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Influence of Forest Floor and Moisture Conditions on Seed Germination and Establishment of Seedlings of *Brachylaena huillensis*

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SUMMARY

Investigations were carried out in Karura and Muguga forests with the objective of finding out the influence of forest floor and moisture conditions on the low regeneration of *Brachylaena huillensis* in the forests. The investigations focused on aspects of field seed germination, seedling establishment conditions and available moisture. The ecological implications of the study results on the regeneration of the tree were also considered. Germination and seedling survival were influenced by the amount and distribution of moisture. Litter reduced germination rates, and survival of germinated seedlings, but only when moisture was limiting.

When moisture was limiting, litter on the forest floor dried faster than the mineral soil and germination was poor for seed that fell on litter. No major problem of a litter barrier was expected, but where litter was suspected of deterring germination and survival, simple scarification of the forest floor, tripled germination capacity.

Results of the studies of seedling establishment and survival in the forest over four dispersal seasons indicated clearly that several seasons of seed dispersal result in no established seedlings. Once in a while, in a year of good rain (in amount and distribution) useful regeneration of *B. huillensis* results. This is clearly reflected by the commonly observed well defined height size classes within a group of regenerating seedling/sapling mosaic of the species in natural conditions.

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INTRODUCTION

All of the sequential stages in the life history of a plant are points at which recruitment of new plants could be limited (Harper 1977; Harper and White 1974). In some cases, the absolute supply of seed is secondary. Cook (1980) reported that high mortality of seedlings determined plant population recruitment independent of absolute seed availability.

The micro-environment of the forest floor has significant influence on seed viability, germination, development and survival of the seedlings. Abbot (1984), while working with six tree species in drier parts of Australia, demonstrated the effects of environment on seed germination and seedling survival.

McCarthy (1961) working on *Mitragyna stipulosa* in Uganda, Primack *et al* (1985) working on Moraceae trees in Sarawak, and Khan *et al* (1986) studying seedling survival of deciduous trees in India, demonstrated the importance of forest floor physical conditions and moisture on seedling establishment and survival.

Once on the ground, the seeds must be in the most precise conditions or 'safe sites' (Naylor 1985), and if able to germinate, the developing seedlings must be able to tolerate the environmental conditions into which the seeds have fallen. By changing the environment through various forms of disturbance, these precise conditions necessary for successful germination and establishment would also be altered.

Brachylaena huillensis grows naturally in the semi-decidous dry forest occurring in the coastal and central regions of Kenya. The ecosystem in which the tree grows is diminishing fast. The tree has been overcut for fencing, but mainly for wood-carving. The tree is presently threatened. Its regeneration and growth in natural conditions are not understood yet seedlings are difficult to find in open areas in the forest.

The tree disperses seed twice during the year. The first seed dispersal occurs during the May-June period while the second takes place from about December to January. The two dispersal periods coincide with the end of the 'long' and 'short' rain seasons. The first dispersal period is followed by three months of cold dry weather while the second is immediately followed by hot and dry weather lasting from January to about end of March. It is important to understand the effect of the three dry months following each seed dispersal on the establishment and survival of seedlings.

Understanding the factors that influence the regeneration of *B. huillensis* is most vital for the sustainable management of the tree in the only and threatened patches of the central semi-decidious tropical forest. The investigations in this study therefore focused on aspects of field seed germination, seedling establishment conditions and the influence of available moisture. Implications of study results on the regeneration of the tree are also discussed.

Materials and methods

Investigations were carried out in Karura and

Muguga natural forests which are in the outskirts of Nairobi. These forests are shown in Fig. 1. Both forests are of semi-deciduous type. Karura and Ngong forests carry *B. huillensis* as a major exploitable species. Muguga, which lies some 15 km to the north-west of Ngong forest station, is a natural reserve and just outside the altitudinal limit

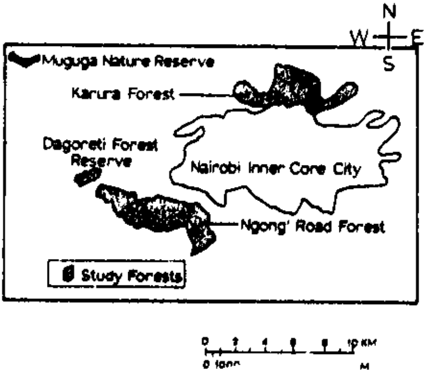

Fig 1: Location of the study site.

for the growth of *B. huillensis*.
The area of study and its surrounding receives rainfall in April and May. A shorter rainy season occurs between mid-October and November. January to March is a fairly dry and hot period. A mean annual rainfall of 980 mm (30 years record) has been experienced.

Temperatures are reasonably equable with a mean annual of 24 °C, minimum 11 °C and maximum of 33 °C. Humidity follows the pattern of temperatures and is lowest between January and March when the temperatures are at their highest level. The soils are generally moderately deep sandy-loams to sandy-clay loams.

Experimental methods

During the dispersal, seed was observed to fall on vegetation, litter or on mineral soil. Depending on the prevailing conditions, the seed may germinate or fail. It was necessary to know the influence of the forest floor conditions on which the seed falls on, its germination and eventual establishment. Seed germination requires moisture. It was therefore necessary to know the changes of soil moisture as indicated by the conditions of the seedlings and particularly by their wilting conditions.

Experiments were therefore set in natural forests to simulate several conditions of the forest floor likely to be met by a falling seed. Simulated forest floor conditions are illustrated below under three experiments. Seed sources were either from expected natural dispersal or collected seed that was placed on specific surface forest floor conditions. Seed sowing in the field was timed to coincide with natural seed dispersal periods.

Germination of sown seed was followed and weekly records on the number and conditions of seedlings made. Germination rates were then derived from the records. For those forest floor treatments where natural dispersal was expected to provide seed, germination and seedling counts were followed mainly for the purpose of determining survival in relation to the availability of moisture. Different coloured straw markers were used to identify 'new' germination and to assist in following survival with time. To assess the role of moisture on the establishment and survival of seedlings, selected plots were supplemented with water over a period as treatment components of the experiments.

Experiments I and II were repeated annually for three years to coincide with three seed dispersal periods. Experimental designs were as illustrated below.

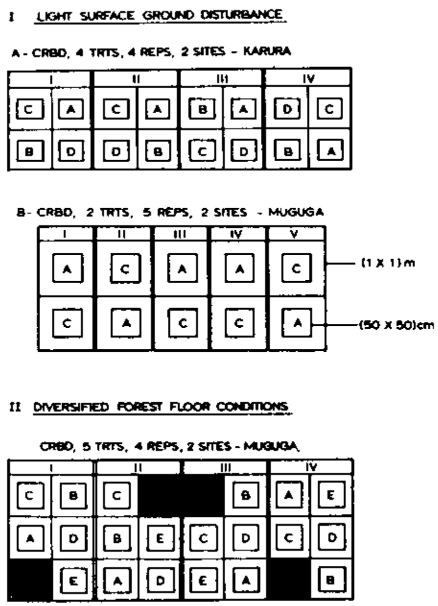

Fig. 2: Plot layout of experiments on the effect of forest floor conditions on seed germination and seedling survival. Refer to text for further explanations.

I *Forest floor disturbance*

This involved surface forest floor disturbance as treatments. The experiment was set up in Karura forest (Fig. 2, IA). The layout was complete randomised block design (CRBD) of four treatments and replicates at two sites. The experiment was also set up in Muguga forest in two treatments and five replicates at two sites (Fig. 2, IB). Treatment sub-plots were 50 x 50 cm within 1 x 1 m plots. Distance between plots was 30 cm.

Treatments included:

A - raked plots sown with seed
B - raked plots not sown with seed
C - undisturbed plots sown with seed
D - undisturbed plots not sown with seed

A raked plot had the vegetation and litter removed while undisturbed plot had natural litter fall and ground herbs left intact. Treatments **A** and **C** were artificially sown with seed while in treatments **B** and **D**, the plots were expected to receive seed from natural dispersal. In each sub-plot, 100 seeds were placed on the surface of treatments **A** and **C**. Half of the experimental blocks were supplied with equal amount of water treatments on weekly bases for seven weeks during the dry period.

II *Diversified forest floor conditions*

In the course of experiment I, it was realised that seed exposure to direct sunlight could have a significant influence on not only the survival of the seed, but also its possibility of ever germinating. Whether the seed remained on the surface of leaves, litter, mineral soil or was burried immediately after dispersal possibly mattered. Experiment I was therefore diversified to include treatments that would address more critically the question of the influence of ground vegetation levels and seed contact with mineral soil on germination and eventually seedling survival.

The experiment was set up in Muguga forest in a CRBD of five treatments and four replicates at two sites (Fig. 2, II). The sub-plot treatments were listed.

A - seed placed at about 0.5 cm depth in raked plots.
B - seed placed on the surface of raked plots.
C - seed placed on the surface of normal forest floor conditions but vegetation clipped just above the litter surface level.
D - seed placed on the surface of normal forest floor conditions.
E - seed placed on normal forest floor condition (like **D**) but the plots had more litter added.

Each sub-plot had 100 seeds placed on as prescribed. As in experiment I, watering during the dry period was undertaken on half of the experimental blocks, weekly for seven weeks.

III *Survival of seedlings from natural seed dispersal*

A third set of experimental plots were established in Karura forest with the aim of monitoring the survival of seedlings that had naturally germinated from normal seed dispersal.

Distribution of random quadrats in the forest was undertaken in three main ways with the aim of addressing some problems of seed dispersal and survival of the resulting seedlings under variable overhead canopy openings. The three replicated conditions included:

A - A layout at three sites of experimental design similar to Fig. 2, IA. Plots **A** and **B** were cleaned off the litter but **C** and **D** were undisturbed.
B - Two parent trees of *B. huillensis*, 100 m apart were selected and 5 quadrats of 1 m square randomly established around each tree.
C - In an open area cleared to the ground and trees felled, five quadrats of 0.5 m square were randomly established. Seed of *B. huillensis* was expected to be supplied from two trees left standing around.

In the three conditions, seedlings within the quadrats were counted weekly as these came up after the seed dispersal. Different colours of straws were used to mark seedlings thus facilitating accurate assessment of the recruitment and mortality dynamics.

Data organisation and analysis

Germination per cent of those experiments and plots where seed was aritificially placed was based on the sown seed. In all cases, calculation of per cent survival was based on the highest germination or highest seedling counts made in each of the experiments. Data for each experiment and season were summarised and analysis of variances (Snedecor & Cochran 1980) were carried out to determine differences among forest floor and moisture supplementation treatments. Trends of seedling survival were interpreted in the light of prevailing weather conditions after seed dispersal had started.

RESULTS AND DISCUSSION

Seed germination was generally low. At week 4, germination was 10.8% in the raked plots but only 4.6% in the litter covered plots, indicating a significant ($p = 0.01$) difference (Table 1). The highest germination occurred during the sixth week in both treatments.

Fig. 3 shows the trend of seedling survival recorded over a period of 40 weeks in Muguga forest. After seed dispersal, germination started after three weeks and no more seedlings appeared after the first six weeks. After this period, seedling populations started to decline. Initially, germination was better and faster for seeds placed on bare ground than those placed on littered plots. The undisturbed plots also suffered higher mortality rates than in the litter cleaned plots.

Watering slowed the rates of seedling mortality (Fig. 3). After weekly supplementation of moisture for seven weeks, significant differences between watered and unwatered plots began to appear (Table 2). For the watered plots, seedling survival for the litter cleaned plots was better (8.5%) than for the undisturbed plots (2.7%). Mortality rates however increased steeply in both forest floor conditions when watering was stopped at the twelfth week.

For the Karura experiment where germination and seedling establishment depended on rain-fed moisture, germination potential was 22%, recorded in the litter cleaned plots that were sown with seed (Fig. 4).

The uncleaned plots also gave an almost equal mean germination potential (20%). For both forest floor conditions, the trend of mortality rates were almost the same.

Table 1: Analysis of variance on the field seed germination from raked and undisturbed forest floors after four weeks.

Source	DF	SS	MS	F	Significance
Site (s)	1	12.656	12.656	<1	NS
Replicates	8	200.220	25.027	...	
Treatments (T)	1	222.551	22.551	224.265	**
SxT	1	4.676	4.676	0.510	NS
Residual	8	73.360	9.170		
Total	**19**	**513.423**			

** *= Significant at 0.01 probability level*
CV = 19.6% (treatment means)

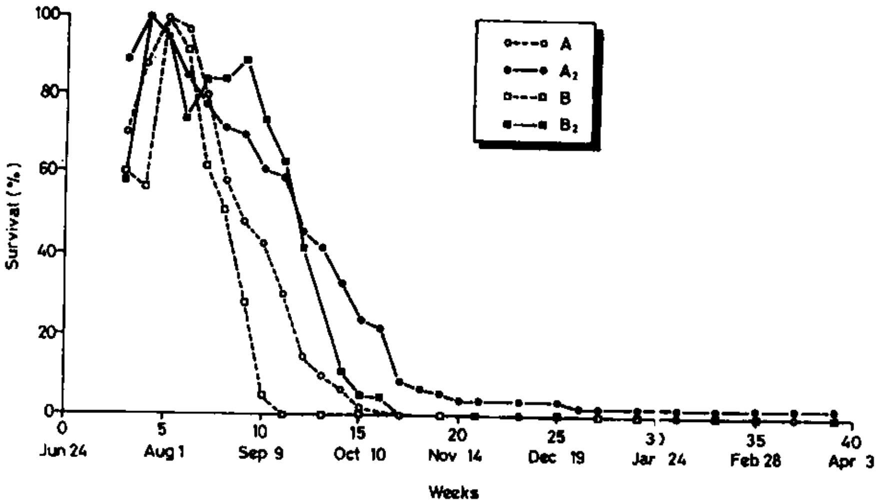

Fig. 3: Weekly survival trend in seedlings of *B. huillensis* under cleaned (**A**) and undisturbed (**B**) forest floor conditions and the role of moisture (**A**, **B** - site 1; A_2 B_2 -site 2).

Germination in litter cleaned and uncleaned plots that were not sown with seed was either poor or nil respectively (Fig. 4).

The highest and fastest rate of seed germination of 12.7% occurred with seed placed at 0.5 cm below the soil surface in the diversified forest floor treatment experiment. The various forest floor treatments indicated significant difference (p=0.01) in the rate of germination at the end of five weeks. Germination rates of the other treatments

Table 2: Summary of analysis of variance for the effect of forest floor conditions and moisture supplementation on survival of seedlings after seven weeks.

Source	DF	SS	MS	F	Significance
Replicates	4	28.409	7.102	0.674	
Water (W)	1	156.800	156.800	14.518	**
Treatments (T)	1	178.204	178.204	16.709	**
WxT	1	2.665	2.665	<1	NS
Residual	12	126.448	10.537		
Total	**19**	**492.526**			

** = *Significant at 0.01 probability level*
CV = *57.2% (treatment means)*

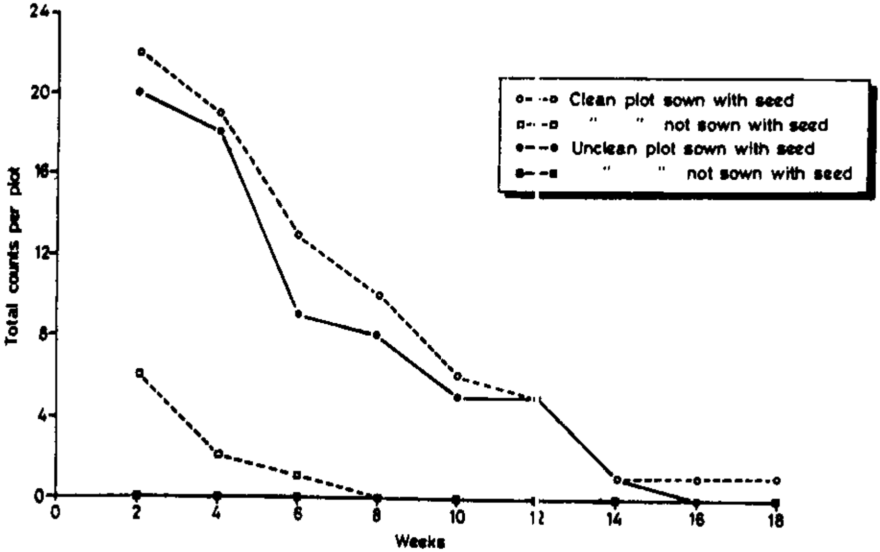

Fig. 4: Weekly survival trend in seedlings of *B. hulllensi* under cleaned (A) and undisturbed (B) forest floor conditions and the role of moistur (A, B - site 1; A_2 B_2 -site 2).

ranged from 4.5% to 6.5%.

Weekly moisture supplementation from weeks 6 to 12 influenced seedling survival. After three weeks, survival was significantly differen for the watered and unwatered plots

Table 3: Summary of analysis of variance for the effect of forest floor conditions and moisture supplementation on survival of seedlings after three weeks.

Source	DF	SS	MS	F	Significance
Blocks	2	56.053	28.026	2.848	
Watering	1	103.639	103.639	10.533	**
Treatments (T)	4	328.311	82.077	8.342	**
WxT	4	43.609	10.90?	1.108	NS
Error	18	177.094	9.839		
Total	**29**	**708.709**			

** = *Significant at 0.01 probability level*
CV = 35% (treatment means)

(Table 3). Seedlings from the seed placed at 0.5 cm below the surface maintained superiority in survival, possibly because initial germination was higher but also the seedlings may have been deeper and better rooted. After six weeks of further watering, no significant difference in survival however was evident among the treatments. Watering was done from mid-August to end of September which are dry months. This

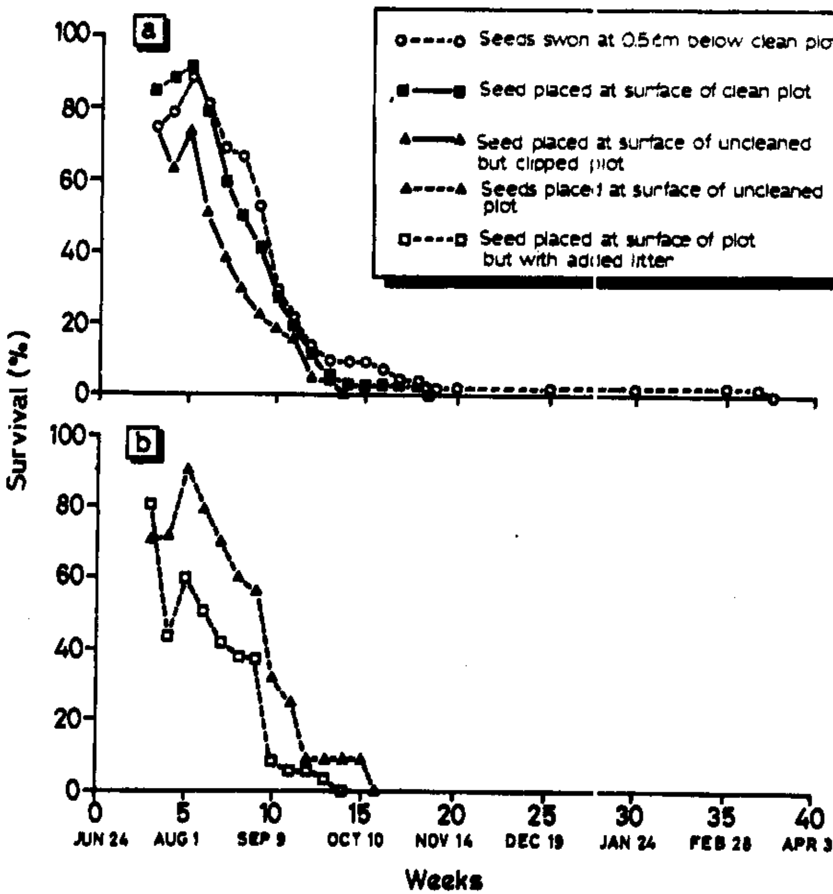

Fig. 5. Weekly survival trend in seedlings of *B. huillensis* unde various forest floor coditions.

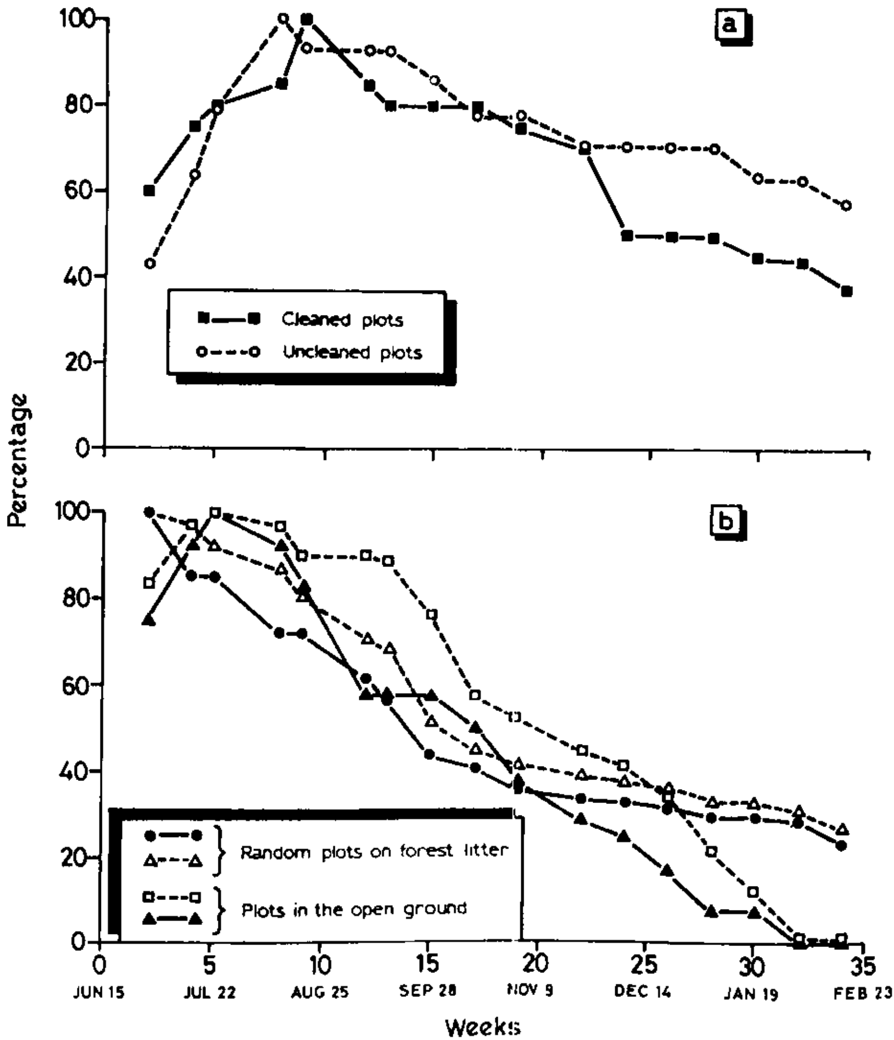

Fig. 6: Germination and survival percentage of seedling on:-
(A) litter-cleaned and uncleaned plots and
(B) random plots in the forest and on open ground.

suggests that rates of loss of soil moisture was much higher than that supplemented on weekly bases.

Fig. 5 shows the mean overall survival trend for the five treatments. Neither the potential nor the actual rate of germination seemed to be critically influenced by forest floor conditions in the present experiment. Except in treatments **A** followed by **B** (Fig. 5A), the others maintained seedlings up to about the 15th week. Treatments **C** and **E** had the fastest rate of seedling mortality. These treatments had seed placed on thick letter on the forest floor and it is most likely that many of the germinated seedlings were not capable of coming into contact with mineral soil, therefore wilting fast with the declining moisture in the dry September month.

Survival of seedlings from naturally dispersed seed

Fig. 6 shows survival percentage of naturally germinated (June/July seed dispersal) seedlings. Seed germination potentials on clean and on litter covered plots were remarkably similar (Fig. 6a). Similar observations were made in plots exposed to light (Fig. 6 (b) I, II). Random plots indicated maximum germinations in early July (Fig. 6 (b) A. B).

Generally, after attaining maximum seedling population, mortality rates were low from July to mid-August. After this period, mortality rate in all the seedling populations was remarkably high (Fig. 6). After August, the ground surface becomes increasingly dry and temperatures are also high. This results in the depletion of soil moisture and hence the high rate of seedling mortality observed after mid-August.

Seed dispersal for three years during the December/January periods did not contribute to the population of *B. huillensis* in either Ngong or Karura forests. Very limited moisture was available during and after this time. Seed that attempted to germinate wilted within the next two weeks on average.

Influence of moisture

Whether germination on litter free or undisturbed forest floor is good or poor, what is possibly most critical is the condition of the available moisture.

Moisture at the time of seed dispersal and later after the seed has germinated may influence not only the germination but also seedling establishment and survival. Seed dispersed in June/July after the 'long' and heavy rains in April/May gave consistently better germination than seed dispersed in December/January, after the 'short' and light rains. Similar observations were made with seedling establishment and survival.

Results of seed germination, seedling establishment and survival under different forest floor conditions were also highly influenced by the prevailing conditions of soil and litter moisture. When the forest floor is moist, germination is similar in the various forest floor conditions. When moisture becomes depleted, the litter surfaces are dry and seedlings germinated on the litter wilts fast. Seedlings germinated directly on mineral soil which remains moist for comparatively longer periods have their roots in soil and establish better.

The pattern of survival trend emphasizes the importance of moisture distribution in time rather than the intensity received, for the successful establishment of seedlings of *B. huillensis*. It is also evident that very few dispersal years contribute to successful new additions of *B. huillensis* into its population. This is supported by the existence of well defined size class (height) distribution of seedlings and saplings within a regenerating group of *B huillensis* in the forests (Kigomo 1988).

CONCLUTIONS

Results from the present series of experiments lead to the conclusions that:

1. Seed of *B. huillensis* on disturbed or littered forest floor has equal germination opportunities so long as moisture is adequately available.

2. Where moisture is initially limiting, seed germination is better on disturbed forest floor than on litter. This is a result of better retention of moisture by the mineral soil and ease in rooting than on litter surface.

3. Seedling establishment and survival are always better on disturbed forest floor conditions. This further suggests that removing surface litter from the forest floor may improve germination, establishment and survival. Moisture is however the most important determinant factor.

4. Seedlings establishment in unshaded (open) sites experienced high mortality. Mortality rate is further accelerated by the higher moisture stress than in the case of seedlings in the shade.

5. For seedlings to develop and attain size capable of surviving through the dry seasons, they will initially require continuous supply of moisture. Such conditions are however not often available in the forests where *B. huillensis* is naturally distributed. It is apparent therefore that several years of seed dispersal are wasted mainly through seed predation in soil, low seed germination in the field, and high mortality rates of seedlings due to moisture stress. This phenomenon will apparently continue until such time that a good rainy year (in amount and distribution) is met when useful contribution into the '*Brachylaena* community' may be made.

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