Research Article

Propagation of Guava Stem Cuttings through Different Concentrations of Indole Butyric Acid

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Abstract | Guava cutting propagation is a very difficult phenomenon; for this reason, appropriate stem portion and different concentrations of IBA due to its known rooting ability were optimized. The present experiment titled "Propagation of guava cv. Safeda stem cuttings through different concentrations of indole butyric acid" was conducted in the lath house of Agricultural Research Institute Tarnab, Peshawar during the years 2017-18. The experiment was laid out in split plot arrangements in RCBD replicated three times with 30 cuttings per replication. In this study IBA, (0.0%, 0.2%, 0.4%, 0.6% and 0.8%) allotted to main plot and guava stem cuttings (soft, semi-hard, and hardwood) were subjected to subplot. The analyzed data showed that the application of IBA concentration at 0.4% significantly increased sprouting percentage (63.84%), number of leaves per plant (13.00), number of roots per plant (10.80), average root length per plant (10.53 cm), number of shoots per plant (3.56), survival percentage (35.62%) and minimize days to sprouting (24.44). Similarly, most of the studied attributes were also significantly influenced by various types of guava stem cuttings for propagations. However, the maximum sprouting percentage (70.55%), number of leaves per plant (13.27), number of roots per plant (9.80), average root length per plant (9.00 cm), number of shoots per plant (3.67) and survival percentage (40.66%) were recorded for softwood cuttings. Whereas the minimum days to spouting (26.20), sprouting percentage (52.75%), number of leaves per plant (9.53%), number of roots per plant (8.87), average root length per plant (8.87 cm), number of shoots per plant (2.60 cm), and survival percentage (27.97%) were recorded in plants propagated through hardwood cuttings. It is concluded that guava cv. Safeda should be propagated through softwood cutting with application of 0.4% IBA concentration. However, it is cost-effective and justifies the propagation of guava through softwood cuttings.

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Introduction

Guava (*Psidium guajava* L.), a member of the Myrtaceae family, is an important and economically valuable fruit crop in Pakistan and other tropical and subtropical regions globally. In Pakistan, guava orchards are extensively cultivated in the provinces of Punjab, Sindh, and Khyber Pakhtunkhwa

(Khushk *et al*., 2009). Guava occupies third position in term of area and production after citrus and mango among major fruits of Pakistan (Khushk *et al*., 2009). Guava has extensive adoptability and higher return per unit area and is preferred by fruit growers (Khushk *et al*., 2009). The soil requirement for guava is from heavy clay to light sandy soil and with a range of soil pHs from 4.5 to 8.5 (Ali *et al*., 2003). The trees are highly productive with proper care and good soil conditions and tolerant to saline and wet conditions (Rai *et al*., 2009). The area with a distinct winter season guava produces good quality fruits. Propagation in guava is also a big problem as all the methods did not give successes in guava plant propagation. There are two methods used for propagation. First is asexual or clonal propagation and the second is sexual propagation. Clonal propagation is an asexual technique to produce new plants from an individual that all have the same genotypes. To maintain uniformity it is a rapid method of superior plants propagating. Different guava cultivars are grown via traditional techniques like budding, grafting, and layering. When it comes to producing a lot number of uniform plants, these methods are time-consuming and laborious. In addition, guava propagation using these techniques is not very rapid. Another method for propagation is sexual method which is propagation by seed, in this method of propagation the genetic purity of the variety could not be maintain due to segregation and recombination character of the plant (Gautam *et al*., 2010; Rai *et al*., 2009). Guava breeding programs face limitations due to the plant's epigynous flower structure, which includes profuse incurved stamens of varying sizes and a prolonged juvenile phase. Additionally, the heterozygous nature of guava and its self-incompatibility further restrict the potential of breeding efforts (Jaiswal and Amin, 1992). As guava is unreliable for producing true-to-type plants from seeds, vegetative propagation through cuttings treated with growth regulators is considered a crucial strategy to prevent genetic segregation and maintain the quality of the variety (Tahseenullah *et al*., 2005). Plants produced through asexual means are true to types. There are only a limited number of reports available on the clonal propagation of guava. Further research is required to develop an optimal method for the rapid production of clonal propagules across various genotypes, which could serve as a valuable resource in establishing a gene bank for future breeding programs. Indole butyric acid (IBA) is commonly used as an auxin to enhance root formation in cuttings due to its strong effectiveness in promoting root initiation (Weisman *et al*., 1988) and its relatively low toxicity and superior stability compared to naphthalene acetic acid and indole-3-acetic acid (Blazich, 1988; Hartmann *et al*., 1990). Given the significant role of IBA in influencing the rooting response of guava, this study aims to determine the optimal IBA concentrations and evaluate different types of guava stem cuttings to improve the growth and survival rates of guava cuttings.

Materials and Methods

An investigation study on the effects of indole butyric acid (IBA) on the rooting of stem cuttings for the propagation of guava cultivar Safeda was conducted in the lath house section of the Agricultural Research Institute, Tarnab, Peshawar, Pakistan, during September 2017 to March 2018. The data for the experiment was recorded in the month of March-April 2018. Different types of guava stem cuttings (softwood, semi-hardwood, and hardwood) were sourced from orchards in Dargai, Malakand, and the Nuclear Institute for Food and Agriculture, Peshawar Khyber Pakhtunkhwa Pakistan.

Experimental design and treatment combination

The research study was carried out using split plot arrangement using Randomized Complete Block design with three replications. Three types of stem cuttings were dipped in five different concentrations of Indole butyric acid (subjected to main plot). There were 15 treatments combinations and the total number of experimental units were 45. Thirty cuttings for each cutting type was used for each treatment, total number of cuttings used during the whole experiment were 1350.

Preparation of indole butyric acid solution

Various concentrations of Indole butyric acid (IBA) (0.0%, 0.2%, 0.4%, 0.6% and 0.8%) were used in the present experiment. To prepare 0.2% IBA solution, 2g were initially added in 90% ethanol solution and then added to distilled water and raised the final volume to 100 ml. The same procedure was used to prepare 0.2%, 0.4%, 0.6% and 0.8% IBA solutions. To avoid fungal growth in cuttings, 2g of fungicide (Radonil-Syngent Int.) was added to the solution. Distilled water was used in control treatments.

Preparation of plastic bags

Plastic bags available for the use of cuttings propagations in the market were purchased. These plastic bags have small holes for aeration and leaching of extra moisture were filled with well rotten farm yard manure (FYM), river silt which contains sand and clay at a ratio of 1 x 1 x 1 x 1. The dimension of the plastic bags were 4 x 7 inches.

Preparation of guava cuttings

The softwood, semi-hardwood, and hardwood stem cuttings of guava were collected from the terminal sections of 10 to 15 years old winter-bearing guava trees in the month of September. These cuttings were 12-15 cm long contained a pair of leaves on the top and 6-8 buds on each cuttings.

Application of IBA

The treatments consisted of IBA solutions at concentrations of 0%, 0.2%, 0.4%, 0.6%, and 0.8%, combined with a fungicide. Using the quick-dip method, the basal portion of each cutting (2–3 cm) was immersed in the prepared solution for 5 seconds. Following this, the cuttings were immediately transplanted into already filled plastic bags.

Softwood cuttings

Softwood cuttings are taken from the tender, succulent new growth of guava plants, just as the shoots begin to harden and mature. These shoots are suitable for softwood cuttings when they can be easily snapped when bent and display a range of leaf sizes, with the oldest leaves fully mature and the newest still small. Due to the delicate nature of soft shoots, extra care is required to prevent them from drying out. In this experiment, the four-angled in cross-session (quadrangular) portion of the stem was used as softwood cuttings.

Semi hardwood cuttings

Semi-hardwood cuttings are typically taken from partially matured wood from the current season's growth, shortly after a growth flush. The wood is relatively firm, with fully developed leaves. In this experiment, the middle portion of the same stems used for softwood cuttings was utilized as semi-hardwood cuttings.

Hard wood cuttings

Hardwood cuttings are collected from dormant, fully mature stems, characterized by firm wood that resists bending. While typically used for deciduous shrubs, they are also suitable for many evergreen species. In this experiment, the remaining sections of the same stems, after taking softwood and semi-hardwood cuttings, were used as hardwood cuttings.

Planting of cuttings

Farmyard manure and silt mixture were filled in plastic bags for the planting of guava cuttings at about 6-7 cm depth. The bags were placed under low tunnels with double polythene sheet to protect in the growing area and to keep the humidity at optimal level. After planting, the cuttings were watered by sprinkler irrigation. During these period weekly or when required irrigation was carried out and other cultural practices were conducted as per requirements.

The following attributes were studied during the experiment.

Days to sprouting

The emergence of new flush of shoots growth on the cutting were recorded in the low tunnel double polythene sheet and days to sprouting were counted from second-week post-planting until observation completed on daily basis. Sprouting was recorded as such when over 50% of the cuttings in each replication had sprouted. The average for the number of days to sprouting were subsequently calculated amongst the three replications.

Sprouting percentage

Sprouting refers to the process where new shoots or buds begin to emerge from the base of the cutting. In the lath house under low tunnel out of the total cuttings planted in plastic bags the sprouted cuttings were counted and the averages were converted in to sprouting percentage. Sprouting percentage data were recorded after 8 weeks of planting of cuttings in plastic bags for all the treatments in each replications.

Number of leaves per plant

Five cuttings were randomly chosen from each treatment across all replications, and the averages were subsequently computed.

Number of roots per plant

After completion of the experiment the data for number of roots per plant were taken for all the fully develop roots and the averages were determined by taking five cuttings at random from each replication of the treatment.

Average root length (cm) per plant

The data for Average root length per plant was recorded with the help of measuring tape after completion of experiment in all replications of each treatment and the average root length per plant was calculated.

Number of shoots per plant

Five cuttings were randomly chosen from each replication of each treatment for this parameter, and the averages were then determined.

Survival percentage

At the conclusion of the experiment, survival data were collected in March-April of the following year 2018. In each treatment of every replication, the number of surviving cuttings were counted, averaged, and converted into a survival percentage. The survived plants were transferred to the nursery of University of Agriculture, Peshawar.

Statistical procedures

The obtained data were analyzed using ANOVA, and statistical software Statistix 8.1 was used with the least significant difference (LSD) at probability rank of 5%. The program MS-Excel/ sigma plot were used for tabulations and graph drawing.

Results and Discussion

Days to sprouting

Data regarding days to sprouting of guava cuttings is presented in Table 1. Different concentrations of Indole butyric acid and cutting types significantly affected days to sprouting of guava cuttings. Maximum days to sprouting (32.78) were recorded in cuttings undipped in IBA solutions. While minimum days to sprouting (24.44) were recorded in cuttings dipped in 0.4% IBA solution. However, this was statistically at par with days to sprouting (26.45 and 26.33) in cuttings dipped in 0.6 and 0.2% IBA solutions respectively (Table 1) furthermore, more days to sprouting (29.07) were found in softwood cutting. The lowest days to sprouting (26.20) were obtained from hardwood cuttings which were statistically at par with days to sprouting (27.20) in semi hardwood cuttings (Table 1). It is evident from the results that days to sprouting were less for semi hardwood and hardwood as compare to softwood cuttings because plants reserve food in wood for coming season fresh growth and hence our early growth in semi and hardwood cuttings were due to the reserved food materials. The increase of IBA concentrations have also decreased days to sprouting up to 0.4% concentration and then again increases due to beyond this limit the IBA concentrations caused toxicity and did not work for reducing the days to sprouting. The findings align with the study of Mankar *et al.* (2009), who suggested that the increasing concentrations of IBA may enhance auxin activity in the cambial region, promoting early initiation of root primordia. Another explanation could be the improved utilization of stored carbohydrates in semi-hardwood and hardwood cuttings, where the application of exogenous auxin increases auxin concentration within the cells, thereby enhancing cell division and accelerating callus formation, as also observed by Kumar and Jadhav (2007) in phalsa. In a similar study, Wahab *et al.* (2001) examined the effects of Indole butyric acid, Indole acetic acid, and naphthalene acetic acid on semi-hardwood guava cuttings, finding that these auxins had little influence on the days to sprouting. Likewise, Luqman *et al.* (2004) observed no significant results of various IBA concentrations on days to sprouting. Both studies, consistent with the present study, suggest that auxins

Table 1: *Days to sprouting, sprouting percentage, number of leaves per plant and number of roots per plant of guava as affected by IBA concentrations and cutting types.*

Treatments	Parameters			
IBA concentrations (I) (%)	**Days to sprouting**	**Sprouting percentage**	**Number of leaves per plant**	**Number of roots per plant**
0	32.78 A	52.22b	8.11D	6.68D
0.2	26.33BC	58.46a	10.56C	8.61C
0.4	24.44 C	63.84a	13.00A	10.80A
0.6	26.45BC	61.28a	11.45B	10.47AB
0.8	27.45 B	60.86a	10.89BC	9.46BC
LSD value (P≤ 0.01) (P≤0.05)	2.2249	5.6155	0.8542	1.1465
Cutting types (CT)				
Soft Wood	29.07 A	70.55A	13.27A	9.80a
Semi Hard Wood	27.20B	54.70B	9.60B	8.93b
Hard Wood	26.20 B	52.75B	9.53B	8.87b
LSD value (P≤ 0.01) (P≤0.05)	1.1524	3.1067	0.4712	0.6736
Interactions (IxCT)	NS	NS	Fig. 1	NS

Means followed by different letter(s) (upper case) are significantly different at 1% level of significance and lower case by 5% level of significance. NS= Non-significant.

exhibit a limited role in influencing the number of days to sprouting. Instead, the sprouting response appears to be determined more by the stored nutrients within the tissue than by hormone activity (Rahman *et al*., 2002).

Sprouting percentage

The data for sprouting percentage are presented in Table 1. The ANOVA results indicate that both Indole butyric acid (IBA) concentrations and cutting type softwood had a significant affect on the sprouting percentage of guava cuttings. The IBA and cuttings interaction were found non-significant. The data for cutting types showed that sprouting percentage were reduced i.e., 70.55, 54.70 and 52.75% for softwood, semi hardwood and Harwood cuttings of guava (Table 1). Bud sprouting in cuttings is generally controlled by the carbohydrates stored within them (Wahab *et al*., 2001). However, an increase in sprouting is of limited importance unless the cuttings are also able to survive successfully. The data presented in Table 1, however, indicate that IBA contributes to enhance sprouting when compared to the control. In some case IBA directly working as auxin or converted to auxin in a process similar to fatty acid β-oxidation and helped to establish a stronger root system that was effective in nutrient absorption compare to control since enhance the cell division and finally to growth of the tissues and cause increase in sprouting percentage in plants. Tien *et al*. (2020) reported that optimal concentrations of IBA could induce the mobilization and utilization of carbohydrates, nitrogen fraction, water and mineral nutrient absorption. Better rooting and sprouting were recorded with appropriate IBA concentrations in *Solanum procumbens* stem cuttings. Similar findings observed by Abdullah *et al*. (2006) and Tahseenullah *et al*. (2005) on stem portion of cuttings from established stock plants of guava revealed a 60% and 71.2% sprouting growth in softwood cuttings. In comparison to our investigation, Luqman *et al*. (2004) observed 37.49% sprouting on guava stem cuttings that were semi-hard wood and had been treated with different concentration of IBA. But all of the IBA treatments exhibited more sprouting in soft wood cuttings than in hard and semi-hard wood cuttings when cutting types were compared. The ability of Indole butyric acid (IBA) to achieve a higher sprouting percentage across all treatments, compared to the control, regardless of cutting type, indicates that IBA is a more effective plant hormone for promoting sprouting in cuttings. Moreover, it is suggested that softwood cuttings are more desirable for higher sprouting success than hardwood and semi-hardwood cuttings. These outcomes agree with the studies of numerous other scientists (Wahab *et al*., 2001; Tahseenullah *et al*., 2005), who reported that auxin treatments were effective for guava stem cutting sprouting. The faster regenerative ability and higher auxin content of young tissue (Rahman *et al*., 2002) could be reasons for the soft wood cutting's comparatively better response to plant hormone treatments than hard and semi hardwood cutting (Wahab *et al*., 2001).

Number of leaves per plant

The data regarding the number of leaves per plant are provided in Table 1. Statistically analyzed data revealed that both IBA concentrations and cutting types had a significant effect on the number of leaves per plant in guava cuttings. Additionally, the interactions between IBA concentrations and cutting types also significantly influenced the number of leaves per plant. The maximum mean number of leaves per plant 13.00 were noted in cuttings treated with IBA concentration (0.4%) followed by 11.45 in IBA concentration (0.6%), which is at par with 10.89 with IBA concentration (0.8%) and 10.56 with IBA concentration (0.2%) treated cuttings while control treated cuttings were comparable low number of leaves per plant by producing 8.11 leaves. The effect of indole butyric acid on types of cuttings were significant with means of 13.27, 9.60 and 9.53 leaves in softwood, semi hard and hardwood cuttings respectively. The interactions of IBA concentrations and cuttings types were also significant (Figure 1). In overall study, maximum numbers of leaves per plant 16.33 were noted in softwood cuttings treated with IBA concentration (0.4%). The minimum number of leaves per plant 6.67 were recorded in semi-hardwood cuttings in control IBA concentration (Figure 1). The earlier experiments of Tahseenullah *et al*. (2005) confirmed these findings of our results. Who recorded the highest (10.22) number of leaves per plant treated in softwood cutting and IBA. A similar study was carried out by Luqman *et al*. (2004), who also noted that in semi-hardwood cuttings treated with high concentrations of 1000 ppm IBA, the largest number of leaves per plant (13.9) were recorded. However, we also obtained more leaves per plant in our trial using soft wood cuttings that had been treated with IBA (Table 1). Hard and semi-hard wood cuttings treated with IBA had the fewest leaves per plant in the current investigations. Due to the fact that soft wood cutting has relatively short internodes and more sprouts per piece of cutting length, hence its results are more number of leaves per plant (Table 1). The interaction was also significant in our present studies, (Figure 1) which shows that irrespective of cutting types and IBA concentrations both have significantly work on number of leaves per plant this is due to because plant increase its canopy to capture maximum sunlight by leaves which is photosynthetic manufacturing engines.

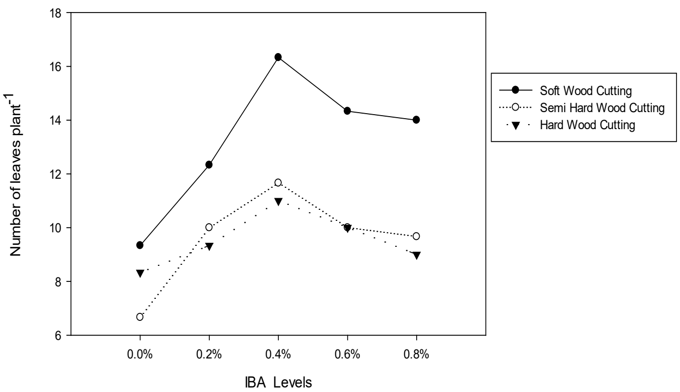

Figure 1: *Interaction of cutting types and IBA (conc) for number of leaves per plant.*

Number of roots per plant

The statistical analysis of the data in Table 1 indicates that all Indole butyric acid concentrations and cutting types had significantly effect the number of roots per plant of guava. The maximum mean number of roots per plant 10.80 were produced by the cuttings treated with IBA concentrations (0.4%), which is at par with 10.47 in the cuttings treated with IBA concentration (0.6%). The minimum 6.68 number of roots per plant were noted in control IBA (0.0%). While the effect of Indole butyric acid on cuttings types were also significant with maximum means values 9.80 were recorded for soft wood cuttings fallowed by 8.93 for semi hard wood cuttings which is at par with 8.87 for hard wood cuttings.

The roots are the first organ of plant which appear on the stem and got developed. However, IBA has given good results in all the concentrations compared to control. This parameter demonstrates once more how effectively IBA works to induce roots in plants that are propagated through cutting. The most important aspect that determines a plant's eventual survival is rooting. IBA is a root promoting hormone which helped in root induction. The increase trend in number of roots per plant with increase in IBA concentrations up to (0.4%) showed progressive responses but beyond this level number of roots per plant were decreased statistically upon completion of the expirment. Similar results of this study were also reported by (Tavares *et al*., 1995; Gonzalez and Schmidt, 1992). Overall mean maximum number of roots per plant was noted in softwood cutting 9.80 compare to semi hard 8.93 and hard wood 8.87 cuttings. It's probable that the cambial activity's role in root induction accounts for the maximum number of roots per plant (Hafeez *et al*., 1991). In the present experiments when the softwood cuttings were treated with Indole butyric acid, greatest numbers of roots were recorded. Our results are supported by previous research conducted by Luqman *et al*. (2004) and Tahseenullah *et al*. (2005), who found that soft wood cuttings treated with 1000 ppm IBA produced 21.2 and 38.03 number of roots respectively. Other researchers have also noted that IBA can induce a rooting response in guava cuttings with softwood and semi-hard wood (Wahab *et al*., 2001; Abdullah *et al*., 2006).

Average root length (cm) per plant

The tabulated data for average root length per plant are shown in Table 2. Statistical analysis indicated that IBA concentrations had a significant effect on the average root length per plant in guava cuttings. While stem cutting types and interactions were non-significant. The maximum mean average root length of 10.53 cm were recorded in the cuttings treated with (0.4%) IBA concentrations which is at par with 10.21 cm in the IBA concentration (0.6%) treated cuttings. These results were followed by 9.19 cm and 8.34 cm with IBA concentrations (0.8%) and (0.2%), respectively. Control treatments have shown minimum average root length of 6.41 cm. The effect of Indole butyric acid on average root length for cuttings types were non-significant with 9.00 cm, 8.93 cm and 8.87 cm in softwood, semi hard and hard wood cuttings, respectively. In the present study, IBA concentrations demonstrated effects independent of cutting type and their interactions. The increase in average root length per plant may be attributed to the influence of IBA on the translocation of metabolites and carbohydrate metabolism, which plays a role in regulating root growth. These findings are supported by Rahman *et al*. (2002), who studied and find the Indole butyric acid (IBA) effects on guava cuttings propagations and found that Indole butyric acid enhanced rooting quality, particularly in terms of root length and quantity. Similarly, Manan *et al.* (2002) observed that hardwood cuttings of guava dipped in 1000 ppm of IBA solution produced the longest roots, measuring 6.5 cm, with IBA treatments and that all the IBA concentrations were better than other treatments.

Table 2: *Average root length per plant (cm), number of shoots per plant, and survival percentage of guava as affected by IBA concentrations and cutting types.*

Treatments	Parameters		
IBA concentrations (I) (%)	**Average root length per plant (cm)**	**Number of shoots per plant**	**Survival percent-age**
0	6.41D	2.44 C	28.40D
0.2	8.34C	3.00 B	33.42B
0.4	10.53A	3.56 A	35.62A
0.6	10.21AB	3.10 B	32.05C
0.8	9.19BC	2.99B	31.83C
LSD value (P ≤ 0.01)	1.1465	0.2644	1.3229
Cutting types (CT)			
Soft Wood	9.00	3.67A	40.66A
Semi Hard Wood	8.93	2.78B	28.17B
Hard Wood	8.87	2.60B	27.97B
LSD value (P≤0.01)	0.6736	0.3036	0.9486
Interactions (I x CT)	NS	NS	Fig. 2

Means followed by different letter(s) (upper case) are significantly different at 1% level of significance and lower case by 5% level of significance. NS= Non-significant.

Number of shoots per plant

The statistical analysis of the data in Table 2 indicates that all Indole butyric acid concentrations and cutting types had significantly affected the number of shoots per plant. The maximum mean number of shoots 3.56 were recorded in IBA concentration (0.4%) treated cuttings. This number of shoots per plant were followed by 3.10 in IBA concentration (0.6%) which is at par with 2.99 and 3.00 with IBA concentrations (0.8%) and (0.2%) respectively. While the minimum number of shoots 2.44 were recorded for control (Table 2). Similarly, the effect of different concentrations of indole butyric acid on number of shoots for cutting types (soft wood, semi hard and hardwood) were also significant. The highest means value 3.67 were recorded for soft wood cuttings while 2.78 were recorded for semi hard wood cuttings which were at par with 2.60 for hardwood cuttings (Table 2). Auxins are produced in large amounts in actively growing regions (Bacarin *et al*., 1994), which may stimulate the growth in the softwood cuttings compare to hardwood and semi-hardwood cuttings, leading to a greater number of shoots per plant. The increase in shoot number at a 0.4% IBA concentration could be due to more number of roots and improved overall growth parameters at this concentration. These findings align with those of Siddiqui *et al.* (2007), who also reported an increased number of shoots per plant at 4000 ppm of IBA in *Ficus hawaii*.

Survival percentage

Eventually plant survival is the key in such studies. The data on survival percentages are presented in Table 2. Statistically analysis indicated that both IBA concentrations and cutting types had a significant impact on the survival percentage of guava cuttings. Moreover, the interaction between IBA and cutting types also significantly influenced the survival percentage. The maximum mean survival of 35.62% were recorded in IBA concentrations (0.4%) treated cuttings followed by 33.42% in IBA concentration (0.2%) treatment. The result 32.05% for IBA concentration (0.6%) was at par with 31.83% percent with IBA (0.8%) concentration. The lowest mean survival of 28.40% were recorded in IBA control (0.0%) treatments. The effect of varying concentrations of indole butyric acid (IBA) on different cutting types was also significant, with 40.66% survival observed in softwood cuttings, 28.17% in semi-hardwood cuttings, and 27.97% in hardwood cuttings, which were statistically comparable. Additionally, the interaction between IBA concentrations and cutting types was found to be significant (Figure 2). Overall, softwood cuttings treated with 0.4% IBA showed the highest survival rate at 47.63%, while hardwood cuttings in the control plot had the lowest survival rate at 25.90%. The higher survival rate observed in cuttings treated with various IBA concentrations, compared to the control, may be attributed to differences in the number of roots per cutting, as well as other factors such as the number of leaves and shoots per plant, which were maximized at the 0.4% IBA concentration. Since (0.4%) IBA promote all these factors, which ultimately provide food / water for further processes and increases the survival of plants compare to other IBA concentrations and control cuttings and consequently have resulted in the high rate of plant survival.

Guava plant survival percentage refers to the percentage of cuttings that have successfully rooted and grown into healthy plants by the conclusion of a plant propagation experiment. It was also maximum in softwood cutting is due to its juvenility and quick regenerative process, and hence the softwood cutting produce more roots, shoots and number of leaves per plant which ultimately increased the survival percentage of softwood cuttings. Tahseenullah *et al.* (2005) studied guava stem cuttings and found that indole butyric acid (IBA) had a significant effect on the survival percentage. They found that in guava soft wood cuttings, IBA produced a high survival rate of 57.2%. Wahab *et al.* (2001) reported that applying auxins to semi-hardwood guava cuttings significantly increases root formation, leading to an improved survival rate. Similarly, Abdullah *et al.* (2006) found that auxin application can stimulate rooting in guava stem cuttings, which indirectly contributes to an increased survival rate. The interaction between cutting types and IBA concentrations were also significant (Figure 2), with the highest value observed for softwood cuttings treated with 0.4% IBA. This may be attributed to the increased metabolic activity of hormones in the younger tissues, as well as a higher concentration of carbohydrates, contributing to the improved survival percentages.

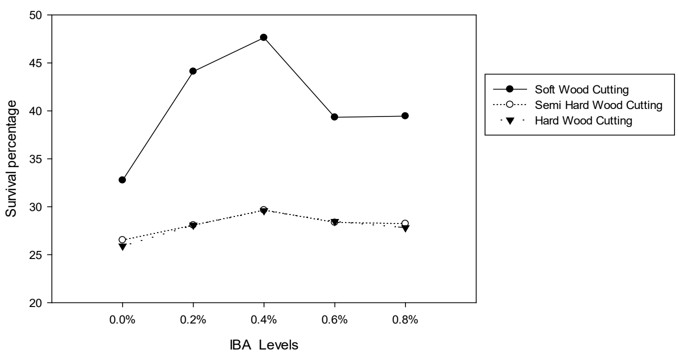

Figure 2: *Interaction of cutting types and IBA (conc) for Survival percentage (%).*

Conclusions and Recommendations

It is concluded from the experiment that the guava cuttings treated with IBA concentrations showed significant differences for sprouting percentage, minimum days to sprouting, produced more number of leaves per plant, number of roots per plant, maximum root length per plant, number of shoots per plant and survival percentage when treated with 0.4% IBA concentration. Moreover, in cuttings types, the soft wood cutting of guava resulted in maximum sprouting percentage, number of leaves per plant, number of roots per plant, root length per plant, number of shoots per plant and maximum survival percentage. However, less number of days to sprouting were recorded in plants propagated through semi-hard wood and hard-wood cuttings.

On the basis of above conclusion, it is recommended that the Indole butyric acid at a concentration of 0.4% is recommended for guava propagation through stem cuttings. And the guava soft wood cutting having pair of leaves on the top was superior in all the parameters studied for the experiment and is recommended for production of guava through stem cuttings.

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Novelty Statement

Optimum concentration of indole butyric acid (IBA) and soft wood cutting having pair of leaves on the top produce high number of guava saplings.

Author's Contribution

Zahoor Ahmad: Principle author and Ph.D. scholar, who conducted research, analyzed the data and wrote draft of this MS.
Muhammad Sajid: Major supervisor who provided essential technical guidance throughout the entire study program.

Conflict of interest
The authors have declared no conflict of interest.

References

Abdullah, A.T.M., M.A. Hossain and M.K. Bhuiyan. 2006. Clonal propagation of guava (*Psidium guajava* L.) by stem cuttings from mature stock plants. J. For. Res., 17: 301-304. https://doi.org/10.1007/s11676-006-0069-2

Ali, N., R.M.S. Mulwa, M.A. Norton and R.M. Skirvin. 2003. Micro propagation of guava (*Psidium guajava* L.). J. Hortic. Sci. Biotech., 78: 739–741. https://doi.org/10.1080/1462031

6.2003.11511692

Bacarin, M.A., M.M.P. Benincasa, V.M.M. Andrade and F.M. Pereira. 1994. Aerial rooting of guava (*Psidium guajava* L.). Effect of butyric acid IBA on root initiation. Sci. St. Paul., 221: 71-79.

Blazich, F.A., 1988. Mineral nutrition and adventitious rooting. In: (eds. T.D. Davis, B.E. Haissig and N. Sankhla), adventitious root formation in cuttings. Adv. Plant Sci. Portland, OR. Dioscorides Press, pp. 11-28.

Gautam, N.N., K. Singh, B. Singh, S. Seal, A. Goel and V.L. Goel. 2010. Studies on clonal propagation of guava (*Psidium guajava* L.) through cuttings under controlled conditions. Austral. J. Crop Sci., 4: 666-669.

Gonzalez, M.G.N. and C.A. Schmidt. 1992. Study of the effect two concentrations of butyric acid IBA and naphthalene acetic acid NAA on rooting of this herbaceous-cas guava *Psidium guajava* L. cv. Kumagai. Rev. Bras. Fruit, 14(3): 229-232.

Hafeez, U.R., M.A. Khan, K.M. Khokhar, H.M. Laghari and H. Rahman. 1991. Effect of season on rooting tip cuttings of guava treated with paclobutrazol. Ind. J. Agric. Sci., 61: 404-406.

Hartmann, H.T., D.E. Kester and J.R. Davies. 1990. Plant propagation principle and practices. Prentice-Hall International, Eaglewood Cliffs Editions. pp. 647.

Jaiswal, V.S. and M.N. Amin. 1992. Guava and jackfruit. In: (eds. F.A. Hammerschlag and R.E. Litz), Biotechnology of perennial fruit crops, Biotech. Agri. CAB. Int., Wallingford, UK. pp. 421-431.

Khushk, A.M., A. Memon and M.I. Lashari. 2009. Factors affecting guava production in Pakistan. J. Agric. Res., 47(2): 201-210.

Kumar, A. and S. Jadhav. 2007. Studies on propagation of Phalsa (*Grewia asiatica* L.) by cutting. M.Sc. thesis University of Agriculture Sciences, Dharwad (Karnataka).

Luqman, M., N. Ali and M. Sajjid. 2004. Effect of different concentrations of indole butyric acid (IBA) on semi hard wood guava cuttings. Sarhad J. Agric., 20: 219-222.

Manan, A., M.A. Khan, W. Ahmed and A. Sattar. 2002. Clonal propagation of guava. Int. J. Agric. Biol., 4(1): 143-144.

Mankar, J.M., R.S. Wankhade and S.R. Bhople. 2009. Effect of some plant growth regulators on rooting and survival of layerage in guava. Annls Plant Physiol., 23(2): 192-195.

Rahman, N., T. Ullah, G. Nabi and T. Jan. 2002. Effect of different growth regulator and types of cuttings on rooting of guava (*Psidium guajava* L.). Quart. Sci., 9: 1-2.

Rai, M.K., V.S. Jaiswal and U. Jaiswal. 2009. Shoot multiplication and plant regeneration of guava (*Psidium guajava* L.) from nodal explants of *in vitro* raised plantlets. J. Fruit Ornament. Plant Res., 17(1): 29-38.

Siddiqui, M.I. and S.A. Hussain. 2007. Effect of indole butyric acid and types of cuttings on root initiation of *Ficus hawaii*. Sarhad J. Agric., 4(23): 919-925.

Tahseenullah, F., U. Wazir, M. Ahmad, F. Analoui, M.U. Khan and M. Ahmad. 2005. A break through in guava (*Psidium guajava* L.) propagation from cutting. Asian J. Plant Sci., 4: 238-243. https://doi.org/10.3923/ajps.2005.238.243

Tavares, M.S.W., E.E. Kersten and F. Siewerdt. 1995. Efeitos do ácido indolbutírico e da época de coleta de enraizamento de estacas de goiabeira (*Psidium guajava* L.). Sci. Agrícol., 52(2): 310-317. https://doi.org/10.1590/S0103-90161995000200018

Tien, L.H., L.D. Chac, L.T.L. Oanh, P.T. Ly, H.T. Sau, N. Hung, V.Q. Thanh, R.V. Doudkin and B.B. Thinh. 2020. Effect of auxins (IAA, IBA and NAA) on clonal propagation of *solanum procumbens* stem cuttings. Plant Cell Biotechnol. Mol. Biol., 21(55-56): 113-120.

Wahab, F., G. Nabi, N. Ali and S. Muslim. 2001. Rooting response of semi-hardwood cuttings of guava to various concentrations of different auxins. J. Biol. Sci., 14: 1984-1987.

Weisman, Z., J. Riov and E. Epstien. 1988. Comparison of movement and metabolism of indole-3-acetic acid in mung bean cuttings. Physiol. Plant, 74: 556-560. https://doi.org/10.1111/j.1399-3054.1988.tb02018.x