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ORIGINAL ARTICLE

Effects of indol butyric acid concentration on propagation from cuttings of papaya cultivars 'Golden' and 'Uenf/Caliman 01'

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Abstract – Introduction. Papaya is one of the very few fruit crops multiplied by seed. Unfortunately, the use of seedlings hampers the preservation of favorable plant characteristics and delays the appearance of the first flowers. In addition, the polygamous nature of papaya imposes planting 3-4 seedlings per hole in order to be certain of obtaining the right sex type. These shortcomings can be circumvented by clonal multiplication. This work aimed to multiply selected papaya cultivars from cuttings using the rooting promoting auxin indole-3-butyric acid (IBA). **Materials and methods.** Two experiments were conducted; the first one followed a completely randomized factorial design, with cultivars 'Golden' and 'Uenf/Caliman 01' as levels of the first factor, and 0, 500, 1,000, 1,500, and 2,000 ppm IBA as levels of the second factor. In this first trial, rooted cuttings of 'Uenf/Caliman 01' were taken to the field and compared to seedlings soon after planting and 4.5 months later. In the second experiment, IBA levels were increased aiming to enhance rooting percentage. Physiological assessments of rooted cuttings were also performed in this second experiment. **Results and discussion.** A concentration of 3,000 ppm IBA gave the best results for 'Golden', while lower concentration (1,500 ppm) seemed indicated for 'Uenf/Caliman 01'. Rooting success in 'Uenf/Caliman 01' was improved by using cuttings obtained from beheaded mother plants. The analyses showed that a few roots were sufficient to maintain good water status and photosynthetic rate in new plantlets. **Conclusion.** Plants propagated from cuttings had early flowering and produced first fruits at a lower height than seedlings in the field.

Keywords: Brazil / papaya / *Carica papaya* / vegetative propagation / rooting / auxins

Résumé – Effets de la concentration en acide indole butyrique sur le bouturage des cultivars de papayer 'Golden' et 'UENF/Caliman 01'. Introduction. Le papayer est l'une des rares cultures fruitières multipliée par graines. Malheureusement, l'utilisation de semences ne permet pas la préservation des caractéristiques génétiques de la plante, en particulier les traits favorables, et retarde l'apparition des premières fleurs. En outre, le statut de plante mâle ou femelle impose de planter 3-4 papayers par trou de plantation afin d'être certain d'obtenir le type sexuel voulu. Ces lacunes peuvent être contournées par la multiplication clonale. Ce travail a pour objectif de multiplier végétativement des cultivars sélectionnés de papayer à l'aide de l'auxine d'enracinement, l'acide indole-3-butyrique auxine (AIB). **Matériel et méthodes.** Deux expériences ont été menées : la première suit une combinaison factorielle totalement aléatoire, avec les cultivars 'Golden' et 'UENF/Caliman 01' comme facteurs de premier niveau, et les concentrations en AIB (0, 500, 1 000, 1 500, et 2 000 ppm) comme facteurs de deuxième niveau. Dans ce premier essai, les boutures racinées de 'UENF/Caliman 01' ont été transférées en plein champ et comparées à des plants issus de semis peu après germination ou âgés de 4,5 mois. Dans la deuxième expérience, les concentrations d'AIB ont été augmentées dans le but d'améliorer le pourcentage d'enracinement. L'évaluation physiologique des boutures racinées a également été effectuée dans ce deuxième essai. **Résultats et discussion.** La concentration de 3 000 ppm d'AIB a montré les meilleurs résultats pour 'Golden', alors qu'une concentration inférieure (1 500 ppm) semblait mieux indiquée pour 'UENF/Caliman 01'. La qualité de l'enracinement de 'UENF / Caliman 01' a été améliorée en utilisant des boutures obtenues à partir de plantes mères décapitées. Les analyses ont montré que quelques racines étaient suffisantes pour maintenir un bon état

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hydrique et un taux de photosynthèse suffisant chez les nouvelles boutures. **Conclusion.** Les plantes multipliées par bouturage ont présenté une floraison précoce et ont produit les premiers fruits à une hauteur inférieure à celle de plantes issues de semis dans le même champ.

Mots clés : Brésil / papayer / *Carica papaya* / multiplication végétative / enracinement / auxines

1 Introduction

Papaya (*Carica papaya* L.) is a peculiar fruit tree (in fact, a giant herb of monopodial growth) of increasing economic interest. Native to Tropical America, papaya is usually referred as a polygamous plant, a species having three primary sex types: female, male and bisexual on different individuals (the most appropriate term for this sexual system is trioecy). The heritability of sex ratio is well known in papaya. Seeds of the group Solo obtained from self-pollinated hermaphrodite flowers produce a proportion of 2:1 hermaphrodite:female plants [1, 2]. This proportion is maintained in gyno-dioecious plants of the Formosa group of papayas, but in the case of F_1 hybrids obtained by crosses between female and hermaphrodite bisexual plants a ratio of 1:1 is derived [2, 3]. Bisexual plants with hermaphrodite complete flowers are commercially preferred because of the better fruits that they bear.

So far papaya remains as one of the very few fruit crops commercially multiplied by seed. The polygamous nature of papaya imposes as another disadvantage the inconvenience of having to plant 3-4 seedlings per hole in order to be almost certain of obtaining at least one hermaphrodite plant per hole [3]. Since the sex of the seedling is better ascertained when the first flowers develop, the selection of the preferred plant, and the removal of the discarded ones, takes place several weeks after planting [2]. This practice is expensive and represents an annoying loss of resources and time that delays the growth of the selected individuals due to the competition with the discarded plantlets [4]. In addition, the high cost of the seed of selected genotypes has led some farmers to use seeds from open pollinated flowers of different generations (F_2, F_3 and F_4); seeds that produce plants of low vigor and large variability in fruit quality [5].

All these disadvantages suggest for the implementation of more convenient procedures of vegetative multiplication of papaya such as cuttings, grafting and micropropagation. The multiplication of papaya from cuttings allows the preservation of favorable plant characteristics and brings forward the appearance of first flowers and fruits at lower trunk height [6–8]. Lower insertion of the first fruits in the trunk increases early yield and facilitates their harvesting [9].

The success of vegetative propagation from cuttings depends on numerous factors, among them the nutritional status of the mother plant, hormonal balance, plant age and sanitary conditions [10, 11]. Plant genotype and the use of rooting hormones are also important. In this regard, as in many other crops, the use of the rooting auxin indol-3-butyric acid (IBA) increases the percentage of rooting in some cultivars of papaya [12], although a strict control of the conditions of the propagation chamber is still needed. In this regard, Allan obtained high success propagating cultivar 'Hortus Gold' when cuttings were placed under intermittent mist in a sandy substrate kept at 30 °C using 1,000 ppm of IBA [6]. Following this same procedure, Fitch *et al.* [4] reached 30% of success rooting the cultivar 'Rainbow'. The control of substrate temperature and the frequency of intermittent mist are emphasized to avoid high losses due to bacterial and fungi proliferation [4]. In this regard, Allan and Carlson [13] reported low success multiplying female plants of the cv. 'Honey Gold' due to the high incidence of stem rot.

Given the strong influence that papaya genotype has on rooting success and the lack of information on the vegetative multiplication of cvs 'Golden' and 'Uenf/Caliman 01', we have initiated a research with the objective of determining the effects of different levels of the auxin IBA on rooting percentage, and on the physiological performance of the plantlets of both cultivars in the nursery and field.

2 Materials and methods

Two experiments aiming to propagate selected papaya cultivars from cuttings were conducted in 2009 at the facilities of the Company Caliman Agrícola S.A. sited in Santa Terezinha, near the town of Linhares, Espírito Santo State, Brazil (latitude 19° 11′13″S, longitude 40° 05′39″W and 29 m a.s.l.).

2.1 Experiment 1

The first experiment followed a completely randomized factorial design (2 × 5), with two cultivars ('Golden' and 'Uenf/Caliman 01') as the levels of the first factor, and five concentrations of the rooting hormone indole-3-butyric acid (IBA) (0, 500, 1,000, 1,500, and 2,000 ppm) as the levels of the second factor. Three replicates and eight cuttings per replicate were used in this experiment. Leafy cuttings 15−25 cm long were obtained from lateral stems of 2.5-year-old hermaphrodite plants of cvs 'Golden' and 'Uenf/Caliman 01'. These cuttings were immediately put in water and transported to the nursery where all but two recently expanded leaves per plant were removed. Then, the base of the cuttings were treated during 20 s with different concentrations of IBA (0, 500, 1,000, 1,500 and 2,000 ppm) diluted in a solution of NaOH 0.1N. A leafy cutting before treatment with IBA is depicted in *figure 1*.

After IBA treatment, the cuttings were transferred to sand-filled perforated trays of 16 L volume and 10 cm height. Cuttings were irrigated with Hoagland's solution two weeks after the transfer to the nursery and weekly thereafter. At the beginning of the experiment and every two weeks, all cuttings were also treated with Captan® to prevent the appearance of fungus diseases at the base of the cuttings. An intermittent misting

Figure 1. Cutting prepared for IBA treatment.

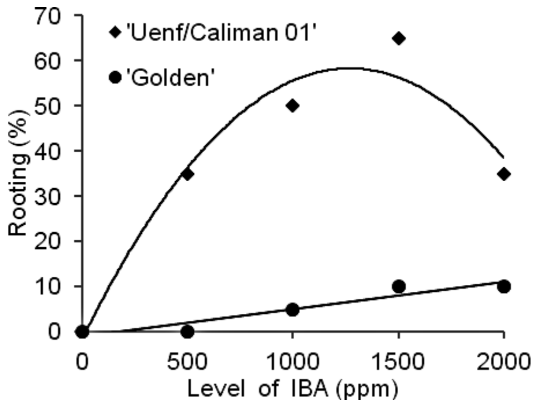

Figure 2. Rooting success in cvs 'Golden' and 'Uenf/Caliman 01', in response to different levels of IBA 70 days after treatment. $N = 120$ cuttings per cultivar (24 cuttings per cultivar and dose). Equations: 'Golden', $Y_i = -1.0 + 0.006x$, $R^2 = 0.90$; 'Uenf/Caliman 01', $Y_i = -1.57 + 0.093x - 0.000037x^2$, $R^2 = 0.95$.

system installed in the propagation chamber was automatically activated when the air temperature reached 31 °C. Environment conditions within the chamber were monitored by a WatchDog Datalogger (Spectrum Technologies Inc., USA).

The percentage of rooting 50 days after IBA treatment was recorded and the effects of the different concentrations compared on both cultivars. Next, successfully rooted cuttings were transferred to black polyethylene bags 0.75 L volume filled with Bioplant® substrate, as commonly performed in Caliman Co, and kept in the nursery for 20 more days. After 20 more additional days of acclimation at the open air, 15 homogenous plantlets of cv. 'Uenf/Caliman 01' were selected from samples of the treatment of 1,500 ppm IBA and planted in the field at 1.5 × 3.5 m distance and adjacent to seedlings of the same cultivar and age. Only one rooted cutting per hole was planted while three seedlings were placed in each planting hole until the sex of seedlings could be determined. Then, two seedlings were removed leaving only one hermaphrodite plant per hole. About 4.5 months after transplanting, the vegetatively propagated plants versus seedlings were compared according to trunk diameter (cm), plant height (cm), and height (cm) of the trunk where the first fruit was bored. Following recommendations made by Fitch *et al.* [4], leaf number, canopy size and portion of the trunk (cm) with developing fruits and number of flowers and fruits present were also compared at that time. Days after transplanting before reaching the onset of flowering were also counted. The performance of vegetatively propagated plants versus seedlings was compared by means of the test of Student using GENES software package [15].

2.2 Experiment 2

In the second experiment, cuttings were obtained from stems formed in response to heavy pruning of 3-year-old hermaphrodite plants of cvs 'Golden' and 'Uenf/Caliman 01'. To promote their branching, mother plants were decapitated at 2 m height in March 4th, 2009. Then, stems 12–30 cm long and about 2 cm at the base were excised about 30 days after decapitating plants [16]. After the removal of the stems, the cuttings were handled as before except that in this experiment, the assessed concentrations of IBA were increased (0, 750, 1,500, 2,250 and 3,000 ppm). The percentage of rooting after 70 days was calculated and compared as before. Next, rooted leafy stems were taken to the nursery as in experiment 1 where a Datalogger WatchDog (Spectrum Technologies Inc., USA) was used to monitor environmental variables. After a period of acclimatization, plant height (cm), trunk diameter 3 cm above ground (cm), and the number of leaves and root volume (cm^3) were determined on rooted leafy cuttings. Finally, measurements were made of the chlorophyll content of different leaves of the vegetatively propagated plants using SPAD-502 Chlorophyll Meter® (Minolta Co., Japan), the efficiency of photosystem II, as the fraction F_v/F_{Max}, using MINI–PAM® fluorimeter (Heinz Walz Gmbh, Germany) and their photosynthesis rate (A) with a infra-red gas analyzer LI-6200® model (LI-COR Biosciences, USA) using artificial light at an intensity of 500 µmol m^{-2} s^{-1}.

The effect of the genotype on the growth of the new plants was determined by analyses of variance and compared by Tukey test at a significance level of 5%. The relationships between morphological and physiological plant characters were studied by Pearson correlation analyses. The effect of IBA concentration on new plants characteristics and on their physiological performance was studied by regression analyses using GENES software package [15].

3 Results and discussion

3.1 Experiment 1

The cultivars 'Golden' and 'Uenf/Caliman 01' responded in a different manner to the increasing levels of IBA. The percentage of rooting increased linearly as did the concentration of IBA in 'Golden', while the rooting success of 'Uenf/Caliman 01' better fit a quadratic curve in response to increasing levels of IBA; that is, rooting success decreased at the highest concentrations of IBA for this last cultivar (*figure* 2). The maximum percentage of rooting in 'Golden' (10%) was reached with both 1,500 and 2,000 ppm IBA,

Table I. Vegetative characteristics of cv. 'Uenf/Caliman 01' papaya cuttings *versus* seedlings: plant height at transplanting (PH1) and after 4.5 months in the field (PH2), trunk diameter (Trunk), leaf number (Leaves) and canopy diameter (Canopy).

Propagation procedure	Vegetative characteristics[y]				
	PH1 (cm)	PH2 (cm)	Trunk (cm)	Leaves	Canopy (cm)
Cuttings	21.3 ± 0.9	67.2 ± 2.8	6.6 ± 0.3	21.3 ± 1.0	187.3 ± 9.9
Seeds	9.3 ± 0.3	126.8 ± 2.2	8.3 ± 0.3	25.2 ± 0.6	179.5 ± 3.8
P value[z]	< 0.0001	< 0.0001	0.0001	0.0027	0.4677

[y] Means ± standard errors (n = 15); [z] t-Student test.

Table II. Reproductive characteristics of cv. 'Uenf/Caliman 01' in papaya cuttings *versus* seedlings after 4.5 months growing in the field: flowering onset (Flowering, in days after transplanting - DAT), flowers per plant (Flowers), height for first fruit (HFruit), fruit number per plant (NbFruits), length of the portion of the stem bearing fruits (SRLength).

Propagation procedure	Reproductive characteristics[y]				
	Flowering (DAT)	Flowers	HFruit (cm)	NbFruits	SRLength (cm)
Cuttings	0.0 ± 0.0	12.3 ± 0.4	25.6 ± 2.3	9.7 ± 0.5	41.6 ± 3.1
Seeds	90.6 ± 1.2	15.4 ± 0.5	68.1 ± 1.4	12.8 ± 0.8	58.7 ± 2.6
P value[z]	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0002

[y] Means ± standard errors (n = 15); [z] t-Student test.

while the rooting success in 'Uenf/Caliman 01' was much higher (65%) and achieved at 1,500 ppm. These levels of rooting success were too low for 'Golden' but satisfactory for 'Uenf/Caliman 01'. Allan and Carlson [13] reported a percentage of 60% rooting of cuttings of cv. 'Honey Gold' using a concentration of 3,000 ppm IBA. A high proportion of the losses in our experiments (around 25% of cuttings in all treatments) was due to stem rot (*Phytophtora palmivora*), despite the application of fungicides to the base of the cuttings. Fitch *et al.* [4] observed similar levels of losses on cv. 'Rainbow' as Allan and Carlson [13] did propagating cv. 'Honey Gold'. All rooted cuttings of the first experiment survived the processes of acclimatization and transplanting indicating that the bottleneck multiplying papaya from cuttings is the rooting of the leafy stems, although other authors suffered additional losses of 35% rooted cuttings during the processes of acclimatization and transplanting [8].

The performance of vegetatively propagated plants and seedlings at transplanting and after 4.5 months in the field are compared in *table I*. Despite that the height of the cuttings was more than double than that of the seedlings at the date of transplanting, seedlings grew more rapidly and after 4.5 months doubled the height of the cuttings. Lower differences were noticed for the number of leaves produced and for the diameter of the trunk (*table I*). The size of the canopy was slightly larger in plants multiplied from cuttings. Similar results have been observed by other authors that compared seedlings *versus* cuttings and/or versus micropropagated papayas [6, 7, 17–19].

The production of flowers and hence of fruit was slightly lower in plants proceeding from cuttings (*table II*) as previously observed by Katoh and Ooishi [20]. This could lead to a reduction of yield at the end of the cycle in plants propagated from cuttings [18, 20], although earlier setting at a lower height favors their use since very tall papayas originating from seedlings have to be cleared from the orchard before the end of their reproductive life. Talavera *et al.* [19] did not perceive any difference in productivity between seedlings and cuttings, while Allan [14] observed, on the contrary, higher productivity for cuttings.

All papayas multiplied from cuttings were already forming flowers at the moment of transplanting. Some of these early flowers aborted, but the pace of producing new flowers was remarkably stable. This early acquisition of flowering led to early production of fruit at much lower trunk height than seedlings (25.6 *versus* 68.1 cm, respectively) (*table II*). As noted before by Allan [6, 7], trunk height for setting and flowering time was positively related *(table II)*. Thus, a lower more convenient trunk height for the first fruits in the cuttings was related to their earlier flowering after transplanting and hence to their precocious harvest. The reduction of the height in which the first fruit appears facilitates harvesting, and may favor early and larger yield since the reproductive portion of the trunk is significantly extended [9].

3.2 Experiment 2

In the second experiment, a different rooting level was observed again on the two cultivars in response to IBA doses. In this regard, 'UENF/Caliman 01' rooted again in a higher proportion, fitting its response to a quadratic curve, with the maximum percentage of rooting (45%) obtained with a concentration of IBA of 1,500 ppm. Rooting percentage of 'Golden' was again very low reaching the maximum value (17%) with the highest concentration of IBA (3,000 ppm) (*figure 3a*). This differential success was in part due to the high proportion of cuttings suffering stem rot in 'Golden' (*figure 3b*). The low percentage of rooting in this cultivar at low levels of IBA suggests the convenience of using a concentration of IBA higher than 3,000 ppm for 'Golden' in future trials and control phytosanitary conditions of the plants as well. Allan *et al.* [21] emphasized the importance of the losses in the propagation

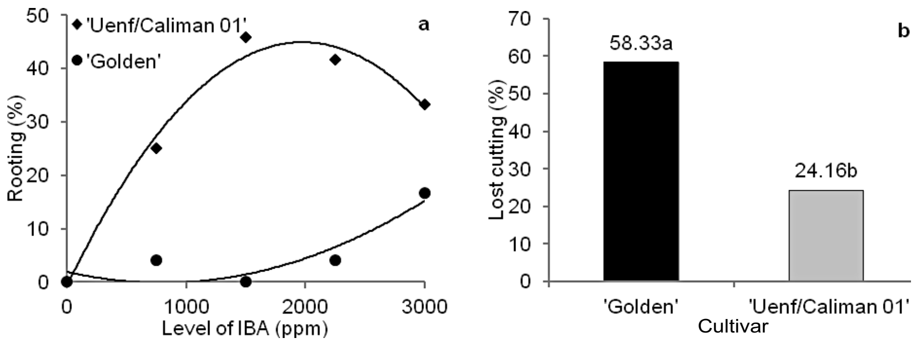

Figure 3. Rooting success 70 days after treatment in papaya cvs 'Golden' and 'Uenf/Caliman 01', in response to different concentrations of IBA. (a) Percentage of rooted cuttings. $N = 120$ cuttings per cultivar (24 cuttings per cultivar and dose). Equations: 'Golden', $Y_i = 1.9054 - 0.0051x + 0.0000032x^2$, $R^2 = 0.83$; 'Uenf/Caliman 01', $Y_i = -0.5957 + 0.046x - 0.00001164x^2$; $R^2 = 0.98$; (b) Losses due to stem rot. Means followed by different letters are significantly different. Separation of means by Tukey test ($P < 0.05$).

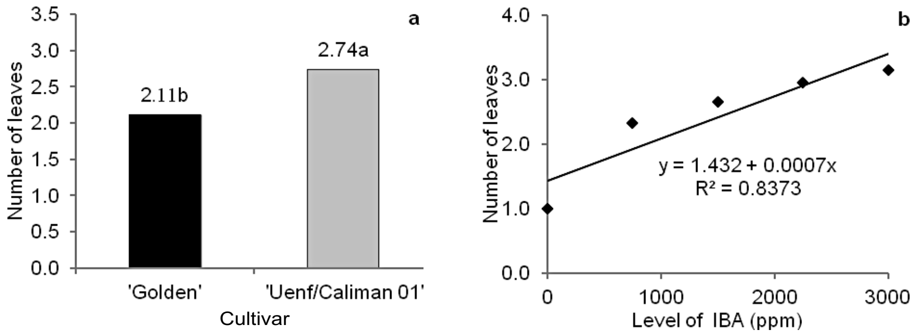

Figure 4. Leaf number in cvs 'Golden' and 'Uenf/Caliman 01' cuttings after 70 days of acclimatization: (a) Cultivar comparison; (b) Effect on leaf number of the levels of IBA applied to the base of 'Uenf/Caliman 01' cuttings. Means followed by different letters are significantly different. Separation of means by Tukey test ($P < 0.05$). $N = 120$ cuttings per cultivar (24 cuttings per cultivar and dose).

of papaya and attributed them mainly to bacterial infections. Survival rates of between 57 and 90% of the cuttings were achieved by Allan in previous trials [6, 14]. Low survival rate could be also influenced by the low lignification degree of the base of the cuttings. For this reason, Allan *et al.* [6, 13] proposed selecting as propagules thick stems with a diameter at the base around 2.5 cm. Unfortunately the production of a high number of lateral shoots with these characteristics remains a challenge in this species of monopodial growth, even after decapitating mother plants to stimulate vigorous lateral sprouting. Thin shoots as a source for cuttings are inappropriate in papaya [22].

After rooting, the cuttings transferred to acclimatization formed new leaves. After 70 days the number of leaves was significantly higher in cv. 'Uenf/Caliman 01' than in cv. 'Golden' (*figure 4a*). A positive effect on the development of new leaves was observed for the concentration of IBA. A significant linear relationship was found between the number of leaves and IBA applied to the base during the rooting process (*figure 4b*). Cuttings that lost their leaves failed to form any root, and finally died.

The same favorable effect of IBA concentration applied to the base was observed on SPAD values that were also significantly higher for 'Uenf/Caliman 01' than 'Golden' (*figure 5b*). 'Golden', a mutation of 'Sunrise Solo' takes its name from the green yellowish color of their leaves, so a lower level of chlorophyll was expected (*figure 5a*). Torres Netto *et al.* [23] relate SPAD records in the leaves of papaya with high nitrogen content and large photosynthetic pigments availability in foliar tissues.

No significant relationships could be detected between the height of the cutting and their photosynthetic activity, neither in cv. 'Golden' nor in 'Uenf/Caliman 01' (*table III*) confirming that cuttings of a height between 13 and 30 cm could be all valid for the vegetative propagation of papaya [6]. On the contrary, a positive effect of the diameter of the base of the cuttings on their photosynthetic activity was observed in 'Golden' (*table III*). A minimum size for the cuttings could be positive since thicker and taller propagules may store a higher amount of carbohydrates that are used for root primordia formation [11]. Nicoloso et al. are of the opinion that cutting size and rooting capacity may depend on the species, after failing to find any significant effect of the cutting size on the propagation of Brazilian ginseng (*Pfaffia glomerata*) [24].

Leaf number improved the performance of the new plants of 'Uenf/Caliman 01' grown in the nursery in terms of their photosynthetic activity. Photosynthetic rate (A) increased with the number of leaves formed by the cuttings. Such relationship could not be probed when the influence of the root volume on A was tested (*table III*). A lack of a significant relationship with the volume of the roots suggests that just a few roots are enough to sustain the photosynthetic machinery allowing success in the survival and growth of the rooted cuttings of 'Uenf/Caliman 01' when transplanted to the field.

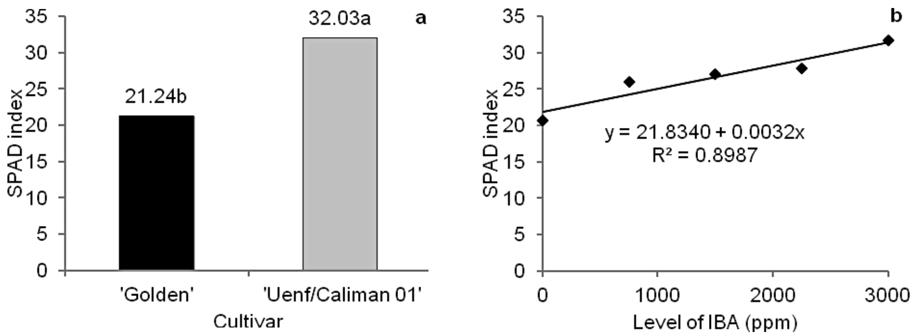

Figure 5. Chlorophyll content estimated by SPAD values in cvs 'Golden' and 'Uenf/Caliman 01' cuttings after 70 days of acclimatization: (a) Cultivar comparison; (b) Effect on SPAD values of the levels of IBA applied to the base of 'Uenf/Caliman 01' cuttings. Means followed by different letters are significantly different. Separation of means by Tukey test ($P < 0.05$). $N = 120$ cuttings per cultivar (24 cuttings per cultivar and dose).

Table III. Linear correlation of the cutting height, cutting diameter, leaf number and root volume with photosynthesis rate (A) and efficiency of photosystem II (FV/Fmax ratio) in papaya cvs 'Golden' and 'Uenf/Caliman 01'.

Variables	A (μmol CO_2 m^{-2} s^{-1})		Fv/Fmax ratio	
	Golden (n = 9)	Uenf/Caliman 01 (n = 37)	Golden (n = 9)	Uenf/Caliman 01 (n = 37)
Cutting height	0.3413^{ns}	-0.0280^{ns}		
Cutting diameter	0.7499^{**}	0.2053^{ns}		
Leaf number	0.8409^{**}	0.4266^{**}	0.0962^{ns}	-0.2745^{ns}
Root volume	0.2666^{ns}	0.2912^{ns}	0.0270^{ns}	-0.0962^{ns}

ns = not significant at 5% by t-test; ** significant at 1% by t-test.

Table IV. Summary of the effects of cultivar, IBA dose, and their interaction on rooting in Experiment 1 (Root1), and 2 (Root2), and on the percentage of cuttings lost in the propagation process, number of leaves formed per surviving plantlet and its chlorophyll content (SPAD) in Experiment 2.

Source of variation	DF	Mean square				
		Root1	Root2	Lost cuttings	Formed leaves	SPAD
Cultivar	1	$7{,}921.87^{**}$	$4{,}083.33^{**}$	$8{,}755.21^{**}$	4.03^{**}	786.23^{**}
IBA	4	$10{,}59.90^{**}$	589.96^{**}	122.40^{ns}	3.72^{**}	96.65^{**}
Cultivar x IBA	4	669.27^{**}	515.62^{**}	96.35^{ns}	0.45^{ns}	28.46^{ns}
Error (within)	20	26.04	32.25	52.08	0.33	14.15
Mean		21.25	16.67	41.25	2.43	26.63
CV (%)		24.01	33.54	17.50	23.73	14.14

DF = degrees of freedom; CV = coefficient of variation. ns = not significant at 5% by F-test; ** significant at 1% by F-test.

Finally, the efficiency of photosystem II was observed not to be completely dependent on the cutting development in the days after transplanting, as the lack of a significant relationship between F_v/F_{max} ratio and the number of leaves and root volume of the cuttings indicate (*table III*). F_v/F_{max} values between 0.75 and 0.85 observed in this experiment are adequate and informative that all new plants were well functioning and not under stress [25]. Reis and Campostrini [26] have recorded values in the range of 0.78 and 0.83 in adult papayas grown in the field under full sun exposition. Critchley [27] reported values close to 0.80 in fully sun exposed leaves and in the range of 0.83–0.85 in leaves in the shadow, while values below 0.725 suggest photo-inhibition damage. For a full understanding of the statistical design and variability associated, a summary of the results obtained in experiments 1 and 2 on rooting failure and success is shown in *table IV*, with details of the average values, coefficients of variation, and degrees of freedom.

4 Conclusion

Papaya cv. 'Uenf/Caliman 01' was successfully propagated from cuttings using IBA concentrations of 1,500 and 2,000 ppm. A very low percentage of rooting was evident for cultivar 'Golden', even at higher concentrations of IBA. Rooting success in 'Uenf/Caliman 01' was improved when cuttings were obtained from severely pruned plants. The analyses of the surviving cuttings showed that a few roots were sufficient to maintain good photosynthetic activity. Papaya plants propagated from cuttings had early flowering in the field and produced the first flowers and fruits at a lower trunk height than papaya seedlings.

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