SOME FACTORS AFFECTING THE SEEDLING GROWTH AND SURVIVAL OF *TRECULIA AFRICANA*

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OKUSANYA, O.T., LAKANMI, O.O. & OSUAGWU, A.E. 1991. Some factors affecting the seedling growth and survival of *Treculia africana*. The effects of six environmental factors on the growth and survival of *Treculia africana* were investigated using multiharvest experiments set out in random design. Full sunlight caused heteroblastic leaf development and produced significantly better growth in dry weight than in 70% shade as from the first harvest. Growth was significantly better in wet soil condition than in the other soil moisture conditions but at different harvest, the least growth being in the water-logged condition. Humus soil produced significantly better growth than the other soil types with the least growth being in sand. The addition of fruit pulp to either sand or red earth significantly improved growth. Acid medium (pH 5.5) significantly enhanced growth better than basic medium (pH 7.5) as from the second harvest. Increase in leaf weight was mainly responsible for the difference. Salinity decreased growth to the extent that seedlings at 30 to 50% sea water concentrations died before the first harvest while those at 20% sea water died at the last harvest. The possible roles of these factors in restricting the distribution of the species to the moist tropical rain forest are discussed as well as the use to which the results could be put in cultivating the species.

Key words: Factors - seedling - growth - survival - *Treculia africana*

Introduction

Treculia africana (Moraceae), commonly called the west African breadfruit, is a high forest tree species growing up to 45 *m* in height. It is characterised by a fluted bole with smooth, light grey thin bark which extrudes abundant milky latex when slashed. The large, heavy green infructescences (fruit heads) weigh up to 15 *kg* and are 20 to 30 *cm* in diameter. Three varieties are recognised on the basis of fruit size (Okafor 1981). At maturity, the fruit head falls down making a loud noise as it hits the ground. The Fanti people in Ghana call it Ototim (meaning the thing that hits the ground with a loud noise). The seeds are embedded in the pulp of the fruit head and are nearly oblong, greyish white in colour with brown testa. The species is of tremendous e conomic importance which includes the edibility of the seeds and the use of the decayed fruit pulp in the control of guineaworm (see Okusanya *et al.* 1990 for more). Details about the distribution, morphology, phenology and anatomy have been described (Keay *et al.* 1964).

Okafor (1976, 1978) successfully propagated the species vegetatively by budding and stem cutting, processes which reduced not only the period to fruiting from an average of 12 *y* to only 4 *y*, but also the fruiting height from 10 to 2 *m*.

The species occurs in the rain forest zone of west Africa, where annual rainfall exceeds 3,000 *mm* and occurring in 8 to 9 *m*. The mean annual temperature is 31°*C* day and 26°*C* night. The rain forest is more or less stratified with lianes and climbers on the tree trunks and the closed tree canopy. Sometimes, there are gaps in the crown. The soil is mostly moist or wet throughout the year. In Nigeria, the distribution of the species is limited to the wetter, southern half of the rain forest zone, giving the impression of a rigid control by moisture.

Despite its enormous economic importance, little research has been carried out with the species. Mabo *et al.* (1988) described the effect of some environmental factors on the germination response of this species. Okusanya *et al.* (1990) studied intraspecific competition among the seedlings of the species.

When the ripe fruits fall to the forest floor, seed germination occurs either in the pulp of the fruit head as it decays or on the forest floor amidst the decaying pulp which is slightly basic, or lastly on soil in other parts of the forest having been dispersed there by forest mammals. After seedling establishment, growth occurs in the slightly acidic humic forest soil which is non-saline (Table 1).

Table 1. Analytical data of the soils used in the experiments, the fruit pulp of *T. africana* and the seedlings at the last harvest in the salinity experiment (in each case, values are means of three determinations ± SEM)

	pH	Moisture	Organic matter	Sodium	Potassium	Magnesium	Calcium	Nitrogen	Phosphate
		(*g* 100 *g*^{1} dry weight)		(milliequivalent 100 *g*^{1} dry weight)				%	ppm
Humic soil	6.5	17.66 ±0.80	19.66 ±1.50	0.13 ±0.02	191.3 ±6.9	4.3 ±0.3	5.3 ±0.3	0.21 ±0.04	29.2 ±3.4
Red lateritic earth	5.6	16.24 ±0.91	8.7 ±0.3	0.26 ±0.03	2.2 ±0.5	2.8 ±0.2	1.12 ±0.02	0.04 ±0.01	16.6 ±2.8
Sand	6.9	9.42 ±0.72	4.1 ±0.2	0.49 ±0.04	12.7 ±1.2	2.9 ±1.4	2.6 ±0.7	0.04 ±0.01	18.6 ±2.4
Fruit pulp	7.2	31.06 ±1.13	81.4 ±3.2	N.D	70.6 ±2.2	2.0 ±0.3	1.6 ±0.2	2.42 ±0.31	85.0 ±5.1
Seedlings at 0% sea water	N.D	N.D	N.D	1.24 ±0.03	1.88 ±0.09	0.38 ±0.04	1.44 ±0.07	N.D	N.D
Seedlings at 10% sea water	N.D	N.D	N.D	3.96 ±0.17	0.51 ±0.06	0.26 ±0.02	0.89 ±0.06	N.D	N.D

N.D. - Not determined

Seedling growth occurs at the peak of the rainy season in May/June, within a cover of herbs and young shrubs and beneath a closed tree canopy that largely provides deep forest shade (Evans 1956). The soil is also wet because of the heavy rains. Consequently, seedling growth and survival of this species might be affected by microclimatic, edaphic and biotic factors.

In view of the prospective cultivation of this economically important species, it was decided to determine how these factors might affect its distribution as well as the best conditions for its cultivation. This paper describes the effects of shade, soil types, soil moisture, pH, fruit pulp and salinity on the seedling growth and survival of the species.

Materials and methods

Seeds were obtained from the large variety fruit heads of a tree in April 1988. They were germinated in vermiculite in seed trays moistened with tap water and kept under natural light in the Botanical Garden of the University of Lagos.

At the two leaf stage, seedlings were carefully transplanted into 12 *cm* wide and 30 *cm* deep black polythene bags which were filled to two-third level with a particular growth medium. The same quantity of medium was used in all the experiments and each bag contained a seedling.

There were ten replicates per treatment per harvest and three to four destructive harvests in each experiment. An exception was the growth experiment that included soil and fruit pulp, where harvesting was done once because of the quantity of the fruit pulp available. The multi-harvest sampling design enables us to follow changes in the growth response of seedlings with time. The time for each harvest was determined when the leaf area of the best treatment was estimated to have doubled (Evans 1972).

Before each harvest, plant height and number of leaves per plant were determined. Afterwards, seedlings were carefully uprooted and soil particles washed off. The plant was separated into root , stem, and leaves. The leaf area was determined by Paton electronic planimeter (CSIRO-Australia).

The plant parts were oven dried at 80°*C* for 48 *h* because of the woody nature of the stem. From these measurements, the total dry weight, leaf area ratio (LAR), plant part weight ratios and shoot: root ratio were determined. The seedlings at the last harvest in the salinity experiment were analysed for sodium, potassium, magnesium and calcium. The soil types used in these experiments and the fruit pulp were also analysed. The analysis was as described in Okusanya *et al.* (1981).

For each experiment, a complete randomised design was used. The ten seedlings to be harvested were selected randomly. The experiments were carried out in the green house of the Botanical Garden of the University of Lagos. Light was from the natural source with a photoperiod of 12 ± 1 *h*, a mean day temperature of 31 ± 1°*C* and night temperature of 23 ± 2°*C*. Relative humidity was about 85% at 0900 *h*. Watering was with 150 *ml* of appropriate solution every other day except where otherwise stated. Analysis of variance or the Student's t-test was used to compare results where appropriate.

Effect of shade

One set of seedlings in humic soil (Table 1) was retained in the open under full sunlight while another set also in humic soil was transferred and kept together in shade in the floor of a hut in the closed secondary forest in the Botanical Garden where light intensity measured with a light meter was about 30% that of full sunlight. Watering was with tap water.

Effect of soil moisture

Four soil moisture regimes were used. The water-logged regime (weight of water 30.1% of soil dry weight) was achieved by putting the bags in plastic containers such that the humic soil was completely covered with tap water. The wet soil regime (weight of water 24.6% of soil dry weight) was achieved by watering the soil to field capacity daily while the moist soil regime (19.8%) was achieved by watering every other day. The dry soil regime (12.1%) was achieved by watering every four days.

Effect of soil types and fruit pulp

Humic, red earth and sand were the soil types used. Each constituted a treatment but when each was mixed with the crushed, dried fruit pulp in the ratio of 3:1, it constituted another treatment. There were therefore six soil type - fruit pulp treatments in the experiment. This was done to determine the effect of soil type on seedling growth and also the effect of fruit pulp when mixed with the soil as it decays on the forest floor. For these treatments, plants were destructively harvested once after 12 weeks. Watering was with tap water.

Effect of pH

The seedlings were potted in acid-washed coarse river sand. They were watered everyday with one-fifth strength Hoagland solution (Hoagland & Arnon 1938) adjusted either to pH 7.5 by the addition of dilute KOH or to pH 5.5 by the addition of H_2SO_4. The pH of the medium was monitored every other day. When the pH tended to fluctuate, the medium was saturated with large quantities of the solution - an action which usually normalised the pH.

Effect of salinity

The seedling in acid-washed coarse river sand (Table 1) were treated with solutions of sea water concentrations of 0, 10, 20, 30, 40 and 50% obtained by mixing appropriate volumes of one-fifth strength Hoagland solution and filtered sea water (salinity 3.3%) collected from the Lagos bar beach. Each solution was used to water the seedlings once a day. Plants which received high concentrations were brought to the appropriate salinity in a step-wise increment. Every week, the medium was leached with 400 *ml* of distilled water followed immediately by the addition of appropriate solution to prevent ion accummulation and to keep the salinity as constant as possible.

Results

Effect of shade

There was 100% survival in the open in full sunlight but only 55% survived in shade at the end of the experiment. In the open, there was heteroblastic leaf development, but uniform leaves were produced in the shade.

Light enhanced growth better than shade. The difference in growth in terms of plant height, number of leaves, leaf area and dry weight was significant as

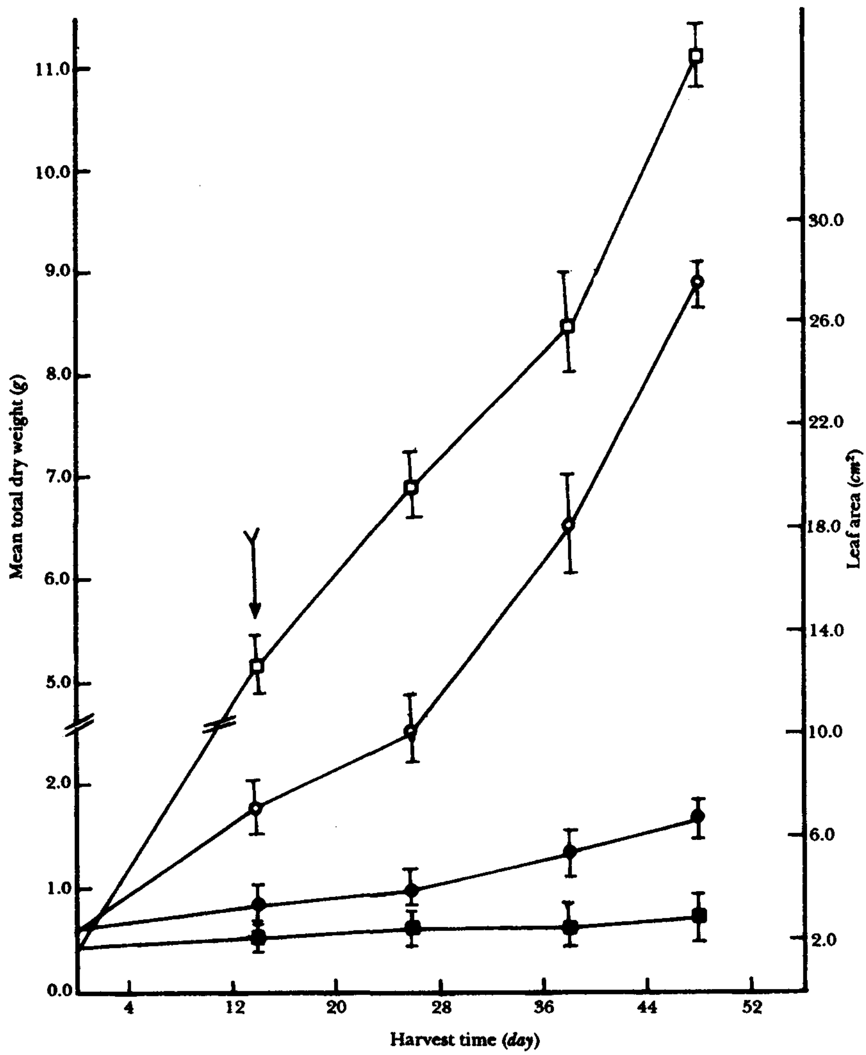

Figure 1. The changes in dry weight of the seedlings of *T. africana* in the open (full sunlight) □——□ and in shade (30% sunlight) ■——■ , and those of leaf area in the open ○——○ and in shade ●——● with time; there were ten replicates per treatment per harvest (bars represent S.D.; arrow indicates the time from when values were significantly different at the 5% level)

from day 14, the first harvest. There was little growth under shade while there were large increases in leaf area, plant height and total dry weight in the open with time (Table 2, Figure 1).

Leaf area ratio (LAR), leaf weight ratio (LWR) and shoot:root ratio (S:R) were higher in shade than in the open, while root weight ratio (RWR) and stem weight ratio (SWR) were higher in the open than in the shade. SWR and S:R decreased slightly with progressive harvests in the open and the shade while RWR and LWR increased.

Table 2. The effects of light and shade on the seedling growth and survival of *T. africana* (mean values of 10 replicates ± SEM at each harvest)

Harvest time (days)	Treatment	Survival (%)	Mean plant height (*m*)	Mean number of leaves	LAR cm^2g^{1}	LWR	SWR	RWR	S:R
14	Light	100	5.9± 0.2	5.2± 0.3	1.38± 0.20	0.28± 0.03	0.48± 0.04	0.24± 0.04	3.17± 0.13
	Shade	100	4.3± 0.3	2.9± 0.2	6.25± 0.49	0.44± 0.05	0.42± 0.02	0.14± 0.02	3.60± 0.21
26	Light	100	7.2± 0.4	7.7± 1.0	1.58± 0.17	0.31± 0.02	0.43± 0.02	0.25± 0.04	3.00± 0.08
	Shade	85	4.3± 0.3	3.3± 0.6	6.67± 0.42	0.47± 0.03	0.36± 0.02	0.16± 0.02	3.60± 0.32
38	Light	100	10.5± 0.5	9.4± 0.6	2.23± 0.31	0.33± 0.04	0.42± 0.03	0.25± 0.02	3.00± 0.11
	Shade	65	5.6± 0.2	4.5± 0.2	8.28± 0.76	0.49± 0.02	0.33± 0.01	0.17± 0.01	3.56± 0.23
48	Light	100	12.2± 0.4	10.6± 0.5	3.38± 0.42	3.34± 0.03	0.40± 0.03	0.26± 0.03	2.85± 0.23
	Shade	55	6.7± 0.8	5.2± 0.4	9.57± 0.69	0.50± 0.04	0.31± 0.01	0.18± 0.01	3.48± 0.29

Effect of soil moisture

Seedlings treated under the water-logged condition produced adventitious roots in contrast to the tap root in the other treatments. There was also noticeable yellowing of the older leaves under this condition.

Analysis of variance showed that the treatments had a significant effect on seedling growth. The best growth in terms of plant height, number of leaves, leaf area and total dry weight was in the wet soil regime which was significantly better than in the moist regime ($p < 5\%$). There was significantly poorer growth, in both dry and water-logged regimes ($p<0.1\%$) (Figure 2). While LAR, SWR and S:R values were the highest in the water-logged regime followed by the dry, the moist and the wet, RWR showed the reverse trend (Table 3). RWR increased with harvest in water-logged and dry conditions but it decreased in the wet and moist conditions. S:R showed the reverse of RWR.

The difference in dry weight between the wet and dry and between the wet and water logged conditions was significant as from day 16, the first harvest, while between the wet and moist it was significant only on day 50, the last harvest.

Effect of soil types and fruit pulp

The best growth in terms of all attributes measured was in humic soil and humic soil mixed with fruit pulp, which was significantly better than in the other treatments ($p<0.1\%$). Growth in red earth mixed with the fruit pulp and in sand mixed with the fruit pulp was next and was significantly better ($p<1\%$) than that in either red earth or in sand alone (Table 4, Figure 3).

LAR was highest in red earth and sand followed by the other treatments and

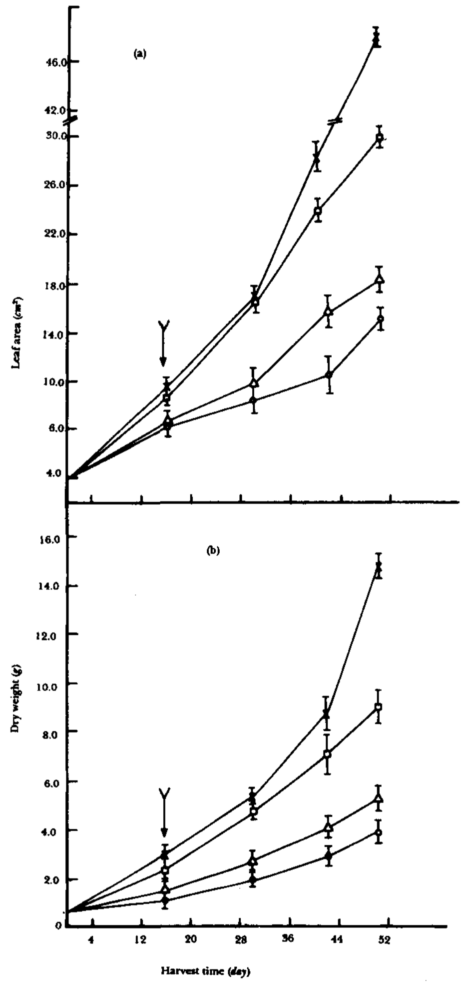

Figure 2. Changes in (a) leaf area and (b) dry weight in the seedlings of *T. africana* under four soil moisture regimes with time (×———× wet soil condition; □———□ moist soil condition; △———△ dry soil condition; ○———○ water-logged condition); mean values of ten replicates per treatment per harvest (bars represent S.D.; arrow indicates the time from when wet treatment values were significantly higher at the 5% probability level than at dry and water-logged treatments)

was least where growth was best. The plant part weight ratios were generally high in humic soil and in other soil types which were mixed with the dried fruit pulp while they were low except for SWR in the red earth and sand.

Effect of pH

The pH treatments had a significant effect on total dry weight on day 28, the second harvest, with growth at pH 5.5 being better than at 7.5. Of the plant parts, it was only leaf weight that showed any significant difference. There was also no significant difference between the values of leaf area throughout the harvests (Figure 4).

Table 3. The effects of four soil moisture regimes on the seedling growth of *T. africana* (Mean values of 10 replicates ± SEM per treatment per harvest)

Soil moisture condition	Harvest time (days)	Mean plant height (*cm*)	Mean number of leaves	LAR $cm^2 g^1$	LWR	SWR	RWR	S:R
Water logged	16	2.4 ± 0.1	3.4 ± 0.5	56.36 ±3.2	0.24 ±0.03	0.55 ±0.04	0.21 ±0.01	3.76 ±0.22
	30	3.6 ± 0.2	4.2 ± 0.3	43.68 ±4.1	0.26 ±0.02	0.50 ±0.03	0.25 ±0.02	3.04 ±0.19
	42	4.5 ± 0.1	5.1 ± 0.4	41.50 ±2.7	0.26 ±0.02	0.48 ±0.03	0.27 ±0.01	2.74 ±0.26
	50	5.8 ± 0.3	6.2 ± 0.2	38.72 ±3.1	0.28 ±0.03	0.44 ±0.01	0.28 ±0.02	2.57 ±0.17
Wet	16	3.9 ± 0.2	4.6 ± 0.3	31.33 ±1.4	0.21 ±0.01	0.44 ±0.02	0.35 ±0.02	1.86 ±0.09
	30	5.7 ± 0.1	6.4 ± 0.2	31.70 +1.2	0.23 +0.02	0.43 +0.01	0.34 +0.01	1.94 +0.07
	42	7.9 ± 0.3	8.1 ± 0.1	33.68 ±1.7	0.25 ±0.02	0.41 ±0.01	0.34 ±0.01	1.94 ±0.03
	50	9.4 ± 0.6	9.2 ± 6.4	32.45 ±1.3	0.27 ±0.04	0.41 ±0.02	0.32 ±0.01	2.13 ±0.41
Moist	16	3.7 ± 0.1	4.2 ± 0.2	35.83 ±2.1	0.21 ±0.01	0.44 ±0.02	0.35 ±0.02	1.86 ±0.04
	30	4.8 ± 0.1	5.6 ± 0.2	36.05 ±0.9	0.23 ±0.01	0.43 ±0.03	0.34 ±0.02	1.94 ±0.02
	42	6.1 ± 0.3	7.1 ± 0.3	34.10 ±1.2	0.25 ±0.02	0.40 ±0.01	0.34 ±0.01	1.86 ±0.03
	50	7.8 ± 0.2	7.9 ± 0.3	33.48 ±1.3	0.26 ±0.02	0.41 ±0.01	0.33 ±0.01	2.03 ±0.11
Dry	16	2.7 ± 0.3	3.8 ± 0.2	39.40 ±1.6	0.22 ±0.01	0.51 ±0.02	0.27 ±0.02	2.70 ±0.23
	30	4.1 ± 0.1	4.9 ± 0.1	36.67 ±1.3	0.25 ±0.02	0.45 ±0.02	0.30 ±0.03	2.33 ±0.17
	42	5.6 ± 0.3	6.3 ± 0.1	39.24 ±2.1	0.25 ±0.01	0.44 ±0.01	0.31 ±0.01	2.23 ±0.14
	50	6.3 ± 0.2	6.8 ± 0.1	33.89 ±1.7	0.26 ±0.01	0.42 ±0.01	0.32 ±0.02	2.13 ±0.31

Table 4. The effect of three soil types and their mixtures with fruit pulp on the growth of *T. africana* seedlings (Mean values of 10 replicates ± SEM)

Treatment	Mean plant height (*cm*)	Mean number of leaves	LAR ($cm^2 g^1$)	LWR	SWR	RWR	S:R
Humic soil	8.4± 0.5	9.2± 1.1	4.89± 0.77	0.33± 0.04	0.49± 0.05	0.29± 0.05	2.72± 0.21
Red earth	6.5± 0.5	6.9± 0.7	8.18± 0.91	0.25± 0.04	0.47± 0.06	0.24± 0.06	0.23± 0.85
Sand	5.6± 0.3	5.0± 0.4	9.06± 0.67	0.25± 0.03	0.48± 0.10	0.26± 0.04	2.05± 0.34
Humic soil plus fruit pulp	8.1± 0.3	8.9± 0.8	4.63± 0.56	0.34± 0.05	0.47± 0.11	0.32± 0.03	2.67± 0.42
Red earth plus fruit pulp	7.2± 0.6	7.6± 0.7	5.80± 0.48	0.27± 0.03	0.44± 0.07	0.28± 0.04	2.06± 0.39
Sand plus fruit pulp	6.8± 0.4	7.6± 0.3	5.77± 0.61	0.26± 0.04	0.45± 0.06	0.29± 0.03	1.97± 0.12

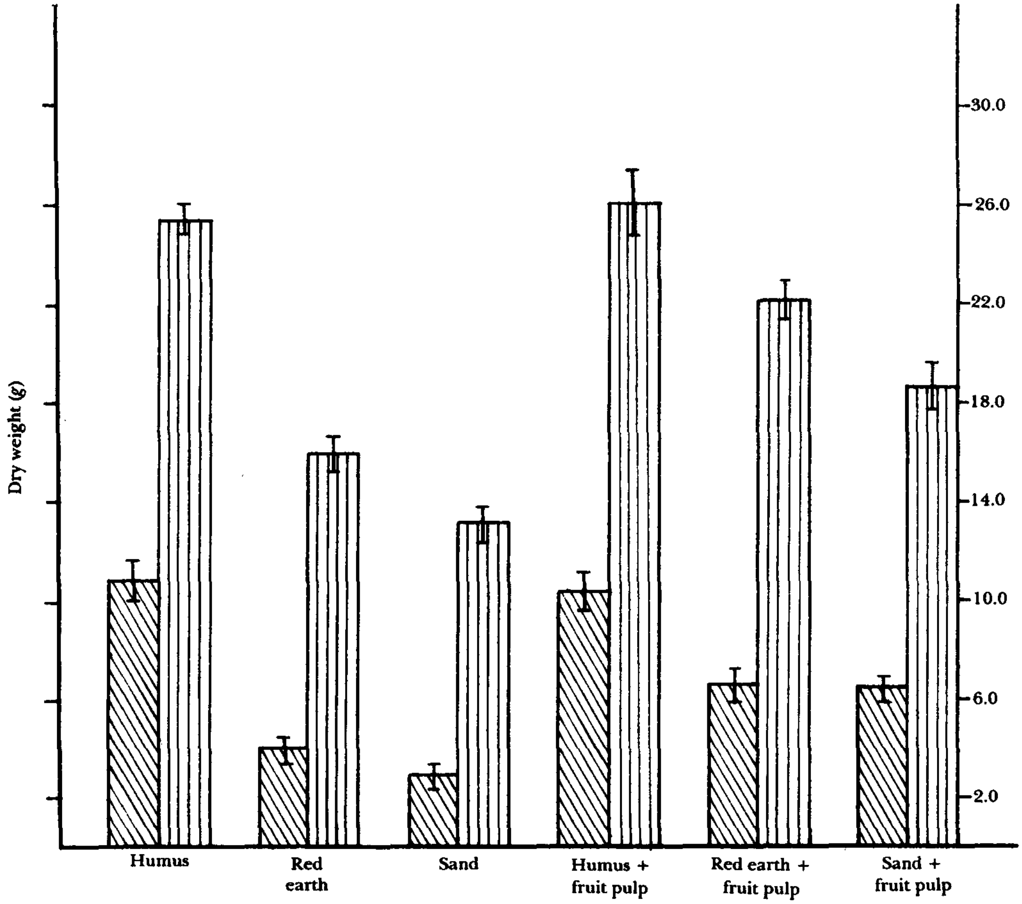

Figure 3. The mean dry weight [hatched] and leaf area [vertical lines] of the seedlings of *T. africana* under three soil types and their mixtures with dried fruit pulp in the ratio of 3:1 (There were ten replicates and bars represent S.D.)

For the plant part weight ratios, the LWR and the S:R were consistently higher at pH 5.5 compared with pH 7.5 for all harvests. However, the values for the SWR, LAR and RWR showed the reverse (Table 5).

Effect of salinity

Seedlings treated with 30-50% sea water concentrations died within eighteen days - the first harvest. Those in 20% sea water died before 55 days - the last harvest. Generally, there was a decrease in growth in terms of dry weight, plant height, number of leaves and leaf area as salinity increased (Table 6, Figures 5a & b). Dry weight value at 0% sea water was significantly higher ($p<1\%$) than at 10% sea water concentration on day 43 - the second harvest. LWR and RWR decreased with increased salinity. However, S:R and LAR in their characteristic manner increased with salinity (Table 6).

Table 5. The effects of two pH treatments on the growth of *T. africana* seedlings (Mean values of 10 replicates ± SEM per treatment per harvest)

Harvest time (days)	pH	Mean plant height (*cm*)	Mean number of leaves	LAR (cm^2g^1)	LWR	SWR	RWR	S:R
					(% total dry weight)			
15	5.5	4.7 ± 0.3	4.60 ± 0.5	34.36 ±4.2	65.50 ±2.5	20.70 ±1.8	13.80 ±2.3	6.24 ±0.8
	7.5	4.8 ± 0.3	3.70 ± 0.4	38.13 ±5.1	50.00 ±3.1	29.17 ±2.3	20.83 ±1.6	3.80 +0.6
28	5.5	6.1 ± 0.4	6.80 ± 0.7	44.67 ±3.8	59.80 ±1.9	25.30 ±1.6	14.68 ±1.4	5.78 ±0.9
	7.5	5.4 ± 0.5	4.67 ± 0.4	52.50 ±6.2	55.50 ±3.2	27.32 ±2.1	17.88 ±1.1	4.63 ±0.3
39	5.5	8.5 ± 0.3	8.22 ± 1.0	33.08 ±2.7	57.13 ±1.4	27.22 ±1.1	15.45 ±1.3	5.49 ±0.4
	7.5	6.9 ± 0.2	6.90 ± 1.0	52.37 ±4.1	52.42 ±1.7	29.50 ±1.3	18.40 ±2.1	4.45 ±0.5
49	5.5	9.8 ± 0.6	9.79 ± 0.8	34.84 ±3.4	56.70 ±1.5	26.00 ±1.0	17.50 ±1.1	4.73 ±0.3
	7.5	7.2 ± 0.4	8.58 ± 0.6	57.82 ±5.1	41.66 ±2.1	34.72 ±2.3	24.12 ±2.3	3.17 ±0.4

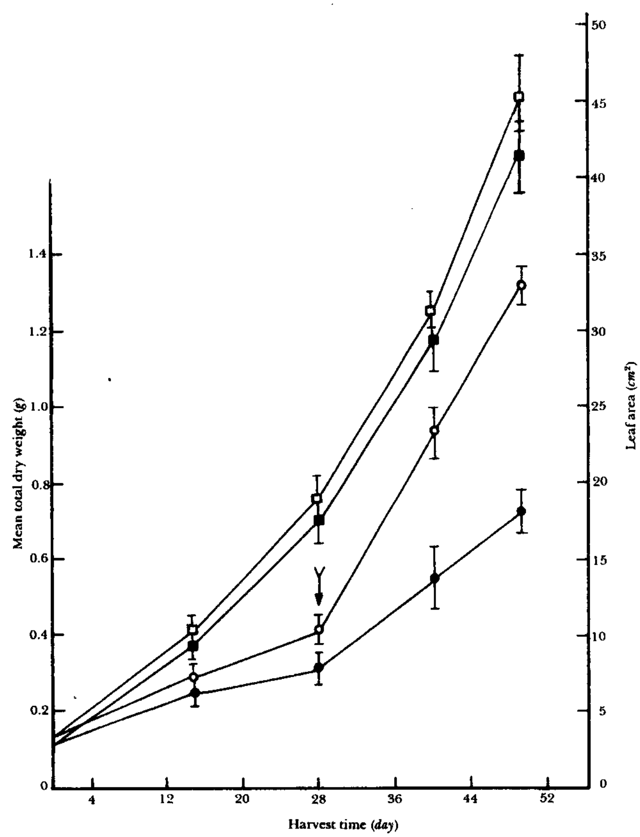

Figure 4. The leaf area of the seedlings of *T. africana* at pH 5 □——□ and at pH 7.5 ■——■, and the dry weight at pH 5.5 ○——○ and at pH 7.5 ●——● at four harvests; mean values of ten replicates per harvest (bars represent S.D.; arrow indicates the time from when treatments show significant difference in their dry weights at the 5% probability level)

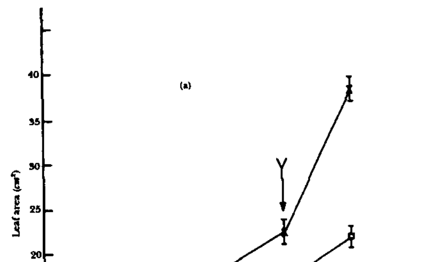

Figure 5. The leaf area (a) and dry weight (b) of seedlings of *T. africana* treated with 0% sea water X———X , 10% sea water □———□ , and 20% sea water △———△ at four harvests; mean values of ten replicates per treatment per harvest (bars represent S.D.; arrow indicates the time that significant differences occurred between the treatments at the 5% probability level; all seedlings treated with 30% sea water and above died within 18 days)

Table 6. The effect of salinity on the seedling growth of *T. africana* (Mean values of 10 replicates ± SEM per treatment per harvest)

	Harvest I at 18 days			Harvest II at 43 days			Harvest III at 55 days		
	Salinity (% sea water concentration)								
Attributes	0	10	20	0	10	20	0	10	20
Plant height	4.20	3.8	3.56	6.33	5.19	4.31	10.61	6.44	plants dead
(*cm*)	±0.3	±0.2	±0.4	±0.2	±0.4	±0.6	±1.2	±1.2	
Number of	5.30	4.00	3.30	6.71	5.42	2.00	8.92	6.11	-
leaves	±0.2	±0.3	±0.2	±0.4	±0.4	±0.5	±0.1	±0.7	
LAR (cm^2g^{-1})	31.59	33.33	41.43	23.35	26.35	45.44	25.48	28.64	-
	±2.7	±3.1	±2.8	±1.6	±1.9	±3.4	±1.4	±3.2	
LWR (% dry	27.11	24.64	19.17	29.42	26.71	21.42	29.27	26.11	-
weight)	±3.1	±4.2	±3.8	±2.6	±2.9	±3.6	±2.4	±2.4	
SWR (% dry	50.32	55.42	65.02	45.61	54.02	64.16	44.51	55.48	-
weight)	±4.1	±3.6	±5.2	±3.1	±4.1	±2.7	±3.1	±4.2	
RWR (% dry	22.76	20.16	16.52	25.16	19.79	14.49	26.47	18.45	-
weight)	±1.6	±1.7	±2.1	±1.4	±0.9	±1.2	±1.4	±1.3	
S:R	3.40	3.97	5.10	2.98	4.08	5.91	2.79	4.42	-
	±0.4	±0.2	±0.3	±0.3	±0.4	±0.3	±0.2	±0.3	

Discussion

Many environmental conditions affect the growth and distribution of plants. The factors tested in this report are by no means exhaustive, but they were considered to be the most important to the growth, survival, distribution and cultivation of this species, bearing in mind its ecological habitat.

In nature, the seeds are expected to germinate and the seedlings to establish and grow under the shade of the mother plant where the heavy fruit heads fall. The low survival and poor seedling growth in shade (Table 2 & Figure 1) indicate that the shade of the mother plant may not be the ideal environment or habitat for the seedlings. The affinity of the species for high light intensity is espoused by the lack of saplings under or near the mother tree and their abundance far away from the mother plants in forest gaps or near road side.

It is therefore suggested that seedlings which establish and grow into saplings and trees are those which are dispersed by forest mammals to areas/gaps in the forest where they receive relatively high amount of light in comparison to the shade of the mother plant.

The results in Table 2 show that the species is intolerant of shade. Oberbauer and Strain (1985) reported that seedlings of *Pentaclethra macroloba*, a neo-tropical tree species of Central America when grown in full sun and partial shade (25% sunlight) showed similar growth and dry weight results. Switching seedlings of *P. macroloba* between the two environments also had no effect on dry weight. Seedlings of *T. africana* under the shade of the mother plant would therefore appear to have little chance of survival because of their shade intolerance. It has also been shown that many seedlings die from intraspecific competition from the many seedlings in the fruit head (Okusanya *et al.* 1990), and perhaps also from interspecific competition from other shade tolerant herbs on the forest floor. In any case, if such seedlings survive, they will take many more years to reach maturity in comparison to those in forest gaps and along road side.

The heteroblastic leaf development of the species in the open as opposed to uniform leaf development in shade may be due to varying light levels caused by sun flecks reaching the seedlings in the open (Bazzaz 1986).

The higher LAR values obtained in shade than in the open is similar to the results obtained for many tropical species. In shade , the seedlings produce disproportionally more leaf area to dry weight, in order to trap what light energy there is, hence the high LAR (Njoku 1960, Wardsworth & Lawton 1968, Okusanya 1978,1979a, Oberbauer & Strain 1985).

The response of seedlings to the soil moisture treatments fits their environmental requirements. The forest soil is wet for nearly nine months of the year and for the remaining period, it is at least moist (Keay 1959). It is under these two soil moisture treatments that the seedlings had their best growth. The development of adventitious roots which exploit only the top soil under the water-logged condition might be responsible for the poor growth under this condition since mineral salt exploitation and absorption will be reduced (Kramer 1969).

The results in Table 1 show that the good seedling growth in humic soil may be due mainly to its high nutrient and organic contents. The humic soil, though well drained, retains a good amount of water - all of these characteristics are similar to those of the forest soil where the species grows.

The results in Tables 1 and 4 and Figure 3 show that the fruit pulp serves as an ameliorating factor to the poor seedling growth in red earth and sand. The pulp provides extra nutrients notably potassium, phosphate and nitrate, which stimulate greater root growth. The pulp may possibly change the physical characteristics of the soil because of its high organic content. Normally, the red earth tends to be water-logged, a condition which inhibits germination (Mabo *et al.* 1988) and growth of the species (Table 3). Also, the sand has low water holding capacity tending to be dry, a condition which is also inimical to germination (Mabo *et al.* 1988) and growth (Table 3). The addition of the fruit pulp appears to ameliorate these adverse conditions.

The results of the effects of pH on plant growth (Table 5) showed that the seedlings can and do survive in both acidic and slightly basic media, but performed significantly better in acid medium. This is no doubt a reflection of its habitat, the forest soil, which is usually slightly acidic due to leaching of the top soil and nutrients. It appears from the results that *T. africana* seedlings are able to adapt to the acidic conditions of the soil.

Field observation of seed germination of the species indicates that the seedlings must be able to tolerate the slightly basic nature of the pulp for sometime before they finally reach the slightly acidic forest soil. The results (Table 5) show that the species is able to do this satisfactorily. Furthermore, since there was no significant difference in growth under the two pH treatments at the first harvest, the slightly basic pH of the fruit pulp does not appear to affect the seedlings before establishment in the more acidic forest soil.

However, since the nutrients in the forest soil are usually leached and most acid soils are poor in nutrients (Vlamis 1953), it appears that the decayed pulp more importantly serves to supply much needed nutrients to the seedlings. This is supported by results which suggest that increased growth occurred when the dried fruit pulp was added to acidic red earth (Table 4 & Figure 3).

Throughout the experiment, there was no difference in the leaf area values at the two pH treatments but there was a significantly higher leaf weight at pH 5.5. This indicates that the greater dry matter accummulation in the leaves may be attributed to thicker leaves. This shows not only the efficiency of the leaves at the acidic pH treatment but also that they were mainly responsible for the higher shoot: root and total dry weight under the treatment.

The response of the species to salinity shows clearly that it is a glycophyte which is incapable of tolerating even low salinity. Most glycophytes cannot adjust their internal osmotic potential at high salinity and some even at low salinity (Levitt 1980). The high sodium content in the seedlings at 10% sea water concentration (Table 1) attests to this. The reduced calcium and potassium contents in the seedlings under this treatment indicates that the uptake of these essential ions was also inhibited at low salinity. These are two ways by which salinity adversely affects the growth of plants (Malakondaiah & Rajeswararao 1979, Levitt 1980, Okusanya & Ungar 1984).

Mabo *et al.* (1988) have reported good germination at 30 to 40% sea water concentration and alluded this to the high protein content of the seeds which may serve as osmoticum (Stewart & Lee 1974). It thus appears that the seeds are more tolerant of salinity than the seedlings. Bernstein and Hayward (1953) have reported that crop species which are very tolerant to salt during germination may be quite sensitive during later stages of growth and *vice versa.* Our results suggest that the absence of the species from saline environments may be due largely to seedlings intolerance of salinity. The synergistic effects of salinity and superior competitive ability of halophytes may prove fatal to the survival and growth of *T. africana* in saline environment.

The characteristic increase in LAR, decrease in RWR and increase in S:R as salinity increased (Greenway 1968, Okusanya 1979b, Levitt 1980, Okusanya & Fawole 1985) were also recorded in this experiment. It was also observed that when the species appeared to be under stress or sub-optimal condition, *e.g.* salinity, water-logging or shade, it responded by an increase in LAR, that is, disproportionate increase in leaf area relative to dry weight. This type of response has been reported for both tropical and temperate species (Njoku 1960, Okusanya 1979a, 1979b, Oberbauer & Strain 1985, Okusanya & Fawole 1985).

The poor growth of *T. africana* under the dry soil condition (Table 3 & Figure 2) coupled with the high rate of evapo-transpiration and low precipitation in the savanna zone of west Africa may partly explain why the species is unable to colonise the dry north of Nigeria and of west Africa.

Similarly, the poor growth of the species in water-logged condition and the lack of germination under the same condition (Mabo *et al.* 1988) may also probably account for the absence of the species in the fresh water swamp and especially at the river banks in the southern coast where many seeds are left when the villagers wash the fruitheads to extract the seeds. Its absence from the mangrove swamp may however be due to the synergistic effect of water-logging and salinity even though the soil pH and soil type may be suitable in this zone.

The moist tropical rain forest thus appears to be the ecological habitat most suited for its growth and survival not only in terms of the soil type, pH moisture and salinity but also because the probable factor which may limit its growth, the low mineral nutrients in the leached acid forest soil, is ameliorated or compensated for by the fruit pulp.

These results may not be applicable to the saplings and the trees which may have different ecological requirements and consequently respond differently to these factors. For example, Whitmore (1984) has reported that the light requirements of a species may change with age. Also the type and chemical composition of soils deep down in the soil profile which the roots of the saplings and trees exploit may be different from the top soil inhabited by the seedlings. It is, however, likely that the effects of these factors on seedling growth and survival will have a far reaching effect on the future stages and distribution of the species. Gross and Werner (1982) have indicated that the distribution and abundance of adults in a plant community is often mediated by events that occur during seedling establishment and growth.

Conclusion

It may be concluded that light and shade, soil moisture, soil pH, soil type and soil salinity affect the seedling growth and survival of *T. africana* and may consequently restrict its distribution to the moist tropical rain forest. It is also clear from the results, that the species may best be cultivated in the open under full sunlight and in rich, wet, non-saline but slightly acidic humus soil.

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