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ORIGINAL PAPER

Banana Peel Waste as an Eco-Friendly Nutrient Medium for Improving Rooting Success in Plum (*Prunus salicina*) Cuttings

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Abstract

The investigation aimed to assess how various fruit peel waste media (PWM) affect the success of rooting and the adaptation of plum (*Prunus salicina*) cuttings under semi-protected conditions. In this research study, we used cuttings of the Kala Amritsari plum variety, subjecting them to six treatments: soil (control), apple PWM, banana PWM, orange PWM, pomegranate PWM, and mixed fruit PWM. Each treatment involved 60 cuttings, with 20 cuttings per replication. We employed a randomized block design (RBD) with three replications for the experimental setup. These cuttings were regularly monitored for sprouting, with assessments made at 15-day intervals. The findings indicate that banana PWM outperforms the other treatments in terms of the time taken for the first sprout, higher sprouting rates, better rooting, increased numbers of root-shoot, more leaves, greater fresh and dry shoot and root weights, higher survival rates, and greater chlorophyll content compared to apple PWM. Conversely, mixed fruit PWM yielded less favorable results compared to the other treatments. Pomegranate and citrus PWM are rich sources of nutrients, which, in turn, result in lower success rates. Banana PWM proves to be a valuable organic rooting medium once the plant's natural requirements are met. The remaining PWM, abundant in nutrients, may be beneficial with some adjustments and dilution.

Keywords Cuttings · Fruit peel · Growing media · Nutritional composition · Sustainability

1 Introduction

The soil fertility status plays a crucial role in enhancing fruit crop production. Farmers typically resort to the use of chemical and inorganic fertilizers like urea, di-ammonium phosphate (DAP), muriate of potash (MOP), among others, for this purpose. However, many farmers are unaware of the adverse effects associated with inorganic fertilizers. Consequently, they apply these fertilizers in excessive quantities, which has detrimental impacts on soil quality and poses a threat to nearby water bodies and ecosystems (Morakinyo et al. 2013; Abuga 2014; Rahman and Zhang 2018; Agmas and Adugna 2020). Moreover, crops grown using these inorganic fertilizers may not be suitable for consumption as they can indirectly lead to various diseases in humans (Savci 2012; Chandini et al. 2019). However, different manures are known and under practice by farmers for eco-friendly nutrition supply to plant growth but many rich in nutrients are still underutilized. In the context of fruit production, fruit peels often remain as residue after fruit consumption. Most of these peels are inedible and are typically discarded as waste without consideration of their potential benefits. Disposing of fruit peels in this manner can contribute to various environmental issues (Essien et al. 2005; Lim et al. 2010).

Utilizing fruit peels as a fertilizer promotes the principles of organic farming, a concept that has gained significant popularity in recent years, driven by heightened public awareness of environmental and food safety concerns (Masarirambi et al. 2010). Fruit peels are among the most remarkable sources of nutrients worldwide, boasting a rich array of both macro and micronutrients, and they play a pivotal role in supporting crop growth and development (Ibrahim et al. 2016). Specifically, pomegranate peel, banana peel, and citrus peel can serve as effective field fertilizers, enhancing soil fertility and enriching the soil microbiota due to their mineral content, which is essential for crop

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growth. Bio-fertilizers derived from citrus peel waste are abundant in nutrients such as carbon, nitrogen, and potassium. Additionally, their higher pH levels and lignocellulose content confer various antimicrobial properties, facilitating the removal of toxic heavy metals from the soil (Zema et al. 2018). Fruit peel wastes are valuable reservoirs of diverse plant nutrients and beneficial soil microbes (Dahunsi et al. 2021).

Plum, a member of the Prunus genus within the Rosaceae family, is cultivated in various regions worldwide (Birwal et al. 2017). *Prunus domestica* L. (European plum) and *Prunus salicina* Lindl. (Japanese plum) are the primary and most cultivated plum cultivars for commercial purposes (Głowacka et al. 2021). Japanese plum is primarily a diploid species, although tetraploidy has been observed (Das et al. 2011; Ben Tamarzizt et al. 2015). The success of propagating plum cuttings can be influenced by various factors, some of which have been explored in recent studies involving the modification of soil nutrients and the utilization of different organic manures. Yang et al. (2019) investigated the impact of varying soil nutrient levels and organic manures on plum harvesting efficiency. According to Kotiyal et al. (2022), the average time for the earliest sprout to appear ranged from 15.17 to 18.73 days. Soil nutrient content was found to have a significant influence on the sprouting percentage, with a higher success rate observed in conditions with greater nitrogen availability (Narula and Kaur 2018). The use of organic manures was positively correlated with increased growth percentages (Krishnanayak et al. 2023), indicating that organic matter may contribute to supporting early development phases. The study also investigated subsequent growth parameters of propagated plum cuttings. The number of shoots and leaves per cutting was significantly affected by nutrient levels, leading to increased shoot and leaf production (Shrivastav et al. 2020). Similarly, the number of roots produced per cutting was influenced by nutrient-rich conditions, highlighting the impact of both soil nutrients and organic manures on the rooting percentage (Roussos et al. 2017). Furthermore, treatments with optimized nutrient levels resulted in significantly greater fresh weights of both shoots and roots, underscoring the importance of proper nutrition in enhancing overall plant vigor during the initial stages of development (Wendling et al. 2016). The study also assessed dry root and shoot weights, which serve as indicators of a plant's long-term viability and rootedness (Kotiyal and Nautiyal 2019). In conclusion, effective management of soil nutrients and the application of organic manures are essential for achieving optimal germination, root development, and growth performance of plum cuttings. Recent studies on plum cutting propagation have illuminated the significant impact of soil nutrient management and organic manure application on key developmental traits. These findings hold promise for enhancing success rates and subsequent growth of propagated plum plants, offering valuable insights for commercial horticulture and sustainable farming practices.

The use of chemicals in abundance is detrimental to both soil and plant health. Currently, chemicals are commonly applied to facilitate the success of cuttings and other propagation materials, often at the expense of natural waste resources going unused. Utilizing nutritious fruit peel waste holds promise for enhancing plant growth and propagation success while serving as a valuable source of nutrient-rich media. The underlying hypothesis for this investigation revolved around the potential of banana fruit peel waste and its nutrient composition to improve the success rate of rooting cuttings by providing the necessary nutrient doses. Therefore, the primary objective of the research was to assess the efficacy of banana peel waste as a nutrient medium as compare to other fruit peel wastes in improving the rooting success rate of plum cuttings.

2 Materials and Methods

The investigation into the impact of various fruit peel waste media (PWM) on the success of rooting and the adaptability of Kala Amritsari plum (*Prunus salicina*) cuttings under semi-protected conditions took place during the 2022-23. The Kala Amritsari plum variety was chosen for our research due to its local adaptation, low chilling requirement, and tolerance to both frost and high summer temperatures (Sharma and Josan 1993). Its relevance to the semi-arid region of the Gangetic plain in India makes it an ideal candidate for studying the effects of banana peel waste as a nutrient medium for improving rooting success in plum cuttings. By focusing on Kala Amritsari, our findings can directly impact local horticulture practices and contribute to sustainable fruit production. The study was conducted within the polyhouse of the Department of Horticulture at Lovely Professional University in Phagwara, spanning from December 30th, 2022, to April 28th, 2023. The experimental area is located at 31.25° North and 75.71° East, with height above sea level 232 m. To structure the research, a Randomized Block Design (R.B.D.) was employed, comprising a total of six treatments (apple PWM, banana PWM, orange PWM, pomegranate PWM, mixed PWM and control) each replicated three times. Within each treatment, there were 60 cuttings, resulting in 20 cuttings per replication.

2.1 Preparation of Treatments

In this research, a total of six distinct treatments (as shown in Table 1) were employed. These treatments included soil,

Table 1 Details of the treatment used for success of Kala Amritsari Plum under the polyhouse

Treatments	Mixture	Ratio
Apple PWM	Apple peel waste + Soil	1:1
Banana PWM	Banana peel waste + Soil	1:1
Orange PWM	Orange peel waste + Soil	1:1
Pomegranate PWM	Pomegranate peel waste + Soil	1:1
Mixed Fruit PWM	Mixed Fruit peel waste + Soil	1:1
Control	Soil only	1

apple PWM, banana PWM, orange PWM, pomegranate PWM, and mixed fruit PWM. Soil was utilized as a control, sourced directly from the agricultural fields of Lovely Professional University in Phagwara, Punjab. The fruit peels used in the experiment were collected from various sources and locations. Apple peels were obtained from the HPMC Fruit Processing Plant in Jarol, Sundernagar, District Mandi (Himachal Pradesh). Banana peels were gathered from fruit juice vendors and hostel mess facilities at Lovely Professional University in Phagwara, Punjab. Orange and pomegranate peels were sourced from fruit juice vendors in District Una (Himachal Pradesh). Upon collection, separate pits measuring 3 feet long, wide and in height were excavated for each type of fruit peel. Surrounding each pit, a brick wall was constructed at each corner and on the pit's surface to prevent any soil from mixing with the fruit peel waste. The collected fruit peels were then cut into small pieces to expedite decomposition within their respective pits. Subsequently, the peels were placed into the pits separately and covered with polythene sheets. Depending on the type of fruit peels used, the decomposition process took between 1 and 2 months. Following decomposition, the resulting media were harvested, ensuring no mixing with the soil. The harvested fruit peel waste materials were stored in a shaded area and subjected to nutritional content analysis. Throughout the experiment conducted within the polyhouse, the temperature 18 ± 4 °C, with a relative humidity varying between 75 and 95%.

2.2 Analysis of Samples

All six treatments, which include soil, apple PWM, banana PWM, orange PWM, pomegranate PWM, and mixed fruit PWM, underwent a comprehensive analysis of their nutritional properties. These analyses were conducted at the Advanced Soil and Leaf Analysis Laboratory, located within the Department of Soil Science and Water Management (Tables 2 and 3).

2.3 Collection and Planting of the Cuttings

The cuttings used in this study were obtained from the authentic plum variety, Kala Amritsari, and were sourced from the College of Horticulture and Forestry in Neri,

Table 2 Analysis of fruit peel waste medias for their nutritional content (macro nutrient)

Fruit Peel Waste Media (PWM)	pH	EC (dSm^{-1})	OC (%)	N ($g\ l^{-1}$)	P ($mg\ l^{-1}$)	K ($g\ l^{-1}$)
Soil	8.90 ± 0.06^{a}	1.02 ± 0.02^{e}	0.37 ± 0.02^{a}	0.10 ± 0.01^{d}	45.98 ± 0.08^{f}	0.14 ± 0.03^{f}
Apple PWM	6.22 ± 0.02^{c}	0.73 ± 0.02^{f}	2.91 ± 0.02^{d}	0.34 ± 0.03^{b}	116.96 ± 0.07^{d}	1.10 ± 0.03^{d}
Banana PWM	7.74 ± 0.07^{b}	1.86 ± 0.03^{d}	1.49 ± 0.02^{e}	0.15 ± 0.01^{d}	67.86 ± 0.07^{e}	0.52 ± 0.01^{e}
Orange PWM	4.65 ± 0.09^{e}	20.10 ± 0.05^{b}	26.70 ± 0.05^{a}	0.46 ± 0.01^{a}	372.77 ± 0.03^{a}	10.33 ± 0.01^{b}
Pomegranate PWM	4.14 ± 0.01^{f}	21.00 ± 0.07^{a}	26.50 ± 0.01^{b}	0.29 ± 0.02^{c}	244.20 ± 0.06^{c}	11.61 ± 0.07^{a}
Mixed Fruit PWM	4.85 ± 0.01^{d}	14.30 ± 0.06^{c}	19.70 ± 0.03^{c}	0.36 ± 0.03^{b}	307.14 ± 0.05^{b}	8.41 ± 0.04^{c}

Data is presented in mean ± standard error of $n = 3$. The letters indicate significance level by Duncan test at 5% probability. Mixed fruit PWM includes apple, banana, orange and pomegranate peel waste mixture in the ratio of 1:1:1:1. The EC and OC refers electrical conductivity and organic carbon of the media, respectively

Table 3 Analysis of fruit peel waste medias for their nutritional content (micro-nutrient)

Fruit Peel Waste Media (PWM)	Ca [cmol (p+)/kg]	Mg [cmol (p+) /kg]	S ($mg\ l^{-1}$)	Zn ($mg\ l^{-1}$)	Cu ($mg\ l^{-1}$)	Fe ($mg\ l^{-1}$)	Mn ($mg\ l^{-1}$)	B ($mg\ l^{-1}$)
Soil	9.31 ± 0.02^{e}	2.84 ± 0.04^{f}	60.50 ± 0.11^{f}	4.17 ± 0.03^{f}	1.18 ± 0.03^{d}	19.20 ± 0.05^{e}	2.69 ± 0.03^{f}	1.25 ± 0.03^{f}
Apple PWM	11.70 ± 0.08^{d}	10.50 ± 0.05^{c}	1431.00 ± 0.09^{d}	21.20 ± 0.06^{a}	3.20 ± 0.03^{b}	114.00 ± 0.09^{b}	128.00 ± 0.07^{a}	3.06 ± 0.04^{d}
Banana PWM	7.59 ± 0.07^{f}	6.46 ± 0.05^{e}	214.00 ± 0.09^{e}	5.39 ± 0.04^{e}	0.80 ± 0.01^{e}	6.50 ± 0.08^{f}	26.50 ± 0.08^{e}	2.72 ± 0.04^{e}
Orange PWM	31.40 ± 0.04^{b}	9.30 ± 0.08^{d}	2971.00 ± 0.00^{a}	20.20 ± 0.05^{b}	2.40 ± 0.04^{c}	101.00 ± 0.07^{c}	52.20 ± 0.03^{c}	23.20 ± 0.07^{a}
Pomegranate PWM	35.70 ± 0.07^{a}	16.00 ± 0.08^{a}	2617.00 ± 0.14^{b}	18.90 ± 0.04^{d}	0.08 ± 0.02^{f}	63.40 ± 0.10^{d}	28.00 ± 0.04^{d}	17.80 ± 0.07^{b}
Mixed Fruit PWM	27.70 ± 0.10^{c}	11.90 ± 0.04^{b}	2239.00 ± 0.13^{c}	19.50 ± 0.04^{c}	3.56 ± 0.03^{a}	128.00 ± 0.08^{a}	68.60 ± 0.03^{b}	9.42 ± 0.03^{c}

Data is presented in mean ± standard error of $n = 3$. The letters indicate significance level by Duncan test at 5% probability. Mixed fruit PWM includes apple, banana, orange and pomegranate peel waste mixture in the ratio of 1:1:1:1

Hamirpur District, Himachal Pradesh. These cuttings, which measured between 15 and 20 cm in length, featured 5 to 6 nodes and had a thickness similar to that of a pencil. The planting of these plum cuttings was conducted on December 30th, 2022.

2.4 Methods

2.4.1 Days Taken to First Sprout

The number of days taken for the first sprout to emerge was determined by counting the days from the initial planting of plum cuttings until the appearance of the first sprout within each replication of every treatment. This observation was recorded daily, starting from the moment the plum cuttings were planted and continuing until the first sprout became visible.

2.4.2 Sprouting (%)

Sprouting was calculated by counting the number of sprouted cuttings out of total number of plum cuttings planted in each replication of each treatment till 60 days of planting the cuttings (Krishnanayak et al. 2023).

$$\text{Sprouting (\%)} = \frac{\text{Number of sprouted cuttings}}{\text{Number of cuttings planted}} \times 100$$

2.4.3 Number of Shoots

The number of shoots was assessed by counting them on 5 randomly selected cuttings from each replication within each treatment. Subsequently, the average number of shoots was calculated. This particular observation was made 90 days after the initial planting of the plum cuttings.

2.4.4 Number of Leaves

The number of leaves per cutting was determined by counting the total number of leaves present on each cutting within every replication of each treatment. This count included all leaves, regardless of their size. The observation for the number of leaves was recorded after 90 days from the initial planting of the plum cuttings.

2.4.5 Number of Roots

The number of roots was assessed by randomly selecting 5 cuttings from each replication within each treatment. For each of these selected cuttings, the total number of roots was counted. Subsequently, the average number of roots per cutting was calculated. This observation was recorded 90 days after the initial planting of the plum cuttings.

2.4.6 Rooting (%)

To determine the percentage of rooted cuttings, 5 cuttings were randomly selected from each replication. These selected cuttings were uprooted, washed with tap water, and the number of rooted cuttings within this group was counted. Subsequently, the percentage of rooted cuttings was calculated based on this count. This particular observation was made 90 days after the initial planting of the plum cuttings (Swarts et al. 2018).

$$\text{Rooting (\%)} = \frac{\text{Number of successful rooted cuttings}}{\text{Number of cuttings planted}} \times 100$$

2.4.7 Shoot Fresh Weight

To determine the fresh weight of roots, all the roots from 5 randomly selected cuttings within each replication of each treatment were carefully removed. These roots were then washed with water to remove any debris, and their individual fresh weights were recorded in grams (g). Following this, the average fresh weight of roots was calculated based on the measurements taken. This specific observation was conducted 90 days after the initial planting of the plum cuttings.

2.4.8 Root Fresh Weight

The fresh weight of roots was quantified in grams (g). To observe the fresh weight of roots, all the roots from 5 randomly selected cuttings within each replication of every treatment were methodically removed. Subsequently, these roots were thoroughly washed with water to remove any debris, and their individual fresh weights were recorded. Following this, the average fresh weight of roots was computed based on the measurements obtained. This particular observation was conducted 90 days after the initial planting of the plum cuttings.

2.4.9 Shoot Dry Weight

The dry weight of the shoots was measured in grams (g). To observe the dry weight of the shoots, all the shoots from 5 randomly selected cuttings within each replication of each treatment were carefully removed and washed with water. Subsequently, these shoots were dried in an electric oven until a constant weight was achieved. After drying, their individual dry weights were recorded, and the average dry weight of the shoots was calculated based on these measurements. This specific observation was conducted 90 days after the initial planting of the plum cuttings.

2.4.10 Root Dry Weight

The dry weight of the roots was measured in grams (g). To observe the dry weight of the roots, all the roots from 5 randomly selected cuttings within each replication of each treatment were meticulously removed and washed with water. Subsequently, these roots were dried in an electric oven until a constant weight was achieved. After drying, their individual dry weights were recorded, and the average dry weight of the roots was calculated based on these measurements. This specific observation was conducted 90 days after the initial planting of the plum cuttings.

2.4.11 Survival Percentage

The percentage of successful rooted cuttings is expressed as a percentage (%). To calculate this percentage, the number of successfully rooted cuttings within each replication of each treatment was divided by the total number of plum cuttings initially planted in that specific replication and treatment. The resulting quotient was then multiplied by 100 to express the success rate as a percentage (Swarts et al. 2018).

$$\text{Survival } (\%) = \frac{\text{Number of successful rooted cutiings}}{\text{Number of cuttings planted}} \times 100$$

2.4.12 Chlorophyll Content

The measurement of chlorophyll content was conducted 30 days after transplanting the plum cuttings. To determine this, 10 leaves were randomly selected from the 5 randomly chosen cuttings within each replication of each treatment. A digital chlorophyll meter (SPAD-502) was used to measure the chlorophyll content of these leaves, and the readings were recorded. Subsequently, the average chlorophyll content was calculated based on these measurements. Chlorophyll content was expressed in SPAD units, which stands for Soil Plant Analysis Division.

2.5 Statistical Analysis

The experimental data were organized in Excel following the Randomized Block Design (R.B.D.) with one factor and three replications for analysis. To assess the overall significance of differences between the treatments, statistical software such as OPSTAT and R was utilized. The Duncan test, a statistical method, was employed to identify significant differences between the means of multiple groups in the experiment. This analysis was performed at a significance level of 5%.

3 Results

3.1 Days Taken to First Sprout

The minimum number of days required for the first sprout to emerge, at 15.62 days, was found to be significantly early ($p \leq 0.05$) in the banana PWM treatment. In contrast, the apple PWM treatment took 16.55 days for the first sprout to appear, which placed it in second position. The control and orange PWM treatments followed closely, with first sprouts appearing at 17.46 and 17.94 days, respectively. On the other hand, the maximum number of days taken for the first sprout to appear was observed in the mixed fruit PWM treatment, where it took 18.75 days. This was followed by another mixed fruit PWM treatment, which took 18.42 days for the first sprout to emerge (as depicted in Fig. 1a).

3.2 Sprouting (%)

The treatment with the highest maximum sprouting percentage, at 88.33%, was observed in the banana PWM treatment. This was followed by the apple PWM treatment ($p \leq 0.05$) and the control treatment, with sprouting percentages of 85% and 76.67%, respectively. Conversely, the treatment with the lowest minimum sprouting percentage, at 53.33%, was found in the mixed fruit PWM treatment. This was followed by the pomegranate PWM and the orange PWM treatments, which had sprouting percentages of 61.67% and 66.67%, respectively (as shown in Fig. 1b).

3.3 Number of Shoots

The highest number of shoots per cutting, at 5.63, was observed in the banana PWM treatment. It was followed by the apple PWM treatment, the soil (control) treatment, the orange PWM treatment, and the pomegranate PWM treatment, which had 4.73, 4.6, 4.23, and 4.17 shoots per cutting, respectively. Conversely, the lowest number of shoots per cutting, at 3.6, was found in the mixed fruit PWM treatment (as depicted in Fig. 2a).

3.4 Number of Leaves

The highest number of leaves per cutting, at 35.05, was observed in the banana PWM treatment. It was followed by the apple PWM treatment, the control treatment, and the orange PWM treatment, which had 30.30, 29.04, and

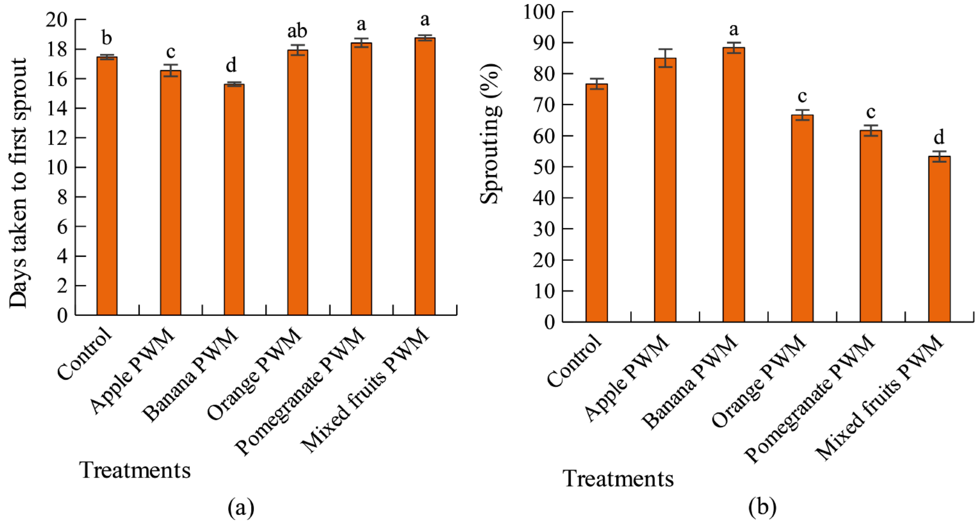

Fig. 1 Effect of different fruit peel waste media (PWM) on days taken to first sprout and sprouting (%) of Kala Amritsari plum under semi protected conditions. The letters indicate significance level at $p \leq 0.05$ and bar represent standard error of mean ($n = 3$) value

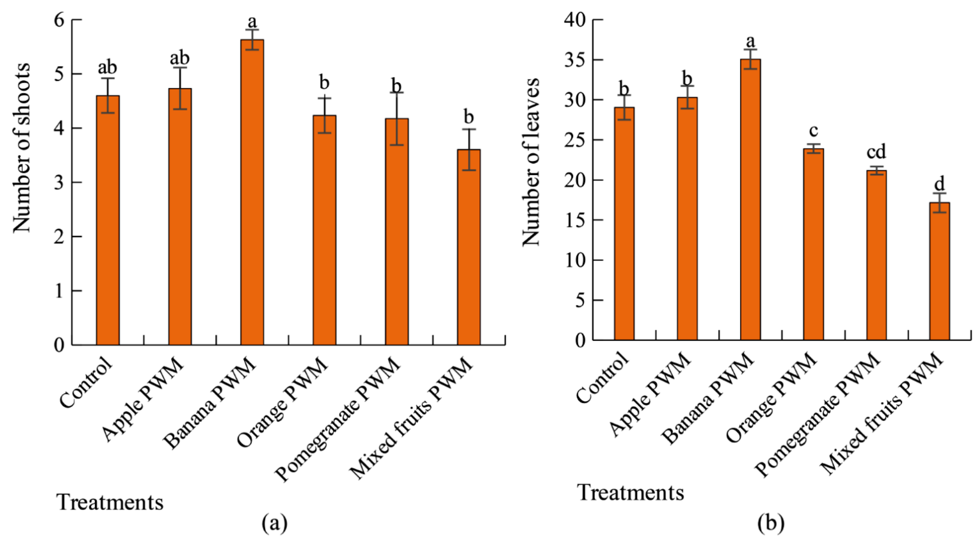

Fig. 2 Effect of different fruit peel waste media (PWM) on shoots and leaves number of Kala Amritsari plum under semi protected conditions. The letters indicate significance level at $p \leq 0.05$ and bar represent standard error of mean ($n = 3$) value

23.9 leaves per cutting, respectively. On the other hand, the lowest number of leaves per cutting, at 17.14, was found in the mixed fruit PWM treatment, followed by the pomegranate PWM treatment, which had 21.16 leaves per cutting (as shown in Fig. 2b).

3.5 Number of Roots

The highest number of roots, at 13.68, was observed in the banana PWM treatment. It was followed by the apple PWM treatment, the control treatment, and the orange PWM treatment, which had 11.5, 8.94, and 7.97 roots, respectively. Conversely, the lowest number of roots, at 4.41, was found in the mixed fruit PWM treatment. This was followed by the pomegranate PWM treatment, which had 6.21 roots (as depicted in Fig. 3a).

3.6 Rooting (%)

Significant differences ($p \leq 0.05$) were observed in the rooting percentage among the treatments during the experiment. The highest rooting percentage, at 76.67%, was found in the banana PWM treatment. It was followed by the apple PWM treatment and the control treatment, which had rooting percentages of 71.67% and 60.00%, respectively. Conversely, the lowest rooting percentage, at 31.67%, was observed in the mixed fruit PWM treatment. This was followed by the pomegranate PWM and the orange PWM treatments, which had rooting percentages of 45.00% and 53.33%, respectively (as shown in Fig. 3b).

3.7 Fresh Weight of Shoot

The highest fresh weight of shoot, at 0.38 g, was observed in the banana PWM treatment. This was followed by the apple

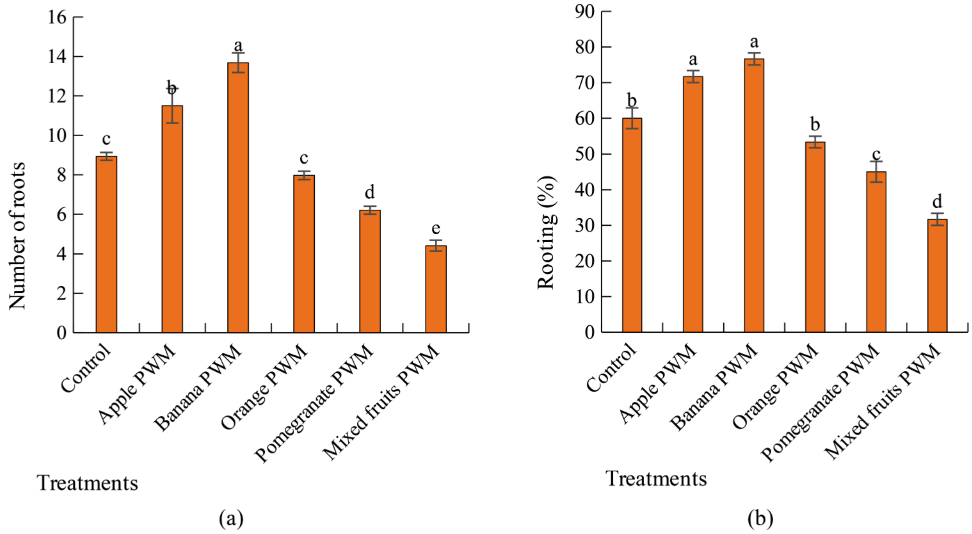

Fig. 3 Effect of different fruit peel waste media (PWM) on number of roots and rooting (%) of Kala Amritsari plum under semi protected conditions. The letters indicate significance level at $p \leq 0.05$ and bar represent standard error of mean ($n = 3$) value

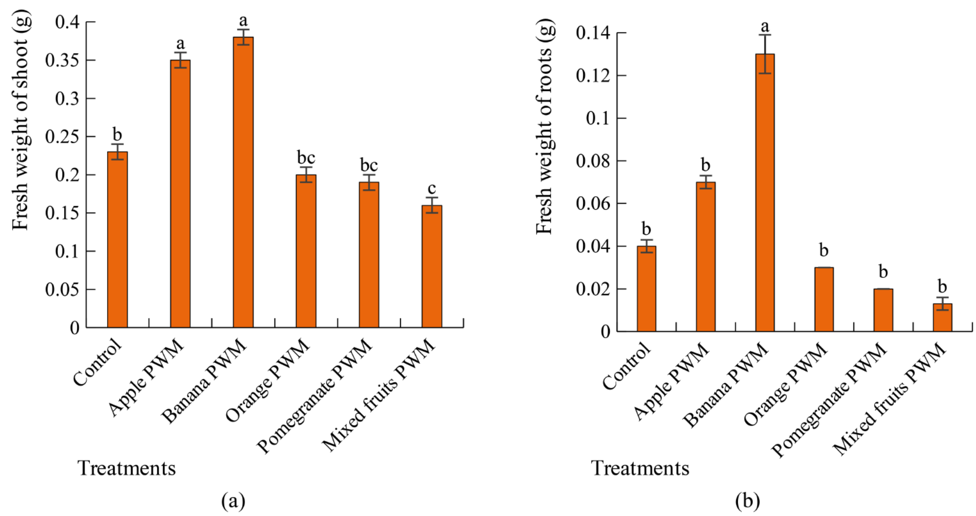

Fig. 4 Effect of different fruit peel waste media (PWM) on fresh weight of shoot and roots of Kala Amritsari plum under semi protected conditions. The letters indicate significance level at $p \leq 0.05$ and bar represent standard error of mean ($n = 3$) value

PWM treatment ($p \leq 0.05$), the control treatment, the orange PWM treatment, and the pomegranate PWM treatment, which had shoot weights of 0.35 g, 0.23 g, 0.2 g, and 0.19 g, respectively. On the other hand, the lowest fresh weight of shoot, at 0.16 g, was found in the mixed fruit PWM treatment (as depicted in Fig. 4a).

3.8 Root Fresh Weight

The highest fresh weight of roots, at 0.13 g, was observed in the banana PWM treatment. It was followed by the apple PWM treatment, the control treatment, the orange PWM treatment, and the pomegranate PWM treatment, which had root weights of 0.07 g, 0.04 g, 0.03 g, and 0.02 g, respectively. In contrast, the lowest fresh weight of roots, at 0.013 g, was found in the mixed fruit PWM treatment (as shown in Fig. 4b).

3.9 Shoot Dry Weight

The highest dry weight of shoot was observed in the banana PWM treatment, with a dry weight of 0.15 g. It was followed by the apple PWM treatment, the control treatment, and the orange PWM treatment, which had dry weights of 0.13 g, 0.09 g, and 0.08 g, respectively. Conversely, the lowest dry weight of shoot, at 0.06 g, was found in the mixed fruit PWM treatment. This was followed by the pomegranate PWM treatment, which had a dry weight of 0.07 g, when compared to the other treatments used in the experiment (as depicted in Fig. 5a).

3.10 Dry Weight of Root

The highest dry weight of root was observed in the banana PWM treatment, with a dry weight of 0.038 g. It was followed by the apple PWM treatment and the control treatment, both

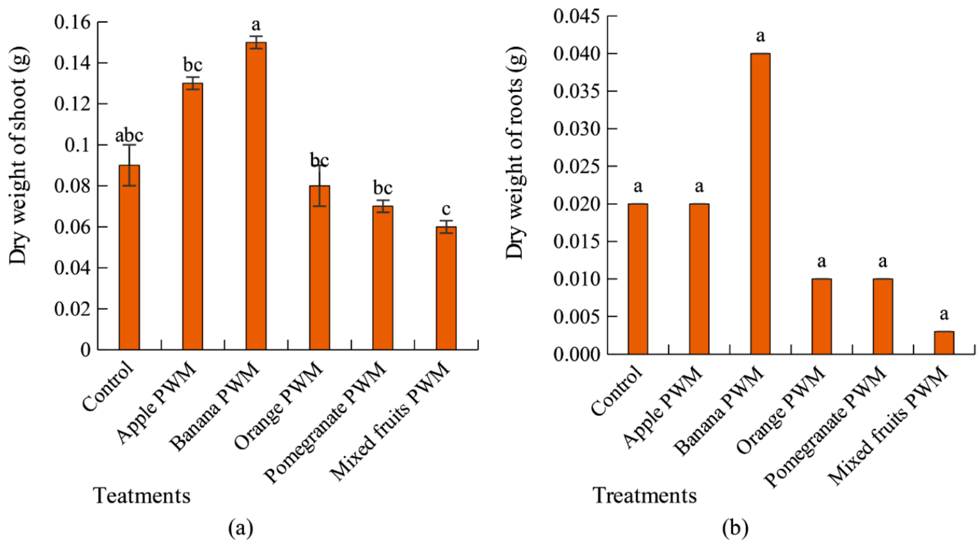

Fig. 5 Effect of different fruit peel waste media (PWM) on dry weight of shoot and roots of Kala Amritsari plum under semi protected conditions. The letters indicate significance level at $p \leq 0.05$ and bar represent standard error of mean ($n = 3$) value

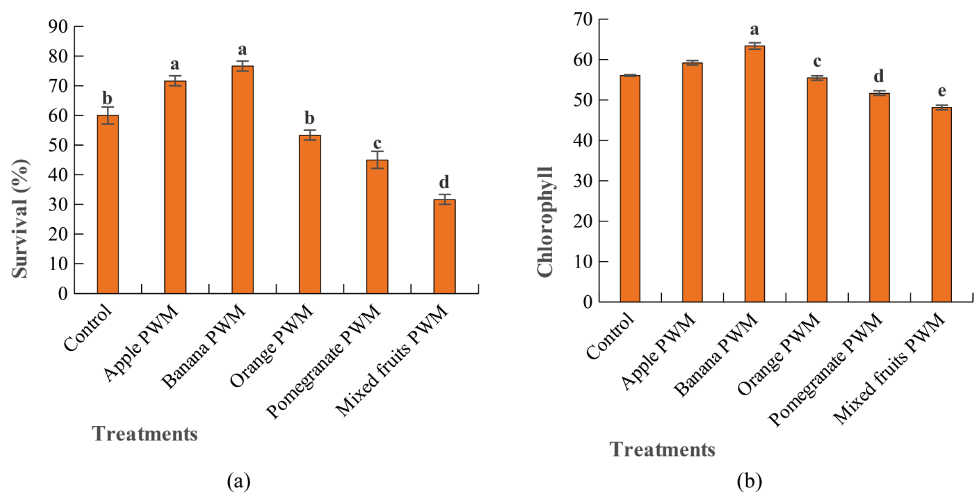

Fig. 6 Effect of different fruit peel waste media (PWM) on survival (%) and chlorophyll content of Kala Amritsari plum under semi protected conditions. The letters indicate significance level at $p \leq 0.05$ and bar represent standard error of mean ($n = 3$) value

of which had the same dry weight of 0.02 g. On the other hand, the lowest dry weight of root, at 0.005 g, was found in the mixed fruit PWM treatment. This was followed by the pomegranate PWM treatment and the orange PWM treatment, which had dry weights of 0.007 g and 0.011 g, respectively, when compared to the other treatments used in the experiment (as shown in Fig. 5b).

3.11 Survival (%)

The highest survival percentage, at 76.67%, was observed in the banana PWM treatment, and this difference was statistically significant ($p \leq 0.05$). It was followed by the apple PWM treatment and the control treatment, which had survival percentages of 71.67% and 60.00%, respectively. Conversely, the lowest survival percentage, at 31.67%, was found in the mixed fruit PWM treatment. This was followed by the pomegranate PWM and the orange PWM treatments, which had survival percentages of 45.00% and 53.33%, respectively (as depicted in Fig. 6a).

3.12 Chlorophyll Content

The highest chlorophyll content, with statistical significance ($p \leq 0.05$), was observed in the banana PWM treatment, at 63.4. It was followed by the apple PWM treatment, the control treatment, and the orange PWM treatment, which had chlorophyll contents of 59.2, 56.07, and 55.47, respectively. Conversely, the lowest chlorophyll content, at 48.13, was found in the mixed fruit PWM treatment. This was followed by the pomegranate PWM treatment, which had a chlorophyll content of 51.67, when compared to the other treatments used in the experiment (as shown in Fig. 6b).

4 Discussion

The use of banana peel waste media (PWM) has been shown to promote early sprouting in cuttings. Fruit peel nutrient analysis (Tables 2 and 3) reveals that banana PWM contains higher nutrient levels compared to other media used for early cutting growth. Improving the physical properties of the growing medium can accelerate sprouting and reduce the number of days required for initiation. However, it's important to note that high electrical conductivity in the growing medium can potentially expose cuttings to excessive chlorine and boron (Wang and Zhao 2015), which can have negative effects on cuttings' food intake, enzyme activity, and physiological processes, ultimately slowing down early cutting sprouting. Similar findings were reported by Minz (2021) in the context of dragon fruit cuttings treated with organic fertilizers.

Banana PWM enhances the quality of the growing medium and facilitates improved water and nutrient uptake by cuttings, leading to enhanced sprouting. The optimal nutrient content of banana peels plays a crucial role in increasing the accumulation of carbohydrates and other essential metabolites during bud differentiation, which contributes to better sprouting. In contrast, mixed fruit PWM results in lower sprouting compared to other treatments due to its relatively high concentrations of sodium, chloride, and boron. These elements can potentially hinder sprouting. These findings align with the studies conducted by Farooq et al. (2018) and Malakar et al. (2019), where grape and coconut seedlings showed improved sprouting when provided with an optimal nutrient supply through organic fruit peel waste. It's worth noting that shoot growth is heavily dependent on root health, and the abundant nutrient content and high electrical conductivity in the medium can influence root functions. Qader (2019) observed that chickpea shoots rooted in banana and orange peel waste exhibited greater growth, while Lad et al. (2020) found that mango shoots showed the highest growth when treated with fruit peel waste. These studies collectively support the notion that fruit peel waste can have a positive impact on shoot and root growth in various plant species.

The treatment using banana PWM resulted in the highest number of leaves per cutting, at 35.05 (Fig. 7b), and this is influenced by factors such as sprout size, sprout number, shoot-root balance, and stored food hydrolysis. It is important to note that the main growth factor affecting shoot weight is the number of leaves, as indicated by Kaur et al. (2018). The presence of available macro and micronutrients in banana PWM, contributes to increased chlorophyll production and a higher leaf count. Banana PWM also enhances root growth in the rooting medium by providing nutrients, porosity, and moisture retention. In contrast, mixed fruit PWM results in the fewest leaves per cutting, likely due to ion imbalances and salt accumulation in the rooting medium, caused by excessive salinity and nutrient density. This aligns with the findings of Teshome (2022), who observed that banana peel extract promotes carrot leaf growth. However, it's worth mentioning that El Barnossi et al. (2022) found that pomegranate peel fertilizer can increase leaf count, and Dhatrika et al. (2018) suggested that fruit waste media can lead to the production of many leaves per cutting. These studies highlight the variability in leaf growth response to different fruit peel waste treatments and underscore the importance of nutrient balance in promoting leaf development. Banana PWM maximizes the number of roots per cutting (Fig. 7a) due to its favorable characteristics for root penetration. Banana PWM offers a friable texture that facilitates root growth, along with an optimal nutrient composition that promotes root development and vascular cambium growth.

In contrast, mixed fruit PWM, with its high nutrient content, pH, and electrical conductivity (Table 2), results in fewer roots and reduced carbohydrate functions. These findings are consistent with those of Haider et al. (2015), who observed the highest number of roots in poplar cuttings when grown in a medium containing organic matter. Among the various nutrients, manganese (Mn) is found to be particularly beneficial in promoting sprouting, vegetative growth, and rooting, while other nutrients show a negative correlation with cutting success (Fig. 8). Manganese promotes auxin formation because it has been observed in previous and current study that rooting and manganese increase synergistically (Vallejos-Torres et al. 2020). Interestingly,

Fig. 7 Effect of different PLW on Kala Amritsari plum cuttings; **(a)** Rotting variation **(b)** Shoot variation

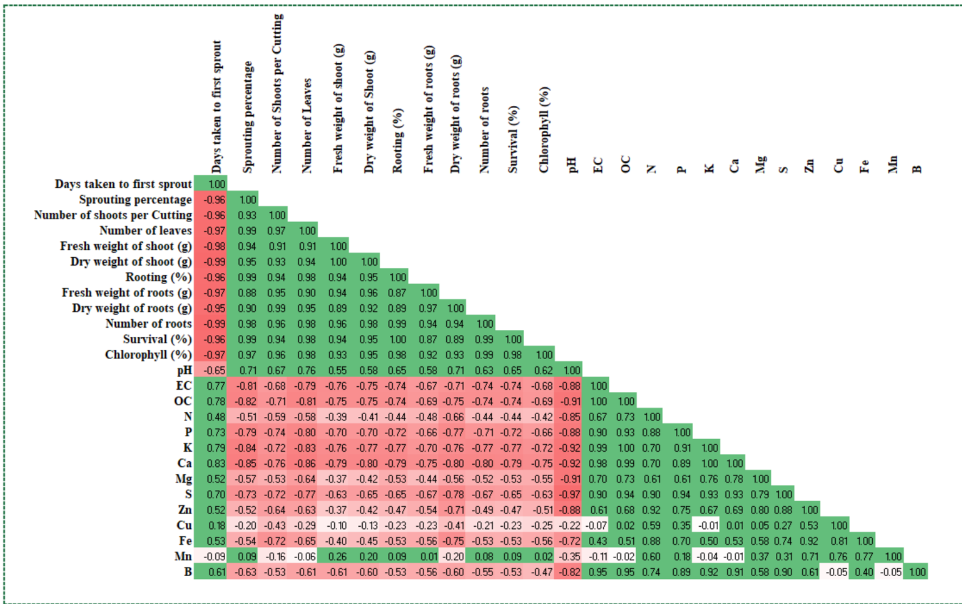

Fig. 8 Correlation between different growth characters and available nutrient of all PWM used for rooting in Kala Amritsari Plum cuttings. The EC and OC refer to electrical conductivity and organic carbon of the media, respectively

the study reveals that Cu and Mn are not correlated with the promotion of boron (B) rooting, while K, Ca, organic carbon, and electrical conductivity of the waste are not correlated with Mn. Electrical conductivity and K are not related to Cu. Furthermore, all the parameters of the cuttings are highly correlated with each other, underscoring the interconnected nature of the various factors influencing cutting success.

Banana PWM exhibited the most favorable rooting performance among all six treatments at the 90-day mark. This success can be attributed to the hydrolysis process, which generates high carbohydrate levels and low nitrogen content, creating conducive conditions for root development in cuttings. The superior rooting performance of banana PWM can also be attributed to its optimal macro and micronutrient composition, as well as its excellent drainage, water retention, and friable rooting medium characteristics, all of which are detailed in Table 2. These factors collectively contribute to a growth environment that is highly favorable for root growth and results in a higher rooting percentage. On the other hand, mixed fruit PWM displayed the lowest rooting percentage, primarily due to its elevated nutrient content, pH levels, and electrical conductivity. These factors have a direct impact on carbohydrate functions and can hinder the formation of roots. This finding is consistent with the results reported by Dvin et al. (2011), who found that using coconut peel husk waste and perlite as a growing medium increased rooting in cuttings.

Banana PWM also exhibited the highest shoot fresh weight among the treatments. This can be attributed to the enhancement of leaf area, which can lead to increased stem elongation, cell division, starch and sugar accumulation, higher leaf chlorophyll content, and an optimized carbon-to-nitrogen (C/N) ratio. These factors are influenced by the physical and chemical properties of the growing medium. In contrast, mixed fruit PWM resulted in the lowest shoot fresh weight, primarily due to its elevated nutrient content, pH levels, and electrical conductivity, which have a negative impact on carbohydrates, leaf chlorophyll content, and cell division. Other factors, including the C/N ratio, also played a role in reducing shoot growth. It is worth noting that the use of growth-controlling chemicals in organic media may have contributed to accelerated plant growth in some treatments, as suggested by Asghar et al. (2020). Additionally, having more leaves, longer shoots, and thicker stems can contribute to increased shoot fresh weight, as noted by Tanwar et al. (2020). El Barnossi et al. (2022) found that pomegranate peel fertilizer increased pea shoots fresh weight under protection, further highlighting the impact of different treatments on shoot growth.

The dry weight of the shoots was also highest in the banana PWM treatment and lowest in the mixed fruit PWM treatment. This difference can be attributed to several factors. In the banana PWM treatment, the enhancement in leaf area led to increased stem elongation and greater leaf area formation through cell division. This, in turn, resulted in higher starch and sugar accumulation, elevated leaf chlorophyll content, and an optimized carbon-to-nitrogen (C/N) ratio. These factors are influenced by both the physical and chemical properties of the growing medium. Conversely, mixed fruit PWM had a very high nutrient content, elevated pH levels, and increased electrical conductivity, all of which had a negative impact on carbohydrate functions, leaf chlorophyll content, and cell division. Other factors, including the C/N ratio, also contributed to reduced shoot growth.

Additionally, the dry weight of the shoots increased with more leaves, longer shoots, and thicker stems, as noted by Tanwar et al. (2020). The composition of the growing medium played a crucial role in enhancing nutrient availability and the physical, biological, and chemical qualities of the environment, ultimately resulting in an increase in the dry weight of the shoots. These findings are consistent with the observations of El Barnossi et al. (2022), who found that using pomegranate peel as fertilizer increased the dry weight of shoots in pea (Pisum sativum) under protected conditions. The dry weight of the roots followed a similar trend as the fresh weight of the roots. The banana PWM treatment had the highest dry weight of the roots, primarily due to its friable nature, which allowed for good root penetration and optimal nutrient availability. The plants in this treatment responded effectively to the medium's nutrient availability, resulting in accelerated root growth and the development of root vascular cambium. This, in turn, increased both the diameter and quantity of the roots, contributing to the higher dry weight of the roots. The mixed fruit PWM treatment affected carbohydrate functions and results in root initiation, and root growth. The presence of excessive nutrients and unfavourable pH and electrical conductivity negatively impacted root development. The observed trends align with previous research. Khot et al. (2019) found that a mixture of soil and organic compost in a 1:1 ratio resulted in the highest dry weight of roots in Bullock's Heart (*Annona reticulata* L.). It is well-established that low salinity and optimal nutrient content in the growing medium promote increased dry root weight (Wang et al. 2018).

The survival percentage at 90 days after planting was highest in the banana PWM treatment and lowest in the mixed fruit PWM treatment. This difference can be attributed to an increase in photosynthetic metabolites and nutrients within the cuttings in the banana PWM treatment. Healthy and increased root development, facilitated by optimal nutrient content in the medium, likely contributed to the higher survival rate. Improved shoot characteristics also play a role in ensuring a maximum survival rate in the semi-protected condition after planting. Conversely, mixed fruit PWM had a very high nutrient content, elevated pH levels, and increased electrical conductivity, all of which directly affected chlorophyll content and root formation processes. These factors reduced the survival rate compared to other media. Disruptions in nutrient uptake and water absorption, increased water stress, ion imbalances, and salt accumulation in the rooting medium were all likely factors contributing to the lower survival rate. The observed variation in chlorophyll content among treatments can be attributed to several factors. In the banana PWM treatment, better root development, nutrient availability, improved rooting media porosity, and higher water retention capacity collectively promoted shoot growth. Increased shoot growth led to a greater number of nodes and leaves, positively impacting chlorophyll content. Chlorophyll content is known to be influenced by leaf area and leaf number. Conversely, mixed fruit PWM had excessive salt concentrations, which negatively affected the cuttings by disrupting nutrient uptake and water absorption, resulting in lower chlorophyll content compared to other treatments. The higher water stress, ion imbalances, and salt accumulation in the rooting medium all contributed to fewer leaves per cutting. These findings align with previous research. Parkhe et al. (2018) observed that tissue culture plantlets of banana grown in a medium containing a mixture of organic waste and soil in a 1:3 ratio had a chlorophyll content of 1.405. Additionally, Danish et al. (2019) found that banana peel extract significantly increased the relative chlorophyll content.

5 Conclusion

The findings of the current research clearly indicates that banana fruit peel waste improves rooting success by supplying an adequate amount of nutrients. Banana peel waste is slightly alkaline, which favors rooting, and it contains optimum levels of nitrogen, phosphorus, and potassium. Consequently, the application of banana fruit peel waste media provides the optimal nutrient supply to the cuttings of Kala Amritsari plum, resulting in a higher success rate of rooting, reaching up to 76.67%. It is also worth noting that other fruit peel waste contains more nutrients than banana peel waste media, but their low pH, high electrical conductivity, and potential toxicity due to nutrient abundance can negatively impact rooting success in cuttings. Therefore, the research suggests that while an optimal nutrient level is necessary for successful rooting in cuttings, other fruit peel waste can be explored for further study by adjusting their proportions and forms to create more suitable rooting media. This would help minimize waste and potentially improve the success rates of plant propagation.

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Declarations

Competing Interests The authors declare no competing interests.

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