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Effect of Drought During the Establishment Period on the Root System Development of Cassava

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Abstract : The effect of different time and duration of progressive drought on cassava, during the establishment stage, i.e., from planting to about three months after planting, was studied with special attention to root system development. Plants exposed to drought, regardless of whether early (from 9-44 days after planting (DAP)) or late (from 44-82 DAP), in the establishment period had significantly fewer leaves and lower shoot dry weight (DW) than well-watered controls. Late droughted plants manifested similar inhibition of shoot growth with those continuously droughted from 9-82 DAP. With regards to root development, early drought caused reduction in the number and length of adventitious roots, number of first, second and third order lateral roots and total root DW. The value of these parameters generally increased after the plants were rewatered. Late drought caused reduction in the number and length of the adventitious roots, and the number of first and second order lateral roots, but not the third order lateral roots, which appeared to be promoted instead by drought. The total root DW also increased in late-droughted plants due to the thickening of adventitious roots. Overall, the results show that cassava has sensitivity to drought stress during its establishment period.
Key words : Adventitious root, Cassava, Drought, Lateral root, *Manihot esculenta*, Root development.

キャッサバの活着期の根系発達に及ぼす乾燥の影響 : Jose R. PARDALES Jr.・Celia B. ESQUIBEL (*Philippine Root Crop Research and Training Center, Visayas State College of Agriculture*)
要　旨 : 活着期，すなわち植え付けから約3カ月後までのキャッサバに対する，乾燥の時期および期間の及ぼす影響を，とくに根系発達に注目して検討した．植え付け後9〜44日に乾燥処理を与えた場合（前期乾燥処理），44〜82日に同処理を与えた場合（後期乾燥処理），いずれも土壌を湿潤に保った対照区と比べて葉数，地上部乾物重が有意に減少した．また，植え付け後9〜82日目まで乾燥処理を与えた区（全期乾燥処理）では，後期乾燥処理区と類似の地上部生長の減少傾向が認められた．根系発達についてみると，前期乾燥処理区では，不定根数・長，第1次・2次・3次側根数，乾物重が減少した．しかし再灌水後，これらの値は増加する傾向を示した．一方，後期乾燥処理区では，同様に不定根数・長，第1次・第2次側根数は乾燥によって減少したが，第3次側根数は促進される傾向を認めた．また，不定根が太くなることによって，根系乾物重も増加した．全体として，これらの結果はキャッサバは活着期においては乾燥に対して感受性が高いことを示している．
キーワード : 乾燥，キャッサバ，根系発達，側根，不定根．

Water stress is one of the major factors that limit crop production. This stress, which is primarily brought about by either shortage of rain or by large variation in the amount of rainfall, influences various plant physiological processes commonly resulting in depressed growth, development and economic yield[1]. The effect of water stress is well studied in cereals[5,10] and legumes[6,11].

Cassava (*Manihot esculenta* Crantz) is a root crop that is relatively drought tolerant and can withstand even 4-6 months of dry season[2]. However, the effect of critical drought during the establishment stage (i.e. the first three months of growth) is not well understood. Since cassava is widely planted in areas in the tropics where rainfall distribution often sharply fluctuates, the amount of soil water during establishment could affect growth. If the initial growth is favored, the plants may be able to withstand adverse conditions during later growth stages. On the other hand, if initial growth is constrained, subsequent growth may be suppressed. For example, when the environment is favorable for root system development during the initial stage of growth the plant can withstand drought during later stages since the roots may have grown deep enough to efficiently absorb water from deeper soil layers.

Drought, depending on its time of occurrence and duration, can change the morphology of the young root system of cassava and may influence the recovery of the roots after rehydration. This study was conducted with the objective of determining the response of cassava root system to different time of drought incidence during the establishment period and the subsequent development of the roots after rewatering.

Materials and Methods

Twenty-centimeter long stem cuttings of cassava. (cv. Golden Yellow) were planted uprightly in 64 clay pots (16.5 cm wide ; 17.0 cm high) filled up with sandy mixed soil containing 2 grams of fertilizer (15% N, P and K). Planting was made with one cutting per pot. Each pot was then applied with 980 ml water to saturate the soil to field capacity. The amount of soil water in the pots was maintained by regularly weighing the pots in an electronic platform balance.

At 9 days after planting (referred to as day 0) half of the total number of pots were not applied with water anymore to induce a drought condition. The other half of the pots were continually well-watered as controls. Each pot in the drought treatment was put inside a plastic bag with the open end tied at the base of the cassava stem cutting to minimize evaporation of water from the soil and to cause a gradual increase of drought with time.

Four root systems were carefully sampled from both the droughted and the well-watered treatments at 18, 35, 47 and 73 days after day 0 (respectively, 27, 44, 56 and 82 DAP). Each root was identified to determine number and length of adventitious roots, number of first, second and third order lateral roots and total root dry weight (DW).

At 35 days after day 0 (44 DAP), right after the second sampling was made, the remaining plants in the well-watered and droughted treatments were divided into two groups and their conditions were reversed. For the droughted plants, half were rewatered to field capacity to simulate early droughting (i.e., droughted from 9-44 DAP only). The other half were maintained unwatered (continuously droughted, i.e., from 9-82 DAP). In contrast, half of the well-watered pots were droughted thereafter to cause late droughting (i.e., from 44-82 DAP) while the other half had its water content maintained at field capacity (continuously well-watered). Fig. 1 shows the procedure of bringing about the droughted and well-watered treatments. The last sampling in all treatments was done at 82 DAP when the plants in the continuously droughted treatment showed signs of irreversible wilting.

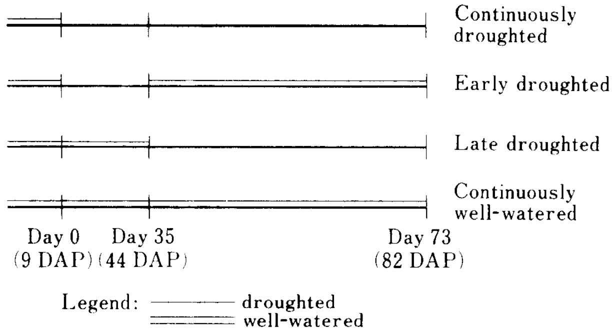

Fig. 1. Schematic diagram of the experimental treatments.

This experiment was conducted from March to June 1994 at the Philippine Root Crop Research and Training Center, ViSCA, Baybay, Leyte, Philippines.

Results and Discussion

1. Shoot development

Plants exposed to drought, irrespective of time of drought incidence and duration, had significantly less number of leaves and shoot DW compared to the well-watered controls (Table 1). In the early droughted plants fewer leaves and lower shoot DW were mainly due to slow production of leaves and smaller leaf area of the fully expanded leaves. On the other hand, in the late-droughted plants the inferior number of leaves and shoot DW were brought about by the rapid senescence of the existing leaves and smaller leaf area of newly formed leaves. Connor and Cock[3] reported that shoot development in cassava is susceptible to soil water content variations, and water stress resulting from drought conditions can lead to smaller leaf number and size in the same plant[12]. The continuously droughted plants exhibited depressed shoot growth (Table 1), apparently because of the combined effect of water stress on early- and late-droughted plants.

When the growing condition of the plants was changed, i.e., from well-watered to droughted, or from droughted to well-watered conditions, a corresponding change in the number of leaves and shoot DW was noted in a matter of days. At 12 days after reversal, the formerly droughted plants manifested an

Table 1. Comparative shoot and root development in droughted and well-watered cassava plants.

Parameter	Early Watered	Early Watered then Droughted	Early Droughted
Number of leaves	16.75± 1.65	0.75+ 0.25	7.25± 1.03
Shoot dry weight (g)	7.53± 0.37	—	2.25± 0.37
Number of adventitious roots	72.50± 3.86	55.25± 0.85	38.00± 1.78
Total length of adventitious roots (cm)	705.35±28.25	631.90±15.86	473.95±46.86
Number of first order lateral roots	798.25±91.79	482.25±72.61	719.50±77.76
Number of second order lateral roots	1040.75±45.00	789.25±69.49	956.25±56.70
Number of third order lateral roots	19.75± 9.23	32.50± 5.55	9.00± 5.21
Root dry weight	1020.08±82.07	1096.25±49.03	886.85±68.75

Parameter	Early Droughted then Watered	Continuously Watered	Continuously Droughted
Number of leaves	19.75± 3.25	16.50± 2.22	1.25± 0.75
Shoot dry weight (g)	7.85± 1.11	10.25± 0.69	—
Number of adventitious roots	52.75± 1.44	64.25± 7.4	37.50± 5.89
Total length of adventitious roots (cm)	746.58± 33.72	800.90± 59.78	475.68±48.98
Number of first order lateral roots	957.50± 80.08	1028.75±156.67	476.25±18.62
Number of second order lateral roots	1051.75±334.22	937.25±138.14	482.25±60.36
Number of third order lateral roots	90.50± 21.96	14.50± 2.96	8.00± 1.47
Root dry weight	1317.73± 43.82	1492.70± 33.84	582.93±25.06

Data are means of 4 replications ± S.E.
Age at sampling are the same for both droughted and well-watered,
early droughted : 44 DAP ; late-droughted : 82 DAP ; continuously droughted : 82 DAP.

increase of 87 and 100% in the number of leaves and total shoot DW, respectively, when based on the values of these parameters before reversal (Table 2). Meanwhile, a respective reduction of 50 and 61% in the number of leaves and shoot DW was noted when well-watered plants were droughted. Reduction of shoot development in late-droughted plants became more pronounced as drought progressed to 38 days after inception (Table 2).

2. Root development

The root development of cassava was also negatively affected by drought regardless of the time of incidence during its establishment period. This indicates that root growth of cassava is sensitive to decreasing water content in the soil. When compared to the well-watered plants, water stress early in the establishment of the plant (early drought) caused marked reduction in the number and total length of adventitious roots (Table 1). In fact, if the number and length of adventitious roots in the early droughted plants is compared with that of the continuously droughted plants, it is very clear that early drought is detrimental enough to cause pronouced inhibition in the production and elongation of adventitious roots (Table 1). This means that the number and length of the adventitious roots of early droughted plants will remain the same if the early drought incidence had to continue for another 38 days, i.e., from 44-82 DAP, as in the continuously droughted. If drought continues throughout most of the establishment

Table 2. Growth value of the different root system component of cassava expressed in percent to that of the values obtained before the growing condition was reversed.

Parameter	Droughted : Rewatered		Watered : Droughted	
	12 days	38 days	12 days	38 days
Shoot				
Number of leaves	87.85±34.37	201.43± 69.81	−50.54±14.36	−70.13±23.39
Shoot dry weight	100.88±26.32	296.61± 95.57	−61.37±15.25	—
Roots				
Number of adventitious roots	50.69±15.64	39.73± 7.39	−20.82±12.45	−23.25± 3.50
Total length of adventitious roots	47.66±18.56	61.30± 18.65	−13.18±12.76	−9.91± 4.65
Number of lst order lateral roots	25.1 ± 9.36	32.26± 5.55	−5.07± 2.49	−37.22+11.34
Number of 2nd order lateral roots	13.67±10.80	14.35± 12.99	−28.91±14.69	−24.61± 3.95
Number of 3rd order lateral roots	48.09±18.57	663.78±377.77	54.67±80.92	63.19± 2.82
Root dry weight	42.13±33.00	52.07± 15.15	16.94±15.94	9.32± 8.42

Values are means of 4 replication±S.E.

period, it will cause reduction in the root system, and, also, the potential storage root yield, since the number of adventitious roots, which differentiate into storage roots is limited.

Except for the number of third order lateral roots which was notably inhibited by early drought, that of the first and second order lateral roots were not appreciatively reduced when compared to those in the well-watered plants (Table 1). The root DW did not also show pronounced reduction because of the fact that the adventitious roots were enlarged and appeared to have tuberized. Pardales and Kono[8] actually observed the same enlarging of the adventitious roots of droughted sorghum. This is probably caused by the compression of the intercellular air spaces and subsequent radial growth of the roots as soil mechanical impedance increases with the intensity of drought, or decreases in soil water potential[4].

At late-drought conditions, the number and total length of adventitious roots and the number of first and second order lateral roots decreased (Table 1). This could be attributed to the disintegration and death in some of these roots due to desiccation caused by increasing drought. However, the number of third order laterals and the root DW increased. At 12 days after the start of drought, notable growth reduction was already observed in root system components (Table 2).

The reduction in the number of adventitious roots by drought later in the establishment period may be critical for cassava because beyond this period, adventitious root formation does not actively take place, even if drought conditions is alleviated. Hence, the number of potential storage roots is reduced. Pardales[7] observed that storage root formation begins early in the growth cycle of cassava. Beyond four months after planting, Pellet and El-Sharkawy[9] noted no apparent change in the number of roots in four cassava varieties. However, if adventitious roots continue to be formed after the establishment period, their differentiation into storage roots would already be late, making the crop unable to produce its potential yield within its normal maturity period.

The droughted plants that were rewatered manifested a general increase in either number or length of their root system components, including their root DW (Table 1). In fact, this was observed just 12 days after rewatering (Table 2). The increase continued until 38 days after rewatering (82 DAP). At this time the number of component roots, the total length of adventitious roots and the dry weight of the roots of the rewatered plants were more or less similar with those of the continuously well-watered plants (Table 1). This result may lead to the assumption that root growth recovery, and that of the shoot in the early-droughted plants after rewatering will enable cassava to produce high yield within its normal maturity period, i.e., if all other growth factors after the drought are optimum. Generally, it appears that cassava, which is widely considered to be a drought tolerant crop[2], has actually some degree of susceptibility to drought stress, especially if drought takes place during its establishment stage. Based on the performance of the well-watered plants, drought occurring at any time during the establishment period caused shoot and root growth reductions.

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