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EFFECTS OF SOIL MOISTURE STRESS ON GERMINATION OF 'HOMESTEAD SELECTION' PAWPAW (*CARICA PAPAYA* L.) SEEDS

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AIYELAAGBE I. O. O. and FAWUSI M. O. A. *Effects of soil moisture stress on germination of 'Homestead Selection' pawpaw* (Carica papaya *L.*) *seeds.* BIOTRONICS **17**, 41–47, 1988. The effects of soil moisture on the germination of 'Homestead Selection' pawpaw seeds were investigated under six moisture regimes created by withholding water for various durations. The objective was to determine the critical soil water potential for germination of pawpaw seeds. Soil moisture stress delayed and retarded seed germination. It also decreased seedling size and seedling survival. The critical soil water potential for germination decreased from −0.01 MPa during the exponential phase to −0.20 MPa during the lag phase. These water potentials were created by withholding water for 3 and 5 days respectively. Although water use efficiency was highest in the soil water potential regime of −0.20 MPa obtained by withholding water for 5 days, −0.01 MPa was considered as critical soil water potential for germination of 'Homestead Selection' pawpaw seeds since lower soil water potentials delayed and retarded seed germination.

Key words: *Carica papaya* L.; pawpaw; critical soil water potential; days after sowing; duration of withholding water; seed germination; soil moisture stress.

INTRODUCTION

Pawpaw is one of the widely consumed fruits in Nigeria (*1*). It is propagated by seeds (*6*). Pawpaw seedling production starts with the nursery, which involves pregerminating the seeds and after which the germinated seedlings are pricked out and transplanted into polyethylene bags. Since the pawpaw seedlings must be ready for field transplanting at the onset of the rainy season starting in May, the nursery commences in February–March in the late dry season. This period is characterised by soil moisture stress. Seed germination is affected by soil moisture stress to a great extent (*5, 10, 11*); thus it is the current nursery practice to water the germination trays daily. It is not certain whether this watering regime is the best for pawpaw, since interspecific differences in the response of seed germination to soil moisture status do occur (*3*). Besides, there is the possibility that slightly longer intervals of watering could produce the same results as daily watering. The possibilities of saving on total water applied and power needed to apply it, and ultimately decreasing pawpaw seedling production costs make the need for studying the response of seed germination of pawpaw to soil moisture status necessary. Ratnam (*9*) listed high costs of planting materials as one of the constraints to large scale fruit growing in Nigeria. It was thus the aim of this experiment to determine the critical soil water potential prerequisite for the optimum germination of pawpaw seeds, which could serve as a guide for nursery men. The inference was based on soil water potential rather than soil moisture content per se because crops respond more to the former than the latter. The 'Homestead Selection' pawpaw used in this study is the recommended variety in Nigeria (*7*). It is the favourite of fruit growers who prize it for its precocity.

MATERIALS AND METHODS

Thirty-six aluminium foil trays $15\times 12.5\times 4.5$ cm with perforations in the base were each filled with 620 g of sandy soil. Its particle size analysis and soil moisture retention properties are indicated in Fig. 1. The chemical constituents of the soil were 2.38% organic matter, 0.15% total N, 13.5 ppm available P, and 0.08, 0.90 and 48 meq/100 g of K, Ca, and Mg respectively. The soil was wetted by standing the trays in water for 8 minutes, thereafter; they were arranged into three replications which spanned the window sill to a work-bench in the laboratory.

Twenty-five seeds were sown 1 cm deep in each tray. Thereafter, five soil moisture stress regimes and a no-stress control were assigned following a randomised complete block design, since an evaporation gradient from the window sill to the work bench was expected. Soil moisture stress regimes were created by withholding water from soil for 3, 5, 7, 10 or 14 days before wetting the soil. Soils watered daily as is the current nursery practice, served as control. Soil moisture content at the end of each stress regime was determined gravimetrically; the corresponding soil water potential under each stress regime was then read off the soil moisture release curve (Fig. 1). Seeds from which the hypocotyl had emerged

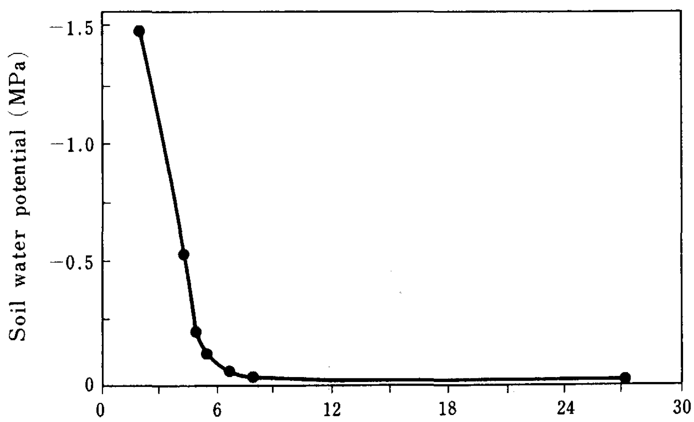

Fig. 1. Soil moisture release curve of sandy soil used.

above the soil surface were considered to have germinated. Seed germination was expressed as a cumulative of daily counts converted to percentages of total seeds sown. Speed of seed germination was assessed during the exponential phase. Seedling survival and water use efficiency were determined by the formulae:

$$\text{Survival factor (SF)} = \frac{\text{Total number of seedlings which survived}}{\text{Total seedling emergence}}$$

$$\text{Water use efficiency (WUE)} = \frac{\text{Total number of surviving seedlings}}{\text{Total water input}} \text{ (seedlings/mm water)}$$

RESULTS

Soil moisture status

Table 1 shows that soil moisture content decreased as the duration of withholding water lengthened. Water potential of soils from which water was withheld for 0, 3, and 5 days corresponded to −0.005, −0.01, and −0.20 MPa respectively. Soils from which water was withheld for longer than 7 days were depleted to −1.50 MPa. The average water application rates required to maintain these soil water potential regimes were 13.3, 12.5, 8.5, 7.3, 3.9 and 3.8 mm water/week respectively.

Seed germination

The earliest set of seeds to germinate were those watered daily on from which water was withheld for 3 days. As the duration of withholding water lengthened, germination was progressively delayed (Table 1).

Seed germination proceeded in two distinct patterns. Germination from soils watered daily, or from which water was withheld for 3 or 5 days were characterized by extended exponential phases spanning 7–8 days, while withholding water for 7, 10 or 14 days curtailed the exponential phase to 2–4 days (Fig. 2). Besides curtailing the duration of the exponential phase, soil moisture stress conditions created

Table 1. Effects of soil moisture stress on some germination factors of pawpaw seeds

Soil moisture stress regime (d.o.w.)*	Soil moisture content (%)	Earliness (d.a.s.)**	Germination speed (seeds/day)	Water use efficiency (seedlings/mm water)	Seedling survival factor
0	18.5±2.5	7.0±0.9	3.9±1.5	0.3	1.00
3	11.9±2.7	8.0±0.3	5.4±1.1	0.4	1.00
5	7.2±2.8	10.0±1.0	2.8±1.2	0.6	0.96
7	1.4±0.8	11.0±0.0	1.8±1.0	0.2	0.80
10	1.2±0.7	13.0±0.0	1.5±0.3	0.3	0.81
14	0.5±0.6	19.0±1.7	1.3±0.7	0.1	0.78

± Represents standard error.
* Duration of withholding water (day).
** Days after sowing.

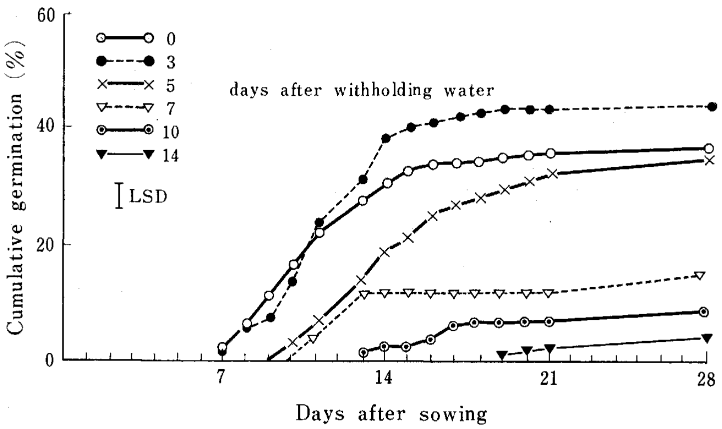

Fig. 2 Effect of soil moisture stress regimes on the germination of 'Homestead selection' pawpaw seeds.

by withholding water for longer than 3 days progressively retarded speed of germination (Table 1).

Cumulative seed germination was not significantly affected by soil moisture stress during the first 10 days after sowing. At 11–15 days after sowing, cumulative seed germination from soils watered daily or from which water was withheld for 3 days did not differ significantly, but both sets of treatments produced significantly higher germination than soils from which water was withheld for 5, 7, 10 or 14 days. At 11–15 days after sowing the effects of withholding water for 5–14 days on seed germination did not differ significantly (Fig. 2); the critical soil water potential for germination during this period was −0.01 MPa. As from 14 days after sowing, withholding water for 3 days produced slightly higher seed germination than daily watering, however the differences were not statistically significant.

Between 16–18 days after sowing the effects of daily watering or withholding water for 3 or 5 days on cumulative seed germination did not differ significantly, but germination from seed trays watered daily or from which water was withheld for 3 days was significantly higher than those from seed trays from which water was withheld for 7, 10 or 14 days. However, during this period, the effect of withholding water for 5–7 days on seed germination did not differ significantly. Between 19–28 days after sowing, the effects of daily watering or withholding water for 3 or 5 days on cumulative seed germination did not differ significantly, but they produced significantly higher germination than withholding water for 7–14 days. The effects of withholding water for 7, 10 or 14 days did not differ significantly (Fig. 2). Thus, the critical soil water potential for this period was −0.20 MPa. Water use efficiency increased gradually with the duration of withholding water up to 5 days. However, durations of withholding water longer than 5 days progressively decreased water use efficiency in seed germination (Table 1).

Early seedling growth

Soil moisture stress significantly retarded early seedling growth. The sensitivity of the various seedling parts to soil moisture stress differed slightly (Table 2).

Table 2. Effects of soil moisture stress on seedling growth of pawpaw twenty-one days after sowing

Soil moisture stress regime (d.o.w.)**	Plant height (cm)	Root length (cm)	Leaf number	Leaf area (cm^2)	Fresh weight (mg)	Dry weight (mg)
0	6.9a	2.4a	6.0a	5.4a	220a	20a
3	5.9a	1.8a	2.1a	4.0a	220a	15a
5	5.4a	1.3b	1.3b	0.4b	170a	9b
7	1.3b	0.4c	0.0c	0.0b	4.4b	0c
10	0.5b	0.2c	0.0c	0.0b	2b	0c
14	0.3b	0.1c	0.0c	0.0b	0b	0c
S.E.***	0.6	0.3	0.2	0.4	8.0	3.0

Values in the same column followed by same alphabets do not differ significantly (DMRT 5.0%).

*** Standard error of means.

** Duration of withholding water (day).

The seedlings produced by daily watering were most luxuriant. The effects of withholding water for up to 5 days on seedling height and seedling fresh weight did not differ significantly from that of daily watering. However, seedlings produced by daily watering or withholding water for up to 5 days were significantly taller and had significantly larger fresh weight than others produced by withholding water for 7–14 days (Table 2). The effect of soil moisture stress on root length, leaf number and dry weight of seedlings was the same. With regards to these parameters, the effects of daily watering and that of withholding water for 3 days did not differ significantly, but they were significantly better than the effects of withholding for 5 days. Withholding water for up to 5 days produced better effects than withholding water for 7–14 days. Soil moisture stress did not significantly influence leaf area (Table 2). Besides affecting seedling size, soil moisture stress progressively decreased the survival of emerged seedlings (Table 1).

DISCUSSION

The early and fast germination of seeds watered daily or from which was withheld for 3 days in response to unrestricted water imbibition by the pawpaw seeds due to high water potentials of the soils. Conversely, withholding water for longer than 5 days allowed the soil to dry out such that water potential was depleted to permanent wilting point in between two successive wettings; this impaired the process of water imbibition prerequisite to the commencement of subsequent processes which culminate in seed germination, until the soils were wetted. These frequent interruptions in the process of germination culminated in the delayed and retarded germination of the pawpaw seeds. Sharples (*10*) and Taylor *et al.* (*11*) showed that water availability in the immediate vicinity of the seed could have a substantial effect on earliness and rate of seed germination. The seeds in trays from which water was withheld for 7–14 days eventually germinated because over time, the pawpaw seeds were able to effectively exploit the brief periods of high soil water potential which occurred immediately after wetting the soil. Öztürk and Mert (*8*) observed similar effects on the germination of *Inula graveolens* seeds. Besides interfering with the process of water imbibition, withholding water for longer than 5 days caused the formation of hard crusts on the soil surface in response to alternate wetting and drying. This in turn mechanically impeded the emergence of the pawpaw seedlings: the germination counts depended on the emergence of the hypocotyl, thus germination counts were low. Fawusi (*2*) observed similar phenomenon in pepper seedlings. The slightly better germination obtained by withholding water for 3 days could be because the daily wetted soils were poorly aerated. Ibikunle and Komolafe (*4*) attributed better germination of cashew nuts in sawdust or its mixtures with other growth media to better aeration.

Results obtained showed that the effects of soil moisture stress on germination of pawpaw seeds decreased with time. The higher critical soil water potential between 11–15 days was because this period corresponded to the exponential phase of germination characterized by rapid seed germination. The simultaneous germination of a large proportion of the pawpaw seeds sown would have removed a substantial amount of soil moisture. This would in turn necessitate the frequent replenishment of soil moisture reserves to sustain the process of germination. The lower value of critical soil water potential as from 19 days after sowing which corresponded to the lag phase of germination, was because the relatively fewer seeds germinating during this period were able to make effective use of lower soil moisture since total water imbibition from soil was lower. The trends of seed germination curves suggested that the lower total seed germination in response to soil moisture stress created by withholding water for 7–14 days was due to the curtailed exponential phase of germination; it further suggested that soil water potential must be kept above the critical values during the first 14 days after sowing.

Seedlings produced by withholding water for 7–14 days were significantly smaller than others because they emerged later. Withholding water for longer than 5 days decreased seedling survival because the soil water potential dropped to -1.50 MPa which caused some of the seedlings to wilt permanently.

The absence of significant differences in total seed germination, seedling size and seedling survival in response to daily watering or withholding water for 3 days, and the slightly faster seed germination rates and higher water use efficiency obtained by withholding water for 3 days, furnish strong reasons for replacing the daily watering schedule currently adopted in the nursery, with that of withholding water for 3 or 5 days. Although water use efficiency for seed germination attained the maximum by withholding water for 5 days, without significantly decreasing total seed germination, this watering regime tended to slightly delay and retard seed germination. Since earliness and fast germination are of vital importance in optimizing labour for pricking out the pregerminated seedlings and subsequent transplanting into polyethylene bags in the nursery, the practice of withholding water for 3 days may be preferred to that of withholding water for 5 days. The moisture content of soils from which water was withheld for 3 days was $11.9 \pm 2.7\%$, which corresponded to -0.01 MPa. -0.01 MPa is thus considered the critical soil water potential for germination of 'Homestead Selection' pawpaw seeds.

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