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Physical And Mechanical Properties of *Acacia mangium* and *Acacia Auriculiformis* from Different Provenances

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Keywords: ***Acacia auriculiformis, Acacia mangium*, provenance, specific gravity, strength properties**

ABSTRAK

Penilaian sifat-sifat fizikal dan mekanikal kayu Acacia mangium dan Acacia auriculiformis dari dua provenan berbeza ia itu Papua New Guinea dan Queensland, Australia telah dijalankan. Tiga sampel pokok yang sihat dari setiap provenan telah diambil dari Indonesia, Malaysia dan Thailand. Objektif utama kajian ini ialah untuk menentukan kesan tapak, spesies atau provenan keatas sifat-sifat kayu ini. Kajian telah dijalankan mengikut piawai BS 373. Keputusan menunjukkan ketumpatan bandingan dan sifat-sifat mekanikal kayu dipengaruhi oleh spesies dan provenan. Sampel dari Indonesia menunjukkan keputusan terbaik berbanding sampel dari Malaysia dan Thailand. A. auriculiformis mempunyai sifat-sifat yang lebih baik berbanding A. mangium. Kajian ini juga mengesahkan bahawa provenan PNG lebih baik dari Queensland.

ABSTRACT

An assessment of the physical and mechanical properties of Acacia mangium and Acacia auriculiformis from two different provenances, Papua New Guinea and Queensland, Australia were carried out. Three healthy trees of each species were sampled from Indonesia, Malaysia and Thailand. The main objective of the study was to determine the effect of site, species or provenance on the properties of these woods. The tests were carried out in accordance with British Standard BS 373 Standard. The results showed that the specific gravity and the mechanical properties of the samples were affected by the species and provenances. The Indonesian samples exhibited the best results in terms of both physical and mechanical properties compared to the Malaysian and Thailand samples. A. auriculiformis recorded better performance than A. mangium. The results also revealed that the Papua New Guinea provenance was superior for both species.

INTRODUCTION

Acacia mangium and *Acacia auriculiformis* are leguminous tree species of the sub-family Mimosoideae. Native to north Queensland, Australia, the trees are also found in Papua New Guinea and the Moluccas Islands of Indonesia. On account of their fast growth, good form and utilization potential of the timber, these species have been chosen as plantation species in Malaysia.

The assessment of the timber quality may involve the consideration of a large number of anatomical, physical and mechanical properties of wood. Nevertheless, certain features are good general indicators of timber properties and uses. Though the *A. mangium* has been studied extensively, little information is available about *A. auriculiformis*. Thus the study of wood structure and its relationship to its physical and mechanical properties of these species is important and very timely.

The density or specific gravity (SG) of *A. mangium* varies depending on the origin of the wood. It ranges from 420-483 kg/m3 based on green soaked volume; in dry condition it varies between 500-600 kg/ m3 (Logan and Balodis 1982; Peh *et al.* 1982; Peh and Khoo 1984;Wang *et al.* 1989; Razali and Kuo 1991). National Research Council (NRC) (1983) reported that *A. mangium* wood has a specific gravity of 0.56 and the plantation-grown timber recorded slightly lower values (0.40 - 0.45). *A. mangium* wood from the natural stands is normally about 0.6. However Sining (1988) reported a slightly higher SG range from the plantation: 0.43 - 0.47 for 6-year-old *A. mangium* grown in Sabah. Keating and Bolza (1982) noted that *A. auriculiformis* from Indonesia recorded higher mean values for most strength properties than *A. mangium*, which falls under the light hardwood classification with low to moderate strength properties (Razali and Mohd. Hamami 1992).

The timber seasons fairly rapidly without developing serious defects, and responds satisfactorily to preservative treatment. It is fairly easily impregnated with preservatives using standard techniques such as the full-cell pressure method (NRC 1983). The timber planes well and sands easily, producing a lustrous, smooth surface without torn fibres. It also drills satisfactorily and turns well, requiring only low to moderate pressure (NRC 1983). Research has been carried out on the utilization of *A. mangium* timber. Tan (1979), Peh and Khoo.(1984), Ong (1987) and Mohd. Zin *et al.* (1991) have studied some of its mechanical and physical properties.

Yong (1984) summarized the mechanical and working properties of *A. mangium* timber in comparison to Light Red Meranti which is in great demand. The specific gravity, modulus of elasticity (MOE) and the hardness value are similar to those of black walnut (*Juglan nigra*), but the modulus of rupture (MOR) and the compression values are somewhat higher than those of walnut. Glue joint strength of *A. mangium* timber was found to be satisfactory (Mohd. Hamami *et al.* 1991b).

Potential Uses of A. mangium and A. auriculiformis

A. mangium timber makes attractive furniture and cabinets, door frames, window parts, mouldings, and sliced veneers. It is also employed as a light-duty building timber for uses such as framing and weathering board (NRC 1983). In 1983, sawing, plywood manufacture and slicing testings were carried out on 12-year-old avenue-grown acacia trees. The tests showed that there were no physical difficulties in carrying out these various operations. Chan (1983) reported low sawing recovery rate (37 - 40%) for sawn timber production. The low rate could be attributed to four factors: small diameter logs, flutings, knots and heart rot.

Peh *et al.* (1982) reported that pulping of timber from a 9-year-old plantation is easy, giving high yields and good strength properties. Pulping with bark was readily done by a neutral sulphite semi-chemical process and the pulp exhibited very good paper-making properties (Logan and Balodis 1982). The pulp is comparable to that obtained from commercial *Eucalyptus* and is suitable for the manufacture of products such as liner boards, bags, wrapping papers and multiwall sacks.

Because of its density and calorific value (4,800 - 4,900 Kcal/kg), the wood makes good fuel (Mohd. Hamami *et al.* 1991a). Although the species has not been planted on a large scale for firewood, it appears well suited for this purpose. It produces reasonably good charcoal, and it is suitable for the manufacture of wood pellets and activated carbon.

Objectives of the Study

The objectives of this study were:

i) To investigate the effect of site, species and provenance variation on the physical and mechanical properties of *A. mangium* and *A. auriculiformis* timbers.
ii) To describe the relationship between the physical and mechanical properties of these timbers.

MATERIALS AND METHODS

Selection of Trees

Three trees of 6-year-old *A. mangium* and *A. auriculiformis* were selected from three different sites namely Serdang, Malaysia (MP01); Bogor, Indonesia (IF01); and a site in Thailand (TS01). The selection was done based on criteria such as bole straightness, absence of excessive defects and good cylindrical form. Their basic mensuration data are shown in Table 1.

TABLE 1
Mensurational data of the sampled trees

Tree	Total height (m)	DBHOB (cm)	Total height (m)	DBHOB (cm)
		Species		
	A. mangium		*A. auriculiformis*	
Site/Provenance				
A1: Indonesia/PNG				
1.T1	20.7	23.5	21.5	16.0
2.T2	23.0	20.0	18.4	20.0
3.T3	15.2	16.0	17.3	14.0
A2: Indonesia/Queensland				
1.T1	17.3	17.0	24.0	16.0
2.T2	14.6	17.0	20.3	16.0
3.T3	15.4	18.0	18.2	15.5
B1: Malaysia/PNG				
1.T1	11.4	17.4	4.4	20.8
2.T2	10.1	15.0	11.9	20.0
3.T3	*9.0*	*14.7*	-	-
B2: Malaysia/Queensland				
1.T1	-	-	4.1	18.6
2.T2	-	-	3.1	13.3
C1: Thailand/PNG				
1.T1	12.9	15.3	12.5	12.2
2.T2	13.1	14.7	11.4	11.5
3 T3	10.4	12.8	10.4	13.0
C2: Thailand/Queensland.				
1.T1	13.1	15.0	12.9	12.1
2.T2	11.0	14.5	11.6	11.9
3.T3	12.09	13.0	12.5	14.9

DBHOB = Diameter at breast height over bark

Vertical Sampling

Sampling along the length of the trees was done on a fixed percentage basis: at breast height (DBH), at the middle and the top of the clear bole height. The percentages were measured from the stumps, which were kept as uniform as possible.

At each sampling position, two cross-sectional discs, of about 5 cm thick were removed, avoiding obvious knots and other defects. Six discs were removed from each tree (*Fig. 1*). The upper discs of each section were used for the anatomical studies, the lower discs for the SG determination. The billets between the sampling points were cut into two-metre bolts and numbered in accordance with the tree number and the position within the tree. These bolts were reserved as physical and mechanical test specimens.

Sample Preparation

The lower, 5-cm thick discs from each height level of every tree were used for the determination of specific gravity (SG), moisture

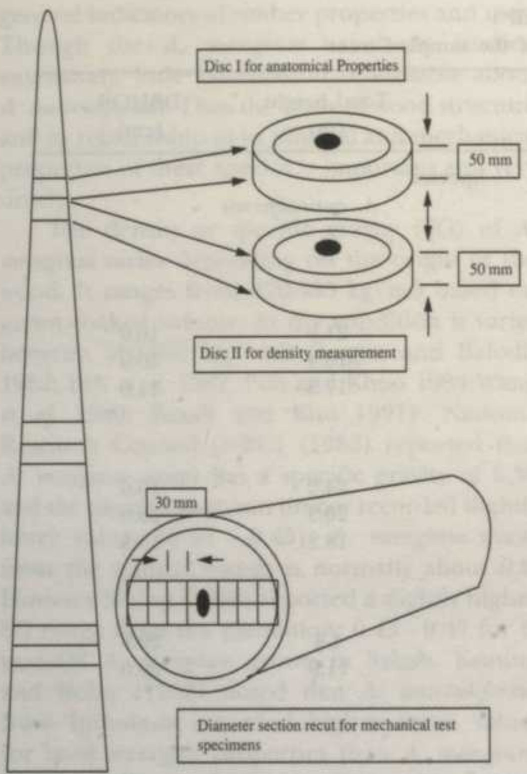

Fig 1. Location of vertical sampling points within a selected tree

content and shrinkage. Three specimen blocks measuring 25 mm in cross section and 13 mm thick were cut from the strips and labelled. Loose fibres in the specimen blocks were removed by rubbing with sand paper; spoilt or defective specimens were rejected. The wood properties determined from each block were SG, moisture content, green to ovendry radial, and tangential shrinkage.

Specific Gravity Determination

Specific gravity (SG) was determined on a green volume, ovendry weight basis. The green volume was obtained by the water immersion or displacement method. The saturated blocks were submerged in a beaker placed on an electric balance which recorded the weight of the water displaced. The formula used to calculate the specific gravity was

$$SG = \frac{\text{ovendry weight}}{\text{weight of the displaced volume of water}}$$

Moisture Content (MC) Determination

The moisture content of the same block was determined by the standard ovendry method. The green weight was obtained by weighing the saturated blocks after soaking them in the water. The formula to calculate MC, expressed as a percentage, was

$$MC = \frac{\text{Weight of wood - ovendry weight}}{\text{ovendry weight}} \times 100$$

Shrinkage Determination

Specimen blocks were placed in water for four days to attain full green volume. In this water-saturated condition, the radial and tangential dimensions were marked and measured to the nearest 0.02 mm using a dial calliper. The blocks were then air dried for a week and oven dried at 105°C for 36 hours. The oven-dried blocks were then weighed and the dimensions were measured again along the points marked earlier using the same dial calliper. The green-to-ovendry shrinkage in radial and tangential directions of the same blocks was determined, expressed as a percentage of the saturated dimension to its ovendry dimension. The formula used was

$$\text{Shrinkage} = \frac{\text{Change in dimension from saturated size}}{\text{Saturated dimension}} \times 100$$

Mechanical Properties Determination

Each of the 2-m bolts were first sawn in half centred at the pith following the north-south direction. From each half a 35-mm thick plank was sawn from the pith. Each plank was cut into test specimens of 30 x 30 cm in cross-section and 45 cm in length at three different sections along the north-south direction to represent three wood types. The innerwood was cut one centimetre from pith, middlewood was cut at the middle section of pith to bark and the outerwood was cut near the bark.

The test specimens were kiln-dried to 12% MC at 60 ± 5% relative humidity and 25 ± 2°C. The moisture content of the samples was tested every day until it reached 12% when kiln-drying was stopped. It took seven days to obtain the required moisture content.

Static Bending Test

The test specimens for the static bending test were then cut into 20 x 20 mm cross-section and 300 mm in length and tested in accordance to the secondary method of BS 373 (British Standards Institution 1957). The specimens were loaded radially (tangential surface) at the centre to failure, on the span length of 280 mm. The modulus of elasticity (MOE) and modulus of rupture (MOR) were obtained from Zwick's universal testing machine interfaced with a personal computer in which a BASIC program was used to calculate the MOE and MOR values immediately after the test was performed.

Analysis of Data

Physical and mechanical properties were analysed using two-way analysis of variance (ANOVA) with replications and interaction. The trees were regarded as sampling units or replications while the site, species and genotype were the source of variation. Thus each tree species at site and genotype was represented by a single mean value.

The ANOVA was used to examine the effects of site, species and genotype and their interactions. Each wood property variable was evaluated independently to determine if variations among site, species and genotype and their interactions were significant. Least significant different (LSD) tests were carried out to examine the differences between pairs of variables at 5% confidence level. Analysis of variance was computed using Statistical Analysis System (SAS) software.

RESULTS AND DISCUSSION

The overall results of this study are summarized in Table 2. The effect of sites on the average values of the properties investigated for these two wood species are shown in Table 3. Comparison of the mean values indicated great differences between all three sites where the samples were taken. Analysis of variance reveals that most of the properties measured differ significantly between sites (Table 3), between species (Table 4) and between provenances (Table 5).

Site Variation: Physical Properties

The mean specific gravity, moisture content and shrinkage found in this study are tabulated in Table 3. The mean SG were 0.42, 0.47 and 0.55 for samples from Malaysia, Indonesia and Thailand, respectively. The average values obtained in this study agreed with the values reported earlier by Mohd. Zin *et al.* (1989) and Razali and Mohd. Hamami (1993)

TABLE 2
Interaction between wood properties of two plantation species with sites, species and provenances

	Physical Properties				Mechanical Properties	
	MC (%)	SG	ST (%)	SR (%)	MOE (MPa)	MOR (MPa)
Source	(Pr>F)					
Sites	**	n.s.	**	**	n.s.	n.s.
Species	n.s.	**	n.s.	n.s.	**	**
Provenance	**	**	**	**	**	**
Site x sp.	**	n.s.	n.s.	n.s.	n.s.	n.s.
Site x p	**	**	**	n.s.	**	**

Legend:
** = significant at p = 0.05
n.s. = not significant
MC = moisture content (%)
SG = Specific gravity
ST = shrinkage (tangential) (%)
SR = shrinkage (radial) (%)
MOE = modulus of elasticity (MPa)
MOR = modulus of rupture (MPa)
SP = species
P = provenance

TABLE 3
Mean values of physical and mechanical properties of two plantation species from different sites

Sites	Physical Properties				Mechanical Properties	
	MC (%)	SG	ST (%)	SR (%)	MOE (MPa)	MOR (MPa)
			Mean Values			
Indonesia	15.54a	0.47ab	4.08a	2.09a	6728a	75.02a
Malaysia	7.79c	0.42b	1.99b	1.27b	6286a	68.15a
Thailand	13.53b	0.55a	3.71a	2.19a	6168a	80.54a

Means within the same column for each property followed by the same letter are not significantly different at p = 0.05

Legend:
MC = moisture content (%)
SG = specific gravity
ST = shrinkage (tangential) (%)
SR = shrinkage (radial) (%)
MOE = modulus of elasticity (MPa)
MOR = modulus of rupture (MPa)

In general, the specific gravity values obtained from Malaysia and Indonesia are lower when compared to the value obtained from Thailand. These values were significantly different. The sites also have a significant effect on the mean moisture content and shrinkage values. Being the driest, Malaysian samples recorded the lowest shrinkage values compared to Thailand and Indonesia counterparts.
Statistical analysis (Table 2) showed that site differences in specific gravity are highly significant. The variation may be due to the genetic differences that are inherited in the individual tree. In addition to the genetically controlled effects, differences were also due to the site micro-environment of the growing trees. According to Panshin and de Zeeuw (1980), environmental factors affect the growth of the trees in particular site. The mean temperature and mean annual rainfall may also have some effect on growth and finally to the amount of wood material produced by the tree.

Site Variation: Mechanical Properties

The effect of site on the mechanical properties of these woods are tabulated in Table 3. In contrast to the physical properties, the mean values of MOE and MOR were not affected by the site, and not significantly different at 95% level of confidence. This indicates that these species will show similar strength properties regardless where they are planted. Mohd. Zin *et al.* (1991) reported that the age and the site have little or no effect on the major strength properties of the *A. mangium*.

Species Variation: Physical Properties

The effect of species on the physical properties of wood is given in Table 4. Variations in wood physical properties especially specific gravity (SG) were greatly influenced by the species. The results revealed that the mean SG of *A. mangium* and *A. auriculiformis* showed significant different at 95% level of confidence. The SG of *A. auriculiformis* in this study was higher than *A. mangium*. The same results were also noted by Keating and Bolza (1982).

However, the moisture content and shrinkage values were not affected by the species. Results from this study showed that mean values of these properties were not significantly different at 95% confidence level.

Species Variation: Mechanical Properties

The effect of species on the physical properties of wood is given in Table 4. The modulus of elasticity (MOE) of *A. mangium* was found to be significantly lower than *A. auriculiformis*. However, the mean values of modulus of rupture (MOR) of these species were not significantly different at 95% confidence level. The strength properties of wood are closely associated with specific gravity. This was also recorded in the results of this study. *A. auriculiformis* recorded

TABLE 4
Mean values of physical and mechanical properties of two different plantation species

Species	Physical Properties MC (%)	SG	ST (%)	SR (%)	Mechanical Properties MOE (MPa)	MOR (MPa)
			Mean Values			
A.. auriculiformis	12.94a	0.56a	3.26a	1.91a	6960a	86.90a
A. mangium	11.63a	0.40b	3.26a	1.79a	5828b	62.23a

Means within the same column for each property followed by the same letter are not significantly different at $p = 0.05$

Legend:
MC = moisture content (%)
SG = specific gravity
ST = shrinkage (tangential) (%)
SR = shrinkage (radial) (%)
MOE = modulus of elasticity (MPa)
MOR = modulus of rupture (Mpa)

higher SG values, which were reflected in the MOE and MOR or strength values. From the preceding discussion, it was clear that *A. auriculiformis* has the edge and performed better than *A. mangium*. It has higher specific gravity and strength values.

Provenance Variation: Physical Properties

The effect of genotype or provenance on the physical properties of *A. mangium* and *A auriculiformis* was also studied. The results are tabulated in Table 5. The mean values show that different properties behave differently. Three

TABLE 5
Mean values of physical and mechanical properties of two plantation species from different provenances

Genotype	Physical Properties MC	SG (%)	ST	SR	Mechanical Properties MOE (%) (MPa)	MOR (%) (MPa)
			Mean Values			
AAPNG	13.68a	0.61a	3.67a	2.29a	7921a	95.23a
AAQ	12.21a	0.52a	2.86b	1.53b	5999b	78.58a
AMPNG	13.56a	0.50a	3.89a	2.23a	7963a	81.30a
AMQ	9.71b	0.31b	2.63b	1.36b	3694c	43.16b

Means within the same column for each property followed by the same letter are not significantly different at $p = 0.05$

Legend:
AAPNG = *A. auriculiformis* from Papua New Guinea
AMPNG = *A. mangium* from Papua New Guinea
AAQ = *A. auriculiformis* from Queensland
AMQ = *Acacia mangium* from Queensland
MC = moisture content (%)
SG = specific gravity
ST = shrinkage (tangential) (%)
MOE = modulus of elasticity (MPa)
MOR = modulus of rupture (MPa)
SR = shrinkage (radial) (%)

provenances (AAPNG, AAQ and AMPNG) recorded no significant differences in the mean values of physical properties, except for radial shrinkage. The only provenance which showed significant difference in mean values of physical properties was AMQ. The mean values from this provenance were significantly lower than the other three provenances.

Provenance Variation: Mechanical Properties

The effects of provenance on the mechanical properties of the wood are tabulated in Table 5. Similar effects were also observed for MOE and MOR of these three provenances. The mean values of MOE and MOR of AAPNG, AAQ and AMPNG provenances were not significantly different at 95% confidence level. The only provenance which showed a significant difference in mean values of mechanical properties was AMQ. The MOE and MOR values from this provenance were much lower than the other three provenances though the moisture content was lower.

CONCLUSION

Few general conclusions could be derived from this study: The specific gravity and the mechanical properties of these timbers were affected by site, species and provenance. Indonesian samples were superior in terms of growth, physical and mechanical properties.

From all sites, *A. auriculiformis* recorded higher physical and mechanical properties and performed better than *A. mangium*. From the results it is clear that Papua New Guinea (PNG) provenances for both species showed better performances in terms of the physical and mechanical properties. On the other hand, provenances from Queensland, Australia did not perform well for both *A. mangium* and *A. auriculiformis*.

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Incorporation of a Preservative in Particleboard: Properties and Durability

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Keywords: Particleboard, Urea formaldehyde, *Hevea brasiliensis*, Boric acid, Durability, Retention, Pycnoporous sanguineus

ABSTRAK

Asid borik (0.5% dan 1.0% w/w) dicampurkan ke dalam papan serapai kayu getah (Hevea brasiliensis) samada dengan mencampur serbuk asid borik dengan perekat urea formaldehid (UF) pada peringkat awal atau dengan menyembur larutan asid borik kepada adunan serpai semasa proses pengadunan. Dua jenis perekat UF (perekat E1 dan E2 digunakan sabagai agen perekatan. Ketumpatan sasaran papan serpai adalah 650 kg/m³. Sifat papan serpai diuji mengikut piawaian JIS A 5908-1983 dan sifat ketahanan terhadap kulat reput putih diuji mengikut piawaian ASTM D2017-71. Bebanan bahan kimia di dalam papan adalah diantara 0.42-0.47% bagi rawatan dengan 0.5% asid borik dan 0.64-0.70% bagi rawatan dengan 0.1% asid borik. Kekuatan kering modulus perpecahan (MOR) dan modulus kekenyalan (MOE) bagi papan yang telah dirawat didapati menurun dengan ketara. Penurunan sifat-sifat ini bertambah apabila tahap bebanan kimia di dalam papan bertambah. Walau bagaimanapun MOR dan MOE di dalam keadaan basah, ikatan dalaman (IB) dan pembekaan ketebalan (TS) bagi papan yang dirawat dengan kedua-dua tahap kepekatan asid borik tidak menunjukan sebarang perbezaan apabila dibandingkan dengan papan yang tidak dirawat (papan kawalan). Papan serpai yang direkat menggunakan perekat jenis E2 didadapati lebih tahan kepada kulat reput putih (Pycnoporous sanguineus) daripada papan yang direkat dengan perekat jenis E1. Kehadiran asid borik di dalam papan meningkatkan ketahanan papan terhadap kulat reput putih, dan ketahanan ini meningkat apabila bebanan bahan kimia di dalam papan meningkat.

ABSTRACT

0.5% and 1.0% (w/w) of boric acid (H_3BO_3) were incorporated in rubberwood (Hevea brasiliensis) particleboards either by initially mixing the boric acid powder with urea formaldehyde adhesive or spraying boric acid solution onto the furnish during blending. Two types of urea formaldehyde, i.e. E1-glue (maximum permissible formaldehyde emmision < 0.1 ppm) and E2-glue (maximum permissible formaldehyde emmision 0.1-1.0 ppm) were used as the bonding agent. The targeted density of the boards was 650 kg/m³. The board properties and durability against white rot fungus were evaluated in accordance with JIS A 5908-1983 and ASTM D2017-71, respectively. The chemical loading in the board was in the range of 0.42-0.47% and 0.64-0.70%, respectively when 0.5% and 1.0% of boric acid (based on the dry-weight of the particles) were incorporated in the boards. The dry modulus of rupture (MOR), dry modulus of elasticity (MOE) of the boric acid-treated boards were significantly reduced. The reduction of the properties increased as the chemical loading in the treated boards *increases. However, wet MOR and wet MOE, internal bonds (IB) and thickness swelling (TS) of treated boards at both concentration levels did not differ significantly compared to the untreated boards. Particleboards bonded with E2-glue were more resistant to white rot fungus (Pycnoporous sanguineus) than those bonded with E1-glue. The presence of boric acid significantly increased the durability of board against white rot fungus, and the resistance towards the fungus increased as the boric acid loading increases.*

INTRODUCTION

Particleboard is generally considered less susceptible to biodeterioration than solid wood (Behr 1972 and Stolley 1958), if it is used in situations where exposure to moisture is likely, biodeterioration can occur, especially for untreated board manufactured from non-durable wood species. Currently all particleboard mills in Malaysia are utilising non-durable wood species such as rubberwood (*Hevea brasiliensis*) and mixed light hardwoods (MLHW).

Improving the durability of the board by preservative treatment is one way of extending its end uses. The addition of such chemicals is necessary to increase the little inherent resistant to decay and insect attack possessed by this type of wood.

Boron compounds were chosen because they provide both the fungicidal and insecticidal properties and could be a suitable preservative for particleboard. Apart from being competitive in cost, boron compounds have low mammalian toxicity, are soluble in water, have an ability to retain the clear and light coloured finish of the treated materials and environmental friendly (Hong *et al.* 1982; Cockroft and Levy, 1973).

Many factors need to be considered for the incorporation of these compounds in the manufacture of wood composite while maintaining the standard mechanical and physical properties requirement. Gillespie (1980) stated that factors like wood species, moisture content, pressing conditions, and preservative or fire retardant treatment critically affect these properties.

This paper reports the properties and durability of boron-treated particleboard.

MATERIAL AND METHODS

Rubberwood (*Hevea brasilliensis*) chips and urea formaldehyde (UF) glue were obtained from local fibreboard mill in Negeri Sembilan and adhesive company in Selangor, respectively. Two types of urea formaldehyde resin, E1-glue, with maximum permissible formaldehyde emission < 0.1 ppm and E2-glue, maximum permissible emission 0.1 to 1.0 ppm were used as bonding agent. Orthoboric acid (H_3BO_3, ANALAR GRADE) was used as a preservative in the treatment.

Preparation of wood particles

Rubberwood chips were flaked into required dimension and then screened into size ranging from 0.5 mm to 1.0 mm. The particles collected from the screen were divided into two groups. The first group was dried to 5% moisture content (MC) and the second group was dried to 3% MC using an electric humidity chamber.

Determination of Gelation Time

Gelation time is a period of time required for the glue to form a gel at a specific temperature. In this study gelation time for the adhesive which was mixed with preservative was determined. Twenty g of UF (65.6% solids) was mixed with ammonium chloride (NH4CI, 1.5% w/w of resin solids) and boric acid (H_3BO_3, 0.5% and 1.0%, w/w of resin solids) in a beaker. The beaker and its content were submerged in boiling water and stirred until the adhesive hardened and gelled. The time that the adhesive mix took to gel was then recorded.

The gelation time recorded for the UF adhesive *per se* was about 290 s. A shorter gelation time was recorded in the mixture of UF adhesive and boric acid, i.e. 265 and 270 s, repectively for UF resin formulated with 0.5% and 1.0% boric acid. These data could be used to calculate the optimum hot press time during board manufacture.

Preparation of Particleboard

A single layer particleboard 340 mm 3 340 mm x 10 mm with targeted density of 650 kg/m^3 and final MC of ca. 10% were made. UF adhesive with two resin types (E1 and E2) each at 11% (based on oven dried weight of the particles) concentration was used as the bonding agent. E2 boards were manufactured only for board durability test. Pre-weighed rubberwood particles from each batch were blended separately. Boric acid was added to the particles by two methods. Method A: by mixing the chemical powder (0.5% and 1.0% w/w of the Oven dry (od) weight of particles) with the adhesive. The boric acid + adhesive mixture was sprayed onto the particles which had been dried to 5% MC using a pressured spray gun. Method B: spraying the furnish which had been prepared from drier particles (3% MC) with boric acid solution at both 0.5% and 1.0% dosages.

The mat forming process was carried out manually using a wooden former (340 mm x 340 mm). The particles were distributed on a stainless steel caul plate covered with a piece of teflon-fiber sheet. The furnish was spreaded uniformly within the former. Once the mat had been formed, another sheet of teflon fiber was placed on the top of the mat. The teflon-fiber sheets were used to prevent the mat from sticking the platens and to gent smooth board surface. The mat was then pressed manually and subsequently followed by hot pressed maintained at 125°C for 270 s. The stepwise pressure was applied at: step 1, 50 kg/m^3 for 150 s, step, 2, 30 kg/m^3 for 90 s and step 3, 25 kg/m^3 for 30 s. The boards were then conditioned in a conditioning room (65± 5% RH and 20±2°C) for one week before they were cut into testing specimens. The number of particleboards and treatment combination made for this study are summarised in Table 1.

Retention of boric acid in the treated particleboard

The retention of boric acid in the treated particleboard was analysed chemically using standard titration method (Anonymous 1986). Five specimens of 10 mm x 10 mm were obtained from each treated board, and were ground into sawdust and passed through number 16-mesh sieve (maximum 1 mm in size). The particles were then analysed separately following the procedure outlined in the standard (Anonymous. 1986).

Physical and Mechanical Properties of the Particleboard

The boards were trimmed at the edges and cut into the required test dimensions as shown in *Fig 1.* There was a total of 60 specimens each for static bending (dry test), static bending (wet test) tests and 30 specimens for each internal bond (IB), thickness swelling (TS), water absorption (WA) tests. All the tests were carried out using Zwick 1400 Universal Testing Machine in accordance with Japanese Industrial Standard (JIS-A-5908-1983) (Anonymous. 1983) .

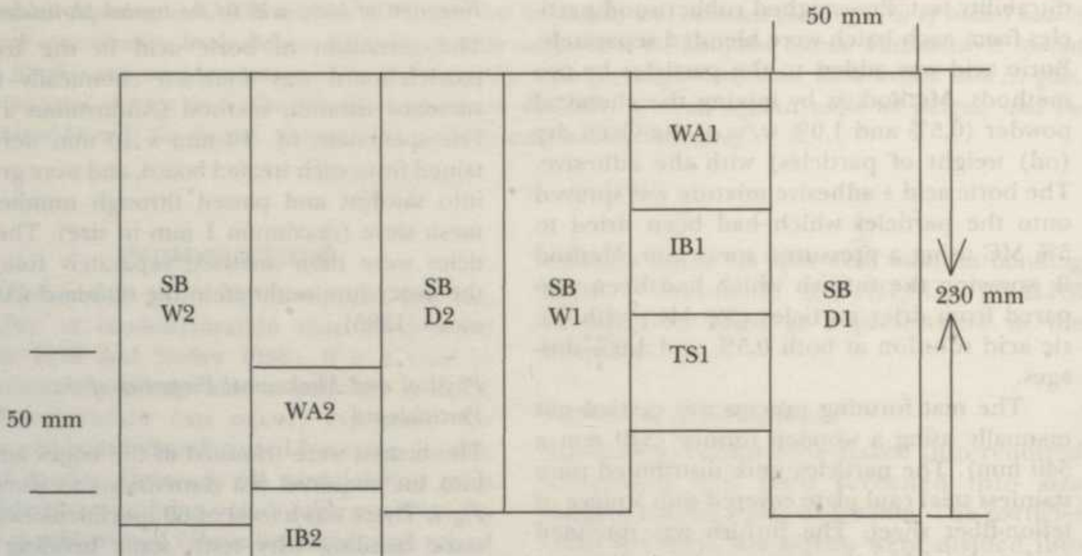
Durability of the Particleboard against Fungus

The test on durability of the treated particleboards against white rot fungus (*Pycnoporous sanguineus*) was carried out in the laboratory using the method specified in the American Standard of Testing Material (ASTM D2017-71) (Anonymous. 1972). The efficacy of the treatment was evaluated based on the percent weight loss caused by

TABLE 1
Number of particleboards and trestment combinations used in the study

Adhesive	Amount of H_3BO_3, (%, w/w)	Application of preservative		
		No. Preservative	Mix with adhesive	Boric acid solution
E1-glue	0	3		
E2-glue	0	3		
E1-glue	0.5		3	3
E1-glue	1.0		3	3
E2-glue	0.5		3	
Total		6	9	6

E 1-glue, maximum permissible emission not more than 0.1 ppm
E 2-glue, maximum permissible emission between 0.1 to 1.0 ppm



SBW = Wet static bending sample
SBD = Dry static bending sample
WA = Water absorption sample
IB = Internal bond sample
TS = Thickness swelling sample

Fig. 1 Cutting patterns of the testing specimens from each board

the degradation of the boards by the fungus. Thirty test blocks, 16 mm x 16 mm were cut from each treated and untreated boards. The blocks were conditioned in a conditioning room until they reached constant weights. Their weights were measured and the blocks were then placed in culture bottles containing white rot mycellium. The bottles together with their contents were then left in an incubating room maintained at 25±20°C and 65-75% relative humidity. At the end of the test period (after the 12th week), the test blocks were removed from the bottles, and the mycellium adhered on the surface of the blocks were brushed off. They were again left in the conditioning room until their weights were constant. The percentage weight loss from the conditioned weight before and after exposure was calculated using the following Equation:

$$\text{Weight loss (\%)} = \{(W_1 - W_2) / W_1\} \; 3 \; 100 \quad (1)$$

Where,

W_1 = Conditioned weight before exposure to fungus

W_2 = Conditioned weight after exposure to fungus

The results obtained were classified into four classes of degradation resistance: 0-10% weight loss is classified into Class A (highly resistance); 11-24% weight loss, Class B (resistance); 25-44% weight loss, Class C (moderately resistance) and above 45% weight loss, Class D (slightly/non resistance) (Anonymous. 1972).

Statistical analysis

All data were statistically analysed using one way analysis and the mean value of each property was separated using Duncan's Multiple Range Test (DMRT) to determine the differences between treatment levels.

RESULTS AND DISCUSSION

Retention of Boric Acid in the Treated Particleboards

The mean retention of boric acid in the boards was determined using standard titration method as described in Table 2. The final chemical loading for boards which were originally incorporated with 0.5% (w/w) boric acid was between 0.46-0.47% (w/w) and 0.42-0.43% (w/w) when employing method A and method B, respectively. However, a markedly lower retention was found in the boards which were originally treated with 1% (w/w) boric acid. For method A, only 0.70% (w/w) boric acid was retained in the boards while for method B, 0.64% (w/w). The lower retention values found in the treated board had been anticipated because the value was analysed based on the od weight of the board while the concentration of boric acid was prepared based on the od weight of particles.

However, it is also interesting to note that a lower retention value was recorded for treated particleboards using boric acid in the form of solution (Method B) compared to those in the form of a mixture of adhesive. The possible explanation for this is the occurrence of steam volatisation of some of the boric acid during hot pressing. It has been found that boric acid, in solution form, to some extent is volatile when dehydrated at a very high temperature, (Zaidon *et al.*1998), hence less amount of boric acid is being retained in the board. Whilst, in the other treatment most of the boric acid may have reacted with the urea formaldehyde during the mixing time and lesser amount was lost by this way as reflected by the higher retention value.

Physical and Mechanical Properties of the Particleboard

The average density, MC and the MOR and MOE for treated and untreated control particleboards are summarised in Table 3. The average density of the particleboard varied from about 581 kg/m^3 to 621 kg/m^3, i.e. markedly lower than the targeted density of 650 kg/m^3. Quite similar values (ca. 9.5%) were recorded for the final MC of the boards. The values in parentheses represent the change in properties compared to the untreated (control) boards.

The following discussion assumes that all the treated specimens have a uniform distribution of boric acid. From Table 2, the MOR and MOE values for boards tested under wet conditions did not differ significantly among the treatment groups, even though a reduction of properties was recorded as the chemical loading in the treated boards increases. The mean value for wet MOR and wet MOE for the untreated control boards were 7.89 N/mm^2 and MOE, 460.9 N/mm^2, respectively. However, when tested under dry condition, the MOR values for boards with boric acid loading ranging from 0.42-0.47% (w/w) were significantly reduced between 9.1-15.7% from 15.02 N/mm^2. While the MOR of those having higher loading (ranging from 0.64-0.70%, w/w) were reduced between 19.6-24.6%. The results also revealed that the higher the boric acid retention in the board, the higher the reduction of MOR. For dry MOE, however, the property was only affected if higher boric acid is retained in the treated board. The MOE values

TABLE 2
Mean retention boric acid-treated particleboard determined using titration method

Boric acid dosage (%, w/w)	Adhesive glue type	No. of samples	Retention of boric acid, % (w/w)	
			Method A1	Method B[2]
0.5	E1	15	0.47 (0.082)	0.42 (0.093)
1.0	E1	15	0.70 (0.013)	0.64 (0.017)
0.5	E2	15	0.46 (0.021)	0.43 (0.024)

[1]Mixing boric acid powder with adhesive before spraying the furnish
[2]Spraying the furnish with boric acid solution
Values in parentheses are standard deviation

Table 3
Mean[1] property values of particleboard treated with H_3BO_3 compared with untreated control groups

Treatment	Chemical loading (%, w/w)	MC (%)	Density (kg/m^3)	Dry MOR N/mm^2	Wet MOR N/mm^2	Dry MOE N/mm^2	Wet MOE N/mm^2
Control	0	9.22	617.3	15.02^{a}[2]	7.89^{a}	1085.8^{a}	460.9^{a}
Method A + 0.5% boric acid	0.47	9.54	620.5	12.71^{b} (-15.7)	6.73^{a} (-14.7)	981.3^{a} (-9.6)	429.5^{a} (-6.8)
Method A + 1.0% boric acid	0.70	9.55	580.9	11.33^{c} (-24.6)	6.65^{a} (-16.7)	922.3^{b} (-15.1)	369.9^{a} (-13.9)
Method B+ 0.5% boric acid	0.42	9.68	620.0	13.65^{b} (-9.1)	6.87a (-12.9)	1036.3^{a} (-4.6)	443.8^{a} (-3.7)
Method B + 1.0% boric acid	0.64	9.78	608.3	12.16^{c} (-19.6)	6.54^{a} (-17.6)	943.6^{b} (-13.1)	416.8^{a} (-9.6)

[1]Mean value of 60 samples
[2]Means in the same column followed by the same letter are not significantly different (a = 0.05) using DMRT
Figures in parentheses are percent change of properties compared to untreated control.

for boards with boric acid loading of between 0.64-0.70% were reduced by ca. 17% from 1085.8 N/mm².

A significant reduction of MOR and MOE when tested under dry condition in the treated boards which may be attributed to one of two possibilities. Firstly, it was possibly due to the final density of the board. As seen in Table 2, the average final density obtained for the boards treated with 1.0% boric acid for both methods (i.e. 580.9 kg/m³ for method A and 608.8 kg/m³ for method B) was appreciably lower than the average density for the control (617.3 kg/m³). Lehmann (1974), stated that the final board density greatly influenced the physical and mechanical properties of particleboard. Higher density particleboard generally produced boards with better strength properties. Secondly, the presence of boric acid in the board coupled with the heat from the hot press to bond the particles will hydrolyse bonds which connect the glucose units and will effectively rupture microfibrils creating shorter cellulose chains. Since most strength properties of wood are closely related to cellulose microfibril integrity will also reduce the bending strength (Ifju 1964). The higher the amount of boric acid present in the particles, the more ruptured the microfibrilsis.

A total different scenario was observed in wet bending strengths. It is known that boron compound is water soluble and it does not fix in the wood after treatment and can easily be leached out when subjected to humid condition or immersed in water. The soaking of the treated specimens prior to the static bending test would result in the leaching out some of the chemical which in turn will not significantly change the properties of the boards.

The descriptive statistics for internal bond (IB), thickness swelling (TS) and water absorption (WA) tests are given in Table 4 for the treated and untreated particleboards. The values in parentheses represent the change in mechanical properties compared to the untreated control.

From Table 4, it can be seen that the incorporation of 1.0 % boric acid significantly reduced the strength of the glue line. The IB values were lowered by 22.5% and 18.4% to 2.23 kN and 2.34 kN for those with chemical loading of 0.70 and 0.64%, respectively. For those treated with smaller amount of boric acid, the IB of the boards was not significantly affected, though a slight reduction (2.8-5.1%) was recorded. The average IB values for these boards were between 2.73 kN to 2.79 kN while the average untreated boards value was 2.87 kN.

TABLE 4
Mean[1] internal bonding and dimensional stability values of boric acid-treated particleboard compared with untreated boards

Treatment	Chemical loading (%, w/w)	Internal Bonding N/mm²	Thickness swelling %	Water absorption %
Control	0	1.15a2	11.76a	87.3a
Method A + 0.5% boric acid	0.47	1.09a (-5.1)	13.36a (14)	80.12b (-8.3)
Method A + 1.0 boric acid	0.70	0.91b (-20.9)	11.04a (-6.0)	93.74a (7.3)
Method B + 0.5% boric acid	0.42	1.12a (-2.8)	11.47a (-4.2)	79.27b (-8.4)
Method B+ 1.0 boric acid	0.64	0.94b (-18.3)	12.75a (8.4)	89.45a (2.0)

[1]Mean values of 6 samples
[2]Means in the same column followed by the same letter are not significantly different (a = 0.05) using DMRT
Figures in parentheses are percent change of properties compared to untreated control.

Internal bond measures the particleboard bonding efficiency and indicates the compatibility of resin adhesive. In this study the incorporation of boric acid in the particleboard to some exten did not adversely affect the glue line properties. However, the IB of the boards will be reduced if larger amount of boric acid is formulated in the particleboard as reflected by the higher reduction of IB values (Table 4).

Thickness swelling (TS) measures the dimensional stability of the boards and is considered important in sizing property. The lower the TS, the better is the dimensional stability of the board. The result shows there is no definite trend in TS values of the boards with respect to concentration levels of boric acid and the treatment methods employed. This phenomenon was verified by the statistical analysis where the values for all treatment groups are not significantly different (Table 4). The TS values of the boards were in the range of 11.0 to 13.4%.

For the water absorption test, a significant reduction of about 8% was recorded for boards with boric acid loading between 4-5%. The water absorption value for the untreated particleboard was 87.33%. Suprisingly, the WA value for boards with higher chemical loading did not differ significantly when compared to the control boards.

Durability of Particleboard against Rotting Fungus (Pycnoporus sanguineus)

The average weight loss of rubberwood particleboard blocks after 12 weeks of exposure to white rot fungus (Pycnoporus sanguineus) is shown in Table 5. All control blocks were completely covered with mycelium whilst no mycelium was seen on the surface of the treated blocks. The average weight loss was 29.54% for

TABLE 5
Average weight loss of rubberwood particleboard blocks test after 12 weeks exposure to *Pycnoporous sanguineus* (white rot fungus)

Blocks	Chemical loading (%, w/w)	Weight loss (%)	Resistance class
UF-E1	0	Mean = 59.54[a1] S.D2 = 2.20 N3 = 30	C
UF-E2	0	Mean = 24.69[b] S.D = 3.76 N = 30	B
UF-E2	0.42-0.46	Mean = 5.11[c] S.D = 0.90 N = 30	A
UF-E1	0.43-1.47	Mean = 5.73[c] S.D = 1.41 N = 30	A
UF-E1	0.64-0.70	Mean = 4.59[c] S.D. = 1.97 N = 30	A

[1]Means in the same column followed by the same letter are not significantly different (p = 0.05) using Duncan' test
[2]S.D - Standard deviations
[3]N – No. of samples
UF-E 1 – Board with maximum permissible emission not more than 0.1 ppm
UF-E 2 – Board with maximum permissible emission between 0.1 & 10 ppm
A – Highly resistant with average weight loss between 0 & 10%
B – Resistant with average weight loss between 11 & 24%
C – Moderately Resistant with average weight loss between 25 & 44%

boards bonded with UF glue type E1 (max. permissible formaldehyde emmision: 0.1 to 10 ppm) and 24.69% for UF glue type E2 (max. permissible formaldehyde emmision: < 0.1 ppm). The significant difference in weight loss between E1-boards and E2-boards suggests that formaldehyde content has significant effect on the durability of the boards. Being an E2-board, more formaldehyde would be emitted when it is being exposed to humid condition. This formaldehyde would act as a barrier on the board surface, and prevent it from fungi attack. This would explain why the E2-board has lower weight loss compared to that of E1-board.

The results also revealed that a chemical loading between 0.42-0.47% has successfully reduced the degradation of the particleboards caused by the white rot fungus. The weight loss caused by the degradation was 5.11% for boards bonded with UF glue type E2 and 5.73% for UF glue type E1. A higher resistance against fungi was found as more boric acid is retained in the particleboard. This is proved by the lesser weight loss (4.59%) of board which has a chemical loading of 0.7%. With special reference to the ASTM (D2017-71) Standard (Anonymous. 1972), the boric acid-treated board can be classified into 'Highly resistance' (Class A) while untreated UF-E2 board into 'Resistance' (Class B) and untreated UF-E1 into 'Moderately resistance' (Class C).

The results found in this study are in good agreement with previous published reports (Carr 1958, William & Amburgey 1987, Grace *et al.* 1992). The authors concluded that boric acid equivalent (BAE) loading in the range of 0.4% to 1.8% (w/w) are very effective to protect wood against rotting fungi.

CONCLUSION

This study shows that a higher retention was achieved in particleboards when they were treated with boric acid in a powder form than in an aqueous solution form.

Some physical and mechanical properties of particleboard are affected by the preservative treatment. The preservative treatment did not affect the wet MOR and MOE of the boards. However, the treatment reduced the dry MOR and MOE. The glue line strength of the board was significantly reduced when higher concentration of boric acid is added. The reduction in dry MOR and MOE values of boric acid-treated particleboard may probably be due to depolymerisation of the celluolse chains.

There was no definite trend on the stability of the boron-treated board. The WA of boric acid-treated boards were not affected by the treatments.

Particleboards bonded with UF-E1 type glue (less formaldehyde content) was more susceptible to white rotting than those bonded with UF-E2 type glue (more formaldehyde content). The presence of boric acid significantly increased the durability of board against white rot fungus, and the resistance towards the fungus increased as the boric acid loading increases.

The mechanical reductions observed in this study for treated particleboards do not, in general, represent a serious detriment to use. Besides, the increase in resistivity against degradation agent will further expand the usage of the particleboards.

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Differential Effects of Food Plants on the Development, Egg Production and Feeding Behaviour of the Diamondback Moth (*Plutella xylostella* L.)

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Keywords: Brassicaceae, *Brassica*, food plants, *Plutella xylostella*, insecticide-resistant management

ABSTRAK

Satu kajian telah dijalankan terhadap perbezaan kesan tumbuhan makanan pada perkembangan larva dan pupa rama-rama belakang intan (DBM) (Plutella xylostella L.) kelakuan memakan oleh larva dan penghasilan telor oleh serangga dewasa betinanya. Tumbuhan makanan yang diguna adalah lima tumbuhan Brassicaceae (Brassica juncea Cosson, B. juncea Cosson var. rugose Bally, B. alba Rebenh, B. oleracea var. alboglabra Bally and B. juncea L. (Czern)) dan satu Capparidaceae (Cleome rutidosperma DC). Masa perkembangan DBM larva atau pupa adalah dikesani secara bererti oleh tumbuhan makanan. Masa perkembangan larvae adalah lebih panjang (10.9 hari) dan bererti apabila diberi makan B. alba (tumbuhan tanaman) dibandingkan apabila larva diberi makan tumbuhan lain. Walau bagaimana pun, tumbuhan makanan liar menyebabkan masa perkembangan DBM pupa lebih panjang dibandingkan apabila tumbuhan ditanam diberikan sebagai makanan larvae. Perhubungan di antara bilangan telor bagi setiap DBM dewasa betina dengan berat pupa (terbentuk daripada larvae diberikan tumbuhan makanan yang berbeza) adalah kuat (r = 0.85). B. juncea mungkin merupakan tumbuhan makanan yang lebih baik (kualiti makanan yang baik) kerana ia menyebabkan berat pupa and bilangan telor yang terhasil adalah lebih tinggi dibandingkan apabila tumbuhan makanan lain (liar atau ditanam) diberi sebagai makanan DBM larvae. Di dalam ujian tiada pilihan, DBM larvae telah mengambil masa yang lebih lama dan bererti untuk sampai kepada B. juncea (liar dan tanaman) dibandingkan dengan masa yang diambil untuk sampai kepada tumbuhan makanan yang lain. Ini menunjukkan kedua-dua tumbuhan makanan tadi mempunyai kurang sebatian kimia penarik pemakan (larvae). DBM larvae mengambil masa yang lebih pendek dan bererti apabila memakan C. rutidosperma dan B. juncea (tanaman) dibandingkan dengan masa yang diambil untuk memakan tumbuhan makanan lain. Di dalam ujian pilihan pula, DBM larvae mengambil masa yang sama panjang untuk sampai kepada semua tumbuhan makanan. Namun begitu, mereka telah mengambil masa yang lama dan bererti untuk memakan B. juncea dibandingkan dengan tumbuhan makanan lain. Potensi C. rutidosperma untuk diguna dalam pengurusan DBM yang rintang terhadap racun serangga juga dibincangkan.

ABSTRACT

Differential effects of food plants on developmental time of diamondback moth (DBM) (Plutella xylostella L.) larvae and pupae, larval feeding behaviour and egg production by the adult were studied. The food plants used were five Brassicaceae plants (Brassica juncea Cosson, B. juncea Cosson var. rugose Bally, B. alba Rebenh, B. oleracea var. alboglabra Bally and B. juncea L. (Czern)) and one Capparidaceae (Cleome rutidosperma DC). The developmental times of DBM larvae and pupae were significantly affected by the food plants. Larval developmental time was significantly longer (10.9 days) when fed on B. alba (cultivated) than on the other food plants. The wild food plants seemed to prolong the developmental time of DBM pupae compared with the cultivated hosts. There was a strong relationship (r = 0.85) between the numbers of eggs laid by DBM adults and the weight of the pupae which developed from larvae fed on various food plants. In contrast to the wild hosts and three other cultivated hosts, B. juncea seemed to be a better food plant (better quality food) as it caused higher pupal weight and egg production by the female adults. In a no-choice test, DBM larvae took a significantly longer time to reach

B. juncea (wild and cultivated) than other host plants, indicating that the former had fewer feeding attractants. DBM larvae spent significantly shorter time to feed on C. rutidosperma and cultivated B. juncea than on other food plants. In a choice test, DBM larvae took about equal amounts of time to reach each food plant. However, they spent significantly longer time feeding on B. juncea than on other food plants. The potential of C. rutidosperma to be used in insecticide-resistant management of DBM is also discussed.

INTRODUCTION

The diamondback moth (DBM) (*Plutella xylostella* L.) is a major pest of *Brassica* crops worldwide (Harcourt 1986). It is one of a few insect pest species that have developed resistance to all pesticides, including *Bacillus thuringiensis* (Talekar and Shelton 1993). It can be found on many Brassicaceae plants (main host or food) and certain non-host plants containing mustard oils (glucosinolates) (Marsh 1917; Thorsteinson 1953; Gupta and Thorsteinson 1960). The abundance of host plants is a key factor in determining the survival rate and population dynamics of DBM and its natural enemies (Marsh 1917; Harcourt 1986; Fox *et al.* 1990; Eigenbrode and Shelton 1992; Hough-Goldstein and Hahn 1992; Ooi 1992; Talekar and Shelton 1993). The presence of different types and concentrations of glucosinolates, which act as feeding attractants or stimulants, between host plants was identified by Cole (1976).

The possible impact of *Brassica vulgaris* R. BR. and *Brassica kaber* D.C. Wheeler on resistance management of DBM in Michigan, USA, was reported by Idris and Grafius (1994, 1996a, b). In India, the Indian mustard (*Brassica juncea* (L.)(Czern.), has been used successfully as a trap crop for controlling DBM (Srinivasan and Krishna Moorthy 1991). A study on the impact of *Cleome rutidosperma* DC (Capparidaceae) on cabbage webworm (CWW), *Hellula undalis* (F.), conducted in Malaysia indicated that this weed is a suitable food plant for CWW (Sivapragasam *et al.* 1994). The objectives of this study were to assess the differential effects of *C. rutidosperma* and *Brassica* host plants on the developmental times of DBM larvae and pupae, larvae feeding behaviour, and egg production of adult females.

MATERIALS AND METHODS

Insect and Host Plant Sources

First generation UPM-resistant strain DBM donated by Malaysian Research Development Institute (MARDI) was used for the study. Four cultivated *Brassica* (*B. juncea* Cosson, *B. alba* Rebenh, *B. juncea* Coss. var. *rugose* Bally, *B. oleracea* var. *alboglabra* (Bally), one wild *Brassica* (*B. juncea* L. (Czern)(Indian Mustard), and one Capparidaceae (*Cleome rutidosperma* DC) were used as DBM food plants. These food plants were raised in clay pots in the greenhouse one month prior to the experiment.

Developmental Times and Egg Production

First instar DBM larvae (3-5 h after hatching) were placed in 15-cm diam Petri dishes and fed with a piece of host plant leaf (4 cm^2 per larva per dish). The food was replaced every 2 days to maintain freshness. The treatments (food plants, five replicates per treatment) were arranged following a complete randomized design, and placed in a growth chamber at 25 $\pm$ 2oC, 12:12 h (L:D) photoperiod and 50% relative humidity (RH) until adult emergence. Treatments were checked daily to record the larval and pupal developmental times. Pupae were weighed when the colour had changed from light green to brownish (about 2 days before adult emergence). The emerged DBM adults were kept for 2 - 3 days in a refrigerator (5°C) before being used in a subsequent experiment.

A modified 500-ml plastic container with a screen lid on top (4 x 5 cm) and on the sides (3 x 3 cm), was used as an oviposition cage. A pair of DBM adults was released in each cage placed under white light (CROMPTONR, 160 Watt, and 80 cm above the top cage with light intensity range of 430 - 500 lux) for 2 days, after which the males was taken out, to ensure mating occurred. A 15-ml test tube (3 x 6 cm) filled with 10% (v/v) diluted honey was placed inside the cage to feed the DBM adults. A single piece of aluminium (Al) foil, 2.5 x 4 cm, with strips on both sides made using forçeps, coated with the juice of cabbage leaves (prepared following Idris 1995) was put in a cage through a cut made in the lid to serve as an oviposition substrate. Treatments were replicated four times, arranged following a randomized complete block design (to minimize the effect of light intensity gradient), and kept at room temperature and

RH. The number of eggs was recorded at 0700 h daily, the same time the Al foil was also replaced, until there were no eggs laid.

Feeding Behaviour of DBM Larvae

Choice and no-choice tests were used to study feeding behaviour of DBM larvae on different food plants. In both tests, a modified 15-cm diam Petri dish (four screen lids, 1 cm diam, were made in the cover for better ventilation) was used. The host plants used were two cultivated *Brassica (B. juncea* Cosson and *B. alba* Rabenh) and two weed species, *B. juncea* L. and *C. rutidosperma.* In a no-choice test, three pieces of leaf (2 cm^2 each) of a plant species were placed in each Petri dish (1, 4.5 or 7 cm from the edge, centre or between the pieces of leaf). One third instar DBM larva, starved for 6 h, was released in the centre of a dish. In a choice test, four pieces of leaf (similar size as for no-choice test and each leaf piece representing a plant species) per replicate were placed in the Petri dishes and arranged as for no-choice test, except the distance between leaf pieces was 5 cm. In both tests, treatments were placed 80 cm below the white light as mentioned above, and kept at room temperature and RH. Times taken by the larvae to reach food (leaf piece) from the point of release (centre of dish), and times spent for feeding during 3 hours' observation (1400 - 1700 h) were recorded using a tape recorder.

Data Analysis

To depict the qualitative trend (not for demarcating quantitative differences) between the pupal weight and number of eggs produced data were analysed using regression analysis (Abacus Concepts 1991). The developmental times of DBM larvae and pupae, times taken by larvae to reach food and times spent by larvae for feeding per plant (food) during 3 hours' observation were analysed using one-way analysis of variance (ANOVA) (Abacus Concepts 1991).

RESULTS AND DISCUSSION

Developmental Times and Egg Production

The developmental time of DBM larvae was significantly ($P < 0.05$, Fisher's Protected LSD) shorter when larvae were fed on *B. juncea* var. *rugose* and *B. oleracea* var. *alboglabra* (cultivated) than on the *B. alba* and *B. juncea* (cultivated), and *B. juncea* (Czern.) and *C. rutidosperma* (wild) (Table 1). Interestingly, the developmental time was significantly ($P< 0.05$, Fisher's Protected LSD) prolonged by the cultivated food plant, *B. alba*, and not by the wild food plants, *B. juncea* (Czern) and *C. rutidosperma.* This indicates that host food plants had different effects on the developmental time of DBM larvae, which might be affected by the glucosinolates, because DBM larvae do not discriminate between different types of glucosinolates present in the food plants (Reed *et al.* 1989). The glucosinolates of *Pieris rapae* L.,

TABLE 1
Developmental times of diamondback moth larvae and pupae fed on different food plants

Food Plants	Common Name	Developmental times (day ± S.E)	
		Larva	Pupa[1]
Cultivated			
Brassica juncea Cosson	Sawi	10.10 ± 2.32b	4.62 ± 0.81 ab
B. juncea Cosson var. *rugose* Bally	Kai Choy	9.12 ± 3.11c	4.10 ± 0.56b
B.alba Rebenh	Kai lan	10.87 ± 1.97a	2.34 ± 1.22c
B.oleracea var. *alvoglabra* bally	Sawi Putih	9.38 ± 2.42	4.01 ± 1.56b
Wild			
B. Juncea L. (Czern)	Indian Mustard	9.89 ± 3.13b	4.86 ± 0.78a
Cleome rutidosperma DC[2]	Purple Maman	9.93 ± 2.65b	5.01 ± 0.85a

[1]From start of pupation until adult emergence; [2]Capparidaceace, others are Brassicaceae
Means in column with same letter were not significantly different ($p > 0.05$, Fisher's Protected LSD)

a food plant that acts as an antifeedant, prolonged developmental time of its larvae to pupation (Hough-Goldstein and Hahn 1992).

The developmental time of DBM pupa was significantly (P < 0.05, Fisher's Protected LSD) longer when larvae were fed wild food plants than with cultivated food plants (Table 1). In contrast, the developmental time of *H. undalis* pupae fed on *C. rutidosperma* was significantly shorter than when fed cultivated *Brassica* species (Sivapragasam *et al.* 1994). Some types of glucosinolates of *C. rutidosperma* were reported to slow down the developmental rate of DBM pupae (Gupta and Thorsteinson 1960; Cole 1976; Wallbank and Wheatley 1976).

There was a strong relationship (r = 0.85, P < 0.05) between the number of eggs laid by adult DBM females and the weight of pupae developed from larvae fed on different food plants (*Fig. 1*). DBM larvae fed on *B. juncea* (cultivated) resulted in higher pupal weight and more productive females (laid more eggs) than those fed on other food plants. This suggests that there are qualitative differences between food plants that affect development and reproduction of DBM. A study conducted by Fox *et al.* (1990) also found that the quality of cabbage plants is positively correlated with the size of DBM larvae or pupae.

Feeding Behaviour of DBM Larvae

In a no-choice test, DBM larvae took significantly (P < 0.05, Fisher's Protected LSD) shorter time to reach *C. rutidosperma* and *B. juncea* var. *rugose* than the other food plants (Table 2). In contrast, the time taken by DBM larvae to reach the food sources in a choice test was not significantly (P > 0.05, Fisher's Protected LSD) different among food plants. This suggests that *C. rutidosperma* and *B. juncea* var. *rugose* have higher concentrations of feeding attractants than other food plants (Cole 1976).

The feeding time spent by DBM larvae in 3-hour observation periods was significantly (P < 0.05, Fisher's Protected LSD) longer on the cultivated than on the wild food plants except in a choice test (Table 2), indicating that wild food plants are not good food sources for DBM. In contrast, Thorsteinson (1953) reported that feeding responses, which were measured as feeding activity per unit time, of DBM on the wild food plants (Capparidaceae; *Capparis flexuosa* and *C. spinosa*) was as active as on the cultivated Brassicaceae plants.

Results show that cultivated *B. juncea* was a better food plant of DBM (higher number of eggs produced per adult female, and longer time spent feeding on it) than the other food plants (Table 1 & 2, *Fig. 1*). This suggests that it should not be planted alone if we want to avoid heavy infestation of DBM and reduce pesticide usage. The *C. rutidosperma* and *B. juncea* var. *rugose* (in both tests) might have a higher concentration of glucosinolates that act as feeding attractants compared with wild *B. juncea* as times taken by DBM larvae to reach *C. rutidosperma*

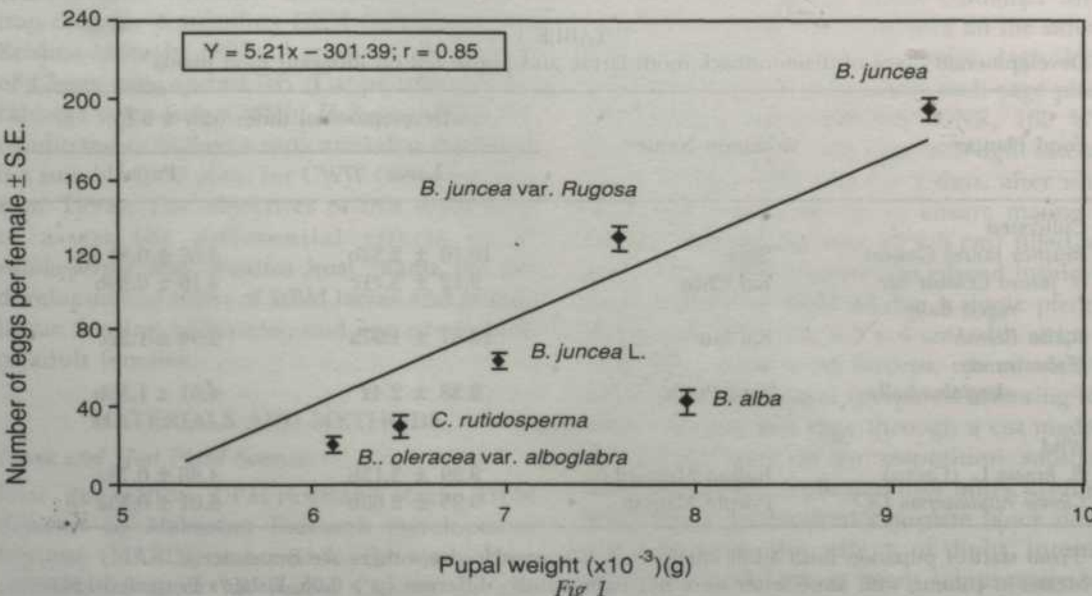

Fig 1

TABLE 2
Time (minutes ± S.E) taken by diamondback moth third instar larvae to (a) reach food and (b) feed in no-choice and choice tests [1,2]

Food Plants	No-choice test		Choice test	
	Reach food	Feed	Reach food	Feed
Cultivated				
Brassica juncea Cosson	28.31 ± 10.32b	30.02 ± 9.01b	4.43 ± 2.10b	35.58 ± 10.13a
B. juncea Cosson var. *rugose* Bally	10.54 ± 3.12c	45.83 ± 8.92a	5.21 ± 2.31b	20.65 ± 5.34b
Wild				
B. Juncea L. (Czern)	50.01 ± 10.67a	15.23 ± 3.50c	5.32 ± 2.05b	10.89 ± 3.54c
Cleome rutidosperma DC	12.43 ± 4.21c	16.54 ± 3.21c	8.93 ± 3.23b	13.75 ± 6.27b

[1]observation was made from 1400 to 1700 h (3 hours)
[2]Means in column with same letter were not significantly different (p > 0.05, Fisher's Protected LSD)

and *B. juncea* var. *rugose* were shorter than to wild *B. juncea* (Table 2). However, *C. rutidosperma* or *B. juncea* var. *rugose* might not have or having similar concentration of feeding stimulant as *B. juncea*. There seemed to be no difference in food quality offered by the two wild food plants as the pupal weight and eggs produced per female are somewhat similar (*Fig. 1*). Although *B. oleracea* var. *alboglabra* and *B. alba* seemed to have similar food quality, as indicated by their effect on the pupal weight or numbers of eggs produced by DBM females, the feeding behaviour of DBM larvae on those varieties was not tested.

C. rutidosperma is a ubiquitous weed in Malaysia while wild *B. juncea* was introduced from India (Henderson 1974; Sivapragasam and Loke 1995). Wild *B. juncea* was also proved to possess an oviposition attractant that makes it possible to use it as a trap crop (Srinivasan and Krishna Moorthy 1991). In Malaysia, it is not practical to interplant wild *B. juncea* with *Brassica* crops due to socio-economic reasons (Sivapragasam and Loke 1995). It can be planted around the field and insecticide sprayed only when necessary. This could reduce the population of DBM and other cabbage pests in the field as well as insecticide-resistance development. Unlike wild *B. juncea*, the effect of *C. rutidosperma* on DBM oviposition behaviour has never been studied. We can diverge DBM oviposition activity from the cultivated brassicas, especially near or at the critical growth stages, to *C. rutidosperma* (if it is found to possess oviposition attractant) planted around or within a field. When *C. rutidosperma* is not needed it can easily be pulled out manually; therefore, weedicide use is not necessary. Since cultivated *B. juncea* seemed to be a good food plant for DBM, it should be interplanted with other crops such as tomato. Bach and Tabashnik (1990) reported that DBM infestation was significantly lower in the cabbage field interplanted with tomato plants than in the field planted with cabbage alone. Wild *B. juncea* can also be planted around the plot or field planted with cultivated *B. juncea* , and this may avoid heavy infestation of DBM on cultivated *B. juncea*.

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Physico-Chemical Characteristics of Exposed Saprolites and Their Suitability for Oil Palm Cultivation

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Keywords: ***saprolite; fertility; weathering; Malaysia***

ABSTRAK

Kajian bertulis mengenai pengurusan tanah kawasan tinggi untuk tanaman kelapa sawit menunjukkan tanah ini adalah rendah kesuburan dan taraf kesesuaiannya. Kajian kami yang bertujuan mendalami masalah tersebut, mendapati bahan saprolit yang berada di bawah lapisan tanah telah terdedah atau hampir ke permukaan akibat kerja-kerja membuat teres pada tanah berbukit, menyebabkan tanah berkenaan kurang sesuai untuk penanaman kelapa sawit. Persampelan tiga profil saprolit yang berbeza kedalaman dan geologi telah dilakukan dan analisis sifat fizik kimia and kesuburannya telah dijalankan. Selain daripada variasi antara sifat saprolit yang berlainan geologinya, saprolit juga mempunyai taraf kesuburan dan sifat fizik yang rendah, mencadangkan bahawa bahan ini tidak sesuai untuk tumbesaran tanaman. Taraf kesuburan saprolit walaupun kurang terluluhawa, adalah rendah daripada tanah. Saprolit mempunyai keupayaan pengikatan phosporus yang tinggi, cas negatif yang rendah, dan dengan itu mempunyai keupayaan pertukaran kation yang rendah. Kesan fitotoksik Al adalah rendah dalam saprolit berbanding dengan tanahnya. Sifat fizik saprolit adalah masif dan tiada pembentukkan struktur dan mempunyai daya penyimpanan air yang tinggi yang kemungkinan tidak terdapat oleh tanaman. Analisis penjelmaan tak berubah isipadu batu kepada saprolit menghasilkan kehilangan ketara kation bes daripada profil, menyebabkan taraf kesuburan saprolit rendah berbanding dengan tanahnya. Penilaian kesesuaian bahan saprolit daripada geologi asal yang berbeza mendapati bahan ini tidak sesuai untuk tanaman kelapa sawit, dengan kecetekan, saliran dan kesuburan saprolit sebagai masalah utamanya.

ABSTRACT

The reviews on the management of upland soils for oil palm cultivation have indicated that these soils are poor in fertility and classified as marginal to unsuitable. Our study aimed at investigating the problem, found that saprolites laying below the soil layers are either exposed directly or near to the surface as the result of unavoidable terracing of slopes to enable cropping, rendering poor crop suitability. Samples from three different saprolitic profiles of varying depth and geology were collected and analyzed for their physico-chemical properties and chemical fertility characteristics. Besides variability in characteristics of different geological origin, the saprolites have poor fertility and physical properties, suggesting that they are poor substrate for crop growth. The fertility status of the saprolites, despite less weathered, were poorer than their soils. Comparatively, they have higher phosphorus retention capacity, lower net negative charge, and thus lower cation retention capacity. The Al phytotoxic effect, however, was lower in the saprolites than in their soils. The saprolites physical properties were characterized by massiveness and lacking of structural development, which enables high water retention but may not be available to plants. The isovolumetric transformation analysis of rock into saprolites showed a significant depletion of base cations from the profiles, instituting poor fertility status of saprolites in comparison to their respective soil layers.

The suitability assessment of saprolite materials of varying geological origin indicates that saprolites are unsuitable for oil palm cultivation, with shallowness, fertility and poor drainage conditions being the major constraints.

INTRODUCTION

Land terracing is an unavoidable procedure in the preparation of upland soils for oil palm cultivation. Depending upon the steepness of the slope, the cutting for terrace bench can reach down to more than a meter deep, which will expose the upper saprolite or commonly cited as the C horizon to the surface or near to the surface. In whatever cases, the crops planted on hilly and upland areas will eventually be utilizing saprolite as the growing substrate. Oil palm is one of the major plantation crops in Malaysia, and is cultivated on inland areas, some are rugged, hilly and sloppy in nature. In Malaysia, the utilization of slope >20° for agriculture is not recommended (Land Conservation Act, 1960), but in some cases, this is not so. Owing to increasing land pressure and also the lack of enforcement, this Act has not been strictly followed (Aminuddin *et al.* 1990). Some observations have shown that where slopes are >10°, terracing will expose saprolites directly to the surface (Burnham, 1978; Hamdan, 1995). These observations, however, noted that the tendency of saprolite exposure would depend upon the soil depth and terracing techniques.

The acid upland soils are known to have many fertility problems. In an undisturbed environment, these soils are inherently infertile. Like all acid soils of the humid tropics, these soils are low in pH, which bring with it many potential associated problems, including H, Al, and Mn toxicity, Ca deficiency, low CEC, high P fixation, and low microbial activity (Tessens and Shamshuddin, 1983; Foy, 1984). Their shallow topsoils are highly susceptible to erosion, and if not managed properly after clearing, can lose much of their original fertility and beneficial physical properties. Reviews on the characteristics and management of upland acid soils did not consider the exposed saprolites as a result of terracing. With the surface soils and subsoils already being considered problematic, one could only imagine what impact the saprolites pose to the fertility of upland soils. This paper attempts to characterize the fertility of saprolites as an agricultural substrate in comparison to their respective soil layers. It is hoped that the results of this study would change our perception on the management approach of these materials so that they may become more sustainable not only for oil palm, but also for cultivation of other perennial crops. To achieve this, three deep saprolitic profiles of different geology and location were selected for the investigation.

MATERIAL AND METHODS

The study was conducted in Peninsular Malaysia which is climatically equatorial with an annual precipitation of 2500 to 3500 mm, a potential evapotranspiration of 1130 mm, and a daily air temperature of 28 to 33°C. The soil moisture regime is udic while the soil temperature is isohyperthermic with a mean annual soil temperature of 28.70 C. The study involved three deep saprolitic profiles of different geology and location. Samples were collected along newly exposed road cuts in the state of Selangor and Pahang, with depths of 10, 15 and 26 meters for schist, basalt and granite regoliths, respectively. These deep profiles were differentiated into various horizons, morphologically described and sampled following the criteria outlined in the USDA Soil Survey Manual (1981), and were classified using the USDA Soil Taxonomy (USDA Soil Survey Staff, 1994) and FAO-Unesco (1988) soil classification systems.

Samples of soil, saprolite and rock were air dried, crushed and sieved through a 2-mm size. The undisturbed core samples were taken for the determination of bulk density and moisture-retention characteristics at 5 to 1,500 kPa using pressure plates. The aggregate stability index and water dispersible clay (WDC) properties were estimated using the methods of turbidity (Molope *et al.* 1985) and sedimentation (Tessens, 1984), respectively. Soil texture was determined using pipette method (Gee and Bauder, 1986). Soil pH was measured in suspension of 1:2.5 (soil:solution) ratio using a glass electrode pH meter, while soil organic carbon was determined by the Walkley-Black dichromate titration method (Walkley and Black, 1934). Soil nitrogen was determined by macro-kjedahl digestion method (Bremner and Mullraney, 1982), and the dithionite citrate bicarbonate method of Mehra and Jackson (1960) was employed to estimate free iron oxide content. For the CEC determination, the leaching method of 1M ammonium acetate buffered at pH 7 was used. The available P and extractable Al were determined by Olsen (Olsen *et al.* 1954) and aluminon (Hsu, 1963) methods, respectively. The phosphate sorption index was determined according to the method of Bache and Williams (1971). The land suitability classification system of Sys *et al.* (1993) was used to evaluate the soil and saprolite suitability for oil palm.

RESULTS AND DISCUSSION

Morphological Descriptions

The morphological properties of the three deep profiles are summarized in Table 1. The solum layers of the profiles were characterized by crumb structure that gradually changes into subangular blocky structure with depth. They had friable consistency with variation in colours from dark brown in basaltic profile to reddish or yellowish brown in schistic and granitic profiles. Drainage was excessive in basaltic, but moderate in schistic and granitic profiles.

The passage from solum to saprolite was shown by an increase in massiveness, a firmer consistency and a decrease in porosity. With depth, saprolites become still firmer and coherent and can be described as saprock (Zauyah, 1986). The granitic and basaltic saprolites were massive but slightly more friable than the schist saprolite. The high content of incompletely weathered crystals such as quartz, feldspar and muscovite in granite, at intense stage of weathering of basalt, could have accounted for the friability of the saprolites. Partly weathered rock fragments of various sizes, sometimes called corestones, are frequently found in the lower zones. All saprolites had variegated colours that vary between profiles of different geology. In basalt and schist saprolites, the matrices were dominantly reddish-brown to reddish-yellow with grayish colours in relict rock fragments. In granitic saprolite with high resistant minerals such as quartz and muscovite, dissolution of feldspars yielded a matrix of yellow-gray and white with reddish weathered stains. The grayish colour became more dominant with depth in all profiles.

Our field observations strongly suggest that the soil solum of the three profiles provide a good medium for crop growth, particularly those developed on basalt, where the soils are very

TABLE 1
Morphological descriptions of the profiles under study

Horizon	Depth (m)	Texture	Colour		Structure	Consistency
			Matrix	Mottles		
Basalt Profile						
Soil	0-2	Clay	10YR 4/4	Nil	Crumb-SAB	Friable-Fluffy
Transition	2-3	Clay	10YR 3/4	nil	SAB	Friable
Upper saprolite	3-6	Clay	2.5YR 3/4	10YR 4/1	Massive	Firm
Lower saprolite	6-10	Clay	2.5YR 3/4	10YR 4/1	Massive	Firm
Saprock	10-15	Silty Clay	2.5YR 3/4	Nil	Coherent	Hard
Granite Profile						
Soil	0-0.5	Clay Loam	2.5YR 7/6	5YR 6/8	Crumb-SAB	Friable
Transition	0.5-3.2	Silty Clay	7.5YR 7/6	2.5YR 6/8	SAB	Friable
Upper saprolite	3.2-12.5	Sandy Clay	10YR 7/8	2.5YR 6/8	Massive	Friable
Lower saprolite	12.5-24.5	Sandy Loam	7.5YR 6/0	2.5YR 6/4	Massive	Firm-Hard
Saprock	24.5-26	Sandy Loam	7.5YR 6/0	2.5YR .4	Coherent	Hard
Schist Profile						
Soil	0-1	Clay	7.5YR 5/6	Nil	Crumb	Friable
Transition	1-1.5	Silty Clay	2.5YR 5/8	10YR 7/2	SAB	Friable-Firm
Upper saprolite	1.5-6	Silty Clay	2.5YR 5/8	2.5YR 6/8	Massive	Firm
Lower saprolite	6-9	Silty Loam	2.5YR 5/0	2.5YR 6/6	Massive	Firm
Saprock	9-10	Silty Loam	2.5YR 5/0	Nil	Coherent	Hard

Note: SAB = Subangular blocky

friable and fluffy. The saprolites, however, are contradictory to the solum in nature, where they are compacted and massive. Such properties of the saprolites, on exposure, would result in low permeability and subsequently encourage surface runoff and soil erosion (Lal, 1986). Root establishment and growth in the massive materials would be hindered, resulting in slow or even stunted and unproductive plant growth.

PHYSICAL CHARACTERISTICS

Saprolite Porosity

Weathering breaks down rocks into saprolites and subsequently into soils. Differences in the geological origin and mineralogy would result in the formation of different saprolites and soils. All the three profiles studied showed drastic changes in bulk density values during the transformation of rock into saprock (Table 2). From the saprock zones onward, the changes in trend for bulk density and total porosity values were more gradual. Variability in the massiveness and porosity of saprolites were observed, with the schist saprolite being most compacted. The granitic and basaltic saprolites, particularly the upper layers, were as porous as their respective soil layers. The mineralogy of the materials, composed mainly of weatherable minerals as in basalt and resistant minerals with weathered materials as in granite, contributed to such high porosity. Despite being porous, the absence of structural development could have induced surface seal and crust, surface runoff and further reduced moisture availability.

The saprolites also exhibited variability in their particle size distribution, as being greatly influenced by their geological origin. The basalt rock dominantly composed of weatherable ferromagnesian minerals, which weathered easily and were responsible for high clay content in the soil (>70%) and saprolite (>55%). These clays were dominantly of kaolinite type (Hamdan, 1995). Schist and granite contained more resistant minerals of quartz, mica and feldspar in composition to weathered slowly forming clay particles, ranging from < 40% in the soils and <30% in the saprolites.

Erosion Risk Potential

Soil erosion through runoff process occurs extensively on exposed upland soils. Reports by Wan Sulaiman and Jamal (1981) and Mokhtaruddin *et al.* (1985) have indicated that oil palm plantations on different soil series with slopes of 8 to 10 %, lost an estimated 5 to 16 metric ton/ha/year of soils through erosion. Could the exposed saprolites pose similar or even greater erosion risk? Two laboratory studies were conducted to estimate the erosion risk on exposed saprolites, namely: (i) water dispersible clay (WDC), and (ii) aggregate stability to water, and the results are presented in Table 2.

The WDC values recorded were higher in surface horizons for all profiles which ranged from 20-34% and drastically declined to <0.5% in the subsoils and saprolite layers. The analysis indicated that high clay dispersion to water is evident in the soils but minimal in the lower subsoils and saprolites, and this consequently suggests that erosion of saprolite upon exposure was minimum. The results of the aggregate stability analysis showed that the upper saprolites of all profiles were generally less stable than their respective soil layers. The lower saprolites, however, were more stable and this is attributed to the high content of partly weathered rock fragments that still holds the materials intact together. The high content of free iron in basalt profile that binds the materials together, resulted in higher stability of aggregate to water in comparison to those of schist and granite.

The present laboratory studies demonstrated that saprolites have minimal risk to erosion upon exposure. Actual field investigation to estimate soil loss on these materials must be determined in order to provide a clearer risk potential.

Saprolite Moisture Retention Capability

Available moisture is crucial for plant growth and productivity, particularly in the upland areas, where water holding capacity is low (Kubota *et al.* 1982). In these soils, which are low in organic matter content, the slow water infiltration rate is further aggravated by surface seal and crust formation, thus inducing even low permeability and encouraging surface runoff (Lal, 1986).

The data in Table 2 shows the variation in the ability of saprolites to retain moisture as influenced by their geological origin and intensity of weathering. Generally, for all profiles, saprolites retained more moisture (130-480 mm/m-1) than soils (60-160 mm/m-1). However, composition of granite saprolites which largely comprised rock and mineral fragments and little

TABLE 2
Physical properties of the profiles under study

Horizon	Granulometry Clay	Silt	(%) Sand	B.D (g/cm³)	Porosity %	LOI %	A.S %	WDC %	Water Retention Characteristics (kPa) 0	0.98	9.8	33	1500	Available Water (mm/m⁻¹)
Basalt Profile														
Surface soil	77.6	12.5	9.9	0.98	62.9	16.8	85.5	33.0	58.5	29.7	26.5	26.1	21.6	61
Subsoil	79.7	13.2	7.1	1.09	58.8	10.8	80.1	0.4	79.8	57.5	35.1	31.2	26.2	163
Transition	66.1	13.6	20.3	1.37	48.3	15.0	83.9	0.6	63.2	55.3	33.7	31.5	22.8	172
Upper saprolite	64.3	20.6	15.1	1.17	55.9	13.2	75.8	0.4	74.9	55.4	46.7	38.1	37.1	129
Lower saprolite	56.5	31.0	12.5	1.07	59.8	10.6	73.2	0.1	107	85.4	60.8	55.6	35.5	375
Saprock	29.5	54.8	15.7	1.17	55.8	9.8	79.5	0.1	68.9	65.0	51.6	51.0	25.8	280
Rock	nd	nd	nd	2.41	nd	0.8	nd	nd	nd	nd	nd	nd	nd	nd
Granite Profile														
Surface soil	36.6	20.2	43.2	1.24	53.2	9.6	69.6	34.0	39.2	31.4	31.0	27.3	21.9	91
Subsoil	39.6	14.9	45.5	1.62	38.8	8.2	54.5	5.4	58.5	47.6	39.6	39.3	32.5	88
Transition	27.4	18.9	53.7	1.40	47.1	8.4	50.6	0.6	59.0	58.4	35.8	28.2	22.2	202
Upper saprolite	24.6	30.8	44.6	1.65	37.8	4.0	47.2	0.2	62.6	55.6	37.2	34.6	18.8	235
Lower saprolite	10.1	23.3	66.6	1.28	51.7	5.0	78.0	0.1	52.6	31.0	20.8	19.1	10.4	137
Saprock	5.4	20.0	74.6	1.89	37.8	3.4	91.5	0.1	46.5	29.1	19.9	15.8	8.3	144
Rock	nd	nd	nd	2.54	nd	0.4	nd	nd	nd	nd	nd	nd	nd	nd
Schist Profile														
Surface soil	41.9	35.7	22.4	1.09	61.6	6.0	43.5	19.6	70.0	39.2	33.4	30.0	26.1	91
Subsoil	50.2	34.1	15.7	1.28	58.8	6.8	18.4	29.0	74.7	59.3	46.2	39.6	35.8	142
Transition	44.3	42.9	12.8	1.58	47.3	5.8	23.2	0.4	82.2	55.6	43.1	39.2	31.2	158
Upper saprolite	39.4	43.2	17.5	1.59	44.8	5.8	24.3	0.4	72.0	66.5	45.9	42.1	12.4	403
Lower saprolite	10.9	79.1	11.0	1.85	49.3	4.2	42.2	0.1	88.7	60.2	57.1	42.2	10.3	480
Saprock	7.4	81.7	10.9	1.95	45.8	2.8	63.3	0.1	52.9	51.2	40.6	23.2	11.1	328
Rock	nd	nd	nd	2.16	nd	0.8	nd	nd	nd	nd	nd	nd	nd	nd

Note: B.D = Bulk density, LOI = Lost on ignition, WDC = Water dispersible clay, A.S = Aggregate stability, nd = not determined weathered matrices, particularly at the lower zones, accounted for the lower moisture retention in comparison to schist and basalt saprolites.

The moisture retention values at different kPa showed variability among profiles. The basalt profile had a low amount of available water in the soils, thus a reduced ability to retain water beyond 1,500 kPa tension, in contrary to its respective saprolites. The high degree of aggregation and abundance of large pores in the soils, and the abundance of micropores of <0.2 µm in diameter in the saprolites, accounted for the differences. The soils of the granite profile retained a reasonable amount of water while its saprolites lost much of its water between saturation-field capacity and much lower levels at 1,500 kPa tension. These characteristics suggest that most of the pores were macropores, developed probably from relict rock structure, dissolution of feldspar and breakdown of quartz or muscovite. The schist saprolites retained the most amount of available water. The moisture retention trend indicated that schist saprolites have high amount of medium pores, ranging from 0.5 to 50 µm in diameter, but not many micropores of <0.2 µm in diameter as demonstrated by the low amount of water retained at 1,500 kPa tension.

The ability of saprolites to retain moisture depends upon their mineralogy and weathering stage. Despite retaining large amount of moisture, as in schist and basalt saprolites, the moisture may not necessarily be accessible to plant roots. O'Brien and Buol (1984) suggested that in order to allow good root penetration, free drainage and storage of available water, there must be sufficient amount of large (>250 µm), medium (>50 µm) and fine (0.5-29 µm) pores in the soil materials, which were found to be lacking in the saprolites.

CHEMICAL FERTILITY CHARACTERISTICS

Organic Matter Contribution

It is universally recognized that soil organic matter plays a crucial role in determining the physico-chemical and microbiological properties of soils (Brady, 1974). The organic matter content of upland soil changes drastically upon clearing and under different land use system. Undisturbed forested upland soils in Thailand, for example, comprising organic matter content which varied from 6 to 11%, but upon cultivation under different crops, their organic matter content dropped to about 1% (Vangnai *et al.* 1986). In our study areas where secondary forest dominates, the organic matter content of the surface horizons was recorded to be in the range of 4 to 4.8% (Table 3). The content, however, dropped significantly to less than 2% and 1% in the subsoils and saprolites, respectively. The small amount of organic material in the upper saprolites and traces in the lower zones, can be attributed to the migration of these materials through cracks and relict of rock fragments, particularly in the granitic saprolites. The nitrogen content also followed a similar trend of distribution in all profiles. From the data, we can assume that the contribution of nutrients from organic matter decomposition to saprolites fertility is insignificant. Saprolite fertility in this situation would, therefore, depend much upon the release of nutrients during weathering.

Soil Reaction

The data in Table 3 show soil pH values indicating a gradual increase with depth that are in the acidic range of 4.12 to 4.65, except for the basalt profile which indicated a gradual decreasing trend. The variation can be explained by the fact that weathering occurred in basalt profile intensely even at the saprock zones in comparison to granite and schist profiles which were abundantly composed of minerals resistant to weathering. This is supported by the abrasion pH values that show a drastic change between rock to saprock transformation in basalt, i.e. from pH 8.91 to 4.95, but this was not observed in schist and granite profiles. The soil pH values, however, suggested that saprolites are as acidic as their respective soil layers.

Aluminium Toxicity

Aluminium is considered to be the major factor retarding plant growth on acid soils. Our study indicates that the exchange sites and soil solutions of the granite and schist soils, and saprolites were dominated by exchangeable Al as shown by the high extractable acidity values. The Al in all these materials exceeded 70% saturation. Throughout the basalt profile, the exchangeable Al was low, ranging from 30 to 40% saturation but the high extractable acidity values suggest that Al was crystallized into gibbsite in the soil layers. All saprolites, however, had high Al saturation values, and should therefore

TABLE 3
Selected chemical properties of the profiles under study

Horizon	Extractable Acidity (cmol(+)/kg soil)	Al 1M KCl (cmol(+)/kg soil)	Al sat %	Avail. P (mg/kg)	P Sorption Index	Soil pH pH_{Water}	Soil pH pH_{KC}	Soil pH $pH_{Abrasion}$	O.C %	N %	Fed %	Feo %	Ratio Feo/Fed
Basalt Profile													
Surface soil	17.95	0.1	4.9	1.69	78	5.34	4.76	8.01	2.61	0.27	12.42	0.18	0.014
Subsoil	16.32	0.3	37.9	1.51	82	4.81	4.52	8.57	0.86	0.13	12.51	0.10	0.008
BC	15.37	0.1	19.6	1.51	82	5.14	5.44	8.21	0.06	0.02	14.92	0.09	0.006
Upper saprolite	15.06	0.4	41.7	1.54	82	4.84	4.47	8.74	0.01	0.01	12.45	0.05	0.005
Lower saprolite	14.51	1.8	81.1	1.51	78	4.73	4.11	8.93	tr	tr	12.32	0.05	0.004
Saprock	17.61	4.2	88.6	1.43	71	4.61	3.92	8.98	tr	tr	12.46	0.05	0.004
Granite Profile													
Surface soil	18.04	4.1	83.3	1.34	63	4.18	3.67	7.65	2.29	0.29	1.49	0.38	0.251
Subsoil	13.12	4.0	84.4	1.32	60	4.28	3.65	7.65	1.14	0.14	1.83	0.13	0.068
BC	10.81	3.0	86.5	1.69	66	4.49	3.91	7.72	0.89	0.11	1.85	0.01	0.005
Upper saprolite	10.23	4.4	88.6	1.31	58	4.65	3.94	7.83	0.14	0.03	2.12	0.01	0.003
Lower saprolite	3.76	3.4	89.9	1.38	57	4.66	3.95	7.58	tr	tr	0.56	0.00	0.004
Saprock	5.23	1.0	57.8	0.11	53	5.76	5.18	7.54	tr	tr	1.12	0.00	0.002
Schist Profile													
Surface soil	13.49	4.1	70.9	0.98	45	4.12	3.41	7.56	2.78	0.24	3.01	0.14	0.044
Subsoil	22.04	4.7	82.1	0.45	43	4.06	3.41	7.61	1.08	0.13	3.34	0.12	0.035
BC	14.78	3.1	82.2	0.27	68	4.31	3.71	7.61	0.23	0.02	3.33	0.05	0.015
Upper saprolite	15.14	3.4	78.5	0.98	54	4.31	3.73	7.62	0.21	0.01	3.49	0.04	0.011
Lower saprolite	3.45	0.2	28.2	0.09	31	4.42	4.03	7.58	tr	tr	3.26	0.01	0.001
Saprock	5.93	0.6	56.6	0.27	27	4.65	4.21	7.54	tr	tr	2.83	0.01	0.001

Continue Table 3,...

Horizon	Cation Exchange Capacity		ECEC	%B.S	Exchangeable Cations				Micronutrients		
	NH_4OAc (pH 7)	NH4Cl	(unbuffered)		Ca	Mg	Na	K	Cu	Mn	Zn
	(cmol(+)/kg soil)				(cmol(+)/kg soil)				(mg/kg)		
Basalt Profile											
Surface soil	6.21	3.47	1.95	29	0.87	0.59	0.11	0.28	0.75	6.76	1.69
Subsoil	2.15	1.52	0.79	23	0.30	0.05	0.05	0.09	1.13	0.64	0.34
BC	1.13	1.02	0.51	40	0.26	0.05	0.05	0.05	0.46	0.01	0.07
Upper saprolite	2.91	1.97	0.86	16	0.29	0.04	0.03	0.10	0.56	0.01	0.24
Lower saprolite	2.99	2.14	2.22	14	0.28	0.06	0.02	0.06	1.32	0.01	0.44
Saprock	5.66	4.57	4.64	8	0.27	0.09	0.02	0.06	3.91	15.8	2.04
Granite Profile											
Surface soil	8.47	4.92	4.92	10	0.44	0.10	0.05	0.23	0.65	3.35	1.42
Subsoil	5.76	4.85	4.74	13	0.51	0.09	0.03	0.11	0.27	2.23	0.69
BC	4.96	3.31	3.47	10	0.31	0.07	0.03	0.06	0.46	0.41	0.82
Upper saprolite	5.61	5.19	4.96	10	0.35	0.08	0.03	0.09	0.17	0.96	0.19
Lower saprolite	3.96	3.69	3.78	10	0.22	0.06	0.02	0.08	1.25	0.17	0.32
Saprock	2.08	1.99	1.73	35	0.38	0.10	0.01	0.24	0.09	9.47	0.27
Schist profile											
Surface soil	8.09	5.81	5.08	12	0.49	0.16	0.05	0.28	6.69	0.72	1.19
Subsoil	7.04	5.73	5.23	8	0.28	0.08	0.03	0.14	10.5	0.48	0.89
BC	4.75	3.15	3.57	10	0.29	0.07	0.03	0.07	1.13	0.17	0.32
Upper saprolite	4.14	3.42	3.93	13	0.33	0.05	0.03	0.12	0.65	0.17	0.34
Lower saprolite	1.57	1.31	0.61	26	0.28	0.05	0.01	0.07	0.84	0.81	0.54
Saprock	1.22	0.74	0.96	29	0.24	0.04	0.01	0.06	0.94	0.33	0.52

Note: Al sat= Al saturation, O.C= Organic carbon, N= Nitrogen, Feo= Oxalate extractable iron, Fed= Dithionite extractable iron, Av. P= Available Phosphorus, ECEC= Effective cation exchange capacity, B.S= Base saturation, tr= traces constitute a reasonably high degree of Al toxicity (Sanchez and Logan, 1992). The Al toxicity test conducted by Hamdan (1995) on similar profiles showed that the subsoils of all profiles studied were Al phytotoxic to root growth in comparison to their respective saprolites. The higher soil pH values in the basalt saprolites accounted for their lower Al phytotoxic level as compared to those of granite and schist.

Phosphate Availability

The P content in all soils and saprolites was very low, recording values < 1.5 mg kg-1, with basalt profile exhibiting the lowest P availability. The data of P-sorption index (Bache and Williams, 1971) showed that P-retention capacity of the profiles studied ranged from high (i.e. granite and schist profiles) to very high (i.e. basalt profile) (Burnham and Lopez, 1982). High Fe oxides (Table 3), particularly in amorphous form, were responsible for the sorption of phosphate in large amounts (Burnham and Lopez, 1982; Fox *et al.* 1971). The saprolites, however, demonstrated slightly lower P-sorption index values in comparison to their respective soil layers, and this can be attributed to lower degree of weathering and subsequently lesser Fe amount in the saprolites.

Saprolite Fertility Status

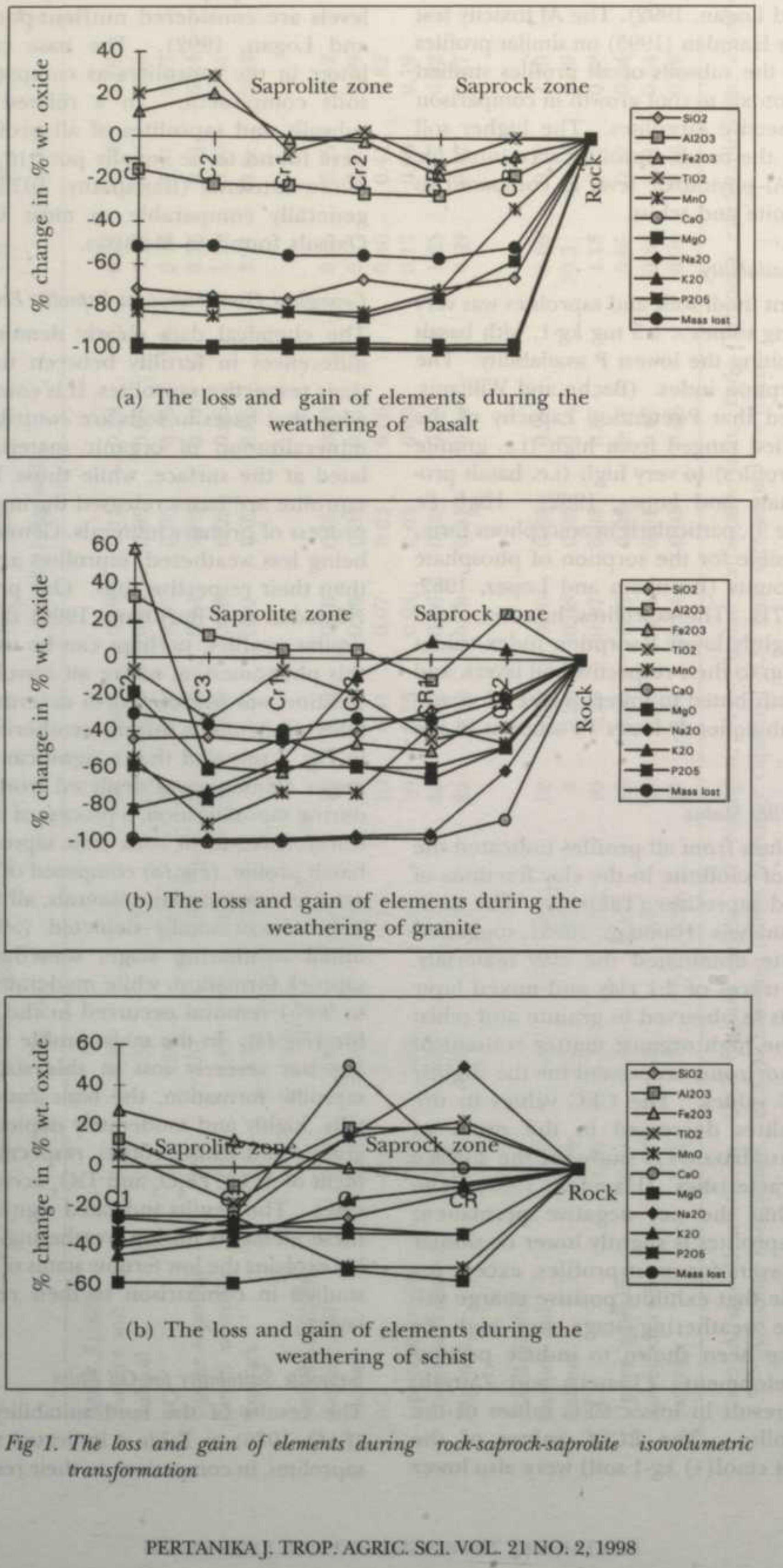
Low CEC values from all profiles indicated the dominance of kaolinite in the clay fractions of the soils and saprolites (Table 3). The x-ray diffraction analysis (Hamdan, 1995), suggested that kaolinite dominated the clay materials, with few or traces of 2:1 clay and mixed layer clay minerals as observed in granite and schist profiles. The high organic matter content of all surface horizons, accounted for the slightly higher CEC values. The CEC values in the three saprolites decreased in the order of granite>schist>basalt. A study on the surface charge characteristics (Hamdan, 1995) demonstrated that the net negative permanent charge of saprolites is slightly lower or similar to the soil layers for most profiles, except for basalt profile that exhibits positive charge values. Intense weathering stage and high Fe content have been shown to induce positive charge development (Tessens and Zauyah, 1982) that result in lower CEC values of the basalt saprolite. The ECEC values of the saprolite (<4 cmol(+) kg-1 soil) were also lower than their respective soil layers, and such levels are considered nutrient-poor (Sanchez and Logan, 1992). The base cations were lower in the saprolites as compared to their soils component. In a related study, the subsoils and saprolites of all profiles studied were found to be equally poor in macro- and micro-nutrients (Kanapathy, 1976), but were generally comparable to most Ultisols and Oxisols found in Malaysia.

Geological Contribution to Saprolite Fertility

The chemical data clearly demonstrated the differences in fertility between the soils and their respective saprolites. It is common knowledge that bases in soils are contributed by the mineralization of organic materials accumulated at the surface, while those bases in the saprolite are bases released during weathering process of primary minerals. Generally, despite being less weathered, saprolites are less fertile than their respective soils. Our previous study (Hamdan and Burnham, 1996) conducted on similar profiles, perhaps can be used to justify this phenomenon, where an isovolumetric calculation was performed to determine the mobility of elements during weathering. The data in *Fig. 1* revealed that a significant amount of major elements was depleted from the profile during saprolitization, a process of isovolumetric transformation of rock into saprolite. In the basalt profile, (*Fig.1a*) composed of easily weathered ferromagnesian minerals, all basic cations were almost totally depleted (>95%) at the initial weathering stage, sometimes cited as saprock formation, while moderate to high (55 to 90%) removal occurred in the granite profile (*Fig.1b*). In the schist profile (*Fig. 1c*), only Mg was severely lost at this stage. During saprolite formation, the basic cations were totally, highly and moderately depleted in basalt, granite and schist profiles, respectively. Enrichment of Al_2O_3, Fe_2O_3 and TiO_2 occurred in most cases. The results indicated significant loss of these elements during weathering. This possibly explains the low fertility status of all saprolites studied in comparison to their respective soil layers.

Saprolite Suitability for Oil Palm

The results of the land suitability assessment (FAO, 1976) in Table 4 indicated that exposed saprolites, in comparison to their respective soils,



(a) The loss and gain of elements during the weathering of basalt

(b) The loss and gain of elements during the weathering of granite

(b) The loss and gain of elements during the weathering of schist

Fig 1. The loss and gain of elements during rock-saprock-saprolite isovolumetric transformation

TABLE 4
Summary of upland soils and the corresponding saprolites with regards to their suitability for oil palm

Parent Material	Land unit	Suitability Class	
Basalt	Soil	Moderately suitable	(S2tf)
	saprolite	Unsuitable	(N1twsf)
Granite	Soil	Marginally suitable	(S3tsf)
	Saprolite	Unsuitable	(N1tsf)
Schist	Soil	Marginally suitable	(S3tsf)
	Saprolite	Unsuitable	(N1twsf)

(Adapted from the FAO, 1976)

Note: S2 = Moderately suitable, S3 = Marginally suitable, N1 = Unsuitable
S = limitation due to shallowness of rooting zones.
f = limitation due to low fertility status.
w = poor drainage, wetness of high water table is the dominant problem.
t = topography (slope)

were only marginally suitable or non-suitable for oil palm cultivation. The physical limitations were attributed to the absence of aggregatiốn, rock fragments, shallow rooting zone, and poor water availability. The absence of organic materials contributed to the lower fertility level of saprolites, while the contribution of nutrients from parent material weathering seemed insignificant (*Fig.1*).

CONCLUSION

The soils of the humid tropics have shown to be managerially problematic, particularly with regards to their fertility. Reviews on research works and crop yields on current plantations in Malaysia, Thailand and Indonesia, have significantly shown that such fertility constraint could be improved. Poor fertility of the saprolite, as shown in this study, is more complex, and could pose a serious limitation to crop production in the upland soil areas. Their physical properties and the potential problems related to these properties is a greater cause for concern. Unlike ordinary soil materials which can be amended and improved to suite crop requirements, saprolites on the other hand, are more difficult as they are not soil but classified as parent material. At even deeper zones, these materials are only partly weathered, composing of rock fragments and corestones. The root permeability, moisture availability, water drainage, compaction, crust formation and runoff are some of the potential problems of saprolites that limit crop productivity.

The management and improvement of saprolitic materials to suite utilization by crops would be an expensive and difficult task. Presently, concerned efforts are being made to manage acid Ultisols and Oxisols in the humid tropics which include even soils of the upland areas. Upon clearing and terracing of these soils, saprolite materials that we know little about, would surface. There are a few, if any, experimental works that deal directly on the properties, utilization, problems and management of such saprolites. This paper highlights the characteristics and potential problems of saprolites that may be faced upon their exposure. Eswaran and Wong (1978) noted that in such steep terraced areas where saprolites are exposed and utilized by crops, the characterization and interpretation of soil potential for agriculture based on soil formation becomes less meaningful. Our results showed that soils of such nature were moderately to marginally suitable but their respective saprolites were rated as unsuitable, with the fertility status, slope, poor drainage and shallowness of rooting zones as the limiting factors. In Malaysia, soils developed on basalt comprising good physical properties, which upon improvement of their fertility level, may be upgraded to class one for oil palm (Paramananthan and Lim, 1979). Future work on the amelioration of exposed saprolite materials to improve their sustainability for oil palm production is necessary.

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Variability in Eggplant (*Solanum melongena* L.) and Its Nearest Wild Species as Revealed by Polyacrylamide Gel Electrophoresis of Seed Protein

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Keywords: *Solanum melongena* L., SDS-PAGE, seed protein, variability

ABSTRAK

Satu kajian telah dilakukan untuk menentukan dan membezakan genotip-genotip terong (Solanum melongena L.) dan spesis-spesis liar terdekatnya dengan elektroforesis gel poliakrilamid natrium dodesilsulfat (SDS-PAGE) keatas protin biji boleh larut. Lima puloh empat aksesi kumpulan-kumpulan tanaman dan spesis liar terong telah digunakan untuk analisis. Hasil dari corak penjaluran elektroforetik menunjukan bahawa terdapat satu variasi yang besar diantara dan didalam kumpulan-kumpulan terong dari segi bilangan, saiz, kedudukan, keamatan warna dan hadir atau tak hadir jalur-jalur protin didalam profil, yang mana boleh digunakan untuk pencaman dan pencirian kultivar-kultivar terong. Kultivar terong jenis buah panjang telah menunjukkan banyak jalur-jalur khusus-sepunya yang memisahkanya dari kumpulan-kumpulan lain. Manakala, satu kevariabelan besar profil protin biji terdapat didalam kultivar-kultivar jenis buah bulat dan primitif dan kumpulan-kumpulan rumpai dan liar terong, termasuk yang paling liar dari S. incanum, yang menunjukan bahawa kumpulan-kumpulan ini mengandungi pelbagai genotip yang berbeza.

ABSTRACT

A study was undertaken to determine and distinguish the genotypes of eggplant (Solanum melongena L.) and its nearest wild species by sodium dodecylsulphate polyacrylamide gel electrophoresis (SDS-PAGE) of soluble seed proteins. Fifty-four accessions of cultivated and wild groups of eggplant were subjected to the analysis. The results of electrophoretic banding patterns show that there was a great deal of variation within and between groups of eggplant in terms of numbers, sizes, positions, staining intensities and presence or absence of protein bands in the profile, which can be used for characterization and identification of eggplant cultivars. Elongated fruit eggplant cultivars exhibited nine common group-specific bands which distinguish them from the other groups. Meanwhile, a great variability in seed protein profiles was detected in the round fruit type and primitive cultivars, weedy and wild groups of eggplant including the truly wild S. incanum, which indicated that these groups consist of diverse genotypes.

INTRODUCTION

Solanum melongena L. (eggplant) has a wide range of morphological diversity ranging from wild and weedy to semi- or fully-cultivated forms. Many characters are overlapping from one group to another group, which makes it difficult to distinguish between and within groups (Lester and Hasan 1991; Karihaloo and Rai 1995). Horticulturally, it is important to be able to recognize and distinguish the different genotypes and, in particular, different cultivars of this species because the cultivars often differ in their fruit quality and other important agronomic characters which are obscure and difficult to detect.

Morphological and physiological characters have traditionally been used for the identification of eggplant cultivars (Brezhnev 1958). Many of these characters, particularly leaf and stem pigmentation and fruit size, shape and colour, which are often important in the definition of an eggplant cultivar, can be discerned only in adult plants. Thus, it is necessary to grow out plants, which is very laborious and time-consuming. Furthermore, the phenotypic characters are strongly influenced by climatic factors and soil conditions, and their use may lead to unreliable or erroneous determinations.

These problems can be avoided by using seed storage protein electrophoresis because protein banding patterns produced through this technique are generally unaffected by external factors and the genotype of each cultivar can be rapidly determined. The seed storage proteins are also known to be highly polymorphic with respect to their size and charge in almost all species investigated (Cooke 1984). Hence, they provide sufficient variability in protein composition to detect differences between genotypes. Furthermore, the seed protein profiles are known for their stability, uniformity and additive nature (Smith 1976). For these reasons, SDS-PAGE of seed proteins is used as a method for cultivar identification in many cultivated species (Sathaiah and Reddy 1985; Gupta and Robbelen 1986; Gardiner and Forde 1988; Huaman and Stegemann 1989; Rao *et al* 1990; Stegemann *et. al* 1992; Yupsanis *et. al* 1992; Wang *et. al* 1994). However, this method has not been widely used for the identification of cultivars and varieties of many vegetables, particularly the eggplant.

To date, seed protein SDS-PAGE of *S. melongena* had been conducted as part of a taxonomic study of the genus *Solanum* (Edmonds and Glidewell 1977; Pearce and Lester 1979) but there was no serious attempt to determine differences between cultivars of eggplant on the basis of protein profiles. The objectives of this study were to determine seed protein banding patterns for 54 accessions of eggplants and to ascertain the level of protein variation present in the species as well as to determine the possibility of using SDS-PAGE of seed proteins for cultivar identification and characterization in eggplants.

MATERIAL AND METHODS

Seed Materials

The seeds of 54 accessions of eggplant complex representing a range of geographical origins and morphological varieties were used (Table 1). They were grouped as i) most advanced cultivars with elongated large fruit (fruit length three times width), ii) advanced cultivars with round fruit (fruit either round, obovate or pear-shape) with diameter greater than 5 cm, iii) primitive cultivars with small fruit (less than 5 cm diameter), iv) prickly plant of weedy (*S. cumingii* Dun.) or wild (*S. insanum* L.) groups and v) the truly wild relative of *S. incanum* L. group (Lester and Hasan 1990).

Preparation of Seed Flour

Dry seeds (0.5 g) were dehulled using a micro Feinmuhle-Culatti sample mill, followed by separation through a Hearson's blower to obtain clean seeds. The seeds were ground in a micro disembrator for 10 - 15 min to produce very fine seed flour, which was then defatted in five changes of diethyl ether and allowed to dry on filter paper.

Protein Extraction

Soluble proteins were extracted by soaking 0.05 g of defatted protein flour in 0.5 ml H_2O in a centrifuge vial. The suspension was centrifuged and 100 µl of protein solution (supernatant) was incubated with 100 µl Tris-HCl buffer (pH = 6.8) consisting of 20% glycerol and 5 mM mercaptoethanol. 0.1 ml of bromophenol blue (W/V) was added into the samples as a tracking dye in order to mark the moving protein front.

Gel Preparation

The crude protein was fractionated by the method of SDS-discontinuous polyacrylamide slab gel electrophoresis (SDS-PAGE) in a vertical format in a Studier-type slab gel apparatus. The separations were performed on 2.5% stacking gel and 12.5% separation gel consisting of 10% sodium dodecyl sulphate (SDS) and Tris-HCl at pH of 6.8 and 8.8 respectively. Fifteen wells were made in the stacking gel by inserting a comb into the gel before polymerization. Ammonium persulphate (10%) was used to initiate the polymerization and N,N,N'N' tetramethylethylenediamine (TEMED) was used as a catalyst (Hames and Rickwood 1986).

Electrophoresis

The 20-µl sample solution of each accession was loaded in the well. Sample solutions of two

TABLE 1
Accessions of Solanum melongena and its nearest wild species used in the study arranged according to their cultivar groups and electrophoresis run of different gels

Cultivar/group name; Run/gel no.	Electrophoresis lane no.	Accession no. (UPM/B...)	Country of origin
Elongated large fruit;			
Run 1:	1	047	Malaysia
	2	200	Philippines
	3	203	"
	4	080	Indonesia
	5	206	Philippines
	6	204	"
	7	082	Malaysia
	8	077	Thailand
	9	161	Malaysia
	10	068	Thailand
	11	014	Malaysia
	12	026	"
	13	007	"
	14	090	"
	15	066	"
Round or obovate large fruit;			
Run 2:	1	017	Malaysia
	2	131	"
	3	028	"
	4	079	Italy
	5	137	Malaysia
	6*	203	Philippines
	7*	026	Malaysia
	8	202	Phillipines
	9	067	Malaysia
	10	071	France
	11	163	France
	12	184	"
	13	198	Phillippines
	14	181	Malaysia
	15	188	Phillippines
Round or obovate large fruit;			
Run 3:	1	214	Phillippines
	2	176	Italy
	3	081	France
	4	073	Spain
	5	178	Italy
	6	083	France
	7	082	Malaysia
	8	161	"
	9	154	Italy
	10	149	Greece
	11	157	Italy
	12	190	"
	13	151	Taiwan
	14	075	"
	15	089	Malaysia

Continued Table 1

Cultivar/group name; Run/gel no.	Electrophoresis lane no.	Accession no. (UPM/B...)	Country of origin
Elongated large fruit;			
Run 4:	8*	082	Malaysia
	9*	161	"
Primitive cultivar;			
Run 4:	1	005	"
	2	023	"
	6	027	"
	7	029	"
Wild/weedy form;			
Run 4:	10	111	"
	11	121	India
	12	311	Thailand
	13	313	"
	14	326	Malaysia
	15	347	Indonesia
Solanum incanum L.			
Run 4:	3	307	Saudi Arabia
	4	295	Kenya
	5	301	India

* = lane with elongated fruit cultivar used as the reference samples

accessions of elongated fruit cultivars chosen as reference proteins were loaded in two wells of standard samples of each gel for comparison and reproducibility checking of the system. The electrophoresis was carried out at about 5^{0}C with a constant current of 30 mA for 5 h. The gels were stained and fixed for 1 h in a solution containing 0.25% brilliant blue R (W/V), 40% methanol and 7% acetic acid, and then gently agitated in destaining solution containing 30% methanol and 10% acetic acid. The resultant protein profiles in the gel were then recorded photographically and stored in 7% acetic acid in the dark. Duplicate electrophoresis runs were performed for each sample.

Analysis of Electrophoregrams

Each electrophoresis run was analysed separately. Comparisons of the protein banding patterns were made between accessions within each gel. The protein bands were examined and assessed visually and identified according to their number, position, size, staining intensity and the presence or absence of the bands in the profile. Bands which were very clear, thick and densely stained were considered as major bands whereas those that were very thin and weakly stained were considered as minor bands. An identification letter was given to each of the major bands.

RESULTS

The electrophoretic banding pattern of SDS-PAGE of seed proteins of eggplant (*S. melongena* L.) and its nearest wild taxa representing diverse morphological groups and geographical origins are depicted in Plates 1-4 and *Fig. 1.* The banding patterns revealed variations in the numbers, positions, width, staining intensities and the presence or absence of bands among different accessions and groups such that each accession or group exhibited a unique banding pattern. The zymograms showed that eggplants have five common major protein bands (a, f, g, h and i). The banding patterns can be divided into 3 regions: region I with one broad strongly staining protein band (band a) moving at the same rate in all accessions; region II with 6 - 11 protein bands (bands b, c, d, e, f, g, and ai, ci, di, ei and fi) of which two bands (f and g) are fast moving at the anodal end and region III consisting of two very broad strongly stained bands (h and i) present in all accessions. Differences in the protein profiles are described below.

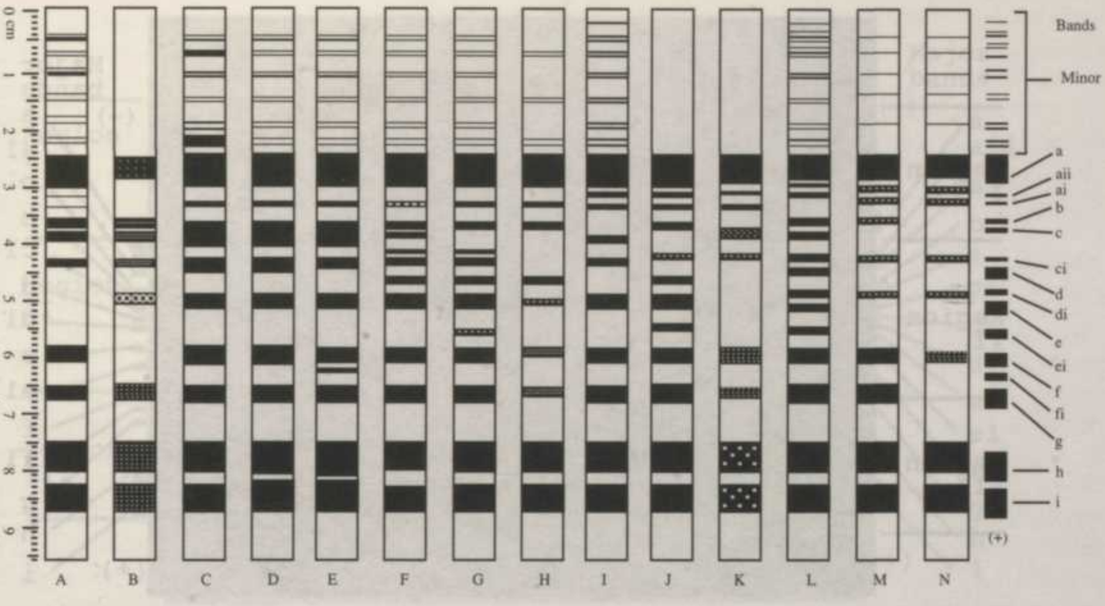

Fig 1. Diagramatic illustration of seed protein banding patterns found in Solanum melongena L. cultivar and its nearest wild species groups. A, elongated fruit cultivar; B – H, round or obovate fruit cultivar; I, primitive cultivar; J- L, wild or weedy (S. insanum) group; M and N, S. incanum group.

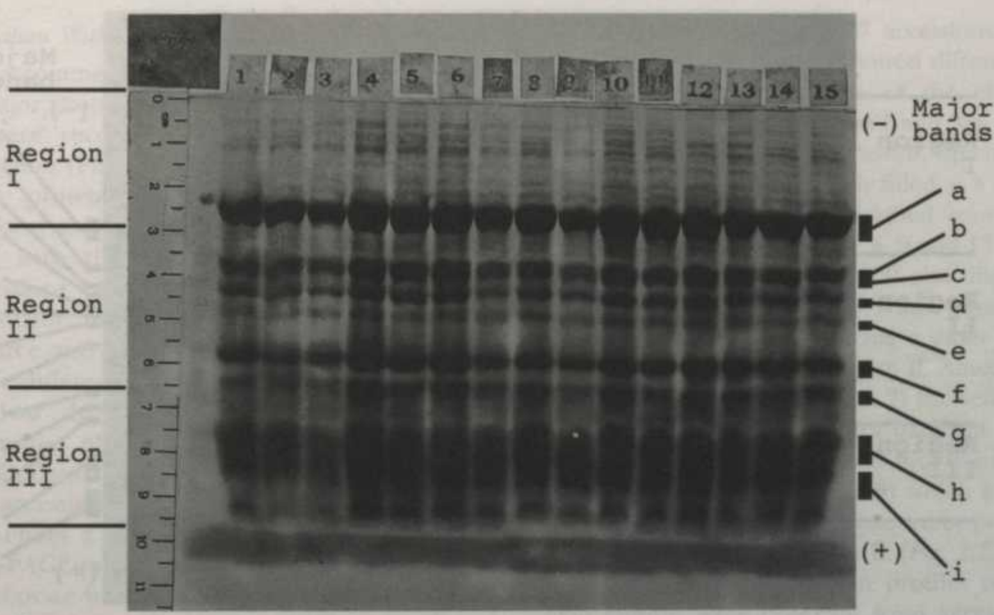

Plate 1. Seed protein banding patterns of elongated fruit cultivars of eggplant (Solanum melongena L.) grown in Southeast Asia. Each lane represents a different accession.

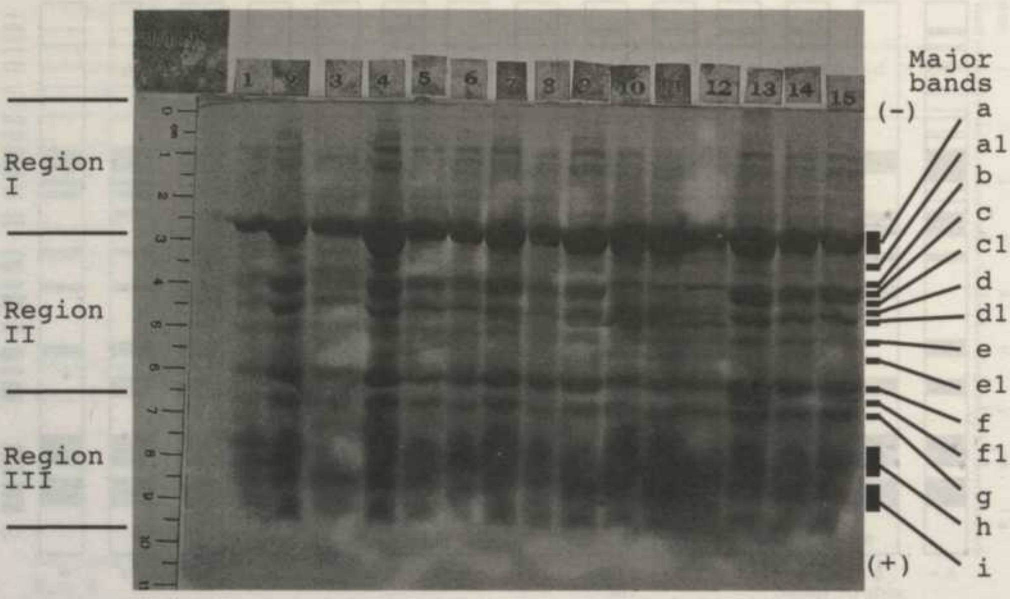

Plate 2. Seed protein banding patterns of typical round fruit cultivars of eggplant (Solanum melongena L.). Each lane represents a different accession. 1 - 3, 5, 8, 9, 13 - 15 = Southeast Asian accessions; 4, 10-12 = Meditterranean accessions; 6 and 7 = accessions of elongated fruit cultivar as references.

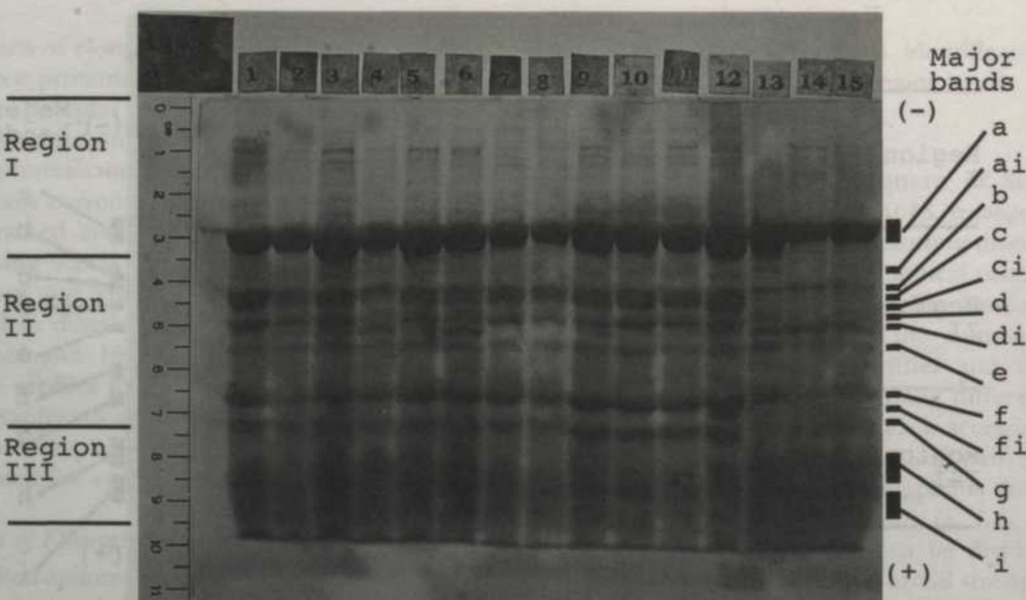

Plate 3. Seed protein banding patterns of round fruit cultivars (pear-shaped or obovate fruit types) of eggplant (Solanum melongena L.). Each lane represents a different accession. 1, 13 - 15 = Southeast Asian accessions; 2 - 6, 9 - 12 = Meditterranean accessions; 7 and 8 = accessions of elongated fruit cultivar as references.

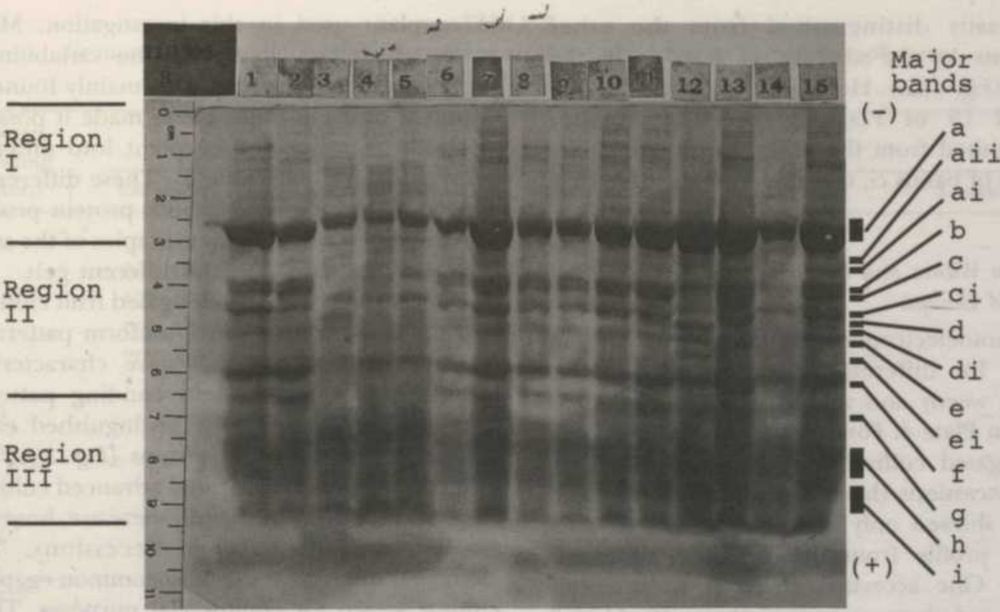

Plate 4. Seed protein banding patterns of a range of eggplant (Solanum melongena L.) groups found in Southeast Asia. Each lane represents a different accession. 1, 2, 6 and 7 = primitive cultivar; 10 - 15 = wild or weedy forms; 3 - 5 = S.incanum L.; 8 and 9 = accessions of elongated fruit cultivar as references.

Variation Within and Between Advanced Cultivars.

For a commercial elongated large fruit cultivar, 9 major protein bands (a, b, c, d, e, f, g, h and i) were recognized in the profiles of each accession (Plate 1 and *Fig. 1(A)*). The pattern of these protein bands was highly constant and uniform among accessions. This result agrees well with the earlier findings that diverse accessions of cultivated eggplant still possess essentially the same major seed protein profiles (Pearce and Lester 1979). Although there are some differences between accessions within this cultivar due to variations in the staining intensities of minor bands in region I of the profiles, such differences were unable to separate the accessions into distinct groups.

Plates 2 and 3 illustrate the characteristic SDS-PAGE protein banding pattern in the round or obovate fruit cultivar group. A wide range of variation in seed protein profiles was found between the accessions of this group. A few accessions, as indicated in lanes 5, 8, 14 and 15 (Plate 2) and lanes 10 and 11 (Plate 3), showed a similar protein banding pattern with accessions of an elongated fruit cultivar in lanes 6 and 7 (Plate 2) and in lanes 7 and 8 (Plate 3) (*Fig. 1(A)*).

There are, however, 20 accessions of the round fruit cultivar which showed differences in protein profiles from those of the elongated cultivar. Two accessions (lanes 1 and 3 of Plate 2) produced very weak staining bands, which may be because the seeds were poorly filled as a result of the hybrid origin of the original source (*Fig. 1(B)*). Six accessions (lanes 2, 4, 9 and 13 of Plate 2 and lanes 1 and 12 of Plate 3) also displayed a different profile (*Fig. 1(D)*) from those of an elongated cultivar by producing a wider band at positions ai, b, c and d in region II. Among these accessions, one (lane 4 of Plate 2) showed densely stained bands with clear minor bands in region I of the profile (*Fig. 1(C)*), and two (lane 13 of Plate 2 and lane 12 of Plate 3) which exhibited a distinctive protein banding pattern by producing an extra band (fi) in region II (*Fig. 1(E)*).

Further, distinct protein profiles of round fruit cultivar were observed from accessions in lanes 2 - 6 and 9 of Plate 3. They were clearly differentiated from the other accessions by the presence of bands ci and di in region II of the profile (*Fig. 1(F)*).

Furthermore, the accessions in lanes 10 - 12 of Plate 2 and lanes 13 - 15 of Plate 3 gave an extremely distinct protein banding pattern. They were easily distinguished from the other accessions by the absence of band c in the profile (*Fig. 1(G)*). However, accessions in lanes 14 and 15 of Plate 3 could be further distinguished from the other accessions by the absence of bands ci, d and ei in the profile (*Fig. 1 (H)*).

Variation Within and Between Primitive Cultivars and Wild Groups.

The photoelectrophoregram of seed protein profiles for different accessions of primitive cultivar, weedy and wild groups of eggplant is shown in Plate 4. For comparison, control lines of elongated cultivar were in lanes 8 and 9. Three accessions (lanes 1, 2 and 6) of primitive cultivar showed only slight differences in seed protein profile from those of the elongated cultivar. One accession (lane 7) of primitive cultivar and three accessions (lanes 10, 11 and 13) of the weedy group shared a similar protein banding pattern (*Fig. 1(I)*) but showed some differences from those of the elongated cultivar by producing densely stained bands and the presence of bands ai and aii in the profiles.

One accession (lane 14) of weedy group (Plate 4)) showed a clear difference in protein profile from those of the elongated cultivar by the absence of bands c, d and e in the profile (*Fig. 1(K)*). One accession in lane 12 of the same group also showed the differences by the absence of bands c and d and the presence of bands ci, di and ei in the profile (*Fig. 1(J)*). Another accession of the weedy group (lane 15) also exhibited a specific protein banding pattern distinct from the other groups by producing bands in all position with thick and densely stained bands, particularly in region I of the profile (*Fig. 1(L)*).

The truly wild *S. incanum* (lanes 3 - 5) was clearly differentiated from the other groups by the absence of bands c, d and e and the presence of bands aii, ai, ci and di in the profile (*Fig. 1(M)*). The accession in lane 3 is even more distinct from the other accessions by the absence of bands b and g in the profile (*Fig. 1(N)*).

DISCUSSION

The overall differential banding patterns of seed proteins revealed both qualitative and quantitative variations between and within the groups of eggplant. There are 14 protein banding patterns (*Fig. 1*) characterizing the different types of eggplant used in this investigation. Major bands which contributed to the variability of protein banding patterns were mainly found in region II of the profile. These made it possible to divide genotypes of eggplant into different cultivars or groups (Table 2). These differences appear reproducible, as similar protein profiles were obtained when further samples of the same accessions were analysed in different gels.

It is evident that the elongated fruit cultivars had the most constant and uniform pattern of major protein bands that gave characteristic group-specific seed protein banding patterns, thus enabling them to be distinguished easily from those of the other groups (*Fig. 1(A)* and Table 2). Although elongated advanced cultivars have many of the same bands, there are, however, small variations between accessions. The elongated fruit type is the most common eggplant cultivar grown for commercial purposes. Thus, they may have a common parent in their pedigrees which could explain the similarity of their electrophoregrams. It is common for the agricultural cultivar seed protein banding pattern to be very stable during commercial seed production, but the pattern may alter slightly when an accession is multiplied, particularly if it is regenerated from a very small sample size (Gardiner and Forde 1987).

The other groups of eggplant did not show a strong common protein banding pattern, but displayed a great deal of variation at the groups level (*Fig. 1(B-N)*). Great variability in seed protein profiles was detected in the round fruit cultivar indicating that the cultivar actually consists of different genotypes. This high variability is not surprising because round fruit cultivar is an outbred heterogeneous population whose accessions were mostly obtained from small isolated populations in diverse agro-ecosystems.

Primitive cultivar also showed variable seed protein banding patterns between different accessions, and the protein banding pattern of the weedy group, including the truly wild *S. incanum*, was even more variable. The substantial differences in the protein profiles within these populations are mainly due to the outbreeding nature of these taxa (Karihaloo and Rai 1995).

The majority of the accessions used in this investigation could be readily distinguished by their soluble seed protein banding patterns. Although in a few cases the weedy accessions showed similar major protein compositions to

TABLE 2
Groups or cultivars of eggplant accessions arranged according to their electrophoresis seed protein banding patterns obtained from this study

Protein banding pattern	Cultivars or groups				
	Elongated fruit	Round fruit	primitive	Wild/weedy	*S. incanum*
A	007, 014, 026, 047, 066, 068, 077, 080, 082, 090, 161, 200, 203, 204, 206,	137, 149, 157 181, 188, 202	005, 023, 027	–	–
B	–	017, 028	–	–	–
C	–	079	–	–	–
D	–	067, 131, 124	–	–	–
E	–	190, 198	–	–	–
F	–	073, 081, 083 154, 176, 178	–	–	–
G	–	067, 071, 151, 163, 184	–	–	–
H	–	075, 089	–	–	–
I	–	–	029	111, 121, 313	–
J	–	–	–	311	–
K	–	–	–	326	–
L	–	–	–	347	–
M	–	–	–	–	295, 301
N	–	–	–	–	307

the accessions of the cultivated group, there are strong differences in the patterns of the minor bands found in the profiles of those accessions. It could be postulated that the weedy group was derived from cultivated eggplant from which it has since been isolated as a feral taxon. Another possibility is that both cultivated and wild taxa developed from a common ancestor (Lester and Hasan 1991; Karihaloo and Rai 1995).

CONCLUSION

The results of this study demonstrate that the SDS-PAGE seed protein banding patterns are reproducible and differ from one accession to another. Therefore the profiles serve as genotype fingerprints for eggplant cultivars and can be used for identification, breeding or patent purposes. This method could be used to construct an atlas of the seed protein profiles of the eggplant group for reference. Furthermore, profiles of important groups could be filed as one crop descriptor. With a substantial variation in seed protein composition in eggplant, it is possible to use the SDS-PAGE technique to identify eggplant cultivars within a couple of hours without the necessity of growing out the plants. The SDS-PAGE pattern of bulk seed extracts could also form a much-needed adjunct to the present system of classifying the eggplant complex and at least partially resolve the various groups which complicate the species.

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Influence of Crop Density and Weeding Frequency on Crop Growth and Grain Yield in Wheat

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ABSTRAK

Influence of seed rates at 100, 125, 150, and 175 kg/ha and four weeding frequencies W_0 *(no weeding),* W_1 *(weeding after 20 days of sowing),* W_2 *(weeding after 20 and 40 days of sowing) and* W_3 *(weeding after 20, 40 and 60 days of sowing) on growth and yield of wheat were studied. The major weeds species were Chenopodium album L., Cynodon dactylon (L) Pers, Dactyloctenium aegyptium L. and Vicia sativa L. The highest grain yield per hectare, panicle length, and filled grains/panicle were obtained with the seeding rate of 125 kg/ha. The lowest grain yield (3.11 t/ha) with minimum effective tillers/plant, panicle length and filled grains/panicle were produced by the highest seed rate (175 kg/ha). The plant population per meter square was significantly influenced by seed rates. Weeding at 20 and 40 days after sowing* (W_2) *gave the highest grain and straw yields along with highest effective tillers/plant, panicle length, and filled grains/panicle. On the other hand no weeding treatment gave the lowest grain and straw yields, effective tillers/plant, panicle length and filled grains/panicle. The critical period of weed competition was between 20 and 40 days after sowing. High seed rate with three times weeding* (W_3) *decreased weed dry weight/*m^2 *significantly.*

ABSTRACT

Influence of seed rates at 100, 125, 150 and 175 kg/ha and four weeding frequencies W_0 *(no weeding),* W_1 *(weeding after 20 days of sowing),* W_2 *(weeding after 20 and 40 days of sowing) and* W_3 *(weeding after 20, 40 and 60 days of sowing) on growth and yield of wheat were studied. The major weeds species were Chenopodium album L., Cynodon dactylon (L) Pers, Dactyloctenium aegyptium L. and Vicia sativa L. The highest grain yield per hectare, panicle length, and filled grains/panicle were obtained with the seeding rate of 125 kg/ha. The lowest grain yield (3.11 t/ha) with minimum effective tillers/plant, panicle length and filled grains/panicle were produced by the highest seed rate (175 kg/ha). The plant population per meter square was significantly influenced by seed rates. Weeding at 20 and 40 days after sowing* (W_2) *gave the highest grain and straw yields along with highest effective tillers/plant, panicle length, and filled grains/panicle. On the other hand no weeding treatment gave the lowest grain and straw yields, effective tillers/plant, panicle length and filled grains/panicle. The critical period of weed competition was between 20 and 40 days after sowing. High seed rate with three times weeding* (W_3) *decreased weed dry weight/*m^2 *significantly.*

INTRODUCTION

Wheat (*Triticum aestivum*) stands first in regard to hectareage and production among the cereal crops of the world. In Bangladesh, wheat is second in importance as cereal crops next to rice. In 1989-90 an area cultivated was 592,000 hectares which produced 890,000 tons of wheat, with an average yield of 1.50 t/ha (Anonymous, 1991). During the last decade considerable efforts were made to increase the production of wheat in order to minimize food shortage in Bangladesh. Introduction of high yielding varieties and cultural practices like optimum fertilization, proper water management and weed control measures were the major efforts.

Weeds became a serious problem with the introduction of high yielding dwarf varieties of wheat and factors like plant population per unit area, fertilization and irrigation are considered essential for achieving high yields. Besides causing considerable reduction in yield, weeds deplete soil fertility, particularly nitrogen within 4 to 6 weeks of crop sowing (Gautem and Singh, 1981). Higher than recommended seed rate, within limits, may provide some degree of weed control in cereal crops (Dewling, 1984). Increasing plant populations per unit area increase competitiveness of plants with consequent reduction in weed growth. This practice may easily be adopted by farmers with a view to reducing weed infestation. Critical period of weed competition is the range within which a crop must be weeded to save the crop from ravages of weeds. It was observed that a weed free period of 30 days from sowing was sufficient to prevent crop loss due to weed competition in a wheat crop (Rahman *et al.* 1990). However, information on systematic approach to determine the time and frequency of weeding required for obtaining maximum yield of wheat is limited.

The objective of the study was to determine the optimum seed rate and time of weeding on the nature and degree of weed infestation, critical period of weed competition and performance of wheat.

MATERIALS AND METHODS

The experiment was conducted at the Bangladesh Agricultural University Farm, Mymensingh, Bangladesh. The trial site was the old Brahmaputra Floodplain region (UNDP/FAO, 1988) consisting of non-calcareous dark grey floodplain soil of silt loam texture. The soil contains about 1.9 % organic matter. The soil pH ranged from 5.6 to 7.4 (BARC, 1989).

The study consisted of two sets of treatments, which were the seeding rates and weeding frequencies. The seeding rates were 100 kg/ha (S_1), 125 kg/ha (S_2), 150 kg/ha (S_3) and 175 kg/ha (S_4). The weeding frequencies were no weeding (W_0), weeding at 20 days after sowing (DAS) (W_1), weeding at 20 and 40 DAS (W_2) and weeding at 20, 40 and 60 DAS (W_3).

The experiment was laid out in a split-plot design with three replications. Seed rates were main plot treatments and weeding frequencies were sub-plots. The unit plot size was 4m 3 2.5m (10 m^2). The land was prepared by harrowing followed by laddering. The land was uniformly fertilized with 80 kg N, 62 kg P_2O_5 and 45 kg K_2O/ha using urea, triple super phosphate and muriate of potash, respectively. The entire quantity of triple super phosphate and muriate of potash and one-third of urea were applied at the time of final land preparation. The remaining two thirds of the urea was top dressed in two equal splits at crown root formation stage (24 days after sowing) and lag vegetative phase (54 days after sowing). Seeds of wheat cultivar Kanchon were sown by hand at 25 cm spacing in 6 cm deep furrows. The crop was irrigated twice, 25 and 55 days after sowing following urea top dressings. There was no major infestation of insect pests and diseases and no plant protection measure was needed.

Effective tillers per plant, plant height, panicle length and filled grains per panicle were recorded from 10 randomly selected sample plants from each sub-plot. On the following day after sampling, the mature crop was harvested plot-wise. The harvested crop was cleaned, threshed and sun-dried. The weed species within quadrates were identified, cleaned and dried for 72 hours at 70°C. Grain and straw yields were recorded and expressed in ton per hectare (at 14% moisture). The plant population in each treatment was recorded using 1 m^2 quadrat.

The data were analyzed statistically and mean differences adjudged by Duncan New Multiple Range Test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The predominant weed species was *Chenopo-dium album* which constituted about 44.6 per cent of the total weed vegetation with a population density of 166.77 plants per square meter and an intensity of 3.21. *Cynodon dactylon, Dactyloctenium aegyptium* and *Vicia sativa* constituted about 14.2, 11.94 and 8.91% of total weed vegetation with intensities of 1.02, 0.86 and 0.64, respectively. Degree of infestation by the weed species *Amaranthus viridis, Cyperus rotundus, Digitaria sanguinalis,* and *Polygonum hydropiper* were 7.42, 6.29, 3.09, 2.19 and 1.34% of weed vegetation with intensities of 0.54, 0.45, 0.22, 0.16 and 0.09, respectively. On the average 7.19 weeds competed against one wheat plant, of which 3.21 belonged to the family Chenopodiaceae, 2.10 to the family Gramineae and the remaining 1.88 to others (Table 1).

Weed Dry Weight

The weed dry weights recorded were comparable in all the weeding treatments at 20 days after sowing. Weed dry weight increased up to 60 days of sowing (Table 2a). The results also indicate that there was active resurgence of weed infestations over the crop growing period (Table 2a). Seed rate had no significant effect in the weed dry weight per m² but there was a decreasing trend in weed dry weight with increasing seed rate (Table 2b). This is possibly as a result of higher plant population discouraged the growth of weed because of intra-crop competition. The dry weight of the weeds per m² was influenced by weeding treatments and responses were found to differ significantly. The maximum weed dry weight was recorded with the no weeding treat-

TABLE 1
Weeds in wheat and their intensity of infestation

Scientific Name	Weed population/m²	Total weed vegetation (%)	Intensity of weed Infestation (no.)
Chenopodium album L.	166.77	44.60	3.21
Cynodon dactylon (L) Pers	53.11	14.20	1.02
Dactyloctenium aegyptium L.	44.66	11.94	0.86
Vicia sativa	33.33	8.91	0.64
Amaranthus viridis L	27.77	7.42	0.54
Cyperus rotundus	23.55	6.29	0.45
Digitaria sanguinalis	11.55	3.09	0.22
Polygonum hydropiper	8.22	2.19	0.16
Others	5.00	1.34	0.09
Total	373.96		7.19

TABLE 2(a)
Weed dry matter production at different stages of crop growth (g/m²)

Treatments	20 DAS	40 DAS	60 DAS	At harvest
W_0 (No weeding)	-	-	-	79.25
W_1 (Weeding at 20 DAS)	10.43	-	-	33.83
W_2 (Weeding at 20+40 DAS)	11.33	20.51	-	23.65
W_3 (Weeding at 20+40+60 DAS)	10.11	21.53	30.55	19.68

TABLE 2(b)
Effect of seed rates and weeding treatments on weed dry weight at harvest (g/m²)

Seed rate (S)	Weed (g/m²)
S_1 (100 kg/ha)	44.68a
S_2 (125 kg/ha)	38.52a
S_3 (150 kg/ha)	37.29a
S_4 (175 kg/ha)	35.29a
Weeding (W)	
W_0 (No weeding)	79.25a
W_1 (Weeding at 20 DAS)	33.83b
W_2 (Weeding at 20+40 DAS)	23.65c
W_3 (Weeding at 20+40+60 DAS)	19.68c

Means within column bearing same letters are not significantly different.

ment up to harvest i.e. W_0 (79.25 g/m^2) which was followed by W_1 (33.83 g/m^2). The lowest weed dry weight was observed in treatments W_2 and W_3. These treatments were not significantly different (Table 2b).

Plant (Wheat) Population

Seed rates significantly influenced the plant population per unit area. The highest plant population (66.75 plant/m^2) was found in plots with highest seed rate (175 kg/ha) followed by 150 kg/ha seed rate (61.75 plant/m^2). The lowest plant population (50.83 plant/m^2) was observed in treatment S_1 (100 kg/ha). Weeding at different times had no significant influence on the wheat population per unit area (Table 4).

Number of Effective Tillers per Plant

Seed rate significantly influenced the number of effective tillers/plant. The highest number of effective tillers (4.32 and 4.19) was produced by treatments S_2 (125 kg/ha) and S_1 (100 kg/ha), respectively. The minimum number of effective tillers (3.23) was produced in highest seed rate i.e. S_4. The lower number of effective tillers in higher seed rates (150 and 175 kg/ha) might be due to competition for space and stress from nutrients or moisture condition of the soil. The number of effective tillers/plant recorded with weed control treatments W_0, W_1, W_2 and W_3 were 3.56, 3.72, 4.26 and 4.15, respectively. There were no significant differences between W_2 and W_3. Previous reports are in agreement with the present finding (Alam, 1992).

Plant Height (Wheat)

Seed rates of S_1, S_2, S_3 and S_4 produced plants with heights of 92.6, 93.08, 93.64 and 93.71 cm, respectively, which did not differ significantly (Table 3). Weeding treatments also did not influence plant heights (Table 4).

Panicle Length (Wheat)

Length of the panicle was found to be the highest at the seed rate of 125 kg/ha (9.52 cm) and 100 kg/ha (9.39 cm). Reported results (Gaffer and Shahidullah, 1985) are in partial agreement with the present finding. The longest panicle length was produced by treatment W_2 (9.55 cm) and W_3 (9.43 cm) i.e. where weeding was done at 20, 40 and 60 days after sowing (Table 4). The shortest panicle 8.79 cm was produced in the no weeding treatment (W_0).

Number of Filled Grain per Panicle

It was observed that seed rate of 125 kg/ha (S_2) produced maximum number of filled grains/panicle (33.02), which was similar with S_1 (100kg/ha) and S_3 (150kg/ha) treatments (Table 3). The lowest number of filled grains/panicle (29.69) was obtained at the seed rate 175 Kg/ha (S_4). The lowest number of filled grains/panicle (28.82) was produced in the unweeded plots which was significantly different from other weeding treatments. It was also reported that weeding of wheat crops up to 42 days after emergence showed a tendency towards a higher number of filled grains/panicle (Alam, 1992).

TABLE 3
Effect of seed rate on crop growth and yield

Treatments	Plant population /m^2	Effective tillers/plant	Plant height (cm)	Panicle length (cm)	Filled grains/ panicle	Grain yield (t/ha)	Straw yield (t/ha)
S_1 (100 kg/ha)	50.83b	4.19a	92.60a	9.39ab	32.95a	3.19bc	4.10a
S_2 (125 kg/ha)	58.17ab	4.32a	93.08a	9.53a	33.02a	3.63a	4.35a
S_3 (150 kg/ha)	61.75a	3.95b	93.64a	8.98b	31.89a	3.44ab	4.47a
S_4 (175 kg/ha)	66.75a	3.23c	93.71a	8.97b	29.69b	3.11c	4.42a

Means within columns bearing same letters are not significantly different.

TABLE 4
Effect of weeding treatments on crop growth and yield

Treatments	Plant population /m²	Effective tillers/plant	Plant height (cm)	Panicle length (cm)	Filled grains/ panicle	Grain yield (t/ha)	Straw yield (t/ha)
W_0 (No weeding)	56.67a	3.56c	92.21a	8.79c	28.82c	3.10c	3.60c
W_1 (Weeding at 20 DAS)	58.33a	3.72bc	92.93a	9.09b	31.16b	3.30b	4.06b
W_2 (Weeding at 20+40 DAS)	60.75a	4.26a	93.08a	9.55a	34.18a	3.51a	4.95a
W_3 (Weeding at 20+40+60 DAS)	61.75a	4.15a	94.81a	9.43a	33.40a	3.46a	4.74a

Means within columns bearing same letters are not significantly different.

Grain Yield

The highest grain yield (3.63 t/ha) was obtained from the treatment S_2 (125 kg/ha). There was no significant variation in grain yield with seeding rates of 125-150 kg/ha (Table 3). The lowest grain yield (3.11 t/ha) was produced by the highest seeding rate (175 kg/ha) likely due to over population causing high competition for space, sunshine, moisture and plant nutrients. Weeding at 20 and 40 days after sowing produced highest grain yield (3.51 t/ha) which was not significantly different from weeding at 20, 40 and 60 days after sowing (3.46 t/ha) (Table 4). The lowest grain yield (3.10 t/ha) was obtained from the treatment with no weeding (W_0). This study shows that the grain yields increase when weeding was done at 20 and 40 days after sowing. Weed infestations before and after this critical period will not cause yield loss. According to some researchers grain yield reduction in cereals due to weed competition was associated with reduced crop vigour, tillering, filled grains per panicle and the individual grain weight (Gupta and Lamba, 1978). The highest grain yield (3.97 t/ha) was obtained in treatment S_2W_2 i.e. a combination of 125 kg seed/ha and weeding at 20 and 40 days after sowing which was followed by S_2W_1 (3.8 t/ha), S_2W_3 (3.77 t/ha) and S_3W_3 (3.70 t/ha). The treatment combination of S_3W_0 produced the lowest grain yield (2.78 t/ha) which was similar to treatments S_1W_0, S_2W_0 and S_4W_0 which produced grain yields of 2.87, 2.97 and 2.95 t/ha, respectively.

Straw Yield

Seed rates of 175, 150, 125 and 100 kg/ha produced straw yields of 4.42, 4.47, 4.35 and 4.10 t/ha, respectively (Table 3). They were not significantly different. Weeding at 20 and 40 days of sowing (W_2) produced higher straw yield (4.95 t/ha) which was followed by W_3 (4.74 t/ha) (Table 4). The lowest straw yield (3.60 t/ha) was obtained in the no weeding treatment (W_0).

CONCLUSION

Weeding of wheat field at 20 to 60 days after emergence together with moderate seed rates ranging between 125 to 150 kg/ha was suitable for higher grain yield of wheat. Weed removal over a period of 20-40 days after wheat emergence at a seeding rate of 125 kg/ha was the best combination for maximum yield.

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Communication

Relationship Between Chest Girth and Live Weight in Tankasa Sheep and Red Sokoto Goats –Validation Tests of Prediction Equations

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Small ruminants (sheep and goats) constitute the bulk of the meat supply (second only to cattle) and hide in Nigeria(Bukar *et al.* 1997). They are a ready source of funds in times of need and are readily affordable by even the low-income earners. The most numerous and well distributed breed of sheep in Nigeria is the Yankasa, while that of goats is the Red Sokoto. These breeds of small ruminants are sold at the market and at the site of slaughter slabs. One of the problems with the purchase of these animals is the subjective assessment of weight. Both buyers and sellers use the rather subjective method of sight and touch at the lumbar vertebrae.

While the use of weighing scales is common in the developed countries, the cost of a set of scales makes it impossible for the local dealers to procure one. Even though weigh bands are used in cattle, pigs and horses in these countries at a low cost, these tools are not readily available in Negeria. However, Osinowo *et al.* (1989) attempted to adopt this approach. Since animals may vary in size and shape with ecological niche, this study was undertaken as a validation test of their prediction equations.

One hundred and thirty one yankasa sheep and 109 Red Sokoto goats of live weight ranging from 2 – 53 and to10 – 42 kg, respectively were used in this study. In both groups, the relationship between chest girth (x, cm) and live weight (y, kg) was clearly curvilinear and was well defined by the following geometric regression equations (Osinowo *et al.* 1989).

1. Yankasa sheep: $Y = 0.00016x^{2.78}$, $r^2 = 0.99$
2. Red Sokoto goat: $Y = 0.0000658x^{3.038}$, $r^2 = 0.98$

Verification of both prediction equations showed close agreement between expected and actual live wight of goats (r = 0.85, n = 109) and sheep (r = 0.97, n = 131). The verification was carried out by taking the chest girth (cm) of the study animals, fixing the value into the regression equation and thus obtaining the expected weight. The expected values were then compared with actual weights of the same study animals using a weighing scale. Since there were close agreements between expected and the actual live weights, the prediction equations could be used for future estimation of bodyweight for these sheep and goats.

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