31	8.96
V_1N_4	9.42	7.96	8.69
V_1N_5	10.52	8.94	9.73
V_2N_1	6.13	5.21	5.67
V_2N_2	6.74	5.88	6.31
V_2N_3	7.92	6.90	7.41
V_2N_4	7.36	6.25	6.80
V_2N_5	8.57	7.42	7.99
V_3N_1	9.87	8.66	9.26
V_3N_2	10.11	9.41	9.76
V_3N_3	11.22	10.17	10.69
V_3N_4	10.84	9.87	10.35
V_3N_5	11.95	10.85	11.40
S. Em. (±)	0.29	0.24	0.26
C. D. (P= 0.05)	0.86	0.70	0.78

Table 4. Effect of integrated nutrient management on dry matter accumulation (g/m^2) of soybean varieties

Treatments	30 DAS			60 DAS			90 DAS			Harvest		
	2019	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
Varieties (V)												
V_1	57.13	45.79	51.46	416.11	380.06	398.09	605.93	556.59	581.26	646.04	593.80	619.92
V_2	50.28	38.66	44.47	367.01	321.92	344.47	532.41	470.37	501.39	557.27	494.61	525.94
V_3	63.40	52.70	58.05	457.54	434.81	446.18	675.71	642.31	659.01	723.87	687.08	705.48
S. Em. (±)	1.10	1.00	1.04	6.21	5.40	5.81	10.41	8.60	9.51	11.55	9.63	10.60
C. D. (P= 0.05)	3.24	2.94	3.04	18.14	15.78	16.98	30.45	25.15	27.80	33.76	28.15	30.98
Nutrient Management (N)												
N_1	51.80	39.54	45.67	377.79	333.09	355.44	551.33	490.36	520.85	579.30	521.02	550.16
N_2	53.87	44.21	49.04	396.45	362.78	379.62	577.02	532.36	554.69	610.86	565.35	588.11
N_3	58.94	47.54	53.24	427.69	393.68	410.69	626.93	583.34	605.14	667.92	620.72	644.32
N_4	57.98	46.19	52.09	411.64	383.86	397.75	600.28	559.17	579.73	641.88	593.30	617.59
N_5	62.09	51.08	56.59	454.18	422.16	438.17	667.85	616.90	642.38	712.00	658.75	685.38
S. Em. (±)	1.56	1.19	1.38	7.58	6.19	6.89	12.06	10.10	11.10	13.25	11.09	12.18
C. D. (P= 0.05)	4.57	3.47	4.03	22.16	18.12	20.14	35.26	29.54	32.44	38.74	32.43	35.60
Interaction (V × N)												
V_1N_1	50.42	37.76	44.09	360.72	317.45	339.09	528.91	472.23	500.57	550.53	502.63	526.58
V_1N_2	53.59	41.47	47.53	400.88	365.62	383.25	574.27	536.16	555.22	613.71	570.25	591.98
V_1N_3	57.16	45.29	51.23	426.69	390.88	408.79	620.35	579.71	600.03	665.76	617.43	641.60
V_1N_4	61.11	51.29	56.20	425.26	398.78	412.02	617.53	567.78	592.66	660.27	605.98	633.13
V_1N_5	63.37	53.13	58.25	466.99	430.34	448.67	688.61	627.08	657.85	739.92	672.72	706.32
V_2N_1	44.37	32.48	38.43	338.53	277.28	307.91	494.21	409.41	451.81	510.62	428.36	469.49
V_2N_2	46.32	37.54	41.93	348.04	300.53	324.29	509.35	441.74	475.55	528.17	463.67	495.92
V_2N_3	54.84	42.92	48.88	379.40	340.08	359.74	551.67	497.93	524.80	577.29	525.25	551.27
V_2N_4	49.26	37.61	43.44	367.62	326.44	347.03	525.12	477.27	501.20	559.95	500.69	530.32
V_2N_5	56.63	42.75	49.69	401.47	365.28	383.38	581.72	525.54	553.63	610.36	555.08	582.72
V_3N_1	60.61	48.38	54.50	434.14	404.56	419.35	630.89	589.45	610.17	676.76	632.07	654.42
V_3N_2	61.72	53.63	57.68	440.44	422.19	431.32	647.49	619.18	633.34	690.71	662.15	676.43
V_3N_3	64.83	54.42	59.63	477.00	450.08	463.54	708.78	672.39	690.59	760.76	719.49	740.13
V_3N_4	63.57	49.69	56.63	442.05	426.38	434.22	658.19	632.46	645.33	705.43	673.23	689.33
V_3N_5	66.29	57.38	61.84	494.10	470.87	482.49	733.23	698.09	715.66	785.72	748.46	767.09
S. Em. (±)	1.79	1.41	1.60	8.82	7.68	8.25	13.73	11.67	12.70	14.88	12.48	13.67
C. D. (P= 0.05)	5.23	4.12	4.68	25.78	22.45	24.11	40.12	34.12	37.12	43.48	36.48	39.96

Table 5. Effect of integrated nutrient management on crop growth rate ($g/m^2/day$) of soybean varieties

Treatments	30-60 DAS			60-90 DAS			90-120 DAS		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Varieties (V)									
V_1	11.96	11.14	11.55	6.33	5.88	6.10	1.60	1.49	1.54
V_2	10.55	9.44	10.00	5.51	4.95	5.23	1.24	1.21	1.22
V_3	13.14	12.74	12.94	7.27	6.91	7.09	1.93	1.79	1.86
S. Em. (±)	0.34	0.31	0.33	0.24	0.21	0.23	0.03	0.02	0.03
C. D. (P= 0.05)	1.01	0.91	0.96	0.71	0.61	0.67	0.09	0.06	0.08
Nutrient Management (N)									
N_1	10.86	9.78	10.32	5.78	5.24	5.51	1.17	1.28	1.23
N_2	11.42	10.62	11.02	6.02	5.65	5.83	1.41	1.39	1.40
N_3	12.29	11.54	11.91	6.64	6.32	6.48	1.72	1.58	1.65
N_4	11.78	11.25	11.52	6.29	5.84	6.06	1.78	1.44	1.61
N_5	13.07	12.37	12.72	7.12	6.49	6.80	1.86	1.76	1.81
S. Em. (±)	0.38	0.34	0.36	0.27	0.24	0.26	0.04	0.03	0.04
C. D. (P= 0.05)	1.11	0.99	1.05	0.78	0.70	0.74	0.12	0.09	0.11
Interaction (V × N)									
V_1N_1	10.34	9.32	9.83	5.60	5.16	5.38	0.86	1.21	1.04
V_1N_2	11.57	10.80	11.19	5.78	5.68	5.73	1.57	1.36	1.47
V_1N_3	12.31	11.52	11.92	6.45	6.29	6.37	1.81	1.51	1.66
V_1N_4	12.14	11.58	11.86	6.41	5.63	6.02	1.71	1.53	1.62
V_1N_5	13.45	12.57	13.01	7.38	6.56	6.97	2.05	1.82	1.94
V_2N_1	9.80	8.16	8.98	5.19	4.40	4.79	0.82	0.94	0.88
V_2N_2	10.05	8.76	9.41	5.37	4.70	5.04	0.94	1.09	1.02
V_2N_3	10.82	9.90	10.36	5.74	5.26	5.50	1.28	1.36	1.32
V_2N_4	10.61	9.63	10.12	5.25	5.03	5.14	1.74	1.17	1.45
V_2N_5	11.49	10.75	11.12	6.01	5.34	5.67	1.43	1.47	1.45
V_3N_1	12.45	11.87	12.16	6.56	6.16	6.36	1.83	1.70	1.77
V_3N_2	12.62	12.28	12.45	6.90	6.56	6.73	1.73	1.72	1.72
V_3N_3	13.74	13.19	13.46	7.72	7.41	7.57	2.08	1.88	1.98
V_3N_4	12.61	12.55	12.58	7.20	6.87	7.03	1.89	1.63	1.76
V_3N_5	14.26	13.78	14.02	7.97	7.57	7.77	2.10	2.01	2.05
S. Em. (±)	0.41	0.38	0.40	0.29	0.27	0.28	0.05	0.04	0.04
C. D. (P= 0.05)	1.20	1.11	1.16	0.84	0.79	0.82	0.15	0.12	0.13

75% RDF+ 1.5 t/ha vermicompost (V_3N_3) (30.40 cm at 30 DAS, 63.08 cm at 60 DAS, 70.09 cm at 90 DAS and 71.68 cm at harvest) and it showed statistical similarity with V_3N_5. Lowest plant height was observed from YEZIN 15 grown under 100% RDF (V_2N_1) throughout the crop growth period.

Pooled data (Table 2) indicated that leaf area index was increased under INM practice over sole RDF. Soybean variety PS 24 grown under application of 75% RDF + 1.5 t/ha vermicompost + 25 kg/ha $ZnSO_4$ (V_3N_5) expressed highest leaf area index *i.e.* 1.77, 5.08, 5.39 and 3.84 at 30, 60, 90 DAS and harvest, respectively. However, PS 24 grown under application of 75% RDF+ 1.5 t/ha vermicompost (V_3N_3) also recorded statistically similar leaf area index *i.e.* 1.74, 4.94, 5.20 and 3.70 at 30, 60, 90 DAS and harvest, respectively. YEZIN 15 grown under 100% RDF (V_2N_1) showed lowest leaf area index during entire period of crop growth. Leaf area index was found to be increasing up to 90 DAS after which it showed declining trend with progress towards crop maturity. Decrease in leaf area index with crop progress towards maturity indicated leaf senescence in response to crop age.

Number of branches/plant were measured during the time of crop harvesting (Table 3). Maximum number of branches/plant were exhibited by Soybean variety PS 24 grown under application of 75% RDF + 1.5 t/ha vermicompost + 25 kg/ha $ZnSO_4$ (V_3N_5) (11.95 in 2019, 10.85 in 2020 and 11.40 in pooled analysis). It was closely followed by PS 24 grown under application of 75% RDF+ 1.5 t/ha vermicompost (V_3N_3) (11.22 in 2019, 10.17 in 2020 and 10.69 in pooled analysis). Lowest number of branches/plant (6.13 in 2019, 5.21 in 2020 and 5.67 in pooled analysis) were exhibited by soybean variety YEZIN 15 grown under 100% RDF (V_2N_1). Proper plant establishment under favourable condition as well as high photosynthesis activity might result in generation of more number of branches/plant in PS 24 under application of 75% RDF + 1.5 t/ha vermicompost + 25 kg/ha $ZnSO_4$.

Pooled results (Table 4) showed that soybean variety PS 24 grown under application of 75% RDF + 1.5 t/ha vermicompost + 25 kg/ha $ZnSO_4$ (V_3N_5) accumulated maximum dry matter (61.84, 482.49, 715.66 and 767.09 g/m^2 at 30, 60, 90 DAS and harvest, respectively), which was next followed and showed statistical similarity by PS 24 grown under application of 75% RDF+ 1.5 t/ha vermicompost (V_3N_3) (59.63, 463.54, 690.59 and 740.13 g/m^2 at 30, 60, 90 DAS and harvest, respectively). Soybean variety, YEZIN 15 grown under 100% RDF (V_2N_1) accumulated lowest dry matter throughout the crop growth period.

Crop growth rate depended on dry matter accumulation of crop during different times of crop growth period. Soybean showed maximum crop growth rate during the period of 30-60 DAS and thereafter, crop growth rate decreased in response to crop's progress towards maturity. It indirectly reflected on photosynthesis activity of crop to produce variable dry matter during different times of crop growth period. According to the pooled data (Table 5), soybean variety PS 24 grown under application of 75% RDF + 1.5 t/ha vermicompost + 25 kg/ha $ZnSO_4$ (V_3N_5) showed maximum crop growth rate *i.e.* 14.02, 7.77 and 2.05 g/m^2/day at 30-60, 60-90 and 90-120 DAS, respectively. However, PS 24 grown under application of 75% RDF+ 1.5 t/ha vermin-compost (V_3N_3) remained statistically at par with V_3N_5 with crop growth rates of 13.46, 7.57 and 1.98 g/m^2/day at 30-60, 60-90 and 90-120 DAS, respectively. Lowest crop growth rate throughout the crop life cycle was exhibited by soybean variety, YEZIN 15 grown under 100% RDF (V_2N_1).

The variation in growth among soybean varieties was perhaps due to their genetic traits as well as interaction with the environment and management practice [3]. YEZIN 15 was introduced from Myanmar, therefore, it probably could not find suitability to grow in West Bengal condition of India. PS 24, on the other hand, showed greater adoption potential to the edapho-climatic condition of West Bengal condition of India. Further, when 75% RDF + 1.5 t/ha vermicompost + 25 kg/ha $ZnSO_4$ was applied, the beneficial impacts of vermicompost and micronutrient zinc on soil health, directly reflected on vegetative growth of the plants through increasing cell division and photosynthesis. Application of 75% RDF+ 1.5 t/ha vermicompost through showing high growth attributes in soybean varieties confirmed the positive role of vermicompost on assimilation of photosynthates and its partitioning towards linear growth leading to rapid cell division and elongation, resulting in greater development of plant vigour. Earlier, the beneficial effect of organic manures on soybean cultivars was reported by Yan et al. [16].

4. CONCLUSION

From the study, it can be concluded that growth of soybean crop varies with the adaption potential of the varieties to an edapho-climatic condition as well as their response to varying nutrient management. Considering the results of the experiment, it is recommended that PS 24 can be successfully grown under application of 75% RDF + 1.5 t/ha vermicompost + 25 kg/ha $ZnSO_4$ during *kharif* season in new alluvial zone of West Bengal, India to achieve high growth of soybean crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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