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RESEARCH ARTICLE

Impact of foliar application of organic formulations on plant growth, seed yield and quality in green gram (*Vigna radiata* L.)

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Abstract

Greengram is one of the most important pulse crops in India. It plays a crucial role in organic farming systems due to its ability to fix atmospheric nitrogen. Productivity in organic farming is generally lower than in conventional systems, primarily due to the need for large quantities of organic amendments to meet crop nutrient requirements. Foliar fertilization serves as an efficient and cost-effective alternative for delivering essential nutrients directly to the plants. In this study, field experiments were conducted during the *Kharif* and *Rabi* seasons of 2024 using green gram (CO 9) seeds, following a Randomized Block Design (RBD) with nine treatments and three replications. Organic formulations including panchagavya, Fermented Fish Extract (FFE), Egg Fermented Extract (EFE) and Seaweed Extract (SWE) were sprayed at critical growth stages, specifically at flower initiation and early pod formation to evaluate their efficacy. The results indicated that two foliar applications of panchagavya 5 % (T_2) recorded the highest plant growth and seed yield parameters. SWE 10 % (T_4) recorded higher seed quality parameters followed by panchagavya 5 % (T_2) which showed comparable performance. Hence, the foliar application of panchagavya 5 % at the flower initiation and early pod formation stages can significantly enhance plant growth, seed yield and quality, ultimately leading to improved productivity in green gram.

Keywords: foliar fertilization; green gram; organic formulations; panchagavya; seed yield; seed quality

Introduction

Pulses are vital components of organic farming systems, as they fix atmospheric nitrogen via biological nitrogen fixation, reducing nitrogen input needs (1). They are also known for offering a high protein content at a lower cost than cereals making them nutritionally significant crop in sustainable agriculture. Green gram is an excellent source of high-quality protein (25 %) and also a good source of riboflavin, thiamine and vitamin C (ascorbic acid) (2). It is also used as a green manure crop due to short duration and nitrogen fixing ability. Greengram is cultivated in countries such as India, Burma, Sri Lanka, Pakistan, China, Fiji and regions of Africa, with India being the world's leading producer. Although India ranks first in terms of area and production of pulses, its productivity remains significantly below the global average. This low productivity is attributed to several factors including the limited availability of high-yielding varieties, inadequate access to quality seeds and a low Seed Replacement Ratio (SRR). Thus, the quality seeds play a vital role in ensuring productivity. Organic farming depends on the use of organic seeds to uphold the integrity of the entire production system, ensuring that crops are cultivated in line with organic principles right from the beginning. With the increasing demand for organic farm produces, there is a growing need for a consistent and reliable supply of organic seeds. Additionally, under organic farming systems, pulses are estimated to encounter an average yield loss of around 20 %, further impacting overall productivity (3–5). The primary drawbacks of organic farming are comparatively low yields and the requirement for large volumes of organic manures to supply adequate nutrient levels to crops. Application of nutrients through foliar spray at critical growth stages offers an efficient alternative to reduce bulk manure requirements. Foliar fertilization significantly enhances nutrient absorption through the stomata or leaf cuticle, resulting in improved crop productivity. Compared to traditional soil application methods, foliar fertilization is reported to be 8 to 20 times more efficient in delivering nutrients to plants (6).

Organic formulations such as panchagavya, FFE, EFE and SWE are derived through the fermentation of on-farm waste materials and other natural sources including animal by-products, plant residues, marine biomass and organic sugars. These formulations are well-suited for organic farming systems. Panchagavya is a traditional organic formulation derived from fermentation of five cow-derived products such as milk, curd, ghee, urine and dung. FFE is an organic biostimulant produced by fermenting fish waste with jaggery, rich in amino acids, micronutrients and beneficial microbes. SWE is a natural biostimulant derived from marine algae, rich in growth hormones like auxins, cytokinins and gibberellins, along with essential micronutrients. EFE is an organic growth enhancer prepared by fermenting eggs with jaggery and lime. These organic formulations are well known for their diverse roles in promoting plant growth, enhancing soil health, improving nutrient uptake and boosting soil microbial activity. These effects collectively lead to increased plant growth, stress tolerance and overall improvements in yield and crop productivity. These inputs provide a sustainable and cost-effective alternative to synthetic fertilizers, thereby promoting eco-friendly agricultural practices (7). With this rationale, the present study was undertaken to evaluate the efficacy of foliar application of various organic formulations on the plant growth, seed yield and quality attributes of greengram (CO 9) under an organic farming system during the *Kharif and Rabi* seasons of 2024.

Materials and Methods

The field experiment was conducted over two seasons during 2024-2025: in a wetland field at Tamil Nadu Agricultural University (TNAU), Coimbatore, for the *Kharif* season and on a private organic farm in Pappampatti, Coimbatore, for the *Rabi* season. The experimental sites are located in the southern agroclimatic zone of India, with geographic coordinates of 11° N latitude and 76° E longitude for the *Kharif* site and 10° N latitude and 77° E longitude for the *Rabi* site, at an altitude of 426.7 m above mean sea level (MSL). The foliar treatments were evaluated for their reliability and consistency through field trials conducted across two locations and seasonal conditions. The weather conditions that prevailed throughout the cropping period during both the *Kharif* and *Rabi* seasons illustrated in Fig. 1 and Fig. 2. The field trial was conducted as a one-factorial experiment laid out in a RBD with three replications. Each replication consisted of plots measuring 12 m^2 (4 m × 3 m). The plots were sprayed with two doses of various organic formulations at flower initiation and early pod formation stages: T_1-panchagavya at 3 %, T_2-panchagavya at 5 %, T_3- SWE (*Turbinaria conoides*) at 5 %, T_4- SWE (*Turbinaria conoides*) at 10 %, T_5- FFE at 2 %, T_6- FFE at 4 %, T_7- EFE at 2 % and T_8- EFE at 4 %. The treatment levels were selected based on findings from previous studies (8-11). Both field trials were conducted in organic fields using organic amendments and manual weed control. Certified seeds of greengram cv. CO 9 were collected from Department of Pulses, TNAU, Coimbatore for the study. The seeds were treated with *Rhizobium* and *Phosphobacteria* biofertilizers, along with the bio-control agent *Bacillus subtilis* and sown in lines at a spacing of 30 cm × 10 cm with a seed rate of 20 kg/ha. Irrigation was carried out at appropriate intervals based on crop requirements and recommended organic plant protection practices were followed to manage pests and diseases. Basal application of vermicompost at the rate of 1.25 tonnes per hectare was given.

Preparation and collection of organic products

Organic inputs such as FFE and panchagavya were procured from the Nammazhvar Organic Farming Research Centre, TNAU, Coimbatore.

Panchagavya

Panchagavya was prepared by mixing 5 kg of fresh cow dung, 1 kg of jaggery and 0.5 kg of ghee. The mixture was stirred thoroughly to achieve a uniform consistency and covered with a moist cloth for four days, with occasional kneading to promote microbial activity. On the fifth day, the remaining ingredients (3 L cow urine, 2 L fermented curd, 2 L milk, 3 L tender coconut water and 10-12 ripe bananas) were added along with 3-5 L water. The enriched mixture was then allowed to ferment for 15 days under aerobic conditions. During fermentation, the container was loosely covered with a nylon mesh to allow airflow while preventing insect contamination (12).

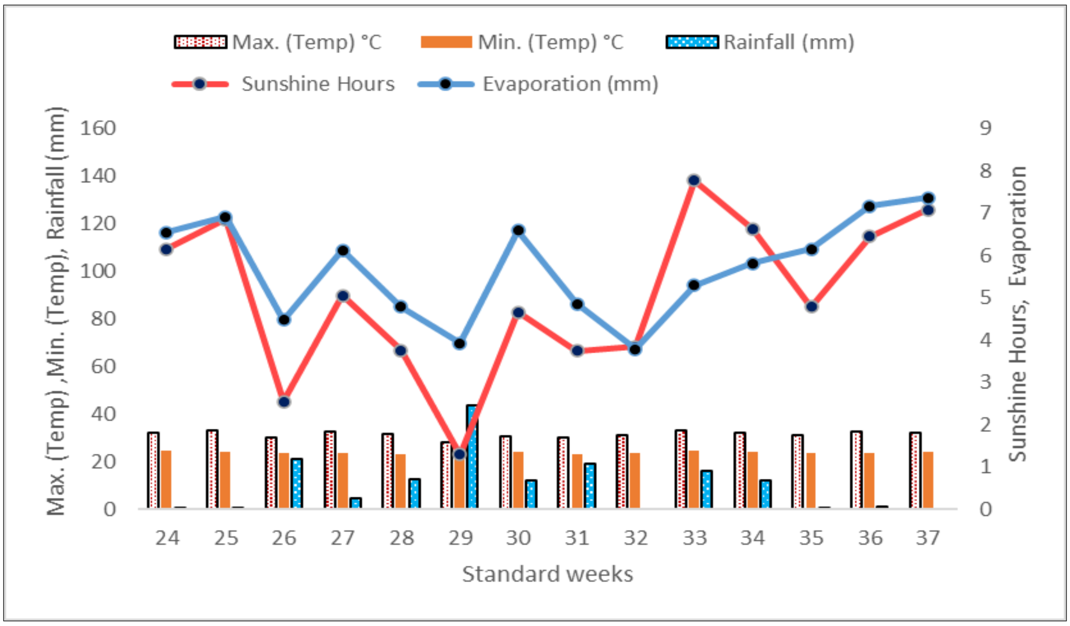

Fig. 1. Weather parameters (maximum and minimum temperature, sunshine hours, rainfall, evaporation and wind speed) during the cropping period of greengram in *Kharif* 2024.

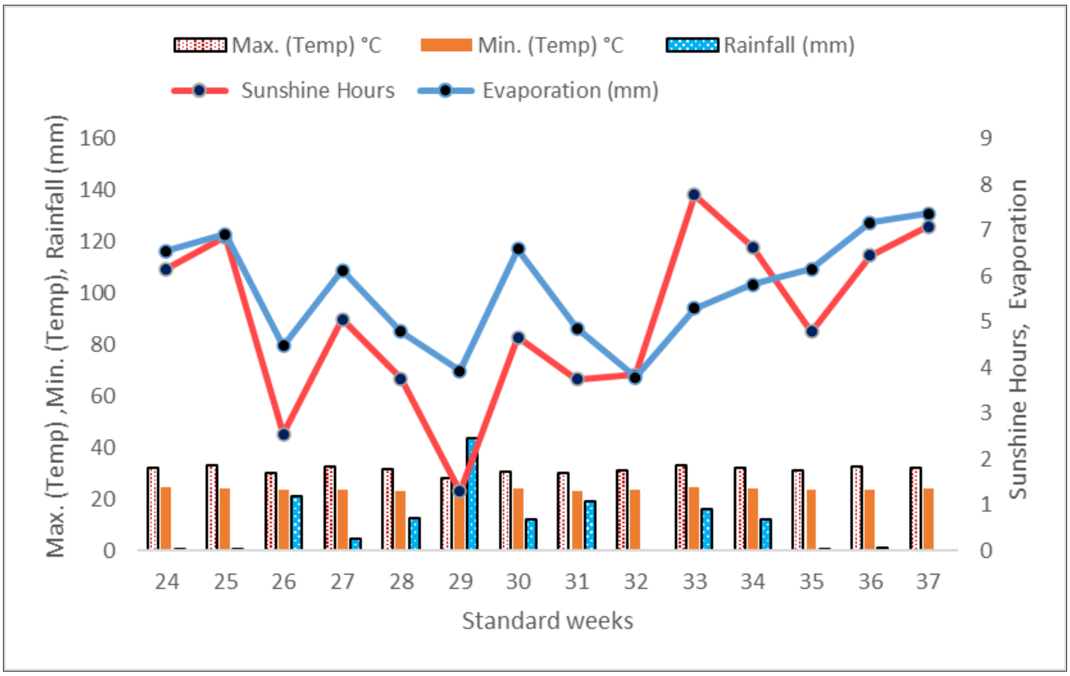

Fig. 2. Weather parameters (maximum and minimum temperature, sunshine hours, rainfall, evaporation and wind speed) during the cropping period of greengram in *Rabi* 2024.

Fermented Fish Extract (FFE)

FFE was prepared by fermenting finely chopped fish waste. 1 kg of fresh fish waste was first cleaned by removing the guts and finely chopped into small pieces. An equal quantity (1 kg) of powdered jaggery was then added and the ingredients were thoroughly mixed and placed in a plastic bucket with a tightly fitting lid. The container was kept covered and left undisturbed to ferment for 15-20 days, with the mixture stirred regularly to ensure uniform fermentation, maintain aerobic conditions and prevent anaerobic spoilage. This process allowed beneficial microbes to break down the fish material, resulting in a nutrient-rich fermented extract (12).

Seaweed Extract (SWE)

Seaweed (*Turbinaria conoides*) was collected from the Mandapam coast, Tamil Nadu, washed with distilled water to remove sand and salt, shade dried for four days and oven-dried at 60 °C for 12 hr. The dried material was ground into a coarse powder, mixed with distilled water (1:20 w/v) and autoclaved at 121 °C for 30 min. The extract was filtered, cooled and used as the stock solution (100 % concentration), which was subsequently diluted to the required levels (13).

Egg Fermented Extract (EFE)

EFE was prepared by placing five whole eggs (with shells) in a clean glass jar and adding freshly squeezed lemon juice from 10-15 lemons until the eggs were completely submerged. The jar was sealed with a lid and kept undisturbed for ten days to allow the acidic lemon juice to dissolve the eggshells and initiate fermentation. After ten days, the softened eggs were thoroughly smashed and mixed into the solution. To this, 250 g of thick jaggery syrup was added in equal proportion of egg-lemon mixture to enhance microbial activity and fermentation. The mixture was then set aside for another ten days to ferment further. After this second fermentation period, the egg extract was considered ready for use as a foliar spray (12).

Growth and yield measurements

After two foliar sprays, growth parameters such as leaf area index (LAI), specific leaf weight and plant height at 45 and 60 days after sowing (DAS) were recorded. Plant height was measured from five randomly selected and tagged plants using a ruler, from the base of each plant to the tip of the uppermost emerging leaf and expressed in centimetres (cm). Soluble protein content in leaf (14), net assimilation rate (NAR) and chlorophyll content (SPAD value) were estimated during the pod maturation stage. LAI was calculated by using the formula:

$$\text{LAI} = \frac{\text{Leaf area per plant}}{\text{Ground area occupied by the plant}} \quad \text{(Eq. 1)}$$

Where,

Leaf area per plant was calculated by multiplying leaf length, leaf breadth, number of leaves and a constant (0.983).

Specific leaf weight was calculated by the ratio of leaf dry weight to its area of assimilating surface.

Specific leaf weight =

$$\frac{\text{Leaf dry weight per plant}}{\text{Leaf area per plant}} \quad \text{(Eq. 2)}$$

NAR was calculated by using the formula:

NAR =

$$\frac{W_2 - W_1}{t_2 - t_1} \times \frac{\ln L_2 - \ln L_1}{L_2 - L_1} \quad \text{(Eq. 3)}$$

Where,

W_1 and W_2 are dry weight (mg) of plants at time t_1 and t_2 respectively. t_1 and t_2 are initial and final days of observation, while L_1 and L_2 indicate the leaf area at time t_1 and t_2 respectively.

Plant biomass was assessed by uprooting whole plant samples, shade-drying them for two days and then oven-drying at 80 °C for 16 hr. Yield attributes including the number of pods per plants, number of filled seeds per pod, seed yield per hectare and hundred-seed weight were recorded at harvest.

Seed quality analysis

The harvested seeds from each treatment plot were dried to moisture content of 8 %. Various seed quality parameters including germination percentage (15), root length, shoot length (15), seedling vigour index (16) and protein content (17) were then assessed to evaluate the impact of the treatments on seed quality.

Data analysis

The data were analysed using AGRES software (18). To determine significance, treatment means were compared using LSD at $P < 0.05$. Microsoft Excel (Office 2019, Microsoft Corporation, USA) was used to prepare the graphical illustrations.

Results and Discussion

The foliar application of organic formulations significantly affected plant growth parameters. The highest LAI (3.55) and plant height at 45 DAS (24.17 cm) and 60 DAS (45.53 cm) were recorded with the foliar spray of panchagavya 5 % (T_2) at the flower initiation and early pod formation stages during *Kharif* 2024. In *Rabi* 2024, foliar spray of panchagavya at 5 % also recorded highest LAI (2.71) and plant height at 45 DAS (19.50 cm) and 60 DAS (41.58 cm), which was on par with the foliar spray treatment of panchagavya 3% in both seasons, as confirmed by LSD test results ($P < 0.05$). On the contrary, lower LAI and plant height were recorded in the control (Table 1). This significant increase in LAI and plant height ($P < 0.05$) was primarily attributed to the foliar application of panchagavya at critical growth stages of greengram. This foliar application facilitates efficient utilization of the spray solution through quick absorption via leaf cuticles and contributes to enhanced plant growth and yield. Plant growth promoting hormones such as auxins and gibberellins present in panchagavya stimulate accelerated cell division and elongation in axillary buds, resulting in increased LAI and greater plant height (19, 20). The foliar application of panchagavya is also known to regulate stomatal opening for extended durations under both optimal and stressful conditions during plant growth, thereby contributing to an increase in LAI (21).

Furthermore, the growth parameters such as specific leaf weight, soluble protein content and chlorophyll content recorded significant differences among foliar spray treatments in both seasons. The highest specific leaf weight was recorded with the foliar spray of panchagavya 5 % (T_2), measuring 2.21 mg/cm^2 during *Kharif* and 2.89 mg/cm^2 during *Rabi* 2024 (Fig. 3). Similarly, the highest soluble protein content (5.94 mg/g and 5.17 mg/g) was also observed with the foliar spray of panchagavya 5 % (T_2) during the *Kharif* and *Rabi* seasons respectively. Chlorophyll content was also

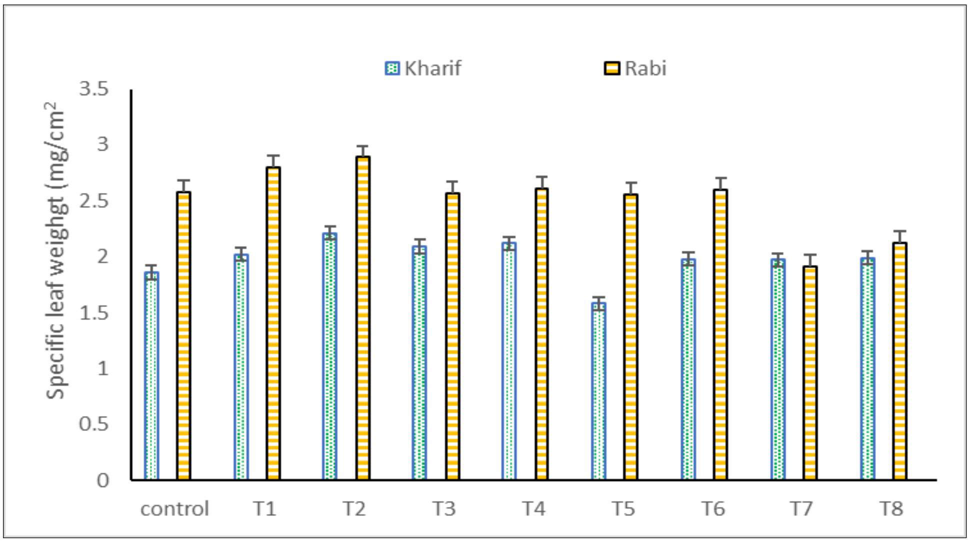

Fig. 3. Effect of foliar application of organic formulation on specific leaf weight of green gram (CO 9) during *Kharif* and *Rabi* 2024.

Table 1. Effect of foliar application of organic formulation on leaf area index and plant height of green gram (CO 9) during *Kharif* and *Rabi* 2024

Treatment	*Kharif* 2024			*Rabi* 2024		
	LAI	Plant height (cm)		LAI	Plant height (cm)	
		(45 DAS)	(60 DAS)		(45 DAS)	(60 DAS)
Control	2.61 ± 0.03	19.53 ± 0.12	1.73 ± 0.05	1.73 ± 0.05	16.75 ± 0.19	35.75 ± 0.18
T_1 - Panchagavya 3 %	3.39 ± 0.05	22.93 ± 0.04	2.42 ± 0.03	2.42 ± 0.03	18.75 ± 0.09	37.83 ± 0.14
T_2 - Panchagavya 5 %	3.55 ± 0.02	24.17 ± 0.09	2.71 ± 0.01	2.71 ± 0.01	19.50 ± 0.01	41.58 ± 0.14
T_3 - SWE 5 %	2.78 ± 0.05	20.67 ± 0.11	2.09 ± 0.03	2.09 ± 0.03	18.08 ± 0.10	36.33 ± 0.14
T_4 - SWE 10 %	3.29 ± 0.08	22.28 ± 0.17	2.26 ± 0.03	2.26 ± 0.03	18.83 ± 0.05	38.92 ± 0.19
T_5 - FFE 2 %	2.72 ± 0.06	21.73 ± 0.11	1.81 ± 0.01	1.81 ± 0.01	17.42 ± 0.19	37.08 ± 0.14
T_6 - FFE 4 %	3.20 ± 0.02	21.93 ± 0.17	2.12 ± 0.03	2.12 ± 0.03	18.42 ± 0.10	37.33 ± 0.23
T_7 - EFE 2 %	2.47 ± 0.02	20.93 ± 0.28	1.79 ± 0.05	1.79 ± 0.05	16.83 ± 0.05	36.17 ± 0.14
T_8 - EFE 4 %	2.53 ± 0.03	21.27 ± 0.14	2.16 ± 0.04	2.16 ± 0.04	17.08 ± 0.28	37.42 ± 0.30
SEd	0.10	0.36	0.09	0.09	0.33	0.42
CD (P = 0.05)	0.21	0.75	0.19	0.19	0.70	0.88

highest in the foliar spray of panchagavya 5 % (T_2), recording 52.80 SPAD value and 49.20 SPAD value during the *Kharif* and *Rabi* seasons respectively. This treatment was on par with foliar spray of panchagavya 3 % (T_1) and FFE 4 % (T_6) in both seasons (Table 2). Increase in these parameters were attributed to the presence of essential nutrients, amino acids and growth-regulators produced by beneficial microbes in panchagavya leading to increased protoplasmic constituents, protein synthesis and resource mobilization from source to sink (4, 22). The increased soluble protein and chlorophyll content observed in panchagavya treated plants may be attributed to the elevated activity of nitrate reductase and glutamate synthase enzymes, stimulated by the presence of growth-promoting compounds (23). The FFE treatment also resulted in a comparable increase in chlorophyll content, which can be attributed to the presence of essential amino acids and nutrients in the extract.

Biomass accumulation traits were highest in the foliar spray treatment with panchagavya 5 % (T_2), which recorded a NAR of 7.93 and 8.44 mg/cm^2/day and plant biomass of 16.03 g and 8.91 g during the *Kharif* and *Rabi* seasons respectively (Fig. 4). Panchagavya application is believed to enhance the internal synthesis of natural auxins, which may have contributed to the initiation of early and vigorous plant growth. The significant increase in dry matter could be due to the enhanced nutrient availability and root nodule formation facilitated by the foliar application of panchagavya (24). The yield parameters such as number of pods per plant, number of filled seeds per pod and seed yield per hectare were significantly enhanced by foliar spray of panchagavya 5 % (T_2), recording 26.61 number of pods per plant, 12.13 number of filled seeds per pod and 875 kg seed yield per hectare during the *Kharif* season and 18.16, 10.93 and 648 kg during the *Rabi* season respectively (Fig. 5). This treatment was on par with foliar spray of panchagavya 3 % (T_1) in both seasons as verified by LSD test results ($P < 0.05$) (Table 3). The observed increase in the number of pods per plant and the number of filled seeds per pod may be attributed to enhanced photosynthetic efficiency, which likely improved nutrient translocation from source to sink. Similar findings were also reported in an earlier study (25).

Enhanced growth parameters including LAI, specific leaf weight, NAR and chlorophyll content, contribute to more efficient nutrient uptake and translocation, thereby supporting reproductive development and resulting in increased yield. The synergistic effect of beneficial microbial populations in panchagavya, which produce plant growth-promoting hormones along with readily available macro and micronutrients released through the fermentation process, contributes to enhanced nutrient uptake, improved plant growth and seed yield (4, 26). The enhanced efficacy of panchagavya foliar application in promoting plant growth and yield, relative to other organic formulations, is mainly due to its multifaceted composition comprising growth

Table 2. Effect of foliar application of organic formulation on soluble protein content, chlorophyll content and plant biomass of greengram (CO 9) during *Kharif* and *Rabi* 2024

Treatment	***Kharif* 2024**			***Rabi* 2024**		
	Soluble protein content (mg/g)	**Chlorophyll content**	**Plant biomass (g)**	**Soluble protein content (mg/g)**	**Chlorophyll content**	**Plant biomass (g)**
Control	4.59 ± 0.09	46.77 ± 0.15	12.93 ± 0.05	3.87 ± 0.01	42.47 ± 0.43	7.78 ± 0.07
T1 - Panchagavya 3 %	5.39 ± 0.03	50.07 ± 0.15	15.33 ± 0.02	4.78 ± 0.01	46.60 ± 0.10	8.60 ± 0.04
T2 - Panchagavya 5 %	5.94 ± 0.08	52.80 ± 0.10	16.03 ± 0.11	5.17 ± 0.03	49.20 ± 0.21	8.91 ± 0.02
T3 - SWE 5 %	5.25 ± 0.02	49.33 ± 0.25	15.23 ± 0.05	4.65 ± 0.02	46.07 ± 0.17	8.19 ± 0.08
T4 - SWE 10 %	5.39 ± 0.02	49.77 ± 0.17	15.53 ± 0.13	4.99 ± 0.06	47.43 ± 0.21	8.32 ± 0.02
T5 - FFE 2 %	5.24 ± 0.02	50.10 ± 0.16	14.87 ± 0.09	4.34 ± 0.01	45.70 ± 0.13	8.05 ± 0.04
T6 - FFE 4 %	5.42 ± 0.04	51.93 ± 0.19	14.90 ± 0.11	4.64 ± 0.01	46.63 ± 0.15	8.47 ± 0.01
T7 - EFE 2 %	4.85 ± 0.02	47.27 ± 0.15	13.67 ± 0.05	4.00 ± 0.02	44.70 ± 0.17	7.94 ± 0.03
T8 - EFE 4 %	5.00 ± 0.02	48.23 ± 0.20	14.03 ± 0.12	4.49 ± 0.01	45.07 ± 0.09	8.21 ± 0.05
SEd	0.11	0.74	0.19	0.06	0.44	0.11
CD (P = 0.05)	0.22	1.57	0.41	0.12	0.92	0.24

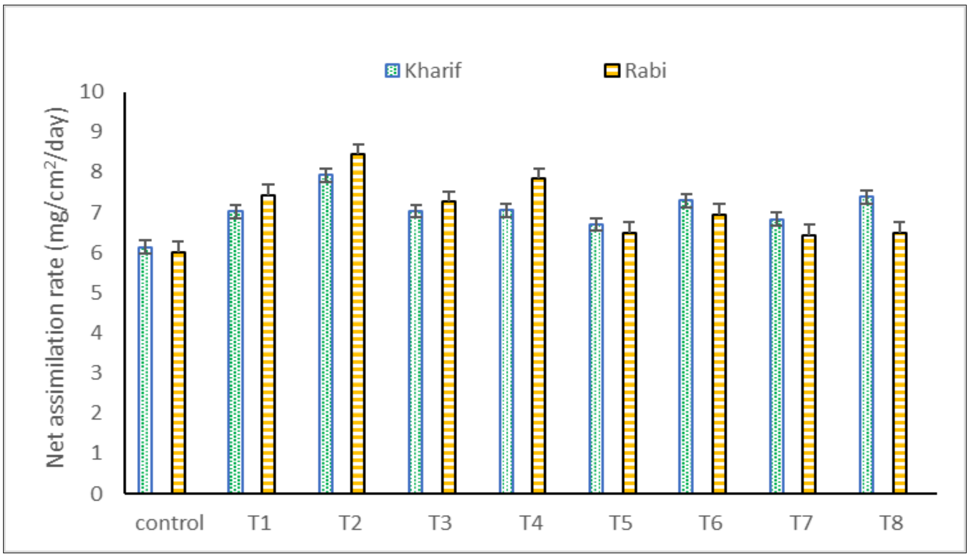

Fig. 4. Effect of foliar application of organic formulation on net assimilation rate of green gram (CO 9) during *Kharif* and *Rabi* 2024.

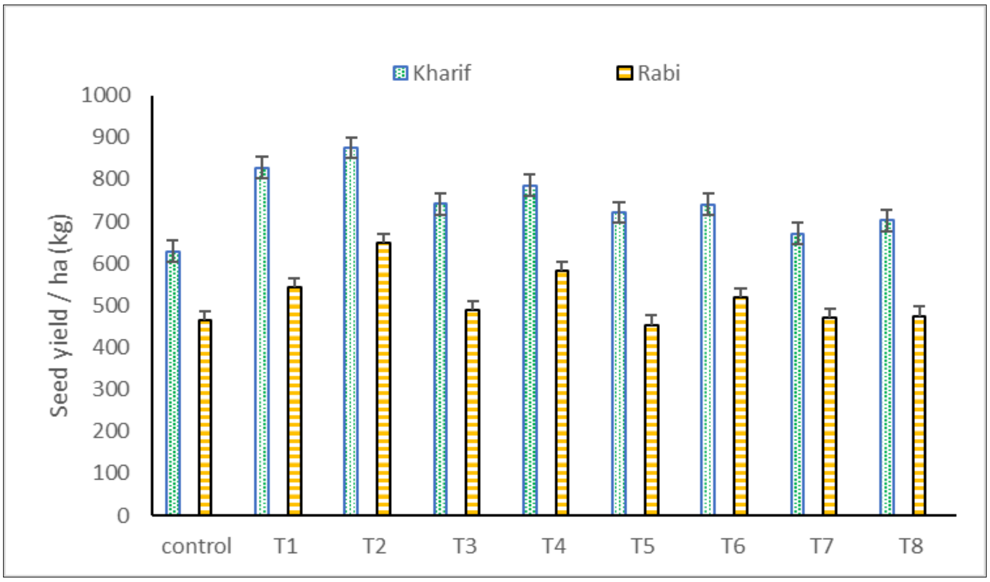

Fig. 5. Effect of foliar application of organic formulation on seed yield per hectare of green gram (CO 9) during *Kharif* and *Rabi* 2024.

Table 3. Effect of foliar application of organic formulation on yield parameters of green gram (CO 9) during *Kharif* and *Rabi* 2024

Treatment	***Kharif* 2024**			***Rabi* 2024**		
	Number of pods/ plant	**Number of filled seeds/pod**	**Hundred-seed weight (g)**	**Number of pods/ plant**	**Number of filled seeds/pod**	**Hundred seed weight (g)**
Control	15.17±0.28	08.73±0.04	2.55 ± 0.01	7.53 ± 0.31	8.33 ± 0.08	2.84±0.024
T_1 - Panchagavya 3 %	24.61±0.42	11.73±0.04	2.58 ± 0.01	13.39±0.51	9.53 ± 0.11	3.17±0.007
T2 - Panchagavya 5 %	26.61±0.45	12.13±0.11	2.78 ± 0.01	18.16±0.65	10.93±0.05	3.30±0.013
T3 - SWE 5 %	16.77±0.31	11.13±0.11	2.63 ± 0.01	11.64±0.07	9.13 ± 0.11	3.11±0.016
T4 - SWE 10 %	18.17±0.50	11.40±0.07	2.81 ± 0.06	15.37±0.09	9.87 ± 0.04	3.41±0.014
T5 - FFE 2 %	15.70±0.16	11.07±0.15	2.63 ± 0.01	9.79 ± 0.34	9.33 ± 0.08	2.99±0.030
T6 - FFE 4 %	16.52±0.18	11.33±0.08	2.63 ± 0.01	14.91±0.59	9.67 ± 0.04	3.21±0.011
T7 - EFE 2 %	15.21±0.29	09.87±0.11	2.50 ± 0.01	8.44 ± 0.13	8.73 ± 0.11	2.94±0.013
T8 - EFE 4 %	16.24±0.18	10.33±0.08	2.78 ± 0.01	11.47±0.45	8.80 ± 0.07	3.29±0.020
SEd	0.67	0.21	0.05	0.93	0.18	0.04
CD (P = 0.05)	1.41	0.46	0.10	1.98	0.38	0.08

promoting, insecticidal and antimicrobial substances that alleviate biotic and abiotic stresses affecting the crop (27, 28). These results are in agreement with earlier research outcomes (27-31).

However, the highest hundred-seed weight was recorded in the foliar spray treatment with SWE (*Turbinaria conoides*) 10 % (T_4), with values of 2.81 g and 3.41 g during the *Kharif* and *Rabi* seasons respectively. Germination percentage was not significantly different in *Kharif* but in *Rabi*, foliar spray treatment with SWE (*Turbinaria conoides*)10 % (T_4) recorded highest values (96 %) (Fig. 6). Root and shoot lengths were higher in the panchagavya 5 % treatment during the *Kharif* season. However, during the *Rabi* season, the seaweed extract treatment recorded higher values for root length (15.48 cm), shoot length (16.30 cm) and vigour index (3050) with panchagavya treatments showing on par performance (Fig. 7). Due to the non-significant differences observed in germination percentage during the *Kharif*

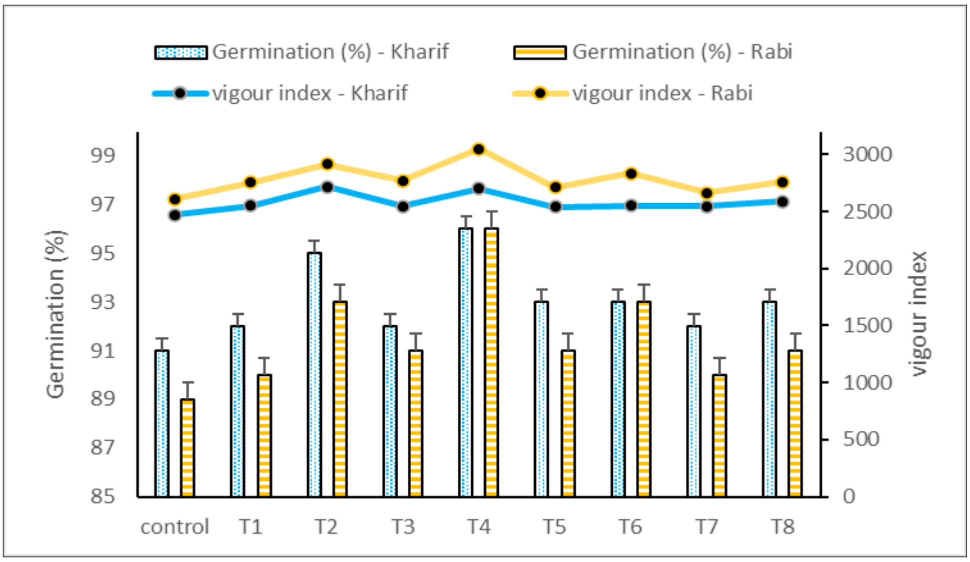

Fig. 6. Effect of foliar application of organic formulation on germination percentage and vigour index of green gram (CO 9) during *Kharif* and *Rabi* 2024.

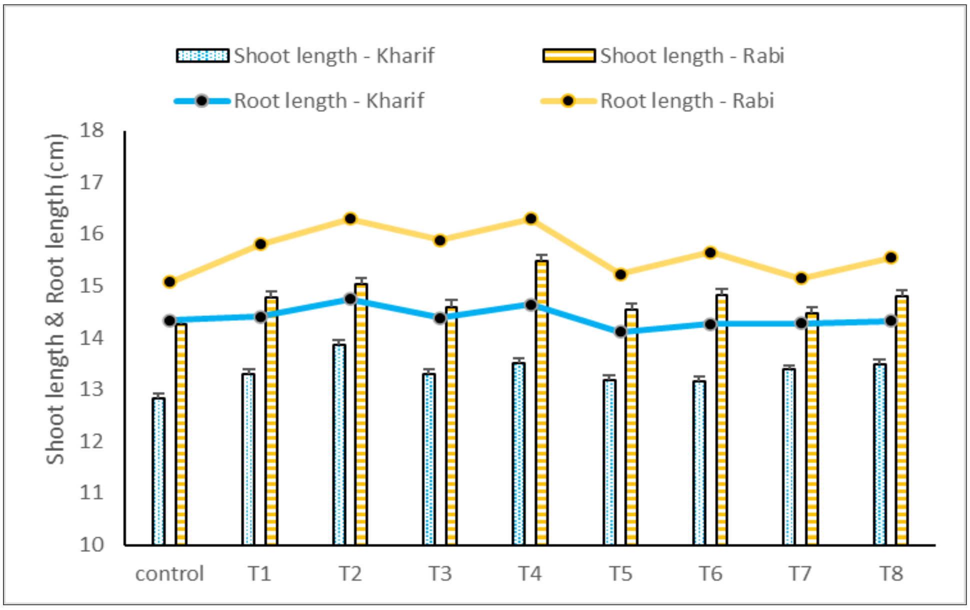

Fig. 7. Effect of foliar application of organic formulation on shoot and root length of green gram (CO 9) during *Kharif* and *Rabi* 2024.

season, the vigour index also showed no significant variation. The highest protein content was also recorded in the SWE 10% treatment, recording 23.74 % and 23.43 % on dry weight basis during the *Kharif* and *Rabi* seasons respectively. This performance was statistically on par with the panchagavya 5 % treatment indicated by LSD test results ($P < 0.05$) (Fig. 8). The positive effects observed in seed quality parameters may be attributed to the synergistic action of nutrients, bioactive compounds such as fucoidan, laminaran and alginate, which promote plant growth and development by enhancing cell wall reinforcement, water retention, biostimulation and stress tolerance and phytohormones such as auxins, cytokinins and gibberellins present in SWE (32). These components are rapidly absorbed through the foliage and efficiently translocated to the reproductive organs, thereby enhancing seed development and improving overall seed quality. However, among the organic formulations, panchagavya showed superior performance in terms of growth and yield and also achieved higher economic returns compared to FFE and EFE treatments (33). The enhanced crop growth recorded during the *Kharif* season might be attributed to more favourable agroclimatic conditions. The combination of ideal temperature, evenly distributed rainfall, sufficient sunshine hours and moderate evaporation created a favourable climate for seed germination, vegetative development and reproductive growth. These conditions would have promoted physiological processes such as photosynthesis, nutrient absorption and biomass synthesis, resulting in better growth and yield. In contrast, the *Rabi* period was observed with erratic rainfall, cooler temperatures and a gradual reduction in sunshine duration. The suboptimal environmental conditions prevailing during the *Rabi* period would have placed abiotic stress on the crop, particularly at the developmentally critical stages, thus affecting overall productivity (Fig. 1, 2). Although seasonal variations influenced plant growth and yield parameters due to differing environmental conditions, the foliar application of panchagavya at 5 % concentration consistently exhibited superior performance across both seasons, proving its efficacy as a reliable organic foliar spray formulation. Low productivity in pulses is consistently attributed to a low seed replacement rate (SRR) and limited adoption of high-yielding varieties (HYVs) (34). Overcoming these constraints through enhanced distribution of quality seeds and accelerated crop improvement programs is crucial for achieving sustainable yield enhancement. In this context, the foliar application of panchagavya presents a promising approach to improving seed yield and quality under organic farming systems.

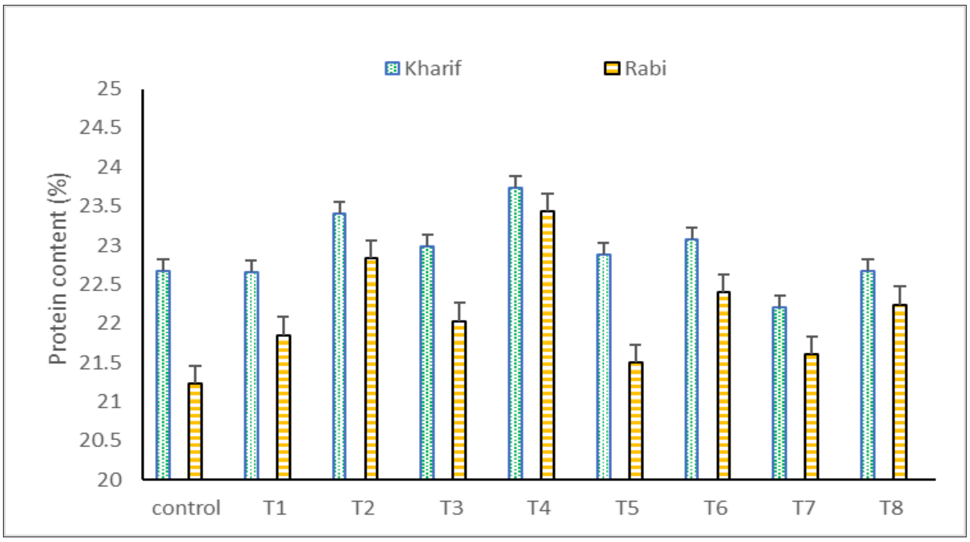

Fig. 8. Effect of foliar application of organic formulation on protein content of greengram (CO 9) during *Kharif* and *Rabi* 2024.

Conclusion

Panchagavya, a traditional organic formulation composed of cow-based products enriched with beneficial microorganisms, plant growth promoting hormones and essential nutrients, plays a vital role in improving growth and productivity in plants. The present findings of this study showed that foliar spray of panchagavya 5 % at flower initiation and early pod formation stages significantly enhanced plant growth, seed yield and seed quality parameters during *Kharif* and *Rabi* (2024) seasons, resulting in an average seed yield increase of over 25 % compared to the control. Thus, the foliar application of panchagavya has demonstrated potential as a promising organic formulation and serves as a viable alternative to synthetic chemical fertilizers, enhancing sustainable and eco-friendly seed and biomass production in green gram. Future research should focus on standardizing the optimal concentration and application frequency of panchagavya across diverse legume crops and agro-climatic zones to maximize its efficacy. Additionally, investigating its synergistic interactions with other organic inputs and biofertilizers may further strengthen its contribution to sustainable agricultural practices.

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Authors' contributions

HMS carried out the experiments, collected data and prepared the manuscript under the supervision of SS. SS conceptualized the study, monitored the research work and evaluated the outcomes. ES, SS and RK provided funding for the experiments. KR, MS and PJ offered valuable insights throughout the study. All authors reviewed and edited the manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare that they have no competing interests.

Ethical issues: None

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