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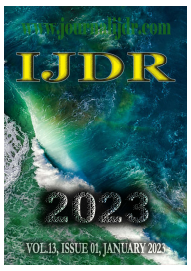

RESEARCH ARTICLE OPEN ACCESS

ABILITIES OF *Citrus limon (L.) Burm. f., Citrus tangelo* AND *Citrus sinensis (L.) Osbeck* AT PROPAGATION BY CUTTINGS in SANDY SOIL

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ABSTRACT

Coming from the Latin acrumen which means sour, the word citrus was given in antiquity to trees with acid fruits. Indeed, citrus fruits refer to several species, the best known of which are oranges, grapefruits, mandarins, clementines and lemons. Species of the genus Citrus are well known but very little studied in Niger. It is with the aim of providing more data that the present study was carried out. The general objective was to study the ability to propagate by cuttings in three citrus species (Citrus limon, Citrus tangelo and Citrus sinensis). The study was carried out on station, in an experimental plot of the Faculty of Agronomy. Polyethylene plastic pots were used for the cultivation of the cuttings. The substrate is composed only of sand. The cuttings are of two types: type 1 with a diameter of between [0.5 to 1] cm and type 2 with a diameter of [1.5 to 2] cm. Among the two types of diameters, part of the cuttings was covered with plastic in order to be able to distinguish the cuttings which will give a maximum rate of recovery. The observations related to the duration of budding, the latency time and the evaluation of the root system. The results showed that the cuttings begin to bud 5 days on average after cultivation. The maximum recovery rate was obtained for Citrus limon cuttings with 93.75% for diameters between [0.5 to 1] cm and 87.5% for those between [1.5 to 2] cm. The root ramifications gave 3 months after the establishment of the cuttings in a cutting of Citrus limon 7 main roots and 174 secondary roots. None of the budded cuttings of Citrus sinensis and Citrus tangelo gave roots. For the cuttings that were not covered with plastic, only two of them budded without root branching in C tangelo and one in C sinensis.

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INTRODUCTION

Niger is a totally landlocked Sahelian country characterized by low rainfall ranging from 300 to 700 mm/year with high inter-annual and intra-seasonal variability (Direction de la Météorologie Nationale du Niger, 2003 quoted in Van Vyve, 2006). The agricultural land potential is estimated at 15,000,000 hectares, mainly in rural areas (Agbegnido and Adamou, 2018). It also has on a good part of its territory, vast areas of production of fruit trees (Aboubakar, 2016). Arboriculture is practiced in the Department of Gaya, the Dallols Foga , Maouri and Bosso, the banks of the Niger River and its tributaries, the valleys of the Aïr and the Oasis of Kawar , the basins of Manga, Mounio and Damagaram and in the GoulbiMaradi valley (Dodo, 2003). According to Baina *et al.* 2007 the main cultivated fruit trees are date palms (*Phoenix dactylifera*), species of the Citrus genus (*Citrus limon, Citrus maxima, Citrus reticulata, Citrus sinensis*), papaya (*Carica papaya*), guava (*Psidium guayava*), banana (*Musa paradisiaca*) and mango (*Mangifera indica*). They are also rich in vitamin A, B and C and the flowers and leaves of the most aromatic varieties are distilled and the essential oils used by the perfume industry (Memento, 2002).

Despite this potential for production land, Niger imports many agricultural products. But it also imports citrus fruits (Eduardo *et al.,* 2019). These citrus fruits represent 9 to 12% of the fruit species grown in Niger (Tankari and Mounkaïla, 2014). The main citrus species grown are orange (*Citrus sinensis*), lemon (*Citrus limon*), mandarin (*Citrus reticulata*), pomelo (*Citrus paradisi*), clementine (*Citrus clementine*) and tangelo (mandarin/ Pomélo), In Niger, the number of citrus plants in production is 136,628, with a production of 45,320 tons (DS/MAN, 2012). The main mode of citrus production is the use of rootstocks. Citrus grafting is essentially carried out on lemon tree rootstocks. However, this combination encounters problems which are the development of lemon tree suckers but also other problems such as the rupture between the rootstock and the scion due to bad weather. The rootstock therefore takes over. Despite all these problems with citrus multiplication in Niger, there are very few studies on citrus in Niger. In order to provide more data on the potential to increase citrus production in Niger, this work was initiated. The objective of this work is to study the aptitude for propagation by cuttings of three (3) citrus species namely *Citrus limon, Citrus tangelo* and *Citrus sinensis*.

MATERIALS AND METHODS

Study site: The production trial for the cultivation of the cuttings was carried out in an experimental plot located at the Faculty of Agronomy of the Abdou Moumouni University of Niamey. The climate is of the Sahelian type with high temperatures (43°) between April and June and low temperatures (15°) between December and January. The rainfall varies from 400 to 600 mm per year except for a few years when up to a total of more than 700 mm is recorded. After taking the cuttings, the plants were transferred to a garden 34 km from Niamey in the urban commune of Kollo.

Plant material: The species concerned by this test are *Citrus limon* (lemon tree), *Citrus sinensis* (orange tree) and *Citrus tangelo* (tangelo).

For each species, cuttings of different diameters were used:

- A first batch of cuttings with a diameter of [0.5 to 1] cm;
- A second batch of cuttings of diameter [1.5 to 2] cm.

Other cuttings of 25 cm in length are taken from the arboriculture plot of the Faculty of Agronomy of Abdou Moumouni University in Niamey on subjects that look healthy.

Production of seedlings in the nursery

Preparation for the test: Polyethylene plastics 20 cm long and 8 cm in diameter were filled only with sand in order to avoid the contamination of pathogenic agents hindering the proper development of the different cuttings. The nursery trial started in early July 2019 and continued for three (3) months. The experimental device was placed under the shade of the feet of trees in the experimental plot of the Faculty of Agronomy. It is composed, for each type of diameter, of six blocks. Each block is made up of three plots representing the three species studied. Within each plot, culture pots in 2 rows were placed. The 1st ^{row} and the second are composed respectively of pots with short plastic cuttings and uncovered cuttings. Each plot is made up of 4 pots with covered cuttings and 4 pots with uncovered cuttings. In total, for each type of diameter and for each type of treatment (covered and uncovered), 28 cuttings were observed. Figure 3 illustrates the experimental device set up.

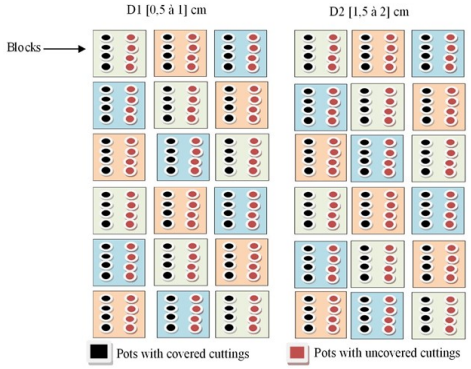

Figure 1. Experimental device in blocks

The figure below shows the plants in the nursery and illustrates the different treatments carried out on these plants.

Figure 2. View of the plants in the nursery as well as the different treatments (covered and non-covered plants)

Cuttings: Cuttings were taken early in the morning to reduce their evaporation. The stems taken were stripped and cut into cuttings 25 cm in length according to two classes of the 2 classes of diameter ([0.5 to 1] cm and [1.5 to 2] cm). The establishment of the cuttings occurs the same day as the collection in order to ensure a good recovery. The observation is done every two (2) days. It consists of observing cutting by cutting, the appearance of buds and evaluating the root system at the end of the experiment. The mortality rate was also assessed.

Planting and monitoring of seedlings: A total of sixty plants, thirty of which per diameter class, were planted in October 2019. Monitoring and observations focused on the onset of flowering and fruiting and height measurements were made once a year over three years (2020; 2021; 2022). The plants were planted and monitored in a private producer's garden located about 30 km from Niamey. The following variables were defined in order to be able to analyze the data:

- The recovery period: time interval between the planting of the cuttings and the budding of the first cutting;
- Recovery time: time between budding of the first cutting and budding of the last viable cutting;
- The recovery rate of cuttings: ratio between the number of cuttings having budded and the total number of cuttings;
- Recovery speed: variation in the rate of vegetated cuttings as a function of time.
- Flowering and fruiting time;
- The average height of the plants.

Data processing: The data collected was entered into Word and Excel. Excel made it possible to perform the calculations of the averages as well as the development of the histograms.

RESULTS AND DISCUSSION

Time and duration of recovery of cuttings: The time and duration of recovery of cuttings in the three (3) species of Citrus are indicated in table 1.

Table 1. Variation in latency time and recovery time of cuttings

Species	Diameter classes	Recovery time		Recovery time	
		Covered	Not covered	Covered	Not covered
C. silt	[0.5-1]	6	-	22	-
	[1.5-2]	8	-	21	-
C.tangelo	[0.5-1]	5	-	27	-
	[1.5-2]	8	-	15	-
C. sinensis	[0.5-1]	5	6	22	4

The latency time is 6 and 8 days in *Citrus limon* cuttings covered with plastic respectively for the diameter between [0.5-1] cm and the diameter of [1.5-2] cm. Also, the same trend was observed in cuttings of *Citrus sinensis* and *Citrus tangelo* with a recovery period of 5 days for those covered with plastic. Indeed, for cuttings not covered with plastics, the latency time is 5 and 12 days respectively for cuttings with a diameter of [0.5-1] cm and [1.5-1.9] cm. As for the numbers of the buds, there is not a very big difference. In each cutting of these species, the number of buds varies from 3 to 5 buds. But for the cuttings not covered with plastic only two cuttings budded: one from *Citrus sinensis* and one from *Citrus tangelo*. The recovery period is 27 days. Thus, the recovery period is shorter for cuttings without plastic in *Citrus tangelo* and *Citrus sinensis*, which is 3 to 4 days. However, this recovery time is longer in cuttings of *Citrus tangelo* and *Citrus sinensis* covered with plastic, which is 27 days. For the cuttings covered with plastic in *Citrus limon,* no cuttings budded.

Recovery speed: Throughout the trial, a difference in variation was recorded within the cuttings of the different species. However, the curves of *Citrus limon* increase considerably until the 18th ^{day} before stabilizing. On the other hand, the evolution of the curves of *Citrus sinensis* and that of *Citrus tangelo* (for the diameter of [0.5 to 1] cm) progresses and becomes constant from the 27th day. Indeed, through the figure the highest recovery rate is observed in the cuttings of *Citrus limon,* on the other hand this rate is very low for the diameter of [1.5 to 2] cm in the cuttings of *Citrus tangelo*.

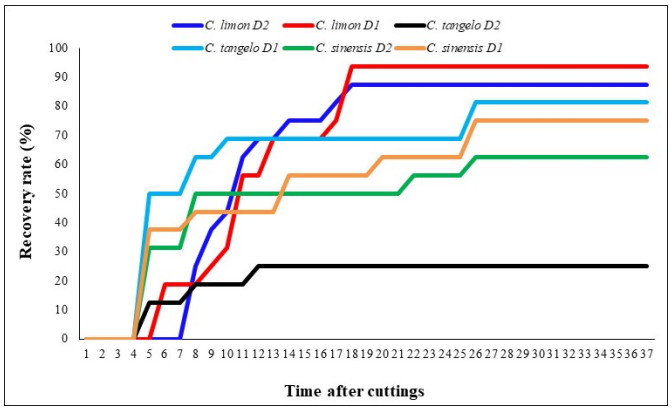

Figure 5. Evolution of the recovery rate of cuttings as a function of time

The mortality rate of cuttings is shown in Figure 6.

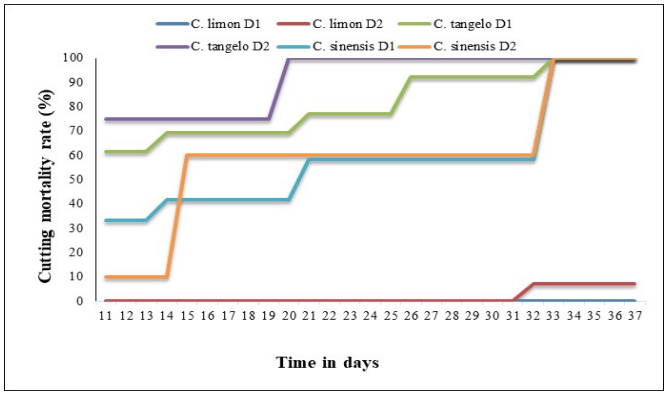

Figure 6. Cutting mortality rate (%) as a function of time

Mortality is greater in cuttings of *Citrus tangelo* and *Citrus sinensis* than in those of Citrus *limon*. In *Citrus limon*, this mortality is low (7.14%). Thus, the results showed that the species best suited to propagation by cuttings is the lemon tree.

Cutting capacity: Table 2 presents the percentage of recoveries of these different cuttings.

Table 2. Cutting rate (%) according to the types of cuttings

Species	Diameter classes	Recovery rate	
		Covered	Not covered
C. silt	[0.5-1]	93.75	-
	[1.5-2]	87.5	-
C tangelo	[0.5-1]	81.5	-
	[1.5-2]	25	-
C sinensis	[0.5-1]	75	6.25
	[1.5-2]	62.5	11.20

The cutting capacity showed variations according to the type of cuttings. In fact, it is:

- 87.5% and 93.75% for *Citrus limon cuttings* covered with plastics respectively for the diameter between [1.5-2] cm and those between [0.5-1] cm and nil for cuttings without plastics;
- 62.5% and 75% for the cuttings with plastics of *Citrus sinensis* respectively for the diameter [1.5-2] cm and for the diameter of [0.5-1] cm and 6.25% for those having no not been covered;
- 25% and 81.5% for cuttings with plastics in *Citrus tangelo* respectively for the diameter of [1.5-2] cm and that of [0.5-1] cm.

Thereby, through this table the best results were recorded in the cuttings covered with plastics. Indeed, the analysis of variance shows that between the two batches of diameter of the two species, *Citrus limon* and *Citrus sinensis*, the difference is not significant at the 5% threshold (*C limon* D2 = 11.40 ±3.28 and D1= 11.20 ±4.49; *C sinensis* D2 = 9 ±1 and D1= 10 ±2.12). But for *Citrus tangelo,* there is a significant difference at the 5% threshold (D2 = 4.60 ±0.89 and D1 = 12 ±1.22) between the two types of diameter batches. However, within the cuttings of these species the difference is significant at the 5% threshold.

Root system

Table 3 shows the branching of the root system of the cuttings.

Table 3. Branching number of the root system of *Citrus limon*

Types of cuttings	Root numbers	
	main roots	secondary roots
Citrus lime	7	174
Citrus sinensis	0	0
Citrus Tangelo	0	0

According to the analysis of the results, none of the cuttings of *Citrus sinensis* and *Citrus tangelo* gave root. On the other hand, the number of branches of *Citrus limon cuttings* is quite high with 7 main roots and 174 secondary roots. The sample was therefore taken from a cutting in *Citrus limon* which gave these numbers of ramifications. The photo above shows the offshoots of the root system of the cutting and the growth of the seedlings.

Figure 7. Appearance of Citrus limon branches and plants: (A) Appearance of the branches of the cutting; (B) Growth of planted seedlings

Plant growth after 3 years: *Citrus limon* seedlings after their development were planted in a real environment, that is to say in the experimental garden in a soil of sandy-loamy texture and watered with water from the borehole located within the garden.

The development of *Citrus limon plants* was determined over three (3) successive years. The results are shown in Figure 8.

Analysis of the figure shows that the heights of *Citrus limon plants* in the first, second and third year are respectively 0.4 m, 1.6 m and 3.2 m.

The photo below illustrates the development of *Citrus limon* after three years of growth.

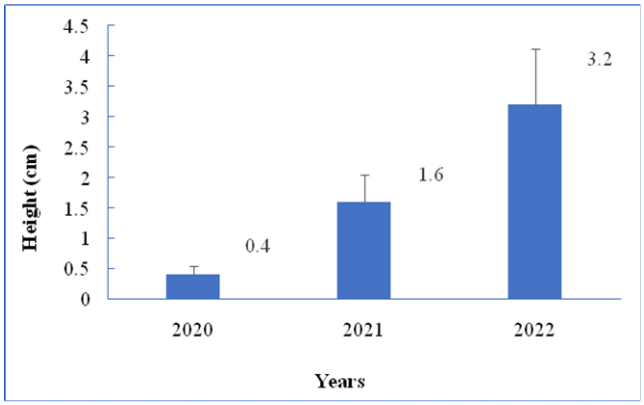

Figure 8. Growth of seedlings after planting

Figure 9. Development of *Citrus limon*

Appearance of reproductive organs: The appearance of reproductive organs on *Citrus limon plants* has been observed. The results are shown in Figure 9.

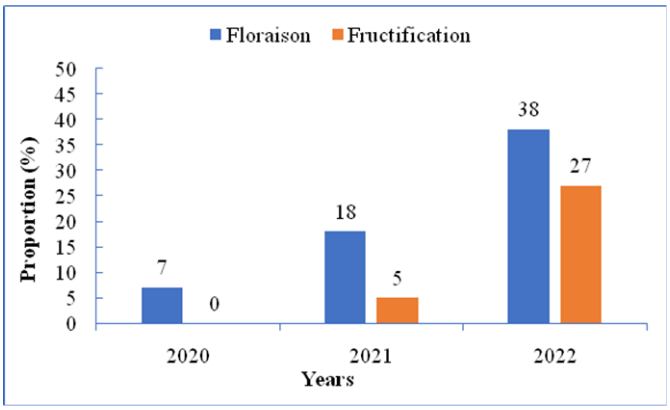

Figure 9. Flowering and fruiting of *Citrus limon* plants

Analysis of this figure shows that flowering was 7%, 18% and 38% respectively in the first year; second year and third year. Fruiting was zero in the first year and very low in the second year (5%) and 27% in the third year. The following photo shows four (4) *Citrus limon fruits*.

Figure 10. Fruiting in *Citrus limon* after three years

DISCUSSION

Lag time varies between cuttings covered with plastic to cuttings without plastic. Indeed, the latency time is longer in cuttings without plastic than in cuttings with plastic. This difference can be explained by the fact that in cuttings covered with plastic evaporation is reduced and humidity is retained. These two factors better promote the recovery of cuttings. For the test carried out by (Yagi, 2016) on the cuttings of *L. hastata* in the winter and warm season, shows that the latency time is shorter during the winter season than the warm one. This suggests that humidity plays an important factor in the success of cuttings. Recovery time is shorter in cuttings without plastic than in those with plastics. Indeed, in the cuttings without plastics only two (2) cuttings budded. This can be explained by the fact that evaporation in its cuttings is higher, which hinders their budding. The resumption of a cutting is due to a revival of activity at the level of one or more vegetative buds which later give rise to a branch. During the trial recovery was very low in the cuttings without plastic with a recovery rate of 6.25%. Indeed, the maximum rate is recorded in lemon tree cuttings with a rate of 87.5 to 93.75%. The low recovery rate in cuttings without plastic may also be due to insufficient humidity and high evapotranspiration. For Bové (1957), the success of cuttings is largely conditioned by the amount of humidity. The recovery rate increased considerably until the 27th day. However, during the test there was a difference in variation within the curves of these species. This difference can be explained by the fact that these species do not have the same cutting capacity. As for the mortality rate, it is higher in cuttings of *Citrus sinensis* and *Citrus tangelo* than in those of *Citrus limon.* This mortality is due to the fact that the cuttings of *Citrus sinensis* and *Citrus tangelo* fails to root.

The number of root branching is greater in *Citrus limon cuttings* with 7 main roots and 174 secondary roots than for the other two species. Indeed, none of the cuttings of *Citrus sinensis* and *Citrus tangelo* gave roots. The rooting problem for *Citrus sinensis* and *Citrus tangelo* may be due to a lack of phytohormones that cause roots to appear. Indeed, the results obtained by Houar et al. (2014) on the effect of different types of auxins on the rooting of jojoba cuttings (*Simmondsia chinensis. L*) show that the rooting of treated cuttings is clearly better than that of untreated cuttings (Control). For the case of our test no Auxinic treatment was made. The lack of rooting can also be linked to the type of substrate used during this test, which is simple sand. Indeed, Zachari et al. (2000) tested three (3) types of substrates as part of their study on the domestication of indigenous agroforestry trees: sawdust, sand and a mixture of sawdust and sand. The rooting of the cuttings proceeded better in the sawdust and in the sand-sawdust mixture than in the sand. Also, for the test carried out by Dichel (2017) on four substrates (4): Sand + perlite, Perlite, Black peat, Peat + perlite in the study of the influence of the substrate on the rhizogenesis of herbaceous olive cuttings “Sigoise” variety multiplied in a nebulization greenhouse. Rooting proceeded better in sand-perlite than in other substrates. There are also environmental factors that can affect the rooting rate of cuttings. Also, the poor rooting may be due to the provenance of the propagule portion. For the specific case of our study, no criterion was retained for the choice of mother plants. This suggests that the plant material could be taken from trees in poor health.

CONCLUSION

This work carried out during the rainy season studied cuttings in citrus fruits. Three (3) species were the subject of this study, they are *Citrus limon, Citrus tangelo* and *Citrus sinensis.* Two types of diameters were used: a diameter between [0.5 to 1] cm and another of [1.5 to 1.9] cm with a length of 25 cm each. These cuttings were planted in polyethylene plastic pots. The observations focused on the latency time, the recovery time of the cuttings and the cutting capacity of these species.

The main characteristics of cuttings of these species made it possible to indicate that:

- Lag time varies when switching from cuttings with plastic to cuttings without plastic. This variation depends on the importance of humidity and evaporation in these cuttings;
- Recovery time decreases from cuttings without plastic to cuttings with plastics during the trial. This decrease allows us to say that the cuttings without plastic do not manage to bud, because they dehydrate more quickly.
- The ability to take cuttings varies between cuttings of these species. Indeed, these results are greater in cuttings with plastic than in cuttings without plastic. The result shows that the two types of cuttings: diameter between [0.5 to 1] cm and [1.5 to 1.9] cm are all suitable for vegetative propagation.

The socio-economic importance developed by citrus fruits and that they are the group of the most cultivated fruits in the world and the second in Niger it is desirable that this study be continued in order to quickly multiply the plans which have a rapid fruit set. This study is of paramount importance because vegetative propagation by cuttings requires only a minimum of space for production. In the light of all the above, it would also be interesting to study the use of phytohormones to induce the rooting of species that are difficult to root during cuttings. To carry out other tests according to the seasons (cold season, hot season) in order to be able to determine the favorable period for the rooting of species that are difficult to take cuttings.

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