UNIVERSITI PUTRA MALAYSIA

REPRODUCTIVE AND SEED GERMINATION CHARACTERISTICS OF WOODY BORRERIA (DIODIA OCIMIFOLIA) IN A PLANTATION ECOSYSTEM

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REPRODUCTIVE AND SEED GERMINATION CHARACTERISTICS OF WOODY BORRERIA (*DIODIA OCIMIFOLIA*) IN A PLANTATION ECOSYSTEM

By

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Woody borreria belongs to the subfamily *Rubioideae* in the family *Rubiaceae*. It is a brush weed 1 to 1.5 m high and reproduces through seeds.

A survey confirmed the presence of woody borreria in every state of Malaysia except Perlis, Kelantan and Penang Island where there were no respondents. In 1993, woody borreria infestations accounted for 4 to 18% of the areas planted with oil palm or rubber. Woody borreria adapts well to shade. The wet season appears to favour the emergence of its seedlings.

The objective of this thesis was to study the basic characteristics of woody borreria in order to develop effective long-term weed management strategies. Eight experiments were conducted.

The study on phenology and reproductive characteristics showed that woody borreria emerged at 7 days after sowing (DAS), produced flowers at 51 days after sowing, fruits at 7 to 14 days after flowering and capsules at 14

to 21 days after fruiting. At 226 DAS, plants grown in the open and under reduced light (36% light transmission) produced 15,000 seeds per plant, while 9% light transmission, 6,500 seeds per plant and; 1% light transmission, less than 10 seeds.

Viability of buried seeds in a oil palm ecosystem was studied by burying seeds wrapped in nylon mesh bags. The number of viable seeds recovered from under dense leguminous cover crops was less than in soils under sparse natural ground vegetation. Deeper burial depths favoured the persistence of seeds. Laboratory experiments showed that leachable water soluble inhibitors from the seed nor the presence of the mature weed did not inhibit germination or emergence. However, dormancy was broken by cutting a small portion of the seed coat to expose the cotyledon. Reducing light intensity to 75 μ moles/m^2/sec did not affect woody borreria germination. Seeds placed in the dark did not germinate. In another study, seeds at burial depths of 4 cm or more did not emerge.

Cohen's model was modified to simulate the management of woody borreria. Level of weed control was the most important factor in reducing woody borreria seed bank. The model predicts the need for 100% level of weed control to eradicate the seed bank. The results indicates the need for re-vegetation of exposed areas following 100% weed control to reduce woody borreria emergence. In addition, cultivation is recommended to reduce seed bank at new plantings.

Abstrak thesis yang dikemukan kepada Senat Universiti Putra Malaysia bagi memenuhi keperluan untuk Ijazah Master Sains Pertanian

CIRI-CIRI PEMBIAKAN DAN PERCAMBAHAN RUMPAI WOODY BORRERIA (*DIODIA OCIMIFOLIA*) DIDALAM EKOSISTEM TANAMAN PERLADANGAN

Oleh

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Woody borreria adalah rumpai jenis pokok renek sub-keluarga Rubioideae dalam keluarga Rubiaceae. Ketinggiannya adalah 1.5 m. Ia membiak melalui biji.

Survei telah mengesahkan kehadiran rumpai di seluruh Malaysia kecuali Perlis, Kelantan dan Pulau Pinang kerana tiada jawapan daripada responden di negeri-negeri tersebut. Pada tahun 1993, woody borreria telah meliputi 3 - 18% daripada kawasan-kawasan yang ditanam kelapa sawit dan getah. Woody borreria boleh sesuaikan diri dan membiak di tempat teduh. Survei juga mendapati musim basah sesuai untuk percambahannya.

Tujuan tesis ini adalah mengkaji beberapa ciri woody borreria supaya pengawalan jangka panjang dapat dibentuk. Lapan kajian telah dilakukan untuk tujuan tersebut.

Keputusan kajian mengenai fenologi dan ciri-ciri pembiakan woody borreria ialah ia bercambah dan muncul dari tanah tujuh hari selepas tanam, berbunga dalam masa 51 hari lepas tanam, keluar buah selepas 7 ke 14 hari selepas berbunga and buah masak 14-21 hari selepas berbuah. Pokok-pokok yang menerima cahaya penuh dan yang menerima 36% cahaya mengeluarkan 15,000 biji 226 hari lepas tanam. Pokok-pokok menerima 9% cahaya mengeluarkan 6,500 biji dan yang menerima 1% cahaya hanya mengeluarkan kurang dari 10 biji.

Kajian menanam biji di beberapa kedalaman tanah menunjukan biji-biji woody borreria lebih cepat hilang kebernasan mereka jika ditanam di tempat yang ditanam kekacang penutup bumi berbanding dengan ditempat yang ada tumbuh-tumbuhan semulajadi. Kebernasan biji juga lebih baik jikalau di tanam pada kedalaman yang lebih. Kajian juga menunjukkan percambahan tidak dihalang oleh kehadiran pokok woody borreria matang atau bahan larut air dari biji sendiri, jika ada. Walau bagaimanapun percambahan boleh di pertingkatkan dengan memotong sebahagian biji. Mengurangkan cahaya ke 75 μ moles/m^2/sec tidak menjejaskan percambahan. Tetapi biji yang di tanam di tempat gelap tidak cambah. Dalam satu kajian lain, woody borreria tidak muncul dari kedalam 4 cm atau lebih.

Model Cohen boleh meramal pengeluaran biji dan bank biji woody borreria. Tahap kawalan rumpai adalah faktor yang paling berkesan mengawal bank biji. Model tersebut meramalkan tahap kawalan 100%

diperlukan untuk mengawal bank biji sepenuhnya. Cara menanam semula dengan pokok-pokok bukan rumpai dicadangkan untuk menutup tempat-tempat lapang akibat kawalan 100%. Pembajakan juga boleh mengurangkan bank biji.

CHAPTER I

INTRODUCTION

Plantations in Malaysia mainly comprise of oil palm and rubber. They are both perennial tree crops with an economic life cycle of 25-30 years. Their life cycle can be divided into two phases; the immature phase which is three years for oil palm and five years for rubber, and the mature phase which extends to the end of the economic life span. The soil is cultivated if at all at planting and is largely left undisturbed thereafter. This form of land management with minimal cultivation encourages perennial weeds.

During the immature phase of plantation crops, weed control operations are carried out up to 15-20 times during the 3 year immature period for oil palm and 19-25 times during the 5 year period for rubber (Chee *et al.*, 1990). It is therefore not surprising that a high proportion of the annual budget is spent on weeding to minimize weed competition in these crops.

Chee *et al*. (1990) reported that the common weed species reduce total dry weight of rubber seedlings by 51% to 77% and reduce oil palm yields by 13% to 21%. Ten percent yield in oil palm reduction translates to 2.5 to 3 ton fresh fruit bunches per hectare annually.

Weeds in tropical plantations grow luxuriously aided by the abundant sunshine and ample supply of moisture. Growing season is continuous through the year. The fertilizer given to the crops is inevitably shared with the weeds as well. Weed growth is rapid and dense; and need to be controlled.

One of such weed is woody borreria. It appears to be an extremely troublesome weed to oil palm growers and attracted much attention towards its control.

Although integrated weed management (IWM, which was coined in the 1970's) is gaining popularity in many areas of weed science, emphasis for woody borreria control appears to be solely on chemical methods (Purusotman *et al*. 1993; Sabudin and Abu Bakar, 1993 and Teng *et al*. 1993). Development of effective long-term weed management strategies requires knowledge of soil seedbank dynamics, weed emergence patterns, phenology and reproductive behavior, weed-crop interference effects, and available control methods (Thill *et al*. 1991). Such information would also be useful in explaining the weediness of woody borreria in certain localities. A literature search indicated that information on these aspects is either lacking or not available.

This study was therefore initiated to investigate its reproductive and germination characteristics in order to manage or control woody borreria more effectively.

CHAPTER II

LITERATURE REVIEW

Nomenclature

The name woody borreria was given to the weed because of its close resemblance to *Borreria laevicaulis* (Ridley) (Yap and Ng, 1986). Matured plants have woody stems, hence the description "woody".

It is also known as hedyotis, short for *Hedyotis verticillata.* How the weed was identified as *Hedyotis verticilla* was rather obscure. Detailed investigation concluded that woody borreria was wrongly referred to as *H. verticillata*; and that woody borreria is *Diodia ocimifolia* (Willd, ex R. & S.) Bremek (Rajan *et al.* 1994). Yap and Ng (1986), Purusotman *et al*. (1993), and Barnes and Chan (1990) were most probably referring to *Diodia ocimifolia* when describing woody borreria since *D. ocimifolia* was of common occurrence in areas referred to in their surveys. Further correspondences with growers and weed scientists also confirmed their referrence to *D. ocimifolia.*

Woody borreria belongs to the subfamily *Rubioideae*, family *Rubiaceae* (Keng, 1969). Members of *Rubioideae* are characterised by solitary or rarely two ovules in each ovary locule.

Linnaeus named the genus *Diodia*, probably reminded by a European plant often found growing by the wayside (Spencer, 1974). The name diodia was derived from the Greek word diod, or diodos or diodeia meaning a passage through, or a thorough fare (Jaeger, 1955). The species name *ocimifolia* probably came from the Latin word ocim or ocimum (Õkimon in Greek) which refers to the aromatic plant, basil (Jaeger, 1955). It could also have come from the word ocym which is likely derived from the word ozõ which means to smell. Indeed, woody borreria has leaves that have a distinctive aroma.

Taxonomic Description

Woody borreria grows to 1 to 1.5 m high. Under natural conditions the plant grows very close to one another and due to competition, it appears slender with few branches. In open and spacious conditions, it produces numerous branches. Stems are woody and wiry. Stems obtusely quadrangular, the angles with retrorse, fine, usually short hairs, leaves oblong-lanceolate, with 5-8 pairs of nerves, scabrous by small bristles near margin only, otherwise finely puberulous or glabrous, 3-7½ cm by ¾-2½ cm; stipular sheath glabrous outside.

Flat side of cocci membranous, at base with an opening; seed on flat side with a very narrow linear groove; ovary rather densely puberulous, much longer than the ⅓-½ mm long calyx-teeth; glomeruli 6-many-flowered;

calyx-lobes 4, slightly unequal, ovate-triangular; corolla-tube 1¾-3 mm, glabrous outside, inside with a ring of hairs at base; throat glabrous; lobes oblong, pubescent, 2-3 mm; filaments 1 mm, in vivo 2½ mm; style when dry ca. 2½ mm, very finely pubescent; fruit 3-4 mm, short-hairy, distinctly pedicelled; seeds distinctly transversely striped, narrow (Backer and Bakhuizen van den Brink, 1965).

Differentiation from Closely Related Species

In the natural enviroment, woody borreria has two close relatives namely *Hedyotis* sp. and *Borreria laevicaulis* with which it closely resembles. *Diodia ocimifolia* can be differentiated from *Hedyotis* sp. by inspecting the capsules. *Diodia ocimifolia* capsules have two seeds while in *Hedyotis* sp. there are many seeds. *Diodia ocimifolia* is different from *Borreria* sp. such as *Borreria laevicaulis* in the flower heads and fruit. In *Diodia* sp., the flower heads are not stalked or indistinctly so, and the two halves of the fruit do not open (Henderson, 1954).

There is a slight difference between *D. ocimifolia* and *D. sarmentosa*. In *O. ocimifolia*, the membrane on the flat side of cocci after the fruit has opened, has a opening while in *D. sarmentosa*, the membrane do not have a opening (Backer and Bakhuizen van den Brink, 1965).

Reproduction

Main mode of reproduction appears to be through seeds. On the average, there are 1,142 seeds on each plant (MAPPS, 1993). Teng *et al*. (1993) estimated the seed production of an adult plant to be 1,800 seeds.

Upon removal of surface vegetation, for example by herbicide treatment, seedlings quickly emerge and cover the ground 3 to 7 days later and soon reach 10 to 15 cm in height after six weeks (MAPPS, 1993). The weed re-establishes within four months after mature plants were removed (Purusotman *et al*. 1993). However, in practice, it is nearly impossible to find a uniform population. Ong and Teo (1990) report that two to three generations of the weed normally co-exist in the same field.

Branches resting on soil surfaces have been observed to root; but it is not known whether woody borreria reproduces by this method as well.

Nutrient Uptake and Immobilisation

The above ground dry matter for mature plants 1.16 m high was 6.94 t/ha, of which 86% composed of stems and 14% leaf tissues (Ong and Teo, 1990).

The leaf area of plant of the above dimension was estimated to be 2.6 x 10^4 m^2/ha. Such plants contains up to 60 kg N, 17 kg P_2O_5, 97 kg K_2O and 17 kg MgO per hectare (Table 1).

Table 1

Nutrient composition of *Diodia ocimifolia* (Ong and Teo, 1990).

Element	Leaf*	Stem*
N	2.05	0.67
P	0.13	0.10
K	1.36	1.14
Mg	0.40	0.11
Ca	1.40	0.11
B	32	12

*All nutrients expressed as percentage of dry matter except boron is in parts per million (ppm).

Distribution

Woody borreria was introduced from tropical America and could be found wild in Java Island (Backer and Bakhuizen van den Brink, 1965). However, there is no record of how and when the weed was introduced to Malaysia.

Henderson (1954) reported only *Diodia sarmentosa.* Burkill's (1966) silence on *Diodia* sp. bears testimony that this weed must have been very obscure or it had no known use in the 1960's.

Woody borreria was first reported as an increasingly noxious weed in oil palm and rubber plantations in Malaysia by Yap and Ng (1986). In their survey, woody borreria was found in 22% of the estates surveyed in Johore. Significant infestations were mostly found in central Johore between Paloh and Layang-Layang, around Sagil, between Skudai and Kota Tinggi, and north of Cha'ah. Their survey did not cover other states in Malaysia. It was

then believed that the weed was confined mostly to Johore. Subsequently, Purusotman *et al*. (1993) reported the presence of woody borreria in Melaka, Negeri Sembilan, Selangor and Perak.

Yap and Ng (1986) suggested that buffaloes, which were introduced to transport oil palm fruit bunches, and goats and cattle assisted the rapid spread of woody borreria through grazing and defaecation of undigested seeds.

Teng *et al*., (1993) reported the seed bearing capacity of woody borreria to be enormous. Its ability to thrive and produce seeds very well in both open and shaded conditions further aided its rapid spread in plantations. These characteristics are typical of a successful weed.

The plant was also observed to be moderately plastic; they are capable of producing many branches under low plant density and become very erect with few branches when over crowded. These characteristics and its ability to flower and seed readily indicate that woody borreria met most of the criteria set by Baker (1965) for weedy plants.

Natural Enemies

There are no natural enemies of *D. ocimifolia* reported. Ants were commonly found on the plants but damage to the plant is not known.

A closely related species, *D. virginiana*, however, has two natural enemies namely a parasitic nematode *Verutus volvingentis* (Cohn *et al*., 1984), and *Diodia vein chlorosis* virus (DVCV) (Larsen *et al*., 1991).

Control and Management

Chemical Control

Yap and Ng (1986) recommended Ustinex Special in mixture with Paraquat (2.25 kg + 1.40 L/ha); TRIBUTON 500 EC (3.50 L/ha); and DASATOX 325 mixed with Paraquat (5.60 kg + 1.40 L/ha) for control of woody borreria under natural shade for up to 150 days.

Metsulfuron-methyl, metsulfuron-methyl mixed with paraquat, metsulfuron-methyl with glyphosate, dicamba with glyphosate, fluroxypyr with glyphosate, and glufosinate-ammonium were also effective in controlling woody borreria (MAPPS, 1993).

Ong and Teo (1990) report that ASSAULT 250 A at 1.30 L/ha or 0.67 L/ha in two rounds was the most effective treatment, followed by TORDON 101 at 1.57 L/ha which give satisfactory weed control for 90 days under 65% shade in oil palm. ROUNDUP at 4 L/ha was also effective in immature cocoa. Due to the low leaf area of woody borreria, Ong and Teo (1990) recommended a higher spraying volume (450 L/ha) for treating sparse infestations of the weed and low spray volumes (65 L/ha by controlled droplet applicator or CDA only) for very dense weed.

Ong (1993) recommended follow-up herbicide treatments at three month intervals to control woody borreria seedlings, before the on-set of flowering.

Weed control may be more effective if herbicides are applied within the first 6 weeks of the wet season. Mark (1983) estimated that approximately 70% of dicotyledonous seedlings emerge during that time.

Integrated Weed Management

Chee *et al*. (1990) described management strategies in which weeds were categorised into three classes (Table 2). Class C weeds should be eradicated, while Class A weeds are encouraged. Class B weeds are only weeded depending on circumstances. Although Chee *et al*. (1990) did not specifically refer to woody borreria in their paper, the principles were implied for the management of all weeds in plantation including woody borreria. Woody borreria would fall under Class C together with noxious weeds such as *Asystasia intrusa* and *Mikania micrantha* which are to be controlled and eventually replaced by Class A weeds.

Table 2.

Classification of ground covers and shade trees in agricultural crops (Chee *et al*., 1990)

Crops	Weed Class		
	A*	B*	C*
Rubber	*Calopogonium caeruleum, C mucunoides, Centrosema pubescens, Desmodium ovalifolium, Mucuna cochinchinensis, Pueraria phaseoloides*	*Axonopus compressus, Nephrolepis biserrata Ottochloa nodosa, Paspalum conjugatum, Digitaria spp , Borreria latifolia*	*Asystasia gangetica, Chromoleana odorata, Imperata cylindrica, Mikania micrantha, Mimosa pudica, Stenochlaena palustris*
Oil palm	- as above -	- as above -	- as above -
Cocoa	*Glricidia maculata*	- as above -	- as above -
Durian	*C caeruluem, C mucunoides, C pubescens, P phaseoloides*	*A compressus, P conjugatum Digitari* spp , *Ageratum conyzoides*	*I cylindrica, Mimosa* spp , *Eleusine indica*
Papaya	-	*A compressus, P conjugatum,*	- as above -
Pineapple	-	-	*I cylindrica, A intrusa, Mimosa* spp , *Clidemia hirta, Pennisetum polystachion*

*A = plants to be encouraged
*B = plants useful but may require control
*C = plants have undesirable characteristics