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RESEARCH ARTICLE

Enhancing cowpea (*Vigna unguiculata* (L.) Walp.) productivity and seed quality through foliar application of organic and inorganic amendments

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Abstract

Cowpea is a significant pulse crop renowned for its adaptability to unfavourable environments, including sandy soils and areas with limited rainfall. To boost the seed yield of VBN 3 cowpea, foliar sprays were given at critical crop growth stages for sustainable agricultural production, irrespective of growing conditions. Foliar fertilization of crops is the most effective way to enhance nutrient availability, thereby rectifying nutrient deficiencies. The trial was proposed to investigate the effect of biological and chemical sources of nutrients through foliar treatment on cowpea's growth, seed yield and seed quality. The crop foliage was sprayed with inorganic and organic products viz., GA_3 at the rate of 100 ppm, KNO_3 at the rate of 1 %, KCl at the rate of 1 %, $CaCl_2$ at the rate of 1 %, Panchagavya at the rate of 3 % and Pulse sprout extracts (Horse gram) at the rate of 3 % along with untreated seeds (control) adopting RBD with seven treatments each replicated three times. Results revealed that the 3 % Panchagavya (3 mL of Panchagavya in 100 mL of water) foliar spray showed significantly improved growth parameters viz, plant height at the rate of 30 DAS, plant height at harvest stage, number of leaves in a plant, leaf breadth, leaf length, number of branches per plant, time taken to first flowering, duration to 50 % flowering and yield metrics viz., number of pods/plant, number of seeds/pod, pod length, seed yield/plant and 100 seed weight. The results indicated that harvested seeds from the same foliar spray treatment exhibited the higher quality characteristics than the control. The control plants showed poor crop growth and lower values for growth and yield attributes. Hence, it was concluded that the field establishment and seed productivity of cowpea may be improved through 3 % Panchagavya spray irrespective of the treatments.

Keywords: cowpea; foliar application; GA_3; panchagavya; seed yield; seed quality

Introduction

Cowpea is an essential crop for resource-poor farmers and is highly ideal for intercropping with other suitable crops. Cowpeas are predominantly cultivated in Africa, especially in the Federal Republic of Nigeria, which accounts for 66 % of the world's production (1). Cowpea is recognized for its wide range of uses in daily life, primarily as a food source, vegetable, feed, forage and green manure. In the semi-arid regions of Africa and Asia, cowpea is a crucial crop because of its capacity to endure harsh growing conditions characterized by coarse, sandy and scanty rainfall. Globally, cowpea is cultivated across 14.5 M ha, yielding 6.5 mMT annually, with millions of people consuming it daily (2). In India, cowpea is predominantly grown in the arid and semi-arid regions of Punjab, Haryana, Delhi and West UP, along with notable areas in Rajasthan, Kerala, Karnataka, Tamil Nadu, Gujarat and Maharashtra. The country produces 2.21 mT of cowpeas across 3.9 million hectares (3, 4).

Seed is a crucial and fundamental input for agricultural production. The effectiveness of various agricultural inputs, such as irrigation, fertilizers and pesticides, in improving productivity and production depends on seed quality as well as standards. The production of both agronomic and horticultural crops is sustainably influenced by seed quality, which accounts for twenty to twenty-five percentage of productivity. Among various agronomic factors responsible for increasing crop productivity, nutrient management plays a vital role in enhancing the production potential of crops prevailing in different agro-climatic conditions. One method of nutrient management is the application of nutrients through the foliage. Foliar treatments serve as a temporary solution, delivering micronutrients rapidly to address severe deficiencies that often arise during the early growth stages. The purpose of foliar application is to supply a plant's major nutrient (primary - N, P, K or secondary - Ca, Mg, S) and micro-nutrients (Zn, Fe, Mn, Cu, B and Mo) or plant hormones (GA_3, NAA, IAA) or bio-stimulant (seaweed extract) and other beneficial substances, which is supplemented at critical growth stages to boost up the varietal potential. Research indicates that crop growth, paired with additional foliar fertilization,

improves the mineral levels in plants and contributes to higher crop yields (5).

The benefits of foliar fertilization encompass its high efficiency, rapid plant reactions and its capacity to reduce or eliminate toxicity symptoms resulting from the accumulation of excess elements in the soil (5). It is recommended to apply foliar solutions directly onto the foliage. The pores on the surface of leaves allow them to absorb certain chemicals and nutrients. Both the stomata and the epidermis are where the absorption occurs. Although total absorption through the epidermis may be high, transport is typically faster through the stomata. Nutrient concentration and day temperature ought to be best to avoid leaf burning and plant food supply ought to be soluble in water to be more practical. Foliar fertilization of crops can serve as a complement to soil fertilization (6). It is a highly efficient method, especially when the roots are unable to absorb the necessary nutrients from the soil (7).

Panchagavya plays a significant role in the traditional Ayurvedic medicinal system and ancient Indian ceremonies. For Hindus, it holds sacred significance and it can be used as an insecticide and fertilizer in agriculture. Panchagavya is a rich source of macronutrients, including nitrogen, phosphorus and potassium, as well as micronutrients essential for plant growth and development. It also contains a variety of vitamins, amino acids and growth regulators, such as auxins and gibberellins, as well as beneficial microorganisms, including phosphorus-solubilizing bacteria, *Azotobacter* and *Pseudomonas*. Panchagavya-sprayed plants usually develop denser canopy and larger leaves (8). The benefits of Panchagavya include the quick uptake of nutrients, the ability to withstand environmental stresses, enhanced photosynthetic activity and improved flowering and fruiting characters (9).

Potassium ions are activators of numerous enzymes, play a crucial role in osmotic regulation within the cell and facilitate the uptake of nutrients, thereby enhancing the healthy growth and ultimately improving the yield characteristics of pulse crops. After Nitrogen, Potassium, in the form of free K+ ions, is one of the most abundant mineral nutrients in leaf biomass, indicating its significant role in plant growth and development, as well as its involvement in plant metabolism. KNO_3, $CaCl_2$ and KCl showed better results in improving the yield attributes of pulse crops (10, 11). The presence of higher accumulation of bioactive substances, total antioxidants and minerals such as N, P, K, Ca, Fe and Zn in the sprouted seeds of horse gram emphasizes their potential role in improving the yield of various crops when applied as a foliar spray. Cowpea can grow in underprivileged conditions with limited resources. To enhance the seed yield and quality of the produced seeds, nutrients have to been supplemented at critical growth stages of crop. Based on the information above, this study was conducted to investigate the impact of foliar application on the field efficacy and seed quality of cowpea.

Materials and Methods

The procured VBN 3 cowpea seeds,which were genetically and physically pure, were obtained from the National Pulses Research Centre, Vamban, Pudukkottai and served as the primary material for the study. The field experiment was conducted at the Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University (AU), Annamalai Nagar, in October 2019, utilizing a randomized block design (RBD) replicated three times. The foliar nutrients was sprayed on cowpea crop at critical crop growth stages of vegetative growth stage, 50 % flowering period and pod formation stage by using knapsack sprayer with organic and inorganic amendments namely T_0 - Control, T_1 - GA_3 at the rate of 100 ppm, T_2 - KNO_3 at the rate of 1 %, T_3 - KCl at the rate of 1 %, T_4 - $CaCl_2$ at the rate of 1 %, T_5 - Panchagavya at the rate of 3 % and T_6 - 3 % Horse gram sprout extract.

Horse gram sprout extract was prepared by soaking 50 g of horse gram seeds overnight and incubating them in a wet cloth for 12 hr to facilitate sprouting. 100 g of sprouts were obtained from 50 g of dry seeds. To prepare a horse gram sprout extract, 100 g of sprouts were ground in a grinder mixer using 100 mL of refrigerated ice water at 5 °C. Then the ground material was squeezed through a cloth bag to obtain a 100 % concentrate of 100 mL of horse gram sprout extract. From the concentrate, required dilution was obtained by dissolving the concentrate in 100 mL of water. Panchagavya was prepared from five cow-derived ingredients after proper fermentation as per procedure (12).

To prepare a 1 % solution, 1 g of nutrients, 1 mL of extracts, or 1 mL of organics was dissolved in 100 mL of water. The treated cowpea plants were observed regularly for recording the growth and yield metrics from each treatment replication wise.From each treatment's replication, five plants were randomly selected and tagged with labels for observation. The seed quality of the resultant seeds from different treatments was assessed using a Completely Randomized Block Design (CRD) with four replications. The seed quality parameters and bio-chemical characters viz., globulin, albumin, protein and NPK content in seeds were measured. The data are analyzed statistically using analysis of variance (ANOVA), with RBD for the field experiment and CRD for the seed quality evaluation of different treatments (13). The means values of each treatment were separated using the least significant differences method (LSD) at 5 % level of significance only when a significant "F" test was obtained (8). Wherever necessary, the per cent values were transformed into angular (arcsine) values before analysis.

Results and Discussion

In agriculture, fertilizer is a crucial source of nutrients for increasing crop yield. Foliar feeding is a crucial strategy for applying chemicals, among other tactics. The mineral status of plants was enhanced by supplemental foliar fertilization, which also increased agricultural yields (14). Highly significant variations were observed in the evaluated parameters in the experiment.The study revealed that among the foliar sprays, Panchagavya applied plants (T_5) recorded the maximum plant height at 30 DAS (56.36 cm), plant height at harvest stage (67.80 cm), number of leaves/plant (63.53), leaf length (10.66 cm), leaf breadth (8.24 cm), number of branches/plant (5.0), time taken to first flowering (38.60 DAS) and duration to 50 % flowering (45.60 DAS) and yield parameters viz. number of pods/ plant (39.67), pod length (20.07 cm), number of seeds/pod (15.00), seed yield/plant (44.73 g) and 100 seed weight (14.86 g).

Growth parameters

Panchagavya foliar applied plants (T_5) recorded significantly higher values for plant height. Panchagavya foliar applied plants (T_5) recorded 11.75 % and 10.13 % increase in plant height at 30 DAS and at harvest stage over the control (T_0) respectively (Fig. S1). At every stage of crop growth, higher plant height was associated with the availability and delivery of nitrogen to plants, which was provided by the foliar application of Panchagavya, which improved protein synthesis. Growth regulators in Panchagavya, including IAA and GA_3, are likely to stimulate cell multiplication, division and enlargement, which contribute to longer internodal distances (14). Chemotrophs and autotrophic microorganisms (ammonifiers and nitrifiers) present in Panchagavya colonize the leaves, boosting ammonia uptake and enhancing the total nitrogen supply, which in turn promotes plant height and vegetative growth (14, 15).

In the present study, plants treated with T_5 foliar application exhibited higher values for number of leaves, leaf breadth, leaf length and number of branches compared to other foliar-treated plants, as shown in Fig. 1. These parameters increased by 20.00 %, 10.07 %, 15.95 % and 16.26 %, respectively, compared to the control. The enhancement in vegetative growth may be attributed to the microbial metabolites present in Panchagavya, which improve nutrient and moisture availability. This helps maintain stomatal opening for a longer duration under both optimal and adverse conditions, ultimately increasing leaf length and breadth (Fig. S2), thereby strengthening the source-to-sink relationship. The notable increase in vegetative growth may be because plants are receiving more N from the foliar application of Panchagavya. Application of Panchagavya may have triggered the synthesis of native auxins, promoting early and active growth as well (15, 16).

The time taken to first flowering and duration to 50 % flowering in days was minimum days in T_5 foliar applied plants (Fig. 1) when compared to other foliar applied plants. T_5 foliar applied plants were 18.32 % and 10.53 % days earlier than control. The early flowering observed in T_5 can be attributed to the growth-promoting compounds such as GA_3, IAA and cytokinin, combined with the availability of essential mineral nutrients. These elements support the expansion of leaf area, improving light interception and facilitating the efficient transfer of photo-assimilates to reproductive structures, thereby promoting early flowering (16).

Yield parameters

In this study, the application of Panchagavya significantly enhanced the pod length (Fig. S3), number of pods/plant (Fig. S4), number of seeds/pod (Fig. S5), seed yield/plant and 100-seed weight compared to other foliar treatments.There was an increase of 15.12 %, 14.25 %, 16.47 %, 16.88 % and 15.75 %, respectively, for the above yield-attributing parameters when compared to the control. The assimilated surface area of the plant system determines the yield of any crop. A good source of plant height and leaf dimensions to sustain and hold the leaves is logically able to raise the photo-assimilates and the distribution of these to different parts is crucial for estimating the crop's overall production. The increased yield may be attributed to the hormones present in Panchagavya, particularly cytokinin, which plays a key role in nutrient partitioning within vegetative parts and enhances nutrient mobilization in reproductive structures. Moreover, the cow dung in Panchagavya acts as a medium that leads to the proliferation of beneficial microbes, while cow urine provides nitrogen, an essential nutrient for crops' growth and development, further contributing to yield enhancement (15, 16).

Yield enhancement in cowpea may also be attributed to increased photosynthetic efficiency, driven by the improved availability of essential nutrients, including macronutrients (N, P, K), as well as vital micronutrients required for overall plant growth and development. Additionally, the availability of amino acids, vitamins and growth regulators such as auxins, cytokinins and gibberellins along with beneficial microorganisms like *Pseudomonas*, *Azotobacter* and *Phosphobacteria*, plays a key part in fertilization, flowering, blooming and seed setting. These factors significantly influence yield-attributing traits such as the number of pods/plant, the number of seeds/pod and 100-seed weight. Furthermore, an ample supply of nutrients during critical growth stages may enhance protoplasmic constituents, accelerating cell division and elongation. This process promotes the development of more reproductive structures while reducing pollen abortion, ultimately enhancing seed yield traits (17-19). It was concluded that the improvement in seed yield could be linked to enhancements in yield attributes, including a high number of pods/plant, more seeds/pod, increased seed yield/plant, greater 100-seed weight and reduced flower drop.

Control (T_0) exhibited the lowest values for plant height at the rate of 30 DAS (49.74 cm), plant height at harvest stage (60.93 cm), number of leaves/plant (57.13), leaf length (8.96 cm), leaf breadth (6.90 cm), number of branches/plant (4.0), time taken to first flowering (45.67 DAS) and duration to 50 % flowering (50.40 DAS) and yield parameters viz. number of pods/plant (33.07), pod length (17.60 cm), number of seeds/pod (12.53), seed yield/plant (37.18 g) and 100 seed weight (12.52 g), as depicted in Fig. 1. The lower performance of control plants in terms of growth and yield based traits could be attributed to inadequate nutrient supply during critical growth stages, which subsequently impacted growth components and, in turn, yield-related parameters comparatively. In line with current research, plants treated with a Panchagavya foliar spray effectively absorbed nutrients during crucial growth stages. Additionally, the presence of IAA and GA in Panchagavya has been shown to have a significant positive influence on crop growth and yield (15, 20, 21).

Seed Quality

In the present study, plants treated with 3 % Panchagavya foliar application exhibited significantly higher values for seed quality parameters, including germination percentage (96 %), speed of germination (12.94), root length (18.80 cm), shoot length (21.73 cm), seedling fresh & dry weight (9.84 & 0.77 g) and vigour index I & II (3877 & 74). In contrast, control treatment exhibited the minimum values for these parameters (Fig. 2). T_5 may have higher seed quality characteristics than control because Panchagavya works in concert to increase and maintain nutrient availability throughout the crop period. Its improved translocation of more metabolites (stored mRNA) during seed maturation, specifically into the seed, as well as its activation of enzymes such as transphosphorylase, dehydrogenase and carboxylase, as well as its increased DNA repair mechanism during the processes of germination and seedling emergence, all contributed to the improvement in seed quality parameters resulting in the higher seed vigor.

The biochemical studies of the harvested seeds had appreciably improved the quality of the cowpea seeds.

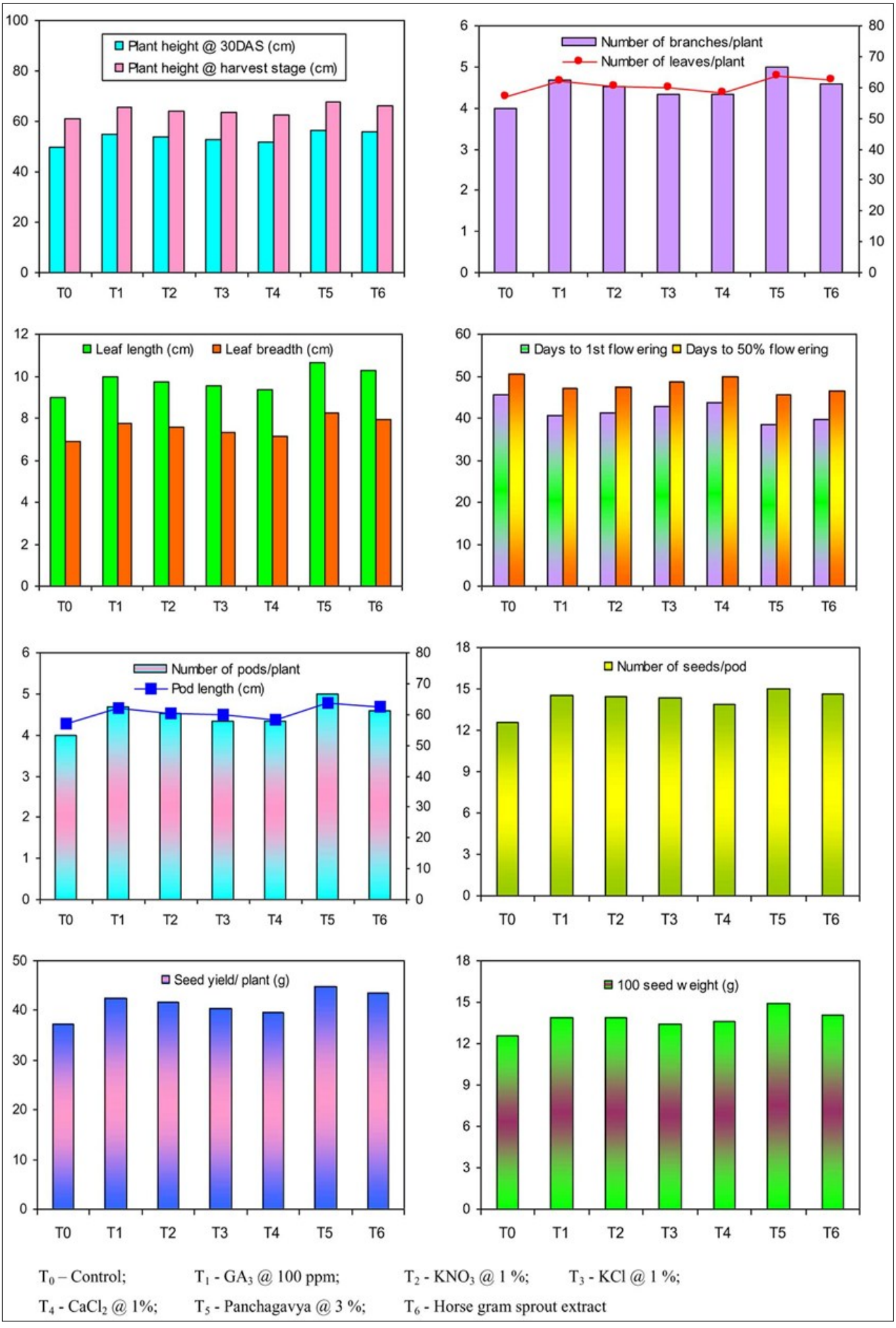

Fig. 1. Effect of foliar application on crop growth and seed yield of cowpea.

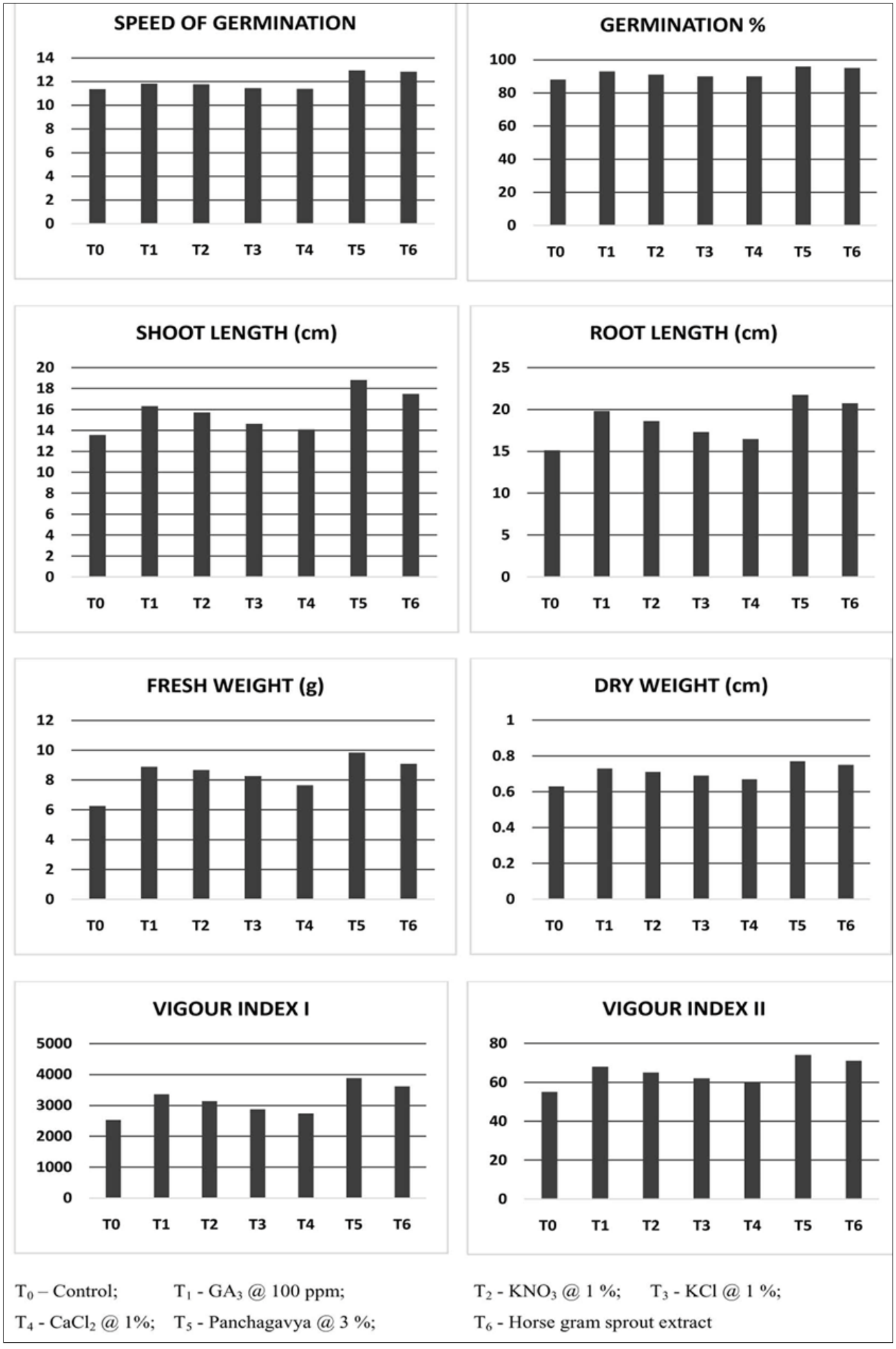

Fig. 2. Effect of foliar application on resultant seed quality of cowpea.

Treatment T_5 (foliar application of Panchagavya) recorded higher globulin, albumin and protein contents (72.27 %, 1.05 % and 25.84 %, respectively) compared to the control in the resultant seeds (Fig. 2). This may be due to the build-up of elevated quantities of seed contents, such as calcium carbonate, which facilitates better ATP production through lipid breakdown and the enzymatic activity of nitrate reductase and glutamate synthase (12). This helps increase the protein, albumin and globulin contents in the seed (18, 22-24).

In the present investigation, T_5 (foliar application of Panchagavya) recorded the significantly highest NPK content (5.20 %, 0.176 % and 22.75 %) (Fig. 2) of the resultant seeds over the seeds harvested from the control (Non-foliar sprayed) plants. In addition to macro and micronutrients, Panchagavya includes growth regulators such auxins and GA, which have been shown to improve plant NPK recovery and increase biomass. Bioactive substances produced by beneficial microorganisms present in Panchagavya favourably enhanced vegetative growth, which in turn influenced the translocation of metabolites into the reproductive structure (source to sink), thereby increasing the NPK content in the resultant seeds (17).

Conclusion

Cowpea is an important pulse crop for human food, animal feed and improving soil fertility. It was well known for its sustainable growth under varied soil and climatic conditions in arid and semi arid regions. The experiment was conducted to study the effect of foliar spray on crop growth and seed yield. The foliar application of 3 % Panchagavya (3 L of Panchagavya in 100 L of water) was found to be significantly superior with irrelevant of all other foliar treatments. Panchagavya provides macronutrients, essential micronutrients, many vitamins, required amino acids, growth-promoting substances and beneficial microorganisms for the better growth of plants. Presence of GA_3 and IAA, macronutrients, micronutrients and beneficial microorganism in Panchagavya might have triggered the synthesis of hormones and other PGRs in the cells that created a beneficial effect and positive stimulus on the growth and yield related parameters of cowpea by acting as organic growth promoter as well as immunity booster. Thus, from this present study, a 3 % Panchagavya foliar spray boosted vegetative growth, yield parameters, nutrient uptake and the resultant seed quality compared to the control. Furthermore, researchers suggested that the effect of organic amendments, such as Panchagavya, may be assessed under diverse soil and climatic conditions on the root growth of the crop. Especially in the the case of pulses, the role of Panchagavya on root nodulation through periodical soil application and foliar application enhances nitrogen fixation and symbiotic association of microorganisms on crop growth as an organic growth promoter and plant health protector

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Authors' contributions

KA conceptualized the study, performed the experiments and drafted the initial manuscript. KS^1 contributed to research design, supervised the experimental work. KS^2 handled the manuscript communication. NP was responsible for data collection and supported statistical analysis. PS contributed to data validation and interpretation. All authors read and approved the final version of the manuscript. [KS^1 stands for K Sasikala and KS^2 stands for K Sivakumar].

Compliance with ethical standards

Conflict of interest: The Authors do not have any conflict of interest to declare.

Ethical issues: None

AI Declaration : During the preparation of this work, the author (s) used Chat GPT by Open AI to enhance language clarity and readability. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the publication's content.

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