ISSN:1511-3701

Pertanika Journal of

TROPICAL Agricultural Science

VOLUME 25 NO.1
MARCH 2002

A scientific journal published by Universiti Putra Malaysia Press

Pertanika Journal of Tropical Agricultural Science

About the Journal

Pertanika a leading agricultural journal in Malaysia began publication in 1978. After 15 years as a multidisciplinary journal, the revamped *Pertanika Journal of Tropical Agricultural Science* will now focus on tropical agricultural research. The journal will be current and regular, bringing the latest information related to plant and animal sicences, fisheries, food sciences and forestry to the attention of research and scientists. It will be published two times a year i.e. in March and September.

Aims and Scope

The journal will accept contributions from managers, researchers and scientists in the fields of biochemistry, ecology, genetics, physiology, pathology and management and production of plants and animals of economic importance. *Pertanika Journal of Tropical Agricultural Science* will consider for publication articles both in English and Bahasa Melayu. Articles must be original reports of research, not previously or simultaneously published in any other scientific or technical journal.

Submission of Manuscript

Three complete clear copies of the manuscript are to be submitted to

The Chief Editor
Pertanika Journal of Tropical Agricultural Science
Universiti Putra Malaysia
43400 UPM, Serdang, Selangor Darul Ehsan
MALAYSIA
Tel: 03-89468854 Fax: 03-89416172

Proofs and Offprints

Page proofs, illustration proofs and the copy-edited manuscript will be sent to the author. Proofs must be checked very carefully within the specified time as they will not be proofread by the Press editors.

Authors will receive 20 offprints of each article and a copy of the journal. Additional copies can be ordered from the Secretary of the Editorial Board.

Published by Universiti Putra Malaysia Press
ISSN No.: 1511-3701

Pertanika Journal of Tropical Agricultural Science

Volume 25 Number 1 (March) 2002

Contents

Pertanika J. Trop. Agric. Sci. 25(1): 1 - 9 (2002) ISSN: 1511-3701

Summer Mid-Day-Night Composition and Abundance of Zooplankton from Lake Ikeda, Japan

SHAHARUDIN ABDUL RAZAK[1] & TOSHIO SAISHO[2]
[1]*Institute of Biological Sciences,*
Faculty of Science,
University of Malaya,
50603 Kuala Lumpur, Malaysia
[2]*Laboratory of Marine Biology,*
Faculty of Fisheries, Kagoshima University,
Shimoarata 4-50-20, Kagoshima City, Japan

Keywords: Summer, midday, midnight, zooplankton, Protozoa, Rotifera, Cladocera, Copepoda, composition, abundance

ABSTRAK

Variasi tengah-hari dan tengah-malam dalam komposisi dan kelimpahan himpunan zooplankton utama dalam Tasik Ikeda, sebuah tasik kawah telah dianalisis semasa musim panas 1986. Protozoa menjuzuki lebih 70% daripada keseluruhan populasi zooplankton dan adalah yang paling melimpah diikuti oleh rotifera (12%), kopepoda (8%) dan kladosera (7%). Kecuali kopepoda dan sebilangan kecil rotifera, kebanyakan zooplankton lain didapati dengan agak lebih sedikit kelimpahan pada waktu malam. Kelimpahan keseluruhan zooplankton paling tinggi didapati pada bermulanya musim panas tetapi beransur berkurangan pada hujung musim panas. Komposisi spesies paling tinggi pada awal musim panas, kekal sehingga pertengahan musim panas tetapi beransur berkurangan dan jarang terdapat spesies pada hujung musim panas, malah beberapa spesies lain jarang didapati atau langsung tidak terdapat dalam sampel.

ABSTRACT

Variations between midday and midnight in the species composition and abundance of the main zooplankton assemblage of Lake Ikeda, a crater-lake were analyzed during the summer of 1986. The protozoans, comprising more than 70% of the whole zooplankton population were the most abundant followed by the rotifers (12%), copepods (8%) and cladocerans (7%). Except for the copepods and a few rotifers, most of the other zooplankton were evident at a slightly higher abundance at night. Total zooplankton abundance was highest during early summer but decreased gradually until the end of summer. Species composition was highest in early summer, and persisted until the middle of summer but gradually decreased with rare occurrences of some species at the end of summer, where some species were either rarely sampled or entirely absent from the samples.

INTRODUCTION

Zooplankton study is important as it could provide ways to predict and increase the productivity of lakes (Borgmann *et al.* 1984; Morgan *et al.* 1978). The aim of this study was to compare the summer midday and midnight compositions of the zooplankton in Lake Ikeda. This lake is a crater-lake situated at the southwestern edge of Kyushu island. One of the earliest researchers to work on this lake was Miyakita (1928). He focussed most of his works on the benthos aspect of this lake. Other well-noted researchers were Yoshimura (1930), Mizuno (1963) and Murayama and Saisho (1967). All these researchers dealt with the overall plankton composition of this lake. So far, no in-depth study on the midday and midnight zooplankton composition and abundance in the summer months, (which are the most reproductive months of the year) has been done on this lake. This study will focus on the midday and midnight zooplankton composition and abundance in summer. The months

involved were June, July, August and September (See *Fig. 2*). These four months were the ones with higher temperatures compared to the rest of the months. August and September were the two months with the highest temperatures. The summer months were chosen for this study because most of the species present in this lake appeared in high abundance compared with the other months. In the other seasons, they were found to be of much less abundance and some species were totally absent from the plankton.

Study Site Description

Lake Ikeda is located in Kagoshima Prefecture, Japan at 31°14'N, 130°34'E and is 88m above sea level (*Fig. 1*). It is a crater-lake situated at the southwestern edge of Kyushu Island, Japan. The mean depth is 135m and the deepest point is at 233m. With a water volume of 1.47 X $10^9 m^3$ it has a residence time of 1.7 per year. It has a surface area of 11 km^2 and a shoreline length of 15 km. For its size, it is very deep and is surrounded by steep slopes except on its northwestern side. It was formed as a crater-lake during the pyroclastic eruption of the Ibusuki Volcanic Group, which occurred around 4,000 years ago. Together with the neighbouring cone-shaped Mt. Kaimon on its southern side, it offers one of the most scenic spots to the southern Kyushu tourist zone, that of the Kirishima-Yaku National Park.

MATERIAL AND METHODS

Field Sampling Methods

Midday and midnight zooplankton specimens were taken at a fixed Station 4 in the summer of 1986 during the months of June, July, August and September. Midday abundance was taken at around noon (1200hrs) and midnight abundance samples were taken at around midnight (2400hrs). Station 4 was chosen because it was the most accessible station in terms of its nearness to research facilities and also that of safety. The others (stations 1,2 and 3) were too far away and considered unsafe especially during night samplings.

Zooplankton samples were collected using a 24 cm diameter Kitahara net (NXX13) by vertical net hauls from a depth of 30 m to the surface at a constant speed of 0.5ms^{-1}. Six replicate samples (ca. 250 ml each) were obtained from Station 4 on each sampling occasion. The samples were preserved with cool sucrose formalin technique (Haney and Prepas 1978) in order to avoid carapace distortion and loss of eggs especially from the brood chamber of adult cladocerans. Surface temperature and dissolved oxygen concentration were measured with a Yellow-Springs Instrument model 57 probe. Water transparency was measured with a 30 cm diameter white Secchi Disc. Measurements were taken from November 1985 to November 1986. Analy-

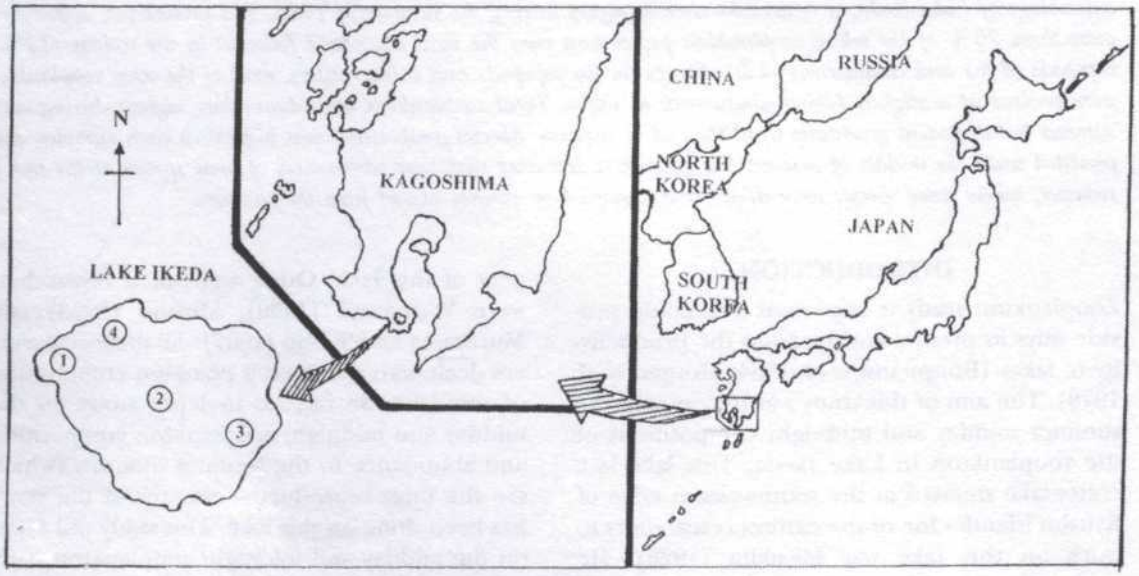


Fig. 1. Locations of Station 4 in Lake Ikeda

TABLE 1
Midday and midnight abundance (mean number/ltre ± standard deviation) of different Protozoa species at station 4 during the summer of 1986 taken by vertical hauls from a depth of 30m to the surface

TAXA	Month			
	June Day(Night)	July Day(Night)	Aug Day(Night)	Sep Day(Night)
PROTOZOA	Numbers/Litre ± Standard deviation			
Peridinium bipes	3.5±0.5(2.4±0.4)	16.0±5.2(77.3±10.4)	r(r)	-(-)
Ceratium hirundinella	433±20.3(590.6±22.4)	116.0±12.5(46.3±6.3)	7.3±0.5(8.5±1.0)	r(1.4±0.3)
Carchesium polypinum	18.8±7.9(19.1±10.2)	1.5±0.3(2.5±0.5)	-(-)	-(-)

TABLE 2
Midday and midnight abundance (mean numbers/litre ± standard deviation) of different Rotifera species at Station 4 during the summer of 1986 taken by vertical hauls from a depth of 30m to the surface

TAXA	Month			
	June Day(Night)	July Day(Night)	Aug Day(Night)	Sep Day(Night)
ROTIFERA	Numbers/Litre ± standard deviation			
Colochilus unicornis	6.6±0.8(4.4±0.4)	r(r)	15.9±3.2(23.9±5.6)	r(r)
Polyerthra euryptera	2.1±0.4(5.9±0.3)	11.3±4.3(4.1±1.2)	r(r)	-(-)
Polyartha trigla	1.2±0.2(7.2±0.9)	4.2±1.2(2.6±0.5)	r(r)	r(2.1±0.6)
Asplanchna priodonta	10.7±3.7(21.1±5.5)	-(-)	r(r)	r(1.3±0.4)
Ploesoma truncatum	8.6±2.2(14.5±4.5)	r(r)	r(r)	3.2±0.9(2.5±0.8)
Trichocerca cylindrica	r(r)	r(1.3±0.4)	r(r)	r(r)
Conochiloides coenabasis	-(-)	6.3±1.4(4.6±0.9)	r(1.0±0.3)	r(-)
Conochiloides natans	r(r)	2.9±0.8(r)	2.8±0.3(12.2±4.7)	r(2.0±0.3)
Hexarthra mira	3.3±0.5(17.4±5.2)	-(-)	r(r)	r(r)
Keratella cochlearis	-(r)	r(-)	-(-)	-(-)
Keratella valga	-(-)	-(-)	1.5±0.3(12.2±4.7)	r(2.0±0.3)

TABLE 3
Midday and midnight abundance (mean numbers/litre ± standard deviation) of different Copepoda species at Station 4 during the summer if 1986 taken by vertical hauls from a depth of 30m to the surface

TAXA	Month			
	June Day(Night)	July Day(Night)	Aug Day(Night)	Sep Day(Night)
COPEPODA	Numbers/Litre ± standard deviation			
Thermocyclops hyalinus	12.3±3.3(4.0±0.4)	12.7±3.2(12.1±2.5)	3.6±0.5(5.8±1.5)	2.4±0.3(5.4±0.8)
Mesocyclops sp.	r(r)	r(r)	-(-)	-(-)
Nauplii	4.3±1.5(7.5±2.0)	21.6±5.5(25.5±5.9)	12.4±3.1(15.5±4.0)	2.8±0.7(2.5±0.5)

TABLE 4
Midday and midnight abundance (mean numbers/litre ± standard deviation) of different Cladocera at Station 4 during the summer of 1986 taken by vertical hauls from a depth of 30m to the surface

TAXA	Month			
	June Day(Night)	July Day(Night)	Aug Day(Night)	Sep Day(Night)
CLADOCERA	Numbers/Litre±standard deviation			
Diaphanosoma brachyurum	-(-)	2.9±0.3(8.5±0.8)	1.2±0.3(2.2±0.4)	r(r)
Bosmina longirostris	2.8±0.2(6.0±0.3)	13.6±3.4(40.6±4.5)	9.1±2.1(10.2±2.4)	4.7±0.4(5.0±0.5)
Ceriodaphnia reticulata	2.9±0.3(2.0±0.2)	3.3±0.4(2.8±0.3)	4.0±0.5(4.3±0.5)	r(r)
Bosminopsis deitersi	4.4±0.9(8.4±1.4)	r(r)	r(-)	r(r)
Alona guttata	r(r)	r(-)	r(-)	r(r)
Holopedium gibberum	-(-)	-(r)	r(r)	r(-)
Monospilus distar	r(r)	r(r)	r(r)	r(-)
Daphnia pulex	r(r)	-(-)	-(-)	-(-)

sis of data was done using the SAS statistical package.

RESULTS

Physical-chemical Parameters

Fluctuations in surface temperature, dissolved oxygen and transparency for Station 4 are shown in *Fig. 2*. Surface water temperature ranges from 10°C to 30°C, with an average of 19.8°C. The hottest month was August while the coldest was February. The four hottest months were June, July, August and September. These were the months chosen to represent the months of summer in this study. Dissolved oxygen ranges from 8.1 to 12.2 mg/L with an average of 9.2 mg/L. Transparency ranges from 4.8 to 9.2 m with an average of 6.3 m. Transparency decreased from spring to summer but increased from autumn to winter.

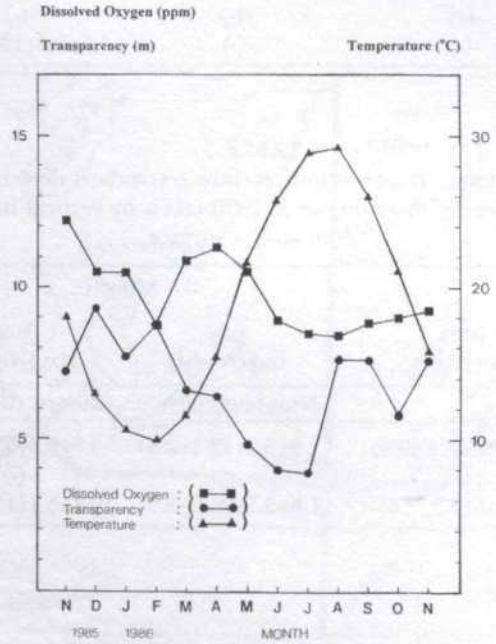


Fig. 2. Fluctuations in dissolved oxygen (ppm), tranparency (m0 and surface temparature (°C) at Station 4 in Lake Ikeda from November 1985 to November 1986

Composition and Abundance

The midday and midnight composition and abundance of Protozoa, Rotifera, Copepoda and Cladocera are shown in Tables 1,2,3 and 4 respectively.

Protozoa

Three species of Protozoa were present in Lake Ikeda. They are *Peridinium bipes* (Stein 1883), *Ceratium hirundinella* (O.F. Muller 1882) and *Carchesium polypinum* (Ehrenberg 1830). *Peridinium bipes's* abundance was highest in July (Day: 16.0 ± 5.2 individuals/litre; Night: 77.3 ± 10.4 individuals/litre) and after that it quickly disappeared from the plankton. Comparing each summer month, *Ceratium hirundinella* was the most abundant species with a maximum in June (Day: 433 ± 25.3 individuals/litre; Night: 590.6 ± 22.4 individuals/litre) and was also found to be less in abundance in July (Day: 116 ± 12.5 individuals/litre; Night: 46.3 ± 6.3 individuals/litre) and diminished drastically the next month (Day: 7.3 ± 1.8 individuals/litre; Night: 8.5 ± 1.2 individuals/litre) (Student's t-test, $P<0.05$). It continued to decrease at the end of the summer month of September. *Carchesium polypinum* was most abundant in June (Day: 18.8 ± 7.9 individuals/litre; Night: 19.1 ± 10.2 individuals/litre) and decreased further in July (Day: 1.5 ± 0.3 individuals/litre; Night: 2.5 ± 0.5 individuals/litre) (Student's t-test, $P<0.05$) and was absent in August and September.

The Protozoa was the most abundant zooplankton and it comprised more than 70% of the total zooplankton found in Lake Ikeda. In June, *Peridinium bipes* had a higher abundance during midday but in July the reverse was found to be true. *Ceratium hirundinella* was most abundant at midnight in June, but in July the midday sample had a higher abundance compared with the midnight sample ($P<0.05$). However in August and September,there was no significant difference between the midnight and the midday sample ($P>0.05$). This was also true of *Carchesium polypinum* ($P>0.05$).

Rotifera

Altogether, 11 species of Rotifers were present in Lake Ikeda. They are *Conochiloides unicornis* (Rouselet 1892), *Polyerthra euryptera* (Wierzejski 1893), *Polyerthra trigla* (Schreyer 1921), *Asplanchna priodonta* (Gosse 1850), *Ploesoma truncatum* (Levander 1894), *Trichocerca cylindrical* (Imhof 1891), *Conochiloides coenobasis* (Skorikov 1914), *Conochiloides natans* (Voigt 1904), *Hexarthra mira* (Hudson 1871), *Keratella cochlearis* (Gosse 1851) and *Keratella valga* (Ehrenberg 1834).

The most abundant rotifer was *Conochilus unicornis* (with a maximum in August) (Day:15.9 ± 3.2 individuals/litre; Night:23.9 ± 5.6 individuals/litre) followed by *Asplanchna priodonta* (with a maximum in June) (Day:10.7 ± 3.7 individuals/litre; Night:21.1 ± 5.5 individuals/litre). The most abundant rotifers found in June were *Ploesoma truncatum* (Day:8.6 ± 2.2 individuals/litre; Night:14.5 ± 4.5 individuals/litre) and *Hexarthra mira* (Day:3.3 ± 0.5 individuals/litre; Night:17.4 ± 5.2 individuals/litre). *Trichocerca cylindrica* (Day: rare;Night: 1.3 ± 0.4 individuals/litre), and *Conochiloides coenobasis* were most abundant in July (Day:6.3 ± 1.4 individuals/litre; Night:4.6 ± 0.9 individuals/litre) and *Conochiloides natans* both in July (Day:2.9 ± 0.8 individuals/litre; Night:rare)and August (Day:2.8 ± 0.7 individuals/litre; Night:12.2 ± 4.7 individuals/litre) while *Keratella valga* (Day:1.5 ± 0.3 individuals/litre; Night:12.2 ± 4.7 individuals/litre) in August. From the end of September onwards, most of the rotifers were diminishing in abundance. *P. euryptera, P.trigla, A. priodonta, P.truncatum, H. mira* and *K. valga* occurred at much higher abundance at midnight compared with midday (Students' t-test, $P<0.05$).

The rotifers made up about 12% of the total zooplankton abundance. Except for *Conochiloides coenobasis*, generally all the other rotifers occurred at a much higher abundance at midnight compared with midday. However in July, *Polyerthra euryptera* and *Polyerthra trigla* had a higher abundance during the midday compared with midnight ($P<0.05$). The reverse was true for both species in June, i.e. midnight was more abundant than midday ($P<0.05$).

Copepoda

Only two species of Copepods were found in Lake Ikeda. The two species were *Thermocyclops hyalinus* (Rehberg 1880) and *Mesocyclops* sp. Both belonged to the cyclopoids. *Thermocyclops hyalinus* occurred in almost equal numbers during the day in June (12.3 ± 3.3 individuals/litre) and July (12.7 ± 3.2 individuals/litre) ($P>0.05$) but at night the July samples (12.1 ± 2.5 individuals/litre) showed a higher abundance compared with the June samples (4.0 ± 1.2 individuals/litre) ($P<0.05$). *Mesocyclops* sp. was rarely seen in

June and July and was absent in August and September. Apart from that, nauplii of both species were present in the samples.

Altogether the copepods comprise 8% of the total number of zooplankton. The cyclopoids together with their nauplii were present throughout all the summer months. Nauplii of both genera were counted together as they could not be easily separated and distinguished. The copepods' abundance was higher during early summer (June) but was not significantly different in July, August and September. In the early summer month of June, more copepods were present during the midday compared with midnight. As for the nauplii, there was no significant difference in abundance between midday and midnight in all the summer months.

Cladocera

Altogether, in this study, eight species of Cladoceras were found to inhabit Lake Ikeda. They were *Diaphanosoma brachyurum* (Lieven 1848), *Bosmina longirostris* (O.F.Muller 1785), *Ceriodaphnia reticulata* (Jurine 1820), *Bosminopsis deitersi* (Richard 1895), *Alona guttata* (Sars 1862), *Daphnia pulex* (O.F.Muller 1785), *Monospilus distar* (Sars 1862) and *Holopedium gibberum* (Zaddach 1855).

The most abundant cladoceran was *Bosmina longirostris* which occurred in all the summer months of June, July, August and September. It was the most abundant in July (Day: 13.6 ± 3.4 individuals/litre; Night: 40.6 ± 4.8 individuals/litre)and then decreased in August (Day: 9.1 ± 3.2 individuals/litre; Night: 10.2 ± 3.9 individuals/litre) ($P<0.05$). *Diaphanosoma brachyurum* was absent from the samples in June but suddenly appeared with a maximum abundance in July (Day: 2.9 ± 0.3 individuals/litre; Night: 8.5 ± 1.7 individuals/litre) and started to decrease in August (Day: 1.2 ± 0.5 individuals/litre; Night: 2.2 ± 0.9 individuals/litre) ($P<0.05$) and further still in September where it rarely appeared. *Ceriodaphnia reticulata* was present from June (Day: 2.9 ± 0.6 individuals/litre; Night: 2.0 ± 0.3 individuals/litre), July (Day: 3.3 ± 0.7 individuals/litre; Night: 2.8 ± 0.5 individuals/litre) and until August(Day: 4.0 ± 0.6 individuals/litre; Night: 4.3 ± 0.6 individuals/litre) but almost disappeared from the plankton in September. There was no significant difference in abundance among all the four months ($P>0.05$). *Bosminopsis deitersi* could only be sampled in June (Day: 4.4 ± 1.3 individuals/litre; Night 8.4 ± 2.2 individuals/litre) and then became too few in number in July and by September it had disappeared. *Alona guttata* was present but too few in number to be of much significance in its abundance. *Holopedium gibberum, Monospilus distar* and *Daphnia pulex* are three new colonizers of Lake Ikeda.

Altogether the Cladoceras comprises 7% of the whole zooplankton abundance. Although *Ceriodaphnia reticulata* occurred in higher abundance during the midday as compared to midnight, it was not statistically significant (Students' t-test, $P>0.05$). On the other hand, more of *Diaphanosoma brachyurum, Bosmina longirostris,* and *Bosminopsis deitersi* were significantly more at midnight compared with midday (Students' t-test, $P<0.05$).

DISCUSSION

Most of the zooplankton species sampled in this lake during the summer months were also inhabitants of other natural lakes and artificial impoundments in Japan (Miura and Cai 1990; Hanazato and Nohara 1992). Comprising about 70% of the whole zooplankton's abundance, the protozoa appeared to play an important role in the zooplankton community of this lake. They could represent an important trophic link between microheterotrophic production and invertebrate predators (Porter *et al.* 1979). They may hold a key role in nutrient regeneration due to their high specific rates of phosphorous excretion (Pace and Orcutt 1981). Future research on these protozoans could help to elucidate processes such as energy flow and nutrient regeneration in this lake.

In Lake Ikeda, the rotifers were more diverse when compared with the other zooplankton community. They were comparable to other lakes in Japan (Miura and Cai 1990; Hanazato and Nohara 1992). The rotifers were considered opportunists (Allan 1976). Its population rises and falls according to its tolerance of environmental conditions. Their total biomass is usually low but this is compensated by a short generation time, thus a fast renewal of population (Hutchinson 1967). After *Polyerthra euryptera, Asplanchna priodonta* was the most abundant rotifer. Apart from its ability to suppress other rotifers, especially *K. cochlearis* (Hoffmann 1983; Sarma 1993), it can also consume algae and small crustacean species, especially small

Bosminidae (Matveeva 1989; Hutchinson 1967) and *Peridinium* (Pourriot 1965). However, in Lake Ikeda, its density crashed immediately after its peak in June. What could have happened is that it could have migrated down to lower water layers at some periods of the day especially during midday, where it can find higher rotifer densities to consume (Vasconceles 1994). Welch (1935) suggested that prey and predation principles are the most important factors involved in diurnal migration of zooplankton. During the day time, the zooplankters descend to the bottom water to hide themselves from their predators and ascend upwards during night hours. Hutchinson (1967) reported that the pattern of zooplanktonic migration may be due to the result of interspecific competition, whereby species dominant during night hours were generally fewer in number during the day. In fact he went on further to state that the interpretation of zooplankton dynamics is impossible without considering the historic, biotic and competitive factors. In the future, it would be interesting to follow the fluctuations in density of rotifers and relate it to more detailed environmental parameters. Physical and chemical properties of the water may limit the occurrence of some species (Elliot 1977; Ruttner-Kolisko 1977; Herzig 1987), but phytoplankton availability (Gilbert and Bogdan 1984; Herzig 1987), competition and predation (Dumont 1977; Hoffmann 1983; Gilbert and Stemberger 1984) are also important.

For the copepods, a significant difference was found in *T. hyalinus* which occurred at higher abundance in June during midday compared with midnight. The rest were not significantly different. The rest are either too few to be sampled or not present in the samples.The species composition of Copepods in Lake Ikeda is similar to other tropical or subtropical lakes (Fernando 1980a,b). In Lake Ikeda, they are represented by only two genera, *Thermocyclops hyalinus* and *Mesocyclops* sp.

Eutrophication is known to affect the specific composition of the zooplankton by altering the environment which could lead to changes in the phytoplankton composition. This in turn could promote the changes in the quantity and quality of available food for the zooplankton (Sandecz 1984). During this study, three species of Cladoceras that were never reported to be present in this lake were encountered in the samples. They were *Daphnia pulex, Holopedium gibberum* and *Monospilus distar.* However, their abundance was too low to be of much significance to the overall zooplankton's abundance. Although they were very few in number, they were nevertheless present. Prior to this report there was no record of their presence (Miyakita 1928; Yoshimura 1930; Mizuno 1963 and Murayama and Saisho 1967). What could have happened is that they could have been introduced from elsewhere together with fish released into Lake Ikeda for stocking purposes. Altogether, this study has managed to detect the presence of eight genera of Cladoceras living in Lake Ikeda. The degree of eutrophication of a lake is closely associated with the zooplankton community, and in an eutrophic environment, the cyclopoid copepods and the cladocerans are dominant (Bradshaw 1964; Patalas 1972; Hillbricht-Ilkowska and Weglenska 1970). It seems that Lake Ikeda is heading towards an eutrophic environment with the continued increase in abundance of cyclopoid copepods and cladocerans compared with previous studies done on this lake by Murayama and Saisho (1967). The presence of *Bosmina longirostris* and *Diaphanosoma brachyurum* in high abundance is usually also associated with an eutrophic environment as *Diaphanosoma* sp. is well adapted to eutrophic environments (Sendacz 1984). This finding is supported by Zago (1974) who reported that with the eutrophication of the Americana Reservoir, *Diaphanosoma* sp. replaced *Daphnia gessneri* as the dominant species of cladocera. Future research on this lake will involve a more in-depth analysis of each zooplankton species together with more detailed measurements of physical-chemical parameters coupled with *in situ* experiment-based analysis in order to elucidate each species' role in the ecology of this lake in its path towards eutrophication.

ACKNOWLEDGEMENT

We would like to thank Mr. Takuya Yoshimine who kindly assisted in the zooplankton samplings, Mr. Shirou Kojima for providing boat transportation to and from the sampling sites, and Mr. Isamu Setoguchi (Head of the Ibusuki Experimental Station) for his kindness in allowing us access to their various research facilities at Lake Ikeda. Thanks are also due to Assistant Professor Dr. Akihiko Shinomiya and Dr. Hiroshi Suzuki for their constructive criticism and suggestions

during the course of this study. One of us (SAR) was sponsored by the Ministry of Education, Science and Culture, Japan (MONBUSHO) during his study in Japan.

REFERENCES

ALLAN, J.D. 1976. Life history patterns in zooplankton. *Am. Nat.* **110**:165-180.

BORGMANN, U., H. SHEAR and J. MOORE. 1984. Zooplankton and potential fish production in Lake Ontario. *Can. J. Fish. Aquat. Sci.* **41**: 1303-1309.

BRADSHAW, A.S. 1964. The crustacean zooplankton picture. Lake Erie 1939-49-59;Kayuga 1910-51-61. *Verh. int. Ver. Limnol.* **15**:700-708.

DUMONT, H.J. 1977. Biotic factors in the population dynamics of rotifers. *Arch. Hydrobiol. Beih.* **8**: 98-122.

ELLIOT, J.I. 1977. Seasonal changes in the abundance and distribution of planktonic rotifers in Grasmere (English Lake District). *Freshwater Biol.* **7**: 147-166.

FERNANDO, C.H. 1980a. The species and size composition of tropical freshwater zooplankton with special reference to the oriental region (South East Asia). *Int. Revue ges. Hydrobiol.* **65**: 411-426.

FERNANDO, C.H. 1980b. The freshwater zooplankton of Sri Lanka, with a discussion on tropical freshwater zooplankton composition. *Int. Revue ges. Hydrobiol.* **65**: 85-125.

GILBERT, J.J. and K.G. BOGDAN. 1984. Rotifer grazing: *in situ* studies on selectivity and rates. In *Trophic interactions within aquatic ecosystems* ed. D.G. Meyers and J.R. Strickler. *American Association for the Advancement of Science, Selected Symposium* **85**: 97-133.

GILBERT, J.J. and R.S. STEMBERGER. 1984. Control of Keratella populations by interference competition from Daphnia. *Limnol. Oceanogr.* **30**: 180-188.

HANAZATO, T. and S. NOHARA. 1992. Seasonal succession and vertical distribution of zooplankton in Lake Ozenuma. *Jap. J. Limnol.* **53**:55-63.

HANEY, J.F. and E. PREPAS. 1978. Sugar-frosted *Daphnia*: An improved fixation technique for Cladocera. *Limnol. Oceanogr.* **23**: 551-559.

HERZIG, A. 1987. The analysis of planktonic rotifer populations: A plea for long-term investigations. *Hydrobiologia* **147**: 163-180.

HILLBRICHT-ILKOWSKA, A. and T. WEGLENSKA. 1970. Some relation between production and zooplankton structure of two lakes of varying trophy. *Polskie Arch. Hydrobiol.* **17**:233-240.

HOFFMANN, W. 1983. Interactions between *Asplanchna* and *Keratella cochlearis* in the PlussSee (North Germany). *Hydrobiologia* **104**: 363-365.

HUTCHINSON, G.E. 1967. *A Treatise on Limnology, II. Introduction to Lake Biology and Limnoplankton.* 1115 p. New York: John Wiley & Sons.

INAMOTO, N., K. YAMASHITA, Y. UENO, H. OKUE, E. IRIKO, K.OKUZONO, T. KORIYAMA, M. AKATSUKI and K. MEHARA. 1986. Studies on the eutrophication of Lake Ikeda-Water quality in deep layer and lake water cycle. *Annual Report of Kagoshima Prefectural Institute of Environmental Science* **2**:141-147 (In Japanese).

KAGOSHIMA PREFECTURAL GOVERNMENT. 1993. Annual report of water quality analysis in Kagoshima prefecture (In Japanese).

MATVEEVA, L.K. 1989. Interactions of rotifers with predatory and herbivorous Cladocera: A review of Russian works. *Hydrobiologia* **186/187**: 69-73.

MIYAKITA, D. 1928. Report on benthos research in the littoral zone of Kyushu area. *Jap. J. Res. Fish.* **23(4)**:132-140. (In Japanese).

MIZUNO, T. 1963. Research on the crater-lake of Kirishima and the limnology of Satsuma Lake. *Jap. J. Limnol.* **24(1-2)**:22-23.(In Japanese).

MIURA, T. and Q.H. CAI. 1990. Annual and seasonal occurrences of the zooplankters observed in the North Basin of Lake Biwa from 1965 to 1979. *Contribution from Otsu Hydrobiological Station, Kyoto University* **337**: 1-35.

MORGAN, M.D., S.T. THRELKELD and C.R. GOLDMAN. 1978. Impact of the introduction of kokanee (Oncorhynchus nerka) and opossum shrimp (Mysis relicta) on a subalpine lake. *J. Fis. Res. Bd. Can.* **35**: 1572-1579.

MURAYAMA, S. and T. SAISHO. 1967. Seasonal variations of plankton at Lake Ikeda. *Mem. Fac. Fish., Kagoshima Univ.***16**:29-33. (In Japanese).

PAGE, M.L. and J.D. ORCUTT JR. 1981. The relative importance of protozoans, rotifers and crustaceans in a freshwater zooplankton community. *Limnol. Oceanogr.* **26**: 822-830.

PATALAS, K. 1972. Crustacean plankton and the eutrophication of the St. Lawrence Great Lakes. *J. Fish. Res. Bd. Can.* **29**:1451-1462.

PORTER, K.G., M.L. PACE and J.F. BATTEY. 1979. Ciliate protozoas as links in freshwater planktonic food chains. *Nature* **277**: 563-565.

POURRIOT, R. 1965. Recherches sur la Ecologie des rotifers. *Vie et. Milieu. Sup.* **21**: 224p.

RUTTNER-KOISKO, A. 1977. Population dynamics of rotifers as related to climatic conditions in Lunzer Obersee and Untesee. *Arch. Hydrobiol. Beih.* **8**: 88-93.

SARMA, S.S.S. 1993. Feeding responses of *Asplanchna brightwelli* (rotifera): Laboratory and field studies. *Hydrobiologia* **255/256**: 275-283.

SENDACZ, S. 1984. A study of the zooplankton community of Billings Reservoir-Sao Paulo. *Hydrobiologia* **113**:121-127.

VASCONCELOS, V.M. 1994. Seasonal fluctuation of planktonic rotifers in Azibo reservoir (Portugal). *Hydrobiologia* **294**: 177-184.

WELCH, P.S. 1935. *Limnology*. 471 p. London: McGraw Hill Book Company.

YOSHIMURA, S. 1930. Scientific biological research on a crater-lake in Southern Kyushu. *Jap. J. Geology.* **42**:381-665.(In Japanese).

ZAGO, M.S.A. 1976. The planktonic Cladocera (Crustacea) and aspects of the eutrophication of Americana Reservoir, Brazil. *Bolm. Zool. Univ. S. Paulo* **1**: 105-145.

(Received: 28 October 1997)
(Accepted: 21 January 2002)

Pertanika J. Trop. Agric. Sci. 25(1): 11 - 17 (2002) ISSN: 1511-3701

Variability of Maize Yield and Some Soil Properties in an Exhaustively Cultivated Field in the School of Agriculture, Ikorodu

A.S FASINA
Department of Crop Production & Horticulture
School of Agriculture, Lagos State
Polytechnic, Ikorodu

Keywords: Soil variability, maize yield variability, exhaustively cultivated, field, Ikorodu

ABSTRAK

Perubahan pengeluaran jagung dan sifat sesetengah tanah di kawasan yang ditanam rapi di Sekolah Pertanian, Ikorodu dikaji menggunakan variasi yang koefisien dan analisis regresi pelbagai langkah bijak selama dua tahun (1990 dan 1991). Perubahan ciri-ciri tanah dan pengeluaran jagung secara individu seperti yang ditunjukkan oleh perbezaan nilai cv yang meluas. Ciri-ciri kimia tanah (ex, Ka, Ex, Avail.P dan Zink) berubah lebih daripada ciri-ciri fizikal tanah (kapasiti pegangan air dan pasir). Perubahan ciri-ciri sesetengah tanah dan pengeluaran jagung berkemungkinan jelas dipengaruhi oleh penggunaan tanah sebelumnya dan aktiviti pengurusan lain di sekeliling kawasan tersebut. Pada tahun 1990, 18 ciri tanah menerangkan 92.51% variasi dalam pengeluaran jagung di kawasan tersebut. Berbanding 87.29% pada tahun 1991, setiap ciri tanah menggunakan pengaruh berlainan ke atas pengeluaran jagung. Ciri-ciri tanah menggunakan pengaruh berlainan ke atas pengeluaran jagung. Ciri-ciri tanah yang menggunakan pengaruh kuat ke atas pengeluaran jagung dalam kawasan tanaman yang mengandungi P, potasium yang boleh berubah, jirim organik, kapasiti pegangan air, kalsium yang boleh berubah, pasir dan zink. Kajian ini menekankan perubahan besar jumlah tanah dan kadar pengeluaran jagung yang boleh wujud dalam kawasan kecil yang ditanam rapi. Pendekatan yang digunakan dalam kajian ini kelihatan munasabah untuk memperbaiki pengeluaran tanaman di kawasan tersebut. Pendekatan ini mungkin berguna dalam memilih ciri-ciri tanah untuk kajian penilaian kesuburan tanah.

ABSTRACT

The variability of maize yield and some soil properties in an exhaustively cultivated field in the School of Agriculture, Ikorodu was examined using a coefficient of variation and stepwise multiple regression analysis for two years (1990 and 1991). The variability of individual soil properties and maize yield as indicated by cv values differed widely. Soil chemical properties (ex, Ca, Mg, Ex, Avail. P and zinc) varied more than the physical properties of the soil (sand and water holding capacity). Variability of some soil properties and maize yield were likely to have been markedly influenced by previous landuse and other management practices around the exhaustively cultivated field. In 1990, 18 soil properties explained 92.51% of the variation in the yield of maize on the exhaustively cultivated field. Compared to 87.29% in 1991, each of the soil properties exerted a different influence on the yield of maize. Soil properties which exerted stronger influences on the yield of maize within the cultivated field were available P, Exchangeable Potassium, organic matter, water holding capacity, Exchangeable calcium, sand and zinc. This study has highlighted the tremendous amount of soil and maize yield variability that may exist within a small exhaustively cultivated field. The approach used in this study seems reasonable for improving crop yield on the field. It would be useful for selecting different soil properties for land and soil fertility evaluation studies.

INTRODUCTION

Much of the existing information on soil variability, including the few on tropical soils (Tomlinson 1970; Areela 1982), concentrates on variability. This is the component of total variability observed over a considerable distance of

between two distinctly different units such as parent materials or land facets (Van Wambeke and Dual 1978). Far less attenttion has been given to the microvariability component, which pertains to the local and often recurrent variations on the scale of a single field (Meerman and Kang 1978).

Research reported by Kang (1977 and 1978) has shown that the effect of soil variability on the growth and performance of crops in the inter tropical areas can be pronounced. In addition, the experience of researchers as a result of the effect of considerable microvariability on agricultural experiments can be very frustrating. A knowledge of the degreee of microvariability of the soil over an area and the factors responsible for this variability is therefore essential for both practical and experimental agriculture.

Presently, there is a lack of information about soil variability and its effects on maize yield around the study area. In view of the proximity of Lagos to the study area where capital or intensive farming is accessible, it is necessary to generate adequate information on landuse or soil management, so as to maximise the use of the land: crop rotation is now difficult in Lagos State because of pressure on the land for industrial and commercial activities within the state. This predisposes the few available areas to be put under heavy use with the aid of fertilizers.

It is therefore necessary to monitor crop yield on such land so as to determine to what extent it has been altered. This will offer information regarding measures to guarantee optimal use of such areas.

Soil exhibits tremendous variations both laterally and vertically. The results of previous soil veritability studies (Ogunkunle 1986) have revealed very high variations between soil properties of two closely spaced spots 10 cm apart on a uniform terrain.

It has also been established that, for most arable crops, the control of crop performance is mainly in the plough layer (0-20cm), where most of the roots are concentrated. Similarly, Sopher and McCracken (1973) found that 70% of corn yield variation was due to soil properties of the plough layer. Lal *et al.* (1975) also observed that the removal of 2.5cm and 7.5cm of the topsoil, respectively resulted in 50 and 90 per cent reductions in maize yield.

This study examined the degree of variation in some soil properties and yield of maize on an exhaustively cultivated field. This study will no doubt furnish some information on the variation of some soil properties and yield of maize, which we hope will be a useful guide to farmers and other landusers. Hence, the information on the topsoil properties controlling yield variation will be very useful for improving food production.

Study Area

The studies were conducted in the experimental farm of the School of Agriculture, Ikorodu. The location is about 15km from Lagos and 30km from Sagamu. The area lies roughly between latitudes 5° 7°N and 5° 10°N and longitudes 3°16 and 5° 18° ease of Greenwich Meridian. It has an altitude of about 50 km above sea level.

The climate is humid tropical with two distinct seasons – the dry (November to March) and the wet (April to October). Mean annual rainfall is at least 132 mm with a maximum in July and September. Mean daily temperature ranges from 25 to 28°C. The humidity is high throughout the year and reaches its peak during the wet season. The mean relative humidity is never below 65%.

The soil has been mapped as Alfisols with Typic Paloustalf as the modal profile (Fasina 1989). It is derived from sedimentary parent material (Moss 1957) with sandy loam and sandy clay texture in the surface and subsoil, respectively. The soil has been exhaustively cultivated with vegetables and maize in the past. This means the continuous planting of the field with vegetables and maize without allowing it to fallow.

MATERIALS AND METHODS

Field studies were conducted for two years (1990 and 1991) during the wet season. TZSR-Y maize needs variety were planted on plots of 0.1ha with inter and inter-row spacings of 90cm and 30cm respectively. NPK (15-15-15) compounded fertilizer and urea were applied at the rate of 200kg/ha and 100kg/ha two weeks after planting respectively. Leaving out the guard rows, 20 maize stands were randomly selected from the middle of the 0.1ha plots for the two year study. At tasselling, 5 surface (0-15cm) core soil samples were taken from around each of the se-

lected stands to form a composite sample for laboratory analysis. The maize cobs were harvested at maturity (15% moisture content) from these stands and the yield per stand (weight of grains in grams) was determined. All experimental procedures were the same for both years.

Laboratory Analysis

Particle size distribution was done using the Bouyoucos hydrometer method (Day 1965) and pH was measured in water (1:1, soil:water). The exchangeable cations (Ca, Mg, Na and K) were extracted in IN NH_4OAC and Na and K were determined by a flame photometer and Ca and Mg on an atomic absorption spectrophotometer. The exchangeable acidity (Al and H^+) was determined by titration of the soil solution with IN KCL and organic carbon was determined by the Walkey-Black method (Allison 1965).

Available P was extracted by Bray's PI solution (Bray and Kurtz 1945) and determined following the Murphy and Rilley method (Murphy and Rilley 1962). Total N was determined by the macro-kjeldahl method (Bromner 1960) and moisture content (%) by gravimetrics. The dicronutrients were leached out with 0.1m NHCI (Wear and Sammer 1948) and were read on the atomic absorption spectrophotometer.

Statistical Analysis

Yield and laboratory data were statistically analysed from plots for variations (mean (X), standard deviation (sd). The coefficient of variation (cv) and the stepwise regressions of yield on soil properties were measured using the SPSS computer program of Lagos State, Agricultural Development Project, Lagos.

RESULTS AND DICUSSION

Variations in Soil Properties and Maize Yield

Variability of individual soil properties and maize yield as indicated by cv values differed widely (Table 1). The exhaustively cultivated field was more uniform in those soil properties which are genetically and morphologically important such as sand, while those properties which are ephemeral and which are related to management (Ex, Ca, Mg, Avail.P, Ex K) were more variable (Table 1). These are the properties that most control maize yield on the field. The cv data obtained for the two year experiment seems to be

TABLE 1
Variability of maize yield and soil properties

Property of Maize Yield	1990			1991		
	x	Sd	CV%	X	SD	CV%
Maize yield (kg) 35.11		0.24	1.08	37	126.75	44.83
Soil p^H	6.76	0.22	3	6.78	0.13	1.91
Organic carbon % 14.2		1.41	0.11	8	3.16	0.45
Total N %	0.12	0.01	8	0.32	0.05	15.62
Available Phosphorus Cmol kg^{-1}	52.49	28.43	54	73.99	53.44	72.22
Calcium (ca) Cmol kg^{-1}	2.47	0.92	37	2.60	0.74	28.46
Magnesium (mg) Cmol kg^{-1}	1.15	0.18	16	1.23	0.15	12.19
Sodium (Na) Cmol kg^{-1}	0.27	0.05	17	0.31	11	35.48
Potassium (K) Cmol kg^{-1}	0.17	0.09	54	0.20	0.07	35.0
Exchangeable acidity Cmol kg^{-1}	0.24	0.08	33	0.28	0.12	52.55
Cation Exchanged Capacity Cmol kg^{-1}	4.44	1.03	5	2.69	0.29	11
Base saturation (BS) %	94.55	2.56	3	93.55	3.00	3.20
Manganese (Mn) - Cmol kg^{-1}	69.37	5.33	8	71.58	8.62	12.04
Iron (Fe) - Cmol kg^{-1}	21.68	4.60	21	21.03	3.89	18.49
Copper (Cu) - Cmol kg^{-1}	1.48	0.19	13	1.56	0.15	9.67
Zinc (Zn) - Cmol kg^{-1}	6.67	2.48	37	6.87	2.99	43.52
Sand - %	0.79	2.38	3	76.15	2.50	3.28
Silt - %	9.00	1.54	17	9.30	1.77	19.03
Clay - %	12.40	2.01	16	14.55	2.55	17.52
Water Holding Capacity (WHC) %	35.61	5.01	14	36.72	1.77	4.82

uniform. Also, the cv values obtained for soil properties in this study were not at variance with what other workers have observed in the past (Beckett and Webster 1971; Chickezie 1984; Unwni 1985; Fasina 1986). The cv values of some chemical properties appeared to be less variable than others. Soil pH base saturation, CEC, total N, manganese and organic carbon were less variable while available P, Ex, Ca, K, Zn, Ex acidity, Fe were more variable on the exhaustively cultivated land. The observed differences in the variability of the chemical properties for the whole area as shown by the cv values (Table 1) could be due to variations imposed by cultivation and management practices employed in the study area.

It has also been shown (Beckett and Webster 1971) that in cultivated areas, contrasting crops, soil amelioration and addition of fertilizers superimposed differences between fields on the variation already present in the native soil. The variation in these chemical properties in the soil would result in variations in the yield of crop cultivated on the field as in the case of this study. This is in accordance with Talukdar and Barthakur (1986) and Gbadegesin (1987). The variations observed in these chemical properties could also be caused by land clearing and preparation that the exhaustively cultivated field has been subjected to over the years. The cv values obtained from maize yield and soil properties in the study when grouped by the method of Wilding and Drees (1978) (Table 2) has put pH, Org C, Total N, base sat Mn, Sand, Cu, ECE, as the least variable properties (CV 15%). Ex.Mg, Ex Na, acidity Fe, silt and clay are moderately variable properties (CV 15-35%) while maize yield, available P, Ex. Ca, Ex K and zinc are extremely variable properties (CV 35%). The result of this grouping agreed with the results obtained by Wilding and Drees (1978) and also with results obtained elsewhere in Nigeria (Fasina 1986; Ogunkunle 1986).

It has been shown that in experiments where specific treatments were applied, variability as high as cv 99% may invalidate the results even with a high degree of replication (Ogunkunle 1988). This shows the importance of calculating the variations in yield data obtained in an experiment.

The variation in the maize yield also signified the variation in soil properties of the exhaustively cultivated field. The variations in soil properties and the type of management systems adopted are thus among the causes of variations in yield parameters observed on the field.

Yield Prediction

In order to have an idea of the contributions of each of the individual soil properties to the variations in the yield of maize on the exhaustively cultivated land, a further analysis of the data was carried out using a stepwise regression model.

The stepwise regression of the maize yield (dependent variable) on the soil properties (independent variables) reveal that 18 soil properties contributed significantly (P 0.01) to the prediction of maize yield in the study area (1990- R^2 value of 92.51%, 1991 – R^2 value of 87.29%) (Table 3). With 8 soil properties in regression, 72% of the variations in maize yield were explained in 1990 while it was 75% for 1991. The regression analysis also revealed that the soil variables were not equal as far as their influence on the yield of the crop was concerned. The soil chemical properties seemed to exert a stronger influence on the yield of the crop in the study area.

For instance, for the two year study Ex Ca and organic carbon were among the first two relevant soil properties (Table 3) that contributed significantly to the yield of maize. The regression values obtained for Available P and Ex Ca (R^2 = 10% - 1990, R^2 = 4% - 1991) and (R^2 = 10% R^2 – 13% - 1991) tend to support the

TABLE 2
Grouping of maize yield and soil properties using CV values for the exhaustively cultivated fields

Group of Properties	Range of CV Values	Soil Property and Maize Yield
Least Variable	15%	pH, org C, total N, Base Saturation, Mn Sand, Cu, CEC
Moderately Variable	15 – 35%	Ex. Mg. Ex Na. Ex. Acidity Fe, Silt and Clay
Extremely Variable	35%	Avail P, Ex Ca, Ex K and Zinc, Maize yield

TABLE 3(a)
Yield prediction (R^2) with increasing number of properties in regression (1990)

No. of Soil Properties in Regression	List of Properties	R^2	R^2%
1	Av.P	24	-
2	Av. P. Ca	34	10
3	Av. P²Ca, org. C	41	7
4	Av. P. Ca. org C, WHC	48	7
5	Av. P. Ca. org C. WHC, Na	55	7
6	Av. P, Ca, org C, WHC, Na, K	62	7
7	Av.P, Ca, org C, Whc, Na K, Base Sat.	68	6
8	Av.P. Ca, org C, WHC, Na, K, B. Sat. Silt	72	4
9	Av.P. Ca, org L, WHC, Na, K, Bsal	76	4
10	Av.P, Ca, org C, WHC, Na K.B. Sat Silt, Zn, Fe	79	3
11	Av.P, Ca, org C, WHC, Na, K.B. Sat, Silt Cu, Fe, Sand	82	3
12	Av.P, Ca, org C, WHC, Na, K, B.Sat, silt, Zn, Fe, Sand, Cu	85	3
13	Av.P, Ca, org C, WHC, Na, K,B.Sat, Silt, Zn, Fe, sand, Cu, Mn	88	3
14	Av.P, Ca, org C, WHC, Na, K.B.Sat, silt, Zn, Fe, Sand, Cu, Mn, CEC	90	2
15	Av.P, Ca, org C, WHC, Na, K,B.Sat, Silt, Zn, Fe, sand, Cu, Mn, CEC, Ph	91	1
16	Av.P, Ca, org C, WHC, Na, K.B.Sat, Silt, Zn, Fe, Sand, Cu, Mn, CEC, PH Total N	91.6	0.6
17	A.P, Ca, org C, WHC, Na, K, B.Sat, Silt, Zn, Fe, Sand, Cu, Mn, CEC, PH, Total N, Mg	91.85	0.25
18	Av.P, Ca, org C, WHC, Na, K, B.Sat, Silt, Zn, Fe, Sand, Cu, Mn, CEC, PH Total N, Mg Ex ac	92.51	0.66

TABLE 3(b)
Yield prediction (R^2) with increasing number of properties in regression (1991)

No. of Soil Properties in Regression	List of Properties	R^2	R^2%
1	WHC	15	-
2	WHC, Ca	28	13
3	WHC, Ca, Org C	38	10
4	WHC, Ca, Org C, Silt	47	9
5	WHC, Ca, Org C, Silt, EC	55	8
6	WHC, Ca, Org C, Silt, Ec, Cu	63	8
7	WHC, Ca, Org C, Silt, Ec, Cu, Sand	71	8
8	WHC, Ca, Org C, Silt, Ec, Cu, Sand, Av.P	75	4
9	WHC, Ca, Org C, Silt, Ec, Cu, Sand, Av.P, PH	79	4
10	WHC, Ca, Org C, Silt, Ec, Cu, Sand, Av.P, PH, Fe	82	3
11	WHC, Ca, Org C, Silt, Ec, Cu, Sand, Av.P, PH, Fe Na	84.5	2.5
12	WHC, Ca, Org C, Silt, Ec, Cu, Sand, Av.P, PH, Fe Na	85.5	1
13	WHC, Ca, Org C, Silt, Ec, Cu, Sand, Av.P, PH, Fe Na, K, Zn,Mg		
14	WHC, Ca, Org C, Silt, Ec, Cu, Sand, Av.P, PH, Fe, Na, K, Zn, Mg	86.84	0.34
15	WHC, Ca, Org C, Silt, Ec, Cu, Sand, Av.P, PH, Fe, Na, K, Zn, Mg, Mn	87.07	0.23
16	WHC, Ca, Org C, Silt, Ec, Cu, Sand, Av.P, PH, Fe, Na, K, Zn, Mg, Mn, Total N	87.20	0.13
17	WHC, Ca, Org C, Silt, Ec, Cu, Sand, Av.P, PH, Fe, Na, K, Zn, Mg, Mn, Total N, CEC	87.26	0.06
18	WHC, Ca, Org C, Silt, Ec, Cu, Sand, Av.P, PH, Fe, Na, K, Zn, Mg, Mn, Total N, CEC, Ex ac	87.29	0.03

results of the coefficient of variation for these two properties in the study area (Tables 1 and 3). The regression also showed the importance of different soil properties in predicting the yield of maize in the field. The differences observed in the yield predictions might be due not only to the individually soil properties but to a combination of crop and soil factors.

Application of Data to Land and Soil Fertility Evaluation Studies

The soil properties observed to be controlling the yield from the exhaustively cultivated field for the two year experiment (Available P, Ex Ca, Ex K, organic matter and water holding capacity, sand and zinc)can be used to evolve a reasonable land evaluation report (sutiability/land capability classification) for the area of study. These soil properties, when combined with other permanent properties of the soil like slope, depth, texture, structure and degree of management can be used for proper landuse and fertility evalution studies.

The results of the regression analysis can also be useful in soil fertility evaluation studies – in terms of artificial soil nutrient requirements(optimum levels of nutrients), and the expected performance and crop yields. This would then make the study more relevant for crop production.

CONCLUSION

Variability of individual soil properties and maize yield as indicated by cv values differed widely. Soil chemical properties were more variable than the physical properties of the soil. The variability of some soil chemical properties and maize yield were likely to have been markedly influenced by past land-use activities and some other management practices around the study area. It was also observed from the study that variations in some soil properties especially chemicals (Available phosphorus, Ex Ca, Calcium and Potassium) properties might lead to variations in maize yield on the field.

With 18 soil properties in regression in 1990, 92.51% of the variations in yield of maize was explained, while for 1991 the same 18 soil properties explained 87.29% in maize variation. The two most relevant soil properties that contributed significantly to the yield of maize were Ex ca and organic carbon for the two year study. The soil chemical properties exert stronger influence on the yield of crop in the study area.

The soil properties found to be relevant to maize yield in this study, if combined with the more permanent characteristics (slope, depth, drainage), may produce reliable landuse classes. Also, the results can be useful in soil fertility evaluation studies – determining optimum levels of nutrients and concentrating more on the most relevant soil properties, thereby saving cost on fertilizer use.

REFERENCES

ALLISON, L.E. 1965. Organic Carbon. In *Method of Soil Analysis*, pt 2, ed C.A. Blade. Agronomy monograph 9.1367 1378 American Society of Agronomy of Agronomy, Madison. Winconsin.

AREELA, O. 1982. Soil variability within land facets in areas of low, smooth relief: A case study on the Gwagwa Plains, Nigeria. *Soil Survey and Land Evaluation* **2(1):** 9-13.

BECKETT P.H.T. and R. WEBSTER. 1971. Soil variability: A review. *Soil Fert.* **34:** 1-5.

BRAY, R.H. and L.T. KURTX. 1945. Determination of total organic and available forms of phosphate in soils. *Soil Sci.* **59:** 225-229.

BROMER, J.M. 1960. Determination of nitrogen in soil by Kjeldahl method. *J. Agric. Science* **59:** 39-45.

CHICKEZIE, I.A. 1984. Quality assessment of a soil map. The variability of mapping units of a detailed soil map. Unpublished M.Sc. Thesis, University of Ibadan.

DAY, P.R. 1965. Particle fractienation and particle size analysis. Agren. Mon. No. 9 Pt, I.C.A Black (Ed.). 545-550.

FASINA, A.S. 1986. Soil map evaluation. An example from Idoffa, Ogun State. Unpublished M.Sc. Thesis, University of Ibadan.

GBADEGESIN, A. 1987. Soil rating for crop production in the Savannah belt of South-Western Nigeria. *Agric. System* (U/C) **23(1):** 27 – 42.

KANG, B.T. 1977. Effect of some biological factors on soil variability in the tropics. II effect of oil-palm trees (Elaeis guineensis jacq) *Plant and Soil* **47:** 451-462.

KANG, B.t. 1978. Effect of some biological factors on soil variability in the tropics III effect of macretermes mounds. *Plant and Soil* **50:** 241-251.

LAL, R. B.T. KANG, F.R. MOORMAN, A.S.R. JUE and J.C MOORMAN. 1975. Soil management problems and possible solutions in Western Nigeria. In *Soil Management in Tropical America*, ed. Bernemisza E and Alvarade, Ap. p. 372-408. North Carolina State University, Raleigh.

MOORMAN, F.R. and B.T. KANG. 1978. Microvariability of soils in the tropics and its agronomic implications with special reference to West Africa: In diversity of soils in the tropics. *ASA Special Publ.* **34:** 29-43.

MOSS R.P. 1957. Report on the classification of soils found over the sedimentary rocks in Western Nigeria. Soil survey Department No. 67, I.A.R.T University of Ife, Moor Plantation, Ibadan.

MURPHY and J.P RILLEY. 1962. A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta* **27:** 31-36.

OGUNKUNLE, A.O. 1986. Spatial variability of some chemical properties in two Ultisol mapping units in Southern Nigeria. *Soil Survey and Land Evaluation* **6:** 26-32.

OGUNKUNLE, A.O. 1988. Influence of weeding implements on soil properties and oil palm yield in Southern Nigeria. *Journal of Food and Agriculture* **2:** 63-69.

SOPHER, C.D. and R.J. MCCRACKEN. 1973. Relationships between soil properties, management practices and corn yield on South Altantic Covered Plain Soils. *Agron. J.* **65:** 595-600.

TALUKDAR H. and H.R. BARTHAKUR. 1986. Seasonal Variation in Azolla biomass production in Jorhat. International Rice Newsletter (IRR, V: II **(3)** p. 28-29.

TAMLINSON, P.R. 1970. Variations in usefulness of rapid soil mapping in the Nigeria Savannah. *J. Soil Sci.* **21:** 162-172.

VAN WAMBELLE, A. and R. DUDAL. 1978. Ma cravariability of soils of tropics. In diversity of soils in the tropics. *ASA Special Publ.* **34:** 13-281.

WILDING, L.P. and L.R DREES. 1978. Spatial variability. A pedologists viewpoint. In diversity of soils in the tropics. *ASA Special Publ.* **34:** 1-12.

(Received: 28 July 1998)
(Accepted: 25 September 2001)

Pertanika J. Trop. Agric. Sci. 25(1): 19 - 26 (2002) ISSN: 1511-3701

The Distribution of Muscle and Bone Weight in Swamp Buffalo (*Bubalus bubalis*), *Bos indicus* and *Bos taurus* Steers

E.R. JOHNSON[1], D.D. CHARLES[2], & D.A. BAKER
[1]*School of Veterinary Science,*
The University of Queensland, St Lucia 4072, Australia
[2]*78 Cairns Street, Kangaroo Point, Queensland 4169*

Keywords: Distribution, carcass components, *Bubalus bubalis*

ABSTRAK

Penyebaran berat otot dan tulang 15 ekor kerbau (Bubalus bubalis) *jantan dibandingkan dengan 15 ekor lembu jantan masing-masingnya daripada baka Angus, Hereford dan Brahman. Penyebaran berat otot dan tulang kerbau menunjukkan peralihan ke arah bahagian hadapan badan. Bahagian yang terlibat ialah servital, toraks dan tulang kaki hadapan dan "piawia tumpulais otot" 5, 7 dan 9. Brahmans menunjukkan penyebaran otot yang sama tetapi tidak setanding dengan kerbau. Skapula di bahagian belakang kerbau juga berlainan. Ianya hipotrofi dibandingkan dengan baka yang lain dengan pembesaran otot* supraspinatus *dan otot* infraspinatus *tetapi otot* subscapularis *yang ringan. Adalah dicadangkan bahawa perbezaan penyebaran itu mencerminkan "traction" masa lampau kerbau dan Brahmans.*

ABSTRACT

The muscle weight distribution and bone weight distribution of 15 buffalo (Bubalus bubalis) *steers were compared with that of 15 steers from each of three breeds of cattle, Angus, Hereford and Brahman. For both muscle weight distribution and bone weight distribution, buffaloes showed a "shift" towards the forequarter. This involved the cervical, thoracic and forelimb bones and standard muscle groups 5, 7 and 9. Brahmans showed a similar but less pronounced distribution to that of the buffaloes. The scapula was an exception in the forequarter of the buffaloes. It was lighter relative to the other breeds with clearly enlarged mm.* supraspinatus *and* infraspinatus *but a lighter m.* subscapularis. *It is suggested that these distribution differences reflect the traction history of buffaloes and Brahmans.*

INTRODUCTION

Cattle were domesticated about 4000 to 6000 years B.C. (Zeuner 1963) although carbon-dated Jericho discoveries suggest that domestication may have occurred as early as 10,000 years B.C. (Boston 1963). The earliest domestication was in Mesopotamia and North West India.

Ploughing and the haulage of two-wheeled carts were practiced in the Mohenjodaro area about 3000 years B.C. and Banjaras carried merchandise on pack bullocks (Von Fürer-Haimendorf 1963). Rouse (1972) and Porter (1991) noted that the muscular power of cattle, particularly zebus, was used for transport and ploughing on most of the Indian sub-continent. Zeuner (1963) produced evidence that *Bos primigenius namadicus* had been in India before early Man and it showed several features in common with the zebu. The muscle power of cattle, particularly zebus, has been used for raising water, draft, cultivation, transport and haulage. Innumerable descendants of zebu native stock have found their way to Africa and South East Asia where they have been used as beasts of burden (Wheaton-Smith 1963).

The Buffalo has a 5000 year history, authenticated on seals struck in the Indus Valley, suggesting that by then, it had already been domesticated (Anon 1981). It was in use, in China, 4000 years ago where its legendary strength was used to supply farm power. It is now used as a "living tractor" in South China, Thailand, Indonesia, Philippines, India and Pakistan. In Egypt, it is the most important domestic animal (Anon 1981).

In the rice fields, the swamp buffalo (*Bubalus bubalis*) is generally preferred to cattle (oxen) as a draft animal because of its slow, steady capacity for work (Rouse 1972). The animal is used for ploughing, harrowing and hauling loaded carts.

The yoke on the working buffalo in Asia has changed very little in the last 1500 years (Anon 1981). This hard, wooden yoke presses on a very small area, about 200 square centimetres, on top of the animal's neck, which probably has not enabled it to exert its full pulling power.

In the current study, the muscle weight distribution and bone weight distribution of the carcass are examined in castrated male swamp buffaloes (*Bubalus bubalis*) and compared with the distributions in *Bos indicus* and *Bos Taurus* steers.

MATERIALS AND METHODS

Fifteen swamp buffalo (*Bubalus bubalis*) steers and fifteen steers each of Angus, Hereford and Brahman breeds were slaughtered, dressed and chilled at 3°C. A side from each carcass was dissected into individual muscles, bones or bone groups, fat and connective tissue using the technique described by Butterfield (1963). Individual muscles were combined into nine "standard" muscle groups (SMG's) and the bones into 11 bones or bone groups as shown in Tables 1 and 2.

Some details of the carcasses are shown in Table 3.

Tests of significance were conducted for the distribution of muscle and bone among the four groups of steers.

TABLE 2

Bone or bone groups	Approximate proportion of total bone weight (%)*
Ossa coxa	11
Patella	0.7
Femur	11
Tibia + tarsus	10
Lumbar vertebrae and 3 ribs	10
Scapula	5.3
Humerus	9
Radius/ulna + carpus	8
Sternum + costal cartilages	7
Cervical vertebrae	7
Thoracic vertebrae + 10 ribs	21

*Johnson, Charles and Baker, from 100 total anatomical dissections

RESULTS

The differences in muscle weight distribution of each Standard Muscle Group (SMG) are shown in Table 4. Buffalo and Brahman steers had less muscle in the spinal (SMG 3) and abdominal (SMG4) groups than Angus and Hereford steers. Buffaloes generally, had a greater weight of muscle concentrated in the forequarters, particularly the shoulder (SMG 5), thorax to shoulder (SMG 7) and intrinsic muscles of the neck (SMG 9). Brahman steers generally, had more muscle concentrated in the proximal hind limb (SMG 1), neck to shoulder (SMG 8) and intrinsic muscles of the neck (SMG 9). Relative to the Herefords, Angus steers showed a lower proportion of hind leg muscles (SMG 1 and SMG 2)

TABLE 1

Standard muscle group (Butterfield 1963)	Description	Approximate proportion of total muscle weight (%)*
1	Muscles of the proximal pelvic limb	32
2	Muscles of the distal pelvic limb	4.5
3	Surrounding spinal column in thorax and lumbar regions	12
4	Abdominal muscles	10
5	Muscles of proximal forelimb	11
6	Muscles of distal forelimb	2.5
7	Muscles of thorax attaching to forelimb	10
8	Muscles of neck attaching to forelimb	7
9	Intrinsic muscles of neck and thorax	10

* Johnson, Charles and Baker, from 100 total anatomical dissections

TABLE 3
Details* of *Bubalus bubalis, Bos taurus* and *Bos indicus* carcasses

Description	Buffalo	Angus	Hereford	Brahman
Chilled carcass	169 - 260	176 - 390	95 - 273	46 - 347
weight (kg)	208.6	271.2	163.7	266.5
	(27.4)	(68.3)	(49.7)	(53.1)
Age (months)	24 - 46	16 - 42	15 - 22	12 - 38
	29.4	25.9	18.7	23.7
	(5.0)	(9.8)	(2.5)	(10.6)
Carcass Composition				
Muscle	58.3 - 69.7	51.4 - 63.3	50.2 - 65.5	55.3 - 65.5
	64.8	57.1	61.5	60.8
	(3.6)	(3.6)	(4.5)	(3.1)
Bone	13.3 - 18.0	10.6 - 17.1	12.6 - 22.0	12.1 - 23.1
	15.3	12.8	16.1	15.4
	(1.4)	(1.7)	(2.8)	(3.2)
Fat	8.6 - 25.5	20.1 - 36.4	9.1 - 35.3	13.4 - 30.3
	17.0	28.1	19.7	21.7
	(5.1)	(5.0)	(7.3)	(5.1)

* Range and mean with standard deviation shown in parenthesis

TABLE 4
Muscle weight distribution of the standard muscle groups

Standard muscle group	Muscle weight distribution (%)			
	Angus	Hereford	Brahman	Buffalo
1	31.6^{a}	321^{a}	33.3	31.7^{a}
2	4.4^{b}	4.8^{a}	4.5^{bc}	4.7^{ac}
3	12.5^{a}	12.6^{a}	12.1	10.5
4	10.5	9.4^{b}	8.7^{a}	9.1^{ab}
5	11.2^{b}	11.5^{a}	11.2^{ab}	12.4
6	2.5^{b}	2.7^{a}	2.6^{ab}	2.7^{a}
7	10.1^{ab}	9.8^{b}	9.1	10.1^{a}
8	7.0^{b}	6.9^{b}	7.6^{a}	7.3^{ab}
9	9.5^{b}	9.3^{b}	10.1^{a}	10.2^{a}

Means with the same superscript are not significantly different (P<0.05)

and forelimb muscles (SMG 5 and SMG 6), but a greater proportion of abdominal (SMG 4) and thorax to shoulder (SMG 7) muscles.

Buffaloes showed a shift in their musculature towards the shoulder, thorax and cervical regions. Brahman steers showed a similar, but less spectacular shift, towards the neck and shoulder region. They also showed an increase of about 1.5% in the muscles of the proximal pelvic limb where some of the carcass's most expensive cuts are located.

Table 5 shows the significantly different individual muscle weight distributions among the four steer groups, listed according to the SMG.

The lowered distribution of SMG 3 and SMG 4 in the buffaloes and Brahmans was supported by the individual muscle weight distribution study. Buffaloes had much less *m. longissimus thoracis et lumborum* (1.3% to 1.7%). *psoas* muscles and *mm. scalenus dorsalis, multifidus dorsi* and *quadratus lumborum.* Brahmans had less *m. longissimus thoracis et lumborum* and less *mm. scalenus dorsalis, iliocostalis* and *spinalis dorsi.*

In SMG 4, buffaloes had generally less of four major muscles (*mm. obliquus internus abdominis, obliquus externus abdominis, transversus abdominis* and *rectus abdominis*). The Brahman steers, like the buffaloes, had less *mm. obliquus*

TABLE 5
Significant differences in individual muscle distribution among *Bubalus bubalis*, *Bos taurus* and *Bos indicus* steer carcasses

Muscle	Breed means			
	Buffalo	Angus	Hereford	Brahman
SMG 1				
Tensor fasciae latae	1.37a	1.29ab	1.29b	1.36ab
Biceps femoris	8.09	7.27a	7.20a	7.41a
Gluteus medius	3.59a	3.70a	3.76a	4.11
Gluteus accessorius	0.45	0.29a	0.29a	0.28a
Gluteus profundus	0.33b	0.35b	0.39a	0.39a
Vastas lateralis	2.84	2.32a	2.43a	2.57
Rectus femoris	2.34	1.99a	2.07a	2.05a
Vastus medialis	0.53	0.72ab	0.75a	0.69b
Vastus intermedius	0.50	0.64a	0.71	0.62a
Gracilis	1.08	1.31a	1.30a	1.45
Sartorius	0.30bc	0.34ab	0.35a	0.29c
Semimembranosus	4.05	5.02a	5.06a	5.42
Adductor femoris	1.40	1.71a	1.80a	1.92
Pectineus	0.50c	0.53bc	0.59a	0.55ab
Gemellus	0.07a	0.07a	0.09	0.08a
Quadratus femoris	0.06a	0.05a	0.07	0.05a
Iliacus	1.05	0.77	0.87a	0.84a
Articularis genu	0.05b	0.06b	0.08a	0.08a
Sacrococcygeal	0.09a	0.13	0.10a	0.08a
SMG 2				
Gastrocnemius + soleus	2.15	1.85b	1.97b	1.94b
Superficial flexor (plantaris)	0.28	0.42ab	0.46a	0.39b
Extensor group	0.53	0.62a	0.70	0.64a
Extensor digitorum lateralis	0.27a	0.20a	0.22b	0.25a
Tibialis anterior	0.13a	0.11bc	0.12ab	0.11c
Tibialis posterior	0.14	0.10b	0.11ab	0.11a
Popliteus	0.34	0.24a	0.27a	0.31
Flexor digitorum longus	0.14b	0.20a	0.20a	0.15b
Flexor hallicus longus	0.60a	0.60a	0.61a	0.54
SMG 3				
Psoas minor	0.29b	0.28b	0.31ab	0.35a
Psoas major	1.29	1.56a	1.58a	1.56a
Quadratus lumborum	0.15b	0.17a	0.16ab	0.17a
Scalenus dorsalis	0.21b	0.29	0.25a	0.22ab
Iliocostalis	0.51a	0.45b\	0.48ab	0.40
Longissimus thoracis et lumborum	5.23	6.93a	6.78ab	6.54b
Spinalis dorsi	1.84a	1.78a	1.82a	1.62
Multifidus dorsi	0.79	0.99a	1.02a	1.06a
SMG 4				
Retractor costae	0.03b	0.05a	0.04ab	0.03b
Obliquus internus abdominis	1.67a	1.99	1.86	1.67a
Obliquus externus abdominis	2.15a	2.49	2.24a	1.88
Transversus abdominis	1.00	1.27	1.16a	1.12a
Rectus abdominis	1.88	2.31a	2.18a	2.14a
Cutaneus trunci et omobrachialis	1.58bc	1.82a	1.64ab	1.45c

TABLE 5 cont'd
Significant differences in individual muscle weight distribution among *Bubalus bubalis*, *Bos taurus* and *Bos indicus* steer carcasses

SMG 5				
Deltoideus	0.60	0.49a	0.52	0.47a
Infraspinatus	2.19a	2.17ab	2.16ab	2.06b
Supraspinatus	1.90	1.50b	1.55ab	1.58a
Subscapularis	1.05	1.15a	1.13a	1.16a
Triceps brachii (caput laterale)	0.68ab	0.67ab	0.69a	0.65b
Triceps brachii (caput longum)	3.75	3.17a	3.15a	3.33
Triceps brachii (caput mediale)	0.11a	0.09b	0.10a	0.08b
Tensor fascia antibrachii	0.13b	0.15a	0.15a	0.14ab
Teres minor	0.18a	0.18a	0,20	0.17a
Teres major	0.47	0.41a	0.42a	0.42a
Biceps brachii	0.67a	0.60c	0.62bc	0.64ab
Coracobrachialis	0.13a	0.13a	0.13a	0.15
Brachialis	0.55	0.43	0.46a	0.46a
SMG 6				
Extensor carpi radialis\	0.78	0.72a	0.73a	0.73a
Extensor digiti tertii	0.15	0.12b	0.12ab	0.13a
Extensor digitorum communis	0.10	0.08a	0.08a	0.08a
Extensor digiti quarti	0.17	0.12	0.14a	0.13a
Extensor carpi ulnaris	0.32	0.26	0.29a	0.30a
Extensor carpi obliquus	0.03	0.03a	0.03a	0.03a
Flexor carpi radialis	0.10b	0.10b	0.11a	0.10ab
Flexor carpi ulnaris	0.10	0.13b	0.13ab	0.14a
Flexor digitorum profundus	0.54b	0.60a	0.63a	0.55b
Anconaeus	0.11a	0.09	0.11a	0.11a
SMG 7				
Serratus ventralis thoracis	1.70a	1.58ab	1.55b	1.25
Pectoralis profundus	3.53	3.81ab	3.89a	3.70b
Pectoralis superficialis	1.50a	1.69	1.42a	1.54a
Latissimus dorsi	2.73	2.24a	2.24a	2.02
Trapezius thoracis	0.67a	0.79	0.70a	0.59
SMG 8				
Trapezius cervicalis	0.48a	0.52a	0.50a	0.29
Omotransversarius	0.68	0.57a	0.56a	0.60a
Brachiocephalicus	1.88	1.56a	1.55a	1.59a
Rhomboideus	1.23a	1.37a	1.29a	2.03
Serratus ventralis cervicalis	3.02ab	2.94b	3.21a	3.10ab
SMG 9				
Serratus dorsalis cranialis	0.20	0.14a	0.12a	0.13a
Cervicohyoideus	0.09	0.02a	0.02a	0.04
Splenius	1.09a	0.81b	0.77b	1.05a
Complexus	1.57	1.68a	1.69a	1.69a
Scalenus ventralis	0.51a	0.44b	0.45b	0.49ab
Rectus capitis ventralis major	0.32	0.18a	0.19a	0.19a
Longissimus capitis et atlantis	0.23	0.33a	0.30a	0.31a
Intertransversarius colli	0.81	0.59b	0.61ab	0.67
Rectus capitis dorsalis major	0.14ab	0.12b	0.13b	0.16a
Obliquus capitis caudalis	0.40a	0.33	0.36b	0.38ab
Rectus thoracis	0.14	0.12a	0.13a	0.12a
Transversus thoracis	0.20ab	0.22a	0.21ab	0.20b
Longus colli	0.91a	0.78b	0.73b	0.98a
Intercostales	2.67b	2.58a	2.76ab	2.84ab

Means with the same superscript are not significantly different (P<0.05)

internus abdominis, obliquus externus abdominis and cutaneous trunci et omobrachialis.

The greater muscle weight distribution in the buffalo forequarter occurred in SMGs 5, 7 and 9. In the latter group, the buffaloes and Brahmans had a similar distribution. In SMG 5, eight muscles were hypertrophied (*mm. deltoideus, infraspinatus, supraspinatus, teres major, brachialis* and all three heads of the triceps group). It should be noted that, concurrent with the relatively lighter scapula, although *mm. infraspinatus* and *supraspinatus* were enlarged, *m. subscapularis* was relatively lighter. In SMG 6, the buffaloes showed a relative enlargement of all six extensor muscles. In SMG 7, the enlarged muscles were *mm. serratus ventralis thoricis and latissimus dorsi.* In SMG 9, the buffaloes showed an enlargement of nine muscles, particularly *mm. splenius* and *intertransversarii cervicis.* Buffaloes and Brahmans, generally, had less of all the major muscles in SMG 4.

The Brahman steers showed a relative enlargement of muscles in SMGs 1, 8 and 9. In SMG 1, they showed increased distribution in *mm. tensor fasciae latae, gluteus medius, gluteus profundus, vastus lateralis* and *rectus femoris.* Most of these are large muscles and clearly explain the superior distribution of the Brahman's proximal hindlimb musculature. In SMG 8, the Brahmans showed an increased distribution in *mm. rhomboideus* and *serratus ventralis cervicis.* In SMG 9, the Brahmans were relatively hypertrophied in six large muscles, *mm. scalenus ventralis, splenius, complexus, longus colli, longissimus capitis et atlantis* and *intercostales.*

Relative to Herefords and Brahmans, Angus showed less muscle in the large muscles of SMG 1 (*mm. biceps femoris, gluteus medius, gluteus profundus, vastus lateralis, rectus femoris, semimembranosus and adductor femoris*); SMG 2 (*m. gastrocnemius et soleus, the extensor group, extensor digitorum lateralis, popliteus* and both *tibial muscles*); SMG 5 (*mm. deltoideus, supraspinatus, biceps brachii, brachialis* and the long and medial heads of the triceps group); SMG 6 (*mm. flexor carpi radialis, flexor carpi ulnaris* and a number of small extensors). Relative to the Herefords and Brahmans, the Angus steers showed a greater proportion of muscle in SMG 4 (*mm. obliquus internus abdominis, obliquus externus abdominis,* and *transversus abdominis*) and SMG 7 (*mm. serratus ventralis thoricis, trapezius thoracis* and both pectoral muscles).

Table 6 shows the significant differences in bone weight distribution among the four groups. Buffaloes showed a lower proportion on bone in the pelvic and lumber areas and a greater proportion of bone in the cervical and thoracic areas, as well as the humerus, radius/ulna and carpus. Although buffaloes had about 1% more muscle in the proximal forelimb, their scapula was significantly lighter than those of the other three groups. Brahmans, like the buffaloes, had a generally lower proportion of bone in the pelvic and lumbar regions but a greater proportion in the limbs (femur, tibia and tarsus, humerus, radius/ulna and carpus). Relative to Herefords, Angus showed a higher proportion of bone in both limbs, in accord with their muscle weight distribution pattern.

TABLE 6
Bone weight distribution

Bone or bone group	Bone weight distribution (%)			
	Angus	Hereford	Brahman	Buffalo
Ossa coxa	11.5a	11.2a	11.2a	10.7
Patella	0.70a	0.75a	0.73a	0.71a
Femur	10.2	11.0a	11.0a	10.8a
Tibia + tarsus	9.7b	10.4a	10.3a	10.1ab
Lumbar Vertebrae + 3 ribs	11.2b	10.6ab	10.3a	10.3a
Scapula	5.3a	5.3a	5.3a	5.0
Humerus	8.2	8.7a	8.8a	9.0a
Radius/ulna + carpus	7.2	7.5b	7.8ab	8.0a
Sternum + costal cartilages	7.5b	6.9ab	6.5a	5.8
Cervical vertebrae	7.3a	7.0a	7.3a	8.1
Thoracic vertebrae + 10 ribs	21.3a	20.5a	20.7a	22.8

Means with the same superscript are not significantly different ($P<0.05$)

DISCUSSION

The Australian water buffalo was introduced from Timor in 1825 (Letts 1972). In South East Asia, the buffalo has long been preferred to cattle as the primary beast of burden. In Australia, over the last 170 years, it has not been used for traction.

Relative to cattle, the buffalo has concentrated more muscle in the forequarter, particularly muscles of the proximal and distal forelimb, thorax to forelimb, and muscles of the neck. This is supported by the bone weight distribution, which shows heavier bone in the cervical and thoracic areas, humerus, radius/ulna and carpus. A notable exception was the scapula, which was lighter in the buffalo than in the three breeds of cattle.

The individual muscle weight distribution study supported the findings of the SMGs, with relatively hypertrophied muscles in the shoulder (eight in SMG 5), distal forelimb (seven in SMG 6), thorax to shoulder (two large muscles in SMG 7) and the intrinsic muscles of the neck (nine in SMG 9). The buffalo showed a reduction in muscle weight distribution in the spinal muscles (four in SMG 3, including a great reduction in m. longissimus et lumborum) and the abdominal muscle group (five expansive muscles in SMG 4). The Brahman steers showed a similar decrease in distribution in these two muscle groups, but an increase in 15 muscles of the three groups, proximal hindlimb (SMG 1), neck to shoulder (SMG 8) and the intrinsic muscles of the neck (SMG 9).

Relative to Herefords and Brahmans, the Angus showed a reduction in muscle weight distribution in 21 muscles of the proximal and distal hindlimb, shoulder and distal forelimb. This group of steers had a markedly increased distribution in the abdominal and thorax to shoulder groups of muscles.

In relation to the shoulder area (SMGs 5 and 7), the buffaloes showed an increased weight distribution in nine muscles including *mm. supraspinatus, infraspinatus, deltoideus, serratus ventralis thoricis, latissimus dorsi* and the two heads of the triceps group, however, *m. subscapularis* was lighter.

Relative to Angus and Hereford steers, Brahmans showed evidence of a shift in muscle and bone weight distribution to the forequarter, although not as pronounced as in the buffalo. The Brahmans had an increased weight of neck to forelimb muscles and intrinsic muscles of the neck. The limb bones of Brahman steers, femur, tibia/tarsus, humerus, radius/ulna and carpus were generally heavier than in the other cattle, particularly the Angus. Brahmans had significantly more muscle (1.2% to 1.7%) in the proximal hind limb than in the other three groups. This is the site of some relatively expensive cuts of meat, thick flank, topside and silverside which confers on this breed a meat production advantage which has been recognized from detailed anatomical studies (Priyanto 1993; Priyanto, Johnson and Taylor unpublished).

Herefords differed from Angus, showing more muscle in the limbs (SMGs 1, 2, 5 and 6) and less in the abdominal group (SMG 4). Angus had heavier bone in the sternum and costal cartilages and in the lumbar vertebrae and last three ribs.

The significantly lighter scapula and *m. subscapularis* in buffaloes may be related to the wooden yoke, which has not changed for at least 1500 years, and this probably prevents the animal from exerting its full pulling power (Anon 1981). It has been estimated that the use of a padded horse collar would allow the buffalo to pull 24% heavier weights. An impeded scapula may have become more compact and lighter while increasing the weight of the muscles clothing the outside of it.

The higher proportion of the weight of muscle in the buffaloes and Brahmans relative to that in Herefords and Angus is possibly a result of their draft animal ancestry. The difference was more pronounced in the buffalo, which has been the preferred beast of burden in China and South East Asia for 4000 years.

ACKNOWLEDGEMENT

We are indebted to Mr. Mal Fisher and Miss Lyn Knott for technical assistance.

REFERENCES

ANON. 1981. *The Water Buffalo: New Prospects of an Underutilized Animal.* Washington: National Academy Press.

BOSTON, E.J. 1963. Cattle breeds in Europe and Africa. In *Man and Cattle* ed. A.E. Mourant and F.E. Zeuner. London: Royal Anthropological Institute.

BUTTERFIELD, R.M. 1963. Estimation of carcase composition: The anatomical approach. In *Symposium of Carcase Composition and Appraisal of Meat Animals*, ed. D.E. Tribe, Pap. No 4 (CSIRO Aust: Melbourne).

LETTS, G.A. 1972. Water Buffalo in Australia. A collection of papers related to the Northern Territory Buffalo Industry. In *Ninth Biennial Conference of the Australian Society of Animal Production*, Canberra.

PRIYANTO, R. 1993. A study of the growth and distribution of beef carcass tissues including their prediction, optimum beef productivity and marketing. Ph.D. Thesis, The University of Queensland, Brisbane.

PORTER, V. 1991. *Cattle. A Handbook to the Breeds of the World. Facts on File.* New York.

ROUSE, J.E. 1972. *World Cattle II. Cattle of Africa and Asia.* Norman: University of Oklahoma Press.

VON FÜRER-HAIMENDORF, C. 1963. The Social Background of Cattle - Domestication in India. In *Man and Cattle* ed. A.E. Mourant and F.E. Zeuner. London: Royal Anthropological Institute.

WHEATON-SMITH, C. 1963. Study in Progressive Hybridization. In *Man and Cattle* ed. A.E. Mourant and F.E. Zeuner. London: Royal Anthropological Institute.

ZEUNER, F.E. 1963. The History of Domestication of Cattle. In *Man and Cattle* ed. A.E. Mourant and F.E. Zeuner. London: Royal Anthropological Institute.

(Received: 3 September 1998)
(Accepted: 14 January 2002)

Pertanika J. Trop. Agric. Sci. 25(1): 27 - 34 (2002)
ISSN: 1511-3701

A Preliminary Study on the Germination of *Eurycoma longifolia* Jack (Tongkat Ali) Seeds

CHAN LAI KENG, SU TIING SAI & CHRIS K.H. TEO
School of Biological Sciences, Universiti Sains Malaysia, 11800 Penang, Malaysia

Keywords: ***In vitro germination, jiffy, endorcarp, MS culture medium, seedlings***

ABSTRAK

Eurycoma longifolia *(Tongkat Ali) menghasilkan buah dalam satu tangkai terdiri daripada 200 - 300 biji. Pokok Tongkat Ali didapati berbuah dengan banyak pada bulan September tetapi bilangan anak benih yang tumbuh di atas lantai hutan hanya sedikit sahaja. Kami mendapati bahawa biji benih yang mempunyai endokarpa keras hanya mula bercambah 43 hari selepas disemai dalam 1:1 campuran pasir dan tanah dan percambahan biji berlaku sehingga 99 hari. Campuran tanah ini adalah setanding dengan kandungan tanah hutan yang paling optimum untuk percambahan biji benih Tongkat Ali. Biji benih yang tidak menanggalkan lapisan endokarpa bercambah dalam pelet jiffy di antara 35 hingga 85 hari. Tetapi dengan menanggalkan lapisan endokarpa, biji benih Tongkat Ali didapati bercambah dalam tempoh masa dua minggu dengan mengkulturkan biji benih secara* in vitro *dalam medium kultur asas Murashige dan Skoog (MS) (Murashige & Skoog, 1962). Biji yang matang didapati bercambah dengan baik dalam campuran tanah dan pasir (1:1) dan juga dalam pellet jiffy. Tetapi biji benih muda dengan menanggalkan lapisan endokarpa bercambah lebih cepat (CVG = 0.2053) secara* in vitro. *Kesemua anak benih didapati mempunyai corak pertumbuhan yang sama dalam jangka masa 120 hari dari segi ketinggian anak benih, bilangan daun yang dihasilkan dan garis pusat batangnya walaupun biji benih dicambah dalam medium percambahan yang berlainan.*

ABSTRACT

Eurycoma longifolia *fruits are borne in large bunches consisting of 200-300 fruits in each bunch. Even though trees produce abundant fruits during the peak fruiting season in September, yet the number of seedlings found growing in the forest floor is very low. Our results indicated that the seeds with hard endocarp sown in a 1:1 soil and sand mixture only start to germinate 43 days after sowing and continue to germinate over a period of 99 days. The soil and sand mixture (1:1) is equivalent to that of the forest sandy soil combination that was optimum for germination of* Eurycoma longifolia *seeds. The seeds with endocarp intact that are sown in jiffy germinated within 35-85 days. However, when the endocarp of seeds were removed, the seeds germinated within two weeks via* in vitro *culture using basic MS medium. The ripe seeds germinated better when sown in the 1:1 soil and sand mixture than in jiffy pellets. But the unripe seeds with the endocarp removed seemed to germinate faster (CVG = 0.2053) when cultured* in vitro *in basic MS medium. All the seedlings were found to have the same growth pattern in terms of seedling height, number of leaves produced, and the stem diameter irrespective of germination methods over a period of 120 days.*

INTRODUCTION

Eurycoma longifolia Jack belongs to the family Simaroubaceae, which is commonly known as Tongkat Ali in Malaysia and Singapore. It is also native to Indochina, Borneo and Sumatra. This tree can grow to about 12 meters and is usually unbranched or with a few upright branches. Each branch is crowned by an umbrella-like rosette of pinnate compound leaves of 20-30 cm in length. Each leaf consists of 20-30 pairs of narrowly oblong, leathery, dark green entire type of leaflets with shining dark brown leaf stalk (Corner 1988). In Malaysia, *E. longifolia* Jack commonly grow at low altitude, up to 700 meters in beach forests on sandy soil as understorey treelets (Nooteboom 1962).

E. longifolia is dioecious, producing hairy, purplish-crimson bell-like flowers in long and branched panicles. The female flowers consist of five petals, an ovary, one style with a 5-lobed

stigma and always with large but sterile stamens. The male flowers produce five stamens with a sterile pistil. The ovoid shape fruits are borne in a large dangling axillary bunch. Its peak flowering season is from June to July and with peak fruiting in September (Corner 1988).

Even though trees produce abundant fruits and seeds during each fruiting season, the number of seedlings found growing around the adult trees is low. Until now, the germination behavior of the seeds has not been studied. Therefore we wished to determine the general morphology of *E. longifolia* fruits and seeds, and how its structures influenced seed germination behavior. Their capacity to germinate under laboratory conditions and the growth pattern of its seedlings were studied. The possibility of using *in vitro* seed germination as an alternative method for enhancing the seed germination of *E. longifolia* Jack was also investigated.

MATERIALS AND METHODS

Fruit and Seed Morphology

E. longifolia fruits were collected from a secondary forest in Penang, Malaysia at three different sites namely Bayan Lepas, Teluk Bahang and Teluk Kumbar. A study was done on the external morphology and cross-section of the fruit and seed.

Germination Test

a. *Effects of Germination Methods and Seed Maturity on Seed Germination*

The fruits were removed from each bunch which consisted of approximately 200 to 300 fruits and grouped as young, unripe, green seeds and matured, ripe, red or dark-red seeds. Twenty seeds were taken randomly from each bunch and from each grouping to study the effect of each of the germination methods on seed germination.

The three germination methods were:-

1. The seeds were sown approximately one cm deep in a 1:1 soil and sand mixture.
2. The seeds were sown in jiffy pellets (Jiffy Products Ltd., Norway). These jiffy pellets were made up of peat soil and each seed was placed in each pellet.
3. The seeds were germinated via the *in vitro* technique. For this technique, the epicarp and mesocarp of the fruits were removed. The seeds were washed with detergent, then rinsed in running tap water for 30 minutes. The seeds were then immersed in a 250 ml conical flask containing 20% (v/v) Clorox® solution which contained 5.25% sodium hypochlorite and three drops of tween-20 for 20 minutes, with continuous agitation. This was followed by rinsing three times with sterile distilled water. Surface sterilization of these seeds was repeated with 15% Clorox® solution for 15 minutes and again rinsed three times with sterile distilled water. The sterilized seeds were then placed on the surface of 15 ml Murashige and Skoog basic medium (MS) (Murashige & Skoog 1962) contained in 25x150mm culture tubes capped with autoclavable plastic caps (Jenaerglas, Rasotherm, Germany).

Twenty seeds were used for each germination method and the study was repeated three times. Percentage of germination for each method was recorded over a 120-day period. Germination was determined by the emergence of the radical and epicotyl on the germination medium surface. The effects of germination methods and maturity of seeds and their interactions on percentage of germination were analyzed using analysis of variance (ANOVA).

b. Influence of Endocarp (testa) on Seed Germination

The endocarp was removed after the seeds were surface sterilized twice as mentioned above. The seeds with the endocarp removed were again surface sterilized with 5% Clorox® solution for 10 minutes, rinsed three times with sterile distilled water and placed in 25 x 150 mm culture tubes containing 15 ml MS basic medium. Twenty seeds were used for each trial and the experiment was repeated three times. Percentage of germination was recorded over a period of 120 days.

c. Determination of the Coefficient of Velocity of Germination

The coefficient of velocity of germination (CVG) was computed based on Hartman and Kaster (1968):

$$CVG = \frac{\text{Total number of germination}}{A_1T_1 + A_2T_2 + \ldots\ldots\ldots + A_nT_n}$$

where A = number of fresh germination recorded at each day interval
T = number of days from sowing.

The effects of germination methods and the maturity of seeds, and their interactions on the coefficient of velocity of germination were computed using ANOVA.

The Growth Pattern of Seedlings

Two weeks after germination, the seedlings were transferred to 15 x 23 cm polybags containing a 1:1:2 mixture of organic manure: top soil: sand. These seedlings in polybags were placed in a plant house at a temperature of between 28-30°C. The height of the seedlings was recorded every week starting from the emergence of the epicotyl, while the stem diameter was recorded every month. Plant height was taken as the distance from the tip of the shoot apex to the first node on the plant. Stem diameter was measured with a pair of calipers (Kern, Germany) at the fifth node of the stem. The number of leaves produced over a fortnight period was estimated by counting the last tagged leaf of the previous recording to the most recently produced leaf.

RESULTS AND DISCUSSION

The fruits of *E. longifolia* were borne in a large dangling axillary bunch. The bunches of fruits that were collected consisted of 200-300 seeds per bunch. The fruits were produced in groups of 1-5 on the bunches (*Fig. 1*).

The fruits were yellow to light green when young, and became red to blackish-red when ripe. The ripe and unripe fruits were distributed randomly in the same bunch. The variation in fruit maturity within the bunch serves to minimize the competition for substrate for successful seed germination at the forest floor which is often overcrowded with secondary growth. As stated by Villier (1972), some seeds appear to be involved in controlling germination by restricting it to periods and conditions most favorable for seedling growth.

The fleshy drupe fruits were ovoid in shape and about 10-20 mm long and 5-12 mm broad. It consisted of a thin shining epicarp, fleshy mesocarp, hard and stony endorcarp. The seed consisted of two large expanded cotyledons and a chlorophyllous capitate embryo. With the endocarp removed, the seed could be seen to be covered with a thin papery covering, which could be easily removed from the inner surface of the endocarp (*Fig. 2*).

Seeds with the endocarp intact sown in the 1:1 soil and sand mixture started to germinate from the 43 days and continued to germinate until 99 days after sowing (Table 1). The inhibition and delay in germination could be due to a high degree of impermeability of the endocarp to water or oxygen or to both. This phenomenon was similar to that of winged bean seeds (*Psophocarpus tetragonolobus L.*) which showed very low percentage of germination due to impermeability of the seed coat to water (Rudrapal *et al.* 1992). Rolston (1978) also reported that impermeability of hard seed coats was typical of legume seeds.

Seeds sown in jiffy pellets germinated earlier and within a shorter period of time (35-85 days) as compared to those sown in 1:1 soil and sand mixture (43-99 days). This was because jiffy pellets consisted mainly of peat soil and were able to retain higher moisture content compared to the 1:1 soil and sand mixture, hence allowing more water absorption by the seeds. None of the seeds with endocarp intact germinated when cultured in vitro using the MS culture medium (Table 1). Blackening occurred on the non-germinated seeds with the endocarp

TABLE 1
Effect of germination methods and seed maturity on the duration of *E. longifolia* seeds germination (days) within a 120-day period

Germination methods for *E. longifolia* seeds [a]	Duration of germination (days)	
	Ripe seeds	Unripe seeds
sown in soil and sand mixture	45-99	43-93
sown in jiffy pellets	37-85	35-70
In vitro culture	No germination	No germination

[a] seeds used for germination are with endocarp intact

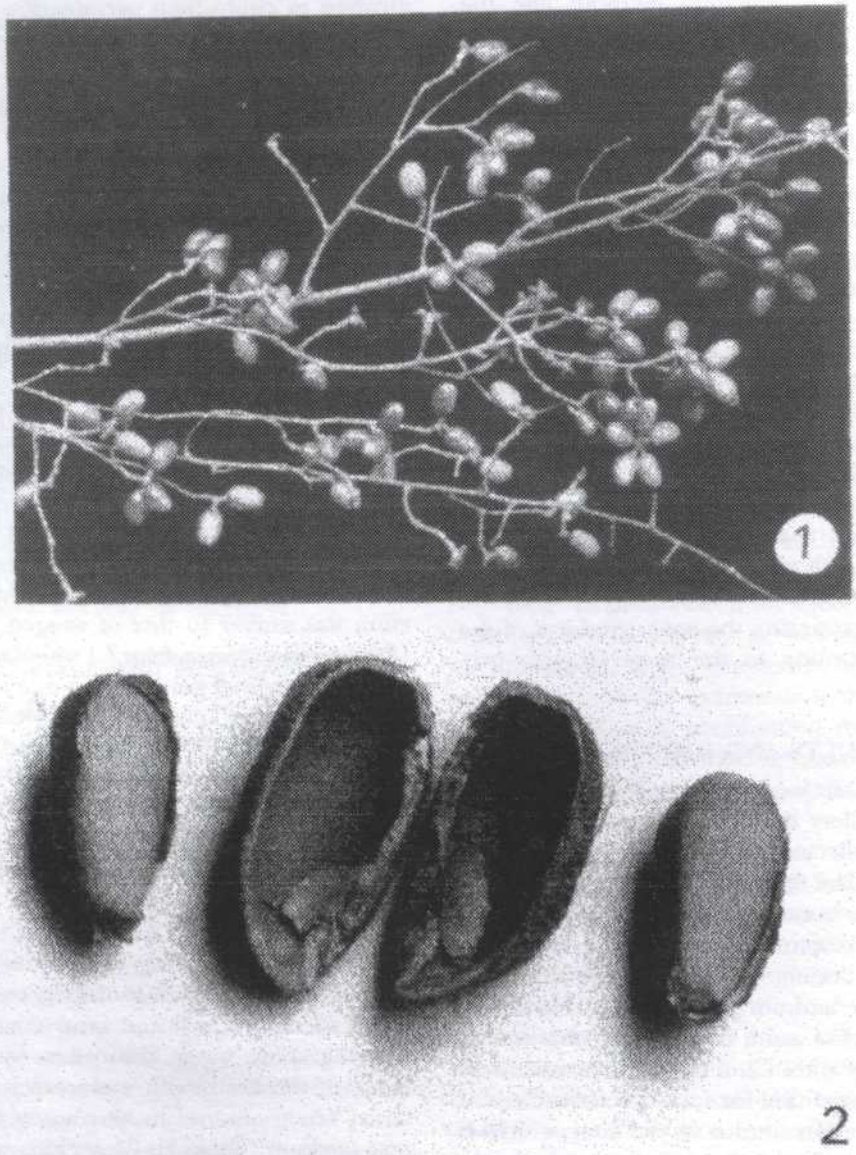


Fig. 1-2. E. longifolia fruits and seeds

1. E. longifolia fruits and groups of 1-5 in part of the bunches. 2. The seed with two large cotyledons and a chlophyllous capitate embryo covered with a thin papaery corvering which was easily removed from the stony endocarp

intact and also in the MS culture medium (*Fig. 3*). However, the seeds without endocarp did not release any black exudates (*Fig. 4*). Marbach and Mayer (1974) reported that black exudates released were mainly phenolic compounds and could contribute to the impermeability of seed coats to water, hence preventing germination of seeds.

Ripe *E. longifolia* seeds sown in a 1:1 soil and sand mixture or jiffy pellets germinated better than the unripe seeds. Ripe seeds sown in the soil and sand mixture (1:1) reached 58% germination over a 120-day period while only 46% of the unripe seeds sown in the same medium germinated at the same duration. Forty six percent of the ripe seeds sown in jiffy germinated over a 120-day period. Only 29% of the unripe seeds sown in jiffy germinated over the same duration. All the ripe and unripe seeds cultured *in vitro* did not germinate (*Fig. 5*). Rudrapal *et al.* (1992) proposed that the delayed germination of immature seeds was due to lower free

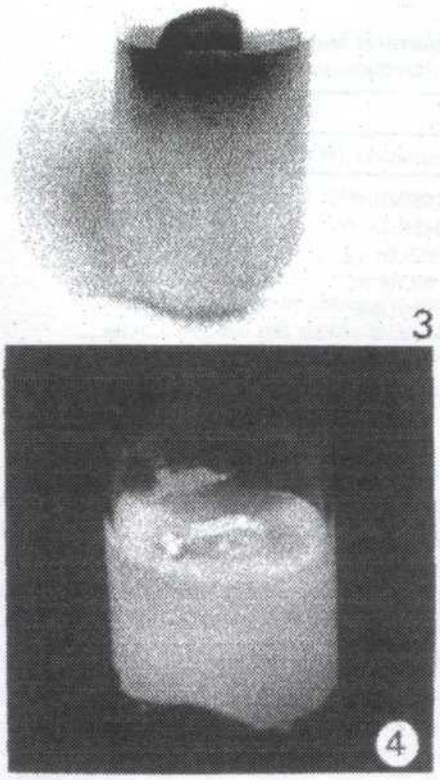


Fig. 3-4. Germination of E. longifolia seeds on MS culture medium.
3. Seed with endocarp intact released black exudates into the MS culture medium.
4. Seed without endocarp on MS culture medium clear of black exudates.

gibberellin content in embryo-cotyledon at the immature stage resulting in slower rate of water imbibition. Analysis of variance indicated that the different germination methods significantly affected (p=0.01) the percentage of germination of *E. longifolia* seeds. However, there were no significant differences in percentage of germination between the ripe and unripe seeds, and there was also no interaction between the ripeness of seeds and the different types of germination methods (Table 2).

The experimental results thus indicated that the stony endocarp did contribute to the germination process of these seeds. This was further supported by our findings on seeds with the endocarp removed starting to germinate 14 days after *in-vitro* cultured on MS medium. They continued to germinate until 64 days and none of the seeds with endocarp intact germinated on the same MS medium (Table 3). Edwards (1968) reported that most of the inhibition compounds that inhibited seed germination were usually located in the fruit wall or seed coat. Hence, this explained that *E. longifolia* seeds without endocarp would be able to germinate earlier.

With *in vitro* germination, the unripe seeds without endocarp germinated faster than the ripe seeds. The unripe seeds without endocarp showed maximum 53% germination while only 30% of the ripe seeds without endocarp germinated in the MS culture medium (*Fig 6*). This was further supported by the CVG results (Table 4) which indicated that unripe seeds with the endocarp removed, sown via the *in-vitro* method was the fastest to germinate, (CVG = 0.2053)

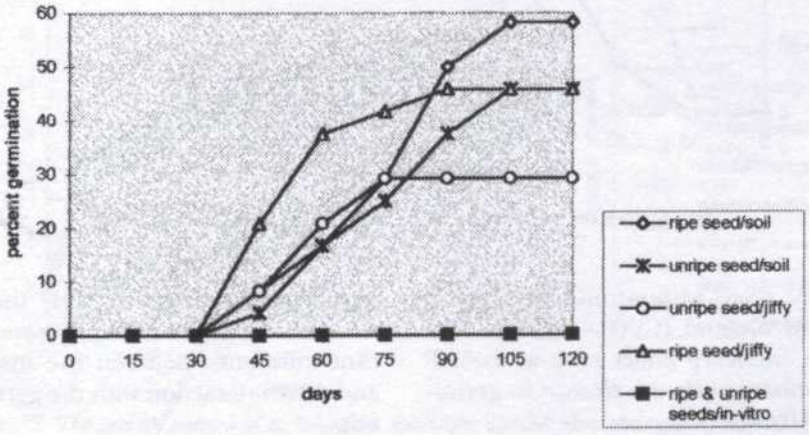


Fig. 5. Germination response of the ripe and unripe seeds of E. longifolia to different germination methods

TABLE 2
Analysis of variance for percentage of germination and coefficient of velocity of germination (CVG)

Source of variation	df	MS	
		Germination (%)[y]	CVG[x]
Treatment	5	1480.68 **	0.0159 **
Factor A (method)	2	3489.78 **	0.0363 *
Factor B (seed type)	1	255.08 ns	0.0015 ns
A x B	2	84.38 ns	0.0028 ns
Error	12	151.64	0.0013

y analysis based on arc sine value.
x analysis considers CVG data for in-vitro method using seeds without endocarp.
** significant at p=0.01.
ns not significant.

TABLE 3
Effect of e seed endocarp on the duration of *E. longifolia* seed germination using in vitro technique

Condition of seeds	Duration of germination (days)	
	Ripe seeds	Unripe seeds
Seeds with endocarp intact	No germination	No germination
Seeds with endocarp removed	18-50	14-64

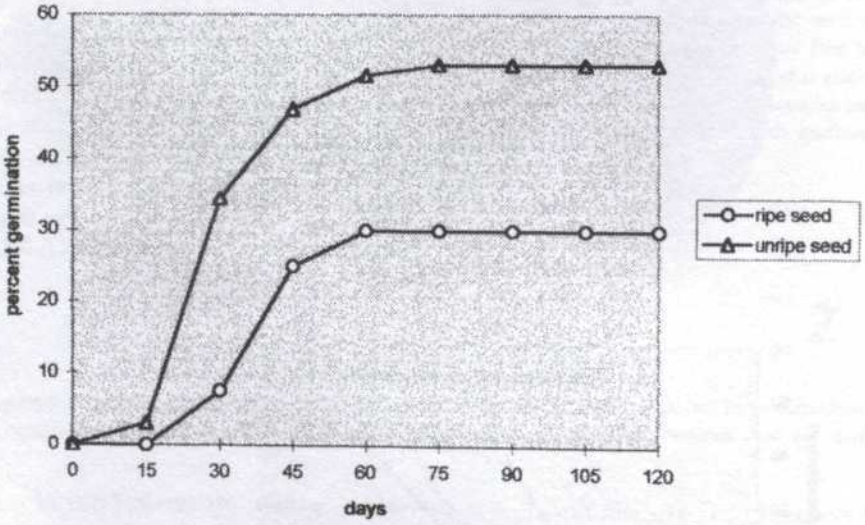


Fig. 6. In-vitro germination of E. longifolio seeds without endocarp

followed by ripe seeds without endocarp using the same *in vitro* method (CVG = 0.1377). The ripe seeds with endocarp intact sown in the 1:1 soil and sand mixture was the slowest to germinate (CVG = 0.0252).

The ANOVA presented in Table 2 also showed that the different germination methods significantly affected (p=0.01) the coefficient of velocity of germination but there was no significant difference between the maturity of seeds and their interaction with the germination methods.

All the seeds sown in the 1:1 soil and sand mixture and in jiffy pellets showed the same

TABLE 4
Mean coefficient of velocity of germination (CVG) for *E. longifolia* seeds germinated with different germination methods

Germination methods	Mean CVG w			
	Ripe seeds		unripe seeds	
sown in soil and sand mixture (1:1)	0.0252	a	0.0362	a
sown in jiffy pellets	0.0424	a	0.0456	a
In vitro v	0.1377	b	0.2053	c

[w] Means separation by Duncan's multiple range test, p=0.05. Values followed by the same letter are not significantly different.
[v] Seeds germinated via *in-vitro* method are with endocarp removed

growth pattern in terms of height, number of leaves produced and the stem diameter of the seedlings. The seedlings showed a rapid growth in height only in the first two weeks after germination followed by a gradual increase in height until 22 weeks. Then the seedlings grew slightly faster from 22 to 28 weeks after germination (*Fig. 7*). However, the stem diameter increase very slowly from sowing until the 5th month, followed by a slightly faster increase in stem girth after that.

The seedlings derived from seeds germinated without the endocarp via the in-vitro method also showed a rapid growth in height during the first two weeks after culturing, followed by reduction in growth rates. These seedlings showed the same growth pattern as seedlings arising from seeds germinated in the 1:1 soil and sand mixture and in jiffy (*Fig. 8*).

The number of leaves produced by the seedlings seemed to follow the same growth pattern as that of seedling height irrespective of germination methods. When seedling growth was slower, the number of leaves produced was reduced (*Fig. 7* & *Fig. 8*). Since all the seedlings were planted in polybags and placed in the plant house, the seedlings were exposed to similar environmental condition, hence they have the same growth pattern irrespective of type of germination medium. Chan (1984) also noted that different varieties of *Carica papaya* L. grown in Malaysia had the same growth pattern because the constant environmental conditions encouraged continuous growth and development.

Our study indicated that *E. longifolia* seeds had a low germination rate. This was due to the impermeability of hard stony endocarps of its

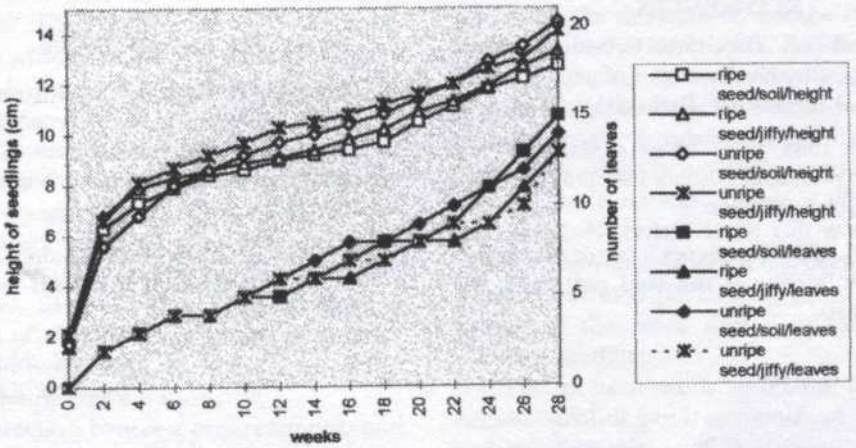


Fig. 7. The growth pattern of E. longifolia seedlings, derived from seeds germinated in soil and sand mixture and in jiffy pellets, in term of height and number of leaves produced

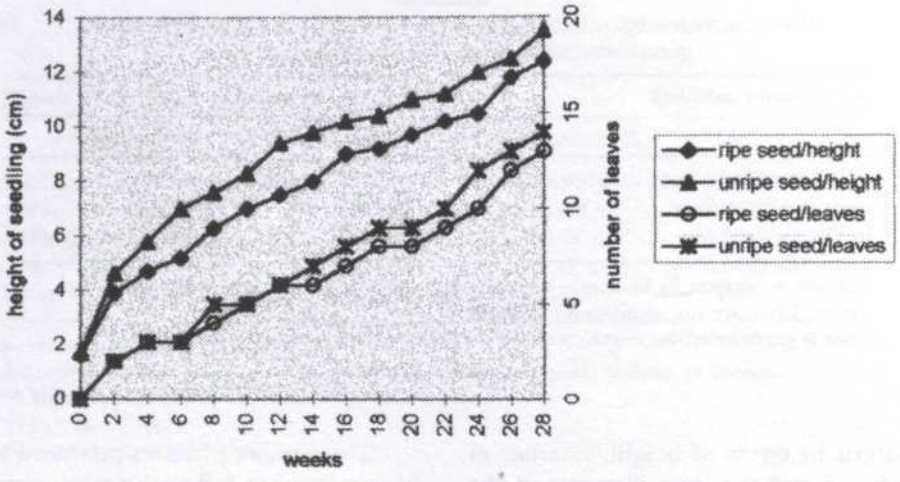


Fig. 8. The growth pattern of E. longifolia in-vitro seedling in term of height and number of leaves produced

seeds to water. The low germination rate of *E. longifolia* seeds could also be the reason why there is poor distribution of its seedlings in the forest floor. Since the seeds germinated faster when cultured in-vitro and there were no differences in the growth pattern of the seedlings, the in-vitro method of germination could be an alternative method for producing faster and more *E. longifolia* seedlings.

ACKNOWLEDGEMENT

We thank Universiti Sains Malaysia for providing research facilities and funding under IRPA Short Term R & D Grant No. 191-9632-0006.

REFERENCES

CHAN, Y.K. and W.K. TOH. 1984. Growth studies on some vegetative characteristics of papaya (*Carica papaya* L.). *Mardi Res. Bull.* **12(1)**: 46-54.

CORNER, E.J.H. 1988. *Wayside Trees of Malaya.* Vol. 2. 3rd edn. p. 698-699. Kuala Lumpur, Malaysia: United Selangor Press.

EDWARDS, M.M. 1968. Dormancy in seeds of charlock II. The influence of the seed coat. *Ann. Bot.* **19**: 601-610.

HARTMAN, H.R. and D.E. KESTER. 1968. *Plant Propagation Principles and Practices.* 2nd ed. London: Prentice Hall.

MARBACH, I. and A.M. MAYER. 1974. Permeability of seed coats to water as related to drying conditions and metabolism of phenolics. *Plant Physiol* **54**: 817-820.

MURASHIGE, T. and F. SKOOG. 1962. A revised medium for rapid growth and bioassays with tobacco tissue cultures. *Physiol. Plant.* **15**: 473-497.

NOOTEBOOM, H.P. 1962. Simaroubaceae. In *Flora Malesiana* ed. C.G.G.J. van Steenis. **6:** 203-206. N.V. Dijkstias Drukkery, The Netherlands.

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

RUDRAPAL, D., H. OKUBO, S. UEMOTO and K. FUJIEDA. 1992. Comparison of the anatomy and physiology of seeds of two varieties of winged bean *(Psophocarpus tetragonolobus). Scientia Horticulturae* **51**: 13-24.

VILLIER, T.A. 1972. Seed dormancy. In *Seed Biology* ed. T.T. Kozlowski. **2:** 219-281. New York: Academic Press.

(Received: 24 February 1999)
(Accepted: 17 August 2001)

Pertanika J. Trop. Agric. Sci. 25(1): 35 - 37 (2002)
ISSN: 1511-3701

Effect of Methanol and Ethanol Pre-Treatments on Seed Germination and Seedling Development of *Dichrostachyscinerea* (L.) Wight and Arn. (Fabaceae)

IDU, M & A.C OMONHINMIN
Department of Botany, University of Benin
PMB 1154, Benin City, Nigeria
E-mail: mcdonald@uniben.edu.

Keywords: Seed germination, methanol and ethanol pre-treatments, seedling

ABSTRAK

Bagi memperbaiki percambahan sebaik mungkin untuk mencapai pemerolehan pembenihan anak benih yang berkualiti, biji benih Dichrostachys cinerea *didedahkan kepada penggemburan tanah dengan alkohol dalam masa pendedahan yang berlainan. Biji benih direndam dalam metanol selama 10 minit mencapai peratus percambahan (72%) dan tenaga percambahan (65%) yang paling tinggi. Begitu juga, prarawatan metanol 5 minit memberi keputusan-keputusan yang baik. Hasil keputusan anak benih daripada rawatan-rawatan tersebut adalah kebanyakannya kelas tenaga tinggi apabila dibandingkan dengan prarawatan alkohol yang lain. Prarawatan metanol dan etanol 2 minit memberi percambahan yang rendah dalam peratusan dan tenaga percambahanm dan anak-anak benih tersebut kebanyakannya adalah dalam kategori tenaga rendah.*

ABSTRACT

To improve germination as well as achieve high nursery recovery of good quality seedlings, seeds of Dichrostachys cinerea *were subjected to alcohol scarification for different exposure times. Seeds soaked in methanol for 10 min achieved the highest percentage germination (72%) and germination energy (65%). Similarly, 5 min methanol pre-treatment gave good results. Seedlings resulting from these treatments were mostly of the high vigour class when compared to other alcohol pre-treatments. The 2 min methanol and ethanol pre-treatments gave low germination in percentages and germination energies, and the resultant seedlings were mostly in the low vigour category.*

INTRODUCTION

Dichrostachys cinerea (L) Wight and Arn. Sub-sp *africana* Brenan and Brummitt (Fabaceae), belongs to a small genus of the sub-family Mimosoideae widespread in the tropical savanna of Africa. It is the ony known member of the genus in Nigeria.

The plant commonly grows as a tree or sometimes as a shrub, often with low branches and dense canopy of branchlets (Keay 1989). This indigenous multipurpose, but under-exploited tree species is important for its fodder and fuel uses, as well as its sand-stabilization ability. Seeds of *D. cinerea* have hard seed coats, which are impermeable to water and gases thereby inhibiting germination.

The interaction between pre-treatments and the degree of hard seededness varies between seeds of the same or different species, and within the same seedlot (Gill *et al.* 1982). The difference in response to dormancy breaking pre-treatments by the seed depends on environmental conditions, the degree of maturation of the seeds and the duration of storage (Gunn 1990). Various methods have been employed in terminating dormancy in seeds with hard seed coats. Alcohol pre-treatments have been reported to be effective in the breakage of dormancy and improvement of germination in seeds, particularly those of the Fabaceae (Etejere *et al.* 1982; Mayer and Poljakoff-Mayber 1989; Gill *et al.* 1990; Idu 1995). However, not much has been reported on the effect of such pre-treatments on germination energy of the seeds and development of the resultant seedlings.

The present study evaluates the effect of various alcohol pre-treatments on germination and seedling vigour of *D. cinerea.*

MATERIALS AND METHODS

Seeds for the study were collected from Gieri, Adamawa State, Nigeria (12°, 20'E, 90°, 14'N). Seeds were removed from ripe pods and stored at constant temperature 28 ± 3°C throughout the experimental period.

Six hundred seeds were divided into two sub-samples of 300 seeds for the methanol and ethanol treatments. Each sub-sample was further divided into one hundred seeds for 3-treatment groups (2,5 and 10 min) exposure period with 5 replicates of 20 seeds each. 100 seeds of 5 replicates served as controls for each pretreatment.

Cleansed seeds were subjected to 70% concentrated methanol and ethanol pre-treatments for 2, 5 and 10 min. respectively and continually stirred. After the designated exposure period, the alcohol was drained and the seeds rinsed thoroughly (five times) in several changes of distilled water before being put up for germination.

Germination technique was as outlined by Dasgupta *et al.* (1976) and Marunda (1990). Treated and untreated (control) seeds were placed on moist filter paper in Petri-dishes under continuous fluorescent light at 10cm above bench level at room temperature. Three (3) mm radicle emergence served as criterion for germination (Idu & Omonhinmin 1999).

Germination was recorded daily for 30 days. After germination and following a randomized design, 10 seedlings were transplanted into segmented wooded trays (240 x 120 x 30cm) filled with sterile soil (pH=6.90) at a planting depth of 2 cm.

Watering was done daily with Harris culture medium. Seedling height measurements were done at 3-day intervals. Seedlings were grouped into vigour categories based on germination and seedling height data. The vigour index of germination was estimated by calculating the daily germination energy percentage maximum (Seward 1980). Seedling height measurement was stopped after 10 weeks.

Analysis of variance for a complete randomized design was carried out on the height data for seedlings grown from ethanol and methanol pre-treated seeds and to test for difference in treatment effect. A comparison of treatments' effect on mean height was carried out using the least significance difference (LSD).

TABLE 1
Germination % and 30 days, germination energies after 8 days and vigour categories based on germination height after 30 days for alcohol pre-treatment

Pre-treatment	*% Germ	Germ En.	HV	LV
Methanol 2 min	31	15	22	9
Methanol 5 min	56	35	32	24
Methanol 10 min	72	65	48	24
Ethanol 2 min	22	9	9	13
Ethanol 5 min	16	6	8	8
Ethanol 10 min	33	15	15	18
Control	12	5	6	8

(Data are average of five replicates)
*% Germ – Percentage germination
Germ. En-P – Germination Energy
Experimental mean height – 6.45 cm after 30 days

NG – Non-germinated seeds
HV – High Vigour above mean
LV – Low Vigour below mean

TABLE 2
Comparison of treatment mean height for *D.cinerea* seedling raised from alcohol pre-treated after 10 weeks

Pre-treatment	Ranked mean	LSD(H)+Mean
Control	5.80 a	7.00
Ethanol 2 min	7.40 b	8.60
Ethanol 5 min	7.60 bc	8.80
Ethanol 10 min	8.60 c	9.80
Methanol 5 min	8.87 d	–
Methanol 2 min	8.90 d	–
Methanol 10 min	9.10 d	–

** Mean followed by the same letter are not significantly different at 5% (LSD)

RESULTS AND DISCUSSION

Table 1 shows the percentage germination achieved after 30 days, germination energies after 8 days and vigour categories after 30 days.

The methanol treatment for 10 min achieved the highest germination percentage of 72% and germination energy of 65%. Five min soaking of seeds in methanol gave 56% germination and germination energy of 35%. The majority of the seeds germinated within the first 9 days. Two min of methanol treatment and 2, 5 and 10 min ethanol pre-treatments gave lower percentage germination and energies. The vigour categories show the methanol pre-treated seeds (2, 5 and 10 min) to be in a higher vigour class than the ethanol pre-treated seeds.

Alcohol stimulates germination in hard coat seeds, particularly those of the Fabaceae, by softening the waxy seed coat, thereby allowing the inflow of water, gaseous exchange and unrestricted expansion of embryonic parts (Mayer and Poljakoff-Mayber 1989). The pre-treatments with high germination energies (5 and 10 min methanol) can be applied in nursery settings to produce uniform planting stock to ensure maximum nursery recovery of high quality seedlings. Poor germination percentage and energies recorded for the ethanol and 2 min methanol pretreatment may be due to reduced severity of the treatment, which did not render the seed coat soft and permeable to water (Marunda 1990; Idu 1995). Such treatments produce seedlings of variable height in the nursery, resulting in poor recovery of good quality planting stock.

The control treatment produced seedlings with the lowest mean height, which suggests poor germination energy from the start of the experiment. This is a further indication that the seeds of *D. cinerea* require pre-treatments before better seedling performance can be achieved.

In conclusion, it is evident that methanol and ethanol pre-treatments had different effects on germination and vigour of *D.cinerea* seeds. The methanol at 10 minutes treatment gave better results and will be an ideal pre-treatment for effective germination of high quality seedlings of *D. cinerea.*

REFERENCES

DASGUPTA, M., R. BASU and R. BASU. 1976. Seed treatment. *Indian Agriculture* **20**: 265-273.

ETEJERE, E.O., M.O. FAWOLE and A. SANNI. 1982. Studies on the seed germination of *Parkia clappertoniana. Turrialba* **32**: 181-185.

GILL, L.S., S.W.H. HUSSAINI and A.H. MUSA. 1982. Germination biology of Mimosa pigra (Leguminosae). *Nigerian Journal of Weed Science* **3**: 11-18.

GUNN, B.V. 1990. Germination pre-treatment of selected Acacia species from the Pilbara region of Western Australia. In *Tropical Tree Seed Research* ed. Turnbull J.W. p. 56-60.

IDU, M. 1995. Seed development and germination responses of two Cassia 1 species. *Org. Int. and Env.* **2**: 65-68.

IDU, M. and A.C. OMONHINMIN. 1999. Effect of oven heat and boiling on the germination and seedling development of *Dichrostachys cinerea* (L.) *Agronomie* **19**: 671-676.

KEAY, R.W.J. 1989. *Treees of Nigeria.* 476p. London: Oxford Science Publ.

MARUNDA, C.T. 1990. Effect of seed pre-treatments on the Development of Acacia auriculiformis and *A. holoserea seedlings.* In *Tropical Tree Seed Research* ed. Turnbull J.W. p. 33-36.

MAYER, A.M. and A. POLJAKOFF-MAYBER. 1989. *The Germination of Seeds.* 207p. London: Pergamon Press Ltd.

SEWARD B.R.T. 1980. The production, handling, testing of forest trees in Zimbabwe. A review of methods and results. *The Zimbabwe Bulletin of Forestry Research:* 8-19.

(Received: 6 January 2000)
(Accepted: 3 October 2001)

Pertanika J. Trop. Agric. Sci. 25(1): 39 - 45 (2002) ISSN: 1511-3701

Drying of Black Pepper (*Piper nigrum* L.) Using Solar Tunnel Dryer

JOY C.M.[1], GEORGE PETER PITTAPPILLIL[2] & K.P. JOSE
[1]*Research Department of Botany, Sacred Heart College, Thevara, Cochin 682 013, Kerala India*
[2]*Department of Physics, Sacred Heart College, Thevara*

Keywords: Black pepper, solar tunnel drying, physico-chemical quality improvement, post-harvest technology, optimum drying conditions

ABSTRAK

Lada hitam (Piper nigrum *L.*) *dikira sebagai raja di kalangan rempah-ratus. Negeri Kerala sahaja menyumbang kira-kira 97% daripada jumlah pengeluaran lada di India. Sebanyak 75 jenis lada ditanam di kawasan-kawasan berbeza di negeri tersebut. Kepedasan dan aroma adalah kualiti lada paling penting, yang merujuk kepada oleoresin dan minyak volatil. Kualiti lada banyak bergantung kepada kaedah-kaedah selepas dituai. Satu kajian yang meluas ke atas kejadian lada hitam dan pengeringan telah dikendalikan. Hanya pengeringan terbuka cahaya matahari secara konvensional dilaksanakan di negeri Kerala. Sampel-sampel lada yang dikumpul daripada pelbagai lokasi dikeringkan dalam pengering terowong yang diimport (Jerman) dan kualiti rempahnya dibanding dengan sampel komersial. Penceluran dilakukan sebelum setiap pengeringan. Standard kualiti ASTA (Pertubuhan Perdagangan Rempah-ratus) dan Agmak diuji ke atas sampel komersial dan sampel yang dikeringkan menggunakan pengiring terowong. Signifikan kepelbagaian kualiti lada kedua-duanya diketahui. Kira-kira enam hari diambil untuk pengeringan sampel-sampel komersial manakala sampel-sampel pengeringan terowong hanya mengambil masa 8 jam. Kandungan piperin dalam sampel komersial hanya 4% berat sementara berat sampel pengeringan adalah 4.5%. Sampel yang dikeringkan dalam terowong mempunyai kualiti fizikal yang lebih baik berbanding sampel komersial seperti yang dispesifikasi oleh ASTA. Pembaikan kualiti dan pengurangan masa pengeringan menjadi bukti kepada sampel yang dikeringkan dalam terowong solar. Pengering terowong solar yang diimport dari Jerman sangat sesuai untuk pengeringan lada hitam. Keadaan optimum diperlukan untuk pengeringan rempah-ratus ini boleh diterangkan. Analisis-analisis kualiti psikokimia membuktikan bahawa pengeringan yang diuji untuk pengeringan lada tersebut adalah cukup efisien bagi menghasilkan lada yang berkualiti untuk dieksport.*

ABSTRACT

Black pepper (Piper nigrum *L.*) *is considered to be the king among the spices. The State of Kerala alone contributes about 97% to the total pepper production in India. Seventy-five pepper varieties are cultivated in different parts of the country. Pungency and aroma are the most important qualities of pepper, which is attributed to oleoresin and volatile oil respectively. The quality of pepper is very much dependent on the post-harvest methods. An extensive survey on the occurrence of the black pepper and drying methods were conducted in this investigation. Only conventional open sun drying is practised in the State of Kerala. Pepper samples collected from different locations were dried in an imported tunnel dryer (Germany) and quality of the tunnel-dried spice was compared with commercial samples. Blanching was done before each drying. ASTA (American Spice Trade Association) and Agmark quality standards were tested on the tunnel dried and commercial samples. Significant variations of pepper quality between sampling stations were noticed. Approximately 6 days were taken for the drying of commercial samples whereas in solar tunnel dryer it took only 8 hours. Piperine content in commercial samples was only 4% by weight while in dryer samples it was 4.5% by weight. Tunnel dried samples had better physical quality than the commercial samples as specified by ASTA. Quality improvement and reduction in drying time were evident for the solar tunnel dried samples. Solar tunnel dryer imported from Germany is highly suitable for black pepper drying. Optimum conditions required for the drying of this spice could be defined. Physico-chemical quality analyses proved that the dryer tested for the pepper drying is efficient enough to produce pepper of export quality.*

INTRODUCTION

The enticement of spices prompted explorers like Columbus and Vasco da Gama to undertake hazardous sea journeys to discover India, 'the land of spices'. Black pepper is considered to be the king of spices. This spice is the dried mature but unripe fruit of *Piper nigrum* L. The State of Kerala alone contributes about 97% of the total production of pepper in India (Ravindran *et al.* 1997). Black pepper is believed to have originated in the evergreen forests of Western Ghats of Peninsular India (Ravindran and Nair 1984). Out of seventy-five pepper varieties cultivated in the country *Panniyur I* is considered to be the most successful variety of the pepper. Major commercial pepper grades exported from India are Malabar garbled, Tellichery garbled and Aleppey garbled (Anon 1997).

Black pepper requires a humid climate with adequate rainfall and temperature for its growth (Gangadharan 1998). *Piper nigrum* L. is mostly dioecious in its wild state while most of the cultivated types are bisexual. Cultivated black pepper is self-pollinated, the mode being geitonogamy aided by rainwater or dewdrops (Ravindran *et al.* 1997). After flowering, six to eight months maturity is needed for harvesting. Harvesting is done during the months of December to February for low land crops and January to April for hill grown pepper.

Post-harvest technology has a tremendous role in the quality improvement of spices (Pruthi 1993). In the case of pepper, spikes are removed from the vines and they are kept as such for a day for despiking. The most common pre-treatment before drying adopted in Kerala and the Karnataka States of India is blanching (Anonymous 1997). The blanched berries require only 2 days for drying in the sun (Pruthi 1992). Blanching minimizes microbial contamination and thus gives a more hygienic product. After blanching, the pepper is sun dried on mats or clean concrete floors. Sun dried pepper berries take 4-5 days for proper drying, depending upon the climatic conditions (Krishnamurthy *et al.* 1993). Sun drying has several limitations. Therefore the use of artificial dryers becomes essential (Shukla 1983). The possible alternate drying technologies are infrared drying, conduction drying, heated air drying, desiccated air drying and refrigerated air drying for agricultural commodities (Shukla and Patil 1992). The use of solar dryers in comparison with open sun drying gave better quality products with lesser drying time (Patil 1989). Kamaruddin *et al.* (1994) have developed a method for the drying of pepper using solar energy. Pruthi (1989) had shown a drying time of 8 hours for 30-40 tones of pepper when dried in a mechanical dryer imported from Holland.

To improve the overall quality of pepper, a solar dryer and some additional appropriate technologies were used to produce pepper of a high microbiological standard, deep black colour and low humidity (Ahlert *et al.* 1997). The quality of black pepper is assessed by its aroma and pungency retained after drying. The pungency of pepper is due to the presence of piperine. According to Mathulla *et al.* (1996) the main pungent principle is piperine which is 2-trans, 4-trans piperidine amide of piperic acid. Piperine from black pepper is a bioactive material, which when consumed with other drugs gives improved effectiveness (Mathew 1998). In the present investigation, black pepper collected from different parts of Kerala are dried in a solar tunnel dryer imported from Germany. Quality improvement and reduction in drying time observed are discussed in this paper.

MATERIALS AND METHODS

Kerala is the southernmost State of India, which occupies an area of 38,863 sq.km, about 1.3 percent of the country. This state is located between 8°18' and 12°48' North latitude, and 74°52' and 77°22' East longitude. Pepper is cultivated in Kerala along the highlands, midlands and lowlands. Sampling locations were identified from all these altitudinal zones. Kalady (lowland), Ezhattumugham (midland) and Kumili (highland) were the sampling sites. Investigation started with an extensive survey in order to understand the post-harvest technologies prevailing in the sampling stations. Freshly harvested 60 kg of black pepper samples were collected thrice from the three sampling stations during the months of January, February and March 1999. Each pepper sample consisted of an assorted mixture of cultivars such as *panniyur I, karimunda, kalluvalli, vellikkinnan, balankotta* and *aimpirian*. The samples were collected in clean polyethylene bags and transported to the research centre within three hours of harvesting. Pepper samples were heaped for one day in

a clean room. After that, despiking was done manually. Blanching was done by immersing the pepper samples in boiling water for exactly one minute with the help of a perforated bamboo basket. Samples were temporarily spread on a clean mat for the draining of excessive water and uniform colouration. Initial moisture content and wet weight of the produce were recorded.

Solar Tunnel Dryer

The solar tunnel dryer was developed at the Institute for Agricultural Engineering in the Tropics and Sub-tropics of Hohenheim university, Germany. It consists basically of a plastic foil covered flat plate solar air heater, a drying tunnel and two small axial flow fans (Esper and Muhlbauer 1996). To simplify the construction and to reduce the production costs, the solar air heater is connected directly to the drying tunnel without additional air ducts (*Fig. 1*). Both the collector and drying tunnel are installed on concrete block substructures to ease loading and unloading of the dryer. The entire floor of both solar air heater and the drying tunnel consists of plastic foam sandwiched between two metal sheets with a groove and tongue system, have a length of 17 meters (10 m for tunnel and 7 m for heater) and 2 meters breadth. The entire bottom surface of the solar air heater of the dryer is coated with black paint (90% absortivity). In the solar tunnel dryer, the crop is spread out on a wire mesh placed 20 mm above the floor, which is covered with a plastic net aimed to sieve the smaller dust and dirt through the holes during drying. The solar air heater and the tunnel are covered with a transparent uv stabilized PE plastic foil 0.2 mm in thickness with a transmissivity of 92% for visible radiation. Two axial flow fans are incorporated in the sandwiched substructure at the back of the air inlet of the solar air heater to suck ambient air into the collector. The capacity of the tunnel ranges from 60 kg to 200 kg wet fruits depending upon the size of the fruit and thickness of the spreading layer. The solar tunnel dryer was successfully tested under field conditions, in about 30 countries with different climatic conditions, drying numerous agricultural commodities, fish and meat. This solar dryer is installed at the Botany research centre of Sacred Heart College and all the drying experiments were conducted in this dryer.

Drying of Pepper

Blanched berries were spread in one fruit thickness on a clean perforated mat kept 2 cm above the surface inside the solar tunnel dryer. No overlapping and clustering of berries were allowed. The dryer system was closed by steering down the pedal carrying the PE foil roof and allowing the samples to dry. Drying started at 9 a.m. in the morning. Temperature and relative humidity of the dryer and ambient air were recorded in two hour intervals from 9 a.m. to 5 p.m. Mercury thermometer and an air guide (USA) instrument were used for the measurement of temperature and relative humidity respectively. The intensity of solar radiation was measured at the roof of the dryer using a pyranometer. All the readings inside the dryer were taken from three distinct zones viz. the junction of solar air heater and drying tunnel, middle of the tunnel just above the crop and at the outlet of the dryer. To provide more or less uniform drying conditions and to develop uniform colour the berries were mixed and respread at every one-hour interval within the dryer. After the completion of drying the pepper, berries were sifted along with the plastic net to settle down the pinheads and other small materials from the dried produce. Dry weights of the samples were taken and amount of spice recovery was calculated. Random subsamples were taken in triplicate for the physico-chemical quality analyses. Analyses were carried out at the Quality Evaluation and Upgradation Laboratory of Spices Board, Cochin and at the Botany research centre of Sacred Heart College, Thevara, Cochin according to the National and International Standards. Physical quality parameters specified by ASTA (1998) and Agmark (Anonymous 1996) were analysed. Chemical quality parameters such as moisture, volatile oil, oleoresin, crude fibre, piperine and total ash were determined using ASTA (1997) methods. Commercially available conventionally dried pepper samples were also collected from the same sampling stations from where the wet samples were collected for solar tunnel drying. These samples were also analysed for the same parameters adopted for tunnel-dried samples for a comparative evaluation of quality. The data collected through the experiments were computed statistically (Snedecor and Cochran 1967).

RESULTS AND DISCUSSION

The survey conducted during this study revealed that agricultural practices, method of harvesting and post-harvest technologies employed in all the three sampling stations were the same for pepper. Single cultivar plantations of black pepper are not available in the sampling areas. In most cases different pepper cultivar produces will be collected and assorted before drying. Only the conventional sun drying method is prevalent in Kerala for pepper drying. The survey revealed that commercially available pepper samples are dried in 5 to 7 days.

Variations in temperature, relative humidity and solar radiation measured inside the dryer during the drying of pepper samples collected from three different sampling stations are given in *Figs. 2, 3* and *4*. Temperature and relative humidity showed an inverse relationship as in the histograms. Minimum solar radiation obtained during the drying period was 15 mA (318 W/m^2), and 43 mA (822 W/m^2) was the maximum. No sudden fluctuation of the solar radiation was noticed during the drying. Maximum and minimum temperatures noticed inside the dryer were 70°C and 34°C respectively, whereas during the drying period ambient air showed a maximum temperature of 41°C and a minimum of 30°C. Relative humidity noticed in the dryer was always less than that of the ambient air. During the drying period ambient air showed a relative humidity between 34% and 60%. Moisture content present in the pepper before and after drying, drying time taken, and spice recovered after drying are represented in Table 1. Only 33.7% of the wet samples were recovered after drying. Drying of samples was completed within eight hours. The results of the physico-chemical analyses done for the tunnel dried and commercially available samples are given in Tables 2 and 3. Analysis of variance between different sampling stations showed strong significance for all the parameters analysed. ANOVA of tunnel dried and commercial samples was also found significant for all attributes studied. In the present investigation pepper samples collected for drying from different sampling stations were assorted in nature. According to Sumathikutty *et al.* (1989) pepper of commerce is a mixture of all the cultivars. In all the drying experiments, pepper was spread inside the dryer in one fruit thickness to reduce the drying time.

Sodha *et al.* (1985) reported that for open sun drying the grain layer thickness should not be more than 5 cm. In Sri Lanka, drying is carried out after immersing the berries in steaming hot water for about 2-3 minutes and dried in a hot air dryer at 47°C to 51°C for 36 hours (Abeysinghe 1982). Before tunnel drying the pepper samples were dipped in boiling water for one minute in the present investigation. However according to Jacob *et al.* (1985) blanching improves the colour but affords pepper fruits depleted of significant quantum of volatiles. After drying, pepper samples showed a size decrease. Pepper after drying shrinks in size and wrinkles are formed in the skin (Thomas and Gopalakrishnan 1992). For black pepper fully mature green berries were dried conventionally in the open sun, which took four-five days to get pepper of commerce (Patil 1989). In the present investigation, all the samples were dried within eight hours in the dryer. Open sun drying is widely practiced in tropical countries but the method is extremely delayed, weather dependent and has the problem of contamination,

TABLE 1
General observations during the drying of black pepper in the solar tunnel dryer and commercial samples

Sampling Stations	Percentage Moisture Content (Before drying)	Spice Recovery (%)	Percentage Moisture Content (After drying)		No. of days for optimum drying	
			Commercial Sample	Solar Dryer	Commercial Sample	Solar Dryer
Kalady	77.7	34.7	12.4	12.4	6	8 hrs
Ezhattumugham	78.1	32.3	13.6	10.4	7	8 hrs
Kumili	76.7	34.2	14.4	10.8	5	8 hrs

TABLE 2
Result of quality analyses of black pepper after drying in solar tunnel dryer from different location

Parameters	Kalady		Ezhattumugham		Kumili	
	Mean*	S.D.	Mean*	S.D.	Mean*	S.D.
Extraneous matter% by wt.	0.28	±0.03	0.14	±0.03	0.11	±0.06
Light berries ,,	0.90	±0.16	5.00	±1.60	0.60	±0.08
Pinheads ,,	0.10	±0.05	0.00		0.00	
Size above 4.25mm ,,	82.9	±2.37	82.5	±1.08	91.4	±2.30
Size above 4.75mm ,,	12.3	±5.20	10.8	±1.40	6.10	±1.30
Moisture ,,	12.4	±1.40	10.4	±0.14	10.8	±0.16
Volatile oil ,,	2.00	±0.00	2.30	±0.22	2.17	±0.02
Piperine ,,	4.30	±0.22	4.70	±0.16	4.50	±0.41
Oleoresin ,,	8.40	±0.14	8.20	±0.14	6.50	±0.42
Crude fibre ,,	11.3	±0.96	12.3	±0.24	12.2	±0.08
Total ash ,,	5.00	±0.82	4.80	±0.45	4.30	±0.16
Whole insects dead % by count	0.00		0.00		0.00	
Insect defiled/infested % by wt	0.00		0.00		0.00	
Excreta mammalian % by mg/lb	0.00		0.00		0.00	
Mould % by wt	0.00		0.00		0.00	

* All values are means of triplicate samples

TABLE 3
Result of quality analyses of commercial black pepper samples collected from different locations

Parameters	Kalady		Ezhattumugham		Kumili	
	Mean*	S.D.	Mean*	S.D.	Mean*	S.D.
Extraneous matter % by wt.	0.18	±0.02	0.49	±0.16	1.58	±0.06
Light berries ,,	1.20	±0.10	6.30	±0.33	2.21	±0.03
Pinheads ,,	0.00		0.90	±0.16	0.54	±0.03
Size above 4.25mm ,,	78.7	±0.58	78.8	±1.28	94.0	±2.89
Size above 4.75mm ,,	19.2	±0..14	23.3	±2.58	5.22	±0.10
Moisture ,,	12.4	±0.30	13.6	±0.42	14.4	±0.57
Volatile oil ,,	1.17	±0.02	1.50	±0.28	2.17	±0.15
Piperine ,,	4.07	±0.06	4.29	±0.03	3.98	±0.06
Oleoresin ,,	7.03	±0.06	8.65	±0.07	8.26	±0.02
Crude fibre ,,	9.41	±0.08	10.5	±0.08	11.5	±0.05
Total ash ,,	4.65	±0.08	4.90	±0.71	4.55	±0.15
Whole insects dead % by count	0.00		0.00		7.00	±1.63
Insect defiled/infested % by wt	0.00		0.15	±0.04	0.39	±0.06
Excreta mammalian % by mg/lb	29.0	±0.82	0.00	0.00		
Mould % by wt	1.80	±0.02	6.40	±0.30	4.45	±0.33

* All values are means of triplicate samples

infestation and microbial attack (Kachru and Gupta 1993; Ratti and Mujumdar 1997). Disadvantages of direct sun drying can be overcome by the use of solar dryers (Blumenberg *et al.* 1997). Maximum temperature inside the dryer during the solar tunnel drying was 70°C. Each spice has a critical dehydration temperature and this temperature can vary with the end use for

which it is put (Shankaracharya and Natarajan 1975). According to Grupp *et al.*(1995) red pepper and green pepper when dried in solar tunnel dryer showed excellent results but needed an alert operator to avoid over drying.

All the results of the present investigation have shown that the method of drying determines the quality of the spice. The quality of black pepper is largely determined by berry size, colour, light berry content, damaged berries, moisture content, foreign matter, insect infestation, animal excreta and microbial load (George 1996). In the present investigation statistical analyses of attributes studied showed significant variation between the samples collected from different sampling locations. Varietal diversity is one of the principal components of diversity in black pepper (Ravindran *et al.* 1997). The samples, both the tunnel dried and commercial samples collected for the study, belonged to different varieties. In black pepper variation in oleoresin, piperine and essential oil contents were noticed among the different cultivars (Ravindran and Nair 1984; Zacharia 1998). The quantity and quality of oleoresin depend to a great extend on the geographical origin of the spice (Shankarikutty *et al.* 1982). Mishra (1998) observed the variation in quantity of oil in different varieties of pepper, which is responsible for difference in aroma and taste. Black pepper dried in solar tunnel dryers was hygienic and performed high quality over commercial samples. All the tunnel dried samples were qualified for ASTA and Agmark standards of pepper quality. A total quality improvement such as colour, appearance, aroma and pungency was achieved through the drying of pepper in solar tunnel dryers. Moreover, it is possible to ensure the quality of spice produced under the optimum conditions of the dryer.

CONCLUSIONS

From the results of the study the following conclusions can be drawn:-

- The solar tunnel dryer is suitable for black pepper drying.
- Physico-chemical qualities of the tunnel-dried samples are significantly high over the commercial samples.
- Optimum drying conditions for the pepper drying can be predicted.
- There is a significant variation of pepper quality attributes depending upon the cultivar and place of growth.
- The importance of post-harvest technology to improve the export quality of pepper is confirmed.

ACKNOWLEDGEMENT

Authors are highly indebted to the Spices Board (Govt. of India), Cochin for providing financial support and laboratory facilities. We are also grateful to the principal, Sacred Heart College, Thevara, Cochin for encouragement and Dr. W. Muhlbauer of Hohenheim University, Germany for installing the solar tunnel dryer for the study.

REFERENCES

ABEYSINGHE, A. 1982. Processing of some minor export crops of Sri Lanka. *Indian Cocoa Arecanut and Spices J.* **5(3)**: 48-55.

AHLERT, B., I. KJER, B. LIEBL, T. FRIES, R. DE WEDEKIND, and T. DE FRIES. 1997. Improving the quality at producer levels. *Endwicklung Landlicker Raum* **31(6)**: 26-28.

ANON. 1996. *Agmark Grade Specifications for Spices.* Spices Board (Govt. of India) Cochin.

ANON. 1997. *Kurumulaku Krishi* (Malayalam) Spices Board (Govt. of India) Cochin.

ASTA. 1997. American Spice Trade Association. *Official Method of Analysis.* Englewood Cliffs, NJ, USA: ASTA.

ASTA. 1998. American Spice Trade Association. *Cleanliness Specifications for Spices, Seeds and Herbs.* Englewood Cliffs, NJ, USA: ASTA.

BLUMENBERG, J., A. KOLB, A. ZOELLNER and TH. BERGSTAINER. 1997. Technische Universitaet Muenchen-Lehrstuhl fuerenergieund Wmweltverfahren technik. Final Report, German Napalies Solar Drying Project. p. 1-77.

ESPER, A. and W. MUHLBAUER. 1996. Solar tunnel dryer for fruits. *Plant Res. & Dev.* **44**: 61-79.

GANGADHARAN, K.K. 1998. *Karutha ponnu* (Malayalam). Farm Information Bureau. Trivandrum.

GEORGE, C.K. 1996. Black pepper : Quality improvement at farm level. In *Quality Improvement of Black Pepper* ed. C.R. Sivadasan and P. Madhusoodanakurupu. p. 7-12. Spices Board (Govt. of India) Cochin.

GRUPP, M., H. BERGLER, M. OWEN JONES and G. SCRODER. 1995. Comparative test of solar dryers (TDC) Serial Report 2/95. Almeria, Spain.

JACOB, C.V., J. VARGHESE, M.T. JOY and T. MATHULLA. 1985. Focus on pepper technology: I Drying of pepper. *Indian Spices* **22(3)**: 27-29. Spices Board (Govt. Of India).

KACHRU, K.P. and P.K. GUPTA . 1993. Drying of spices: Status and challenges. In *Proc. Post-harvest Technology of Spices* ed. C.S. Narayanan, B. Shankarikkutti, Nirmala Menon, P.N.-Ravindran and B. Sasikumar. p. 15-17. Cochin, India: Spices Board (Govt. of India).

KAMARUDDIN, A., TAMRIN, F. WENUR and R.B. KEEY. 1994. Drying of black pepper using solar energy. In *Proc. 9th International Drying Symposium*, ed. Rudolf, **B**: 887-895. Gold Coast, Australia.

KRISHNAMURTHY, N., S.R. SAMPATHU, H.B. SOUBHAGYA and M.L. SHANKARANAYANA. 1993. Farm processing of some spices- pepper, turmeric and ginger. In *Proc. Post-harvest Technology of Spices* ed. C.S. Narayanan, B. Shankarikkutti, Nirmala Menon, P.N. Ravindran and B. Sasikumar. p. 50-52. RRL Spices Board, Cochin.

MATHEW, A.G. 1998. Spice oil and oleoresin industry in India. *IFCON* 1998.CFTRI, Mysore.

MATHULLA, T., A. ISAC, N.C. ROY and A.G. MATHEW. 1996. Spice oleoresins. *Pafai J.* **18(1)**: 9-13.

MISHRA, R.M. 1998. Spice oil-its production and quality assessment. *Pafai J.* **20(2)**: 13-18.

PATIL, R.T. 1989. Drying studies on black pepper. *J. Food Sci. Technol.* **26(4)**: 230-231.

PRUTHI, J.S. 1989. Diversification of pepper utilization by the development of value added processed products. *Indian Cocoa Arecanut and Spices J.* **13(1)**: 1-7.

PRUTHI, J.S. 1992. Post-harvest technology of spices: Pre-treatments, curing, cleaning, grading and packing. *J. Spices and Aromatic Crops* **1**: 1-29.

PRUTHI, J.S. 1993. *Major Spices of India: Crop Management Post-harvest Technology.* New Delhi: ICAR.

RATTI, C and A.S. MUJUMDAR. 1997. Solar drying of foods: Modelling and numerical simulation. *Solar Energy* **60(3/4)**: 151-157.

RAVINDRAN, P.N. and M.K. NAIR. 1984. Pepper varieties. *Indian Cocoa Arecanut and Spices J.* **7(3)**: 67-69.

RAVINDRAN, P.N., B. SASIKUMAR and K.V. PETER. 1997. Black pepper, ginger and turmeric. In *Natural Resources of Kerala* ed. Balachandran Thampi, N.M. Nayar and C.S. Nair. p. 296-304. WWF-India: Trivandrum.

SHANKARACHARYA, N.B and C.P. NATARAJAN. 1975. Technology of spices. *Arecanut and Spices Bulletin* **7(2)**: 27-43.

SHANKARIKUTTY, B., C.S. NARAYANAN, K. RAJAMAN, M.A. SUMATHIKKUTTI, M. OMANAKKUTTI and A.G. MATHEW. 1982. Oils and oleoresins from major spices. *J. Plantation Crops* **10(1)**: 1-20.

SHUKLA, B.D. 1983. Drying of maize in freely ventillated crib with solar air heater in Kenya. *Tropical Agriculturae* Trinidad **61(11)**: 45-47.

SHUKLA, B.D. and R.T. PATIL. 1992. Dryers and drying technology for food crops. *Indian J. of Agricultural Sciences* **62(9)**: 579-589.

SNEDECOR, G.W. and E.A. COCHRAN. 1967. *Statistical Methods.* New Delhi Oxford and IBH Publ. Co.

SODHA, M.S., P.K. BANSAL, A. DANG and S.B. SHARMA. 1985. Open sundrying and analytical study. *International Journal of Drying Technology* **3(4)**: 517-527.

SUMATHIKKUTTI, M.A., B. SHANKARIKKUTTI, K. RAJARAMAN, C.S. NARAYANAN and A.G. MATHEW. 1989. Quality criteria of pepper grades from pure cultivars. *Indian Perfumer* **33(2)**: 147-150.

THOMAS, P.P. and N. GOPALAKRISHNAN. 1992. A process for the production of unwrinkled dry ball shaped green pepper. *Indian Spices* **29(4)**: 9-10. Spices Board (Govt. of India).

ZACHARIA, T.J. 1998. Quality analyses of major spices. *Pafai J.* **20(2)**: 25-31.

(Received: 31 January 2000)
(Accepted: 27 November 2001)

Pertanika J. Trop. Agric. Sci. 25(1): 47 - 51 (2002) ISSN: 1511-3701

The Removal and Burning of Pineapple Residue in Pineapple Cultivation on Tropical Peat: An Economic Viability Comparison

*O.H. AHMED, M.H.A. HUSNI, A.G. AWANG NOOR[1] & M.M. HANAFI
Department of Land Management, Faculty of Agriculture,
Universiti Putra Malaysia,
43400 UPM Serdang, Selangor, Malaysia
**E-mail: osman60@hotmail.com*
[1]Faculty of Forestry, Universiti Putra Malaysia,
43400 UPM Serdang, Selangor, Malaysia

Keywords: Pineapple residues, economic viability, open burning, tropical peat

ABSTRAK

Kajian dijalankan bertujuan membanding kebaikan kesan serta kos pembakaran 'in situ' sisa nanas dan pembuangan sisa nanas dari ladang sebelum penanaman semula, ke atas pertumbuhan nanas di tanah gambut tropika. Rawatan yang digunakan adalah: (i) sisa (daun, 'crowns', dan 'peduncles') dikeluarkan dari ladang diikuti dengan pembajaan (RRF), dan (ii) sisa (daun, 'crowns', dan 'peduncles') dibakar diikuti pembajaan (amalan biasa) (RBF). Di akhir kajian, berat purata buah untuk setiap rawatan ditentukan. Berat ini kemudiannya didarabkan dengan kepadatan pokok iaitu 56,250 untuk mendapatkan hasil dalam 1 hektar. Hasil didarab jumlah hasil/ha dengan harga jual ladang akan memberi jumlah pulangan kasar pengeluaran tanaman ini. Kos pekerja pula telah ditentukan berasaskan sistem gaji yang diamalkan di ladang nanas. Harga pasaran ladang digunakan sebagai kayu pengukur kos bahan penanaman serta lain-lain bahan. Kos tanah pula dikira berasaskan sewa tahunan ladang nanas. Semua pengiraan kos tertakluk pada 12% kadar faedah harga kapita. Di bawah Akta Kualiti Alam Sekitar 1978 pindaan 1998 dan Indeks Pencemaran Udara (API) pencemar akan dikenakan denda atas perlakuan pembakaran secara terbuka yang mengakibatkan pencemaran udara. Kesemua ini akan diambil kira semasa membuat penganggaran kos penanaman nanas. Pembakaran sisa tidak meningkatkan hasil secara bererti. Analisis ke atas kos telah membuktikan perolehan keuntungan menerusi pengeluaran sisa nanas (RRF) berbanding pembakarannya. Penerimaan konsep RRF memerlukan kajian yang lebih mendalam tentang cara sesuai yang boleh digunakan untuk meningkatkan kualiti atau menghasilkan sisa produk yang tinggi nilai komersialnya. Kos kajian ini harus ditanggung bersama oleh pihak kerajaan, ladang-ladang nanas serta orang ramai.

ABSTRACT

The study was conducted to compare the benefits and costs of in situ burning of pineapple residues with removal of pineapple residues (before replanting) in pineapple cultivation on tropical peat. Treatments used were: (i) residues (leaves, crowns, and peduncles) removal followed by fertilization (RRF) and (ii) residues (leaves, crowns, and peduncles) burnt followed by fertilization (usual practice) (RBF). At the end of the study, the average fruit weight per treatment was recorded. Fruit weight multiplied by the plant density of 56,250 will give the total yield per hectare. The product of the total yield/ha and farm-gate price will give the gross revenue of crop production. Cost of labour was based on the wage system practiced by the pineapple estates. Farm-gate market prices were used for assessing farm materials and other inputs. Cost of land was based on the annual rental value for pineapple plantations. An interest rate of 12% was charged on the capital used. Under the Environmental Quality Act, 1978 amended in 1998, and according to the Air Pollutant Index (API) the polluters have to pay the principal fine imposed for polluting the air through open burning of pineapple residues. All these costs will be taken into account when calculating the production cost of pineapple. Burning did not significantly increase yield. Cost and benefit analysis revealed that removal of pineapple residues (RRF) is more economically viable than burning the residues (RBF). Adoption of RRF requires further studies in selecting the most suitable method of enhancing the quality of the environment or developing product(s) of commercial value from pineapple residues. The cost of the study should be borne partly by the government, the pineapple estates, and the public.

INTRODUCTION

Pineapple (*Ananas comosus*) is generally grown on mineral soils (Py *et al.* 1987). On these soils, pineapple residues are usually shredded or ploughed back into the soil after cropping or before replanting. In Malaysia, the crop is largely (17,000 ha) and uniquely cultivated on peat (AGRIQUEST 1999/2000). This practice has been in existence for nearly a century (Selamat and Ramlah 1993). The inherent nature of peat does not allow shredding or ploughing of these residues into the soil before replanting. This, coupled with the lack of an effective and efficient mode of handling pineapple residues often result in the residues being recycled through open burning. The practice is also known to reduce the incidence of disease and pest outbreaks (Jordan 1985), as well as labour costs (land preparation).

Despite these benefits, the environmentally damaging effects of open burning on the environment need to be addressed seriously. The ripplling effects of the 1997/98 haze across South East Asia are still fresh in most people's memories and have left an indelible mark in the minds of the inhabitants of this region and the world at large. Currently, open burning of most crop residues including pineapple has been outlawed (Environmental Quality Regulations 1974 amended in 1998). Non- conformity to this ruling will incur a penalty of RM 100,000.00. This new regulation has put the entire pineapple industry at a crucial crossroad. The closest alternative to the burning of pineapple residues is the in situ decomposition of the residues. However, the building or piling up of the partially decomposed residues with time is envisaged or inevitable since it takes not less 13 months or more before the decomposition of these residues. Besides, with the addition of partially decomposed organic matter to the already existing one, a prolonged adoption of any of the practices mentioned without proper handling of the residues may not only lead to the outbreak of fire, disease, and pests but also, the likelihood of inefficient fertilization because of the massive accumulation of these residues on the soil surface.

One of the possible ways to handle or manage pineapple residues without jeopardizing or sacrificing the quality of the environment is to remove the residues or convert these residues into value added products of commercial potential. An innovative or noble approach along this line will not only help generate additional income to offset or defray some of the accompanying costs of removing pineapple residues from the field before replanting but also create job opportunities. However, before embarking on such an idea, it is only befitting that a study be conducted to compare the yield as well as the economic viability of removing pineapple residue with that of the open burning of these residues (usual practice).

The objective of the study therefore was to compare the benefits and costs of in situ burning of pineapple residues with that of removal of pineapple residues in pineapple cultivation on tropical peat.

MATERIALS AND METHODS

The study was conducted at Simpang Rengam Pineapple Estate, Simpang Rengam, Johore with the treatments: (i) residues (leaves, crowns, and peduncles) removed followed by fertilization (RRF) and (ii) residues (leaves, crowns, and peduncles) burnt followed by fertilization (usual practice) (RBF). The experimental unit was the individual plants planted in a 4 m x 12 m plot. A total of 300 suckers (Gandul; most commonly grown variety) were planted in each plot. The experimental plot was a randomized complete block design (RCBD) with four replications.

At the end of the maturity period (2 years), the average fruit weight for each treatment was determined from a total of 100 fruits. Fruit weight was multiplied by plant density of 62,500 less 10% (56,250) to calculate the total yield per hectare. The adjusted factor of 10% was taken into account because of the possible mortality of some of the plants before harvest.

The product of the total yield per hectare and farm-gate price gave the gross revenue of crop production. In this study, the farm-gate price was used in all the analyses.

The cost of labour was based on the wage system as practiced by the estate. The farm-gate price was used to accommodate cost of all farm materials and other inputs. The cost of land was calculated based on the annual rental value for pineapple plantations. An interest rate of 12% on the capital cost was adopted. Fines imposed on polluters (OECD 1975) were calculated in accordance with the Malaysian Environmental Quality Act, 1978 (amended in 1998) on burning of waste and the Air Pollutant Index (API).

From the API categorization (DOE 1996) (Table 1) the maximum fine of RM 100,000.00 (Environmental Quality Act 1978,) for open burning was apportioned as follows:

TABLE 1
API category of fines

API	Category	RM
0 - 50	Good	10,000.00
51 - 100	Moderate	15,000.00
101 - 200	Unhealthy	30,000.00
201 - 300	Very Unhealthy	50,000.00
301 - 500	Hazardous	75,000.00
> 500	Dangerous	100,000.00

The moderate category which corresponds to the RM 15,000.00 was used to calculate the cost of pollution per ha. This figure was arrived at by dividing RM 15,000.00 by 7.87 ha. The "moderate" category was selected based on the fact that since the much practiced open burning has been going on for more than 30 years, suspension of some air pollutants in the atmosphere due to burning was not ruled out and hence the category "good" was not applicable. Similarly, as burning is carefully regulated by the estate and complaints are yet to be lodged, neither of the categories succeeding "moderate" was deemed appropriate. The Land Expectation Value (LEV) was used to compare the viability of the two practices. The economic value of residue management is estimated based on "with" (RRF) and "without" (RBF) project frameworks. Using this approach, the economic cost of environmental pollution can be evaluated based on the incremental net benefit, calculated as the difference between net benefits of RRF and RBF practices.

The current practice of residue management is through open burning of leaves, crowns, and peduncles. The other alternative open to plantation owners is to invest in the removal of crop residue (RRF). This is costly, and will therefore affect the profitability of the pineapple farming system over time. Thus, the cost is measured in terms of the loss in the long-run net profitability of the plantation farming system for not investing in the removal of the crop residues. That is, the cost of the environmental pollution is the difference between the (present value) net returns of the pineapple plantation with RRF and the (present value) net returns with RBF practices. The relationship is clearly shown by the following formula: $INB = NB^{RRF} - NB^{RBF}$, where INB = Incremental net benefit (present value), NB^{RRF} = Net benefit of RRF practice (present value), and NB^{RBF} = Net benefit of burnt practices (present value).

The assumption made is that a pineapple plantation is managed based on a sustainable yield basis. Such an assumption enables the calculation of the incremental net benefit using the Land Expectation Value (LEV) framework (Klemperer 1996).

The land expectation value is written as:

$$LEV = \frac{INBt}{(1 + i)^t - 1}$$

where INB = Incremental net benefit at end of pineapple rotation (2 years), t = length of pineapple rotation (2 years), and i = rate of interest.

RESULTS AND DISCUSSION

The estimated yields from RBF and RRF were 56.81 and 56.25 Mg/ha, respectively. The difference of 0.56 Mg/ha was not statistically significant at P (0.05) using the t-test. The corresponding gross revenue of the pineapple production (benefit) of LRBF and RRF amounted to RM 9,090.00 and RM 9,000.00, respectively (Table 2).

The difference in the RBF and RRF management practices is demonstrated in the costs of labour, pollution, and yield (Table 2). The cost of farm materials, maintenance, and land were similar for both practices (Table 2).

The overall costs of labour of the RBF and RRF practices were estimated at RM 2248.15 and RM 2,422.78, respectively. The difference of RM 174.63 was due to the different methods employed during land preparation. During this phase, about RM 218.95 (9.04% of the total cost of labour for RRF) was spent on crop residue removal and transportation as against RM 44.32 (1.53% of the total cost of labour for residue burning (RBF)). Compared to the other labour-related activities (Table 2), the cost involved in crop residue burning (RBF) was among the cheapest for farm activities. Unlike RRF, labour cost was the third most expensive activity. Perhaps, this justifies the burning of pineapple residues in pineapple plantations, as the amount of RM 1,74.63 saved through this practice is approximately 94.03% higher than RM 90.00 (difference between the revenues of RRF and RBF; RM 9,090.00 - 9,000.00). The result further

TABLE 2
Present value (12% interest) of cash flow per ha basis for burning and removal of pineapple residues

Activity	Year 1	Year 2
	RM	
RBF (Burning residues)		
Inflow (Benefit)		
Yield	0	9,090.00
Outflow (Costs)		
Land preparation	44.32	0
Preparation of suckers	898.44	0
Planting	1,054.69	0
Fertilization	123.75	0
Pesticides application	39.83	0
Hormoning	42.67	0
Harvesting	0	44.45
Suckers	0	2,343.75
Fertilizer	0	1,657.78
Pesticides	0	166.28
Hormone	0	188.32
Land	42.08	0
Maintenance	181.48	0
Net Benefit		**2,262.16**
RRF (removal of residues)		
Inflow (Benefit)		
Yield	0	9,000.00
Outflow (Costs)		
Land preparation	218.95	0
Preparation of suckers	898.44	0
Planting	1,054.69	0
Fertilization	123.75	0
Pesticides application	39.83	0
Hormoning	42.67	0
Harvesting	0	44.45
Suckers	0	2,343.75
Fertilizer	0	1,657.78
Pesticides	0	166.28
Hormon	0	188.32
Land	42.08	0
Maintenance	181.48	0
Net Benefit		**1,997.47**
Incremental Net Benefit		**264.69**
* Pollution: Using fines of RM 100,000.00	2,382.47	0
Incremental Net Loss at RM 100,000.00 fine		**120.31**

RM 3.80 = 1 USD

suggests that the practice of burning crop residues may not only be essential for the avoidance of tillage related problems and practices, but also helps in the reduction of labour costs for pineapple production.

The cost of pollution at a fine of RM 100,000.00 was estimated to be RM 2,382.47. The net benefits for RBF and RRF practices were estimated at RM 2,262.16 (excluding cost of pollution) and RM 1,997.47, respectively (Table 1). If the usual burning practice of the estate is followed, the incremental net benefits of RBF practice over the RRF practice will be RM 264.69 (RM 2,262.16 - 1,997.47). This suggests that burning is feasible at 12% interest rate. However, if the environmental cost of pollution of RM 2,382.47 ha-1 is included [assuming pollution is a cost to plantation owners (Gittinger 1982)], the cost of production will increase to RM 9,210.31, with net loss of RM 120.31 (RM 9,090.00 - 9,210.31). The loss incurred with the inclusion of the pollution value further implies that no attempt should be made to adopt burning as part of the pineapple residue management.

Policy Implication

The imposition of the RM 100,000.00 fine renders the existing burning of pineapple residues as a non-viable practice, and hence demonstrates the need to resort to residue removal. The current stringent law imposed on open burning puts the present and future prospects of the entire pineapple industry at stake. In order for the pineapple industry to remain in business, it is proposed that all parties involved i.e. the government, the public and the estate owners should pool resources available to set up a common fund for research on how to develop technique(s) that will add value, or develop product(s) of commercial value from these pineapple residues. As many as 15,000 tonnes of pineapple residues are produced per cropping season and burnt openly (Ahmed *et al.* 1999). Recommendations from the respective parties will be subject to decisions of the policy makers.

CONCLUSION

Under the new ruling, removal of pineapple residues (RRF) before replanting looks economically viable. However, in order to overcome waste disposal problems, there is the need to improve the value or develop products which are commercially viable from these pineapple residues if this type of waste management is to be adopted fully by pineapple planters or growers.

ACKNOWLEDGEMENT

We thank Mr. Lee Sing Kim, Mr. Koh Soo Koon and Mr. Faisol Abdul Ghani of the Simpang Rengam Pineapple Estate for their help, the National Council for Scientific Research and Development, Malaysia for financial support and the staff of the Soil Fertility Laboratory for their analyses.

REFERENCES

AGRIQUEST SDN. BHD. 1999/2000. *Malaysia Agricultural Directory and Index.* Kuala Lumpur: AGRIQUEST Sdn. Bhd.

AHMED, O.H., M.H.A., HUSNI, R.S. SYED OMAR, M.M. HANAFI and S.K. KOH. 1999. The effects of residue management practices on phosphorus and potassium uptake in pineapple. *Malaysian Journal of Soil Science* **3**: 29-37.

DEPARTMENT OF ENVIRONMENT. 1996. *Malaysia Environmental Quality Report, 1996.* Kuala Lumpur: Department of Environment.

ENVIRONMENTAL QUALITY ACT. 1974. *Act 127 and Subsidiary Legislations.* Kuala Lumpur: International Law Book Services.

GITTINGER, J.P. 1982. *Economic Analysis of Agricultural Projects.* 2nd ed. Baltimore: John Hopkins Univ. Press.

JORDAN, C.F. 1985. *Nutrient Cycling in Tropical Forest Ecosystems.* New York: John Wiley and Sons.

KLEMPERER, W.D. 1996. *Forest Resource Economics and Finance.* New York: McGraw-Hill.

ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT (OECD). 1975. *The Polluter Pay Principle: Definition, Analysis, Implementation.* Paris: OECD Press.

PY, C., J.J. LACOEUILHE and C. TEISSEN. 1987. *The Pineapple Cultivation and Uses* (translated by Daphe and J. Goodfellow). 15 rue Victor-Cousin, Paris (ve).

SELAMAT, M.M. and M. RAMLAH. 1993. The response of pineapple cv. Gandul to nitrogen, phosphorus, and potassium on peat soils in Malaysia. *ACTA Horticulturae* **334**: 247-254.

(Received: 7 July 2000)
(Accepted: 27 February 2002)

Pertanika J. Trop. Agric. Sci. **25(1)**: 53 - 62 (2002)

ISSN: 1511-3701

Utilization of Agricultural Wastes for the Growth, Leaf and Soil Chemical Composition of Cocoa Seedlings in the Nursery

E.I. MOYIN JESU & B. ATOYOSOYE

Agronomy Department
Federal College of Agriculture
Akure, Ondo State
Nigeria

Keywords: Wood ash, cocoa pod husk, rice bran, cocoa seedling, nursery, organic residue treatment

ABSTRAK

Satu eksperimen mengkaji keberkesanan abu kayu, serbuk kulit, sekam padi dan abu tandan kelapa sawit digunakan biasanya buah koko atau dicampur dengan baja najis itik dan ayam ke atas daun, komposisi kimia tanah dan pertumbuhan anak benih koko di tapak penyemaian, yang dikendalikan di Akure (Lat 7°N', 5°10'E) di zon hutan hujan Nigeria sepanjang tahun 1997 hingga 1999. Sebanyak 12 rawatan sisa organik yang setiap satunya digunakan dalam 30 g per 10 kg tanah (6+/ha) dalam satu polibeg dibanding dengan NPK 15-15-15 (iaitu pembajaan yang dicadangkan) yang menggunakan 2 g per 10 kg tanah (400 kg/ha) dan satu rawatan kawalan. Rawatan-rawatan tersebut diulangi sebanyak empat kali dan diatur dalam pola rawak yang lengkap. Sisa-sisa dan tanah tersebut dianalisis secara kimia sebelum biji-biji benih disemai. Dua biji benih koko (Theobroma cacao (L)) *ditanam dalam setiap polibeg dan dijadikan satu pokok selepas 14 hari. Parameter pertumbuhan seperti ketinggian pokok, kawasan daun, parameter pertumbuhan stem seperti ketinggian pokok, kawasan daun, ukuran lilit stem, seperti ketinggian pokok, kawasan daun, ukuran lilit, pengeluaran daun, akar dan berat sukatan tunas diukur. Kandungan nutrien daun dan p^H tanah serta kandungan (organik juga ditentukan). Keputusan-keputusan menunjukkan bahawa rawatan sisa organik secara signifikannya meningkatkan ($p<0.05$) pertumbuhan pokok, daun, kandungan N, P, K, Ka, Mg dan Na, pH tanah dan ciri-ciri organik meningkatkan pertumbuhan, daun dan nutrien tanah lebih daripada rawatan baja NPK kecuali untuk tanah N dan P. Tanah yang rendah pH apabila dibajakan dengan NPK melambatkan percambahan biji benih koko dan pertumbuhan berikutnya. Di antara rawatan-rawatan sisa tanaman, abu kayu dan abu tandan kelapa sawit meningkatkan kebanyakan kandungan tanah dan nutrien daun serta parameter-parameter pertumbuhan anak benih koko sementara tanah dirawat dengan kombinasi abu tandan kelapa sawit dan baja najis ayam belanda menunjukkan pertumbuhan kandungan daun dan tanah N, P, K, Ca dan Na pH tanah dan kandungan ciri-ciri organik.*

ABSTRACT

An experiment investigating the effectiveness of wood ash, cocoa pod husk, rice bran and oil palm bunch ash used ordinarily or in combination with duck and turkey manures on the leaf, soil chemical composition and growth of cocoa seedlings in the nursery, was conducted in Akure (Lat 7°N', 5°10'E) in the rainforest zone of Nigeria during the period of 1997 to 1999. Twelve organic residue treatments, each applied at 30 g per 10 kg soil (6t/ha) in a polybag were compared to the NPK 15-15-15 (i.e recommended fertilization) applied 2 g per 10 kg soil (400 kg/ha) and a control treatment. The treatments were replicated four times and arranged in a completely randomized design. The residues and soils were chemically analyzed before seeds were sowed. Two cocoa seeds (Theobroma cacao (L.)) *were planted into each polybag and thinned to one plant after 14 days. The growth parameters such as plant height, leaf area, stem growth parameters such as plant height, leaf area, stem girth, leaf production, root and shoot dry weight were measured. The leaf nutrient contents and soil pH and organic C content were also determined. The results showed that the organic residue treatments significantly increased ($p<0.05$) the plant growth, leaf N, P, K, Ca, Mg and Na contents soil pH and organic matter (O.M) compared to the control treatment. All the organic residue treatments increased the growth, leaf and soil nutrients more than NPK fertilizer treatment except for soils N and P. The low pH of the soils when fertilized with NPK delayed*

germination of cocoa seeds and the subsequent growth. Among plant residue treatments, the wood ash and oil palm bunch ash increased most the soil and leaf nutrient contents and growth parameters of cocoa seedlings while the soil treated with the combination of oil palm bunch ash + turkey manure indicated the best of growth, leaf and soil N, P, K, Ca, and Na contents, soil pH and organic matter content.

INTRODUCTION

Cocoa *(Theobroma cacao)* originated from the upper amazon region of Latin America and it was introduced into Nigeria from Fernandopo in 1974 (Opeke 1982). Cocoa belongs to the genus *Theobroma* in the family stericulaceae and over 200 species of cocoa are recognised worldwide but all the cultured species belong to the single species *Theobroma cacao.*

Opeke (1982) reported that in Nigeria, cocoa serves as a valuable source of cocoa butter and beverages while the residual cocoa powder is used in cake biscuits, cocoa food, cocoa mixes and other confectioneries. The cocoa pod husk is a good source of organic fertilizer as it improves soil fertility (Adv Dappah *et al.* 1994). Potassium hydroxide when extracted from the husk can be used in soap making. Cocoa is also one of the main sources of foreign exchange earning for Nigeria, Ghana and Cote d'Ivore (Are 1967).

In spite of the utilization and importance of the crop, the cocoa production in Nigeria is facing serious problems at present, because the trees are ageing and there is a scarcity of new cocoa seedlings to replace about 571, 864 hectares of ageing cocoa trees in the field. This replacement is becoming difficult because there is scarcity of top rich soil to grow young cocoa seedlings in the nursery as a result of urbanisation and deforestation practices coupled with the continued decline in fertility of the field soils. Efforts to supplement the soil fertility through the use of inorganic fertilizers to grow cocoa seedlings are limited by the high cost of purchase, scarcity at the farmers' level and continued deterioration of soil properties (Folorunso *et al.* 1995).

Umoti *et al.* (1990) reported that both cocoa and oil palm were heavy drains of plant nutrients in the nursery and field. High productivity of these could be achieved and sustained by massive application of inorganic fertilizers. However, inorganic fertilizers have become very expensive (N1,500.00 per bag) especially for the low income farmers who constituted the major producers of both palm oil and cocoa in Nigeria. This assertion was further supported by Obatolu (1999) who reported that 305 kg Urea/ha/yr, 250 kg SSP/ha/year and 80 kg Kd/ha/yr would be required annually for cocoa production either in the nursery or field. Hence, in monetary terms, the cost of the inorganic fertilizers would be colossal. Therefore, the complementary use of organic fertilizer materials derived from the oil palm cocoa production, food crops such as rice, maize, cassava and trees could help to bring down the high cost.

The potentials of oil palm bunch ash, cocoa pod ash, rice bran, wood ash, sawdust duck and turkey manure as sources of fertilizers have been established (Omoti 1989; Ahenkorah *et al.* 1981; Obatolu 1983; Oladokun 1986; Folorunso 1999) in growing maize, cassava, oil palm, coffee and okra crops. The abundance of the cocoa pod husk, oil palm bunch ash, rice bran and wood ash have been established in Nigeria. For instance, Gill and Duffus (1986) reported that about 220,000 metric tones of dry cocoa pod husk were produced in Nigeria and about 60% of it was produced in Akure are of Ondo State, Nigeria. Folorunso (1999) also established the abundance of oil palm ash, rice bran and sawdust in the Akure area of Ondo State, Nigeria because of the rainforest ecology.

There is a scarcity of research information on the use of oil palm bunch ash, cocoa pod husk, rice bran and wood ash, used in ordinary form or in combination with duck manure and turkey manure to grow cocoa seedlings in the nursery and field. Therefore, there is justification to investigate these organic wastes to grow cocoa seedlings in the nursery to replace the old and non productive stock on the field for optimum production as a means of increasing the income base of the farmers and that of producing states by going into large scale production. The objectives of the study were therefore, to investigate the growth performances of cocoa seedlings as influenced by the organic residues applied alone or with duck and turkey manure in the nursery, and to determine the leaf nutrient contents and soil chemical properties of the cocoa seedlings as influenced by the organic residues.

MATERIALS AND METHODS

The experiment took place at Akure (lat 7°N', 5°10'E) in the rainforest zone of Nigeria during the period of 1997 to 1999.

The annual rainfall is 1300 mm and a temperature of 70°C. The soil is a sandy loam, skeletal, kaolin tic, isohyperthermic toxic paleustalf (Alfisol) or Ferric Luvisol (F.A.O).

Source and Preparation of Agricultural Crop Residues

Cocoa pod husk, woodash, oil palm bunch ash obtained from the cocoa farm plots, cassava processing unit and oil-palm processing unit of Federal College of Akure. The turkey and duck manure were got from livestock units and nearby farms in large quantities. Rice bran was collected from the 05-6 variety processed at College rice mill. The organic residues were processed to allow decomposition. The dried cocoa pod husks were ground using hammer mill while the rice bran was chopped into pieces, wetted and allow to decompose. The turkey and duck manure were stacked to allow for mineralization and placed under shade.

The College has 300 hectares each of cocoa, oil palm plantations from which high quantities of cocoa pod husks and empty oil palm bunches were available. It also had 200 hectares of rice fields from which sizeable quantities of rice bran could be obtained. The livestock unit had 6,000 turkey birds and the nearby farm had 4,000 ducks from which reasonable quantities of turkey and duck manure were collected for growing cocoa seedlings. The processing of tubers from 200 hectares of cassava generated high quantities of wood ash derived from fuel wood and planks purchased from the nearby sawmill. Generally, all the organic residues used were easily available, sustainable and cheap for growing cocoa, oil palm, kola seedlings in commercial quantities.

Analysis of the Organic Material Used for the Experiment

Two grammes of each organic material were weighed into a clean dry tecator digestion tube and 25ml of HNO_3 was added down the neck of the flask and swirled to ensure that the organic material was thoroughly wetted. Five millimeters of H_2SO_4 and $HCLO_4$ were added and the mixtures were swirled again. It was then placed on the digestion block and heated carefully. Digest-ion continued until the samples were clear and the acids were completely volatilized. The samples were allowed to cool and 10 ml of distilled water was added. Filtration into a 100 ml volumetric flask was done and the filtrate was left to cool before it was made to the mark with distilled water.

The filtrates collected from 25-5-5 ml HNO_3–H_2SO_4 digestion method were used for the determination of % P, K, Ca, Na and Mg by taking an aliquot of the plant digests into a 50 ml volumetric flask. For % P, 20 ml of phospho vanado molybate solution was added and allowed to stand for at least 2 hours. The color absorbance was measured on spectronic 20 at 442 um. The % K, Ca and Na contents, and an aliquot were measured into a 100 ml flask and diluted. 1 ml of the sample solution was taken, the flame photometer was adjusted, followed by the aspiration of the diluted sample solution. The solution was read in ppm (mg/kg) and later converted to % contents. Mg content was determined using atomic absorption spectrophotometer.

The % nitrogen was determined by weighing 2 g of each organic material into a digestion flask and 5 ml of HNO_3 with selenium and copper-sulphate tablets were added. After addition of sodium hyroxide, the distillate was collected, boric acid was added with an indicator before it was fitrated with 0.1M dil HCL.

Soil Analysis Before Planting

30 core soil samples were collected from 0.15 cm depth on the site, mixed thoroughly and the bulked sample was taken to the laboratory, air-dried and sieved with 2 mm sieve and ready routine analysis.

The soil pH(1:1 soil/water and 1:2 soil/0.01M $CaCl_2$) were determined using a glass/calomel system (Crockford and Nowell 1956). Organic carbon determination was done using the wet dichromate method (Walkley and Black 1934). The organic C was multiplied by 1.723 to get organic matter (O.M). The exchangeable cations were extracted using 1M NH_4OAC pH 7 solution and the amount of K, Ca and Na contents were determined on flame photometer using appropriate element filters while Mg content in the extract was read on atomic absorption spectrophotometer (Jackson 1958). The exchangeable acidity (H^+ and $Al3^+$) was measured from 0.01M HCI (Mclean 1965). Total nitrogen was determined by mocrok-jedahl

method (Jackson 1964) and the soil available phosphorus was extracted by Bray P1 extractant with Murphy Riley blue coloration (Murphy and Riley 1962) and the concentration measured on spectronic 20 at 882 um.

Nursery Experiment

The site was cleared and overhead shade was built for the nursery to prevent sun scorching. 10 kg of the sieved top soil were placed into each polybag measuring 30 x 11 cm. Twelve organic residue treatments viz: cocoahusk, rice bran, wood ash, oil palm bunch ash, cocoa pod husk + duck manure, wood ash + duck manure, oil palm bunch ash + duck manure, cocoa pod husk + turkey manure, rice bran + turkey manure, wood ash + turkey manure and oil palm bunch ash + turkey manure, a nursery recommended chemical fertilizer NPK 15-15-15 applied at 2 g per bag (400 kg/ha) and a control (no fertilizer no manure) were prepared.

The residues were applied at a ratio of 30 g (6t/ha) per bag for the ordinary forms of rice bran, wood ash, oil palm bunch ash and cocoa pod husk while their combination with turkey and duck manure were applied at a ratio of %0:50% by weight (15 g each).

The treatments were incorporated into the soil using handtrowel and were allowed to decompose for two weeks before cocoa seeds were sowed. Each treatment had six polybags each in a set totalling (14 x 6) 84 polybags including the NPK 15-15-15 treatment and control (no fertilization). They were arranged in completely randomized design and replicated four times (84 x 4). The total number of polybags for the treatments and their replication four times totalled 336 polybags.

The seeds germinated 14 days after sowing and the growth parameters such as plant height (cm), leaf area (cm2), stem girth (cm) and number of leaves were recorded weekly commencing at the 3rd week to the 14th week after sowing using ruler, vennier calibre and visula counts respectively. At harvest, 20 weeks after sowing, the cocoa seedlings were uprooted carefully for the determination of tap root length and shoot weight.

Weeds in the polybags were regularly controlled. Termite control using Basudin at two weeks interval was carried out and the cocoa seedlings were watered daily.

Chemical Analysis of the Cocoa Seedling Leaves

Leaf samples were taken from the middle and upper parts of the cocoa seedlings at the 15th week after sowing with secatour for each organic treatment, parked into labelled envelopes, oven-dried at 70°C. The dried leaves were weighed into small crucibles and dry-ashed for 6 hours in a muffle furnace at 450°C.

The nutrients in the ashed leaves were extracted with water. % N was determined by micro-kjedahl method (Jackson 1964). The %P was determined by using vanado-molybade yellow coloration and the content was read on spectronic 20 at 442 um. The % K and Ca were read on the flame photometer using appropriate element filters while the % Mg was determined on atomic absorption spectrophotometry (Jackson 1958).

Soil Analysis After Planting

Soil samples were taken from each polybag treated with different organic residue treatments using handtrowel at 20 weeks after sowing. The soils were air dried, sieved with 2 mm sieve for routine analysis of total N, available P, exchangeable K, Ca, Mg and Na contents, soil pH and organic matter as described earlier under soil analysis before planting.

Statistical Analysis

The data collected from the treatment effects of the organic residues on the growth parameters such as height, leaf area, stem girth, leaf population, root length and shoot weight, leaf and soil N, P, K, Ca, Mg soil pH and organic matter were analysed using ANOVA F-test and their means were separated and compared along the treatment effects using Duncan Multiple Range at 5% level.

RESULTS

Soil Analysis Before Planting

The physical and chemical properties of the soils used for growing the cocoa seedlings are presented in Table 1. Using the established soil levels in South-West Nigeria for cocoa seedlings, the soils are low in organic matter if compared with the critical level of 3% O.M (Agboola and Corey 1973). The total nitrogen is less 0.13% considered as optimum for cocoa production (Obatolu 1989).

TABLE 1
Chemical analysis of the soil before the experiment parameters

Parameters	
1. Soil pH (1:1 soil/water)	5.50
2. Soil pH (2:1 $Cacl_2$)	5.35
3. Organic C(%)	0.24
4. Nitrogen (%)	0.05
5. Phosporus (mg/kg)	4.43
6. Potassium (cmole/kg)	0.09
7. Calcium (cmole/kg)	0.12
8. Magnesium (cmole/kg)	0.15
9. N+ (cmole/kg)	0.08
10. C.E.C (cmole/kg)	0.44

The low values of soil K, Ca, Mg, Na, P, Total N, and O.M were indications of soils with poor fertility status and cocoa seedling growth on the soil would respond favourably to the application of the organic residues. The soils were sandy loam in texture, skeletal, kaolinitic, isohyportheme oxic paluestalf (Alfisol) or Ferric Luvisol (FAO) or Akure series.

Chemical Composition of the Agricultural Crop Residues

Table 2 shows the chemical properties of the agricultural crop residues used in the experiment. The duck manure had lower content of N, P, K, Ca and Mg compared to turkey manure. The oil palm bunch had lower content of N and P than that of wood ash. However, the K, Ca and Mg contents were higher in oil palm bunch ash than in the wood ash.

TABLE 2
Nutrients contents (%) of the agricultural wastes used for the experiment

Agricultural wastes	N	P	Ca	Mg	K
1. Cocoa pod husk	1.83	2.37	1.19	0.58	0.41
2. Rice bran	0.076	0.002	0.036	0.012	0.041
3. Wood ash	1.54	0.80	0.12	0.93	0.25
4. Oil palm bunch ash	0.15	0.32	0.19	0.75	0.45
5. Duck manure	1.52	2.59	0.77	0.29	0.75
6. Turkey manure	2.10	5.10	0.21	0.60	0.53

The cocoa pod husk had the highest available contents of P, K, Ca and Mg while the nutrient composition (P, K, Ca and Mg) of wood ash was slightly lower than similar nutrient content in oil palm bunch ash.

Effect of Agricultural Crop Wastes on Wastes on Growth of Cocoa Seedlings

Table 3 shows the data on plant height, leaf area, stem girth, leaf number, tap root length and shoot weight of cocoa seedlings in different agricultural crop wastes treatments.

The oil palm bunch ash + turkey manure treatment increased the plant height significantly ($p<0.05$) when compared to the oil palm bunch alone and control treatments. The wood ash, oil palm bunch ash, cocoa pod husk, rice bran applied alone or combined with the turkey and duck manure treatments increased the plant height of cocoa seedlings when compared to NPK treatment. The cocoa seedlings in NPK treatments did not germinate early.

Amongst the sole forms of agricultural waste treatments, the wood ash treatment had the highest plant height increment compared to cocoa pod husk, rice bran and oil palm bunch ash.

The agricultural wastes amended with turkey and duck manures increased the leaf area of cocoa seedlings compared to the wastes applied alone. The wood ash treatment increased the leaf area most compared to rice bran and cocoa pod husk treatments.

The oil palm bunch ash + turkey manure treatments increased the stem girth, leaf number, tap root length and shoot weight significantly ($p<0.05$) compared to wood ash + duck manure, rice bran + turkey manure and oil palm bunch ash + duck manure treatments.

The unamended wood ash and oil palm bunch ash treatments increased the stem girth, leaf number, tap root length and shoot wieght when compared to the unamended rice bran and cocoa pod husk.

Leaf Chemical Composition

Table 4 presents the leaf chemical composition of cocoa seedlings under the different agro-wastes used. The amendment of oil palm bunch ash with turkey manure treatment significantly ($p<0.05$) increased N, P, K, Ca, Mg and Na contents in cocoa leaf compared to other treatments. The cocoa leaf nutrient contents in

TABLE 3
The mean plant height, leaf area, stem girth and leaf number, of cocoa seedlings under different agricultural crop wastes used

Treatments (cm)	Plant height (cm^2)	Leaf area (cm)	Stem girth	Leaf Number Weight (g) At harvest	Fresh Shoot length (cm) at harvest	Tap root
1. Control	4.20a	12.30a	0.53a	3.06a	20.00a	3.00a
2. NPK 15-15-15	8.30b	21.42b	0.98b	5.50ef	60.00b	10.00b
3. Cocoa pod husk	12.80e	35.40e	1.26de	5.20e	100.00d	12.20d
4. Cocoa pod husk + duck manure	16.50h	54.16g	1.601	5.72fg	138.00g	15.10f
5. Cocoa pod husk + turkey manure	16.75hi	63.10i	1.68ij	7.0lh	163.00i	20.10h
6. Rice bran	9.45c	23.53c	1.10c	4.20b	85.00c	11.20c
7. Rice bran + turkey manure	15.53g	54.53gh	1.54h	6.30h	123.00f	14.00e
8 Rice bran + duck manure	12.10d	31.60e	1.12c	4.80c	86.00c	11.30c
9. Wood ash	13.10e	38.36f	1.32f	5.60d	113.00e	13.80e
10. Wood ash + duck manure	16.08gh	63.40i	1.70j	6.99h	153.00h	17.00g
11. Wood ash + turkey manure	18.80l	68.30j	1077k	8.0j	220.00jk	25.00l
12. Oil palm bunch ash	12.30d	31.08d	1.20d	5.00cd	102.0d	12.10l
13. Oil palm bunch ash + duck manure	16.66h	71.10k	1.86l	7.50j	225.00jq	25.00j
14. Oil palm bunch ash + turkey manure	19.40j	77.10l	2.21lm	9.00l	250.0m	27.00k

Treatment means within each group followed by the same letters are not significantly different from each other using Duncan Multiple Range Test at 5% level.

the unamended and amended organic treatments were higher than that of chemical fertilizer and the control treatments.

Soil Chemical Analysis at the End of Experiment

Table 5 shows the soil pH, O.M, N, P, K, Ca and Mg contents of soil at the end of the experiment. The oil palm bunch ash + turkey treatments increased the soil pH, O.M, N, P, K, Ca and Mg contents compared to the unamended wastes and the control treatments. The sole forms of the agricultural waste treatments increased the soil pH, O.M, N, P, K, Ca and Mg contents compared to the control treatments.

TABLE 4
The % leaf chemical composition of cocoa seedlings under different agricultural treatments

Treatments	N	P	K	Ca	Mg
1. Control (no fertilizer)	0.04a	0.16a	0.08a	0.02a	0.02a
2. NPK 15-15-15	2.40i	2.75m	0.56b	0.03a	0.04ab
3. Rice bran	0.32b	0.24ab	0.58b	0.24b	0.14bc
4. Cocoa pod husk	0.45c	0.35c	0.93c	0.45c	0.26
5. Wood ash	0.73d	0.66d	1.26d	0.63d	0.44e
6. Rice bran + duck manure	0.92ef	0.73de	1.44e	0.67de	0.53f
7. Wood ash + duck manure	1.42i	1.63j	2.30k	1.14gh	0.73hi
8. Cocoa pod husk + duck manure	1.72kl	2.30k	3.20l	2.16l	1.10l
9. Rice bran + turkey manure	1010g	1017gh	1065g	0.93f	0.66gh
10. Cocoa pod hukd + turkey manure	1.26h	1.45l	1077gh	1020hi	0.82j
11. Wood ash + turkey manure	1.58j	1.44i	1.93ij	1.53jk	0.84j
12. Oil palm bunch ash manure	0.85de	0.88f	1.48ef	0.99fg	0.58g
13. Oil palm bunch ash + duck manure	1.62jk	1.06g	1.86i	1.40j	0.92jk
14. Oil palm bunch ash + turkey manure	2.20m	2.50l	3.70m	2.55m	1.33m

Treatment means within each column followed by the same letters are not significantly different from each other using Duncan Multiple Range Test at 5% level.

TABLE 5
The soil chemical composition of cocoa seedlings after transplanting under different agricultural crop waste treatments

Treatments	% N	mg/kg P	cmol/kg K	Ca	Mg	PH	O.M
1. Control	0.03a	3.20a	0.06a	0.03a	0.02a	5.20a	0.24a
2. NPK 15-15-15	0.31h	36.20m	0.63d	0.08b	0.04ab	5.10a	0.26a
3. Rice bran	0.12b	11.30b	0.23b	0.26c	0.18c	6.40b	0.92b
4. Cocoa pod husk	0.18c	14.10c	0.44c	0.34d	0.22cd	6.70d	0.98bc
5. Wood ash	0.25e	17.20d	0.96e	0.84e	0.45e	6.90f	1.56d
6. Rice bran + duck manure	0.19c	19.10e	0.95e	0.86e	0.47ef	6.60c	1.80e
7. Cocoa pod husk + duck manure	0.28fg	22.30f	1.10g	0.92fg	0.50fg	6.80e	1.92f
8. Wood ash + duck manure	0.30h	24.50g	1.30ij	0.96gh	0.52gh	6.90f	1.99fg
9. Oil Palm Bunch Ash + duck manure	0.27ef	26.40gh	1.26hi	1.32l	0.66k	6.50e	2.46jk
10. Rice bran + turkey manure	0.21cd	27.20hi	0.99ef	0.88ef	0.56i	6.90f	2.10h
11. Cocoa pod husk + turkey manure	0.26e	21.80ij	1.40k	1.20ij	0.51fg	7.00g	2.30l
12. Oil Palm bunch ash + turkey manure	0.34i	34.10l	1.72m	1.40m	0.87m	7.30h	2.58m
13. Wood ash + turkey manure	0.20cd	29.70k	1.53l	1.22jk	0.71l	6.90f	2.51l
14. Oil palm bunch ash	0.23e	22.00f	1.20h	1.61i	0.62j	6.80e	2.40j

However, N, P and K contents in chemical fertilizer treated soil increased over the unamended and amended residues but were lower in the soil pH, O.M, Ca and Mg.

DISCUSSION

The soils normally used for growing cocoa seedlings were generally low in pH, O.M, N, P, K, Ca and Mg and these could be responsible for the poor growth of cocoa seedlings as reflected by the control treatment. The observation supported that of Agboola (1982c) who had reported poor growth responses of cocoa seedlings in soils not fertilized. It was expected that the application of rice bran, wood ash, oil palm bunch ash and cocoa pod husk alone or in combination with turkey and duck manures to the soil would increase the growth responses of cocoa seedlings.

The increase in the plant height, leaf area, stem girth, tap root length and shoot weight of cocoa seedlings grown with the sole and amended agricultural wastes could be due to their rich chemical composition. The observation agreed with Omoti *et al.* (1990) and Obatolu (1999) who reported that oil palm bunch ash, *Chromelina adoration* and cowdung applied at 15t/ha increased the plant height, leaf area and shoot growth of cocoa seedlings.

The nutrient contents on the leaf of cocoa seedlings under the control treatment were below the critical levels of 0.25% P, 1.19% K, 0.8% Ca and 0.7% Mg as reported by Jones and Eck (1973). Thus, the leaves of cocoa seedling were showing deficiency symptoms of P (purple colouration), K (burnt leaf margin), Ca (stunted root growth) and N (yellow colouration).

The application of sole and amended forms of cocoa pod husk, rice bran, oil palm bunch ash and wood ash increased the leaf N, P, K, Ca and Mg contents of cocoa seedlings over the control treatment and this could be attributed to their chemical composition (Table 2). This finding agreed with that of Adv-Dapph *et al.* (1994) and Folorunso (1999) who reported that cocoa pod husk, poultry manure and oil palm bunch ash were good sources of N, P, K, Ca, Mg to the soils for uptake of coffee and Okra crops.

However, the increase in leaf and soil chemical composition and growth performances of cocoa seedlings in the organic residues amended with turkey and duck manures compared to their sole forms could be attributed possibly to enhancement of their degradation rate by the manure and lower C/N ratio. Since turkey and duck manures are richer in N, P, K, Ca and Mg nutrient content than the plant residues, they are expected to improve soil nutrient availability and echanced soil fertility.

This observation agreed with that of Obatolu (1999) who reported the nutrients' superiority of *Chromelina adoration* amended with cowdung applied at 15t/ha for growing cocoa seedlings in the nursery compared to either *Chromelina adoration* of cowdung applied alone.

The N, P, K, Ca and Mg nutrients in this organic residue treatment were very important for the growth of cocoa seedlings. For instance, nitrogen is known to be mainly responsible for plant shoot and root growth (Ojeniyi 1984). Shortage of P is associated with reduction in plant gowth and K is essential for carbohydrate formation, synthesis of protein and promotion of meristematic tissue (Tisdale and Nelson 1966). The Ca and Mg nutrients encouraged root growth and chloropyhll formation in cocoa seedlings (Ahenkorah *et al.* 1981 and Oladokun 1986).

The better effect of oil palm bunch ash, cocoa pod husk and wood ash on the growth, leaf and soil chemical composition of cocoa seedlings compared to rice bran is consistent with the fact that their soils had higher values of soil pH, O.M, K, Ca and Mg nutrients than that of the latter. The observation agreed with Folorunso (1999) who reported that the rice bran had relatively low C, N, Ca, Mg and Zn contents and a high C/N ratio of 1:23 which would make it more resistant to degradation and their nutrients made more slowly available compared to wood ash, cocoa husk and oil palm seedlings.

The fact that wood ash, oil palm bunch ash and cocoa husk increased the soil pH is consistent with previous findings that ash contains mainly K, Ca and Mg (Ojeniyi 1995) and that cocoa husk is a major source of K (Adv-Dappah *et al.* 1994). The increased soil pH by these residues has confirmed that they were soil ameliorant and Froth (1984) has emphasised the importance of wood ash, oil palm bunch ash and cocoa pod husk with regards to increased availability of cations such as K, Ca and Mg in the soil. The inferior performance of rice bran in improving the soil

pH could be due to its high C:N ratio and consequent immobilization of soil nutrients, especially the cations (Folorunso 1999).

The NPK fertilizer also reduced the soil pH of cocoa seedlings and this might be as a result of $NH4^+$ sorption on the soil surface. The continuous use of 400 kg/ha NPK 15-15-15 (2 g/10 kg soil) was the blanket fertilizer recommendation used for cocoa seedlings both in the nursery and field in Nigeria. The above statement was corrobarated by Barber (1962) who reported that large applications of NPK fertilizer continuously might influence the cation concentration in the soil solution and on the exchange phase.

The low soil pH and reduction in organic matter on soils fertlized with the chemical fertlizer adversely affected the Ca and Mg contents of the soils. The observation could be adduced to the high soil P and K which could negatively influence the Ca and Mg availability because of high K/Ca, P/Mg and K/Mg ratio. The implication is that high soil K will result in nutrient imbalance and hidden toxicity for crops (Bear 1950) and could be responsible for the delay in germination and the subsequent poor growth of cocoa seedlings in the experiment.

Therefore, the use of the sole and amended forms of wood ash, oil palm bunch ash, cocoa pod husk and rice bran in the improvement of soil fertility for cocoa seedlings is consistent with the view of Swift and Anderson (1992) who reported that one important mechanism to improve nutrient recycling is through the use of applied organic inputs and retention of crop residues. Yet in many tropical cropping systems, little or no agricultural residues are returned to the soils leading to decline in soil O.M.

CONCLUSION

Agricultural wastes such as rice bran, cocoa pod husk, oil palm bunch ash and wood ash are effective sources of nutrients because their addition to the soil have enhanced the leaf and soil N, P, K, Ca, Mg, soil pH and O.M, plant height, leaf area, stem girth, root growth and shoot weight of cocoa seedlings.

Rice bran was the least effective while the amended residues with turkey and duck manures improved their effects on these above-mentioned parameters for cocoa seedlings.

It is therefore recommended that agricultural residues such as wood ash, spent grain, cocoa husk pod and oil palm bunch ash and their amendment with turkey and duck manures at 30 g per 10 kg soil (6t/ha) are very useful as fertilizer materials for improving the nutrient availability and ensuring sustainable cultivation of cocoa seedlings on lowly fertile soil in humid tropics.

This recommendation corroborates with the fact that inorganic fertilizers are scarce and expensive for the resource poor farmers who are the growers of cocoa seedlings in most developing countries.

REFERENCES

Adv-Dappah, H.K, J. Cobbina and E.O. Asare. 1994. Effect of cocoa pod ash on the growth of maize. *Journal of Agric. Science* Cambridge **132**: 31-33.

Agboola A.A. 1974. Organic materials as fertilization. *F.A.O. Bull* **27**: 147-152. Rome, Italy.

Agboola A.A. 1982c. Organic manuring and green manuring in tropical agricultural system. In *Proceedings of 12th International Congress of Soil Science*, p. 198-212, 8-16 Feb, New Delhi, India.

Agboola A.A. and R.B. Corey. 1973. Soil testing NPK for maize in the soil derived from metamorphic and igneous rocks of Western State of Nigeria. *Journal of West African Science Association* **17(2)**: 93-100.

Are L.A. 1967. Attempts to improve the performance of budded cacao materials in the green house: Effect of rootstock, age, and time of budding. In *Proc. 2nd International Cacao Research Conference*, Bahia, Brazil.

Ahenkorah Y, B.J. Halm and R.S. Amondo. 1981. Cocoa pod husk as source of potash fertilizer. *Turlalba* **31(4)**: 287-292.

Barber S.A. 1962. Exchange equilibra, selectivity and effective diffusion coefficient of K in soils. *Soil Science Soc. of Amer. J.* **43**: 39.

Bear F.E. 1950. Cation-anion relationship in plants and their bearing on crop quality. *Agronomy Journal* **42**: 176-178.

Crockford, L. and R. Nowell. 1956. *Laboratory Manual of Physical Chemistry. Experiments 31 and 32*, p. 558-559. New York: John Wiley and Sons.

FOLORUNSO, O.O. 1999. Use of plant residues for improving soil fertility and the yield of Okra *Abelmuschus esculentum* L and Amaranths *Amaranthus Viridis* L.Ph.D Thesis, Federal University of Technology, Akure.

FROTH, H.P. 1984. *Fundamental of Soil Science.* 7th edition. p. 214-245. Published by Macmillan Press Ltd.

FOLORUNSO, O.O., A.A. AGBOOLA and G.O. ADEOYE. 1995. Use of fractional recovery model to calculate potassium needs of some soil series in South Western Nigeria. *Journal of Technical Education,* NBTE **1(2)**: 55-67.

GILLS and DUFFUS. 1986. Cocoa market report No. 322, March 1986.

JACKSON, M.L. 1988. *Soil Chemical Analysis.* p. 57-67. Englewood Cliffs, N.J: Prentice Hall.

JACKSON, M.L. 1964. *Soil Chemical Analysis.* p. 86-92. Englewood Cliffs, N.J: Prentice Hall Inc.

JONE, B.J. and H.V. ECK. 1973. Plant analysis an aid as in fertilizing corn and grain sorphum. In *Soil Testing and Plant Analysis Revised* ed. L.M. Walsh and J.D. Beaton. *Soil Sci. Soc. Amer:* 349-364. Madison Wisconsin, U.S.

MCLEAN E.O. 1965. *Aluminium. Methods of Soils Analysis Part 2* ed. MC.A. Black. p. 927-932. Agronomy 9, Amer Soc. Agron. Madison Wisconsin, U.S.A.

MURPHY, J. and J.P. RILEY. 1962. A modified single solution method for determination of phosphate in natural waters. *Analytics Glumi-Acta* **27**: 31-36.

OBATOLU L.R. 1983. Cocoa/Arable crop inter-cropping. Ph.D Thesis, University of Ibadan, Ibadan, p. 50-60.

OLADOKUN M.A.O. 1986. Use of cocoa pod husk as fertilizer for maize production. *Nigerian Journal of Agronomy* **1(3)**: 103-109.

OBATOLU L.R. 1999. The growth of cocoa seedlings in the nursery using Chromelina odoration and cowdung. In *Proc. of 26th Annual Conference of Soil Science Society of Nigeria,* Nov 17-22, Bening, Nigeria.

OJENIYI S.O. 1984. Compound chemical fertilizer and food crop production. Effects of NPK 15-15-15 fertilizer on pepper, cowpea and maize. *Nigeria Journal of Applied Science* **2**: 91-95.

OJENIYI S.O. 1995. That our soil may not die. In *10th Inaugural Lecture of Federal University of Technology,* p. 3, March 23, Akure.

OMOTI U., L.P. OBATOLU and J.A. FAGBENRO. 1990. Complimentary use of organic and inorganic fertilizers for tree and forest crop production in Nigeria. In *Proc. of 3rd Annual Organic Fertilizer Conference,* p. 163-175, Durbar Hotel, Kaduna, Nigeria.

TISDALE S.L. and W.L. NELSON. 1966. *Soil Fertility and Fertilizers.* p. 20-26. New York: Macmillan Publishing Ltd.

WALKEY A. and I.A. BLACK. 1934. An examination of Degtajaroff method for determining soil organic acid filtration method. *Soil Sci.* **37**: 29-38.

(Received: 4 September 2000)
(Accepted: 9 October 2001)

Pertanika J. Trop. Agric. Sci. 25(1): 63 - 68 (2002)

ISSN: 1511-3701

Effects of Palm Fat Blends Inclusion on the Quality of Chicken Frankfurters

S.S. TAN[1], A. AMINAH[1], A.S. BABJI[1] & MOHD SURIA AFFANDI[2]

[1]*Department of Food Science,*
School of Chemical Sciences and Food Technology,
Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
[2]*Malaysian Palm Oil Board,*
No 6, Persiaran Institusi, Bandar Baru Bangi,
43000 Kajang, Selangor, Malaysia

Keywords: Palm fats, slip melting point, palm stearing, iodine value, solid fat content, palm olein

ABSTRAK

Tiga jenis lelemak sawit (PF) diproses daripada pelbagai adunan minyak sawit (PO) dan stearin sawit (POs) pada nisbah PO:POs bersamaan dengan 60:40, 70:30 dan 80:20 (berat/berat). Takat gelinciran (SMP), nilai iodin (IV) serta kandungan lemak pepejal (SFC) PF diukur. Lapan formulasi sosej ayam kemudian diproses menggunakan lelemak sawit PF60:40, PF70:30, PF80:20 serta olein sawit (POo) pada paras lemak 20% dan 25%. Ukuran-ukuran suhu pencincangan, kestabilan emulsi (ES) serta keupayaan memegang air (WHC) dilakukan ke atas adunan sosej ayam. Pada tahap lemak 25%, adunan daging yang dicampur dengan PF60:40 dan POo masing-masing mencatatkan suhu tertinggi dan terendah di akhir proses pencincangan. Adunan daging PF60:40 dan PF80:20 menghasilkan kehilangan cecair yang lebih rendah pada tahap 20% berbanding 25% ($P<0.05$). Formulasi yang dicampur dengan PF menunjukkan keupayaan memegang air yang lebih tinggi daripada formulasi POo ($P<0.05$).

ABSTRACT

Three types of palm fats (PF) to be incorporated into meat batters were prepared from palm oil (PO) and palm stearin (POs) with the ratio of PO:POs at 60:40, 70:30 and 80:20 (wt/wt). The slip melting point (SMP), iodine value (IV) and solid fat content (SFC) of PF were measured. Eight formulations of frankfurters were then produced using PF60:40, PF70:30, PF80:20 and palm olein (POo) at 20% and 25% of fat levels. Chopping temperature, emulsion stability (ES) and water holding capacity (WHC) of meat batters containing PF and POo were measured. At 25% fat level, meat batters mixed with PF60: 40 recorded the highest final chopping temperatures at the end of comminution, while POo recorded the lowest value. Fluid loss of meat batters prepared with PF60:40 and PF80:20 were significantly lower at 20% fat level compared to that of 25% ($P<0.05$). Higher WHC was exhibited by meat batters containing various PF compared to the one with POo ($P<0.05$).

INTRODUCTION

Studies of incorporation of plastic fats into meat emulsion have been reported by Lee *et al.* (1981a, 1981b, 1981c), Septon *et al.* (1993) and Babji *et al.* (1998). Effects of fat's physical properties in emulsion stabilization were investigated by Lee *et al.* (1981c). Thermal stability of emulsion was inversely related to fat's softness and heating rate. Fluid release during heating commenced at about 10°C below the softening point of the fat and the temperature at which fluid loss commenced rose with the increase in solid fat content (SFC). Lee *et al.* (1981c) also suggested that emulsions prepared with soft fats (SFC around 20% at 70°C) was thermally less stable unless fat is dispersed uniformly throughout the matrix.

Unlike medium hard fat, soft fat was not uniformly dispersed during comminution. Stable emulsions were obtained when dispersions were prepared with fat containing 30% solid at 16% product fat level, 40% solid at 22% level, and 50% solid at 28% level (Lee *et al.* 1981c). In margarine, the fat blend is designed to have SFC of less than 3% at 35°C for clean melting in the mouth (Gunstone 1996). Thus, the high SFC

values and softening points (>50°C) in soy-based plastic fats studied might render them impractical to be incorporated into meat products.

Studies on replacement of animal fat with palm oil products in beef burgers were reported by Babji *et al.* (1998) and Shiota *et al.* (1995). The potential of palm fat to replace animal fat in processed meats seems promising. The physicochemical characteristics of palm fractions can be tailored to imitate functional properties of various animal fats. Moreover, palm oil also possesses several important physical properties and benefits which include high stability to oxidation; natural solids content; stability in the beta prime crystalline form; ready and increasing availability worldwide; competitive priced, nutritionally healthy and balanced composition (Anon 1991). Therefore, the objectives of the present study were to investigate various palm fats and palm olein, and level of fats on the thermal stability of chicken frankfurters.

TABLE 1
Formulations for chicken frankfurters

Ingredient	Composition of meat batters (%)	
	20% Fat level	25% Fat level
Chicken Trimming (CT)	44.19	39.19
Palm fats with PO:POs =60:40, 70:30, 80:20 or palm olein	20.00	25.00
Iced water	25.71	
Soy protein isolate (ISP)	1.78	
Chicken flavour	1.78	
Salt	0.49	
Golden syrup	1.20	
Dextrose	1.00	
Phosphate	0.49	
Pepper	0.33	
Curing salt	0.01	
Sodium erythrobate	0.02	
Potato starch	3.00	

MATERIALS AND METHODS

Experimental Design

The design consisted of a 4 x 2 factorial arrangement with the factors being types of fat (PF60:40, PF70:30, PF80:20 and palm olein) and levels of fat (20% and 25%).

Materials

Three types of palm fats with different ratios of palm stearin (POs): palm oil (POo) at 60:40, 70:30 and 80:20 were provided by the Malaysian Palm Oil Board (MPOB). Palm olein (PO_o) with the brand name Sawit Emas was obtained from a local retailer. Chicken trimming was purchased from Dinding Poultry Sdn. Bhd., Setiawan, Perak.

Formulation

Formulations for chicken frankfurters are shown in Table 1.

Processing

Frozen chicken trimming was manually cut into 2 cm^3 cubes and minced through a 4 mm-diameter grinder plate. The minced chicken trimming was stored at -18°C until used. Before the actual frankfurter processing, pre-emulsion was prepared. Isolated soy protein (ISP) was chopped with palm olein (POo) or palm fats (PF) and water at a ratio of 1: 5 :5 (w/w/w) with a mixer (Hobart Ditosama). The ISP-water mixture was chopped for 4 minutes. Due to the difference in physical state between POo and PF, the chopping time after fat incorporation also varied. The pre-emulsions of POo and PF were further mixed for 3 and 7 min, respectively, after the addition of fats. The pre-emulsions were kept in a chiller until used.

Before processing, dextrose, phosphate, chicken flavour, sodium erythrobate, pepper and curing salt were diluted in iced water. Salt was added to frozen minced chicken trimming (CT), and chopped in a mixer (Hobart Ditosoma) for 4 min. Pre-emulsion and part of the iced water mixed with various ingredients were then added and chopping continued for another 1 min. Chopping was carried on for another 1 or 3 minutes after the remaining POo or PF was added. The remaining ingredients, namely potato starch, corn syrup and iced water mix were added to the meat batter and chopped for another 2 min to ensure a thorough mixing and to obtain a homogenised meat batter. Temperature of meat batters was recorded at the end of blending.

Emulsion Stability

The emulsion stability for meat batter was determined by using the combined and modified method of Miller *et al.* (1968) and Decker (1985) as described by Seri Chempaka *et al.* (1996). A

10 g sample of frankfurter batter was placed on a coiled wire attached halfway to a graduated glass cylinder (2 cm x 11.5 cm) and covered with aluminium foil. The samples were cooked in a closed water bath of 70°C for 60 min. The level of water in the water bath covered $\frac{3}{4}$ of the tubes. The coils and samples were removed and the weight of the released liquid was recorded (w). Emulsion stability was calculated as:

$$ES(\%) = \frac{w}{20} \times 100\%$$

Water Holding Capacity

Water holding capacity (WHC) was determined by the modified technique of Wierbicki (1957). Approximately 20 g of the sample were homogenised with 40 ml of distilled water. Ten grams of homogenate were weighed and put into a graduated centrifuge tube. The homogenate was centrifuged at 2000 rpm for 5 min. The volume of insoluble protein (v) was recorded, and WHC(%) was calculated as shown below:

$$\% \text{ WHC} = v / 10 \times 100\%$$

Iodine Value, Slip Melting and Solid Fat Contents of Palm Fat

Iodine values (IV) and slip melting points (SMP) of palm fats were determined by Wij's and Capillary tube methods (Siew *et al.* 1995), respectively. Solid fat content (SFC) of palm fats was measured by 'wideline nuclear magnetic resonance (NMR) Bruker NMS120 Minispec Analyzer' using the PORIM parallel method (Siew *et al.* 1995).

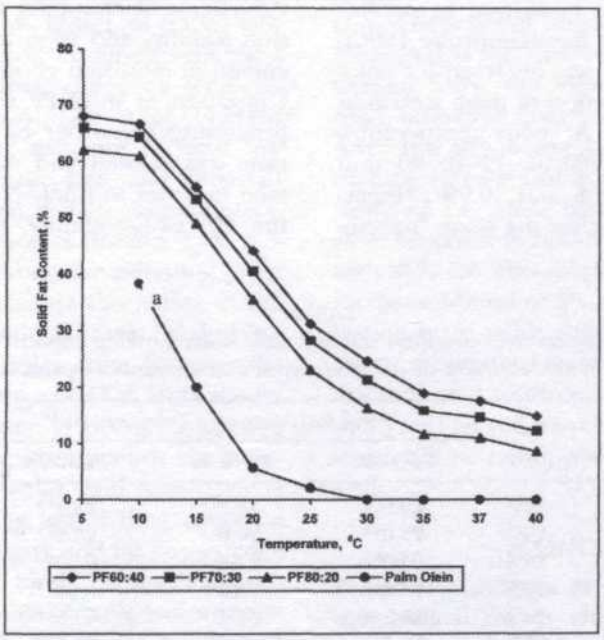
Statitiscal Analysis

Data collected from this study were analysed using PC-SAS version 6.04. If F value was significant, comparison of means by Duncan multiple range test (Cody and Smith 1991) was subsequently carried out.

RESULTS AND DISCUSSION

Physical Characteristics of Palm Fats and Palm Olein

The physical characteristics of palm fats (PF) and palm olein (POo) are shown in *Fig. 1* and Table 2. The slip melting points (SMP) increased while iodine value (IV) decreased along with the



[a] The SFC value of palm olein (POo) is quoted from Siew (1998)

Fig. 1. Effect of heating on the solid fat content (SFC) of various palm fats and palm olein

TABLE 2
Slip melting point (SMP) and iodine value (IV) of various palm fats and palm olein

	Palm fat (Palm oil : Palm stearin)			POo [a]
	PF60:40	PF70:30	PF80:20	
SMP (°C)	49.1	47.3	45.5	21.5
IV	44.7	46.5	49.0	56.8

[a] The values of SMP and IV of palm olein (POo) are quoted from Siew (1998)

increment of stearin in PF. The IV measures the content of unsaturation or double bonds capable of reaction with halogen, and it is a good index of the degree of unsaturation in fat products. The solid fat content (SFC) of PF at various temperatures was measured and monitored at different temperatures to give a plot of percentage of solid against temperature (*Fig. 1*). The slope of this curve and the temperature at which there is no solid phase provide useful information about the melting and rheological behaviours of the fat under investigation (Gunstone 1996). Solids remaining at the mouth temperature give a feeling of 'waxiness' to the product and these properties are important in confectionery and in spreading fats (Gunstone 1996). In this study, higher SFC was observed for palm fats with a greater proportion of palm stearin at any given temperature. At body temperature (37°C), SFC for the PF60:40, PF70: 30 and PF80:20 was 17.5%, 14.6% and 10.9%, respectively. It is uncertain whether the same "mouth-coating" effect of high SFC in confectionery and spreading fats will also be applied in meat products, especially comminuted meat products where fat has been finely distributed and emulsified. As more and more research focuses on fat substitution in meat products using various kinds of fat, the role of SFC should be investigated further, especially with regard to the physical and sensory attributes of the meat products.

Effects of Type and Level of Palm Fats and Palm Olein at Chopping Temperature

The final temperature of the meat batters at the end of comminution is shown in Table 3. Final chopping temperatures of meat batters containing palm fat PF60:40 and palm olein (POo) were significantly lower than those of PF70:30 and PF80:20 at 20% fat level. Effects of rising fat concentration on final chopping temperatures appeared unclear as no clear trend was shown from the data obtained. The final chopping temperature of meat batters containing POo at 25% was the lowest among all formulations tested. In processing comminuted meat products, temperature of meat products should be kept as low as possible to avoid denaturation of meat protein. Halmer and Saffle (1963) studied the effects of chopping temperatures on emulsion stability and reported that breakdown occurred in emulsion chopped to 16°C or higher. Utilisation of solid PF was found to affect the processing behaviour of frankfurters. A longer time was needed and more energy was generated in order to finely comminute and disperse the PF. Consequently, meat batters prepared

TABLE 3
Final chopping temperature, emulsion stability and water holding capacity of meat batters as influenced by the addition of different types and amounts of palm fats and olein

		Palm fat(Palm oil : Palm stearin)[f]			POo [f]
		PF60:40	PF70:30	PF80:20	
Final chopping	20%	$20.0^{b\,y}$	$23.3^{a\,x}$	$23.7^{a\,x}$	$20.0^{b\,x}$
Temperature (°C)	25%	$25.0^{a\,x}$	$20.0^{c\,y}$	$23.3^{b\,x}$	$18.5^{d\,y}$
Emulsion stability	20%	$0.00^{b\,y}$	$2.44^{a\,x}$	$0.00^{b\,x}$	$0.00^{b\,x}$
(% Fluid loss)	25%	$3.95^{a\,x}$	$1.49^{b\,x}$	$3.90^{a\,y}$	$0.25^{b\,x}$
Water holding	20%	$38.0^{c\,x}$	$64.3^{a\,x}$	$59.5^{b\,x}$	$34.3^{d\,x}$
Capacity (%)	25%	$33.5^{c\,y}$	$62.7^{a\,x}$	$45.5^{b\,y}$	$21.3^{d\,y}$

[a-d] Mean values within the same row bearing different superscripts differ significantly ($P<0.05$)
[x-y] Mean values within the same column bearing different superscripts differ significantly ($P<0.05$)
[f] Fat used for frankfurter processing: PF = Palm fat; POo = Palm olein

with PF had generally recorded higher chopping temperatures compared to the ones containing POo. Besides raising the chopping temperature, the addition of PF also elevated the viscosity of meat batters. Meat batters containing PF were observed to be thicker than those of POo. Thicker meat batter is problematic during processing, because low flow-ability of meat batter results in low recovery, machine jamming, stuffing difficulty and overall poor handling. The impaired appearance of frankfurters such as holes at the surface and loose skin after cooking might be due to insufficient meat content in casings or to the possibility that the meat was not compact enough during stuffing.

Emulsion Stability

The emulsion stability of meat batters is shown in Table 3. Emulsion stability is used to determine the fat and water binding ability of the batter and is crucial to frankfurter production. At 20% fat concentration, meat batters mixed with PF60:40, PF80:20 and POo exhibited no fluid loss after heating. Fluid loss of meat batters containing 25% of PF60:40 and PF80:20 were the highest among all formulations and were significantly different from that of POo at the same level. The difference in emulsion stability between solid fat (PF) and liquid oil (POo) may be due to the difference in physico-chemical properties of fat and final chopping temperature (Webb *et al.* 1975). Lee *et al.* (1981b) studied the microscopic structure of meat batters prepared from plastic fats, and reported that emulsion breakdown at high chopping temperature is a consequence of increased fat mobility after softening. Beyond the softening point of fat, its mobility overcomes the ability of the protein matrix to maintain uniform fat distribution by restraining fat coalescence. Between the cooking temperature range of 43 to 70°C, the fat within the protein lattice is in an expanding liquid form while the proteinaceous shell surrounding it is in a semi-solid rigid state (Jone & Mandigo 1982). Cooking would then cause fat to separate from the matrix and fat coalescence occurs, developing interstitials causing a discontinuity of matrix. Fluid loss of meat batter incorporated with liquid oil at both fat levels were extremely low indicating a very stable emulsion. In contrast with PF, POo had exhibited the maximum mobility during addition. Thus, it is envisaged that a different mechanism had taken place in the stabilisation of meat batters containing different types of fat. The hypothesis proposed by Lee *et al.*(1981b) might be well suited for meat batters prepared with plastic fats, such as palm fats in this study. Initial and total emulsification of fat droplets, together with protein entrapment do play important roles in the stabilisation of meat emulsion containing liquid oil and plastic fat. As plastic fats melt within a wide temperature range, effect of initial emulsification and protein entrapment ceased as temperature rose. Melted fat coalesced and eventually led to the disruption the meat emulsions, resulting in emulsion breakdown.

Water Holding Capacity

Contrary to the result of emulsion stability, water holding capacity (WHC) of meat batters containing palm fats (PF) were higher than meat batters containing palm olein (POo) ($P<0.05$) (Table 3). WHC of meat batters formulated with PF60:40, PF80:20 and POo decreased when fat content was raised from 20 to 25%. WHC of meat batters containing POo was observed to be the lowest for both fat leveis. Determination of centrifuge loss in unheated meat, as in the determination of WHC, belongs to a group of measurements using mechanical force and is dependent on the plasticity of the meat. Meat that is soft and easily compressed by centrifugal force will express more juice than a solid, inflexible material (Honikel 1987). Therefore, the soft batter of POo showed a lower reading in total insoluble protein compared to those of PF. Meat batters containing 20% fat were observed to retain more water than batters with 25% fat. This might be due to the fact that further addition of 5% extra fat had overloaded the meat protein's ability to bind water and fat. When mechanical forces, such as centrifugation are subjected to the mixture, the loosely bound water and fat will be released and therefore, less water will be entrapped within the protein portion.

CONCLUSION

Palm olein shows a greater potential to substitute animal fat in chicken frankfurters as it possesses no manufacturing problem and results in a more stable meat emulsion compared to the various palm fats tested. Low recovery and defective products are among problems encountered when palm fats were to totally substitute animal

fat. The plasticity and a wide melting temperature range of palm fats caused difficulty in chopping and resulted in lower quality meat products. Further research is being carried out to improve the quality of the frankfurters so that palm olein blended frankfurters can be as good as or better than conventional frankfurters.

ACKNOWLEDGEMENT

The authors wish to thank the Malaysian Palm Oil Board (MPOB) and Universiti Kebangsaan Malaysia (UKM) for granting research funds that support this type of research work.

REFERENCES

ANON. 1991. *Basic Background Information on Palm Oil.* Kuala Lumpur: Malaysian Palm Oil Promotion Council.

BABJI, A.S., A.R. ALINA, M.Y. SERI CHEMPAKA, T. SHARMINI, R. BASKER and S.L. YAP. 1998. Replacement of animal fat with fractionated and partially hydrogenated palm oil in beef burgers. *Int. J. Food Sci & Nutr.* **49:** 327-332.

CODY, R.P. and J.K. SMITH. 1991. *Applied Statistics and the SAS Programming Language.* Englewood Cliffs: Prentice Hall.

DECKER, C.D. 1985. Rolston Purina, St Louis, MO. Cited in Seri Chempaka, M.Y and Babji, A.S. 1996. Effect of non-meat proteins, soy proteins isolate and sodium caseinate, on the textural properties of chicken bologna. *Int.J. Food Sci. & Nutr.* **47:** 323-329.

GUNSTONE, F.D. 1996. *Fatty Acid and Lipid Chemistry.* London: Blackie Academic & Professional.

HAMMER, G.F. 1992. Processing vegetable oil into frankfurter-type sausages. *Fleischwirtsch* **72(9):** 1268-1265.

HELMER, R.L. and R.L. SAFFLE. 1963. Effect of chopping temperature on the stability of sausage emulsions. *Food Technol.* **17:** 565.

HONIKEL, K.O. 1987. The water binding of meat. *Fleischwirtsch* **67(9):** 1098-1102.

JONES, K.W. and R.W. MANDIGO. 1982. Effects of chopping temperature on the microstructure of meat emulsions. *J. Food Sci.* **47:** 1930-1935.

LEE, C.M. and A. ABDOLLAHI. 1981a. Effect of hardness of plastic fat on structure and material properties of fish protein gels. *J. Food Sci.*: 1755 -1759.

LEE, C.M., R.J. CAROLL and A. ABDOLLAHI. 1981b. A microscopical study of the structurel of meat emulsions and its relationship to thermal stability. *J. Food Sci.* **46:** 1789-1793, 1804.

LEE, C.M., J.W. HAMPSON and A. ABDOLLAHI. 1981c. Effect of plastic fats on thermal stability and mechanical properties of fat-protein gel products. *JAOCS.* **48:** 983-987.

MILLER, W.O., R.L. SAFFLE and S.B. ZIRKLE. 1968. Factors which influence the water-holding capacity of various types of meat. *J. Food Sci* **22:** 89- 92. Cited in Seri Chempaka, M.Y and Babji, A.S. 1996. Effect of non-meat proteins, soy proteins isolate and sodium caseinate, on the textural properties of chicken bologna. *Int.J. Food Sci. & Nutr.* **47:** 323-329.

PARK, J., K. S. RHEE, J. T. KEETON and K. C. RHEE. 1989. Properties of low-fat frankfurters containing monounsaturated and omega-3 polyunsaturated oils. *J. Food Sci.* **54(3):** 500-504.

SAFFLE, R.L. 1968. Meat emulsions. *Adv. Food Res.* **16**: 105-160.

SHIOTA, K., S. KAWAHARA, A. TAJIMA, T. OGATA, T. KAWANO and T. ITO. 1995. Sensory evaluation of beef patties and sausages containing lipids with various component fatty acids. *Meat Sci.* **40:** 363-371.

SEPTHON, S.W., K.O. HONIKEL and A.C. CLEGG. 1993. Finely comminuted meat products: The effect of various fat sources on the stability. *Fleischwirtsch* **73 (11):** 1281-1285.

SIEW, W.L., T.S. TANG and Y.L. TAN. 1995. PORIM test methods. Palm Oil Research Institute of Malaysia.

SIEW, W.L. 1998. Crystallisation of palm olein. *PORIM Information series:* 73.

WEBB, N.B., V.N.M. RAO, A.J. HOWELL, B.C. BARBOUR and R.J. MONROE. 1975. Effect of lipid and chopping temperatures on sausage emulsion stability in a model system. *J. Food Sci.* **40:** 1210 -1213.

WIERBICKI, E., M.G. TIEDE and R.C. BURELL. 1957. Water holding capacity. Centrifugal method. *Fleischwirtschs* **10:** 951.

(Received: 18 January 2001)
(Accepted: 27 February 2002)

Pertanika J. Trop. Agric. Sci. 25(1): 69 - 73 (2002)

ISSN: 1511-3701

COMMUNICATION

Resistance of Some Forest Plantation Timbers Against Rotting Fungus and Their Durability in Ground Contact

ZAIDON A., KAMARUL AZLAN, M., FAIZAH, A.H. & MOHD HAMAMI S.

Department of Forest Production
Faculty of Forestry
Universiti Putra Malaysia
43400 UPM, Serdang, Selangor

Keywords: Plantation timbers, heartwood, white rot, stakes, graveyard test

ABSTRAK

Empat spesies kayu hutan ladang, Acacia crassicarpa, Acacia auriculiformis, Gmelina arborea (yemane) *and* Azadirachta excelsa *(sentang)) telah diuji sifat ketahanan semula jadi terhadap kulat pereput putih (*Pycnoporous sanguineus*) dan juga ketahanannya selepas 3 bulan pendedahan kepada tanah.* Hevea brasiliensis *(kayu getah) dan* Neobalanocarpus heimii *(cengal) digunakan sebagai sampel kawalan. Sampel kayu ini dinilai menurut Piawaian ASTM dan disediakan dari bahagian kayu teras. Kehilangan berat sampel kayu spesies kayu-kayu ini berjulat 7.69 hingga 14.69% bagi kayu teras luar dan 13.16 hingga 24.20 bagi kayu teras dalam. Secara puratanya semua kayu hutan ladang yang diuji termasuk dalam kelas tahan daripada serangan kulat pereput putih. Dalam kelas ini* G. arborea *merekodkan tahap kehilangan berat paling tinggi (19.88%), diikuti oleh* A. crassicarpa *(19.53%),* A. excelsa *(15.44%) dan* A. auriculiformis *(10.75%).* H. brasiliensis *dan* N. heimii *masing-masing mengalami kehilangan berat 61.20% dan 2.16%. Selepas 3 bulan pendedahan kepada tanah,* A. auriculiformis *memperolehi tahap ketahanan paling tinggi terhadap kulat pereput sementara* A. excelsa *pula paling tahan terhadap serangan anai-anai.* A. crassicarpa *dan* G. arborea *pula, masing-masing tidak tahan terhadap serangan anai-anai.*

ABSTRACT

Four plantation species, Acacia crassicarpa, Acacia auriculiformis, Gmelina arborea (yemane) *and* Azadirachta excelsa (sentang)) *were tested for their natural resistance towards a white rot fungus* (Pycnoporous sanguineus) *and for their durability after three months' exposure to the ground.* Hevea brasiliensis *(rubberwood) and* Neobalanocarpus heimii *(cengal) were used as controls. Samples were prepared from the heartwood portion. The weight loss of the timbers caused by the white rot fungus and their durability in ground contact were evaluated in accordance with ASTM Standards. The weight loss values for the outer heartwood of the plantation timbers ranged from 7.69 to 14.69% while those for the inner heartwood ranged from 13.16 to 24.20%. On average, all the plantation timbers fell in the class of resistant against white rot fungus. Within the class,* G. arborea *had the highest average weight loss value (19.88%), followed by* A. crassicarpa *(19.53%),* A. excelsa *(15.44%) and* A. auriculiformis *(10.75%).* H. brasiliensis *and* N. heimii *had weight loss values of 61.20% and 2.16%, respectively. After three months of exposure in the ground,* A. auriculiformis *was the most durable against decay fungi whilst* A. excelsa *was the most durable against termite attack. The least durable against decay and termite attack were* A. crassicarpa *and* G. arborea, *respectively.*

INTRODUCTION

The scarcity of commercial timber species has led many wood processing industries towards the utilisation of exotic, secondary and plantation species. The development of commercial forest plantations in Peninsular Malaysia began in 1957 and the launching of the Compensatory Forest Plantation Programme (CFPP) in 1982 accelerated the planting of exotic species such as *Acacia* spp., *Gmelina arborea, Azadirachta excelsa* and several other species (Thai 1994).

Unlike the commercial timbers, the service life and natural durability of these plantation timbers against deteriorating agents have scarcely been documented. The *Acacia* spp. originally from Australia, have been tested for their service life in their country of origin but under climatic conditions totally different from Malaysia. Degradation of wood due to biological agents proceeds at a much faster rate in the tropical regions than in the temperate regions and decay of wood may be three or four times more rapid (Willeitner and Liese 1992). For these reasons, it is very important to know the natural durability of the potentially available species in the territory concerned, and also the hazards to which they may be exposed and the means by which they can be protected. Such information can be used as guidelines for the utilisation of these timbers.

This paper reports on the resistance of selected plantation timber species against a rotting fungus and their durability in ground contact.

MATERIALS AND METHODS

The plantation species used in this study were *Acacia mangium, Acacia auriculiformis, Acacia crassicarpa, Gmelina arborea* (yemane) and *Azadirachta excelsa* (sentang). The trees were 10 years old and were obtained from Universiti Putra Malaysia (UPM) plantations. Timbers of *Neobalanocarpus heimii* (cengal), a durable species and *Hevea brasiliensis* (rubberwood), a non-durable species, were used for comparison purposes.

Two tests were carried out to assess the durability of the timbers. The tests were standard accelerated laboratory test and field test (graveyard test). Wood blocks, (14 x 14 x 14) mm3 were cut from the heartwood of the stem of each species. Fifteen blocks were obtained from the inner part of the heartwood, i.e., from near the core to the middle portion of the heartwood, and another 15 from the outer part (15 blocks), which is from the middle of the heartwood to the periphery. For the controls, 15 blocks were randomly cut, each from rubberwood and cengal heartwood. Apart from the controls, another 16 reference blocks were prepared from the rubberwood and these blocks were used as a guide for terminating the incubation period. The blocks were tested against white rot fungus (*Pycnoporous sanguineus* Wuflex Fries) in accordance with the method specified in the American Standard of Testing Material, ASTM D 2017-71 (Anon 1972).

The resistance of the plantation species against the fungus was calculated based on the percentage weight loss $((W_a - W_b) / W_a) \times 100)$ from the conditioned weight before (W_a) and after exposure (W_b). An analysis of variance was performed on the weight loss value to detect any difference among the species studied at 95% confidence interval. The results obtained were classified into four classes of degradation resistance: 0-10% weight loss was classified into highly resistant; 11-24% weight loss, resistant; 25-44% weight loss, moderately resistant and above 45% weight loss, slightly/non resistant (Anon 1972).

For the graveyard test, timber stakes of size (25 x 25 x 300) mm^3 were used. A total of 30 stakes was prepared from the heartwood of each species. All stakes were planted in the ground at Ayer Hitam Forest Reserve, Puchong, Selangor. A Standard procedure (ASTM D 1758-74, Anon 1974) was followed. The first inspection of the stakes was done two months after installation. A dull blade was used and probed into the stakes which was pulled from the ground to determine the depth and extent of decay. The assessments of the damage on the stakes were rated separately as follows: 10 (sound), 9 (trace of decay / trace of termite attack), 7 (moderate decay / moderate termite attack), 4 (heavy decay / heavy termite attack) and 0 (Failure to decay / failure to termite attack) (Anon 1974). The results discussed in this paper are based on data obtained up to three months after installation.

RESULTS AND DISCUSSION

Resistance of Plantation Timbers Against White Rot Fungus

After exposure to the fungus, all the wood blocks exhibited a reduction in weight showing that deterioration had occurred (Table 1). A significant lower weight loss value was recorded for the blocks taken from the outer heartwood when compared to the blocks obtained from the inner heartwood blocks of the plantation timbers. The weight loss for the outer heartwood ranged from 7.69 to 14.69% whilst for the inner heartwood it was 13.16 to 24.20%. These findings corroborate with those summarised by Scheffer and Cowling (1966). They found that in many hardwood

TABLE 1
Mean percentage weight loss of wood blocks caused by the white rot fungus, *Pycnoporous sanguineus*

Species	Density[1] (gcm^{-3})	Weight loss (%)			
		Outer heartwood	Inner heartwood	Mean wt. loss	Decay resistance class[2]
Acacia auriculiformis	0.70 (30)	7.69 ± 0.207[3] (15)	13.16 ± 0.258 (15)	11.12 ± 0.236e[4] (30)	Resistant
Acacia Crassicarpa	0.67 (30)	14.69 ± 0.542 (15)	24.20 ± 0.741 (15)	19.53 ± 0.647b (30)	Resistant
Azadirachta excelsa	0.60 (30)	12.46 ± 0.281 (15)	18.43 ± 0.228 (15)	15.44 ± 0.233d (30)	Resistant
Gmelina arborea	0.58 (30)	13.92 ± 0.477 (15)	22.33 ± 0.827 (15)	19.88 ± 0.652b (30)	Resistant
Control					
Hevea brasiliensis	0.55 (30)	-	-	61.20 ± 0.987a (30)	Non-resistant
Neobalanocarpus heimii	0.88 (30)	-		2.16 ± 0.013f (30)	Highly resistant

[1] Density (based on air dry volume), [2]decay resistance class (Anonymous 1974),[3]standard deviation and [4] means followed by the same letter are not significantly different ($p > 0.05$) using Duncan Multiple Range Test (DMRT) and values in parentheses are number of samples.

species the inner heartwood shows lower durability than the outer heartwood.

Among the plantation species, *G. arborea* showed the highest weight loss with an average of 19.88%. This was followed by *A. crassicarpa* (19.53%) and *Azadirachta excelsa* 15.44% with least weight loss in *A. auriculiformis* (11.12%). The weight loss values for all the plantation timbers fell within the range of 11-24% and was therefore classified as resistant to the white rot fungus (Anonymous 1974). For the controls, *H. brasiliensis* is non resistant while *N. heimii* is highly resistant to the white rot fungus with average weight loss values of 61.20% and 2.16%, respectively.

Variability in the resistance of the plantation species timber against the white rot is possibly due the extractive contents in the heartwood. Extractives in heartwood are known to be toxic and important elements in determining decay resistance to fungi, a range of insects (Rudman and Gay 1963) and marine borers (Bultman 1976). Many of the extractives imparting decay resistance are the hydrolysable and condensed tannins, lignans, alkaloids, terpenoids, flavanoids and a few others (Eaton and Hale 1995). The amount of these compounds vary between species and genera. The relationship between extractives and natural durability of the plantation timbers is worth investigating.

Durability of Plantation Timbers in Ground Contact
Stakes were examined for decay and termite attack after three months' exposure in the ground. Each stake was graded separately according to type of damage even though decay and sign of termite attack might occur on the same stake. The majority of the analysed stakes had a whitish appearance and soft surface which indicates white-rot and some stakes had crack and shrink surfaces indicating the presence of brown rot. Termite activities were also noticed on the surface of the stakes in the ground. The termite was identified as *Macrotermes* sp. Table 2 summarises the results of the decay and termite damage assessment of the timbers.

Assessment of Decay - At the end of the third month, all *A. auriculiformis* stakes were still sound (Grade 10). However, the average percentage of sound stakes for the other plantation timbers ranged from 77 to 90%. *G. arborea* had the highest percentage and *A. crassicarpa* the lowest percentage of stakes that were sound. A trace of decay (Grade 9) was seen in 16% of *A. crassicarpa*, and 20% of *A. excelsa* stakes. Moderate decay (Grade 7) was only recorded in *A. crassicarpa*

TABLE 2
Decay and termite ratings of wood stakes after 3 months' exposure in soil

Species	No. of stakes	Decay Grades (No. of stakes)	Termite Grades (No. of stakes)
A. auriculiformis	30	10(30) [100%] Avg. rating 10	10(16) 9 (8) 7 (5) 4(1) [53%] [27%] [17%] [3%] Avg. rating 9.0
A. crassicarpa	30	10(23) 9(5) 7 (2) [77%] [16%] [7%] Avg. rating 9.6	10(24) 9(4) 7(2) [80%] [13%] [7%] Avg. rating 9.7
Aadirachta. excelsa	30	10(24) 9(6) [80%] [20%] Avg. rating 9.6	10(30)) [100%] Avg. rating 10
G. arborea	30	10(27) M(3) [90%] [10%] Avg. rating 9	10(12) 9(7) 7(4) 4(2) 0(3) M(2) [40%][23%][13%][13%][13%] [8%] Avg. rating 7.3
H. brasiliensis	30	10(8) 9(11) 7(5) 4(4) M(2) [27%][37%][17%][13%] [6%] Avg. rating 7.7	10(2) 9(7) 7(3) 4(11) 0(5) M(2) [6%] [23%] [10%] [37%] [17%] [6%] Avg. rating 4.9
N. hemii	30	10(30) [100%] Avg. rating 10	10(30) [100%] Avg. rating 10

10, 9, 7, 4, 0 are grade number, ( ) = number of stakes, [ ] = percent grade of stakes, M = missing stake

(7%). The average rating for the plantation timbers were between 9 to 10. For the control timbers, all stakes of *N. heimii* remained in their original states, whilst for *H. brasiliensis* only 27% of the stakes were sound (Grade 10), with 37% in Grade 9 and 17% in Grade 7. The remaining 13% were heavily decayed and 6% were missing. The average rating for this timber was 7.7. From Table 2, it can be seen that all the plantation timbers showed a remarkably low percentage of decayed stakes (0-23%) when compared to *H. brasiliensis* (83%). This implies that these timbers are more durable than rubberwood when they are used in contact with the ground.

Although the values recorded for the field test was taken in a short period of time, in most cases, there was a similar trend in the field and laboratory data (Table 1). For instance, *A. auriculiformis* which exhibited the lowest weight loss in the laboratory test, was not decayed after three months' exposure in the soil. On the other hand, 23% of the less resistant *A. crassicarpa* stakes were either slightly or moderately decayed when in ground contact. The same trend was observed in the control stakes of *H. brasiliensis*. Eaton and Hale (1995) reported that in most species, the laboratory and field data are comparable although some wood species appeared less durable in laboratory tests.

Assessment of Termite Damage - After three months' exposure, assessment of the termite damage recorded from the plantation timbers varied from sound (Grade 10) to failure due to termite attack (Grade 0). The average ratings were from 7.3 to 10. About 40-100% of all the plantation timbers remained in their original states (Grade 10) with no sign of termite attack on *A. excelsa*. The worst condition of failure due to termite attack (Grade 0) was observed on *G. arborea* (13%). The average rating for this timber was 7.3. Although *A. auriculiformis* was resistant to fungal degradation, 3% of the stakes were heavily attacked by termites (Grade 4). On the other hand, even though *A. excelsa* exhibited no sign of termite attack, 20% of its stakes were slightly decayed.

When compared to *H. brasiliensis*, all the plantation species tested were more durable against termite attack. At the end of the three months' exposure, 94% of the rubberwood stakes were attacked by termites with an average rating of 4.9. Only *A. excelsa* timber was comparable to *N. heimii*.

From the field test, it appears that there was no relationship between the degradation due to fungi and termite for the plantation timbers over the 3-month period. For example, *A. auriculiformis* and *G. arborea*, were more resistant

against decay than termite attack but the reverse occurred with *A. excelsa*. Further trials should be conducted to determine the durability over a longer exposure period.

CONCLUSION

The outer heartwood of the plantation species was more resistant against the white rot fungus, *P. sanguineus* than the inner heartwood. All the plantation timbers were in the class of resistant. Within the class, *A. auriculiformis* had the lowest weight loss values followed by *A. excelsa*, *A. crassicarpa* and *G. arborea*. All the plantation timbers were more resistant against the fungus when compared to rubberwood (non-resistant).

In ground contact, *A. auriculiformis* had the highest resistance against decay fungi followed by *G. arborea*, *Azadirachta excelsa* and *A. crassicarpa*. The highest resistance of plantation timbers against termite attack was *A. excelsa*. This was followed by *A. crassicarpa*, *A auriculiformis* and the least resistant was *G. arborea*. All the plantation timbers were more durable than rubberwood in ground contact but less durable when compared to *N. heimii*. There was no relationship between the degradation due to rotting fungi and termite for the plantation timbers over the 3-month period in the ground.

REFERENCES

ANON. 1972. American society for testing material: Accelerated laboratory test of natural decay resistance of woods. American Standard of Testing Materials (ASTM D2017-71). Philadelphia, USA.

ANON. 1974. American society for testing material: Evaluating wood preservative by field tests with stakes. American Standard of Testing Materials (ASTM D1758-74). Philadelphia, USA.

BULTMAN, J.D. 1976. Research at the Naval Research Laboratory on Bioresistant tropical hardwoods: An overview, in Chemical Basis for Natural Resistance. In *Proceedings of a Workshop on the Biodeterioration of Tropical Hardwoods*. p. 1-6. Naval Res. Lab. Dept., Navy, Washington D.C.

EATON, R.A. and M.D.C. HALE. 1995. *Wood: Decay, Pests and Protection*. London, UK: Chapman & Hall.

RUDMAN, P. and F.J. GAY. 1963. The causes of natural durability of timber. X. The deterrent properties of some three-ringed carboxylic and heterocyclic substances to subterannean termite (Nasutitermes exitiosus Hill). *Holzforchung* **17(1)**:21-25.

SCHEFFER, T.C. and E.B. COWLING. 1966. Natural resistance of wood to microbial deterioration. *Ann. Rev. of Phytopath.* **4(3)**:167-200.

THAI, S.K. 1994. Forest plantation development in Peninsular Malaysia. In *Proceedings of International Workshop BIOREFOR*, p. 19-22. Kangar, Malaysia.

WILLEITNER, H. and W. LIESE. 1992. Wood protection in tropical countries: A manual on the know-how. Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), Eshborn, Germany.

(Received: 30 October 2000)
(Accepted: 30 January 2002)

Preparation of Manuscript

A full article should not exceed 10 printed pages (one printed page is roughly equivalent to 3 type-written pages) including figures and tables.

A short communication, not exceeding two printed pages, is intended for rapid publication.

Typing and Paper
Manuscripts should be typewritten on A4 paper, double spaced, and of letter quality with 4cm margins on all sides.

Title page
This page should bear the title of the paper with the full name of the author(s), followed immediately by the address. Author citation should also be provided. A short title not exceeding 60 characters should be provided for the running headline.

Abstract
Abstracts in Bahasa Melayu and English, each not exceeding 200 words, should follow immediately after the names and affiliation of author(s). Papers from outside of Malaysia may be submitted with an English abstract only.

Keywords
Up to a maximum of 10 keywords are required and they should be placed directly below the abstract.

Illustrations & Photographs
Illustrations including diagrams and graphs will be referred to as 'figures' and photographs as 'plates' in the text and numbered consecutively in Arabic numerals. All photographs (glossy black and white prints) should be supplied with appropriate scales.

Illustrations should be of print quality; outputs from dotmatrix printers are not acceptable, Illustrations should be on separate sheets, about twice the size finished size in print. all letters, numbers and legends must be included on the illustration with the author's name, short title of the paper, and figure number written on the verso. A list of captions should be provided on a separate sheet.

Tables
Tables should conform to page size. Vertical lines should be avoided.

Measurements
Metric units must be used for all measurements.

Equations and Formulae
These must be set up clearly and should be typed triplespaced. Numbers identifying equations should be in square brackets and placed on the right margin of the text.

Scientific Names
Scientific names should be given for all organisms.

Abbreviations
Standard abbreviations should be used.

Citations and References
Items in the reference list should be referred to in the text by inserting, in parentheses, the year of publication after the author's name. If there are more than two authors, the first author should be cited followed by '*et al*'. The names of all authors, however, will appear in the reference list.

In case of citing an author(s) who has published more than one paper in the same year, the papers should be distinguished by addition of a small letter, e.g. Choa (1979a); Choa (1979b); Choa (1979c).

References should be arranged alphabetically according to first author. Serial titles are to be given in full.

Examples of reference citations are provided:

Monographs
Turner, H.N. and S.S.Y. Yong. 1969. Quantitative Genetics in Sheep Breeding. Ithaca: Cornell University Press.

Serials
Ho, Y.W. and A. Nawawi. 1991. Effect of carbon and nitrogen sources on growth of *Ganoderma boninense* from oil palm. *Journal of Plant Protection in the Tropics* **8**: 37-43

Chapter in Edited Book
Roberts, D.W. 1980. Toxins of entomopathogenic fungi. In *Microbial Control of Pests and Plant Diseases*, ed. H.D. Burgess, p. 441-463. New York: Academic Press.

Proceedings
Hussein, M.Y. 1986. Biological control of aphids on potatoes by inundative releases of predators. In *Biological Control in the Tropics*, ed. M.Y. Hussein and A.G. Ibrahim, p. 137-147. Serdang: Universiti Pertanian Malaysia Press.

Unpublished Materials (e.g. theses, reports & documents)
Normah, M.N. 1987. Effects of temperature on rubber (*Hevea brasiliensis* Muell - Arg.) Seed storage. Ph.D. Thesis, 206p. Universiti Pertanian Malaysia.

The abbreviation for Pertanika Journal of Tropical Agricultural Science is *Pertanika J. Trop. Agric. Sci.*

Pertanika Journal of Tropical Agricultural Science
Volume 25 Number 1 (March) 2002

Contents

ISSN 1511-3701