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Unveiling the Impact of Plant Growth Regulator Infused Tamarind Seed Polysaccharide (TSP) Polymer Coating on Seed Quality Behaviour of Cowpea var. VBN 3

Pravina K [a++*] and P R. Renganayaki [b#]

[a] *Department of Seed Science and Technology, Tamil Nadu Agricultural University, Madurai, Tamil Nadu, India.*
[b] *Department of Plant Genetic Resources, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.*

Authors' contributions

This work was carried out in collaboration between both authors. Author PK designed the study, performed the statistical analysis, wrote the protocol, literature collection and wrote the first draft of the manuscript. Author PRR supervised and corrected the entire studies. Both authors read and approved the final manuscript.

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ABSTRACT

A laboratory experiment was conducted in 2023 at the Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore, to evaluate the effectiveness of Tamarind Seed Polysaccharide (TSP) polymer as a natural alternative to synthetic seed coatings

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[++] *PhD scholar;*
[#] *Professor;*
**Corresponding author: E-mail: pravikannaiya@gmail.com;*

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for improving the planting value of cowpea seeds. The treatments included T_0 – Control, T_1 – GA_3 10 ppm, T_2 – GA_3 20 ppm, T_3 – GA_3 30 ppm, T_4 – GA_3 40 ppm, T_5 – GA_3 50 ppm, T_6 – BRs 0.5 ppm, T_7 – BRs 1.0 ppm, T_8 – BRs 1.5 ppm, T_9 – BRs 2.0 ppm, and T_{10} – BRs 2.5 ppm. Data were analyzed statistically using a Completely Randomized Design (CRD) with ANOVA. Significant differences were observed among the treatments for all seed quality parameters. Seeds coated with TSP polymer enriched with 3 mL of 1.0 ppm brassinosteroids (T_7) recorded the highest speed of germination (36.96), germination percentage (94%), root length (20.66 cm), shoot length (23.58 cm), vigour index I (4159), and vigour index II (58). In contrast, the uncoated control seeds exhibited the lowest performance in terms of speed of germination (33.74), germination percentage (88%), root length (17.85 cm), shoot length (20.63 cm), vigour index I (3386), and vigour index II (52). The findings indicate that cowpea seeds coated with 8 g of TSP polymer infused with 1.0 ppm BRs exhibited superior germination and seedling vigour compared to other treatments. Hence, this formulation can be recommended as an eco-friendly, biopolymer-based pre-sowing seed treatment suitable for organic agricultural systems.

Keywords: TSP polymer; seed coating; plant growth regulators; cowpea; organic agriculture.

1. INTRODUCTION

Cowpea (*Vigna unguiculata*) is a crucial legume crop for tropical and subtropical regions, including India, prized for its drought tolerance and ability to grow in marginal soils with low fertility, a wide pH range (4.0–9.0), and high sand content. It is a cornerstone of food and nutritional security, providing dietary protein, vitamins, and minerals, while its residues serve as valuable animal feed. Furthermore, its capacity for biological nitrogen fixation enhances soil fertility, solidifying its role in sustainable, low-input agricultural systems (Tripathi & Singh, 2001). Despite its significance, cowpea productivity remains suboptimal, primarily due to constraints in the availability and distribution of high-quality seeds. The establishment of a uniform and vigorous crop is fundamentally dependent on the use of genetically pure, physically sound, and pest-free seed (Halmer, 2006; Ventura *et al.,* 2012). To address these challenges, various seed enhancement technologies such as priming, pelleting, and coating have been developed to bolster germination and seedling establishment under adverse conditions (Farooq *et al.,* 2013; Afzal *et al.,* 2016). Among these, seed coating has emerged as a precise delivery mechanism for nutrients, protectants, and bioactive compounds, applied to the seed without altering its form to improve overall quality and vigour (Rocha *et al.,* 2019). However, a significant limitation of conventional seed coatings is their reliance on synthetic polymers, which are often slow to degrade and may contain toxic additives, rendering them unsuitable for organic and environmentally sensitive farming. In this context, biopolymers derived from natural sources offer a sustainable alternative due to their biodegradability, non-toxicity, and ecological compatibility (Struminska *et al.,* 2014). Polysaccharide-based superabsorbent hydrogels, in particular, are attractive for this purpose; they are typically abundant, inexpensive, and biocompatible, with excellent water-retention properties that improve seed-soil contact (Kamath & Park, 1993). Tamarind Seed Polysaccharide (TSP), extracted from the seeds of *Tamarindus indica*, is one such promising biopolymer (Sagar Pal et al., 2008). A byproduct of the tamarind pulp industry, TSP is commercially available and possesses ideal characteristics for coating, including high viscosity, strong adhesive strength, and excellent film-forming ability, which have been leveraged in the pharmaceutical and food sectors (Ella et al., 2011). Its innate biodegradability makes it an excellent candidate for developing organic seed coatings. (Bhattacharya *et al.,* 1993; Marathe *et al.,* 2002). Tamarind seed is shown to be a valuable and sustainable source of polysaccharides for developing edible films, with strong potential to replace traditional plastic packaging, extend shelf life, and contribute to the valorization of agricultural waste for postharvest fruit preservation (Phumkacha, *et al.,* 2025).The functionality of a seed coating can be significantly advanced by incorporating Plant Growth Regulators (PGRs), which are endogenous phytohormones that govern plant development and stress responses (Hedden & Thomas, 2012). Growth-promoting PGRs like gibberellins and brassinosteroids are especially relevant. Gibberellic acid (GA_3) is known to stimulate germination, promote cell elongation, and enhance nutrient mobilization (Bose & Tandon, 1991). Brassinosteroids, similarly, improve stress tolerance by boosting antioxidant enzyme activity and promoting early seedling growth (Hayat *et al.,* 2011; Slathia *et al.,* 2021). Therefore, the integration of these potent PGRs into a TSP-based biopolymer matrix represents a novel, eco-friendly strategy to enhance seed performance. The present study was conceived to investigate the efficacy of a PGR-infused TSP biopolymer coating on the germination behaviour, and seedling vigour, of cowpea seeds.

2. MATERIALS AND METHODS

The tamarind seed polysaccharide (TSP) was synthesized from defatted tamarind kernel powder following the method of Kannan and Manavalan (2007) with slight modifications as] initially, tamarind kernel powder was defatted using a benzene–ethanol mixture (1:1, v/v) at a 1:2 (w/v) ratio and kept for 24 hours. The mixture was then centrifuged at 5000 rpm for 30 minutes, after which the supernatant was discarded, and the residue was oven-dried at 40°C. Subsequently, 20 g of the defatted powder was blended with 200 ml of 0.01 M hydrochloric acid to form a slurry, which was dispersed in 300 ml of boiling 0.01 M HCl. The mixture was maintained at 90°C in a water bath for 30 minutes and then cooled to room temperature. After centrifugation at 4000 rpm for 10 minutes, the supernatant was collected, and TSP was precipitated by adding an equal volume of ethanol. The resulting precipitate was filtered through muslin cloth and dried in a hot air oven at 50°C. Finally, the dried polysaccharide flakes were ground into a fine powder using a mixer.

“To prepare polymer, 10 g of Tamarind Seed Polysaccharide (TSP) was taken and added one ml of glycerol were dissolved in 200 ml of water by stirring with a mechanical stirrer at 4000 rpm. After complete dissolution of the polysaccharide 4 g of agar was dissolved with the solution and heated for 90°C in water bath for 20 minutes. The solution was cooled at room temperature and stored in refrigerator” (Sivasakthi 2022). The extracted polymer was enriched with different concentrations of plant growth regulators (PGRs) to enhance its biostimulant potential. For enrichment, 3 mL of each concentrated PGR solution was uniformly mixed with 100 g of TSP polymer. The treatment details were as follows:

Sample: Certified seeds of cowpea VBN 3 procured from National Pulse Research station, Vamban, Pudukottai district

T_0 – Control (Uncoated seed),
T_1 – GA_3 10 ppm,
T_2 – GA_3 20 ppm,
T_3 – GA_3 30 ppm,
T_4 – GA_3 40 ppm,
T_5 – GA_3 50 ppm,
T_6 – Brassinosteroids (BRs) 0.5 ppm,
T_7 – BRs 1.0 ppm,
T_8 – BRs 1.5 ppm,
T_9 – BRs 2.0 ppm, and
T_{10} – BRs 2.5 ppm.

After enrichment, 8 g of the TSP polymer was used to coat 1 kg of cowpea seeds. The coated seeds were air-dried to restore their original moisture content. The control and treated seeds were then subjected to germination studies

2.1 Observation

2.1.1 Speed of germination (Maguire, 1962)

Number of germinated seeds were counted from first day onwards. From the number of seeds germinated on each counting day up to eigth day a and the speed of germination was computed adopting the formula

$$\text{Speed of Germination} = \frac{X_1}{Y_1} + \frac{X_2}{Y_2} + \ldots + \frac{X_n}{Y_n}$$

X1 - Number of seeds germinated at first observation day
X2 - Number of seeds germinated at second observation day
Y1 - Number of days from sowing to first observation day
Y2 - Number of days from sowing to second observation day
Xn- Number of seeds germinated on nth observation day
Yn- Number of days from sowing to nth observation day

2.1.2 Seed germination (%) (ISTA, 2013)

The germination test was conducted using the rolled paper towel method with four replications of 100 seeds each. The germination chamber was maintained at 25 ± 5°C, 95 ± 5% relative humidity, and illuminated with fluorescent light (750–1230 lux). At the end of the 8th day, normal seedlings were counted, and the mean germination percentage was determined using the following formula:

$$\text{Germination percentage (GP)} = \left(\frac{\text{Number of normal seedlings germinated}}{\text{Total number of seeds sown}}\right) \times 100$$

2.1.3 Root length (cm)

Ten seedlings were randomly chosen from each replication after the germination count and the length of the roots from the collar area to the tip of the primary root was measured and average value expressed in centimetres.

2.1.4 Shoot length (cm)

Shoot length was measured on the same seedlings that were used to measure the length of the roots. The distance along the shoot from the collar to the tip of the primary leaf was measured and the average value was expressed in centimetres.

2.1.5 Dry matter production (g seedlings^{-10})

The seedlings chosen to measure the root and shoot lengths were placed inside a paper cover and dried for 24 hours in both the shade and a hot air oven with the temperature maintained at 80°C. The seedlings were weighed using an electronic balance.

2.1.6 Vigour index I and II

Abdul-Baki and Anderson's (1973) formula was used to calculate the vigour index values, and the mean values were reported as whole numbers**.**

Vigour index I = Germination (%) x Root length (cm) + Shoot length (cm)
Vigour index II = Germination (%) x Dry matter production (10 seedlings^{-g})
Design of the experiment: With four replications, the experiment was done in a complete randomized design.
Statistical tool: ANOVA

3. RESULTS AND DISCUSSION

To improve the performance of Tamarind Seed Polysaccharide (TSP) polymer coatings on seed quality, the polymer was enriched with two plant growth regulators (PGRs) - gibberellic acid (GA_3) and brassinosteroids (BRs) and their effects on the physiological attributes of cowpea seeds were evaluated. Significant variation was observed among treatments for all parameters studied. Seeds coated with TSP polymer infused with 3 mL of 1.0 ppm BRs (T_7) recorded the highest speed of germination (36.96), germination percentage (94%), root length (20.66 cm), shoot length (23.58 cm), vigour index I (4159), and vigour index II (58), which were statistically comparable with all treatments except the control (T_0). The uncoated control seeds exhibited the lowest performance in terms of speed of germination (33.74), germination percentage (88%), root length (17.85 cm), shoot length (20.63 cm), vigour index I (3386), and vigour index II (52). Although seedling dry weight did not differ significantly among treatments, but the highest value (0.618 g/10 seedlings) was observed in TSP polymer coating infused with 1.0 ppm BRs, and lowest recorded in control seeds (0.594 g/10 seedlings) (Table 1; Fig. 1). The incorporation of PGRs into the TSP polymer significantly improved seed germination and seedling vigour, with the maximum enhancement observed in seeds coated with TSP polymer enriched with 3 mL of 1.0 ppm BRs. Compared to the control, BR-infused TSP coating improved cowpea germination by approximately 6%. A higher rate of germination is a strong indicator of seed vigour, as rapidly germinating seeds establish faster and utilize available resources more efficiently, leading to better growth and yield. “The vigour developed during the initial growth phase greatly influences both yield and resultant seed quality. Similarly, dry matter accumulation reflects the degree of cell compactness and the number of cells within plant tissues, serving as an indicator of overall biomass production. The improvement in germination and vigour parameters may be attributed to the carbon-rich TSP polymer matrix and the growth-promoting effects of brassinosteroids. Tamarind seeds are known to contain approximately 65% non-fibre carbohydrates**,** along with several essential amino acids such as isoleucine, leucine, lysine, methionine, phenylalanine, and valine. They also provide essential fatty acids and important minerals, including calcium, magnesium, phosphorus, and potassium” (Joseph *et al.,* 2012) and “The natural protein and fat content of TSP improved the water barrier properties of the edible films, helping protect the moisture loss” (Phumkacha *et al.,* 2025). Plant growth regulators comprising promoters, inhibitors, and retardants play a vital role in regulating internal physiological and biochemical mechanisms through pathways associated with protein and nucleic acid metabolism. Among these,

Table 1. The effect of PGRs infused TSP polymer coating on seed quality parameters on cowpea var. VBN 3

Treatments	**Speed of germination**	**Root length (cm)**	**Shoot length (cm)**	**Dry matter production (g / 10 seedlings)**	**Vigour Index I**	**Vigour Index II**
T_0 - Control	33.74	17.85	20.63	0.594	3386	52
T_1 - GA_3 10 ppm	36.91	20.46	23.29	0.616	4022	57
T_2 -GA_3 20 ppm	36.87	20.55	23.39	0.617	4042	57
T_3 - GA_3 30 ppm	36.65	20.49	23.40	0.617	4082	57
T_4 - GA_3 40 ppm	36.52	20.40	23.36	0.618	4026	57
T_5 - GA_3 50 ppm	36.00	20.37	23.32	0.617	4249	56
T_6 - BRs 0.5 ppm	36.60	20.63	23.51	0.617	4105	57
T_7 - BRs 1.0 ppm	**36.96**	**20.66**	**23.58**	**0.618**	**4159**	**58**
T_8 - BRs 1.5 ppm	36.56	20.50	23.42	0.616	4085	57
T_9 - BRs 2.0 ppm	36.65	20.43	23.32	0.615	4025	56
T_{10}- BRs 2.5 ppm	36.14	20.40	23.25	0.615	3928	55
Mean	36.23	20.24	23.13	0.623	4009	56
SEd	0.377	1.273	0.323	NS	58.76	0.923
CD (p=0.05)	0.771	2.602	0.660	NS	120.09	1.887

NS*- Non significant*

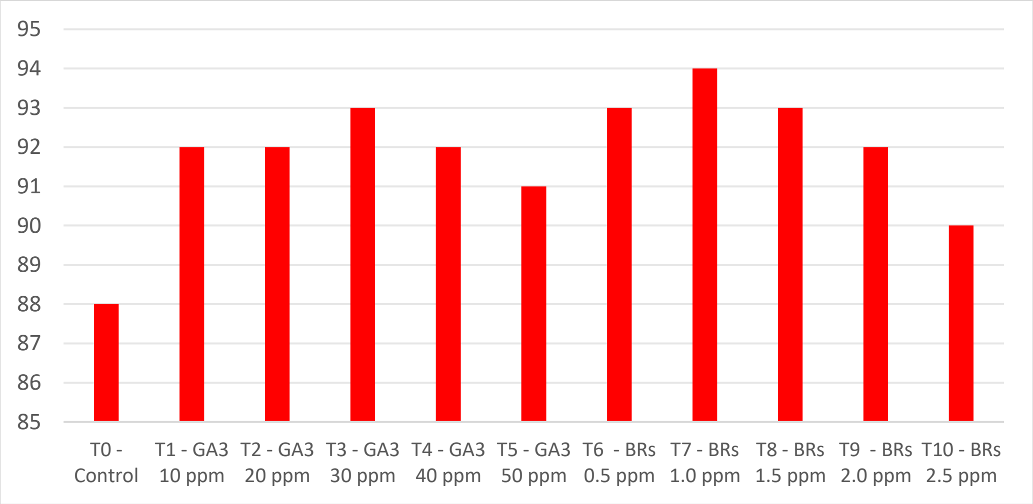

Fig. 1. The effect of PGRs infused TSP polymer coating on germination percentage (%) on cowpea var. VBN 3

T_0- Uncoated seed

T_7 - 3 ml of 1.0 ppm BRs infused TSP polymer coated seed

Plate 1. Visible difference in seedling growth

brassinosteroids (BRs) are steroidal plant hormones essential for normal growth and development. BR signalling influences cell division and elongation and regulates physiological processes such as etiolation, reproduction, and stress tolerance. Earlier studies support these findings: Kato *et al.,* (1983) reported that "pre-treatment with brassinolide enhanced germination and seedling emergence in rice. Similar stimulatory effects of BRs on seed germination and seedling growth" were also reported by Srivastava *et al.,* (2011) in mung bean, Sumathi *et al*., (2018) in pigeon pea, and Pravina et *al.,* (2023) in greengram. The enhanced germination and vigour observed in the present study likely result from the synergistic interaction between the carbon source supplied by the TSP polymer and the physiological stimulation induced by BRs**.** According to **"**Wei and Li (2016)**,** BRs modulate root meristem activity and lateral root formation in a concentration-dependent manner, with low concentrations promoting root growth and higher doses showing inhibitory effects. In Plate 1, the visual differences in seedling growth are evident in treatment T_7, where secondary root proliferation likely enhanced nutrient absorption, leading to better establishment, growth, and potential yield. Overall, the findings clearly demonstrate that TSP polymer coatings enriched with brassinosteroids (1.0 ppm) effectively enhance seed germination, seedling vigour, and early growth in cowpea. This highlights the potential of BR-infused TSP polymer as a biopolymer-based, eco-friendly seed coating material for improving seed quality and ensuring rapid crop establishment.

4. CONCLUSION

This the study clearly indicates that TSP polymer enriched with 3 mL of 1.0 ppm BRs can serve as an effective biopolymer coating for enhancing seed germination and vigour in cowpea. The improvement in seed quality parameters could be attributed to the synergistic effect of the carbon-rich matrix of the TSP polymer and the growth-promoting role of brassinosteroids.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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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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