EFFECT OF INDOLEBUTYRIC ACID, GIRDLING, AND WOUNDING ON ROOTING OF *ARTOCARPUS HETEROPHYLLUS* L. CUTTINGS

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ABSTRACT

Effects of girdling, wounding, different concentrations of indolebutyric acid (IBA), and stem maturity on the rooting of jackfruit stem cuttings under intermittent mist were evaluated. Stems were girdled and allowed to remain on the trees for 40 days. Girdled and non-girdled cuttings were treated with 0, 5000, and 10000 ppm IBA and inserted in a 1 vermiculite:1 perlite (by volume) mixture. Two wounding cuts were made at the base of half of the cuttings. Wounded and non-wounded cuttings were treated with IBA and placed in the medium described earlier. In the absence of IBA there was no rooting on any cuttings. Significant girdling by IBA by stem maturity interaction was observed with respect to rooting index, percent rooting, length of primary roots, fresh and dry weights of roots, and dry matter content of roots. Wounding did not increase the rooting of cuttings. There was no significant difference in rooting percentages of wounded and non-wounded cuttings between 5000 and 10000 ppm IBA. However, girdled cuttings of semi-hardwood stems gave the highest percentage of rooting (77%) with 10000 ppm IBA. Induction of primary roots per cutting increased with IBA. Girdled cuttings of semi-hardwood stems produced a greater number of vegetative shoots than non-girdled cuttings. Higher concentration of IBA decreased the number of vegetative shoots per cutting. Total sugar and starch content in girdled cuttings was significantly higher than that of the non-girdled cuttings.

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CHAPTER I

INTRODUCTION

Jackfruit (Artocarpus heterophyllus L.) is an important and popular fruit of Southeast Asia. It is used as a vegetable in the green stage and as a fruit when it ripens. The fruit is rich in carbohydrate and is one of the supplemental foods of the rural people in the eastern part of India, Srilanka, and Bangladesh. During the summer months poor people live on this fruit; therefore, it is often called "poor man's food". Besides being used as a table fruit, it can be used for making confectioneries such as jam, jelly, syrup, candy, and canned fruit. Jackfruit seed is a good source of starchy flour.

Jackfruit (family Moraceae) is indigenous to India. It is an evergreen monoecious tree growing to about 20 m tall. It produces large fruits which are borne along the trunk and the main branches. The large fruits can weigh up to 40 kg (Singh, 1969). Jackfruit is usually propagated by seeds so there is considerable variation among trees, particularly in the shape, size, and quality of the fruits. Another critical disadvantage of this method is that the seedling trees generally take from 4 to 8 years to come into bearing in south India, and in cooler regions it may take up to 14 years to fruit (Singh, 1961). On the other hand, the vegetative method of propagation has been found to reduce the time required for trees to come into bearing. In cooler regions, vegetative propagation hastens time to bearing considerably and thus helps to overcome a serious economic problem (Rao, 1965; Singh, 1961). In view of this, commercial jackfruit should be propagated by vegetative means to maintain fruit shape, size, quality, and to hasten bearing.

Propagation of fruit trees by cuttings is one of the easiest and least expensive methods of vegetative propagation. However, there are some species in which root initiation in cuttings does not occur easily. Jackfruit is one of them. Little work has been done on propagating jackfruit by stem cuttings. Additional research is required to standardize the method of propagating jackfruit by stem cuttings. Therefore, the following experiments were undertaken 1) to determine the effects of indolebutyric acid, girdling, and age of cutting on rooting of cuttings; 2) to determine the percentages of sugar and starch in the girdled and non-girdled cuttings; and 3) to determine the effects of wounding and indolebutyric acid on rooting of cuttings.

CHAPTER II

REVIEW OF LITERATURE

In herbaceous plants adventitious roots usually originate just outside and between the vascular bundles (Priestly and Swingle, 1929). On the other hand, in woody perennial plants, where one or more layers of secondary xylem and phloem are present, adventitious roots in stem cuttings usually originate in the young secondary phloem, although they may also arise from other tissues such as vascular rays, cambium, lenticels, or pith (Curtis, 1918; Kraus et al. 1936).

Lek (1925) found that sprouting buds promote the rooting of cuttings in willow, poplar, currant, and grape.

The rooting ability of the cutting can be altered by girdling, wounding, or chemical treatments. Girdling is used to increase the rooting of cuttings in propagating media (Garner, 1944; Higdon and Westwood, 1963; Hunter,1932; Jauhari and Rahman, 1958; Mendes, 1959; Thakurta and Dutt, 1941) and to stimulate root initiation in situ in various types of layering (Higdon and Westwood, 1963). Stoltz and Hess (1966) reported that rooting cofactors 1, 2, and 4 were found in the tissues above and below the girdle of two hibiscus varieties. The concentration of the auxin decreased after girdling in most tissues. There was a substantial increase of rooting cofactor 4 in the tissues above the girdle of the easy-to-root variety, but not in the difficult-to-root variety or in the tissues below the girdle of either variety. Dhua (1983) reported 90 percent success in rooting jackfruit stem cuttings from etiolated and girdled shoots treated with 3000 ppm IBA in combination with 2000 ppm ferulic acid.

The rooting of cuttings is stimulated by endogenous substances moving from the leaves to the base of the cutting (Sachs, 1882). The importance of carbohydrates in root formation of cuttings has been emphasized by several investigators (Kraus and Kraybill, 1918; Reid, 1926; Schradar, 1924; Starring, 1923). Scott (1972) reported that auxin moves from the top to the bottom of the plant, and root growth and development appear to be a consequence of this pattern of auxin movement.

There are differences in rooting responses between different parts of the shoots. Loreti and Hartmann (1964) reported that woody basal portions of one-year-old leafy stem root more readily than the soft terminal section in olive.

The majority of earlier investigations showed negative results with different methods of vegetative propagation of jackfruit (Khan, 1946). Recently, it has been found jackfruit can be propagated vegetatively by layering, budding, grafting, and stem cutting (Biswas and Hossain, 1984; Chatterjee and Mukherjee, 1980a; Chatterjee and Mukherjee, 1980b; Jauhari and Mehra, 1960; Mukherjee and Chatterjee, 1979; Rao, 1965; Sen and Bose, 1959; Singh, 1955; Teaotia et al. 1963). However, very little work has been done on propagating jackfruit by stem cutting.

Most of the earlier trials on propagation by cutting were unsuccessful. Artocarpus species can be propagated by cuttings of young lateral growth (Anonymous, 1935), but this requires pruning to encourage lateral branching as a preparatory step for making cuttings. Morton (1966) reported cuttings of young wood root under mist. Only in one trial was a low percentage of rooting obtained. At the Madras

State Fruit Stations, hardwood cuttings of all types failed to root (Khan, 1946). At Burlier, no rooting was obtained with heeled, slit, or nontreated shoot cuttings made in November and February or on cuttings of the current season's wood, previous season's wood, or old wood taken at intervals throughout the year.

Use of growth substances produced no improvement in rooting in a trial at the National Botanic Garden, Lucknow (Singh, 1955). In this trial apical, semi-hardwood, and hardwood cuttings were treated with IPA (indolepropionic acid) at 100 ppm, NAA (naphthaleneacetic acid) at 500 ppm and 1000 ppm, and combinations of NAA 500 ppm + IAA (indoleacetic acid) 500 ppm and NAA 1000 ppm + IAA 1000 ppm. No rooting was obtained with any of the treatments.

The method which has been successful is the double-stimulant polyethylene bag method used by Hurov in Sabah (Lambourne, 1976; Leon, 1968). Using semi-hardwood cuttings, he immersed the bases of cuttings for 12-14 hours in 100-300 ppm of various stimulatory chemicals (including two fungicides, two dyes, vinegar, and oxalic acid) followed by a quick dip treatment in 2000 ppm IBA (indolebutyric acid). The cuttings were then rooted in closed polyethylene bags. This double chemical treatment resulted in 20-30% rooting but no rooting by cuttings treated with IBA alone.

Recently, the successful rooting of cuttings of jackfruit induced by using plant growth regulators is receiving considerable attention. Mukherjee and Chatterjee (1979) obtained maximum rooting (84%) and survival (50-75%) of jackfruit cuttings by using forced and etiolated shoots treated with 5,000 ppm IBA. The next best treatment was forced and etiolated shoots treated with 10,000 ppm IBA and forced non-etiolated shoots treated with 5,000 ppm IBA. No rooting was obtained unless shoots (whether forced and etiolated or not) were dipped in IBA before inserting in the rooting medium. Chatterjee and Mukherjee (1980a) found leafy cuttings with 2-3 leaves or non-leafy cuttings, when dipped in 5,000 and 10,000 ppm of IBA, resulted in 90 and 60% rooting, respectively, after 45 days. Control treatments, and non-leafy cuttings with IBA at 5000 ppm and 10000 ppm did not root.

The planting medium for propagating cuttings influences the successful induction of rooting. Chatterjee and Mukharjee (1980b) reported that of three media (vermiculite, leaf mould, and sand) used for planting of cuttings, vermiculite proved to be the best with 86% rooting and 58% survival, whereas sand was the worst with 70% rooting and 43% survival after 1 year.

Wounding disrupts schlerenchymatous tissue that helps root emergence in stem cuttings. Root production on stem cuttings can be promoted by wounding in a number of plant species such as juniper, arborvitae, rhododendron, maple, magnolia, and holly (Wells, 1962). Wounded cuttings of invigorated shoots of jackfruit treated with 5,000 ppm IBA resulted in 75-77% rooting 46-66% survival. On the other hand, non-wounded cuttings yielded only 67% rooting and 38% survival (Chatterjee and Mukherjee 1981). However, Reddy (1974) did not find any promoting effect of wounding in rooting of cutting of mango and guava.

CHAPTER III

EFFECTS OF INDOLEBUTYRIC ACID, GIRDLING, AND AGE OF CUTTING ON ROOTING OF JACKFRUIT STEM CUTTINGS

Abstract

A factorial experiment with 2 levels of stem girdling (girdled and non-girdled), 3 levels of indolebutyric acid (IBA) (0, 5,000, and 10,000 ppm), and 2 levels of stem maturity (softwood and semi-hardwood) was conducted to evaluate the effects of girdling, IBA, and maturity on the rooting of jackfruit stem cuttings. Stems were girdled and allowed to remain on the trees for 40 days. Cuttings were treated with 0, 5,000, or 10,000 ppm IBA and placed in 1 vermiculite:1 perlite (by volume) mixture under intermittent mist. There was no rooting of either softwood or semi-hardwood stems at 0 ppm IBA. Significant girdling by IBA by stem maturity interaction was observed with regard to rooting index, percent rooting, length of primary roots, fresh and dry weights of roots, and dry matter content of roots. The highest rooting, 77 percent, was obtained by treating girdled cuttings of semi-hardwood stems with 10,000 ppm IBA. The number of primary roots per cutting increased with IBA concentration. The number of vegetative shoots on girdled cuttings of semi-hardwood stems was significantly greater than on non-girdled cuttings. The percentages of total sugar and starch were significantly higher in girdled cuttings than in non-girdled cuttings.

Introduction

Rooting in stem cuttings is stimulated by substances translocated from the leaves to the base of the cutting (Kato and Ito, 1917). This inherent ability of the cutting to form roots can be altered by pretreatments such as girdling, wounding, or chemical treatment to improve rooting in difficult-to-root plant species (Garner, 1944; Higdon and Westwood, 1963; Hunter, 1932; Jauhari and Rahman, 1958; Mendes, 1959; Thakurta and Dutt, 1941). Also, it is now well known that there are differences in rooting responses between cuttings of different maturities (Loretis and Hartmann, 1964).

Jackfruit is a difficult-to-root plant, but there are strong horticultural and economic reasons for developing a method to propagate jackfruit from stem cuttings. The present investigation was, therefore, undertaken to determine the effect of girdling, IBA, and stem maturity on rooting of jackfruit stem cuttings.

Materials and Methods

This experiment was conducted at the University of Hawaii at Manoa from September 9 to November 19, 1984. Branches of jackfruit trees at the Waiakea Experiment Station and the U.S. Department of Forestry Arboretum (Hilo) were girdled on July 30, 1984. Girdling was done by removing a complete ring of bark 0.5 cm wide on the stem. Forty days later, cuttings were taken from girdled and non-girdled branches. One or two cuttings were made per branch. The succulent tip, approximately 5 cm of the stem was not used in the experiment. The cutting made below this succulent portion of the stem was designated the "softwood" cutting, and the cutting made from the same stem below the softwood cutting or from a different stem at the same position was designated the "semi-hardwood" cutting. Average diameters of the girdled and non-girdled cuttings at the base were 3.2 and 2.2 mm, respectively. Mean length of girdled and non-girdled cuttings was 13.2 cm. Three leaves were kept on each cutting with the leaves trimmed in half to reduce transpiration which increases the life of the cuttings for better rooting.

The experiment was a 3 X 2 X 2 factorial design with 3 levels of indolebutyric acid (IBA) (0, 5,000, and 10,000 ppm), 2 levels of stem girdling (non-girdled and girdled), and 2 levels of stem maturity (softwood and semi-hardwood). All treatments were replicated 5 times. Number of cuttings per replication was 5. IBA (United States Biochemical Corporation, Cleveland, Ohio 44128) was not readily soluble in water so it was first dissolved in 50 percent ethyl alcohol

(95%),and then the desired volume was achieved with distilled water. The girdled and non-girdled cuttings were dipped in the IBA solutions for 5 seconds followed by a captan powder (25%) coating at the base of the cuttings to avoid fungal diseases. The cuttings were then inserted in flats in a 1 vermiculite: 1 perlite (by volume) mixture. Cuttings were placed under intermittent mist in a saranhouse at the Magoon Facilities. Misting frequency was 4 seconds of spray per minute.

The effects of IBA, girdling, and age of the cutting on rooting were evaluated by percentage of rooting, number of primary roots per cutting, length of primary roots, fresh and dry weight of roots, % dry matter content of roots [(dry wt./fresh root wt.)X100], and rooting index. Rooting index is a subjective assessment of the quality and quantity of roots on cuttings. It is measured by grouping the cuttings into categories including no rooting (1), light rooting (2), medium rooting (3), and heavy rooting (4). The growth and development of new vegetative shoots were also observed. Data were statistically analyzed by analysis of variance, Duncan's multiple range test, Bayes least significant difference, t-test, and regression analysis. The percentage of rooting data were arcsine transformed before analysis.

Chemical analysis of sugar and starch of jackfruit stem cuttings

Chemical analyses were carried out for the quantitative determination of total sugar and starch in the girdled and non-girdled branches of jackfruit. The girdled and non-girdled branches were obtained from trees at the Waiakea Experiment Station and the U.S Department of Forestry Arboretum (Hilo) on September 10, 1984. The branches were kept overnight under intermittent mist in a saranhouse at Magoon. On the following day, the cuttings were prepared for rooting as previously described, and sample cuttings for chemical analysis were taken and stored in a cold room at 0°C for one day.

Procedure for sugar determination

Two-gram stem samples were taken from the basal end of girdled and non-girdled branches. The stems were cut into small pieces to make a homogenous mass. The samples were replicated five times. The samples were homogenized in 18 ml ethyl alcohol (95%), and the ethanol was filtered. One ml of ethanol filtrate (filtered portion) was used for the determination of total sugar in the sample. Twenty-five ul phenol, 80% by weight, and 2.5 ml concentrated sulfuric acid was added in the ethanol solution and mixed. After 10 minutes, the solution was mixed again thoroughly. The absorbance of the characteristic yellow orange color was measured at 485 nm with a spectrophotometer (Spectronic 20, Bausch & Lomb) (Davis, 1984). Percentage of total sugar was calculated on a dry weight basis, and the data were statistically analyzed by analysis of variance and t-test. The percentage of sugar data were arcsine transformed before analysis.

Procedure for starch determination

The very low amounts of starch in the jackfruit stem sections were estimated as follows: ethanol insoluble (filtered out portion) was washed repeatedly by ethyl alcohol (95%) and oven dried at 60°C for 24 hours. The starch was dissolved in 1N NaOH in a boiling water bath (Outlaw, 1979), a process that also destroyed any remaining reducing materials (Lust et al., 1975). Neutralized samples were then hydrolized with amyloglucosidase in 0.1M acetate buffer, pH 4.4.

The reducing materials formed were assayed by the Nelson-Somogyi method (Marais et al., 1966). The absorbance of the characteristic blue color was read at 540 nm with a spectrophotometer.

Results

The percentage of rooting increased as the IBA concentration increased (Table 1). No rooting occurred with 0 ppm IBA. Significant girdling by IBA by stem maturity interaction on percentage of rooting of cuttings was observed (Appendix Table 1). The percentage of rooting increased in girdled and non-girdled cuttings of softwood and semi-hardwood stems as the concentration of IBA increased (Table 2). In softwood stems, maximum rooting occurred in non-girdled cuttings at 10,000 ppm IBA. In semi-hardwood stems the highest percentage of rooting (77.0) was obtained in girdled cuttings at 10,000 ppm IBA. The percentages of rooting obtained by girdled and non-girdled cuttings of softwood and semi-hardwood stems with IBA were significantly greater than that of the controls. In inducing roots, 5,000 and 10,000 ppm IBA were significantly different between girdled and non-girdled cuttings of softwood and semi-hardwood stems. Significant girdling by IBA by stem maturity interaction was observed with respect to rooting index (Appendix Table 2). For softwood stems the rooting index increased in non-girdled cuttings with increases in IBA concentration (Table 3). Rooting indices of non-girdled cuttings at 5,000 and 10,000 ppm IBA were not significantly different. However, IBA was not effective in girdled cuttings. In semi-hardwood stems, the rooting index increased in non-girdled cuttings with IBA concentration (Table 3). The rooting index of girdled cuttings increased with 10,000 ppm IBA. Production of primary roots in jackfruit cuttings increased with 10000 ppm IBA (Table 4). Number of primary roots produced by 0 and 5000 ppm IBA was not significantly different.

Primary root length was influenced by stem maturity. Maximum length of roots was produced by cuttings taken from semi-hardwood stems (Table 5). Significant interaction between cutting type, IBA, and stem type on root length was observed (Appendix Table 4). For softwood stems root length of non-girdled cuttings increased with 10,000 ppm IBA (Table 6). IBA did not affect root length of girdled cuttings. For semi-hardwood stems, root length of non-girdled cuttings was greatest at 5,000 ppm IBA (Table 6). Root length of girdled cuttings increased with 10,000 ppm IBA. In semi-hardwood stems, root length obtained by non-girdled cuttings with 5,000 ppm IBA and girdled cuttings with 10,000 ppm IBA were 10.58 and 9.20 cm, respectively, which were significantly greater than that of the root lengths obtained by other treatments.

Mean root fresh weight of semi-hardwood stems was significantly greater than that of the softwood stems (Table 7). The fresh weight of roots was not affected by cutting type and IBA for softwood stems (Table 8). For semi-hardwood stems, the fresh weight of roots from non-girdled cuttings increased with IBA. The fresh weight of roots from girdled stems increased with 10,000 ppm IBA. The maximum root fresh weight (1.49 g) was obtained by girdled cuttings taken from semi-hardwood stem at 10,000 ppm IBA. Cuttings taken from semi-hardwood stems gave greater root dry weight than the cuttings from softwood stems (Table 9). In softwood stems, cutting type and IBA did not affect root dry weight (Table 10). In semi-hardwood stems, dry weight of roots of non-girdled cuttings increased with IBA. Root dry weight of girdled cuttings increased with 10000 ppm IBA. Significant interaction between cutting type, IBA, and stem type on dry matter content of root was observed (Appendix Table 7). Dry matter content of roots in girdled and non-girdled cuttings of softwood and semi-hardwood stems increased with IBA (Table 11). Maximum dry matter content of root (18.35%) occurred in non-girdled cuttings at 10,000 ppm IBA when the cuttings were taken from softwood stems. In semi-hardwood stems, dry matter accumulation in root was greatest in non-girdled cuttings treated with 5,000 ppm IBA.

After 40 days girdled branches had significantly higher percentages of total sugar and starch than non-girdled branches (Tables 12 and 13) (Appendix Tables 8 and 9).

During rooting of the cuttings, vegetative buds started to grow in the leaf axils on the cuttings. There was a significant maturity by girdling interaction with regard to the number of vegetative shoots on cuttings (Appendix Table 10). For semi-hardwood stems the number of vegetative shoots on non-girdled cuttings was significantly greater than that on girdled cuttings (Table 14). However, there was no significant difference with girdled and non-girdled cuttings of softwood stems. During rooting of cuttings under mist, some of the leaves turned yellow and abscised. Non-girdled cuttings retained a greater number of leaves per cutting than the girdled cuttings after 45 days (Table 15). It was also observed that stem maturity had a significant effect on the retention of leaves on the cuttings (Appendix Table 11). Cuttings obtained from softwood stems retained a greater number of leaves per cutting than those from semi-hardwood stems (Table 16).

Discussion

In jackfruit stem cuttings no rooting occurred without IBA treatment. The effect of IBA on rooting of cuttings was influenced by girdling and stem maturity. The highest percentage of rooting was obtained in girdled cuttings of semi-hardwood stem (Table 2). This agrees with the findings of Dhua et al. (1983) who obtained 90 percent rooting in semi-hardwood stem cuttings of jackfruit by etiolated and ringed shoots treated with IBA and ferulic acid. Loreti (1964) found that the basal portion of one-year-old stems of olive rooted more readily than the soft terminal portion of the stems. The second highest rooting, 53.6 percent occurred in non-girdled cuttings of semi-hardwood stems treated with 5000 ppm IBA (Table 2). However, in softwood stems, 5,000 and 10,000 ppm IBA treatment was not significantly different in inducing roots. The highest rooting, 77 percent produced by girdled cuttings of semi-hardwood stems may be due to higher percentages of total sugar and starch in the cuttings (Tables 12 and 13) (Kraus and Kraybill, 1918; Reid, 1926; Schradar, 1924; Starring, 1923) and to the inducing effect IBA. Higher percentages of rooting obtained by non-girdled cuttings may be due to inducing effect of IBA.

Rooting index is used as an indicator to determine the quality and quantity of rooted cuttings. Rooting index is correlated with the percentage of rooted cuttings, number of primary roots per cutting, and length of roots. IBA at 10,000 ppm induced the maximum number ofprimary roots per cutting. This agrees with the observations of Dhua et al. (1983) who obtained the highest number of primary roots per cutting in jackfruit with 10,000 ppm IBA. Greater number of primary roots per cutting may be due to the root formative effect of IBA and regenerating capacity of the stem cuttings. Maximum length of primary roots in the cuttings of semi-hardwood stems may be due to the stored carbohydrates in the cuttings and to the cell dividing effect of IBA (Haissig, 1972). Number of primary roots per cutting and length of primary roots influence the significant girdling, IBA, and stem maturity interaction on rooting index.

Quality of roots is also determined by the fresh and dry weight of roots and percent dry matter in roots. Increased root fresh and dry weight in cuttings taken from semi-hardwood stems may be due to the supply of more carbohydrates by the leaves and stem to the roots. Fresh and dry weight of roots was not affected by girdling and IBA when the cuttings were taken from softwood stems. However, girdled cuttings of semi-hardwood stems produced maximum root fresh and dry weights with 10,000 ppm IBA. This may be explained by the greater number of primary roots produced by IBA. Girdling, IBA, and stem maturity had a significant interaction in accumulating dry matter in roots. Maximum accumulation of dry matter occurred in the non-girdled treatment of softwood stems. Non-girdled cuttings of softwood stems retained a greater number of leaves; hence, highest dry matter content in roots may be explained by the accumulation of carbohydrates translocated from the leaves to the roots.

Growing buds on the cuttings promote the development of roots in cuttings of a number of plant species (Lek, 1925). In the present experiment there was no significant difference in bud development between girdled and non-girdled cuttings in softwood stems (Table 14). However, in softwood stems, highest rooting was obtained with non-girdled cuttings at 10,000 ppm IBA. On the other hand, non-girdled cuttings produced a greater number of vegetative buds in semi-hardwood stems, but girdled cuttings gave the highest percentage of rooting. Thus, it seems to indicate that sprouting buds on jackfruit cuttings did not increase rooting of cuttings.

Table 1. Effect of IBA on percentage of rooting of jackfruit cuttings.

IBA (ppm)	Rooting (%)
0	0.0 c[z]
5000	26.2 b
10000	47.4 a

[z]Means with main effect separated by Duncan's multiple range test, 5% level.

Table 2. Effect of girdling, IBA, and stem maturity on percentage of rooting of jackfruit cuttings.

		Rooting (%)	
Girdling	IBA (ppm)	Softwood stem	Semi-hardwood stem
Non-girdled	0	0.0 b[z]	0.0 d
	5000	20.3 ab	53.6 ab
	10000	46.1 a	34.1 bc
Girdled	0	0.0 b	0.0 d
	5000	16.8 ab	12.2 cd
	10000	26.5 ab	77.0 a

[z]BLSD at 5% level for interaction (girdling, IBA, and stem maturity) =34.

Table 3. Effect of girdling, IBA, and stem maturity on rooting index of jackfruit cuttings.

Girdling	IBA (ppm)	Rooting index^z Softwood stem	Rooting index^z Semi-hardwood stem
Non-girdled	0	1.00 b^y	1.00 c
	5000	1.24 ab	2.04 ab
	10000	1.72 a	1.60 b
Girdled	0	1.00 b	1.00 c
	5000	1.28 ab	1.12 cb
	10000	1.60 ab	2.52 a

^{z}Rooting index reflects the quality and quantity of rooted cuttings 10 weeks after planting. 1=no rooting, 2=light rooting, 3=medium rooting, 4=heavy rooting.

^{y}BLSD at 5% level for interaction (girdling, IBA, and stem maturity) =0.59.

Table 4. Effect of IBA on the number of primary roots per cutting.

IBA (ppm)	Primary roots/cutting
0	0.0 b[z]
5000	3.3 b
10000	11.4 a

[z]Means with main effect separated by Duncan's multiple range test, 5% level. Includes non-rooted cuttings.

Table 5. Effect of stem maturity on the length of primary roots of jackfruit cuttings.

Stem maturity	Length of roots (cm)
Softwood	1.86 b[z]
Semi-hardwood	4.15 a

[z]Means with main effect separated by t-test, 5% level. Includes non-rooted cuttings.

Table 6. Effect of girdling, IBA, and stem maturity on the length of primary roots of jackfruit cuttings.

		Length of roots (cm)	
Girdling	IBA (ppm)	Softwood stem	Semi-hardwood stem
Non-girdled	0	0.00 b[z]	0.00 c
	5000	0.74 ab	10.58 a
	10000	4.69 a	4.31 b
Girdled	0	0.00 b	0.00 c
	5000	2.49 ab	0.83 bc
	10000	3.21 ab	9.20 a

[z]BLSD at 5% level for interaction (girdling, IBA, and stem maturity) =3.99. Includes non-rooted cuttings.

Table 7. Effect of stem maturity on fresh weight of roots of jackfruit cuttings.

Stem maturity	Root fresh weight (g)
Softwood	0.15 b^{z}
Semi-hardwood	0.51 a

^{z}Means with main effect separated by t-test, 5% level. Includes non-rooted cuttings.

Table 8. Effect of girdling, IBA, and stem maturity on fresh weight of roots of jackfruit cuttings.

		Fresh weight of roots (g)	
Girdling	IBA (ppm)	Softwood stem	Semi-hardwood stem
Non-girdled	0	0.00 a[z]	0.00 d
	5000	0.04 a	0.80 b
	10000	0.32 a	0.65 bc
Girdled	0	0.00 a	0.00 d
	5000	0.14 a	0.13 cd
	10000	0.36 a	1.49 a

[z]BLSD at 5% level for interaction (girdling, IBA, and stem maturity) =0.56. Includes non-rooted cuttings.

Table 9. Effect of stem maturity on dry weight of roots of jackfruit cuttings.

Stem maturity	Root dry weight (g)
Softwood	0.03 b[z]
Semi-hardwood	0.07 a

[z]Means with main effect separated by t-test, 5% level. Includes non-rooted cuttings.

Table 10. Effect of girdling, IBA, and stem maturity on dry weight of roots of jackfruit cuttings.

		Dry weight of roots (g)	
Girdling	IBA (ppm)	Softwood stem	Semi-hardwood stem
Non-girdled	0	0.00 a[z]	0.00 d
	5000	0.01 a	0.12 ab
	10000	0.06 a	0.09 b
Girdled	0	0.00 a	0.00 d
	5000	0.04 a	0.02 cd
	10000	0.06 a	0.18 a

[z]BLSD at 5% level for interaction (girdling, IBA, and stem maturity) =0.07. Includes non-rooted cuttings.

Table 11. Effect of girdling, IBA, and stem maturity on dry matter content of roots of jackfruit cuttings.

		Dry matter (%)[z]	
Girdling	IBA (ppm)	Softwood stem	Semi-hardwood stem
Non-girdled	0	0.00 c[y]	0.00 b
	5000	3.94 bc	17.06 a
	10000	18.35 a	8.69 ab
Girdled	0	0.00 c	0.00 b
	5000	9.93 ab	3.14 b
	10000	7.48 bc	14.26 a

[z]% dry matter = (dry root weight/fresh root weight)X100.

[y]BLSD at 5% level for interaction (girdling, IBA, and stem maturity) =9. Includes non-rooted cuttings.

Table 12. Sugar analysis for girdled and non-girdled branches of jackfruit.

Girdling	Total sugar (%)^z
Non-girdled	2.81 b^z
Girdled	20.75 a

^{z}Mean separation within column by t-test, 5% level.

Table 13. Starch analysis for girdled and non-girdled branches of jackfruit.

Girdling	Starch (%)^z
Non-girdled	0.54 b^z
Girdled	3.52 a

^{z}Mean separation by column by t-test, 5% level.

Table 14. Effect of stem maturity and girdling on the number of new vegetative shoots on jackfruit cuttings.

Stem maturity	Girdling	Number of vegetative shoots per cutting
Softwood	Girdled	1.43 a[z]
	Non-girdled	1.30 ab
Semi-hardwood	Girdled	0.86 b
	Non-girdled	1.44 a

[z]BLSD (Bayes Least-Significant Difference) at 5% level for interaction (stem maturity and girdling)=0.54. Includes non-rooted cuttings.

Table 15. Effect of girdling on the retention of leaves on jackfruit cuttings during rooting.

Girdling	Number of leaves/cutting
Girdled	1.45 b[z]
Non-girdled	2.25 a

[z]Means with main effect separated by t-test, 5% level. Includes non-rooted cuttings.

Table 16. Effect of stem maturity on the retention of leaves on jackfruit cuttings during rooting.

Stem maturity	Number of leaves/cutting
Softwood	2.31 a[z]
Semi-hardwood	1.39 b

[z]Means with main effect separated by t-test, 5% level. Includes non-rooted cuttings.

CHAPTER IV

EFFECTS OF WOUNDING AND INDOLEBUTYRIC ACID ON ROOTING OF JACKFRUIT STEM CUTTINGS

Abstract

A factorial experiment with 3 levels of indolebutyric acid (IBA) (0, 5000, and 10000 ppm) and 2 levels of wounding (non-wounded and wounded) was conducted to determine the effects of IBA and wounding on the rooting of jackfruit stem cuttings. The wounded and non-wounded cuttings were treated with IBA and placed in a 1 vermiculite: 1 perlite (by volume) mixture under intermittent mist. There was no rooting with 0 ppm IBA. IBA significantly increased rooting percentage, number of primary and secondary roots per cutting, length of primary roots, root fresh and dry weights, dry matter content, and rooting index. However, there was no significant difference between the 5000 and 10000 ppm IBA treatments. Wounding did not affect the rooting of cuttings. IBA at 10000 ppm significantly decreased the number of vegetative shoots per cutting.

Introduction

Root induction on stem cuttings can be promoted by wounding the base of the cutting in a wide variety of plant species (Wells, 1962). Wounding is of special advantage with cuttings of some difficult-to-root plants in which continuous sclerenchyma rings between the phloem and cortex constitute an anatomical barrier to rooting. Wounding disrupt schlerenchyma ring that helps root emergence in stem cuttings. Day (1932) indicated that wounding had a definite effect upon the rapidity and quantity of water absorbed by the unrooted cuttings of California Privet, Chaenomeles, and Muscat grapes and resulted in higher rooting. Wounding may also increase the uptake of auxin.

Chatterjee and Mukherjee (1981) reported that invigoration, wounding, and 5000 ppm IBA gave a higher percentage of rooting over invigorated, non-wounded and non-invigorated, non-wounded jackfruit cuttings. Mukherjee and Chatterjee (1979) also pointed out that no rooting was obtained in jackfruit cuttings without IBA even under forcing, etiolation, and wounding. Although invigoration and etiolation of shoots before making the cuttings promote better rooting, these are time consuming processes whereas wounding is quickly accomplished. The present study was, therefore, undertaken to determine the effect of IBA and wounding on rooting of jackfruit cuttings.

Materials and Methods

This experiment was conducted at the University of Hawaii at Manoa from July 11 to September 11, 1985. The experiment was carried out in a 3 X 2 factorial with 3 levels of indolebutyric acid (IBA) (0, 5,000, and 10,000 ppm) and 2 levels of wounding (non-wounded and wounded). Semi-hardwood stems were obtained from the Lyon Arboretum, Manoa. Green, smooth stems having a diameter of 3 to 3.5 mm were taken from a healthy jackfruit tree. The average length of the cuttings was 10.5 cm. To wound the cuttings a vertical strip of bark, 1 to 1.5 cm long and 0.2 to 0.3 cm wide, was removed on each side of the base of the cutting. This was done to 50% of the cuttings. Three leaves were kept on all cuttings with the leaves trimmed 50% to reduce transpiration and thereby increase the longevity of the cutting.

Indolebutyric acid is not readily soluble in water; therefore, the required quantity of IBA was first dissolved in 50 percent ethyl alcohol, and then the desired volume was achieved with distilled water. The 0 ppm IBA solution was prepared with an equal volume of ethyl alcohol (95%) and distilled water.

The wounded and non-wounded cuttings were dipped in the 0, 5,000, and 10,000 ppm IBA solutions for 5 seconds. The bases of the cuttings were coated with 25 percent captan powder to avoid fungal diseases. The cuttings were inserted in flats in a 1 vermiculite: 1 perlite (by volume) mixture. All the treatments were replicated 4 times. Total number of cuttings per replication was 10. The flats were placed under intermittent mist in a saranhouse at the Magoon Facilities. The misting spray was 5 seconds per minute for the first 35 days and 5 seconds spray per 2.5 minutes for the remaining 27 days of the experiment.

The root inducing effects of IBA and wounding were evaluated 9 weeks after planting. The evaluation was based on the percentage of rooted cuttings, number of primary and secondary roots per cutting, length of primary roots, fresh and dry weight of roots, dry matter content of roots [(dry wt./fresh root wt.)X100], rooting index, and the subsequent growth and development of new vegetative shoots. Rooting index is a subjective assessment of the quality and quantity of roots on cuttings. It is measured by grouping the cuttings into categories including no rooting (1), light rooting (2), medium rooting (3), and heavy rooting (4). All the data were subjected to analysis of variance, Duncan's multiple range test, and regression analysis. Data for percent rooted cuttings and dry matter content of roots were arcsine transformed before analysis.

Results

Root induction did not occur in the absence of IBA on either wounded or non-wounded cuttings. With IBA treatment,the percentage of rooting, rooting index, number of primary and secondary roots per cutting, length of primary roots, dry and fresh weight of roots, and dry matter content of roots increased in both wounded and non-wounded cuttings (Tables 17, 19, 21, 23, 25, 27, 28, and 31). For the above parameters the IBA treatments were significantly greater than the control (Tables 18, 20, 22, 24, 26, 29, 30, and 32), but there were no significant differences between 5,000 and 10,000 ppm IBA.

There was no significant difference between wounded and non-wounded cuttings with respect to the above parameters (Appendix Tables 12, 13, 14, 15, 16, 17, 18, and 19).

During rooting of cuttings, new vegetative shoots developed on the cuttings. The number of vegetative shoots per cutting decreased in wounded and non-wounded cuttings at the higher concentration of IBA (Table 33), and this decrease was significant at 10,000 ppm (Table 34). Wounding had no significant effect on the number of vegetative shoots on cuttings (Appendix Table 20), nor was there a significant difference between 0 and 5,000 ppm IBA with regard to vegetative shoot development.

During rooting, some of the leaves turned yellow and abscised. The number of leaves retained per cutting after 54 days by non-wounded and wounded cuttings was significantly different (Appendix Table 21).

Discussion

The results of the experiment showed that there was no significant difference in rooting percentage with IBA between wounded and non-wounded cuttings. Wounding at the base of the cutting did not increase rooting in jackfruit. This agrees with the findings of Reddy (1974) who did not get any promoting effect on rooting percentage with wounding in mango and guava, but does not agree with Chatterjee and Mukherjee (1981) who obtained higher percentage of rooting on jackfruit cuttings with invigorating, wounding, and IBA. Callus formation at the base of the cutting was observed in most of the wounded and non-wounded cuttings. Thus, there was no relation between wounding and callusing. There was also no relation between callusing and rooting on cuttings. So, it seems that the formation of callus and the formation of roots are independent in jackfruit. Root emergence on cuttings was observed at the node and internode. No rooting occurred at the base of the cuttings through callus which indicated that there was no mechanical barrier to rooting of cuttings in jackfruit. Stangler (1956) found that the root primordium in carnation grow outward until it reaches the fibers of the pericycle, then grow downward, and emerge through the basal cut surface of the cutting.

Root production in jackfruit cuttings may be explained due to the inducing effect of IBA. The development of root initial cells are dependent upon either applied or endogenous auxin (Haissig, 1972). Without IBA, wounded and non-wounded cuttings did not produce any roots. This seems to indicate that the endogenous auxin level in jackfruit stems was too low to induce root initiation. However, cuttings treated with IBA produced an appreciable percentage of rooting.

IBA induced higher numbers of primary and secondary roots per cutting and greater length of primary roots. This agrees with the observations of Mukherjee and Chatterjee (1979) who obtained a greater number of primary roots with IBA in etiolated shoots and the greatest length of primary roots with IBA, etiolated, and forced cuttings in jackfruit. Greater numbers of primary and secondary roots per cutting may be due to the root formative effect of IBA (Thimann, 1935). Greater length of the primary roots may be explained by IBA reacting on the cell wall causing expansion of the cells, cell division of meristematic cells, and subsequent enlargement of the primary roots (Haissig, 1972). Fresh and dry weight of roots were greater with IBA. This may be due to the greater production of primary and secondary roots on cuttings by IBA (Tables 22 and 24). Dry matter content of roots was also increased with IBA which indicated that IBA produced better quality roots on cuttings. Roots act as a metabolic sink for carbohydrates translocated from leaves and shoots resulting in a greater accumulation of dry matter in roots. Rooting index is generally used as an indicator for determining the quality and quantity of rooted cuttings. Rooting index was significantly greater with IBA (Table 20). Rooting index is directly correlated with percentage of rooted cuttings, number of primary and secondary roots per cutting, and length of primary roots. Since auxin has a promotive effect on these rooting characters, rooting index is, therefore, directly influenced by IBA.

Sprouting buds promote the development of roots in cuttings of a number of plants such as willow, poplar, currant, and grapes (Lek, 1925). It is assumed that hormone-like substances are formed in the developing buds and translocated through the phloem to the base of the cuttings where they stimulate rooting (Lek, 1925; Scott, 1972). Greater number of vegetative buds developed in the control treatment of wounded and non-wounded cuttings. However, it appears they did not induce any rooting of cuttings. This may be due to the insufficient production of auxin by the buds necessary for root initiation. The lesser number of vegetative buds produced on cuttings by 10,000 ppm IBA may be due to the suppression of bud growth by IBA.

Table 17. Effect of wounding and IBA on percentage of rooting of jackfruit cuttings.

Wounding	IBA (ppm)	Rooting (%)
Non-wounded	0	0.00
	5000	40.32
	10000	43.61
Wounded	0	0.00
	5000	27.66
	10000	32.62

Table 18. Effect of IBA on percentage of rooting of jackfruit cuttings (non-wounded and wounded cuttings combined).

IBA (ppm)	Rooting (%)
0	0.0 b[z]
5000	34.1 a
10000	38.2 a

[z]Mean separation within column by Duncan's multiple range test, 5% level.

Table 19. Effect of wounding and IBA on rooting index of jackfruit cuttings.

Wounding	IBA (ppm)	Rooting index[z]
Non-wounded	0	1.00
	5000	1.80
	10000	2.05
Wounded	0	1.00
	5000	1.55
	10000	1.70

[z]Rooting index is the average score representing the quality and quantity of rooted cuttings. 1=no rooting, 2=light rooting, 3=medium rooting, 4=heavy rooting.

Table 20. Effect of IBA on rooting index of jackfruit cuttings (non-wounded and wounded cuttings combined).

IBA (ppm)	Rooting index[z]
0	1.00 b[y]
5000	1.68 a
10000	1.86 a

[z]Rooting index is the average score representing the quality and quantity of rooted cuttings.

[y]Mean separation within column by Duncan's multiple range test, 5% level.

Table 21. Effect of wounding and IBA on the number of primary roots per cutting.

Wounding	IBA (ppm)	Primary roots/cutting
Non-wounded	0	0.00
	5000	10.25
	10000	12.66
Wounded	0	0.00
	5000	9.08
	10000	8.98

Table 22. Effect of IBA on the number of primary roots per cutting (non-wounded and wounded cuttings combined).

IBA (ppm)	Primary roots/cutting
0	0.00 b[z]
5000	9.66 a
10000	10.82 a

[z]Mean separation within column by Duncan's multiple range test, 5% level. Includes non-rooted cuttings.

Table 23. Effect of wounding and IBA on the number of secondary roots per cutting.

Wounding	IBA (ppm)	Secondary roots/cutting
Non-wounded	0	0.00
	5000	63.55
	10000	50.40
Wounded	0	0.00
	5000	50.56
	10000	60.89

Table 24. Effect of IBA on the number of secondary roots per cutting (non-wounded and wounded cuttings combined).

IBA (ppm)	Secondary roots/cutting
0	0.00 b[z]
5000	55.65 a
10000	57.05 a

[z]Mean separation within column by Duncan's multiple range test, 5% level. Includes non-rooted cuttings.

Table 25. Effect of wounding and IBA on length of primary roots of jackfruit cuttings.

Wounding	IBA (ppm)	Length of roots (cm)
Non-wounded	0	0.00
	5000	8.74
	10000	7.13
Wounded	0	0.00
	5000	6.70
	10000	7.22

Table 26. Effect of IBA on length of primary roots of jackfruit cuttings (non-wounded and wounded cuttings combined).

IBA (ppm)	Length of roots (cm)
0	0.00 b[z]
5000	7.72 a
10000	7.18 a

[z]Mean separation within column by Duncan's multiple range test, 5% level. Includes non-rooted cuttings.

Table 27. Effect of wounding and IBA on fresh weight of roots of jackfruit cuttings.

Wounding	IBA (ppm)	Root fresh weight (g)
Non-wounded	0	0.00
	5000	0.70
	10000	0.44
Wounded	0	0.00
	5000	0.68
	10000	0.51

Table 28. Effect of wounding and IBA on dry weight of roots of jackfruit cuttings.

Wounding	IBA (ppm)	Root dry weight (g)
Non-wounded	0	0.00
	5000	0.13
	10000	0.09
Wounded	0	0.00
	5000	0.10
	10000	0.11

Table 29. Effect of IBA on fresh weight of roots of jackfruit cuttings (non-wounded and wounded cuttings combined).

IBA (ppm)	Root fresh weight (g)
0	0.00 b[z]
5000	0.69 a
10000	0.48 a

[z]Mean separation within column by Duncan's multiple range test, 5% level. Includes non-rooted cuttings.

Table 30. Effect of IBA on dry weight of roots of jackfruit cuttings (non-wounded and wounded cuttings combined).

IBA (ppm)	Root dry weight (g)
0	0.00 b[z]
5000	0.11 a
10000	0.09 a

[z]Mean separation within column by Duncan's multiple range test, 5% level. Includes non-rooted cuttings.

Table 31. Effect of wounding and IBA on dry matter content of roots of jackfruit cuttings.

Wounding	IBA (ppm)	Dry matter[z] (%)
Non-wounded	0	0.00
	5000	21.01
	10000	21.20
Wounded	0	0.00
	5000	19.43
	10000	23.68

[z]% dry matter = (dry root weight/fresh root weight)X100.

Table 32. Effect of IBA on dry matter content of roots of jackfruit cuttings (non-wounded and wounded cuttings combined).

IBA (ppm)	Dry matter[z] (%)
0	0.00 b[y]
5000	20.22 a
10000	22.44 a

[z]% dry matter = (dry root weight/fresh root weight)X100.

[y]Mean separation within column by Duncan's multiple range test, 5% level. Includes non-rooted cuttings.

Table 33. Effect of wounding and IBA on the number of vegetative shoots on jackfruit cuttings.

Wounding	IBA (ppm)	Vegetative shoots/cutting
Non-wounded	0	1.37
	5000	1.12
	10000	0.55
Wounded	0	1.20
	5000	0.80
	10000	0.62

Table 34. Effect of IBA on the number of vegetative shoots on jackfruit cuttings (non-wounded and wounded cuttings combined).

IBA (ppm)	Vegetative shoots/cutting
0	1.29 a[z]
5000	0.96 a
10000	0.59 b

[z]Mean separation within column by Duncan's multiple range test, 5% level. Includes non-rooted cuttings.

APPENDIX

Table 1. Effect of girdling, IBA, and stem maturity on rooting percentage of jackfruit cuttings.

Source	df	SS	MS	F
Replications	4	0.5268	0.1317	1.56 NS
Girdling	1	0.0105	0.0105	0.12 NS
IBA	2	2.4411	1.2206	14.44 ***
Stem maturity	1	0.2637	0.2637	3.12 NS
Gi X IBA	2	0.4043	0.2022	2.39 NS
Gi X St	1	0.0469	0.0469	0.55 NS
IBA X St	2	0.1493	0.0747	0.88 NS
Gi X IBA X St	2	0.8489	0.4245	5.02 **
Error	44	3.7199	0.0845	
Total	59	8.4114		

NS, **, *** = Not significant, significant at 1% (**), or 0.1% (***) levels.

Table 2. Effect of girdling, IBA, and stem maturity on rooting index of jackfruit cuttings.

Source	df	SS	MS	F
Replications	4	2.1507	0.5377	2.29 NS
Girdling	1	0.0027	0.0027	0.01 NS
IBA	2	7.3973	3.6987	15.73 ***
Stem maturity	1	0.8640	0.8640	3.67 NS
Gi X IBA	2	1.7653	0.8827	3.75 *
Gi X St	1	0.0027	0.0027	0.01 NS
IBA X St	2	0.4480	0.2240	0.95 NS
Gi X IBA X St	2	2.5013	1.2507	5.32 **
Error	44	10.3453	0.2351	
Total	59	25.4773		

NS, *, **, *** = Not significant, significant at 5% (*), 1% (**), or 0.1% (***) levels.

Table 3. Effect of girdling, IBA, and stem maturity on the number of primary roots in jackfruit cuttings.

Source	df	SS	MS	F
Replications	4	28.1760	7.0440	0.13 NS
Girdling	1	74.3707	74.3707	1.36 NS
IBA	2	1375.7613	687.8807	12.60 ***
Stem maturity	1	195.1207	195.1207	3.57 NS
Gi X IBA	2	130.8213	65.4107	1.20 NS
Gi X St	1	22.5707	22.5707	0.41 NS
IBA X St	2	327.0013	163.5007	2.99 NS
Gi X IBA X St	2	257.3013	128.6507	2.36 NS
Error	44	2402.1560	54.5945	
Total	59	4813.2793		

NS, *** = Not significant, significant at 0.1% (***) level.

Table 4. Effect of girdling, IBA, and stem maturity on length of primary roots of jackfruit cuttings.

Source	df	SS	MS	F
Replications	4	29.4079	7.3519	0.62 NS
Girdling	1	8.7784	8.7784	0.74 NS
IBA	2	299.3961	149.6981	12.57 ***
Stem maturity	1	79.2350	79.2350	6.65 **
Gi X IBA	2	85.7568	42.8784	3.60 *
Gi X St	1	10.9654	10.9654	0.92 NS
IBA X St	2	43.7456	21.8728	1.84 NS
Gi X IBA X St	2	205.0681	102.5341	8.61 ***
Error	44	524.0681	11.9106	
Total	59	1286.4214		

NS, *, **, *** = NOt significant, significant at 5% (*), 1% (**), or 0.1% (***) levels.

Table 5. Effect of girdling, IBA, and stem maturity on fresh weight of roots of jackfruit cuttings.

Source	df	SS	MS	F
Replications	4	0.3043	0.0761	0.37 NS
Girdling	1	0.0405	0.0405	0.20 NS
IBA	2	5.0495	2.5248	12.38 ***
Stem maturity	1	2.0321	2.0321	9.96 **
Gi X IBA	2	1.3432	0.6716	3.29 *
Gi X St	1	0.0005	0.0005	0.00 NS
IBA X St	2	1.3323	0.6662	3.27 *
Gi X IBA X St	2	1.5549	0.7775	3.81 *
Error	44	8.9735	0.2039	
Total	59	20.6308		

NS, *, **, *** = Not significant, significant at 5% (*), 1% (**), or 0.1% (***) level.

Table 6. Effect of girdling, IBA, and stem maturity on dry weight of roots of jackfruit cuttings.

Source	df	SS	MS	F
Replications	4	0.0093	0.0023	0.70 NS
Girdling	1	0.0002	0.0002	0.06 NS
IBA	2	0.1002	0.0501	15.18 ***
Stem maturity	1	0.0260	0.0260	7.88 **
Gi X IBA	2	0.0172	0.0086	2.61 NS
Gi X St	1	0.0008	0.0008	0.24 NS
IBA X St	2	0.0152	0.0076	2.30 NS
Gi X IBA X St	2	0.0284	0.0142	4.30 *
Error	44	0.1455	0.0033	
Total	59	0.3428		

NS, *, **, *** = Not significant, significant at 5% (*), 1% (**), or 0.1% (***) levels.

Table 7. Effect of girdling, IBA, and stem maturity on dry matter content of root of jackfruit cuttings.

Source	df	SS	MS	F
Replications	4	0.0559	0.0139	2.28 NS
Girdling	1	0.0094	0.0094	1.54 NS
IBA	2	0.2143	0.1072	17.57 ***
Stem maturity	1	0.0009	0.0009	0.15 NS
Gi X IBA	2	0.0059	0.0029	0.48 NS
Gi X St	1	0.0000	0.0000	0.00 NS
IBA X St	2	0.0052	0.0026	0.43 NS
Gi X IBA X St	2	0.1208	0.0604	9.90 ***
Error	44	0.2694	0.0061	
Total	59	0.6818		

NS, *** = Not significant, significant at 0.1% (***) level.

Table 8. Effect of girdling on the quantity of sugar in jackfruit cuttings.

Source	df	SS	MS	F
Girdling	1	0.08179	0.08179	430.47 ***
Error	8	0.00159	0.00019	
Total	9	0.08338		

*** = Significant at 0.1% level.

Table 9. Effect of girdling on the quantity of starch in jackfruit cuttings.

Source	df	SS	MS	F
Girdling	1	0.00222	0.00222	37.00 ***
Error	8	0.00053	0.00006	
Total	9	0.00275		

*** = Significant at 0.1% level.

Table 10. Effect of girdling, IBA, and stem maturity on the number of new vegetative shoots of jackfruit cuttings.

Source	df	SS	MS	F
Replications	4	0.9640	0.2410	1.09 NS
Girdling	1	0.7707	0.7707	3.48 NS
IBA	2	1.4040	0.7020	3.17 *
Stem maturity	1	0.6827	0.6827	3.08 NS
Gi X IBA	2	0.3693	0.1847	0.83 NS
Gi X St	1	1.8027	1.8027	8.13 **
IBA X St	2	0.9373	0.4687	2.11 NS
Gi X IBA X St	2	0.6173	0.3087	1.39 NS
Error	44	9.7560	0.2217	
Total	59	17.3040		

NS, *, ** = Not significant, significant at 5% (*), or 1% (**) levels.

Table 11. Effect of girdling, IBA, and stem maturity on the retention of leaves on jackfruit cuttings during rooting.

Source	df	SS	MS	F
Replications	4	0.8227	0.2057	0.45 NS
Girdling	1	9.6000	9.6000	20.97 ***
IBA	2	1.3173	0.6587	1.44 NS
Stem maturity	1	12.6960	12.6960	27.74 ***
Gi X IBA	2	0.4960	0.2480	0.54 NS
Gi X St	1	0.2667	0.2667	0.58 NS
IBA X St	2	0.0160	0.0080	0.02 NS
Gi X IBA X St	2	1.1573	0.5787	1.26 NS
Error	44	20.1373	0.4577	
Total	59	46.5093		

NS, *** = Not significant, significant at 0.1% (***) level.

Table 12. Effect of wounding and IBA on rooting percentage of jackfruit cuttings.

Source	df	SS	MS	F
Replications	3	0.0885	0.0295	1.73 NS
Wounding	1	0.0429	0.0429	2.51 NS
IBA	2	0.7368	0.3684	21.54 ***
WoundingXIBA	2	0.0217	0.0109	0.64 NS
Error	15	0.2563	0.0171	
Total	23	1.1462		

NS, *** = Not significant, significant at 0.1% (***) level.

Table 13. Effect of wounding and IBA on rooting index of jackfruit cuttings.

Source	df	SS	MS	F
Replications	3	0.6367	0.2122	1.57 NS
Wounding	1	0.2400	0.2400	1.78 NS
IBA	2	3.3633	1.6817	12.47 **
WoundingXIBA	2	0.1300	0.0650	0.48 NS
Error	15	2.0233	0.1349	
Total	23	6.3933		

NS, * = Not significant, significant at 5% (*) level.

Table 14. Effect of wounding and IBA on the number of primary roots per cutting.

Source	df	SS	MS	F
Replications	3	122.2826	40.7609	2.19 NS
Wounding	1	15.6978	15.6978	0.84 NS
IBA	2	564.7699	282.3849	15.17 **
WoundingXIBA	2	14.1616	7.0808	0.38 NS
Error	15	279.3106	18.6207	
Total	23	996.2225		

NS, ** = Not significant, significant at 1% (**) level.

Table 15. Effect of wounding and IBA on the number of secondary roots per cutting.

Source	df	SS	MS	F
Replications	3	5201.6419	1733.8806	1.84 NS
Wounding	1	4.1583	4.1583	0.01 NS
IBA	2	16944.0905	8472.0453	8.97 **
WoundingXIBA	2	553.5069	276.7535	0.29 NS
Error	15	14164.1979	944.2799	
Total	23	36867.5955		

NS, ** = Not significant, significant at 1% (**) level.

Table 16. Effect of wounding and IBA on length of primary roots of jackfruit cuttings.

Source	df	SS	MS	F
Replications	3	25.8858	8.6286	1.50 NS
Wounding	1	2.5480	2.5480	0.44 NS
IBA	2	297.3117	148.6559	25.87 ***
WoundingXIBA	2	5.7896	2.8948	0.50 NS
Error	15	86.1815	5.7454	
Total	23	417.7166		

NS, *** = Not significant, significant at 0.1% (***) level.

Table 17. Effect of wounding and IBA on fresh weight of roots of jackfruit cuttings.

Source	df	SS	MS	F
Replications	3	0.5274	0.1758	1.60 NS
Wounding	1	0.0014	0.0014	0.01 NS
IBA	2	2.0150	1.0075	9.14 **
WoundingXIBA	2	0.0078	0.0039	0.04 NS
Error	15	1.6528	0.1102	
Total	23	4.2044		

NS, ** = Not significant, significant at 1% (**) level.

Table 18. Effect of wounding and IBA on dry weight of roots of jackfruit cuttings.

Source	df	SS	MS	F	
Replications	3	0.0139	0.0046	1.70	NS
Wounding	1	0.0001	0.0001	0.03	NS
IBA	2	0.0617	0.0308	11.41	***
WoundingXIBA	2	0.0012	0.0006	0.22	NS
Error	15	0.0404	0.0027		
Total	23	0.1173			

NS, *** = Not significant, significant at 0.1% (***) level.

Table 19. Effect of wounding and IBA on dry matter content of roots of jackfruit cuttings.

Source	df	SS	MS	F
Replications	3	0.1667	0.0555	6.69 **
Wounding	1	0.0088	0.0088	1.06 NS
IBA	2	0.3205	0.1602	19.30 ***
WoundingXIBA	2	0.0046	0.0023	0.28 NS
Error	15	0.1247	0.0083	
Total	23	0.6253		

NS, **, *** = Not significant, significant at 1% (**), or 0.1% (***) levels.

Table 20. Effect of wounding and IBA on the number of new vegetative shoots of jackfruit cuttings.

Source	df	SS	MS	F
Replications	3	0.5046	0.1682	1.65 NS
Wounding	1	0.1204	0.1204	1.18 NS
IBA	2	1.9633	0.9817	9.63 **
WoundingXIBA	2	0.1633	0.0817	0.80 NS
Error	15	1.5279	0.1019	
Total	23	4.2795		

NS, ** = Not significant, significant at 1% (**) level.

Table 21. Effect of wounding and IBA on the retention of leaves on jackfruit cuttings during rooting.

Source	df	SS	MS	F
Replications	3	1.7213	0.5738	8.39 **
Wounding	1	0.5704	0.5704	8.34 **
IBA	2	0.4825	0.2413	3.53 NS
WoundingXIBA	2	0.1358	0.0679	0.99 NS
Error	15	1.0263	0.0684	
Total	23	3.9363		

NS, ** = Not significant, significant at 1% (**) level.

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