Enhancing Graft-Take Success in Jackfruit (*Artocarpus heterophyllus* Lam.) Var. "EVIARC Sweet" Seedlings by Pre-Grafting Treatments

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Abstract

The effects of different pre-grafting treatments in enhancing graft-take success in jackfruit seedlings were evaluated. This study aimed to assess the effects of wounding in reducing latex in rootstock and the effects of cold temperature and flowing water as scion pre-grafting treatments. The study was laid out in 2 x 3 factorial experiment arranged in randomized complete block design (RCBD) with three replications. The treatments were composed of different rootstock and scion pre-grafting treatments. Days from grafting to shoot and leaf emergence, percent graft-take, number of leaves, average numbers of shoots per grafted seedling, moisture content of the medium, chemical properties of the scion, chemical properties of the potting medium and agro-climatic data were gathered and subjected to analysis of variance for RCBD. The results revealed that the highest percent graft-take (55%) was obtained from unwounded rootstocks grafted with pre-cured scions with flowing water treatment. Lowest percent graft-take (38.33%) was achieved by wounded rootstocks grafted with pre-cured scions under cold temperature treatment. Pre-cured scions without pre-grafting treatment and pre-cured scion with flowing water, regardless of the rootstocks used, revealed the lowest number of days to shoot and leaf emergence. On the contrary, pre-cured scions subjected to cold temperature showed the highest number of days for the shoot and leaf to emerge. Moreover, pre-cured scion with flowing water gave significantly the highest number of shoots and leaves, while pre-cured scions without pre-grafting and cold temperature treatment showed the lowest number of shoots and leaves.

***Keywords**:* jackfruit, graft-take, wounding, cold temperature, flowing water treatment

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1. Introduction

The jackfruit tree (*Artocarpus heterophyllus* Lam.) is one of the most widely distributed and cultivated fruit tree species. It is a multipurpose species with high consideration as a potential source of income for both the rural and urban people of the tropics and subtropics. It provides food, fuel, timber and medicinal extracts (Southampton Centre for Underutilized Crops [SCUC], 2006). It is a nutritious fruit rich in protein, potassium, calcium, iron, vitamins A, B, C and carbohydrates. In some regions, due to high levels of carbohydrates, jackfruit supplements some other staple foods in periods of scarcity. The pulp of the jackfruit is starchy and fibrous, and is a source of dietary fiber. The presence of isoflavon antioxidants and phyto-nutrients in the fruit indicates that jackfruit has cancer fighting properties. It is also known to help cure ulcers and indigestion (Asia-Pacific Association of Agricultural Research Institution [APAARI], 2012).

In terms of propagation, the sexual method is still the cheapest and the most convenient method, particularly in jackfruit-growing countries (SCUC, 2006). However, since jackfruit trees are crossly pollinated, progeny segregates and produce diverse types of heterozygous trees showing high degree of variability in many characteristics such as tree growth habit, canopy architecture, leaf shape and fruit quality (APAARI, 2012). In addition, the time taken by seedlings to reach fruit-bearing age is usually longer, and those trees grow taller than those propagated by vegetative methods – a constraint in management and harvesting. Among the asexual propagation methods tried, approach grafting or inarching has shown greater success (Angeles, 1983) but it is only suitable for small-scale propagation (Coronel 1983). One method with potential is cleft grafting, which has been found to give 30-80% graft-take. If it can be perfected to give consistently higher success rates, it is a much better system than inarching for perpetuating and propagating outstanding varieties (Acedo, 1992).

Based on previous works, jackfruit is considered as one of the most difficult to propagate by vegetative means due to its latex, which is reported to hinder the normal process of callus formation and graft union (Soepadmo, 1991). Thus, in order to reduce the accumulation of latex flow during grafting and improve graft-take success, conceptualization of feasible technology adaptive to small and large nurseries such as scion and rootstock conditioning must be employed.

There is a need to generate more information related to the techniques of using cleft grafting method in propagating jackfruit seedlings. In the light of individual and interaction effects of scion pre-defoliation and rootstock wounding as conditioning technology on improving graft-take percentage, this study aimed to evaluate the effects of rootstock wounding and scion pre-grafting treatments (cold temperature and flowing water) in reducing latex and increasing the survival rate in grafting jackfruit.

2. Methodology

2.1 Preparation of Scion Stock

The scions of jackfruit var. EVIARC Sweet were obtained from the Regional Scion Grove of the Department of Agriculture situated at Balinsasayao, Abuyog, Leyte. Shoots from previous season with extension growth were pre-cured by cutting all the leaves approximately 15 cm long from the shoot apex using a pruning shear but leaving a small portion of the petiole. This was to avoid damage of the coming axillary buds. All shoot tips were also removed.

The scions were gathered after pre-curing for 12 days. The shoots were cut at least 10-13 cm long from the tip using a pruning shear. After collection, the scions were wrapped and rolled immediately in moist newsprint or fresh banana leaves. The rolled pack was placed inside a plastic bag and transported immediately to the Fruit Crop Nursery of the Department of Horticulture, Visayas State University (VSU), ViSCA, Baybay City, Leyte wherein the actual grafting operation was conducted.

2.2 Preparation of the Seedling Rootstock

Jackfruit seeds grown as rootstocks were taken from the Department of Food Science and Technology, VSU, Leyte. These seeds were the leftover of a jackfruit processing. Sorting was done to separate seeds that were damaged, injured and of small size from healthy and uniformed sized ones. Selected seeds were sown in a seed bed and transplanted in individual black polyethylene bags with a dimension of 3 cm x 3 cm x 8 cm after one and a half weeks. To ensure good growth of the seedlings, application of complete fertilizer (14-14-14) with the rate of 10 g per 8 L of water was done two weeks before the grafting operation. When the seedlings reached two and a half months old, another sorting was done to select healthy and vigorous seedlings.

A total of 180 rootstocks seedlings were used in the actual grafting operation. These rootstocks were starved of water one week before the grafting process.

2.3 Pre-curing of Scions

Shoots of similar sizes and physiological stages of maturity were defoliated 10-13 cm from the shoot apex, leaving a small portion of the petiole to protect the coming axillary buds, and collected 12 days prior to actual grafting process. Newly defoliated shoots were tagged thereafter to avoid confusion. The scion sticks were cut from the mother plant at approximately 10 cm length and pre-grafting treatments were imposed according to treatments.

2.4 Scion Pre-grafting Treatments

Right after harvesting, scions were subjected to cold temperature and flowing water as pre-grafting treatments. This was done by putting the newly cut scion sticks inside the refrigerator for 12 hours (h) at 10 °C temperature. Flowing water pre-grafting treatment was done by putting the scion sticks in an upright position under a flowing faucet for 8 h and then allowing it to dry an hour before the actual grafting operation.

2.5 Rootstock Wounding

Conditioning of rootstocks was carried out through girdling by wounding. In this method, six diagonal wound cuts approximately one and a half inches above the potting media surface in rootstock were made. Other rootstocks were held unwounded for purposes of comparison.

2.6 Grafting and Grafting Materials

Grafting operation was performed by a skilled plant propagator of the Department of Horticulture Nursery Project. Cleft grafting method was employed following the procedure recommended by the Department of Agriculture. Sharp grafting knives, pruning shears, polyethylene strips and ice candy wrappers were prepared as these are the materials necessary during the grafting operation.

2.7 Experimental Design and Treatments

The study was laid out in 2 x 3 factorial arranged in a randomized complete block design (RCBD). All treatments were replicated three times with 10 sample plants per replicate.

The first factor was rootstock wounding treatments and the second factor was scion pre-grafting treatments. The treatments were as follows:

Factor A (Rootstock Wounding)
- A1 - no wounding
- A2 - wounding

Factor B (Scion Pre-grafting Treatments)
- B1 - pre-cured scions without pre-grafting treatment
- B2 - pre-cured scions with flowing water treatment
- B3 - pre-cured scions under cold temperature treatment

2.8 Data Gathering

2.8.1 Days from Grafting to Shoot and Leaf Emergence

Days from grafting to shoot and leaf emergence were determined by counting the number of days from grafting up to the emergence of the shoots and the first pair of the leaves of the scion.

2.8.2 Percent Graft-take

The percentage of success of cleft grafting was computed using Formula 1 below. The number of successfully grafted seedlings was determined after removing the polyethylene strip used to wrap the scion to minimize excessive transpiration.

$$\text{Graft-take (\%)} = \frac{\text{Number of successful grafts}}{\text{Total number of grafted seedlings}} \times 100 \qquad (1)$$

2.8.3 Number of Leaves and Average Number of Shoots per Graft

The number of leaves was determined by counting the number of fully opened and functional leaves above graft union per seedling at the termination of the study.

The shoots produced above the graft union per graft were counted at the termination of the study. The sum of all the shoots was divided by the number of sample seedlings.

2.8.4 Moisture Content of the Medium

A total of 10 g of soil medium were taken from the seedling rootstocks one day before grafting operation. Soil samples were placed in paper boxes and oven-dried until constant weight was obtained. Moisture content was computed using Formula 2.

$$\textit{Moisture content (\%)} = \frac{\textit{Fresh weight - Oven dried weight}}{\textit{Fresh weight}} \times 100 \qquad (2)$$

2.8.5 Chemical Properties of Scion and Potting Medium

The samples of pre-cured and not pre-cured scions were prepared. Also, the potting medium samples used in growing the seedlings were collected, crushed, and air-dried for three days. Both samples were then submitted to the Central Analytical Services Laboratory of PhilRootcrops, VSU, Baybay City, Leyte, for the analyses of the pre-cured and not pre-cured scions samples' dry matter, sugar, and starch content; and the potting medium samples' pH, organic matter (OM) percentage, nitrogen, phosphorus and potassium contents.

2.8.6 Agro-climatic Data

Data on temperature (°C), relative humidity (RH) (%) and rainfall were monitored throughout the duration of the study. Data were obtained at the VSU-PAGASA Agro-meteorological Station.

2.8.7 Statistical Analysis

Data were recorded, consolidated, tabulated and statistically analyzed through analysis of variance (ANOVA). Least significance difference (LSD) test was used to determine the significant differences among treatment means. Statistical analysis was carried out using the computer software Statistical Tool for Agricultural Research (STAR).

3. Results and Discussion

3.1 Percent Graft-take

Rootstock wounding and scion pre-grafting treatments were found to have significant effects on the percent graft-take of Jackfruit seedlings at 30 days after grafting. Pre-cured scion with flowing water treatments (55.00%) obtained the highest percentage graft-take as compared to pre-cured scions without pre-grafting treatment (41.67%) and pre-cured scions subjected to cold temperature treatments (38.33%), respectively (Table 1). Moreover, regardless of the scion used, unwounded rootstocks gave significantly higher percentage graft-take (52.22%) compared to wounded rootstocks (37.78%).

Table 1. Percent graft-take, days to shoot and leaf emergence, number of shoots and leaves of jackfruit (*A. heterophyllus* Lam.) seedlings as influenced by rootstock wounding and scion pre-grafting treatments

Treatments	Percent Graft-take (%) 30 Days after Grafting	Days to Emergence		Number of	
		Shoot	Leaf	Shoots	Leaves
Factor A					
A1	52.22^{a}	21.69	23.44	2.44^{a}	4.59
A2	37.78^{b}	21.48	23.00	1.74^{b}	3.85
Factor B					
B1	41.67^{b}	20.97^{b}	22.50^{b}	1.89^{b}	4.11^{b}
B2	55.00^{a}	20.39^{b}	22.17^{b}	2.78^{a}	5.44^{a}
B3	38.33^{b}	23.40^{a}	25.00^{a}	1.61^{b}	3.11^{b}
p-value (a)	0.0038**	0.7638^{ns}	0.5709^{ns}	0.0316*	0.1409^{ns}
p-value (b)	0.0108*	0.0125*	0.5709^{ns}	0.0177*	0.0070**
CV (%)	17.68	6.86	6.93	28.61	23.29

Treatment means in a column with the same letter and those that have no letters are not significantly different from each other (LSD). Treatments: Factor A - Rootstock Wounding (A1- unwounded; A2 - wounded), Factor B - Scion Pre-grafting Treatments (B1 - Pre-cured scions with no pre-grafting treatment; B2 - Pre-cured scions with flowing water treatment; B3 - Pre-cured scions under cold temperature treatment)

Exposing the scion's basal part in flowing water was found to have effectively removed the latex accumulated at the cut end of the scion. Exposing to flowing water reduced the rate of transpiration in scion upon harvesting. Consequently, it accelerated the recovery of the scion from water stress during transport, thereby paving the way better to shoot emergence and leaf development. Waite *et al.* (2013) reported that water soaking of grapevine cuttings for a couple of hours is a common practice in grapevine nurseries. It is routinely done to remunerate moisture loss during harvesting and transportation.

3.2 Shoot and Leaf Emergence

Rootstock wounding was found to have no significant effect. However, scion pre-grafting treatments differed significantly (Table 1). Pre-cured scions with flowing water treatment (20.39 days) and those with no pre-grafting treatments (20.97 days) had shoots emerging remarkably earlier than the pre-cured scions subjected to cold temperature treatments (23.40 days) and leaf emergence (25 days). This result might possibly be due to its carbohydrate reserves that had accumulated after defoliation (Table 2).

Table 2. Chemical analysis of jackfruit (*A. heterophyllus* Lam.) scions subjected to defoliation and different pre-grafting treatments

Scion Treatments	Total Dry Matter (%)	Total Sugar (%)	Total Starch (%)
Scion defoliated 1 day before grafting	70.80	2.80[b]	7.42[b]
Pre-cured scions with no pre-grafting treatments	74.88	4.32[a]	8.73[b]
Pre-cured scions with flowing water treatment	72.33	3.93[b]	9.29[b]
Pre-cured scions under cold temperature treatment	76.69	3.75[b]	10.99[a]
p-value (a)	0.7888[ns]	0.0011**	0.0499*
p-value (b)	0.4767[ns]	0.0001**	0.0011**
CV (%)	6.34	3.72	5.92

Maiti and Biswas (1980) reported that defoliation results in abrupt increase on the sucrose content of shoots. This helps in solute translocation towards the shoot apex, resulting in higher meristematic activity at the bud level. This condition also favoured better graft union as a result of better sap movement, good callus initiation and stimulation of cambium division.

3.3 Number of Shoots per Leaves

Rootstock wounding revealed significant effect on the number of shoots per graft. However, no significant differences were observed on the number of leaves. On the other hand, scion pre-grafting treatments revealed significant effect on both number of shoots and leaves per graft (Table 1). Pre-cured scions with flowing water treatment obtained the highest number of shoots (2.78), which consequently resulted in the highest number of leaves (5.44). Comparable effects were observed on pre-cured scions with no pre-grafting treatments and pre-cured scions subjected to cold temperature treatment.

Regardless of the scion pre-grafting treatments, unwounded rootstocks obtained the highest number (2.44) of shoots per graft compared to wounded rootstocks (1.74).

Pre-cured scions with flowing water treatment revealed significant result on the percent graft-take as well as on the number of days toward shoot and leaf emergence. A possible reason would be that flowing water treatment was able to rehydrate back the loss of moisture from harvest to the transportation period of scions to the nurseries. Thus, it is logical to speculate that right after the soaking treatment, scions were able to absorb ample amount of water and recover from stress. Consequently, this resulted in an earlier shoot and leaf emergence compared to other pre-grafting treatments. It, therefore, follows that more number of shoots and leaves were developed from this treatment (Table 1).

3.4 Chemical Analysis

In addition, chemical analysis (Table 2) revealed a significant difference in terms of total sugar and total starch but not in total dry matter. The pre-cured scions with no pre-grafting treatment (4.32%) have relatively high sugar contents as compared to pre-cured scions under cold temperature (3.75%) and those exposed in flowing water pre-grafting treatments (3.93%). Moreover, pre-cured scions subjected to cold temperature treatment (10.99%) were significantly high in starch content as compared to other pre-grafting treatments.

3.5 Chemical Properties of the Potting Medium

Analysis on the soil pH, percent OM, percent moisture content, total N, P and K are presented in Table 3. Soil samples collected from the pots, where jackfruit seedlings were grown were grayish dark in color and soft with sandy loam texture. Chemical analysis revealed that it had 11.05% O.M., 46.53% moisture content, 0.48% total N, 835.76% total P, 2463.42% total K and a pH of 6.07.

Table 3. Chemical properties of the potting medium used in growing the jackfruit seedling rootstocks

	pH 1:2:5 ratio	Moisture Content (%)	OM (%)	Total N (%)	Total P (mg/kg)	Total K (mg/kg)
Initial	6.31	46.93	11.47	0.48	894.52	2533.17
Final	5.83	46.13	10.63	0.47	777.00	2393.67
Mean	6.07	46.53	11.05	0.48	835.76	2463.42

3.5.1 Soil pH

Measured in pH units, soil pH or soil reaction is essentially an indication of the acidity or alkalinity of soil. The pH scale starts from 0 to 14 and the neutral point is at pH 7. As the quantity of hydrogen ions in the soil increases, the soil pH decline, therefore turning more acidic. Starting from pH 7 to 0, the soil is progressively much acidic, and from pH 7 to 14, the soil is progressively more alkaline or basic. The optimum range for some vegetable plants is in the range of 6.3 to 6.8. Preferable pH range for optimum plant growth varies among crops because some crops may grow well in acidic or neutral pH soils while other crops may thrive best in alkaline soils.

Acedo (1992) has stated that the ideal pH range in developing jackfruit seedlings is 5.0-7.5, cultivated in deep, sandy-loam or clay-loam soil of medium fertility and good drainage. So, based on the soil pH analysis of the medium (Table 3) which is 6.07, the pH reading was within scope and revealed to be ideal. Eventually, soil pH displays a primary function in nutrient accessibility, for instance, when the soil pH is inadequate, some of the macronutrients (nitrogen, phosphorus, potassium, calcium, and magnesium) are bound in the soil and inaccessible to plants.

3.5.2 Organic Matter

Results revealed that the medium used contain high OM (%) (Table 3). Soil organic matter is primarily considered an important constituent of the soil because of its vital functions such as acting as source of nutrients for plants, helping as medium for soil accumulation, increasing nutrient exchange, holding moisture, reducing compaction, decreasing surface crusting and promoting water infiltration into the soil (Bot and Benites, 2005).

3.5.3 Total Nitrogen, Phosphorus and Potassium

Total nitrogen measures N in some organic and inorganic forms. Total nitrogen is not plant-available N and is not the total of NH_4-, N^+, NO_3- nitrogen (Horneck *et al.*, 2011). Nitrogen is very essential since it is a major constituent of chlorophyll, the compound by which plants utilize sunlight energy to create sugars from water and carbon dioxide in the process of photosynthesis. It is similarly a major constituent of amino acids, the building blocks of proteins. Nitrogen is a constituent of energy transfer compounds, which include ATP (adenosine triphosphate). ATP permits cells to preserve and utilize energy released in metabolism. In this study, the total nitrogen ranges from 0.47% to 0.48% (Table 3).

Soils commonly contain over 20,000 ppm of total potassium. Some of this is a structural constituent of soil minerals and is inaccessible to plants. Plants can utilize merely the exchangeable potassium on the surface of soil particles and potassium dissolved in soil water. This often amounts to less than 100 ppm (Horneck *et al.*, 2011). The total phosphorus content of most surface soils is low, averaging only to 0.6%. This compares to an average soil content of 0.14% nitrogen and 0.83% potassium (Table 3).

3.6 Environmental Conditions during the Conduct of the Experiment

3.6.1 Temperature

Data on temperature were obtained at the VSU-PAGASA Agro-meteorological Station located approximately 200 m away from the experimental area. Temperature was recorded from the start of the experiment until its termination. Temperature recording was done at every 8:00 AM and 2:00 PM. The mean morning and afternoon temperatures recorded were 27.68 and 31.38 °C, respectively (Figure 1).

Plant species normally have an optimum temperature range for growth and development, outside of which they suffer reduced productivity and quality. Each chemical and biochemical process has a temperature optimum that differs among species. Temperature is one of the most important environmental factors inflicting heavy economically relevant yield losses by reducing plant growth and development, causing wilt and necrosis and retarding the rate of truss appearance and fruit ripening (Schwarz *et al.*, 2010). Janick *et al.* (1981), as cited by Salleva (2013), reported that temperature between 27-29 °C was optimal for callus formation. Hartmann (1990), as cited by Salleva (2013), pointed out that 10-32 °C was conducive to wound healing process. In addition, Johnson and Miles (2011) reported that successful grafting of vegetables requires high RH and optimal temperatures for one week following the grafting to reduce transpiration of the scion until rootstock and scion vascular tissues are healed together and water transport is restored. They added that higher temperatures result in an increased rate of evaporation and decreased RH although the evaporation rate varies with the air movement and saturation vapor pressure. The temperature means recorded were within the temperature range ideal for wound healing of graft union.

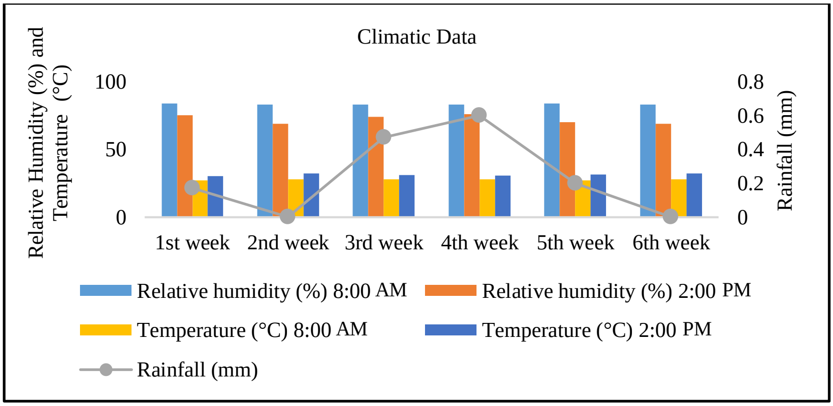

Figure 1. The average weekly temperature (°C), RH (%) and rainfall (mm) during the conduct of the experiment (February-March, 2015) obtained from the VSU-PAGASA Agro-meteorological Station

3.6.2 RH and Rainfall

The amount of moisture in air is usually manifested as RH, which is the percent of the total water vapor air can hold at a specific air temperature. The average RH recorded in the morning (8:00 AM) was 83.25% while that in the afternoon was 72.17%. The lowest RH recorded in the morning was 82% while the lowest in the afternoon was 65% (Figure 1).

Vu *et al.* (2013) stated that temperature and humidity are the key environmental factors that influence the healing and acclimatization of grafted seedlings. Jang *et al.* (2013) generally emphasized that 75-80% RH fasten the photosynthetic rate, although RH may change the photosynthesis rate otherwise in different environmental conditions. Additionally, higher RH of over 90% reduces the photosynthesis rate owing to decreased stomatal aperture and it reduces the scion's transpiration rate, which prevents it from drying out. Moreover, high RH may result in the development of many diseases because of available excess water. Then, under low RH conditions, the photosynthesis rate is likely to reduce because of water stress elicited by unnecessary transpiration.

Rainfall is essentially the quantity of rain within a given area at a given time. Rainfall is a vital agro-meteorological data due to its unmediated relationship with temperature and RH. The trend of the average weekly rainfall recorded during the entire duration of the experiment (Figure 1) showed fluctuations; the highest mean rainfall recorded was on the 4th week (0.60 mm) while the lowest was recorded on the 2nd and 6th weeks (0.00 mm). Generally, increase in grafting success does not just demand close connection between scion and rootstock vascular bundles, and rootstock and scion compatibility, but proper environmental conditions as well in order to facilitate rootstock and scion union.

4. Conclusion

Significant differences were observed on rootstock wounding and scion pre-grafting treatments except in dry matter. No significant differences were observed on wounded and unwounded rootstocks on the number of days to shoot and leaf emergence, as well as on the number of leaves. The use of scion subjected to flowing water treatment significantly gave higher percentage graft-take compared to other scion pre-grafting treatments (scions without pre-grafting and cold temperature treatments).

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