PRODUCTION AND HANDLING OF SEEDS OF *ACACIA XANTHOPHLOEA*, *BRACHYSTEGIA SPICIFORMIS* AND *TRACHYLOBIUM VERRUCOSUM*

by

E. Murugi Kariuki

B.Sc.F., University of Nairobi

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ABSTRACT

The current information available on the seed-production processes of Acacia xanthophloea Benth. Brachystegia spiciformis Benth. and Trachylobium verrucosum (Gaertn.) Oliv. is limited to botanical description and generalities. The general reproductive development of A. xanthophloea was investigated in the Kibwezi Forest and that of B. spiciformis and T. verrucosum in the Arabuko-Sokoke Forest in Kenya.

Acacia xanthophloea had two flowering periods per year. These were synchronized with relatively dry periods. The other species flowered only once per year, but flowering was again synchronized with the single relatively dry period in that vicinity. Fruits of all three species developed during wetter periods and dried to maturity in somewhat drier periods. Developing fruits of all three species were eaten by baboons. The legumes of A. xanthophloea and T. verrucosum were indehiscent, whereas those of B. spiciformis dehisced explosively.

Fruits were collected from trees in the stands under study, and seeds extracted by hand. The seeds of all three species had thick, hard seedcoats, as is common for leguminous trees. Samples of seeds of each species were pretreated in 13 ways to determine whether germination could be enhanced. Seeds of B. spiciformis germinated best without pretreatment (control) and thus seedcoats were not impermeable to water. Pretreatments, except nicking the seeds at the micropylar end, were not effective. Seeds of A. xanthophloea and T. verrucosum had water-impermeable seedcoats. Impermeability was overcome by nicking the seeds. Other effective pretreatments were three hot-water pretreatments of varying duration and pretreatment for 32 min in concentrated sulphuric acid for A. xanthophloea, and for 32 min and 16 min in concentrated sulphuric acid for T. verrucosum.

Cutting tests of nongerminated seeds showed that most of T. verrucosum and A. xanthophloea were apparently still viable, but those of B. spiciformis were dead. X-ray analysis showed that 0.3% of T. verrucosum, 10% of A. xanthophloea and 40% of B. spiciformis seeds had damaged embryos. The damage was caused by insect or by fungal and/or bacterial infection.

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E.M.K

INTRODUCTION

Valuable indigenous trees in Kenya were once abundant but, owing to heavy commercial exploitation and slow growth rate after regeneration, many species have been much reduced in number and are no longer available for utilization. The government's plans have been to afforest areas by planting fast-growing exotic and indigenous timber tree species to increase the timber availability. Afforestation with indigenous species has been given less attention and hence seed problems associated with them have not been investigated (cf. Shehaghilo, 1980). When the need to grow more indigenous trees both naturally and artificially was realized, it became evident that seed availability and other needs had to be considered (Hasan, 1973; Kimariyo, 1973; Shehaghilo, 1980).

For successful planting-stock production, a thorough understanding of problems associated with seed production, seed collection, and seed handling is a prerequisite. Such information is lacking for most of the important species in Kenya, as in other tropical countries (e.g., Hasan, 1973; Kimariyo, 1973; Shehaghilo, 1980).

In Kenya, seeds of economically important tree species are collected from the various forest stations and trans-

ported to the central storage station (Kenya Agricultural Research Institute, Forestry Research Department), where there are cold storage facilities. Very few indigenous species have been included in this operation.

Recently there has been an increased awareness of the importance of indigenous species, as they are adapted to given specific locations. Improved seed production and handling of indigenous species are being emphasized, and phenological studies of the given species are being undertaken.

Three indigenous species which have gained some prominence are Acacia xanthophloea Benth., Brachystegia spiciformis Benth. and Trachylobium verrucosum (Gaertn.) Oliv. These leguminous species have been singled out because they are economically important in Kenya and are nitrogen-fixing trees. Experimental work is in progress at the University of Nairobi, Kenya, to determine the amount of nitrogen fixed and the micro-organisms associated with nitrogen fixation by these species.

Information available on the seed-production processes of these species is limited to botanical description and generalities. The inflorescences are bisexual and the flowers are pollinated by insects or animals (Dale and Greenway, 1961). The fruits are typical legumes (or pods) and the seeds are assumed to have impermeable seed coats, which result in natural germination being spread over several months. No information is available on the timing of flow-

ering, or the period of fruit and seed development. For efficient artificial regeneration, more must become known on the timing and effectiveness of the seed-production processes of these species and, also, means must be determined which will overcome seed-coat dormancy and enhance germination.

The objectives of this study are:

1. To develop methods for improving seed procurement of A. xanthnphloea, B. spiciformis and T. verrucosum, by undertaking a detailed biological study on the total sequence of floral and fruit and seed development.

2. To determine which of several 'wet' and 'dry' seed pretreatment methods will be most effective in enhancing germination of seeds of A. xanthophloea, B. spiciformis and T. verrucosum.

The remainder of this report will be divided into four parts. In the first part, what is known of the three species and their botanical affiliations will be described. Also, leguminous seed structure and pretreatment methods that have been studied will be reviewed. In the second part, the experimental procedure for the biological studies and the seed-pretreatment experiments will be described. The results of both portions of the study will be presented in the third part. The fourth and final part will contain evaluation and discussion of the results, and recommendations for improved production and handling of seeds of A. xanthophloea, B. spiciformis and T. verrucosum in Kenya.

The approach to achieving objective 1 was firstly to devise a survey system to be used to record the developmental processes related to flowering, and fruit and seed production. Secondly, stands containing the species under study were selected and the survey started. Records were kept for a period of 12 months.

The approach to achieving objective 2 was to pretreat replicates of seeds of each of the three species in 13 ways and to test the response by assessing the subsequent germination of the pretreated seeds, over 28 days, under standard conditions.

REVIEW OF LITERATURE THAT RELATES TO SEED PRODUCTION BY *ACACIA XANTHOPHLOEA*, *BRACHYSTEGIA SPICIFORMIS* AND *TRACHYLOBIUM VERRUCOSUM* IN KENYA

GENERAL CONSIDERATIONS

Seasonality exposes plants to regular, periodic changes in the quality and abundance of resources. Almost all tropical environments vary seasonally in temperature, humidity, rainfall, wind speed and day length, although the amplitude of the variation may be small. All of these factors are known to play a role, alone or in combination, in triggering developmental changes in tropical plants. Developmental and phenological patterns of natural forest vegetation in tropical Africa are little known (Lieberman, 1982).

Frankie *et al*. (1974b), Kamra (1976) and Doran *et al*. (1983) stated that, for trees in tropical countries, little attention has been given to the total sequence of floral development, the pollination mechanism and fruit/seed development. This leads to considerable uncertainty as to what factors may affect the seed production process and to when tree seeds should be collected. As collections of seeds increase in size and range, and require a greater period of time, seed maturity becomes a critical problem.

In some species, seeds collected a few weeks before natural seedfall are of low quality and will not store well because they deteriorate rapidly (Edwards, 1984). Therefore, those involved in planning seed collection should understand the reproductive biology of a given genus or species, so that the planning, timing and execution of seed-collection operations may be undertaken efficiently (Doran et al., 1983).

THE FAMILY LEGUMINOSAE

The Leguminosae (or Fabaceae according to many taxonomists, e.g., Heywood (1979)) is a very large family of herbs, shrubs and trees with a great variety of habits including aquatics, xerophytes and climbers. It comprises 650 genera and 18,000 species. Many species are of enormous importance to man (Heywood, 1979; Polhill et al., 1981).

The leaves of leguminous species are usually alternately arranged, trifoliate or pinnately compound, and stipulate. However, there are many exceptions: for example, in many species of Acacia pinnately compound leaves are not developed in young seedlings and the petioles are flattened into phyllodes (Heywood, 1979).

A feature common to most Leguminosae is the presence of root nodules containing bacteria (Rhizobium species), which are capable of taking up atmospheric nitrogen and converting it into other nitrogenous compounds.

The family is divided into three subfamilies,

Mimosoideae, Caesalpinioideae and Papilionoideae. The following description of flowers of the three subfamilies is based on information given by Dale and Greenway (1961), Hutchinson (1973) and Heywood (1979). The flowers are regular and unisexual or bisexual in Mimosoideae, and irregular and bisexual in Caesalpinioideae and Papilionoideae. There are five sepals which are more or less fused and in some irregular flowers the calyx may be organized into two or four lobes. In Mimosoideae the five petals are small and equal, whereas in the Caesalpinioideae there is a range of irregularity in the corolla extending from the flowers of Cassia in which the five petals are nearly the same size, to those of the Judas tree (Cercis siliquastrum L.) which has flowers similar to those of the Papilionoideae. The five petals of the flowers of the Papilionoideae are organized into a butterfly shape with one outstanding dorsal petal (the standard), two lateral petals (the wings) and two lower ventral petals more or less fused along their contiguous margins to form a keel.

In Mimosoideae the stamens are usually numerous showing partial fusion of the filaments, whereas in the Caesalpiniodeae they are usually ten or fewer in number, and free (Heywood, 1979).

The inflorescence is usually an erect or pendulous raceme and sometimes, as in Mimosa, the flowers are arranged in tight clusters. All the Leguminosae characteristically have a single carpel, the single ovary is superior, and sur-

mounted by the style and stigma. The ovules vary in number from two to many and are inserted in two alternating rows on a single placenta. The ovary develops to form the fruit (legume or pod) and the ovules develop to form seeds after fertilization (Heywood, 1979).

The genera of concern in the current study belong to two of the subfamilies. Acacia is in the Mimosoideae, and Brachystegia and Trachylobium are in the Caesalpinioideae. Members of Mimosoideae are mainly tropical and sub-tropical trees and shrubs (approximately 56 genera and up to 3,000 species). The leaves are usually bipinnately compound and the flowers, which are massed into heads or spikes, are regular with the petals valvate in the bud and with ten or more stamens. The unicarpellate, superior ovary usually produces a dehiscent legume. Leaves of Kenyan species are alternately arranged, stipulate and bipinnately compound. They often bear glands on the rachis and some have nastic or 'sleep' movements in response to shock or onset of night.

Members of Caesalpinioideae are similarly mainly tropical and sub-tropical trees and shrubs (approximately 180 genera and 2,500-3,000 species). The leaves are usually pinnately, but sometimes bipinnately, compound, and the flowers are usually more or less irregular with the lateral petals (wings) covering the standard in the bud. There are ten or fewer free or monadelphous stamens. The superior ovary may develop to form either a dehiscent or an indehiscent legume depending on the species.

ACACIA XANTHOPHLOEA BENTH.

Acacia xanthophloea grows widely in the southern part of Africa to east Africa. It usually grows in riparian or at lake-side situations (Dale and Greenway, 1961; Palmer and Pitman, 1973). Acacia xanthophloea grows in most provinces in Kenya (Dale and Greenway, 1961).

Acacia xanthophloea is a flat-topped tree with a yellow powdery bark. It often grows to about 16 m high, though a height of 26 m has been observed where the crown spread was 41 m and the trunk diameter at breast height was 1.36 m. The tree is usually single- and straight-stemmed, and has erect but arching branching commencing some distance above ground. This branching pattern provides for an irregular crown outline and an overall spread frequently in excess of the height of the tree (Dale and Greenway, 1961; Palmer and Pitman, 1973).

The pinnately compound leaves grow up to 10 cm long (but usually are about 4 cm long). They have three to ten pairs of pinnae and about fifteen to twenty pairs of pinnules per pinna (Figure 1B). The rachis is pubescent, and paired, straight stipular spines up to 4 cm long are produced at the nodes (Figure 1B and C).

Acacia xanthophloea has yellow, golden or pinkish flowers, borne in pedunculate globose heads, which occur in clusters of eight to ten at nodes or near the extremities of

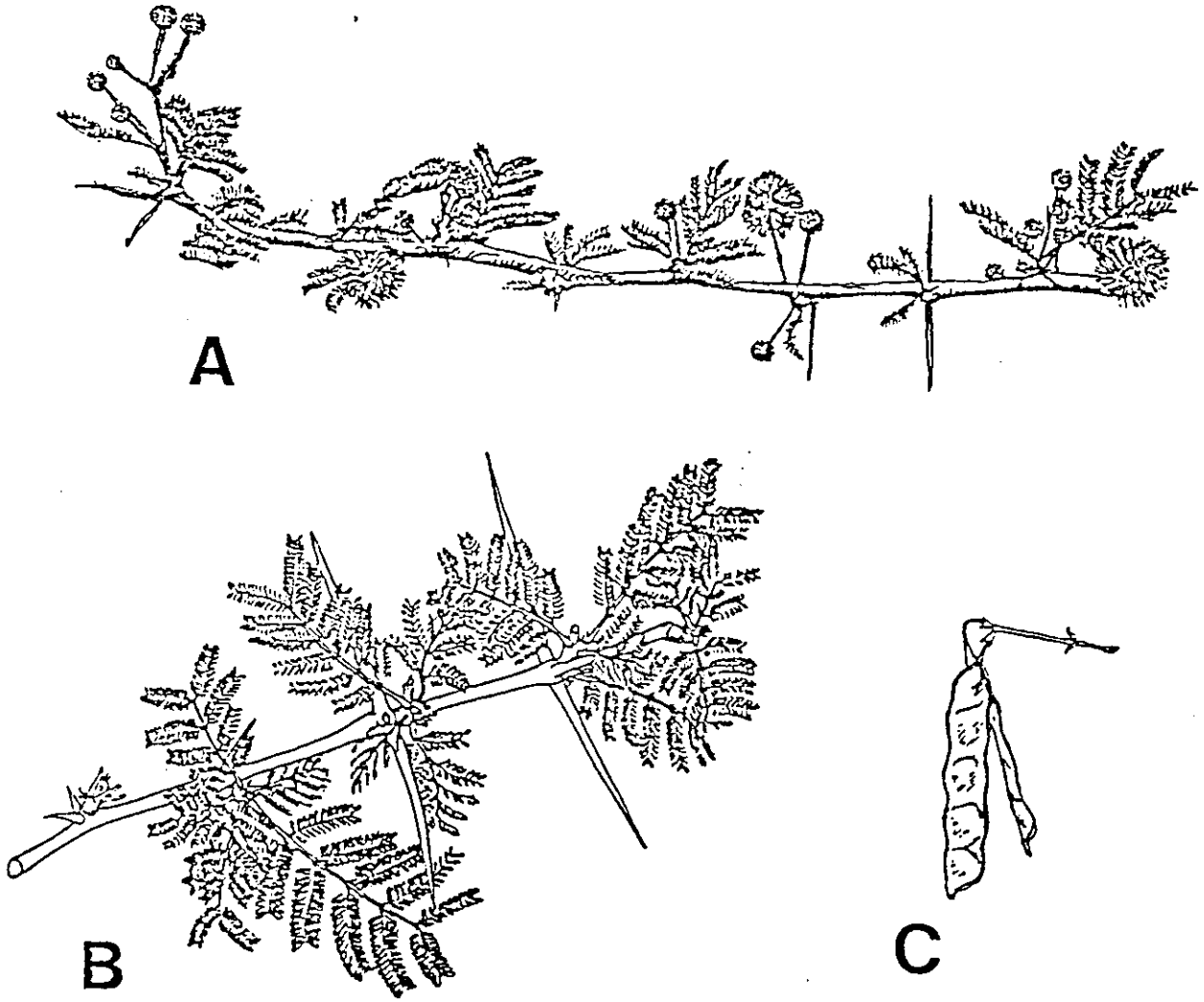

Figure 1. Features of a flowering branchlet (A), a twig (B), and fruits (C) of Acacia xanthophloea Benth. (from Palmer and Pitman, 1973).

branchlets (Figure 1A). The heads are about 10 mm in diameter. Each is borne on a slender, green, pubescent peduncle, which is up to 3 cm long. Each peduncle has a fairly prominent involucel located just below its centre point.

The pods are borne in bunches. They are straight, up to 75 mm long and 10 to 12 mm wide, more or less parallel-sided and sometimes have marked constrictions between the seeds (Figure 1C). They are somewhat coriaceous and are glabrous, transversely venose and indehiscent. When dry they are light- to dark-brown. There are as many as nine seeds per pod, these being ellipsoidal, up to 9 x 8 mm, though often smaller. The seeds are olive green to brown and the 5 x 4 mm areole, has the form of an indistinct lighter-coloured, narrow, horseshoe-shaped marking, surrounding a slightly darker centre (Dale and Greenway, 1961; Palgrave, 1977; Palmer and Pitman, 1973).

The seeds are avidly fed on by herbivores and bruchid beetles. The seeds typically have a low germination rate, presumably because of the impervious seed coat (Palmer and Pitman, 1973; Southgate, 1983). In Kenya, A. xanthophloea pods are collected either from low branches after ripening or from the ground after abscission.

BRACHYSTEGIA SPICIFORMIS BENTH.

Brachystegia spiciformis grows in the south-eastern part of Africa to east Africa. It usually grows in open,

deciduous forests in south-eastern Africa (Dale and Greenway, 1961; Palgrave, 1977). In Kenya, B. spiciformis grows in mixed forests on sandy soils in the coast province (Dale and Greenway, 1961).

Brachystegia spiciformis is a tree which grows to heights of 18 m. It has a flat-topped crown and a short main trunk up to 1 m in diameter at breast height. The bark is dark brown and smooth when young; later, it cracks into rectangular shapes. The pinnately compound leaves have two to seven (usually three to five) pairs of pinnae (Figure 2A and D). The pinnae are very variable in shape, size and pubscence, but usually ovate. The rachis usually has conspicuous stipellar expansions between the pairs of pinnae.

The flowers are small and occur in racemose or spiciform inflorescences, which are simple or have one or two branches (Figure 2A). There is either no perianth, or the flowers have one to three narrow scales (Figure 2B). There are ten stamens which are united into a tube at the base. The ovary is on a stalk of its own length. The pod is more or less oblong up to 11 cm long and 4 cm broad (Figure 2C). It is dark brown and smooth when mature and it splits explosively (Dale and Greenway, 1961; Palgrave, 1977).

The hard-coated seeds are dark brown when mature. They are 2 to 3 cm long and 1 to 2 cm broad, and are eaten, for example, by baboons. They are difficult to collect,

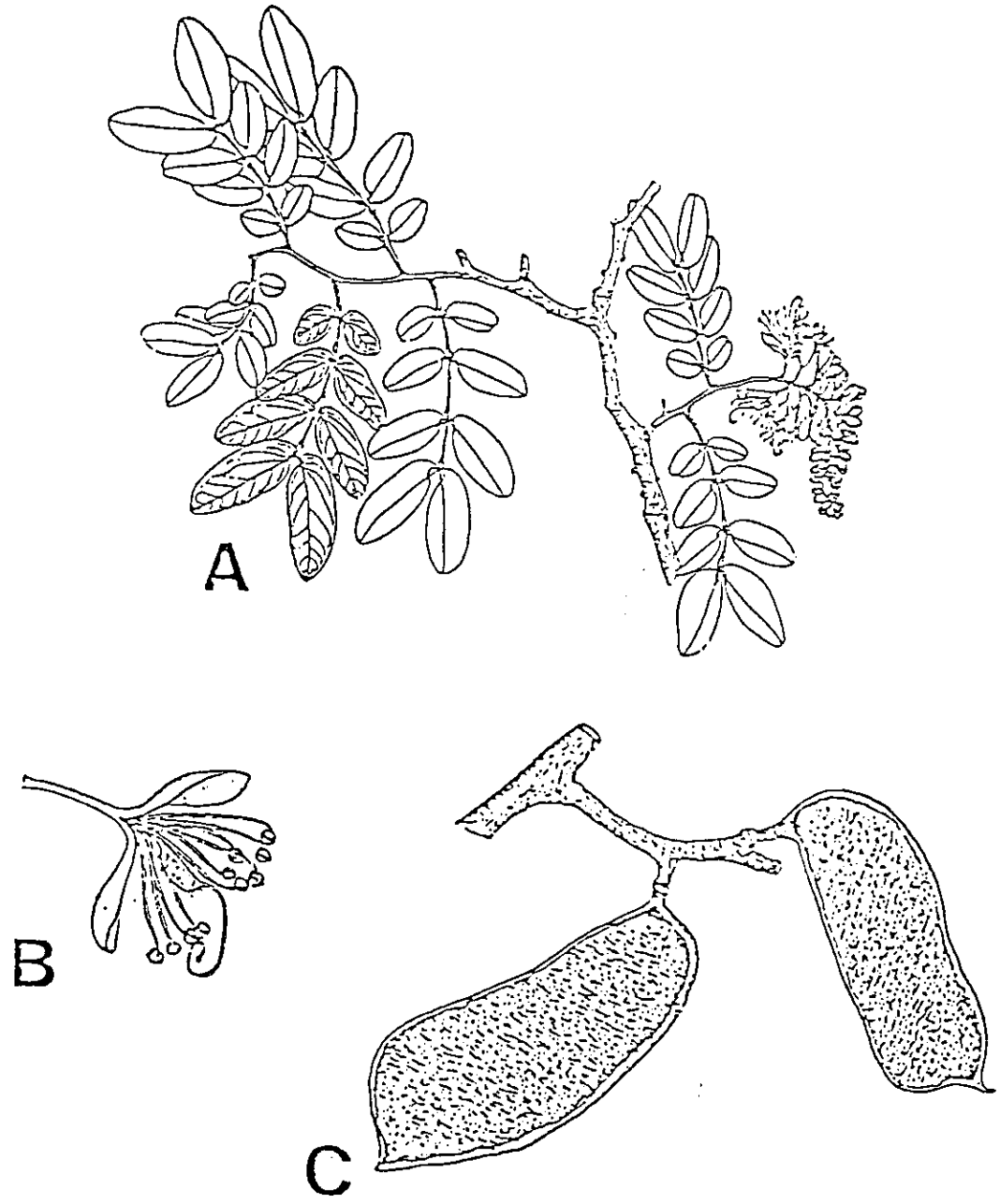

Figure 2. Features of a flowering branchlet (A), a flower (x2) (B), and a fruiting branchlet (C) of Brachystegia spiciformis Benth. (from Dale and Greenway,1961).

because of the explosive dispersal mechanism. Therefore, the ripened fruits are collected before dispersal. In Kenya, ladders are used to assist in reaching the fruits.

TRACHYLOBIUM VERRUCOSUM (GAERTN.) OLIV.

Trachylobium verrucosum is indigenous to East Africa and is occasionally planted in west Africa (Dale and Greenway, 1961; Palgrave, 1977). In Kenya, T. verrucosum grows in mixed evergreen coastal forests (Dale and Greenway, 1961).

Trachylobium verrucosum is a timber tree which grows to heights of 30 m with a clear cylindrical bole to 12 or 15 m. It has a smooth bark, which is patterned in grey, green, brown and white, and which often has short longitudinal shallow cracks. The bark, when blazed, is reddish, and the sapwood white.

The compound leaves have only one pair of oppositely arranged pinnae on a 3-cm-long petiole. Each pinna is obliquely oblong or elliptical, up to 7 cm long, coriaceous, glabrous, and lustrous above. The apex of each pinna is shortly and bluntly acuminate, the margins are entire, and the base is rounded (Figure 3A).

The flowers (Figure 3B and C) are small with white and pink petals, and are borne in axillary panicles. The calyx consists of four sub-equal sepals. There are ten stamens which are slightly connate at the base.

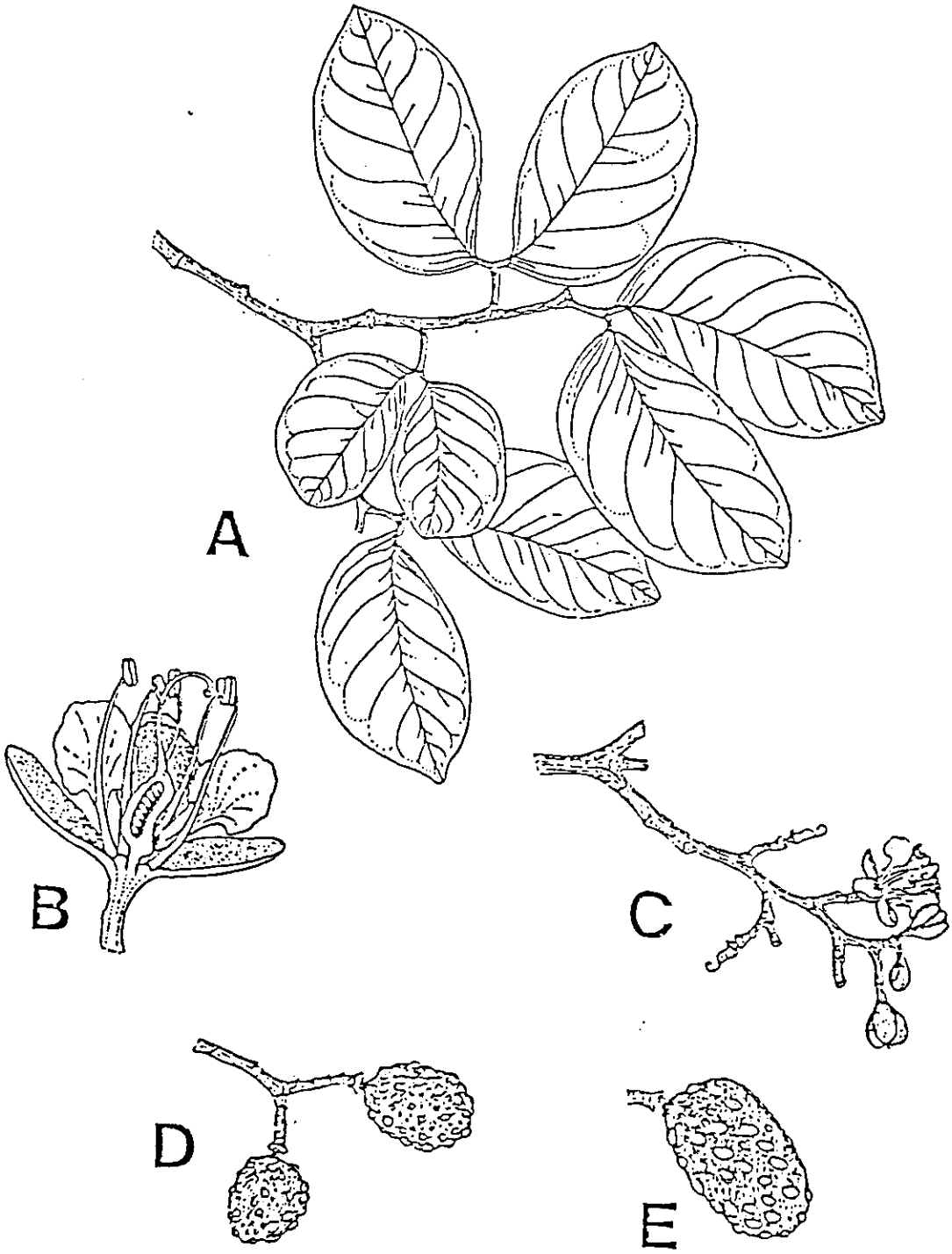

Figure 3. Features of a branchlet (A), flowers (x2) (B), parts of an inflorescence (C) and fruits (D and E) of Trachylobium verrucosum (Gaertn.) Oliv. (from Dale and Greenway, 1961).

The indehiscent fruit is stout (Figure 3D and E), oblong (up to 5 cm long and 3 cm broad), covered with coarse gum warts, and is one- or two-seeded (Dale and Greenway, 1961). Young fruits are eaten by baboons.

The seeds are brown to reddish-brown when mature. They range from 2 to 4 cm long and 1 to 2 cm broad and have hard seed coats. In Kenya, the ripened fruits that are on low branches may be picked, but those on high branches are collected from the ground after abscission.

REVIEW OF PRETREATMENT OF SEEDS OF LEGUMINOUS TREE SPECIES

DORMANCY AND SEED STRUCTURE

A viable seed is in a state of dormancy when it will not germinate when placed in conditions normally considered to be adequate for germination, that is, when the seed is provided with suitable temperature, adequate moisture and oxygen (Tran and Cavanagh, 1984). The causes of dormancy are many and varied and may include: impermeability of the seed coat to water and gases, immaturity of the embryo, special requirements for light, presence of inhibitors, and mechanical restriction of embryo growth and development or of radicle extension in germination (Wang, 1975; Jann and Amen, 1977; Nikolaeva, 1977; Tran and Cavanagh, 1984; Riggio-Bevilacqua et al., 1985).

According to Rolston (1978) dormant seeds, such as those with impermeable seed coats, which are common among seeds of leguminous tree species, permit extension of life to many seeds so that seedlings derived from them are distributed in time as well as in space. Not only do impermeable seeds remain viable for a long time, but under natural conditions increments of a seed population become permeable to water and germinate in successive intervals.

Seed dormancy creates problems for handling of seeds for artificial regeneration of tree species. Tran and Cavanagh (1984) stated that the most notable problem in achieving satisfactory germination is finding a means of breaking dormancy. In artificial conditions (nursery, greenhouse, or laboratory) 'satisfactory' germination means germination of all, or the vast majority of seeds in a seedlot at one time, or within a short period of time.

External morphological features shared by leguminous seeds that retain their testas at maturity, are a cuticle, testa (spermaderm) and hilum, all derived from maternal tissue (Gunn, 1981a). Rolston (1978) stated that the testa and its structures, the hilum, micropyle, strophiole, and chalaza, have all been implicated as barriers to water or as areas of weakness where imbibition occurs.

Internal morphological features shared by all leguminous seeds are two cotyledons that are usually straight, and an embroynic axis with a well defined radicle, poorly defined hypocotyl and poorly defined epicotyl. The epicotyl includes leaf primordia in some species. Endosperm may be copious to absent (Gunn, 1981b).

According to Tran and Cavanagh (1984), it is not known whether impermeability is due to mechanical processes (e.g., shrinkage and closer packing of the cells in the seed coat as the seed matures), or to chemical effects (e.g., impregnation of the cell walls with hydrophobic substances). A combination of both mechanical and chemical effects may

exist, and the operative mechanisms may differ among various species (Werker, 1980/81; Tran and Cavanagh, 1984).

The seeds of Mimosoideae (excluding the hilum) are bilaterally symmetrical. The seed coat is smooth to rarely pitted or wrinkled, glossy to rarely dull, monochrome brown to black, occasionally dichrome due to mottling, and rarely monochrome red to dichrome red/black. Each usually bears a pleurogram (65-70% of the species), sometimes bears fracture lines (33-45%), and is rarely winged (6%). Seed coats of some species of Acacia are arillate. The hilum is continuous to the tip of the radicle (Gunn, 1981b).

The seeds of Caesalpinioideae (excluding the hilum) are bilaterally symmetrical. The seed coat is smooth to rarely wrinkled, glossy to rarely dull, monochrome tan to black or rarely red, and rarely dichrome due to mottling. It occasionally bears a pleurogram (9-13%), or fracture lines (15-26%), is rarely winged (2-3%), and is occasionally arillate (7-22%). The hilum is continuous to the tip of the the radicle (Gunn, 1981b).

As far as can be ascertained, the structures of the seeds of the species which are the subject of this project have not been investigated in any depth.

SEED PRETREATMENT

Seeds are fairly resistant to extreme external conditions provided they are in a state of desiccation. Because removal of seed coats by various means leads to

increased germination (Clemens et al., 1977; Khan, 1977; Doran et al., 1983), impermeable seed coats are important contributors to dormancy and longevity. Various pretreatments that will induce hard seeds to germinate have been known for many years (Rolston, 1978; Duran and Tortosa, 1985). Crocker, as early as 1906, was aware of most ways in which seed coats or other seed coverings are understood to affect germination (Tran and Cavanagh, 1984). Chapman (1936) used several methods to pretreat black-locust (Robinia pseudoacacia L.) seeds.

Scarification, dry heat, hot water, acid pretreatments, solvents, and impactions or percussion have been tried at one time or another with varying success. Such factors as the species, age of the seed, size of the seed, time of harvest and variability within a species can all contribute to erratic germination response (Tran and Cavanagh, 1979).

Treatments used to render the seed coat permeable, so as to raise the percentage germination or to shorten the period required to realise optimum germination can be grouped in two major classes (Cavanagh, 1980; Bebawi and Mohamed, 1985). 'Wet' pretreatments include boiling in water; soaking in hot water, in acids, in organic solvents, or in oxidizing agents; freezing; and the use of gases (Krugman et al., 1974; Doran et al., 1983). 'Dry' pretreatments include exposure to heat, to fluctuating temperatures, or to microwave energy; impaction or percussion;

and nicking, chipping, or scarifying by some mechanical means (Krugman et al., 1974; Tran and Cavanagh, 1979; Doran et al., 1983; Bebawi and Mohamed, 1985).

Wet Pretreatments

Soaking in hot or cold water is effective in some species but not in others. Different species require different temperatures and different durations (Bonner et al., 1974; Kahre, 1983; Bebawi and Mohamed, 1985). A frequently used technique is to immerse the seeds in four to ten times their volume of boiling water (100°C), remove the heat source, and allow the seeds to soak in the gradually cooling water for 12 to 24 h. This method is widely applied, but can give erratic results (Cavanagh, 1980; Doran et al., 1983; and Tran and Cavanagh, 1984).

Soaking in concentrated sulphuric acid is the most common method of treating impermeable leguminous seeds. The effect on the seed coat is similar to that of prolonged boiling and the seed coat is left dull and shallowly pitted. It is a more effective method than boiling water for many impermeable seeds (Bonner et al., 1974; Krugman et al., 1974; Doran et al., 1983; Tran and Cavanagh, 1984). According to Doran et al. (1983) the optimum soaking period in sulphuric acid depends on the species. It is usually in the range of 20 to 60 min.

Other wet treatments used are soaking in ethanol, xylene, methanol or acetone. These solvents have been used

on a laboratory scale to treat seeds, especially Acacia seeds (Krugman et al., 1974; Doran et al., 1983).

Dry Pretreatments

Dry pretreatments most commonly involve some form of scarification. It is the aim when scarifying to abrade the seed coat so as to permit water absorption. Physical scarification may be performed by hand, or by use of specially designed machines (Bonner et al., 1974; Kahre, 1983). Piercing, chipping, nicking or filing the testa of individual seeds is a technique especially suitable for small quantities of seed. The percentage germination reached following piercing, chipping, nicking or filing the testa of individual seeds generally approximates the germination capacity (Bonner et al., 1974; Doran et al., 1983). Tran and Cavanagh (1979) stated that microwave energy is mostly effective in improving the germination of Acacia seeds. Microwave energy caused the seedcoat to develop an extensive network of cracks. Percussion is ineffective for many species and its usefulness is confined to seeds which are flat or disc-shaped, and which also have a relatively thin seedcoat. Fluctuating temperatures are sometimes effective, the durations and values vary with the type of species (Doran et al., 1983; Tran and Cavanagh, 1984). However, within any seedlot not all the seeds are equally 'hard'. This leads to a variable response to a given pretreatment; hence, the germination percentage attained varies with the seedlot

(Doran et al.,1983).

MATERIALS AND METHODS

BIOLOGICAL STUDIES

The reproductive development of A. xanthophloea was investigated in the Kibwezi Forest in southern Kenya and that of B. spiciformis and T. verrucosum in the Arabuko-Sokoke Forest in southeastern Kenya (Figure 4). The Kibwezi Forest is situated at an elevation of about 90 m. Its annual rainfall ranges from 510 to 760 mm and falls in two periods, March to May and October to December. The maximum rainfall occurs in April and November. The maximum and minimum annual temperature ranges are 30° to 34°C, and 18° to 22°C, respectively. The soil is a well-drained dark sandy loam. The natural vegetation type is woodland.

The Arabuko-Sokoke forest is situated at 30 m above sea level. Its annual rainfall ranges from 760 to 1015 mm. Most of this falls from April to July, with the maximum falling in May. The maximum annual temperature range is 30° to 34°C, and the minimum mean annual temperature is 22°C. There are two distinct soil types: white sandy soil and sandy-loam soil. The natural vegetation type is sub-humid tropical forest.

In the Kibwezi Forest, A. xanthophloea occurs as a dominant tree species near rivers or areas with high water

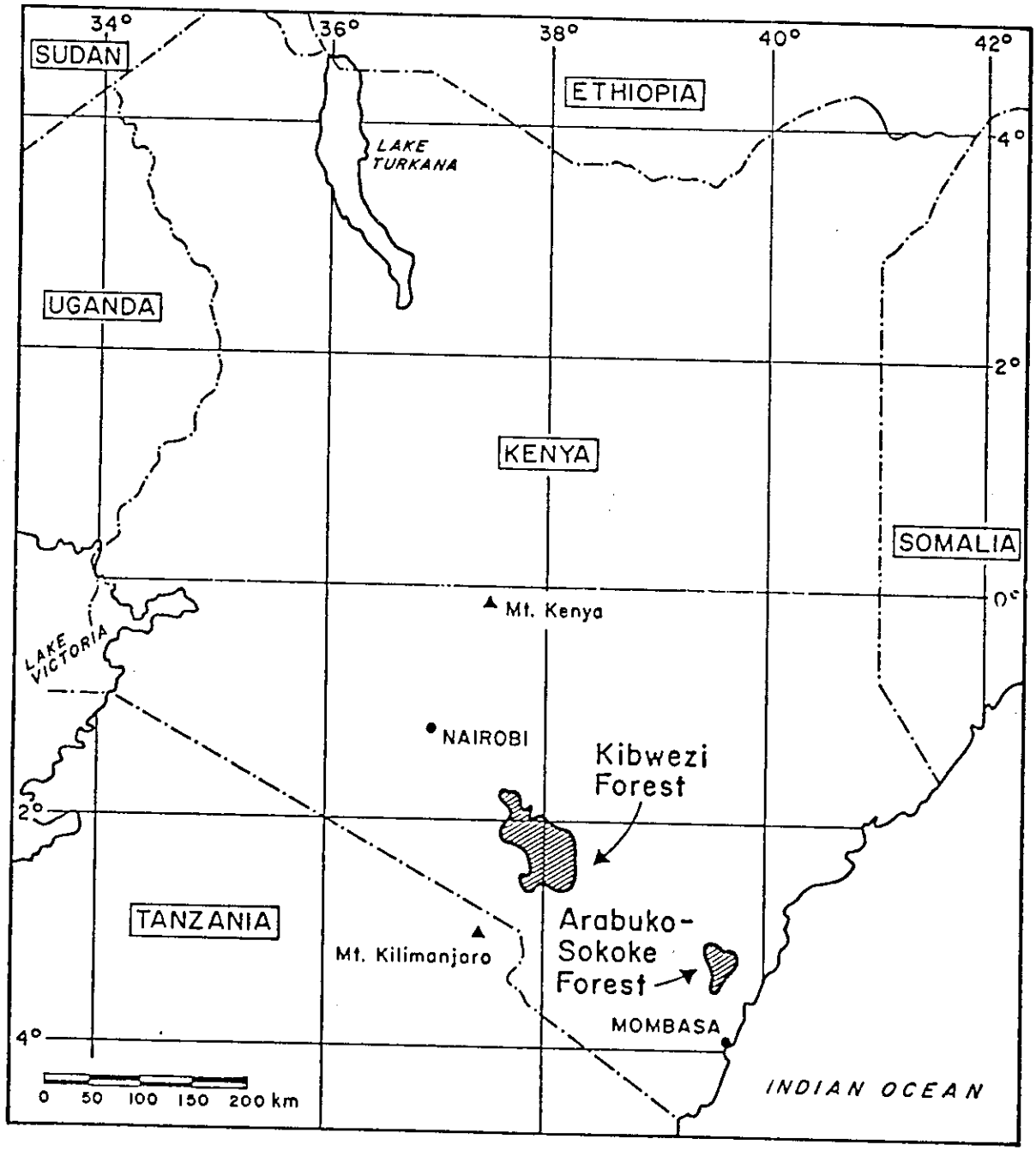

Figure 4. The location of Kibwezi and Arabuko-Sokoke Forests of Kenya.

tables. In the Arabuko-Sokoke Forest, B. spiciformis and T. verrucosum occur as dominant tree species on sandy-loam soils, and on sandy soils, respectively.

Within the two forests, sites were selected on the basis of whether the respective study species was dominant, and whether the site was accessible by vehicle. On each site, ten trees were marked for detailed observation, and unmarked trees of the given tree species were also used for general observations. The marked trees were dominant or predominant in their respective populations.

Development of the trees was assessed weekly, by observing with aid of binoculars. More frequent observations were made during periods of flowering and fruit formation. Records were made of flowering time, type of pollination, fruit formation, fruit ripening and fruit type. These observations were recorded by forest workers in the two Forest Stations. The workers were given their instructions by the writer.

SEED PRETREATMENT AND GERMINATION TESTS

The seeds used in this study were collected during 1984 and 1985. Those of A. xanthophloea were collected from Kibwezi Forest, and those of B. spiciformis and T. verrucosum were collected from Arabuko-Sokoke Forest. The seeds were placed in polythene bags that were sealed and transported either with the writer by air in September 1984,

or by air mail subsequently, to Fredericton, NB, where they were stored at 1° to 5°C until used. A total of 5,200 seeds of each of A. xanthophloea and T. verrucosum were used for germination tests. These were divided into four replicates of 100 seeds in each of 13 pretreatments. For B. spiciformis, for which fewer seeds had been collected, four replicates of 80 seeds were used in each of 13 pretreatments, for a total of 4,160 seeds.

All the seeds were surface-sterilized by first soaking them in 30 to 35% hydrogen peroxide for one hour and then thoroughly rinsing them in sterile water before pretreatment. All the pretreatments were conducted under a laminar-flow hood.

The seeds were pretreated using different 'dry' or 'wet' methods. The first three pretreatments in the following listing were 'dry'.

1. Control. The seeds were kept dry until they were placed for germination.

2. Nicking. By use of sharp cutting pliers the coat of each seed was nicked at the micropylar end.

3. Dry abrading. Seeds were abraded for 12 h using a Tumblex-finishing apparatus (Anonymous, 1970). The essential components of this process were a machine which provided for rotation and vibration, and an abrasive medium (Tumblex TG) (Anonymous, 1970).

4. Wet abrading. The seeds were abraded for 12 h in a Tumblex-finishing apparatus with Tumblex TG (Anonymous,

1970) and a small amount of water.

5. Soaking in hot water for 6 h. Seeds were placed in just-boiled water (100°C) and left to cool for 6 h.

6. Soaking in hot water for 12 h. Seeds were placed in just-boiled water (100°C) and left to cool for 12 h.

7. Soaking in hot water for 24 h. Seeds were placed in just-boiled water (100°C) and left to cool for 24 h.

8. Soaking in concentrated sulphuric acid for 8 min.

9. Soaking in concentrated sulphuric acid for 16 min.

10. Soaking in concentrated sulphuric acid for 32 min.

11. Soaking in xylene for 8 min.

12. Soaking in xylene for 16 min.

13. Soaking in xylene for 32 min.

The seeds were thoroughly rinsed with sterile water after pretreatment and then placed on moist sterilized Kimpak (cellulose wadding) in sterilized polycarbonate Spencer-Lemaire germination boxes of 28 x 24 x 10 cm dimension (Wang and Ackerman, 1983). Sterilization had been achieved by autoclaving the prepared germination boxes for 20 min at 121°C and 105 kPa. Immediately following autoclaving, each box was sealed with Parafilm until used under the laminar-flow hood. To each box, 200 ml of distilled water was added. Each seed-loaded germination box was then placed randomly in one of two Conviron G30 germinators at constant 20°C with a daily 16 h flourescent-

light photoperiod and 8 h of dark. The relative humidity in the germinators was maintained at over 85%. The germination boxes were randomly arranged on the germinator trays. Germination counts were made every other day. The criterion for germination was that the radicle had protruded from the seed coat and had achieved an exposed length equivalent to that of the longest dimension of the seed. The germination tests ran for 28 days.

Cutting Test

After 28 days the ungerminated seeds were sectioned and classified according to the seed content. White and firm seed content was classified as fresh, with the seed being still considered viable. Rancid, insect-damaged (with or without the presence of the insect), severely discoloured and not firm seed content was classified as dead. Seeds with no content were classified as empty.

X-ray Analyses

For X-ray analysis of seeds the following procedure was used. A sample of seeds of each pretreatment of each species was placed on an acetate sheet. This was done for each pretreatment. Each sheet with its sample was placed in the dark in a soft X-ray machine (Hewlett-Packard Faxitron model 43804 N) over a sheet of Kodak Industrex Instant 600 paper. This machine had a pre-set amperage of 3 mA. The kilovoltage and exposure time were changed after a series of

test exposures had been made to suit the seed-size and seed-shape characteristics of the particular species. For A. xanthophloea, the machine was set at 15 kV and the seeds exposed for 60 s; for T. verrucosum, it was set at 20 kV and the seeds exposed for 135 s; and for B. spiciformis it was set at 20 kV and the seeds exposed for 90 s. After exposure, the paper was immediately processed in a Kodak Industrex Instant Processor. Images examined were classified according to Simak's (1980) classification of broad-leaved seeds (Figure 5).

Data Analysis

Analysis of variance (Zar, 1974) was used to test whether there were differences among pretreatments. The mean square for the error term was therefore used to provide values for the F-ratio for testing for the levels of significance. After the F-value was found to be significant, some mean-separation tests were conducted, for example, the Scott-Knott mean-separation test (Scott and Knott, 1974) and Duncan's multiple-range test (Zar, 1974).

Figure 5. Type C, embryo and seed-cavity classification of broad-leaved seeds: 0 = empty; I = less than 50% content; II = 50-75% content; III = greater than 75% content but the embryo has poor contact with the seed coat; IV = as class III, but the embryo has good contact with the seed coat (from Simak, 1980).

RESULTS

BIOLOGICAL STUDY

In the years 1984 and 1985, A. xanthophloea had two flowering periods, that is, there was flowering in June to August of 1984 and January to March of 1985 (Table 1). The major pollination agents observed on and around the flowers were bees, butterflies and birds (Table 1). These agents were observed mainly in the mornings. During the June to August period in 1984, there was no rainfall (Table 2), and apparent loss of flowers was minimal. Heavy rains occurred during the flowering of January to March, 1985 (Table 2). Many flowers fell during these rains. The subsequent fruit set was reduced.

The fruits formed and developed in August to October of 1984 and in March to May of 1985 (Table 1). These periods included considerable rainfall (Table 2). The fruits ripened and dried in the relatively dry seasons, that is, in November of 1984 to January of 1985 and July to August of 1985 (Table 1) and were dry by the ends of those periods. The indehiscent fruits that escaped predation fell close to the parent tree. Baboons and birds were observed feeding on young fruits and to a lesser extent on ripened fruit. Bruchid beetles were observed in collected seeds.

Table 1. Summary of flowering, fruiting and seed/fruit dispersal of A. xanthophloea, B. spiciformis and T. verrucosum.

	Acacia xanthophloea	Brachystegia spiciformis	Trachylobium verrucosum
Flowering and pollination [a]	1. January to March 2. June to August	January to March	July to August
Agents of pollination	Bees, butterflies and birds	Bees, butterflies and wind	Bees, butterflies and birds
Fruiting period	1. March to May 2. August to October	April to June	September to November
Seed/fruit maturation [b]	1. July to August 2. November to January	July to September	December
Type of fruit	Indehiscent legume	Dehiscent legume	Indehiscent legume
Agents that feed on or use seeds	Insects, e.g. bruchid beetles, birds and wild animals feed on the seeds, man collects young and ripened fruits for fodder	Baboons feed on young fruits	Baboons and birds feed on young fruits.
Agents of seed dispersal	Birds, man and herbivores	Explosive mechanism	Most of the seeds drop near the trees
Method of fruit collection	From the ground and low branches	From the trees before fruits dry-up	From the ground and from the trees
Seed collection problems	It is difficult to collect the seeds from the trees.	It is difficult to collect seeds from very tall trees.	

[a] A lot of flowers fell if heavy rains occurred during flowering, and the subsequent fruit set was reduced.
[b] Some of the fruits were aborted before maturity.

Table 2. Rainfall and temperature data of 1984/85 for Kibwezi Forest Research Station.

Year		Months											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1984	Monthly rainfall (mm)	-	0.5	33.1	119.7	0.0	0.0	0.0	0.0	3.2	11.3	264.9	91.1
	Cum. rainfall (mm)	-	0.5	33.6	153.3	153.3	153.3	153.3	153.3	156.5	167.8	432.7	523.7
	No. days of rain	-	1	2	2	0	0	0	0	2	8	18	6
	Cum. no. days of rain	-	1	3	5	5	5	5	5	7	15	33	39
	Mean monthly temp.(C)	24.5	24.7	24.8	24.8	22.8	21.4	20.4	20.4	22.6	23.0	22.7	21.8
1985	Monthly rainfall (mm)	4.4	112.2	53.3	26.1	0.0	0.0	0.0	0.0	0.0	84.5	-a	-
	Cum. rainfall (mm)	4.4	116.6	169.9	196.0	196.0	196.0	196.0	196.0	196.0	280.5	-	-
	No. days of rain	2	9	2	5	0	0	0	0	0	5	-	-
	Cum. no. days of rain	2	11	13	18	18	18	18	18	18	23	-	-
	Mean monthly temp.(C)	23.1	23.8	23.4	23.9	23.5	22.4	20.0	18.9	20.4	22.6	-	-

[a] Data not available

Fruits were gathered from the ground or from lower branches on the trees where thorns did not hamper collection.

Brachystegia spiciformis had a single flowering period in each of 1984 and 1985. Flowering occurred in January to March of 1984 and 1985 (Table 1), which were relatively dry periods (Table 3). The major pollinating agents observed on and around the flowers were bees and butterflies. There was also wind pollination.

The fruits formed and developed from April to June of 1984 and 1985, when the rainfall was high (Table 3). Very few fruits formed in 1984, whereas in 1985 there was abundant fruit formation. Baboons were observed feeding on young fruits. Fruits were collected before they dehisced explosively.

Trachylobium verrucosum had one flowering period from July to August in each of 1984 and 1985 (Table 1). There was moderate rainfall during the 1984 flowering period and much heavier rainfall during the 1985 period (Table 3). The major pollinating agents observed on and around the flowers were bees, butterflies and birds, mainly before noon.

The fruits formed and developed from September to November (Table 1). This period had moderate rainfall (Table 3). Baboons and birds were observed feeding on the young fruits. The fruits ripened and dropped starting in December. The pods were indehiscent. The fruits and seeds were collected from under the trees.

Table 3. Rainfall and temperature data of 1984/85 for Gede Forest Research Station

Year		Months											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1984	Monthly rainfall (mm)	0.0	0.0	0.0	170.5	230.5	201.0	63.0	16.5	25.3	76.0	3.3	0.0
	Cum. rainfall (mm)	0.0	0.0	0.0	170.5	401.0	602.0	665.0	681.5	706.8	782.8	786.1	786.1
	No. days of rain	0	0	0	15	18	14	10	4	3	6	8	0
	Cum. no. days of rain	0	0	0	15	33	47	57	61	64	70	78	78
	Mean monthly temp. (C)	27.1	26.7	28.5	26.3	25.5	24.5	23.9	24.1	24.6	25.1	26.8	26.9
1985	Monthly rainfall (mm)	0.0	10.0	13.0	213.5	264.0	60.5	124.5	138.5	32.0	32.0	-[a]	-
	Cum. rainfall (mm)	0.0	10.0	23.0	236.5	500.5	561.0	685.5	824.0	856.0	888.0	-	-
	No. days of rain	0	1	6	13	15	10	13	11	8	7	-	-
	Cum. no. days of rain	0	1	7	20	35	45	58	69	77	84	-	-
	Mean monthly temp. (C)	27.3	27.8	28.5	27.9	25.3	25.1	24.5	24.9	24.9	26.1	-	-

[a] Data not available

In each of the three species there was an overlap in the flowering, fruiting and fruit-maturation periods. The months given for the different development stages were the peaks when numerous flowers, fruits or drying fruits were evident.

GERMINATION OF SEEDS OF ACACIA XANTHOPHLOEA

Some pretreated seeds of A. xanthophloea germinated rapidly (Figure 6). Germination began on day 2 and was essentially completed by day six, but a few seeds germinated later. Five pretreatments were effective in enhancing germination, and a sixth showed some response (Figure 6, Table 4 and Appendix I). Nicking the seed coats at the micropylar end was the most effective pretreatment (77% germination). All the nicked seeds that germinated, did so within six days. The three hot-water pretreatments were reasonably effective (germination between 53 and 62%), but the responses were not proportional to the soaking periods. Two soaking periods (12 and 24 h) produced a more rapid response, but the 6 h soaking period produced the best percentage germination (Figure 6). Pretreatment for 32 min in concentrated sulphuric acid produced a germination percentage equivalent, at day 28, to the shortest and longest hot-water pretreatments (Table 4), but the rate of germination was somewhat slower, and hence germination was more prolonged than that following hot-water pretreatments

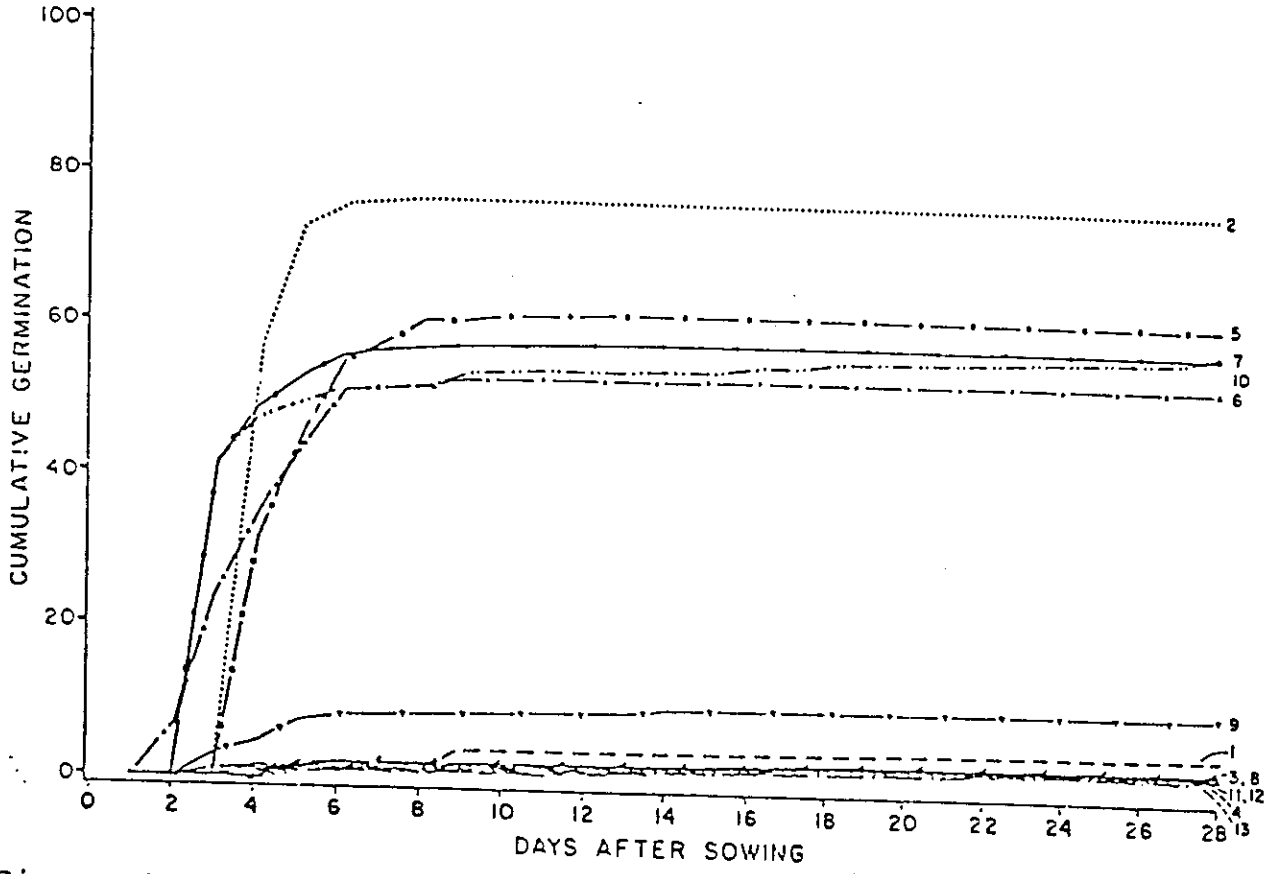

Figure 6. Germination of pretreated seeds of Acacia xanthophloea: 1 - control; 2 - nicking; 3 - abrading (dry); 4 - abrading (wet); 5 - hot water (6 h); 6 - hot water (12 h); 7 - hot water (24 h); 8 - conc. sulphuric acid (8 min); 9 - conc. sulphuric acid (16 min); 10 - conc. sulphuric acid (32 min); 11 - xylene (8 min); 12 - xylene (16 min); 13 - xylene (32 min).

Table 4. Scott-Knott mean-separation test for Acacia xanthophloea following analysis of variance of germination results.

Pretreatments	N	Mean[a] (%)	
1 Control	4	4.50	E
2 Nicking	4	76.75	A
3 Abrading (dry)	4	2.75	E
4 Abrading (wet)	4	2.25	E
5 Hot water (6 h)	4	62.25	B
6 Hot water (12 h)	4	53.50	C
7 Hot water (24 h)	4	58.00	B
8 Conc. sulphuric acid (8 min)	4	2.75	E
9 Conc. sulphuric acid (16 min)	4	10.00	D
10 Conc. sulphuric acid (32 min)	4	58.25	B
11 Xylene (8 min)	4	2.50	E
12 Xylene (16 min)	4	2.50	E
13 Xylene (32 min)	4	1.50	E

[a] Means followed by the same letter are not signficantly different at the 0.05% level.

(Figure 6). Pretreatment for 16 min in concentrated sulphuric acid produced only 10% germination. Other pretreatments were not effective.

Some of the seeds in the various pretreatments germinated abnormally (Table 5). Abnormal germination (the radicle coiled and grew back into the seed coat, or the epicotyl and cotyledons protruded from the seed coat before the radicle) was mostly associated with hot-water pretreatments and with long exposure to sulphuric acid.

The cutting test after 28 days confirmed that some of the seeds would probably still have germinated given enough time. Other seeds were dead due to various reasons, such as insect damage and fungal infection, and a few of the seeds were empty (Table 5). The cutting test results corresponded with the germination test results (Figure 6 and Table 5). The pretreatments that were effective had few fresh seeds remaining. The highest incidence of dead seeds occurred in hot-water pretreatments (17.5 to 31.0%). Abrading and nicking the seeds when dry were associated with substantial numbers of dead seeds (20%), and soaking the seeds in concentrated sulphuric acid was associated with somewhat fewer dead seeds (15 to 17.5%). In the other pretreatments about 10% of the seeds were dead.

Of the non-pretreated seeds that were X-rayed, 10% had insect damage and 90% were fully developed (in Class IV, Figure 5). Images of X-rayed pretreated seeds showed that

Table 5. Mean numbers of germinated and ungerminated seeds of different category of A. xanthophloea per pretreatment after the 28-day germination test.

Pretreatments	Germination %(X)	Abnormal germination %(Y)	% of seeds in germination test			
			Fresh (Z)	X+Y+Z	Dead[a]	Empty
1. Control	4.50	1.00	86.25	91.75	8.25	0.00
2. Nicking	76.75	2.75	0.00	79.50	19.50	1.00
3. Abrading (dry)	2.75	0.75	76.25	79.75	20.25	0.00
4. Abrading (wet)	2.25	0.50	86.25	89.00	11.75	0.00
5. Hot water (6 h)	62.25	5.75	1.50	69.50	31.00	0.00
6. Hot water (12 h)	53.50	5.00	16.75	75.25	24.75	0.00
7. Hot water (24 h)	58.00	12.25	11.00	81.25	17.50	1.25
8. Conc. sulphuric acid (8 min)	2.75	2.25	80.00	85.00	15.00	0.00
9. Conc. sulphuric acid (16 min)	10.00	1.25	71.25	82.50	17.50	0.00
10. Conc. sulphuric acid (32 min)	58.25	8.00	15.25	81.50	16.00	2.50
11. Xylene (8 min)	2.50	0.25	86.25	89.00	11.00	0.00
12. Xylene (16 min)	2.50	0.00	88.25	90.75	9.25	0.00
13. Xylene (32 min)	1.50	1.25	85.25	88.00	11.50	0.50

[a] Some of the dead seeds had fungal and/or bacterial infection.

there was no apparent damage caused by the pretreatments. The X-ray results corresponded with the cutting test and the germination results, although the samples were different.

GERMINATION OF SEEDS OF BRACHYSTEGIA SPICIFORMIS

The germination of seeds of B. spiciformis was relatively low (highest 46%, Figure 7, Table 6 and Appendix II). Germination began on day 5 and was essentially completed by day 14, but a few seeds germinated later. Seven pretreatments had relatively high germination results (Figure 7). The control and nicked seeds had similar numbers of germinants by day 28 (46 and 45%), but germination of nicked seeds was faster (Figure 7). The three xylene pretreatments were reasonably effective (germination between 30 and 43%), but the responses were not proportional to the soaking periods. The 8 and 16 min soaking produced better germination (40 and 43%) than did the 32 min soaking period (30%). Abrading the seeds when dry and soaking in hot water for 12 h had similar results (37 and 33% germination). The other six pretreatments were not effective (Figure 7).

A few of the seeds in the various pretreatments germinated abnormally (Table 7). Abnormal germination (the radicle coiled, or the embryo split and the cotyledons swelled outwards, splitting the seed coat) was mostly associated with hot-water pretreatments (6 and 12 h), nicking

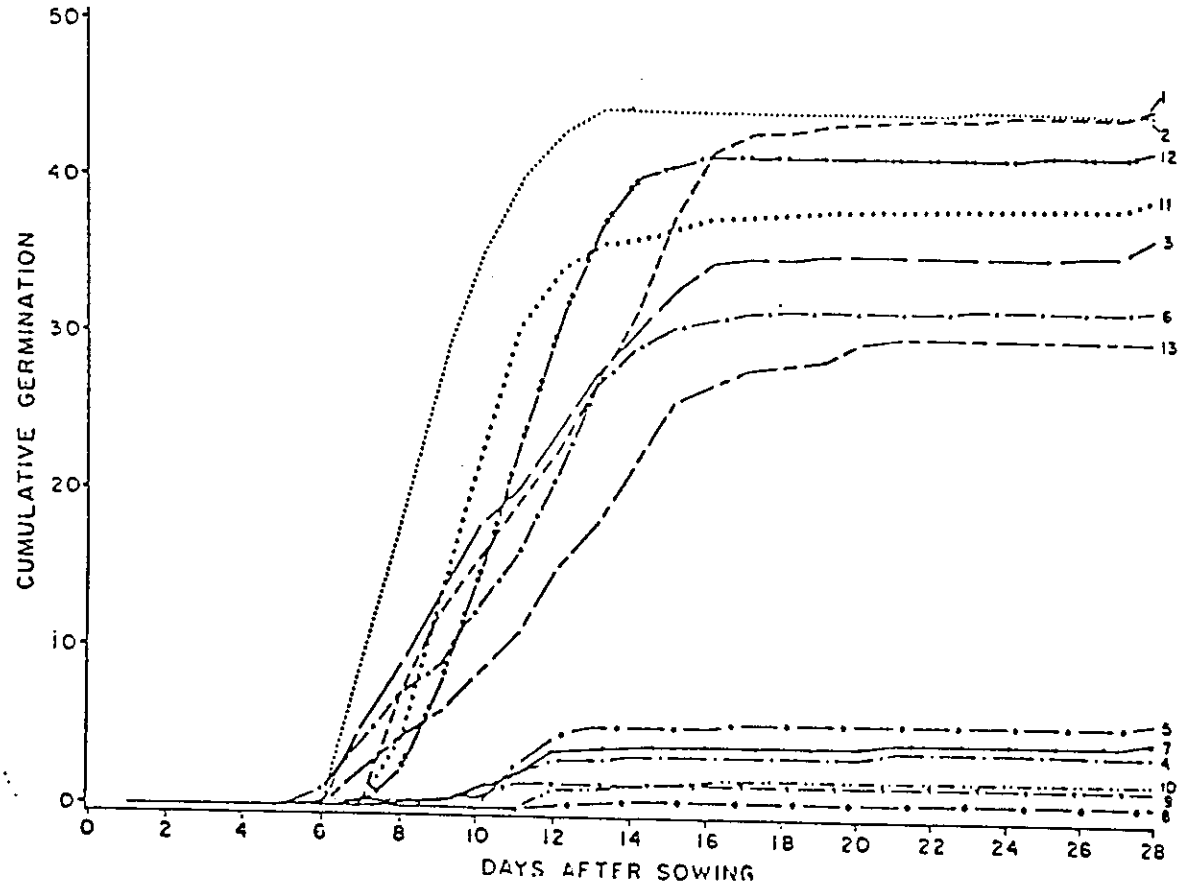

Figure 7. Germination of pretreated seeds of Brachystegia spiciformis: 1 - control; 2 - nicking; 3 - abrading (dry); 4 - abrading (wet); 5 - hot water (6 h); 6 - hot water (12 h); 7 - hot water (24 h); 8 - conc. sulphuric acid (8 min); 9 - conc. sulphuric acid (16 min); 10 - conc. sulphuric acid (32 min); 11 - xylene (8 min); 12 - xylene (16 min); 13 - xylene (32 min).

Table 6. Scott-Knott mean-separation test for *Brachystegia spiciformis* following analysis of variance of germination results.

Pretreatments	N	Mean[a] (%)	
1 Control	4	45.63	A
2 Nicking	4	45.00	A
3 Abrading (dry)	4	37.19	B
4 Abrading (wet)	4	3.75	C
5 Hot water (6 h)	4	5.94	C
6 Hot water (12 h)	4	32.50	B
7 Hot water (24 h)	4	4.69	C
8 Conc. sulphuric acid (8 min)	4	0.63	C
9 Conc. sulphuric acid (16 min)	4	1.56	C
10 Conc. sulphuric acid (32 min)	4	1.88	C
11 Xylene (8 min)	4	39.69	A
12 Xylene (16 min)	4	42.81	A
13 Xylene (32 min)	4	30.31	B

[a] Means with the same letter are not significantly different at the 0.05% level.

Table 7. Mean numbers of germinated and ungerminated seeds of different category of B. spiciformis per pretreatment after the 28-day germination test.

Pretreatmets	Germination %(X)	Abnormal germination %(Y)	% of seeds in germination test			
			Fresh (Z)	X+Y+Z	Dead[a]	Empty
1. Control	45.63	0.00	2.19	47.81	52.19	0.00
2. Nicking	45.00	1.88	0.00	46.88	53.13	0.00
3. Abrading (dry)	37.19	0.00	1.88	39.06	60.94	0.00
4. Abrading (wet)	3.75	0.00	1.13	5.00	95.00	0.00
5. Hot water (6 h)	5.94	3.75	4.69	14.38	85.63	0.00
6. Hot water (12 h)	32.50	1.88	3.75	38.13	61.88	0.00
7. Hot water (24 h)	4.69	0.00	4.06	8.75	91.25	0.00
8. Conc. sulphuric acid (8 min)	0.63	0.94	3.75	5.31	94.69	0.00
9. Conc. sulphuric acid (16 min)	1.56	0.31	1.88	3.75	96.25	0.00
10. Conc. sulphuric acid (32 min)	1.88	0.00	0.63	2.51	97.50	0.00
11. Xylene (8 min)	39.69	0.63	1.56	41.88	58.13	0.00
12. Xylene (16 min)	42.81	0.00	3.44	46.25	53.75	0.00
13. Xylene (32 min)	30.31	0.00	7.19	37.50	62.50	0.00

[a] Most of the dead seeds had fungal and/or bacterial infection.

the seeds, exposure to concentrated sulphuric acid (8 and 16 min) and exposure to xylene for 8 min.

The cutting test after 28 days confirmed that most of the ungerminated seeds were dead. Only a small proportion of the seeds were still viable. The dead seeds had fungal, bacterial and/or insect damage. This species was very susceptible to fungal and bacterial infection compared to the other two species. Some of the fungus and bacteria could have been seed borne. The highest incidence of dead seeds (86 to 98%) occurred in the three sulphuric-acid pretreatments, wet abraded seeds, and in two of the hot-water pretreatments (6 and 24 h) (Table 7). All the other pretreatments had relatively high numbers of dead seeds (52 to 62%).

Of the non-pretreated seeds that were X-rayed, 40% had necrosis where the epicotyl was connected to the cotyledons and there was a lesser incidence of insect damage. Images of X-rayed pretreated seeds showed that there was no apparent damage caused by the pretreatments.

GERMINATION OF SEEDS OF TRACHYLOBIUM VERRUCOSUM

Germination of pretreated seeds of T. verrucosum began on day 8 (Figure 8). The radicles protruded by day 6, but it took two days for the radicles to extend to the required length. Three pretreatments were effective in enhancing germination (Figure 8). Nicking the seed coats at the

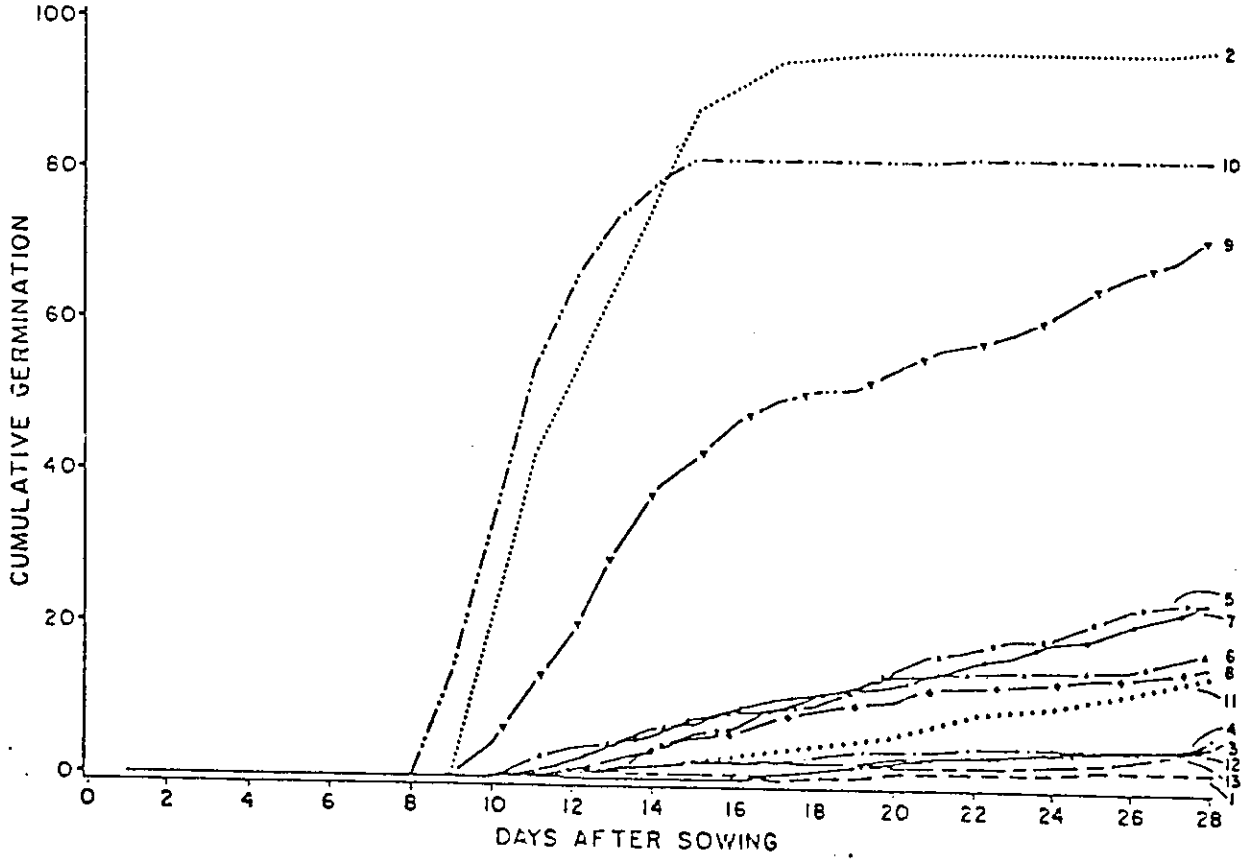

Figure 8. Germination of pretreated seeds of Trachylobium verrucosum: 1 - control; 2 - nicking; 3 - abrading (dry); 4 - abrading (wet); 5 - hot water (6 h); 6 - hot water (12 h); 7 - hot water (24 h); 8 - conc. sulphuric acid (8 min); 9 - conc. sulphuric acid (16 min); 10 - conc. sulphuric acid (32 min); 11 - xylene (8 min); 12 - xylene (16 min); 13 - xylene (32 min).

micropylar end was the most effective pretreatment (97% germination). Seeds soaked in concentrated sulphuric acid for 32 min germinated rapidly (to 83%). Seeds soaked in concentrated sulphuric acid for 16 min germinated slowly, but persistently, during the test period, to reach 73% germination by day 28 (Figure 8, Table 8 and Appendix III). Some seeds in the other pretreatments began germination on day 12 and germination continued slowly until the experiment was terminated. The three hot-water pretreatments, soaking in concentrated sulphuric acid (8 min) and in xylene (8 min) had a positive effect on some of the seeds, although the number of seeds that germinated was low and the rate of germination was slow. The other five pretreatments were not effective.

A small proportion of the seeds in the various pretreatments germinated abnormally (Table 9). Abnormal germination (the radicle coiled or showing negative geotropism, or the embryo split and the cotyledons swelled outwards) was associated mostly with soaking in concentrated sulphuric acid for 32 min, and to a lesser extent with soaking in xylene for 8 min, in sulphuric acid for 8 and 16 min and in hot water for 12 and 6 h (Table 9).

The cutting test confirmed that most of the seeds would still have germinated given enough time. There were very few dead seeds, except where concentrated sulphuric acid was used the percentage of dead seeds increased (Table

Table 8. Scott-Knott mean-separation test for Trachylobium verrucosum following analysis of variance of germination results.

Pretreatments	N	Mean[a] (%)	
1 Control	4	1.50	F
2 Nicking	4	97.2	A
3 Abrading (dry)	4	5.25	F
4 Abrading (wet)	4	6.00	F
5 Hot water (6 h)	4	24.00	D
6 Hot water (12 h)	4	17.25	E
7 Hot water (24 h)	4	24.25	D
8 Conc. sulphuric acid (8 min)	4	15.50	E
9 Conc. sulphuric acid (16 min)	4	72.75	C
10 Conc. sulphuric acid (32 min)	4	82.75	B
11 Xylene (8 min)	4	14.50	E
12 Xylene (16 min)	4	4.75	F
13 Xylene (32 min)	4	5.00	F

[a] Means with the same letter are not significantly different at the 0.05% level.

Table 9. Mean numbers of germinated and ungerminated seeds of different category of T. verrucosum per pretreatment after the 28-day germination test.

Pretreatments	Germination %(X)	Abnormal germination %(Y)	% of seeds in germination test: Fresh (Z)	X+Y+Z	Dead	Empty
1. Control	1.50	0.00	97.50	99.00	1.00	0.00
2. Nicking	97.25	0.25	0.00	97.50	2.50	0.00
3. Abrading (dry)	5.25	0.00	94.50	99.75	0.25	0.00
4. Abrading (wet)	6.00	0.25	93.75	100.00	0.00	0.00
5. Hot water (6 h)	24.00	0.50	75.00	99.50	0.50	0.00
6. Hot water (12 h)	17.25	1.25	81.25	99.75	0.25	0.00
7. Hot water (24 h)	24.25	0.00	73.50	97.75	2.25	0.00
8. Conc. sulphuric acid (8 min)	15.50	0.50	82.75	98.75	1.25	0.00
9. Conc. sulphuric acid (16 min)	72.75	1.50	22.25	96.50	3.50	0.00
10. Conc. sulphuric acid (32 min)	82.75	6.00	3.00	91.75	8.25	0.00
11. Xylene (8 min)	14.50	2.25	81.75	98.50	1.50	0.00
12. Xylene (16 min)	4.75	0.00	95.00	99.75	0.25	0.00
13. Xylene (32 min)	5.00	0.00	94.75	99.75	0.25	0.00

9). A few seeds had fungal infection. The cutting test results corresponded with the germination test results (Figure 8 and Table 9). The three pretreatments that were effective had few fresh seeds remaining compared to the other pretreatments.

The X-ray images of non-pretreated seeds showed that about 0.3% of the seeds had insect damage on the cotyledons. Images of X-rayed pretreated seeds showed that there was no apparent damage caused by the pretreatments. The X-ray results corresponded with the cutting test and the germination results, although the samples were different.

DISCUSSION

BIOLOGICAL

The description of flowering, pollination, and fruit formation and development in this study is not detailed because of the way in which the data were collected by workers in the respective forests. The data from the Kibwezi Forest on A. xanthophloea were more consistent, although not as detailed as planned, compared to the data from the Arabuko-Sokoke Forest, which were recorded less often than they should have been and with little detail. The information from both stations on floral formation, pollination and fruit formation was general and not quantified. The two forest workers who recorded these data had other duties to perform, and might not have had as much time as required for this study.

Despite these drawbacks, the biological study provided information on seasonal organization of flower, fruit and seed formation. Flowering of A. xanthophloea, B. spiciformis and T. verrucosum occurred in relatively dry periods, and fruiting occurred in rainy periods in this study. Frankie et al. (1974a), Janzen (1978), Bowen and Eusebio (1982), and Lieberman (1982) mentioned that the time of flowering of many tropical species appears to be

correlated with prevailing climatic conditions. In Kenya, the major climatic conditions are wet and dry seasons. Acacia xanthophloea flowered twice in a year. This corresponded with two relatively dry seasons at the Kibwezi Forest. Brachystegia spiciformis and T. verrucosum flowered once a year, corresponding with the one relatively dry season per year at the Arabuko-Sokoke Forest.

Bees, butterflies and birds were frequently observed on and around the flowers of all three species and were judged to be agents of pollination. In the case of B. spiciformis, where many flowers occurred in the upper crowns of dominant trees, wind was also judged to be effective in pollination. Doran et al. (1983) stated that insects, especially bees and butterflies, are the major pollinators of Acacia species. Acacia species, including A. xanthophloea, are known as honey producers, which supports the role of bees in pollination. Along with the correspondence of flowering (pollination) with relatively dry periods, flowering might also be related to activity periods for pollination agents.

Heavy rainfall during flowering led to flower fall. This could result from mechanical pressure of raindrops on the flowers, or from abortion of unpollinated flowers. Rain would reduce the activity of insects and hence the amount of pollination. Palgrave (1977) and Doran et al. (1983) found, for Acacia species, that despite the number of flowers produced, there were few pods per inflorescence. They did not

relate this to success of pollination nor to rain falling during the pollination period, but the limited observations of the current study suggest that such relationships may exist.

The fruits of all three species formed and developed during relatively wet periods and then ripened and dried during relatively dry periods. The young fruits were green. With advancing maturity, they turned brown. Those of A. xanthophloea became fibrous and those of B. spiciformis became woody, whereas those of T. verrucosum remained relatively soft (presumably unlignified). These observations corresponded with general information given by Dale and Greenway (1961), Palgrave (1977), and Watson (1980).

The seed-dispersal mechanisms of A. xanthophloea and T. verrucosum are not specialized; the fruits simply drop, after ripening, near the parent tree. In contrast, B. spiciformis has a highly specialized dispersal mechanism. When its fruits dry they split open explosively and the seeds are ejected from the parent tree. These differing mechanisms dictate that means of collecting seeds must be adapted to the characteristics of the species concerned.

In each species, baboons, and on some occasions other animals, were observed feeding on the developing fruits. Such activity will have more effect in seasons of relatively low fruit set. In such seasons, seed-collection operations may be severely hampered. This suggests that seeds for re-

forestation projects should be collected only when the trees carry fruits abundantly. This would also result in lesser proportional insect damage to seeds (Palmer and Pitman, 1973; Doran et al., 1983).

Janzen (1978), Bowen and Eusebio (1982), Doran et al. (1983), and Edwards (1984) have each stated that detailed knowledge of the reproductive cycle of a given tree species, and of the interaction of that species with other tree species, with pollination agents, and with climatic factors that influence the tree's response, is a prerequisite for better seed production and handling. This study has provided some pertinent information for A. xanthophloea, B. spiciformis and T. verrucosum in Kenya. Additional, and more detailed information is required, however, to improve seed production, and collection and handling of fruits of the three tree species.

SEED PRETREATMENT AND GERMINATION TESTS

Some of the pretreatments of A. xanthophloea and T. verrucosum seeds were effective and led to different responses but pretreatments of B. spiciformis seeds (except nicking) were not effective in comparison with the control. The seeds of T. verrucosum that germinated took a longer time for the radicle to extend to the test-criterion length compared to the other two species. Seeds of A. xanthophloea and T. verrucosum germinated best after nicking the seeds at the micropylar end. This confirmed that A. xanthophloea and

T. verrucosum seeds have impermeable seed coats, which restrict water imbibition, and hence germination. For B. spiciformis the control had the best results, but nicking the seeds at the micropylar end had similar results. This suggests that there was no physical dormancy in seeds of this species. Other studies conducted on leguminous seeds with hard seed coats suggest that manual scarification, such as nicking the seed coat at the micropylar end, promotes rapid germination of all viable seeds by permitting the uptake of water. The percentage germination following the nicking may be taken as a close approximation to the potential germination of a seed sample and is a useful figure for comparison when assessing the effectiveness of other pretreatments (Clemens et al., 1977; Tran and Cavanagh, 1979; Cavanagh, 1980; and Doran et al., 1983).

The three hot-water pretreatments were effective on the seeds of A. xanthophloea. The 6 h soaking period elicited a slower response, but had the best percentage germination compared to the other two hot-water pretreatments. The hot-water pretreatments were not as effective with seeds of B. spiciformis and T. verrucosum. This emphasizes the positive effect of heat on the A. xanthophloea seeds, which supports other studies on Acacia species in which hot water or burning of the seed coat have been effective (Villiers, 1972; Doran et al., 1983). Soaking seeds in hot water for different durations has been used in many studies on seeds with hard seed coats. For example,

Cavanagh (1980), Doran et al. (1983), and Tran and Cavanagh (1984), found that soaking seeds in hot water (boiling or nearly boiling) for varying lengths of time, depending on the species, led to successful, though sometimes, erratic results.

Pretreatment for 32 min in concentrated sulphuric acid produced a high response in seeds of A. xanthophloea and T. verrucosum. These results support those reported by Rolston (1978), Doran et al. (1983), and Bebawi and Mohamed (1985) who stated that sulphuric acid improved permeability of leguminous seeds. The other two sulphuric-acid pretreatments were less effective on the A. xanthophloea and T. verrucosum seeds. This suggests that pretreatment for at least 32 min in concentrated sulphuric acid is required. In contrast, pretreatment of B. spiciformis seeds with sulphuric acid was not effective and was probably harmful. Thus, the effectiveness of pretreatment in sulphuric acid, and duration of pretreatment when effective, varies with species.

In general, no other pretreatments were effective. The lack of effect of abrading the seed-coat surfaces suggests that a longer period of abrasion, or abrasion with a more rasping material, would be required for A. xanthophloea and T. verrucosum seeds.

Abnormal germination occurred occasionally. It is possible that it could have resulted from embryo damage during seed pretreatments. It was more frequent for all three species, after the hot-water pretreatments and long

exposure to sulphuric acid. Duran and Tortosa (1985) stated that, if the seeds are exposed to concentrated sulphuric acid for a duration whereby the seed coat is dissolved, the embryo is bound to be damaged and this could lead to abnormality or death.

There were different apparent causes for the inability of some of the seeds to germinate. These included insect damage, fungal and/or bacterial infection, empty 'seeds', incompletely developed embryos, or simply, dormancy. There were very few dead ungerminated seeds of T. verrucosum. In contrast, 10% of the seeds of A. xanthophloea and 52% of the seeds of B. spiciformis were dead. There was a relatively high incidence of dead seeds after the sulphuric-acid pretreatments. Hot-water pretreatments also led to a relatively high number of dead seeds of A. xanthophloea and B. spiciformis. Thus, although these pretreatments can be effective promoters of germination, they can also reduce the germination of a seed-lot. The B. spiciformis seeds had a large proportion of the seeds with fungal and bacterial infection compared to the other two species.

X-ray images of pretreated and non-pretreated seeds showed that, as a whole, most of the T. verrucosum seeds were fully developed. Only a small proportion of the seeds had insect damage. In contrast, 10% of A. xanthophloea seeds had insect damage, and 40% of B. spiciformis seeds had necrosis where the epicotyl was connected to the cotyledons. These values corresponded with the germination

results. Insects are known to be a major cause of seed damage and loss of viability (Kamra, 1976). This was evident in the seeds of A. xanthophloea, but to a lesser extent in seeds of B. spiciformis and T. verrucosum. Brachystegia spiciformis had a high proportion of the seeds with diseased embryos. This could have been due to improper handling of the seeds during collection, extraction, storage or transportation, but the possibility of the presence of a seed pathogen in the developing fruits should be investigated.

The results from the germination and cutting tests, and the X-ray images, corresponded, although the seed samples used for X-raying were different, but from the same seedlot. X-raying would be an effective preliminary test in seed testing procedures in Kenya.

This study has provided information on response of seeds of A. xanthophloea, B. spiciformis and T. verrucosum to different pretreatments and different durations of pretreatments. The A. xanthophloea and T. verrucosum seeds had physical dormancy. Therefore, mechanical abrasion ought to give satisfactory results. Further investigation is required to find an optimum mechanical-abrasion condition. This is important because, compared to nicking the seeds or soaking the seeds in concentrated sulphuric acid, mechanical abrasion is not expensive or dangerous to the forest workmen. Burning the seeds of A. xanthophloea for different durations ought also to be tested. This species grows in

areas where there are frequent fires and the seeds may be conditioned to respond to a certain level of seed-coat removal by burning, by germinating rapidly. Biological pretreatments of the seeds ought also to be investigated. Information should be acquired on the effect of biotic factors (for example, seeds passing through digestive systems of animals) on the seeds of A. xanthophloea and T. verrucosum. This study has shown the seeds of B. spiciformis to be different in several respects from those of the other two species investigated. More information is required on the processes of seed production and seed handling of B. spiciformis.

LITERATURE CITED

Anonymous. 1970. Tumblex Finishing Norton Company. Abrasive Materials Division. Worcester, MA, 76 pp.

Bebawi, F.F. and S.M. Mohamed. 1985. The pretreatment of seeds of six Sudanese acacias to improve their germination response. Seed Sci. & Technol. 13: 111-119.

Bonner, F.T., B.F. McLemore and J.P. Barnett. 1974. Presowing treatment of seed to speed germination. Pp. 126-135 In Schopmeyer, C. S., compiler, Seeds of woody plants in the United States. U.S. For. Serv., Agric. Handbk. No. 450, 883 pp.

Bowen, M.R. and T.V. Eusebio, 1982. Seed handling practices: Four fast-growing hardwoods for humid tropical plantations in the eighties. Malay. For. 45: 534-547.

Cavanagh, A.K. 1980. A review of some aspects of the germination of acacias. Proc. Roy. Soc. Vict., 91: 161-180.

Chapman, A.G. 1936. Scarification of black locust seed to increase and hasten germination. J. For. 34: 66-74.

Clemens, J., P.G. Jones and N.H. Gilbert. 1977. Effect of seed treatments on germination in Acacia. Aust. J. Bot. 25: 269-276.

Dale, I.R. and P.J. Greenway. 1961. Kenya trees and shrubs. London: Buchanan's Kenya Estates Ltd. in Association with Hatchards, 654 pp.

Doran, J.C., J.W. Turnbull, D.J. Boland and B.V. Gunn. 1983. Handbook on seeds of dry-zone acacias. A guide for collecting, extracting, cleaning, and storing the seed and for treatment to promote germination of dry-zone acacias. Rome : FAO, 92 pp.

Duran, J.M. and M.E. Tortosa. 1985. The effect of mechanical and chemical scarification on germination of charlock (Sinapis arvensis L.) seeds. Seed Sci. & Technol. 13: 155-163.

Edwards, D.G.W. 1984. The role of seeds and seed research in combating the exploitation of the world's forest resources. Seed Sci. & Technol. 12: 757-765.

Frankie, G.W., H.G. Baker and P.A. Opler. 1974a. Comparative phenological studies of trees in tropical wet and dry forests in the lowlands of Costa Rica. J. Ecol. 62: 881-919.

Frankie, G.W., H.G. Baker and P.A. Opler. 1974b. Tropical plant phenology: Applications for studies in community ecology. Pp. 287-296 In Lieth, H., ed. Phenology and seasonality modeling. New York, Heidelberg, Berlin: Springer-Verlag, 444 pp.

Gunn, C.R. 1981a. Seeds of Leguminosae. Pp. 913-925 In Polhill, R.M. and P.H. Raven, eds. Advances in legume systematics. Part 1 and 2. Proc. Int. Legume Conf., 24-29 July, 1979, Kew, England, 1049 pp.

Gunn, C.R. 1981b. Seed topography in the Fabaceae. Seed Sci. & Technol. 9: 737-757.

Hasan, S.M. 1973. Scope of research on problems of tree seed in Bangladesh. Proc. IUFRO Working Party on Seed Problems. Int. Symp. on Seed Processing. Bergen, Norway: Vol. II, Pap. No. 14, 8 pp.

Heywood, V.H. 1979. Flowering plants of the world. Oxford, London, Melbourne: Oxford University Press, 335 pp.

Hutchinson, J. 1973. The families of flowering plants. 3rd edit., Oxford: Clarendon Press, 510 pp.

Jann, R.C. and R.D. Amen. 1977. What is germination? Pp. 7-28 In Khan, A.A., ed. The physiology and biochemistry of seed dormancy and germination. Amsterdam, New York, Oxford: North-Holland Publishing Company, 447 pp.

Janzen, D.H. 1978. Seeding patterns of tropical trees. Pp. 83-128 In Tomlinson, P.B. and M.H. Zimmermann, eds. Tropical trees as living systems. Cambridge, London, New York, Melbourne: Cambridge University Press, 675 pp.

Kahre, L. 1983. Germination Sensu lato. Pp. 35-83 In Thompson, J.R., ed. Advances in research and technology of seeds, Part 8. Int. Seed Testing Assoc. Pudoc-Wageningen, The Netherlands, 126 pp.

Kamra, S.K. 1976. Use of X-ray radiography for studying seed quality in tropical forestry. Stud. For. Suecica, No. 131, 34 pp.

Khan, A.A. 1977. Seed dormancy: changing concepts and theories. Pp 29-50 In Khan, A.A., ed. The physiology

and biochemistry of seed dormancy and germination. Amsterdam, New York, Oxford: North-Holland Publishing Company, 447 pp.

Kimariyo, P.E. 1973. Handling hardwood seeds in Tanzania. Proc. IUFRO Working Party on Seed Problems. Int. Symp. on Seed Processing. Bergen, Norway: Vol. II, Pap. No. 16, 7 pp.

Krugman, S.L., W.I. Stein and D.M. Schmitt. 1974. Seed biology. Pp. 5-40 In Schopmeyer, C.S., Compiler, Seeds of woody plants in the United States. U.S. For. Serv., Agric. Handbk. No. 450, 883 pp.

Lieberman, D. 1982. Seasonality and phenology in a dry tropical forest in Ghana. J. Ecol. 70: 791-806.

Nikolaeva, M.G. 1977. Factors controlling the seed dormancy pattern. Pp. 51-74 In Khan, A.A., ed. The physiology and biochemistry of seed dormancy and germination. Amsterdam, New York, Oxford: North-Holland Publishing Company, 447 pp.

Palgrave, K.C. 1977. Trees of Southern Africa. Cape Town: C. Struik Publishers, 959 pp.

Palmer, E. and N. Pitman. 1973. Trees of South Africa. Vol. I & II. Covering all known indigenous species in the Republic of S. Africa, S.W. Africa, Botswana, Lesotho and Swaziland. Cape Town: A.A. Balkema, 1497 pp.

Polhill, R.M., P.M. Raven and C.H. Stirton. 1981. Evolution and systematics of the Leguminosae. Pp. 1-26 In Polhill, R.M. and P.H. Raven, eds. Advances in legume systematics. Part 1 and 2, Proc. Int. Legume Conf., 24-29 July, 1979, Kew, England, 1049 pp.

Riggio-Bevilacqua, L., G. Roti-Michelozzi and G. Serrato-Valenti. 1985. Barriers to water penetration in Cercis siliquastrum seeds. Seed Sci. & Technol. 13: 175-182.

Rolston, M.P. 1978. Water impermeable seed dormancy. Bot. Rev. 44: 365-396.

Scott, A.J. and M. Knott. 1974. A cluster analysis method for grouping means in the analysis of variance. J. Biometrics, 30: 507-512.

Shehaghilo, I.M. 1980. An outlook of seed storage problems of some useful indigenous trees in Tanzania. Pp. 13-16 In Wang, B.S.P. and J.A. Pitel, compilers and eds. Proc. IUFRO Working Party on Seed Problems.

Int. Symp. on Forest Tree Seed Storage. Petawawa, Ont., Canada, 23-27 September, 1980, 243 pp.

Simak, M. 1980. X-radiography in research and testing of forest tree seeds. Sveriges Lantbruksuniv., Inst. F. Skogsskotsel, Rapp. 3, 34 pp.

Southgate, B.J. 1983. Handbook on seed insects of Acacia species. Rome: FAO, 30 pp.

Tran, V.N. and A.K. Cavanagh. 1979. Effects of microwave energy on Acacia longifolia. J. Microwave Power, 14: 21-27.

Tran, V.N. and A.K. Cavanagh. 1984. Structural aspects of dormancy. Pp. 1-44 In Murry, D.R., ed. Seed physiology, Vol. 2. North Ryde, New South Wales, Australia: Academy Press, 267 pp.

Villiers, T.A. 1972. Seeds dormancy. Pp. 219-281 In Kozlowski, T.T., ed. Seed biology, Vol 2. New York, London: Academic Press, 447 pp.

Wang, B.S.P. 1975. Tree and shrub seed. Pp. 34-43 In Bradnock, W.T., ed. Advances in research and technology of seeds, Part 1. Int. Seed Testing Assoc. Pudoc-Wageningen, The Netherlands, 84 pp.

Wang, B.S.P. and F. Ackerman. 1983. A new germination box for tree seed testing. Can. For. Serv. Inform. Rep. P1-X-27, 15 pp.

Watson, L. 1980. Caesalpinioideae of the world. General descriptions and keys. Micro-Fiche. In Polhill, R.M. and P.H. Raven, eds. Advances in legume systematics. Part 1 and 2. Proc. Int. Legume Conf., 24-29 July, 1979, Kew, England, 1049 pp.

Werker, E. 1980/81. Review. Seed dormancy as explained by the anatomy of embryo envelopes. Israel. J. Bot. 29: 22-44.

Zar, J.H. 1974. Biostatistical analysis. Englewood Cliffs, NJ: Prentice-Hall, Inc., 620 pp.

APPENDICES

APPENDIX I

DUNCAN'S MULTIPLE-RANGE TEST FOR A. XANTHOPHLOEA FOLLOWING ANALYSIS OF VARIANCE OF GERMINATION RESULTS.

Pretreatments	N	Mean[a] (%)	
1 Control	4	4.50	E
2 Nicking	4	76.75	A
3 Abrading (dry)	4	2.75	E
4 Abrading (wet)	4	2.25	E
5 Hot water (6 h)	4	62.25	B
6 Hot water (12 h)	4	53.50	C
7 Hot water (24 h)	4	58.00	B C
8 Conc. sulphuric acid (8 min)	4	2.75	E
9 Conc. sulphuric acid (16 min)	4	10.00	D
10 Conc. sulphuric acid (32 min)	4	58.25	B C
11 Xylene (8 min)	4	2.50	E
12 Xylene (16 min)	4	2.50	E
13 Xylene (32 min)	4	1.50	E

[a] Means followed by the same letter are not significantly different at the 0.05% level.

APPENDIX II

DUNCAN'S MULTIPLE-RANGE TEST FOR B. SPICIFORMIS FOLLOWING ANALYSIS OF VARIANCE OF GERMINATION RESULTS.

Pretreatments	N	Mean[a] (%)	
1 Control	4	45.63	A
2 Nicking	4	45.00	B A
3 Abrading (dry)	4	37.19	B D C
4 Abrading (wet)	4	3.75	E
5 Hot water (6 h)	4	5.94	E
6 Hot water (12 h)	4	32.50	D C
7 Hot water (24 h)	4	4.69	E
8 Conc. sulphuric acid (8 min)	4	0.63	E
9 Conc. sulphuric acid (16 min)	4	1.56	E
10 Conc. sulphuric acid (32 min)	4	1.88	E
11 Xylene (8 min)	4	39.69	B A C
12 Xylene (16 min)	4	42.81	B A
13 Xylene (32 min)	4	30.31	D

[a] Means with the same letter are not significantly different at the 0.05% level.

APPENDIX III

DUNCAN'S MULTIPLE-RANGE TEST FOR T. VERRUCOSUM FOLLOWING ANALYSIS OF VARIANCE OF GERMINATION RESULTS.

Pretreatments	N	Mean[a] (%)	
1 Control	4	1.50	F
2 Nicking	4	97.25	A
3 Abrading (dry)	4	5.25	F
4 Abrading (wet)	4	6.00	F
5 Hot water (6 h)	4	24.00	D
6 Hot water (12 h)	4	17.25	E D
7 Hot water (24 h)	4	24.25	D
8 Conc. sulphuric acid (8 min)	4	15.50	E
9 Conc. sulphuric acid (16 min)	4	72.75	C
10 Conc. sulphuric acid (32 min)	4	82.75	B
11 Xylene (8 min)	4	14.50	E
12 Xylene (16 min)	4	4.75	F
13 Xylene (32 min)	4	5.00	F

[a] Means with the same letter are not significantly different at the 0.05% level

VITA

Canidate's full name:	Esther Murugi Kariuki
Place of Birth:	Nanyuki, Kenya April 27, 1958
Permanent address:	Kenya Agricultural Research Institute, Forestry Research Department, P.O. Box 74, Kikuyu, Kenya.
Schools attended:	Tumutumu Girls Secondary School, Karatina, 1972 to 1975
	Highlands Girls High School, Eldoret, 1976 to 1977
Universities attended:	University of Nairobi, Nairobi, Kenya, 1978 to 1981. B. Sc. F.
	University of New Brunswick, Fredericton, N.B., Canada 1983-86. M.F. (Candidate)