

INFLUENCE OF PLANT DERIVED EXTRACTS ON *IN VITRO* MICROTUBERIZATION OF POTATO (*SOLANUM TUBEROSUM* L.) CV. KUFRI HIMALINI

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ABSTRACT

The present investigation was conducted to evaluate the influence of plant derived extracts on *in vitro* microtuberization of potato (*Solanum tuberosum* L.) cv. 'Kufri Himalini' as potential natural supplements or alternatives to synthetic plant growth regulators. The study was conducted during 2025 at the Plant Tissue Culture Laboratory, Department of Horticulture, UAS, GKVK, Bengaluru, Karnataka, using newly developing sprouts from healthy potato tubers as explants in a completely randomized design (CRD). Coconut water, potato homogenate, banana homogenate and tomato homogenate were evaluated at 10, 15 and 20 per cent concentrations and compared with MS medium supplemented with 2 mg/L BAP and basal MS medium without PGR or extract. Microtuberization provides compact, disease-free propagating material with advantages in handling, storage, transportation and seed production. The results revealed that 2 mg/L BAP recorded the earliest tuber initiation (45.60 days), highest tuberization response (60.00, 72.00 and 86.00%), number of microtubers (2.60, 3.40 and 4.00), average weight (160.75, 168.95 and 176.95 mg) and size (8.44, 8.86 and 9.06 mm) at 50, 70 and 90 days, respectively. Among the plant derived extracts, 20 per cent coconut water was most effective and comparable with BAP recording 46.60 days for tuber initiation and 60.00, 70.00 and 84.00 per cent tuberization response, 2.40, 3.00 and 3.80 microtubers, at 50, 70 and 90 days, respectively. Its average microtuber weight was 173.29 mg and size were 8.94 mm at 90 days. Further, 15 per cent coconut water and 20 per cent potato homogenate were also comparable with BAP for most microtuberization parameters, particularly during the later stages. Thus, 20 per cent coconut water, followed by 15 per cent coconut water and 20 per cent potato homogenate, showed considerable potential as natural supplements and potential alternatives to synthetic PGRs for *in vitro* microtuber production in potato cv. 'Kufri Himalini'.

KEYWORDS: BAP; Coconut water; *In vitro*; Kufri Himalini; Microtuberization; Plant derived extracts; Potato; Potato homogenate

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a natural autotetraploid ($2n=4x=48$) belonging to the family Solanaceae and is native to the Andean highlands of Peru and Bolivia (Hawkes, 1967). It is one of the world's major food crops and is valued for its carbohydrates, dietary fibre, antioxidants, vitamins and minerals. Potato is also reported to possess several health-promoting properties, including antidiabetic, anti-obesity, anticancer, antimicrobial and anti-inflammatory activities (Zaheer and Akhtar, 2016; Beals, 2019). It is particularly rich in vitamins B₁, B₆ and C and minerals such as potassium, copper, manganese and phosphorus (Górska-Warsewicz et al., 2021). Globally, potato ranks fourth among major food crops after rice, wheat and maize and is an important crop for food security and farmer livelihoods (Kowalczewski et al., 2022; Kumar et al., 2022).

However, potato production is constrained by the limited availability of quality seed tubers and the accumulation and spread of viral and bacterial diseases through conventional vegetative propagation (Singh et al., 2021). Seed tuber propagation also requires large quantities of planting material, has a relatively slow multiplication rate and involves high production, storage and transportation costs (Char et al., 2023; Ranalli, 2007). Therefore, the development of efficient methods for producing high-quality, disease-free planting material is essential for sustainable potato production.

Plant tissue culture provides an effective approach to overcoming these limitations by enabling the rapid, season-independent production of disease-free and genetically uniform planting material (Char et al., 2023; George et al., 2008). *In vitro* micropropagation using nodal segments and shoot tips on suitable culture media

has become an important component of modern seed potato production systems (Naik and Karihaloo, 2007). It also facilitates the conservation and maintenance of pathogen-free germplasm (Hussey and Stacey, 1981). Among the various tissue culture-derived propagules, microtubers are small, disease-free tubers produced under *in vitro* conditions and offer considerable potential for quality seed production (Badoni and Chauhan, 2009). They are uniform, compact, easy to handle and store and can be used directly as planting material or further multiplied for seed production (Ranalli, 2007; Kefi et al., 2020). However, microtuber induction and development are influenced by several factors, including carbohydrate availability, hormonal balance, sucrose concentration, photoperiod, temperature and plant growth regulator (PGR) composition (Gopal et al., 2004; Xu et al., 2021). Therefore, further refinement of microtuberization protocols is necessary for their efficient and economical utilization (Kefi et al., 2020).

Synthetic PGRs, particularly cytokinins, auxins and gibberellins, are widely used to regulate shoot multiplication, morphogenesis and tuberization under *in vitro* conditions (George et al., 2008). However, their repeated or prolonged use may increase production costs and, under certain culture conditions, may contribute to genetic instability or somaclonal variation (Bairu and Aremu, 2012). These limitations have stimulated interest in natural and environmentally sustainable alternatives to synthetic growth regulators (Du Jardin, 2015). Plant derived extracts contain a diverse range of biologically active compounds, including phenolics, amino acids, vitamins, minerals and naturally occurring phytohormones, which can influence cell division, nutrient uptake, morphogenesis and stress tolerance (Ertani et al., 2013; Yakhin et al., 2017). Their application as biostimulants in plant tissue culture has consequently received increasing attention (Rouphael and Colla, 2020).

Several low-cost organic supplements, including coconut water, banana homogenate, potato homogenate, yeast extract, tomato and pineapple-based extracts, have been explored as alternative or supplementary components of tissue culture media (Häkkinen et al., 2020; Hamdeni et al., 2022). These natural supplements provide readily available carbohydrates, vitamins, amino acids, minerals and endogenous growth-promoting compounds that can support *in vitro* growth and development (Khorsha et al., 2016; Thejaswini and Narasimhan, 2017). Their incorporation into culture media has been reported to enhance shoot proliferation, rooting and morphogenesis and, in some cases, reduce dependence on synthetic PGRs (George et al., 2008; Khan et al., 2009; Saa et al., 2022). In addition to their biological benefits, the use of locally available plant-derived supplements may contribute to reducing the cost of tissue culture media and improving the economic feasibility of large-scale micropropagation.

Although plant derived supplements have shown considerable potential in *in vitro* plant regeneration, their systematic evaluation for potato microtuberization remains relatively limited (Naik and Karihaloo, 2007). In particular, information on the comparative response of potato to different plant-derived extracts during microtuber induction and development is inadequate. Identifying suitable natural supplements that can effectively support microtuberization while reducing reliance on synthetic PGRs could contribute to the development of economical and sustainable seed potato production systems. Therefore, the present study was undertaken to evaluate the effect of selected plant derived extracts on *in vitro* microtuberization of potato (*Solanum tuberosum* L.) cv. Kufri Himalini, with the objective of identifying suitable natural and cost-effective supplements for enhancing microtuber production and their potential use as alternatives or supplements to synthetic PGRs in *in vitro* seed potato production.

MATERIAL AND METHODS

Experimental site

The present investigation entitled “Influence of plant derived extracts on *in vitro* microtuberization of potato cv. Kufri Himalini” was conducted at the Plant Tissue Culture Laboratory, Department of Horticulture, University of Agricultural Sciences, GKVK (Gandhi Krishi Vigyan Kendra), Bengaluru-560 065, Karnataka, India, during 2025 to 2026.

Plant material and source of explants

Potato cv. ‘Kufri Himalini’, a medium-maturing and high-yielding cultivar developed by ICAR-Central Potato Research Institute (CPRI), Shimla, Himachal Pradesh was used for the present investigation. The plant material was obtained from the Regional Horticultural Research and Extension Centre (RHREC), Bengaluru, UHS, Bagalkot and the Horticultural Research and Extension Centre (HREC), Hassan, UHS, Bagalkot. Newly developing sprouts from healthy potato tubers were used as explants for the study (Fig. 1).

Preparation of plant derived extracts and culture medium

Fresh coconut water (CW) was collected from young, tender coconuts and filtered through four layers of cheesecloth. Banana homogenate (BH), potato homogenate (PH) and tomato homogenate (TH) were prepared by homogenizing 100 g of fresh tissue separately in a mixer grinder and stored under refrigerated conditions until use. Murashige and Skoog (1962) basal medium was used for the microtuberization study. Sucrose was added at 60 g L⁻¹ and the medium was supplemented with CW, BH, PH and TH, each at 10, 15 and 20 per cent concentrations, along with the respective treatments described in Table 1. Two additional treatments were included: MS basal medium without plant growth regulator (PGR) or plant derived extract and MS medium supplemented with 2 mg L⁻¹ BAP as the PGR treatment. The pH of the medium was adjusted to 5.7, followed by the addition of Phyto-agar at 6 g L⁻¹. The medium was dispensed into culture vessels and autoclaved at 121°C and 15 psi for 15 to 20 min before use.

Micropropagation of plantlets

Healthy tuber sprouts were used as explants for *in vitro* establishment. Five explants were inoculated into sterilized culture jars containing 40 mL of standard Murashige and Skoog (1962) medium supplemented with vitamins, 30 g L⁻¹ sucrose, 6 g L⁻¹ agar, 0.5 mg L⁻¹ NAA and 1.0 mg L⁻¹ kinetin. The pH of the medium was adjusted to 5.7 before adding agar, followed by autoclaving. The culture jars were closed with polyvinyl carbonate caps, sealed with household plastic film and incubated at 25 ± 2°C under a 16 h light and 8 h dark photoperiod, with an illumination intensity of approximately 2000-3000 lux using cool fluorescent tubes for four weeks. The sprout explants developed into well-rooted plantlets, which were subsequently cut into single-node segments and transferred to fresh MS medium of the same composition. The multiplication cycle was repeated at four-week intervals by subculturing single-node segments under the same culture conditions until sufficient *in vitro* plantlets were obtained for the microtuberization experiment.

In vitro tuberization

Shoots bearing 5-6 nodes obtained from the multiplication stage were transferred to solid MS medium supplemented with coconut water (CW), banana homogenate (BH), potato homogenate (PH) and tomato homogenate (TH), each at 10, 15 and 20 per cent concentrations. Two additional treatments were included: MS basal medium without PGR or plant-derived extract (control) and MS medium supplemented with 2 mg L⁻¹ BAP as the PGR treatment. The pH of the medium was adjusted to 5.7 before autoclaving at 121°C and 15 psi for 20 min. Each 250 mL culture jar containing 40 mL of medium was inoculated with five shoots and incubated under complete darkness at 25 ± 2°C. The experiment consisted of five replications per treatment, with five shoots per replication, and was repeated twice. Observations on *in vitro* microtuberization were recorded at 50, 70 and 90 days after transfer (DAT) to the microtuberization medium. The parameters recorded were days to begin tuberization, percentage of explants responding to tuberization, number of microtubers per plantlet, average fresh weight of microtubers (mg) and average microtuber size (mm) at 50, 70 and 90 DAT.

Experimental design and statistical Analysis

The *in vitro* microtuberization experiment was conducted in a completely randomized design (CRD) with five replicates and were used to evaluate all of the data. The significance of treatment effects was assessed using the F-test at the 1 per cent level of significance. Statistical analysis was carried out using OPSTAT online software (Sekhar *et al.*, 2019).

RESULTS

Days to begin tuberization

Data presented in Fig. 2 revealed that the minimum number of days for tuber initiation was recorded in T₂ (MS + 2 mg/L BAP), taking only 45.60 days, owing to the direct and potent tuber-inducing action of the synthetic cytokinin BAP. Among the plant derived extracts, T₄ (MS + 15 % Coconut water), T₅ (MS + 20 % Coconut water) and T₈ (MS + 20 % Potato homogenate) recorded the earliest response, requiring 49.20, 46.60 and 50.60 days, respectively, and were found to be statistically on par with T₂, indicating that these extracts, being rich in endogenous cytokinin-like substances and carbohydrate reserves, were able to trigger tuber induction nearly as promptly as the synthetic hormone treatment. The maximum delay in tuber initiation was recorded in the treatment (T₁, Basal MS medium), which took 61.80 days in the complete absence of any hormonal or extract supplementation.

Per cent of explants responded to tuberization (%)

Data on per cent of explants responded to tuberization, presented in Table 2, revealed that T₂ recorded the highest response at all the stages of observation, with 60.00, 72.00 and 86.00 per cent at 50, 70 and 90 days, respectively. Among the plant derived extracts, only T₅ (MS + 20 % Coconut water) remained statistically on par with T₂ throughout the observation period, recording 60.00, 70.00 and 84.00 per cent response at 50, 70 and 90 days, respectively, which may be attributed to the sustained availability of natural cytokinins and osmotic sugars in 20 per cent coconut water that were sufficient to maintain a consistently high proportion of explants under active tuber inducing conditions comparable to BAP. The lowest per cent response was recorded in the treatment (T₁) at all the stages, with only 40.00, 52.00 and 66.00 per cent response at 50, 70 and 90 days, respectively.

Number of microtubers

Data pertaining to the number of microtubers produced per explant are presented in Table 3. The number of microtubers produced per explant increased progressively with the advancement of culture period from 50 to 90 days. Results revealed that T₂ (MS + 2 mg/L BAP) recorded the highest number of microtubers at all the stages of observation, with 2.60, 3.40 and 4.00 microtubers at 50, 70 and 90 days, respectively. Among the plant derived extracts, T₃, T₄ and T₅ (10 %, 15 % and 20 % Coconut water) along with T₈ (20 % Potato homogenate) remained statistically on par with T₂ during the 50th day of observation, recording 2.00, 2.20, 2.40 and 2.20 microtubers, respectively. This parity narrowed during the 70th and 90th day, when only T₄ and T₅ (15 % and 20 % Coconut water) along with T₈ (20 % Potato homogenate) continued to remain on par with T₂, recording 2.80, 3.00 and 2.80 microtubers at 70 days, and 3.60, 3.80 and 3.40 microtubers at 90 days, respectively, which may be attributed to the sustained supply of natural cytokinins and carbohydrate reserves in these extracts at their higher concentrations being adequate to support continued tuber initiation nearly on par with BAP. The lowest

number of microtubers was recorded in the treatment without any growth hormones and extracts (T₁) at all the stages, with only 0.40, 1.00 and 1.60 microtubers at 50, 70 and 90 days, respectively.

Average weight of microtubers (mg)

The average weight of microtubers increased progressively with the advancement of culture period from 50 to 90 days across most treatments (Table 4). Among the treatments, MS medium supplemented with 2 mg/L BAP (T₂) recorded the highest average microtuber weight at all stages, with values of 160.75, 168.95 and 176.95 mg at 50, 70 and 90 days, respectively. However, 15 and 20 per cent coconut water (T₄ and T₅) and 20 per cent potato homogenate (T₈) performed comparably with the growth regulator treatment, particularly at the later stages of microtuber development. At 90 days, T₅ (20 % coconut water) and T₈ (20 % potato homogenate) recorded 173.29 and 169.46 mg, respectively, compared with 176.95 mg under T₂. The treatments with 10 per cent supplements generally produced lower microtuber weights. The higher microtuber weight observed with coconut water and potato homogenate may be attributed to their natural supply of growth-promoting substances, vitamins, minerals and organic nutrients that support cell division, enlargement and tuber bulking.

Average size of microtubers (mm)

The average size of microtubers increased with the advancement of culture period in most treatments (Table 5 and Fig. 3). The maximum microtuber size was recorded in MS medium supplemented with 2 mg/L BAP (T₂), with values of 8.44, 8.86 and 9.06 mm at 50, 70 and 90 days, respectively. However, 15 and 20 per cent coconut water (T₄ and T₅) and 20 per cent potato homogenate (T₈) performed on par with the growth regulator treatment, particularly during the later stages. At 90 days, T₄, T₅ and T₈ recorded microtuber sizes of 8.56, 8.94 and 8.08 mm, respectively, compared with 9.06 mm in T₂. Among the treatments, basal MS medium (T₁) recorded the lowest microtuber size, with values of 3.88, 4.14 and 5.04 mm at 50, 70 and 90 days, respectively. The enhanced microtuber size under coconut water and potato homogenate treatments may be attributed to the presence of natural growth-promoting compounds, nutrients and organic constituents that stimulate cell division, cell enlargement and microtuber development.

DISCUSSION

Potato tubers are the major planting material in conventional propagation and preserve the genetic characteristics of a variety. Microtubers are small, *in vitro*-produced tubers that are easier to handle, store and transport than plantlets, making them useful propagating materials (Tabori *et al.*, 1999). They can also serve as explants for genetic transformation studies (Gordon and William, 1993). Although microtubers are delicate and dormant, proper storage at 5-6 °C for 3-4 months, with controlled greening, promotes skin hardening and protection against shrinkage, rotting and microbial infection (Naik and Sarkar, 1997). Considering these advantages, the present study evaluated the effect of plant derived extracts on microtuberization in potato cv. 'Kufri Himalini', with respect to tuberization initiation, explant response, number, size and weight of microtubers at 50, 70 and 90 days after transfer. Microtubers developed under the different treatments represented in Fig. 4.

The present study revealed that plant derived extracts considerably influenced microtuberization in potato cv. Kufri Himalini. Among the treatments, 15 and 20 per cent coconut water (T₄ and T₅) and 20 per cent potato homogenate (T₈) performed comparably with MS + 2 mg/L BAP (T₂) for several microtuberization parameters. Their better performance may be attributed to the presence of natural growth-promoting compounds, cytokinin-like substances, carbohydrates, vitamins, minerals and other organic nutrients, which favour tuber induction, cell division and subsequent tuber enlargement. Cytokinins play an important role in regulating cell division, differentiation and organ formation, while an adequate supply of carbohydrates is essential for assimilate accumulation and starch deposition during tuber development. Thus, the interaction between hormonal signals and carbohydrate availability plays an important role in regulating potato microtuber formation and development (Aksenova *et al.*, 2012; Gopal *et al.*, 2004; Long *et al.*, 2024). The carbohydrates supplied through the culture medium can be utilized for energy production and subsequently accumulated as starch in developing stolons, resulting in stolon swelling and microtuber formation (Gopal *et al.*, 2004).

Among the plant derived extracts, 20 per cent coconut water (T₅) was the most effective treatment overall. It consistently produced responses close to BAP, recording 84 per cent responding explants, 3.80 microtubers per explant, 173.29 mg average weight and 8.94 mm average size at 90 days, compared with 86 per cent, 4.00 microtubers, 176.95 mg and 9.06 mm, respectively, under BAP. The superior response of coconut water, particularly at 20 per cent, may be attributed to its combination of cytokinin-like substances, readily available sugars, minerals and other growth-promoting constituents, which collectively stimulate cell division and differentiation and enhance assimilate accumulation during tuber development. The role of cytokinin in microtuber formation is particularly important because it can influence carbohydrate metabolism and alter the source-sink relationship in favour of developing microtubers (Saljooghianpour, 2017). BAP and coconut water have also been reported to modify the distribution of plant biomass towards developing potato microtubers, thereby favouring tuber growth and enlargement (Aksenova *et al.*, 2012).

The positive effect of coconut water observed in the present study is supported by previous investigations. Al-Amery *et al.* (2025) reported that kinetin and coconut milk significantly influenced *in vitro* microtuber formation in potato, both individually and in combination. Similarly, Wuisan *et al.* (2025) found that coconut water concentration significantly affected potato microtuber induction, with 30 per cent coconut water producing the optimum response under their experimental conditions. Sembiring *et al.* (2021) also reported that coconut water significantly influenced the number, diameter and fresh weight of potato microtubers. Further, Sembiring *et al.* (2020) demonstrated that BAP and coconut water enhanced *in vitro* microtuber formation, with 5 mg/L BAP + 75 mL/L coconut water producing the fastest tuberization and highest number of microtubers. Although the optimum concentration differed among studies, the consistent positive response to coconut water supports its role as an effective natural source of growth-promoting and nutritional compounds for potato microtuberization. Such differences in optimum concentration may be attributed to variation in genotype, basal medium composition, culture conditions, sucrose level and endogenous hormonal status of the explants.

The 20 per cent potato homogenate (T₈) was the next best plant derived treatment, particularly with respect to microtuber bulking, producing an average microtuber weight of 169.46 mg at 90 days. Its effectiveness may be associated with the supply of potato-derived carbohydrates and organic nutrients, which provide an additional carbon source for assimilate accumulation and starch deposition in developing microtubers. During tuber formation, the developing stolon becomes a strong sink for assimilates, resulting in cell enlargement and storage of starch within the tuber tissues. In contrast, banana and tomato homogenates showed comparatively lower responses, suggesting that their nutritional and growth-promoting composition was less favourable for efficient microtuberization under the conditions of the present study. The comparatively better response of higher concentrations of coconut water and potato homogenate further indicates that both the source and concentration of the plant derived supplement influence the efficiency of microtuber induction and development.

The basal MS medium (T₁) recorded the poorest response, with the latest tuber initiation (61.80 days) lowest percentage of responding explants (40.00, 52.00 and 66.00 per cent), lowest number of microtubers (0.40, 1.00 and 1.60) and smallest microtubers (3.88, 4.14 and 5.04 mm) at 50, 70 and 90 days, respectively. The poor response under basal MS may be due to the absence of additional growth-promoting and readily available organic constituents required for efficient tuber induction and bulking. Overall, 20 per cent coconut water (T₅) emerged as the most effective plant derived supplement, followed by 15 per cent coconut water (T₄) and 20 per cent potato homogenate (T₈), as their performance closely approached that of BAP for several microtuberization traits. These findings suggest that coconut water, particularly at 20 per cent, has considerable potential as a natural supplement and partial substitute for synthetic growth regulators in the *in vitro* production of microtubers in potato cv. Kufri Himalini.

CONCLUSION

The present study demonstrated that plant derived extracts influenced *in vitro* microtuberization of potato cv. 'Kufri Himalini'. The treatment with 2 mg/L BAP (T₂) recorded the overall superior response for days to tuber initiation, percentage of explants responding, number of microtubers, average microtuber size and weight. Among the plant derived extracts, 20 per cent coconut water (T₅) was the most effective, followed by 15 per cent coconut water (T₄) and 20 per cent potato homogenate (T₈), showing responses comparable to BAP for several parameters. Thus, 20 per cent coconut water has considerable potential as a natural supplement and partial alternative to synthetic PGRs for *in vitro* microtuber production.

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Fig. 1. Explant used for *in vitro* culture: a) sprouts excised from tubers



Fig. 2. Impact of plant derived extracts on the days to begin tuberization

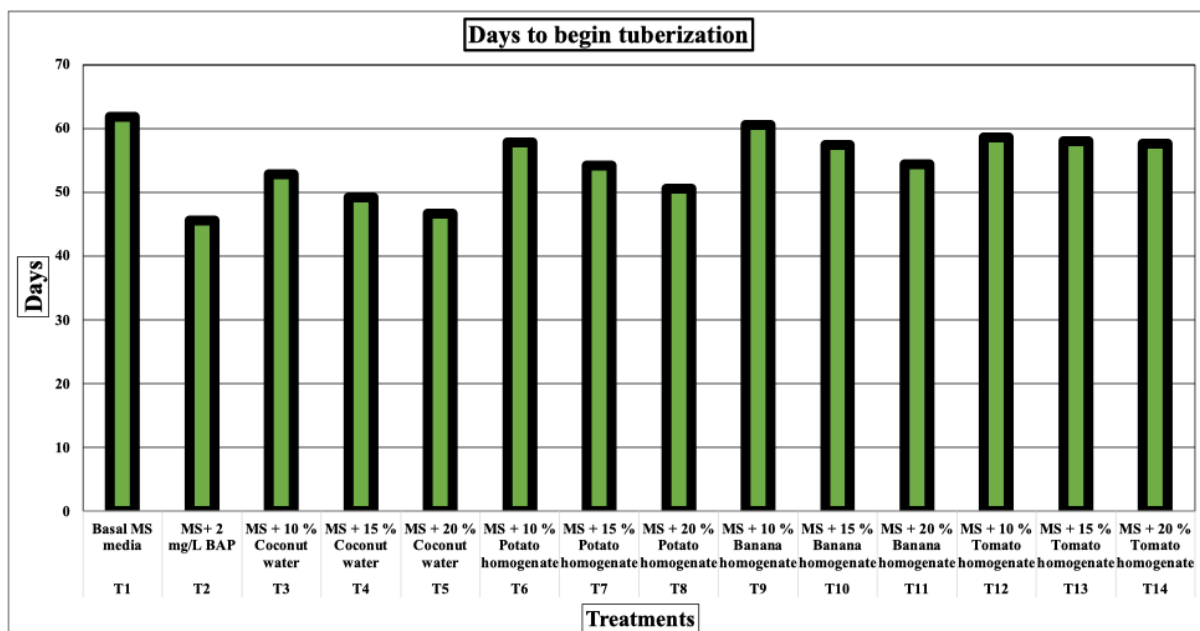
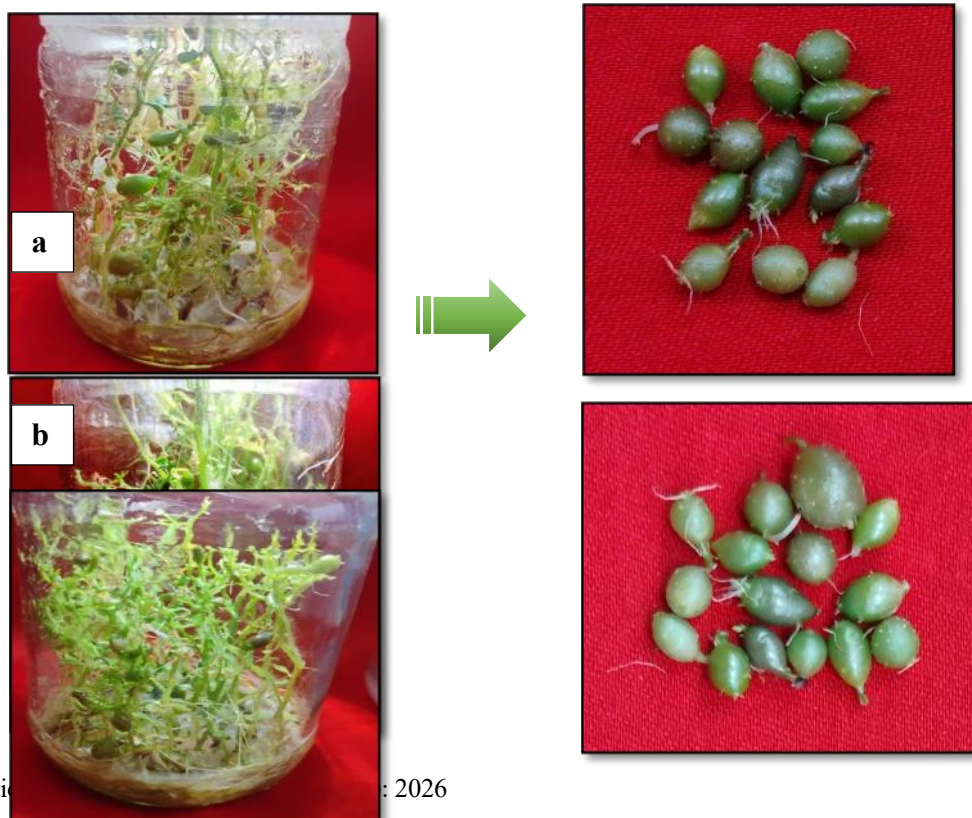




Fig. 3. Increase in microtuber size with advancement of culture period from 50 to 90 days in potato cv. 'Kufri Himalini'.

Fig. 4. Microtubers formed under different treatments: (a) Plant growth regulator (MS + 2 mg/L BAP), (b) Coconut water (20%), (c) Coconut water (15%), (d) Potato homogenate (20%), and (e) Basal MS medium



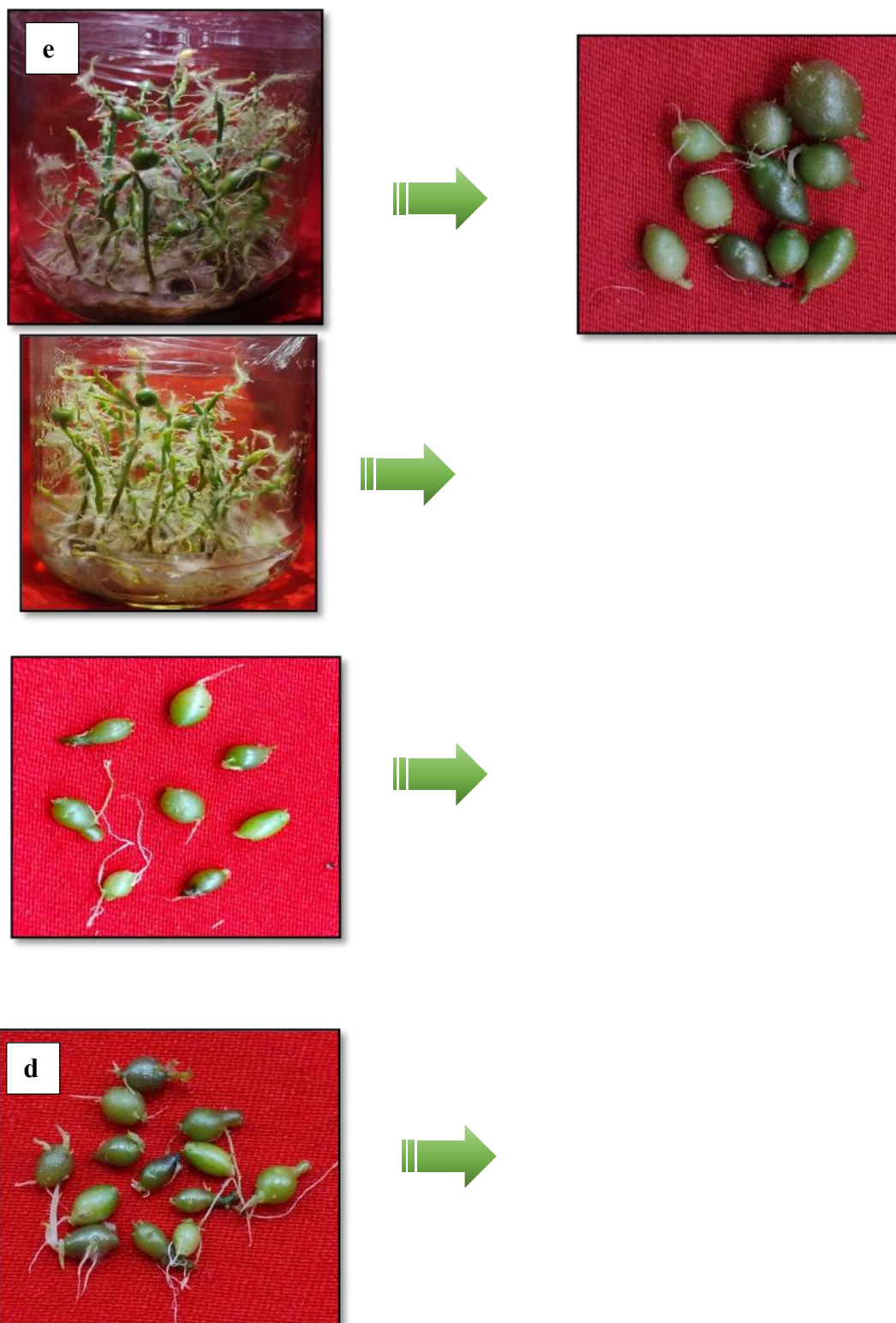


Table 1. Effect of plant derived extracts on *in vitro* microtuberization of potato plantlets

Treatment	Explant	Details
T ₁	<i>In vitro</i> shoots	Full-strength MS basal medium
T ₂		2 mg/L BAP
T ₃		10 % (v/v) Coconut water
T ₄		15 % (v/v) Coconut water
T ₅		20 % (v/v) Coconut water
T ₆		10 % (w/v) Potato homogenate
T ₇		15 % (w/v) Potato homogenate

T ₈		20 % (w/v) Potato homogenate
T ₉		10 % (w/v) Banana homogenate
T ₁₀		15 % (w/v) Banana homogenate
T ₁₁		20 % (w/v) Banana homogenate
T ₁₂		10 % (w/v) Tomato homogenate
T ₁₃		15 % (w/v) Tomato homogenate
T ₁₄		20 % (w/v) Tomato homogenate

Table 2. Effect of plant derived extracts on percent of explants responded to tuberization (%)
 ** Significant at $p=0.01$.

Table 3. Effect of plant derived extracts on number of microtubers produced

	Treatments	Percent of explant responded to tuberization (%)		
		50 days	70 days	90 days
T ₁	Basal MS media	40.00	52.00	66.00
T ₂	MS+ 2 mg/L BAP	60.00	72.00	86.00
T ₃	MS + 10 % Coconut water	52.00	64.00	74.00
T ₄	MS + 15 % Coconut water	58.00	68.00	82.00
T ₅	MS + 20 % Coconut water	60.00	70.00	84.00
T ₆	MS + 10 % Potato homogenate	42.00	54.00	68.00
T ₇	MS + 15 % Potato homogenate	50.00	62.00	74.00
T ₈	MS + 20 % Potato homogenate	54.00	66.00	80.00
T ₉	MS + 10 % Banana homogenate	42.00	54.00	68.00
T ₁₀	MS + 15 % Banana homogenate	46.00	58.00	72.00
T ₁₁	MS + 20 % Banana homogenate	48.00	60.00	74.00
T ₁₂	MS + 10 % Tomato homogenate	42.00	54.00	68.00
T ₁₃	MS + 15 % Tomato homogenate	44.00	54.00	70.00
T ₁₄	MS + 20 % Tomato homogenate	46.00	56.00	70.00
	<i>F</i>-Test	**	**	**
	SEm ±	0.20	0.21	0.28
	CD at 1 %	0.77	0.79	1.04

** Significant at $p=0.01$.

Table 4. Effect of plant derived extracts on average weight (mg) of microtubers produced

	Treatments	Number of microtubers		
		50 days	70 days	90 days
T ₁	Basal MS media	0.40	1.00	1.60
T ₂	MS+ 2 mg/L BAP	2.60	3.40	4.00
T ₃	MS + 10 % Coconut water	2.00	2.60	3.00
T ₄	MS + 15 % Coconut water	2.20	2.80	3.60
T ₅	MS + 20 % Coconut water	2.40	3.00	3.80
T ₆	MS + 10 % Potato homogenate	0.80	1.40	2.00
T ₇	MS + 15 % Potato homogenate	2.00	2.60	3.20
T ₈	MS + 20 % Potato homogenate	2.20	2.80	3.40
T ₉	MS + 10 % Banana homogenate	0.60	1.20	1.80
T ₁₀	MS + 15 % Banana homogenate	1.20	1.80	2.40
T ₁₁	MS + 20 % Banana homogenate	1.40	2.00	2.60
T ₁₂	MS + 10 % Tomato homogenate	0.60	1.20	1.80
T ₁₃	MS + 15 % Tomato homogenate	0.60	1.20	1.80
T ₁₄	MS + 20 % Tomato homogenate	0.80	1.40	2.00
	F-Test	**	**	**
	SEm ±	0.27	0.20	0.19
	CD at 1 %	1.02	0.74	0.71

** Significant at $p=0.01$.

Table 5. Effect of plant derived extracts on average size (mm) of microtubers produced

	Treatments	Average weight of microtubers (mg)		
		50 days	70 days	90 days
T ₁	Basal MS media	91.32	95.23	101.94
T ₂	MS+ 2 mg/L BAP	160.75	168.95	176.95
T ₃	MS + 10 % Coconut water	135.04	143.73	151.53
T ₄	MS + 15 % Coconut water	152.35	158.98	169.44
T ₅	MS + 20 % Coconut water	156.96	165.29	173.29
T ₆	MS + 10 % Potato homogenate	98.52	104.29	110.49
T ₇	MS + 15 % Potato homogenate	128.83	137.46	145.46
T ₈	MS + 20 % Potato homogenate	151.86	156.62	169.46
T ₉	MS + 10 % Banana homogenate	88.75	97.46	106.41
T ₁₀	MS + 15 % Banana homogenate	120.11	127.94	134.92
T ₁₁	MS + 20 % Banana homogenate	124.40	131.99	139.99
T ₁₂	MS + 10 % Tomato homogenate	93.16	102.84	105.24
T ₁₃	MS + 15 % Tomato homogenate	112.35	114.24	122.04
T ₁₄	MS + 20 % Tomato homogenate	113.22	121.22	129.15
	F-Test	**	**	**
	SEm ±	2.50	3.59	2.66
	CD at 1 %	9.43	13.54	10.02

** Significant at $p=0.01$.

	Treatments	Average size of microtubers (mm)		
		50 days	70 days	90 days
T ₁	Basal MS media	3.88	4.14	5.04
T ₂	MS+ 2 mg/L BAP	8.44	8.86	9.06
T ₃	MS + 10 % Coconut water	7.26	7.48	7.66
T ₄	MS + 15 % Coconut water	8.14	8.42	8.56
T ₅	MS + 20 % Coconut water	8.52	8.78	8.94
T ₆	MS + 10 % Potato homogenate	4.88	5.06	6.96
T ₇	MS + 15 % Potato homogenate	6.88	7.12	7.36
T ₈	MS + 20 % Potato homogenate	8.10	8.38	8.08
T ₉	MS + 10 % Banana homogenate	4.48	4.62	6.42
T ₁₀	MS + 15 % Banana homogenate	6.06	6.32	7.86
T ₁₁	MS + 20 % Banana homogenate	6.44	6.76	7.98
T ₁₂	MS + 10 % Tomato homogenate	4.20	4.30	5.84
T ₁₃	MS + 15 % Tomato homogenate	5.26	5.58	6.00
T ₁₄	MS + 20 % Tomato homogenate	5.76	5.98	7.16
	<i>F</i>-Test	**	**	**
	SEm ±	0.10	0.13	0.27
	CD at 1 %	0.38	0.50	1.02