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Improving Growth and Yield of Green Gram [*Vigna radiata (*L.) Wilczek] with Optimum Sowing Time and Bio Input Applications

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted to examine the effects of sowing windows and nutrient management over two consecutive *Summer* seasons (2022-23 and 2023-24) at the Agricultural Research Farm, Banaras Hindu University. The treatments consisted of four sowing windows for greengram D_1: 1st Sowing (8th March and 14th March), D_2: 2nd Sowing (15th March and 21st March), D_3: 3rd Sowing (22nd March and 28th March), D_4: 4th Sowing (29th March and 4th April) in 2022-23 and 2023-24, respectively and five nutrient management practices N_1: 100% recommended dose of

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fertilizers (RDF) (15, 40, 20 kg NPK ha^{-1}), N_2: 70% RDF+ 15% recommended dose of nitrogen (RDN) through Poultry manure + Consortia of biofertilizers @ 10 ml kg^{-1} seeds, N_3: 70% RDF+ 15% RDN through Poultry manure + *Panchagavya* @ 30 ml L^{-1} (2-spray), N_4: 70% RDF+ 15% RDN through Poultry manure + Seaweed extract @ 2 ml L^{-1} (2-spray), N_5: 70% RDF+15% RDN through Poultry manure + Consortia of biofertilizers @ 10 ml kg^{-1} seeds + *Panchagavya* @ 30 ml L^{-1} & Seaweed extract @ 2 ml L^{-1} both as tank mix (2-spray) thereby making twenty treatment combinations were tested in split plot design with three replications. Results revealed that the crop sown on March 8 and March 14 over two consecutive years yielded higher plant height (41.3 and 42.4 cm at harvest), number of primary branches $plant^{-1}$ (5.60 and 5.74 at harvest), absolute growth rate (AGR) (g day^{-1}), crop growth rate (CGR) (g m^{-2} land area day^{-1}), relative growth rate (RGR) (g g^{-1} day^{-1}), net assimilation rate (NAR) (g m^{-2} day^{-1}) and grain yield (982 and 998 kg ha^{-1}). Furthermore, under nutrient management application of 70% RDF+15% RDN through Poultry manure + Consortia of biofertilizers @ 10 ml kg^{-1} seed + *Panchagavya* @ 30 ml L^{-1} & Seaweed extract @ 2 ml L^{-1} both as tank mix (2-spray) exhibited significantly higher in growth parameters such as plant height (40.0 and 41.2 cm at harvest), number of primary branches $plant^{-1}$ (5.60 and 5.78 at harvest), CGR (g m^{-2} land area day^{-1}), RGR (g g^{-1} day^{-1}) and grain yield (940 and 959 kg ha^{-1}). This research contributes valuable insights in optimizing sowing windows and nutrient management for enhanced growth and productivity of greengram (*Vigna radiata* L.).

Keywords: Growth rate; Panchagavya; seaweed extract; sowing dates; yield.

ABBREVIATIONS

RDF : Recommended dose of fertilizers
RDN : Recommended dose of nitrogen
AGR : Absolute growth rate
CGR : Crop growth rate
RGR : Relative growth rate
NAR : Net assimilation rate

1. INTRODUCTION

Pulses represent the second most significant category of food crops following cereals and serve as the primary source of vegetable protein. These crops are recognized for enhancing the physical properties of soil through their tap root systems, which penetrate deeper soil layers, and their capacity to utilize atmospheric nitrogen via biological nitrogen fixation, a process that is both economically viable and environmentally sustainable. Pulses exhibit drought resistance and contribute to the prevention of soil erosion due to their deep root systems and effective ground cover. Furthermore, pulses engage in symbiotic relationships to fix atmospheric nitrogen. In India, pulses are cultivated over an area of 28.90 million hectares, yielding a total production of 26.06 million tonnes, with an average productivity of 902 kg ha^{-1} (Agricultural Statistics at a Glance, 2023).

Greengram [*Vigna radiata* (L.) Wilczek], commonly referred to as mungbean, is a self-pollinated leguminous crop cultivated during both the *Kharif* (July-October) and *Summer* (March-June) seasons in the arid and semi-arid regions of India. Its cultivation across various seasons and cropping systems is facilitated by its shorter growth duration and reduced sensitivity to photoperiod and thermal variations. The adoption of greengram cultivation during the *summer* season has gained widespread acceptance due to the availability of new varieties, which contribute to additional income, enhance soil fertility, and promote efficient land utilization (Dodwadia and Sharma, 2012). The crop can also tolerate higher temperatures and thus can be successfully grown during summer season when temperature rises beyond 35°C (Pathak *et al.,* 2025). Post-harvest, greengram plants can be utilized as green fodder or green manure. In India, greengram ranks as the third most important pulse crop after chickpea and pigeon pea, with significant cultivation in the states of Rajasthan, Madhya Pradesh, Punjab, Haryana, Uttar Pradesh, Maharashtra, Karnataka, Andhra Pradesh, and Tamil Nadu. It is a rich source of protein and vitamin B, offering an excellent protein content of 24.5%, along with high-quality lysine (460 mg g N^{-1}) and tryptophan (60 mg g N^{-1}). Additionally, it contains notable quantities of ascorbic acid and riboflavin (0.21 mg 100 g^{-1}) (Azadi *et al.,* 2013).

Planting time constitutes a critical non-monetary factor in realizing the yield potential of improved crop varieties, as it facilitates optimal synchronization between the vegetative and reproductive phases of the crop (Kumar *et al.,* 2015; Kumar *et al.,* 2016). Greengram is frequently cultivated on marginal lands and is typically provided with suboptimal fertilizer doses in local varieties, resulting in low productivity. The indiscriminate application of inorganic fertilizers leads to multi-nutrient deficiencies, thereby reducing yield (Sahoo *et al.,* 2024). Consequently, maintaining nutrient balance is essential for enhancing crop yields. To optimize greengram production, it is imperative to employ a balanced and efficient fertilizer strategy that integrates inorganic, organic, and biofertilizers, along with foliar application, to achieve higher yields and reduce production costs. There is an urgent need to decrease the reliance on chemical fertilizers and instead increase the use of organic manures, which are known to enhance the physico-chemical properties of soil and supply nutrients to plants. Biofertilizers fulfil several crucial functions in enhancing soil fertility, crop productivity, and overall agricultural production, owing to their environmentally friendly nature (Nepali *et al.,* 2025). Foliar application is advantageous due to its rapid and efficient nutrient utilization, prevention of losses through leaching and fixation, and regulation of nutrient uptake by plants.

2. MATERIALS AND METHODS

The study was conducted on Gangetic Alluvial soil (*Inceptisols*) characterized by a sandy clay loam texture, slight alkalinity, and low levels of organic carbon and nitrogen, at the Agricultural Research Farm, Banaras Hindu University, during the *Summer* of 2022-23 and 2023-24. The treatments consisted of four sowing windows for greengram D_1: 1st Sowing (8th March and 14th March), D_2: 2nd Sowing (15th March and 21st March), D_3: 3rd Sowing (22nd March and 28th March), D_4: 4th Sowing (29th March and 4th April) in 2022-23 and 2023-24, respectively and five nutrient management practices N_1: 100% RDF (15, 40, 20 kg NPK ha^{-1}), N_2: 70% RDF+ 15% RDN through Poultry manure + Consortia of biofertilizers @ 10 ml kg^{-1} seeds, N_3: 70% RDF+ 15% RDN through Poultry manure + *Panchagavya* @ 30 ml L^{-1} (2-spray), N_4: 70% RDF+ 15% RDN through Poultry manure + Seaweed extract @ 2 ml L^{-1} (2-spray), N_5: 70% RDF+15% RDN through Poultry manure + Consortia of biofertilizers @ 10 ml kg^{-1} seeds + *Panchagavya* @ 30 ml L^{-1} & Seaweed extract @ 2 ml L^{-1} both as tank mix (2-spray) thereby making twenty treatment combinations were tested in split plot design with three replications. The recommended dose of fertilizers (RDF) was 15, 40, 20 kg NPK ha^{-1}. However, full RDF was applied as basal as per the treatment. The average N content in the poultry manure during both the years was 1.6%. The consortia of biofertilizers (NPK consortia) were used as seed treatment at the rate of 10 ml kg^{-1} seeds. *Panchagavya* is a fermented organic formulation comprising beneficial microorganisms derived from cow dung, cow urine, cow ghee, cow milk, cow curd, and additional ingredients such as sugarcane juice, tender coconut water, toddy or grape juice, and ripe banana. The preparation of *Panchagavya* began with the combination of fresh cow dung and ghee, which were placed in a wide-mouthed container (such as a mud pot, concrete tank, or plastic can) and thoroughly mixed twice daily for three days. On the fourth day, the remaining ingredients were incorporated into the mixture. This mixture was then stirred twice daily for a period of 15 days. Consequently, the *Panchagavya* stock solution was ready for use after 18 days (Natarajan, 2008). The seaweed extract used for the foliar spray was IFFCO Sagarika, which is rich in macro- and micronutrients, essential amino acids, and plant growth hormones such as auxins, gibberellins, and cytokinins. Foliar application of *Panchagavya* & seaweed extract was applied at initiation of 50% flowers and at 15-20 days after the first spray.

In greengram cultivation, the mean maximum temperatures recorded were 36.3°C and 37.8°C, while the mean minimum temperatures were 19.6°C and 21.1°C, with average temperatures of 28.0°C and 29.4°C for the years 2022-23 and 2023-24, respectively. The total rainfall was 21.4 mm and 5.6 mm, with average relative humidity levels of 52.8% and 52.6%. Wind speeds were recorded at 3.62 and 4.01 km hr^{-1}, with daily sunshine hours averaging 8.78 and 8.59, and evaporation rates of 6.39 and 6.61 mm day^{-1} during both the years. Under conditions of assured irrigation, where moisture was consistently available, the increased duration of sunshine, greater temperature variation, and reduced humidity likely created a more favorable environment for photosynthesis, nutrient uptake, and overall crop metabolism. Three irrigations were administered in accordance with standard crop management practices. The weather conditions in the second year were more favorable for greengram cultivation. Growth parameters such as plant height (cm), the number of primary and secondary branches per plant, AGR, CGR, RGR and NAR at intervals of 25-50 DAS and 50-harvest, as well as seed yield (kg ha^{-1}), were recorded during the two years of experimentation. To assess dry matter accumulation, five plants were randomly selected from rows designated for destructive sampling and were severed at the base. Following a period of air drying, the entire plant sample was subjected to oven drying at 72°C until a constant weight was achieved. Subsequently, the weight of the plants was measured and recorded in grams. The leaf area is determined using a leaf area meter. The AGR, CGR, RGR, and NAR were computed using the following formula

2.1 Absolute Growth Rate (AGR)

It indicates at what rate the crop is growing. It is expressed in g day^{-1}.

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_1 and W_2 are dry matter at times t_1 and t_2 respectively.

2.2 Crop Growth Rate (CGR)

It is the rate of growth of crop per unit area. It is expressed in g m^{-2} day^{-1}.

$$CGR = \frac{1}{S} \frac{W_2 - W_1}{t_2 - t_1}$$

Where, S is the plant spacing in square meter

2.3 Relative Growth Rate (RGR)

It is the increase in dry weight over time per unit weight of the plant and is defined as the amount of dry matter produced by one gram of existing dry matter in a day.

$$RGR\ (g\ g^{-1}\ day^{-1}) = \frac{\ln W_2 - \ln W_1}{t_2 - t_1}$$

Where, ln W_2 and ln W_1 are the natural logarithm of total dry weight of the plant at the time of t_2 and t_1 respectively.

2.4 Net Assimilation Rate (NAR)

It indirectly indicates the rate of net photosynthesis. It is expressed as gram of dry matter produced per m^2 of leaf area in a day.

$$NAR\ (g\ m^{-2}\ day^{-1}) = \frac{(W_2 - W_1)(\ln L_2 - \ln L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

Where, L_1 and W_1 are leaf area and dry weight of plants at time t_1, and L_2 and W_2 are leaf area and dry weight of plants at time t_2.

The collected data were subjected to statistical analysis as outlined by Gomez and Gomez (1984). The interpretation of treatment effects was conducted using Fisher's critical difference at the P=0.05 significance level.

3. RESULTS

3.1 Plant Height (cm)

Data regarding the plant height of greengram, as influenced by sowing windows and nutrient management, are presented in Table 1. The plant height exhibited a rapid increase with the progression of the crop's phenophases up to harvest, after which growth nearly ceased.

The data indicated that the plant height of greengram was significantly enhanced by sowing windows. Significantly taller plants were observed by sowing the crop on 8th and 14th March (D_1) at all dates of observation, although this was statistically comparable to the crop sown on 15th and 21st March (D_2) during both the years. The shortest plants were observed from the crop sown on 29th March and 4th April (D_4).

The results further indicated that plant height (40.0 and 41.2 cm at harvest) was markedly increased with application of 70% RDF (10.5, 28, 14 kg NPK ha^{-1}) + 15% RDN-poultry manure (2.25 N kg ha^{-1}) + consortia of biofertilizers @ 10 ml kg^{-1} seed + *Panchagavya* @ 30 ml lit^{-1} & seaweed extract @ 2 ml lit^{-1} both as tank mix (2-spray) (N_5), which was statistically similar to N_3 treatment, involving 70% RDF + 15% RDN-poultry manure + *Panchagavya* @ 30 ml lit^{-1} (2-spray) and N_4, involving 70% RDF + 15% RDN-poultry manure + seaweed extract @ 2 ml lit^{-1} (2-spray) at 50 DAS and at harvest during both years of the experimentation. In contrast, the treatment receiving 100% RDF (N_1) produced shorter plants at all dates of observation.

3.2 Primary Branches Plant^{-1}

The data concerning the number of primary branches plant^{-1}, as influenced by sowing windows and nutrient management, are presented in Table 2. Branching increased rapidly with the progression of the crop's phenophases up to 50 days after sowing (DAS), thereafter it seized.

Table 1. Effect of sowing windows and nutrient management on plant height of greengram

Treatments	Plant height (cm)					
	25 DAS		50 DAS		At harvest	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Sowing windows						
D_1: 1st Sowing	12.3	12.7	34.1	34.7	41.3	42.4
D_2: 2nd Sowing	11.7	12.1	32.6	33.1	39.7	40.8
D_3: 3rd Sowing	10.9	11.5	31.1	32.2	38.3	39.1
D_4: 4th Sowing	10.0	10.8	29.5	30.6	36.2	37.1
SEm±	0.23	0.25	0.66	0.73	0.76	0.79
LSD (P=0.05)	0.80	0.85	2.30	2.52	2.63	2.75
Nutrient management						
N_1: 100% RDF	11.2	11.7	30.3	31.4	37.3	38.2
N_2: 70% RDF + 15% RDN-Poultry manure + Consortia of biofertilizers @ 10 ml kg^{-1} seeds	11.6	12.1	31.6	32.4	38.4	39.3
N_3: 70% RDF + 15% RDN-Poultry manure + *Panchagavya* @ 30 ml lit^{-1} (2-spray)	10.9	11.4	32.4	33.1	39.6	40.5
N_4: 70% RDF + 15% RDN-Poultry manure + Seaweed extract @ 2 ml lit^{-1} (2-spray)	10.7	11.3	32.0	32.8	39.0	40.1
N_5: 70% RDF + 15% RDN-Poultry manure + Consortia of biofertilizers @ 10 ml kg^{-1} seeds + *Panchagavya* @ 30 ml lit^{-1} & Seaweed extract @ 2 ml lit^{-1} both as tank mix (2-spray)	11.7	12.2	32.8	33.6	40.0	41.2
SEm±	0.17	0.20	0.46	0.51	0.49	0.61
LSD (P=0.05)	0.49	0.57	1.33	1.46	1.40	1.75

Table 2. Effect of sowing windows and nutrient management on primary branches plant^{-1} of greengram

Treatments	Primary branches plant^{-1}					
	25 DAS		50 DAS		At harvest	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Sowing windows						
D_1: 1st Sowing	3.30	3.40	5.14	5.32	5.60	5.74
D_2: 2nd Sowing	3.12	3.28	5.00	5.12	5.46	5.60
D_3: 3rd Sowing	2.90	3.01	4.70	4.82	5.08	5.20
D_4: 4th Sowing	2.88	2.92	4.34	4.42	4.74	4.82
SEm±	0.07	0.08	0.11	0.11	0.12	0.14
LSD (*P*=0.05)	0.25	0.27	0.37	0.39	0.41	0.47
Nutrient management						
N_1: 100% RDF	3.05	3.15	4.43	4.50	4.68	4.78
N_2: 70% RDF + 15% RDN-poultry manure + consortia of biofertilizers @ 10 ml kg^{-1} seeds	3.18	3.24	4.73	4.80	5.13	5.23
N_3: 70% RDF + 15% RDN-poultry manure + *Panchagavya* @ 30 ml lit^{-1} (2-spray)	2.95	3.06	4.93	5.08	5.43	5.58
N_4: 70% RDF + 15% RDN-poultry manure + seaweed extract @ 2 ml lit^{-1} (2-spray)	2.85	2.95	4.85	4.95	5.28	5.35
N_5: 70% RDF + 15% RDN-poultry manure + consortia of biofertilizers @ 10 ml kg^{-1} seeds + *Panchagavya* @ 30 ml lit^{-1} & seaweed extract @ 2 ml lit^{-1} both as tank mix (2-spray)	3.23	3.36	5.05	5.28	5.60	5.78
SEm±	0.06	0.06	0.07	0.07	0.08	0.09
LSD (*P*=0.05)	0.17	0.18	0.19	0.21	0.24	0.26

A detailed analysis of the data revealed that among the sowing windows, the higher number of primary branches plant^{-1} were observed by sowing crop on 8th and 14th March (5.60 and 5.74 at harvest). However, this was statistically comparable to 15th and 21st March sowing at all dates of observation during both the years. The lower branching was recorded on 29th March and 4th April sowing.

Regarding nutrient management, the treatment N_5, comprising 70% RDF + 15% RDN-poultry manure + consortia of biofertilizers @ 10 ml kg^{-1} seeds + *Panchagavya* @ 30 ml lit^{-1} & seaweed extract @ 2 ml lit^{-1} both as tank mix (2-spray), resulted in the higher number of primary branches plant^{-1} (5.60 and 5.78 at harvest) and it was statistically comparable to 70% RDF + 15% RDN-poultry manure + *Panchagavya* @ 30 ml lit^{-1} (2-spray) (N_3) treatment at harvest during both years of the study. The lowest branching plant^{-1} was observed in N_1 involving 100% RDF throughout the study period.

3.3 Growth Rate

The data pertaining to the growth rates, including absolute growth rate (AGR), crop growth rate (CGR), relative growth Rate (RGR), and net assimilation rate (NAR) of greengram, as influenced by sowing windows and nutrient management, are presented in Table 3 and 4. The findings demonstrated that both sowing windows and nutrient management significantly impacted the growth rates at various dates.

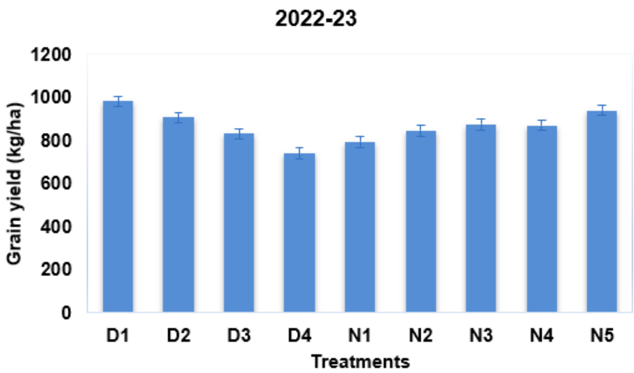

Fig. 1 (A)

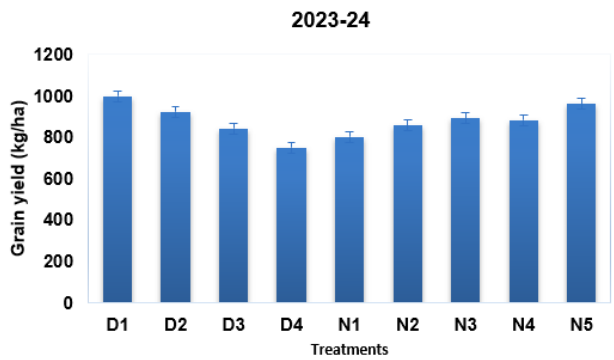

Fig. 1 (B)

Fig. 1 (A & B). Effect of sowing windows and nutrient management on seed yield (q ha^{-1}) of greengram during both the years

**D$_1$: 1st Sowing (8th March and 14th March), D_2: 2nd Sowing (15th March and 21st March), D_3: 3rd Sowing (22nd March and 28th March), D_4: 4th Sowing (29th March and 4th April) in 2022-23 and 2023-24, respectively and five nutrient management practices N_1: 100% RDF (15, 40, 20 kg NPK ha^{-1}), N_2: 70% RDF+ 15% RDN-Poultry manure + Consortia of biofertilizers @ 10 ml kg^{-1} seeds, N_3: 70% RDF+ 15% RDN-Poultry manure + Panchagavya @ 30 ml L^{-1} (2-spray), N_4: 70% RDF+ 15% RDN-Poultry manure + Seaweed extract @ 2 ml L^{-1} (2-spray), N_5: 70% RDF+15% RDN-Poultry manure + Consortia of biofertilizers @ 10 ml kg^{-1} seeds + Panchagavya @ 30 ml L^{-1} & Seaweed extract @ 2 ml L^{-1} both as tank mix (2-spray)*

Table 3. Effect of sowing windows and nutrient management on absolute and crop growth rate of greengram

Treatments	Absolute Growth Rate (AGR; g day^{-1})				Crop Growth Rate (CGR; g m^{-2} land area day^{-1})			
	25-50 DAS		50-harvest		25-50 DAS		50-harvest	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Sowing windows								
D_1: 1st Sowing	0.28	0.31	0.108	0.121	9.38	10.26	3.60	4.02
D_2: 2nd Sowing	0.25	0.28	0.106	0.116	8.36	9.27	3.53	3.87
D_3: 3rd Sowing	0.24	0.26	0.088	0.087	7.84	8.71	2.93	2.91
D_4: 4th Sowing	0.22	0.24	0.074	0.071	7.26	8.00	2.46	2.37
SEm±	0.01	0.01	0.002	0.003	0.21	0.26	0.06	0.07
LSD (*P*=0.05)	0.03	0.03	0.006	0.009	0.74	0.91	0.22	0.25
Nutrient management								
N_1: 100% RDF	0.22	0.24	0.087	0.090	7.22	8.02	2.91	2.99
N_2: 70% RDF + 15% RDN-Poultry manure + Consortia of biofertilizers @ 10 ml kg^{-1} seeds	0.24	0.26	0.090	0.091	8.00	8.78	2.99	3.03
N_3: 70% RDF + 15% RDN-Poultry manure + *Panchagavya* @ 30 ml lit^{-1} (2-spray)	0.26	0.29	0.099	0.104	8.61	9.56	3.31	3.48
N_4: 70% RDF + 15% RDN-Poultry manure + Seaweed extract @ 2 ml lit^{-1} (2-spray)	0.26	0.28	0.092	0.097	8.60	9.39	3.06	3.22
N_5: 70% RDF + 15% RDN-Poultry manure + Consortia of biofertilizers @ 10 ml kg^{-1} seeds + *Panchagavya* @ 30 ml lit^{-1} & Seaweed extract @ 2 ml lit^{-1} both as tank mix (2-spray)	0.26	0.29	0.102	0.112	8.61	9.56	3.40	3.74
SEm±	0.01	0.01	0.002	0.002	0.17	0.18	0.05	0.06
LSD (*P*=0.05)	0.02	0.02	0.005	0.006	0.49	0.53	0.15	0.18

Table 4. Effect of sowing windows and nutrient management on relative growth rate and net assimilation rate of greengram

Treatments	Relative Growth Rate (RGR; g g^{-1} day^{-1})				Net Assimilation Rate (NAR; g m^{-2} day^{-1})			
	25-50 DAS		50-harvest		25-50 DAS		50-harvest	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Sowing windows								
D_1: 1st Sowing	0.055	0.056	0.0095	0.0095	7.37	7.42	1.66	1.79
D_2: 2nd Sowing	0.053	0.054	0.0087	0.0090	7.19	7.36	1.63	1.57
D_3: 3rd Sowing	0.051	0.053	0.0087	0.0079	7.07	7.11	1.55	1.35
D_4: 4th Sowing	0.051	0.053	0.0081	0.0072	6.90	6.98	1.44	1.24
SEm±	0.001	0.001	0.0002	0.0002	0.15	0.16	0.03	0.03
LSD (*P*=0.05)	NS	NS	0.0006	0.0006	NS	NS	0.10	0.11
Nutrient management								
N_1: 100% RDF	0.049	0.051	0.0083	0.0078	6.63	6.54	1.42	1.35
N_2: 70% RDF + 15% RDN-Poultry manure + Consortia of biofertilizers @ 10 ml kg^{-1} seeds	0.050	0.051	0.0084	0.0082	6.94	7.00	1.46	1.35
N_3: 70% RDF + 15% RDN-Poultry manure + *Panchagavya* @ 30 ml lit^{-1} (2-spray)	0.054	0.057	0.0089	0.0086	7.39	7.56	1.53	1.48
N_4: 70% RDF + 15% RDN-Poultry manure + Seaweed extract @ 2 ml lit^{-1} (2-spray)	0.051	0.052	0.0089	0.0086	7.15	7.25	1.52	1.40
N_5: 70% RDF + 15% RDN-Poultry manure + Consortia of biofertilizers @ 10 ml kg^{-1} seeds + *Panchagavya* @ 30 ml lit^{-1} & Seaweed extract @ 2 ml lit^{-1} both as tank mix (2-spray)	0.057	0.059	0.0092	0.0089	7.54	7.73	1.94	1.86
SEm±	0.001	0.001	0.0002	0.0002	0.12	0.12	0.03	0.03
LSD (*P*=0.05)	0.002	0.002	0.0005	0.0005	0.34	0.36	0.08	0.08

Among the sowing windows, the crop sown on 8th and 14th March (D_1) exhibited a significantly higher AGR and CGR during the periods of 25-50 DAS and from 50 DAS to harvest, comparable to the results observed in the second sowing. Additionally, RGR and NAR were also reported significantly higher in the same treatment but the treatments were failed to reach the level of significance during 25-50 DAS. The lower values were recorded on 29th March and 4th April (D_4) during both the years.

Further analysis of the data revealed that the AGR and CGR during 25-50 DAS and from 50 DAS to harvest increased markedly with the application of 70% RDF + 15% RDN-poultry manure + consortia of biofertilizers @ 10 ml kg^{-1} seeds + *Panchagavya* @ 30 ml lit^{-1} & seaweed extract @ 2 ml lit^{-1} both as tank mix (2-spray) (N_5), which was found on par with 70% RDF + 15% RDN-poultry manure + *Panchagavya* @ 30 ml lit^{-1} (2-spray) (N_3) and 70% RDF + 15% RDN-poultry manure + seaweed extract @ 2 ml lit^{-1} (2-spray) (N_4) during 25-50 DAS. Similarly, the RGR and NAR also registered significantly higher in N_5 treatment and remained statistically superior over other treatments. The lowest values were observed with the application of 100% RDF (N_1) during the two-year trial.

3.4 Grain yield (kg ha^{-1})

The data pertaining to grain yield (kg ha^{-1}) as influenced by sowing windows and nutrient management recorded at harvest are presented in Figure 1 (A & B). Significant variation in grain yield was observed among the different treatments. A perusal of the data demonstrated that among the sowing windows, the first sowing i.e. on 8th and 14th March (D_1) achieved the highest grain yield (982 and 998 kg ha^{-1}), which was significantly greater than the yields from other sowing windows. This was followed by the second sowing i.e. on 15th and 21st March (D_2) with yields of 907 and 921 kg ha^{-1}. The lowest grain yield was observed in the fourth sowing i.e. on 29th March and 4th April (D_4) during the study period.

Further results indicated that among nutrient management, the N_5 treatment, consisting of 70% RDF + 15% RDN-poultry manure + consortia of biofertilizers @ 10 ml kg^{-1} seeds + *Panchagavya* @ 30 ml lit^{-1} & seaweed extract @ 2 ml lit^{-1} both as tank mix (2-spray), recorded the highest grain yield (940 and 959 kg ha^{-1}). This was followed by the N_3 treatment i.e. application of 70% RDF + 15% RDN-poultry manure + *Panchagavya* @ 30 ml lit^{-1} (2-spray) with yields of 874 and 890 kg ha^{-1}. In contrast, the N_1 treatment, which involved 100% RDF, resulted in the lowest grain yield.

4. DISCUSSION

Among the various sowing windows, the crop sown on 8th and 14th March (D_1) exhibited the highest values for growth parameters and grain yield. The observed enhancement in growth parameters associated with the initial sowing can be attributed to the extended days to maturity, which prolong the growth period. This extension facilitates optimal utilization of available resources and creates favorable conditions for timely and adequate plant development. Consequently, the timing of sowing is considered a critical factor in enhancing growth parameters. In contrast, the second, third, and fourth sowings of greengram required fewer days to maturity, thereby limiting the crop's capacity to effectively utilize the available resources and environmental conditions. This limitation may be due to the significantly higher dry matter production, which results in a larger source for photosynthesis and consequently more translocation of photosynthates to the sink, as reported by Kumar *et al.* (2015). Mukherjee (2021) noted that the increase in seed yield with an early sowing date might be due to higher yield attributes, as seed yield is known to have a positive association with these parameters. The higher yield obtained in timely sowing was due to favorable temperature and humidity during the growth period and nodulation formation stage, resulting in better growth (Sahu *et al.,* 2019).

Application of 70% RDF + 15% RDN-poultry manure + consortia of biofertilizers @ 10 ml kg^{-1} seeds + *Panchagavya* @ 30 ml lit^{-1} & seaweed extract @ 2 ml lit^{-1} both as tank mix (2-spray) (N_5), resulted in the highest values for plant height, number of primary branches per plant, growth rate and grain yield. The beneficial effects of poultry manure, when used in conjunction with the recommended fertilizer dosage, can be attributed to its role in enhancing the physical, chemical, and biological properties of the soil, thereby promoting plant growth. This observation is consistent with the findings of Patel and Gangwar, (2023), who demonstrated that organic manures and fertilizers enhanced cell production, promote plant vigor, and accelerate leaf growth, thereby improving growth parameters. According to Rahul *et al.* (2022), *Panchagavya* not only supplies nutrients but also hydrates leaf cells and enhances chlorophyll content, thereby increasing photosynthetic activity. The direct application of *Panchagavya* solution onto the foliage allows for immediate nutrient absorption (Behera *et al.,* 2024). Foliar application of seaweed sap contributes to the altered partitioning of photosynthates, favoring either shoot biomass synthesis or grain synthesis (Raverkar *et al.,* 2016). Consequently, nutrients positively influence vegetative growth and, as a result, positively affect the crop (Sahoo *et al.,* 2025). Jadhav and Kulkarni (2016) found that foliar application of *Panchagavya* significantly improved greengram productivity. Similarly, Shariff *et al.* (2017) asserted that the use of organic manures and an organic foliar spray is instrumental in augmenting seed yield.

5. CONCLUSION

Based on two years of experimentation, it can be concluded that crops sown on March 8 and March 14 exhibited superior growth parameters and yield. In terms of nutrient management, the application of 70% RDF + 15% RDN-poultry manure + consortia of biofertilizers @ 10 ml kg^{-1} seeds + *Panchagavya* @ 30 ml lit^{-1} & seaweed extract @ 2 ml lit^{-1} both as tank mix (2-spray), enhanced the growth and productivity of greengram.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors declare that no generative AI technologies, including large language models such as ChatGPT and COPILOT, or text-to-image generators, were utilized in the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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