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Antimicrobial Resistance of *E. coli* Isolates from Pig Farm Workers, Nondiarrhoeic and Diarrhoeic Piglets

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Keywords: ***E. coli*, antimicrobial resistance, pig, human, diarrhoea**

ABSTRAK

Kajian kerintangan antibiotik ke atas 274 pencilan E. coli *daripada pekerja ladang, anak babi yang tidak cirit birit dan anak babi yang mengalami cirit-birit terhadap 11 agen antimikrob telah dijalankan untuk menentukan bentuk resistan antibiotik* E. coli. *Lima ladang babi terlibat dalam kajian ini. Kerintangan antimikrob adalah lebih tinggi serta ketara (P<0.05) dan hampir 100% bagi sulphasoxazole, streptomycin dan tetracycline pada pencilan babi bila dibandinghan dengan pencilan manusia. Purata peratusan kerintangan antibiotik di antara ladang tidak menunjukan perbezaan yang ketara (P>0.05) tidak kira sumber pencilannya. Analisis statistik menunjukan bahawa kerintangan antibiotik adalah rendah serta ketara (P<0.05) bagi pencilan dari pekerja ladang bila dibandingkan dengan pencilan-pencilan dari anak babi yang tidak cirit birit dan yang mengalami cirit-birit. Peratusan pencilan yang kerintangan terhadap sekurang-kurannya 8 antibiotik ialah 27.7, 5.6 dan 1.0 masing-masing bagi babi yang cirit-birit, babi yang tidak cirit birit dan pekerja ladang. Kajian ini juga menunjukan bahawa purata kerintangan antimikrob adalah lebih tinggi bagi ladang yang besar (P<0.01) dan bagi ladang yang tidak mempunyai doktor veterinar yang tetap (P<0.05).*

ABSTRACT

Antimicrobial resistance of 274 E. coli *isolates from farm workers, nondiarrhoeic and diarrhoeic piglets to 11 antimicrobial agents was investigated to determine the antimicrobial resistance pattern of* E. coli. *Five pig farms were involved in this study. Antimicrobial resistance was significantly higher (P<0.01) and almost 100% for sulphasoxazole, streptomycin and tetracyline in porcine isolates compared with human isolates. The mean percentages of antibiotic resistance between farms were not significantly different (P>0.05) irrespective of source of isolate. Statistical analysis showed that the antibiotic resistances were significantly lower (P<0.05) in farm worker isolates than in nondiarrhoeic and diarrhoeic piglet isolates. The percentages of isolates resistant to at least eight antibiotics were 27.7, 5.6 and 1.0 for isolates from diarrhoeic, nondiarrhoeic piglets and farm workers respectively. The present study also indicated that the mean antimicrobial resistance was significantly higher in larger farms (P<0.01) and in farms without a resident veterinarian (P<0.05).*

INTRODUCTION

Frequent and often indiscriminate use of veterinary drugs, particularly the antimicrobial agents, either in animal feeds as a growth promotant or for the treatment of diseases has resulted in the increase and spread of antimicrobial-resistant bacteria in animals both overseas (Findland 1975; Dubel *et al.* 1982) and in Malaysia (Khor *et al.*

1982; Tan and Chin 1982; Bahaman and Liman 1985). This endangers both animal and human health because it is generally accepted that resistant bacterial strains of animal origin can reach humans in contaminated food products.

Salam *et al.* (1986) have shown that the prevalence of antimicrobial-resistant organisms is correlated with the therapeutic use of antimicrobial agents in the farm. They found in an institutional pig farm that *Staphylococcus aureus* was resistant to penicillin and streptomycin (the two antibiotics commonly used in this pig farm) as well as tetracycline and ampicillin. Other studies have shown multiple antibiotic resistance in *E. coli* isolated from pigs (Chin 1983; Bahaman and Liman 1985; Linton 1986).

Although a number of studies abroad have shown the spread of antimicrobial-resistant organisms, particularly *E. coli,* from animal to man (Levy *et al.* 1976; Linton *et al.* 1977; O'Brian *et al.* 1982; Linton 1986), no such study has been carried out in Malaysia. Therefore, the objective of the present study is to determine the relationship between the antimicrobial resistance between *E. coli* isolated from pigs and pigfarm workers.

MATERIALS AND METHODS

Five commercial pig farms were selected for the study, based on farm size, the availability of a resident veterinarian, and location of the farm. Farm 1 was an institutional farm, with no other farms within a 10-km radius. Farms 2 and 5 were the closest–at least 5 km apart, whereas Farms 3 and 4 were located in an intensive pig-farming area of 86 farms with about 90,000 pigs. Two farms (Farms 1 and 5) have resident veterinarians.

The utilization of antibiotics at subtherapeutic and therapeutic levels in feed and for the treatment of diseases respectively in these farms over the last five years is shown in Table 1 and Table 2.

All farms used streptomycin, tetracyline, sulphonamides with or without trimethoprim combinations, tylosin, penicillin and chloramphenicol in the treatment of livestock diseases within the last five years. Gentamycin, neomycin and kanamycin were not used in Farm 1.

All categories of livestock feeds were medicated. The diets prepared were creep, weaner, grower and breeder rations. Creep feeding was introduced to piglets two weeks old. Tetracy-

TABLE 1
Antimicrobial drug usage (therapeutic) in pig farms in the last 5 years

Drug	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5
Ampicllin	Yes*	Yes	Yes	Yes	Yes
Penicillin	Yes	Yes	Yes	Yes	Yes
Chloramphenicol	Yes**	Yes	Yes	Yes	Yes
Gentamycin	No	Yes	Yes	Yes	Yes
Kanamycin	No	Yes	Yes	Yes	Yes
Neomycin	No	Yes	Yes	Yes	Yes
Streptomycin	Yes	Yes	Yes	Yes	Yes
Tetracylines	Yes	Yes	Yes	Yes	Yes
Sulphomides + Trimethoprim	Yes	Yes	Yes	Yes	Yes
Tylosin	Yes	Yes	Yes	Yes	Yes

*Since 1987

**terminated usage 2 years before the study

TABLE 2
Antimicrobial drug usage (in feed) in pig farms in the last 5 years

Drug	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5
Neomycin	Yes	No	No	No	No
Tetracyclines	Yes	Yes	Yes	Yes	Yes
Sulphonamides + trimethoprim	No	Yes	Yes	Yes	Yes
Tylosin/ Erythromycin	No	No	Yes	Yes	Yes
Penicillin	No	Yes	Yes	No	Yes
Lincomycin	No	No	No	Yes	No
Virginiamycin	Yes	No	No	Yes	No

cline was used subtherapeutically in all farms. Other antimicrobial agents commonly used at subtherapeutic level were sulphonamides, penicillins, tylosin, lincomycin and viginiamycin. The antibiotic levels varied between 50-200 ppm in pig feed rations. Except for Farm 1, subtherapeutic feeding was not withdrawn in finisher feeds.

The lactating sows and suckling pigs were housed in individual farrowing pens with crates on slatted plastic-coated flooring in all farms. Diarrhoeic piglets were normally medicated with a neomycin-kaolin-pectate drench and with antimicrobial therapy peculiar to farm usage.

Sample Collection and Treatment

Approximately 2 g of faeces from five individual non-diarrhoeic suckling piglets (3-4 weeks old) from different non-diarrhoeic litters were collected in presterilized MacCartney bottles. About 6-9 ml of stool samples from individual diarrhoeic piglets in different litters from the non-diarrhoeic specimens were collected by abdominal squeezing and thumping of diarrhoeal contents into sterile test-tubes.

Human faecal samples were collected from 4-5 farm volunteers from each farm into presupplied sterilized autoclave plastic bags.

All samples were kept in ice (4°C) in polystyrene ice chests or kept in a refrigerator, transported to the laboratory and kept at -20°C until processed.

One gram of a composite faecal sample from a respective study group for each farm was serially diluted in phosphate buffer and plated onto MacConkey agar. Twenty to twenty-five isolated colonies growing on agar plates of the highest dilutions, with 30 to 200 colonies per plate, were randomly selected. These isolates were picked according to the proportion of lactose and non-lactose fermenters. The cultures were reisolated in MacConkey agar at 37°C overnight. Single isolated colonies on MacConkey agar were used in the identification of species using the API-20E Enteric system. Gram staining was performed to confirm gram-negative status. *E. coli* isolates were purified in MacConkey agar and were subcultured in stock culture agar slants and refrigerated. Data was analysed using analysis of variance and comparison of means by Kruska-Walls test to determine the significance of difference between the means.

Antibiotic Susceptibility Testing

Pure cultures were subjected to antimicrobial susceptibility testing by the Kirby Bauer technique on Mueller-Hinton agar on duplicate plates. *E. coli* ATCC strain 25922 was used as the control organism. Antimicrobial susceptibility discs (Difco) were used to determine resistance. The antimicrobial agents used were Ampicillin-Ap (10μg), Cephalothin-Cf (30 μg), Chloramphenicol-C (30 μg), Neomycin-N (30 μg), Streptomycin-S (10 μg), Tetracycline-Te (30 μg), Trimethoprim-Tr (5 μg) and Sulphasoxazole-Su (300 μg).

Zone inhibition diameters were measured with vernier callipers (+ 0.01 mm) and intepreted

TABLE 3
Incidence of antimicrobial resistance of *E. coli* in pigs and farm workers

Source of Isolates	Number of Isolates/Number Resistant	Per cent Resistance
Non-Diarrhoeal Pigs		
Farm 1	23/23	100
Farm 2	23/23	100
Farm 3	18/18	100
Farm 4	18/18	100
Farm 5	19/19	100
Overall	101/101	100
Diarrhoeal Pigs		
Farm 1	15/15	100
Farm 2	17/17	100
Farm 3	19/19	100
Farm 4	18/18	100
Farm 5	19/19	100
Overall	88/88	100
Farm Workers		
Farm 1	15/4	26.7
Farm 2	19/3	15.8
Farm 3	20/13	65.0
Farm 4	19/6	31.6
Farm 5	12/8	66.7
Overall	85/34	41.2

as resistant, intermediate or sensitive according to National Committee for Clinical Laboratory Standards (NCCLS).

RESULTS

A total of 101, 88 and 85 faecal isolates of *E. coli* from nondiarrhoeic and diarrhoeic piglets and farm workers respectively were tested (Table 3).

All faecal isolates from nondiarrhoeic and diarrhoeic piglets were resistant to at least one antimicrobial agent in contrast to 41.2% of isolates from pig farm workers. The incidence of multiple resistance was observed in all isolates from diarrhoeic piglets and in 96.3 + 2.55% of isolates from nondiarrhoeic piglets. However, the mean frequency of multiple resistance in farm workers (29.9 + 6.62%) was significantly lower ($P<0.01$) than in nondiarrhoeic and diarrhoeic piglets.

In isolates from nondiarrhoeic piglets, the antimicrobial resistance was high for tetracycline (98.3%), streptomycin (91.6%) and sulphasoxazole (75.7%) and low for gentamycin and nalidixic acid (0.9%) (Table 4). The resistance frequencies were 35.5, 32.3, 31.4 and 24.7% for chloramphenicol, kanamycin, neomycin and ampicillin respectively.

In isolates from diarrhoeic piglets, the resistance to tetracycline, streptomycin and sulphadimidine was 95.5, 92.3 and 90.9% respectively. The resistance to nalidixic acid was only 1%. However, the resistance to ampicillin, gentamycin and kanamycin and trimethoprim was significantly higher ($P<0.05$) in nondiarrhoeic pig isolates (Table 4) even though these antibacterial drugs were not used in feeds in these farms. The resistant bacteria emerged as a result of extensive therapeutic use of these

TABLE 4
Antimicrobical resistance of isolates of *E. coli* in non-diarrhoeal and diarrhoeal pigs and farm workers

	Antimicrobial Agent (% Resistance)								
Samples	AP	C	Gm	K	N	S	Te	Tr	Su
Non-Diarrhoeal Pigs									
Farm 1	4	17	0	0	0	74	91	17	61
Farm 2	26	4	4	12	13	100	100	13	65
Farm 3	27	89	0	100	100	100	100	17	100
Farm 4	56	67	0	44	39	100	100	28	100
Farm 5	11	0	0	5	6	84	100	0	63
Mean	24.8[a]	35.4[b]	0.8[d]	32.4[a]	31.4[b]	91.6[d]	98.2[d]	15.0[c]	75.8[d]
Diarrhoeal Pigs									
Farm 1	130	20	13	27	47	100	100	47	60
Farm 2	82	77	12	41	47	94	94	100	100
Farm 3	37	37	11	47	42	34	100	32	100
Farm 4	33	67	0	83	83	83	89	56	94
Farm 5	100	68	32	63	63	100	95	95	100
Mean	53.0[b]	53.8[b]	13.6[b]	52.2[b]	56.4[b]	92.2[d]	95.6[d]	66.0[d]	90.8[d]
Farm Workers									
Farm 1	7	20	0	7	7	13	13	13	27
Farm 2	5	5	0	5	5	16	11	5	16
Farm 3	25	5	0	5	5	50	50	5	65
Farm 4	0	11	0	11	11	26	32	0	11
Farm 5	25	0	0	0	0	16	33	0	25
Mean	12.4[a]	8.2[a]	0[a]	5.6[a]	5.6[a]	24.2[c]	27.8[c]	4.6[c]	26.8[c]

a, b Values in different columns bearing different superscripts are significantly different ($p < 0.05$).

c, d Values in different columns bearing different superscripts are significantly different ($p < 0.01$).

antibacterials and colonized the intestine of non-diarrhoeic piglets. Antimicrobial resistance of diarrhoeal isolates to chloramphenicol varied from 20 to 76.5% between farms but was not significantly different ($P>0.05$) from the nondiarrhoeic isolates. There was also no significant difference between the resistance of either isolate to streptomycin, tetracycline and sulphasoxazole.

The faecal *E. coli* isolates from farm workers showed resistances not exceeding 30% for all antimicrobial agents tested. The resistance observed was high for tetracycline (27.7%), streptomycin (24.4%) and sulphadimidine (26.6%), Therefore, the antimicrobial resistance in isolates from farm workers was similar to isolates from diarrhoeal and non-diarrhoeal porcine origin although at a significantly lower frequency ($P<0.01$). Resistance to ampicillin and chloramphenicol was lower, at 12.4% and 8.2% respectively. Resistance against cephalothin, gentamycin, neomycin, kanamycin and trimethoprim was lowest.

The sample sizes of faecal isolates by source and farm were too small for conclusive comparison. However, statistical analysis showed that antibiotic resitances were significantly lower in farm workers' samples than in i) nondiarrhoeic piglets for chloramphenicol, neomycin ($P<0.05$); tetracycline, streptomycin and sulphadiazine ($P<0.01$) and ii) diarrhoeic isolates for ampicillin, chloramphenicol, gentamycin, kanamycin, neomyin ($P<0.05$); tetracycline, streptomycin, sulphasoxazole and treimethoprim ($P<0.01$).

However, there was no significant difference ($P>0.05$) between the variance of mean of

TABLE 5
Resistance to number of antibiotics

Samples	Per cent Resistant to at Least 2	4	6	8
Non-Diarrhoeai Pigs				
Farm 1	87	17	0	0
Farm 2	100	26	43	0
Farm 3	100	100	89	11
Farm 4	100	94	39	17
Farm 5	95	11	0	0
Mean	96.4[d]	49.6[d]	34.2[c]	5.6[a]
Diarrhoeal Pigs				
Farm 1	100	53	27	13
Farm 2	100	100	82	29
Farm 3	100	63	47	11
Farm 4	100	89	72	22
Farm 5	100	100	90	63
Mean	100.0[d]	81.1[d]	63.6[d]	27.6[b]
Farm Workers				
Farm 1	27	13	13	0
Farm 2	16	11	5	0
Farm 3	55	20	5	5
Farm 4	26	11	11	0
Farm 5	25	0	0	0
Mean	29.8[c]	11[c]	6.8[c]	1.0[a]

a,b Values in the same column bearing different superscripts are significantly different ($P < 0.05$).

c, d Values in the same column bearing diferent superscripts are significantly different ($P < 0.01$).

antimicrobial resistance between farms for all three groups of isolates.

A total of 27, 33 and 16 antibiotypes were observed from nondiarrhoeic pigs, diarrhoeic pigs and farm workers respectively. The more common antibiotypes were i) in nondiarrhoeic pig isolates, TeSSu (26.7%), TeS (13%) and TeSSuNKC (10.9%); ii) in diarrhoeic isolates, TeSSuNKCAPTr (17.1%), TeSSuCApTr (13.6%) and TeSSu (9.1%); and iii) in farm workers, TeSSu (71.%) and TeSSuAp (4.7%) were most common.

The median resistance was 3.8, 6.5 and 0.8 antibiotics for nondiarrhoeic piglets, diarrhoeic piglets and farm workers respectively. Table 5 shows 27.7% of diarrhoeic porcine isolates were resistant to at least eight antibiotics in comparison with 5.6 and 1.0% observed in nondiarrhoeic pig and farm worker isolates ($P<0.05$) respectively. With respect to resistance to at least five antibiotics, 74.3% of diarrhoeic were resistant compared with 39.9 and 6.8% in nondiarrhoeic pigs and farm workers isolates, respectively.

The mean multiple antimicrobial resistance (MAR) index, which is defined as the mean number of resistance observed over the number of antibiotics tested expressed as a percentage (Krupperman 1983), showed that diarrhoeic pigs had the highest MAR index (Table 5).

There were significant differences ($P<0.05$) in MAR index between the three groups of isolates. No significant difference in the mean MAR index between farms was observed.

DISCUSSION

In all five farms under study, the frequency of antimicrobial resistance observed in diarrhoeal swine isolates was significantly higher than those

of nondiarrhoeic isolates for ampicillin, gentamycin, kanamycin and trimethoprim ($P<0.05$), although these four antibacterial drugs were not included in feeds. This suggests that the indiscriminate therapeutic use of antimicrobial drugs is more likely to cause resistance than the use of these drugs in feeds as a growth promotant. Our results, which showed a higher prevalence of antimicrobial resistance in large herds with no veterinary supervision than in small herds with veterinary supervision, support our hypothesis. This finding also concurs with a study on pigs in an institutional farm (Salam *et al.* 1986) on the pattern of resistance of *E. coli* and *Staphylococcus aureus*, which showed increased resistance to drugs in the treatment of livestock in the farm.

On an individual farm basis, Farm 1 had lower antibiotic resistance frequencies for chloramphenicol, ampicillin and kanamycin. In this farm the use of chloramphnicol had been terminated two years earlier. Ampicillin was recently introduced in the treatment of piglet diarrhoea while kanamycin was not used. However, in Farm 5 where ampicillin was the therapeutic drug of choice, all diarrhoeic strains isolated were resistant to it. Individual farm preference for the use of chloramphenicol (Farm 2) and kanamycin (Farm 4) for therapeutic use was associated with higher antibiotic resistance frequencies for these drugs in porcine isolates.

The observation of antibiotic resistance patterns of human isolates cannot be compared with piglets' isolates directly as they may not be epidemiologically linked. An extensive epidemiological survey is therefore required involving a larger number of farms. However, the antibiogram characteristics of faecal isolates of *E. coli* from farm workers is significantly lower than nondiarrhoeic piglet isolates for chloramphenicol and neomycin ($P<0.05$), streptomycin, tetracycline and sulphadimidine ($P<0.01$). It is, therefore, consistent with the finding that most antibiotic resistance in human pathogens relates to the use of antimicrobial drugs in human, rather than in veterinary medicine (Prescott and Baggot 1988). Our results also indicated that the bacteria may develop resistance and colonize human intestines irrespective of whether the drugs are used therapeutically or prophylactically in farms. Thus, it is unfair to ban or withdraw the antibiotic usage in animal feeds as a growth-promotant while allowing the indiscriminate use of these drugs therapeutically.

The farm workers involved in our study did not report increased incidences of diarrhoeal episodes while working with livestock. This agrees with the findings of Linton *et al.*(1977), that there is little evidence that strains of *E. coli* enteropathogenic for man arise from animals.

Although no significant differences ($P>0.05$) were observed between the mean resistances to antibiotics tested between farms for all three groups of isolates, it was observed that there was a trend towards higher incidence of antimicrobial resistance with increasing herd size (Farm 1 versus Farms 2-5). Lower antimicrobial resistance prevalence was observed in nondiarrhoeic swine isolates and in farms with veterinary supervision (Farm 1 and 5 versus Farms 2, 3 and 4). However, statistical analysis was not performed as the sample sizes were too small for comparison, and this observation must be substantiated by more extensive epidemiological studies. Another observation which tended to agree with the findings of Bahaman and Liman (1985) was that multiple antimicrobial resistance to the number of antibiotics was higher in large than in small farms. This may explain the differences observed between Farms 1 and 5 (Farm 1 had 50 sows versus Farm 5 which had 500 sows).

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Sulphur and Sodium Inputs from Rainfall in Relation to Proximity of Sites from the Coast in Peninsular Malaysia

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Keywords: sulphur, sodium, rainfall, accession

ABSTRAK

Penentuan pengumpulan sulfur (S) dan natrium (Na) menerusi hujan pada tempat-tempat yang berlainan jarak dari pantai di Semenanjung Malaysia telah dijalankan. Pengumpulan S pada lokasi didapati bersumber dari laut dan kegiatan manusia dengan pengumpulan di kawasan tengah dan selatan lebih dipengaruhi oleh aktiviti industri. Pengumpulan Na pada lokasi dipengaruhi oleh monsoon, pengumpulan yang tinggi di kawasan timur pada musim tengkujuh dan kawasan barat pada musim monsoon barat-daya. Nisbah Na:S terkumpul didapati rendah dari nisbah mereka dalam air laut, ini menunjukan kesan kehadiran S bersumber daratan dan kegiatan manusia teradap S terkumpul.

ABSTRACT

Sulphur (S) and sodium (Na) accessions through rainfall at sites of varying distances from the coast in Peninsular Malaysia were monitored. Results indicate that S accession was of anthropogenic and marine origin, with S deposition at sites in the central and south transects being influenced more by industrial activities. Na accession was related to the monsoons, with sites on the east coast having high accumulations during the northeast monsoon, and sites on the west coast during the southwest monsoon. Na:S ratio was lower than their ratio in sea water, indicating that S accession was from anthropogenic and terrestrial origins.

INTRODUCTION

Peninsular Malaysia lies between 1° to 7° N latitude and 100° to 105° E longitude. It has an annual average of 2500 mm rainfall and experiences two monsoons, the northeast and southwest. Strong winds during the monsoons bring sea-spray containing appreciable amounts of sulphur (S). Major inputs of S in Peninsular Malaysia are of marine and terrestrial origin (Lefroy and Aminuddin 1990). The source of marine S as wind-driven sea-spray is an integral of S accession from the atmosphere and is highly correlated with the monsoonal seasons. Decline in S accession with distance from the coast has been observed in other regions. In Korea, for example, a decline from 28.3 to 11.7 kg S ha^{-1} from the coast to the interior mountain areas was observed (Shin 1987). In Queensland, Australia, a reduction from 6 to 3 kg S ha^{-1} occurred from the coast to a location 40 km inland (Probert 1976). Lefroy (1988) reported a decline from 22 to 7 kg S ha^{-1} from the coast to a site 13 km inland in New South Wales, Australia. In the Federal Republic of Germany, an average deposition (wet and dry) on bare soil of 23 kg S ha^{-1} y^{-1} was reported (Mayer and Ulrich 1978). In the Zhejiang province in China, annual rates of S deposition were in the range of 13-27 kg S ha^{-1} y^{-1} (Lu and Shi 1979). Martin (1980) reported that rain-deposited S at 20 open-country sites over the United Kingdom depended on rainfall amount and was typically 8-12 kg S ha^{-1} y^{-1}. When dry deposition is included, the values range from 10-16 kg S ha^{-1} y^{-1}. With sea spray, especially at sites within 10 km of the west coast, values increased to a range of 20-50 kg S ha^{-1} y^{-1}. The purpose of this paper is to determine the accession of S at different sites in relation to Na

and the influence of proximity of sites to the coast in Peninsular Malaysia.

MATERIALS AND METHODS

Transect lines were drawn on the geographical map of Peninsular Malaysia. These transects cover the north, central and south regions (*Fig. 1*). They were drawn so as to parallel the direction of the incoming monsoonal winds (ca. 45°). Sites on the transects were selected based on distances of 1, 5, 15 and 45 km away from both the west and east coasts except for sites on the south transect where the innermost distance was 30 km, due to the narrow land mass. A total of 24 sites were chosen.

A rainfall sampler containing mixed ion exchange resins, Amberlite IR-120 an acidic cation exchange resin and IRA-400, basic anion exchange resin (Lefroy 1988), was placed at each site from April 1990 to March 1991. Every two months, adsorbed ions were eluted from the resins in the laboratory with 2M HCl. Sulphur and sodium (Na) contents in eluents were determined as proposed by Freney (1986) and Pratt (1965). The rainfall for the sites was calculated based on the accumulated rainwater present in the container of the sampler.

Fig.1: Locations of transects

TABLE 1
Rainfall data of sites on transects (mm)

				North Transect				
Distance(km)	1	5	15	45	45	15	5	1
N.E.Monsoon	1748	1255	1176	1069	2126	887	1185	1017
S.W.Monsoon	831	637	648	1768	919	887	840	1034
				Central Transect				
N.E.Monsoon	2006	1945	1357	950	2259	1755	2971	1432
S.W.Monsoon	1012	761	1552	1099	1945	1043	772	1131
				South Transect				
Distance(km)	1	5	15	30	30	15	5	1
N.E.Monsoon	1406	2157	1724	1704	1746	1892	1991	1193
S.W.Monsoon	1512	1782	1665	1348	1886	1754	1264	1085

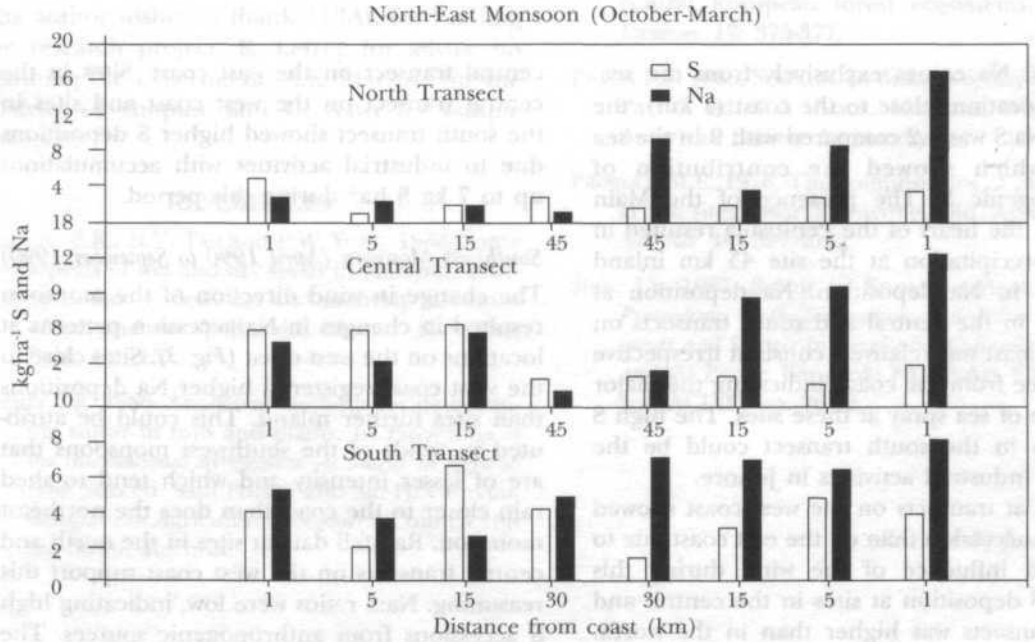

Fig.2: Sulphur and sodium accessions during N.E. monsoon

RESULTS AND DISCUSSION

Northeast Monsoon (October 1990 to March 1991)

Rainfall during this period was higher than that of the southwest monsoon (Table 1). The difference in rainfall between the monsoons was highest in the north transect and lowest in the south transect. Similar rainfall trends, especially for sites on the east coast, have been reported by Cheang *et al.* (1986). Na accessions at locations on the east coast in the north transect decreased at sites located further inland; however, S accession remained relative constant (*Fig. 2*). This can be explained by the fact that S in rainfall can be of both anthropogenic and marine ori-

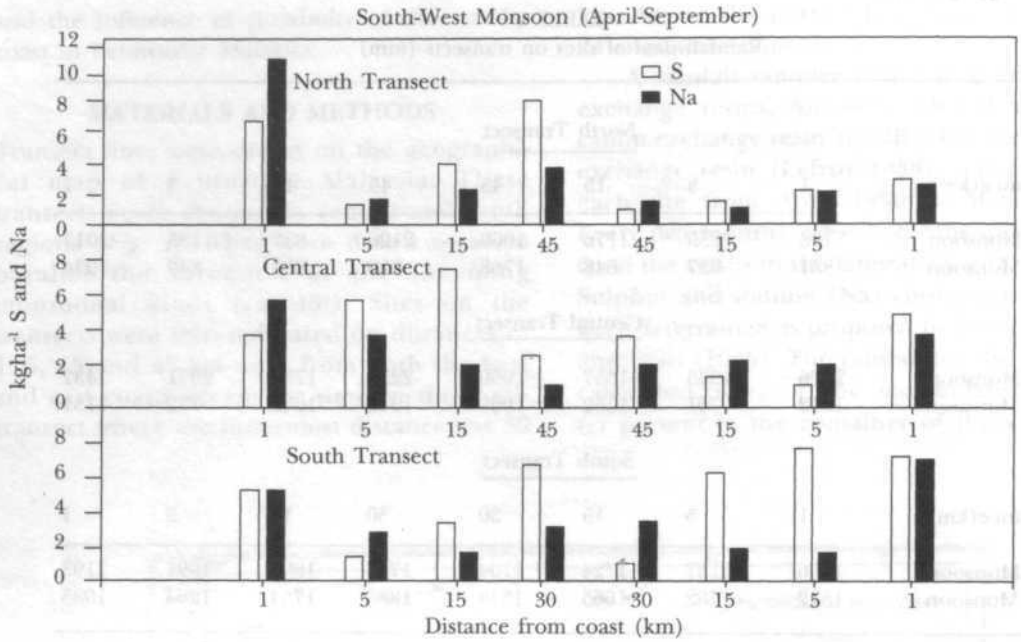

Fig.3: Sulphur and sodium accessions during S.W. monsoon

gin whilst Na comes exclusively from the sea. Even at locations close to the coast (1 km), the ratio of Na:S was 5.2 compared with 9 in the sea water, which showed the contribution of anthropogenic S. The presence of the Main Range in the heart of the Peninsula resulted in higher precipitation at the site 45 km inland and also in Na deposition. Na deposition at locations in the central and south transects on the east coast was relatively constant irrespective of distance from the coast, indicating the major influence of sea spray at these sites. The high S accession in the south transect could be the result of industrial activities in Johore.

Sites at transects on the west coast showed lower Na accession than on the east coast due to decreased influence of the wind during this period. S deposition at sites in the central and south transects was higher than in the north. This could again be the result of industrial activities in the central and southern regions of west Peninsular Malaysia. Such activities include a power generating plant using coal, oil refineries, palm oil refineries and pineapple processing plants. The low Na:S ratio indicates that S deposition was of terrestrial and anthropogenic origin. In general, during the northeast monsoon, S deposition at sites in the north transect was below 4 kg ha^{-1} and was similar to sites in the central transect on the east coast. Sites in the central transect on the west coast and sites in the south transect showed higher S depositions due to industrial activities with accumulations up to 7 kg S ha^{-1} during this period.

Southwest Monsoon (April 1990 to September 1990)

The change in wind direction of the monsoon resulted in changes in Na accession patterns at locations on the west coast (*Fig. 3*). Sites close to the west coast registered higher Na depositions than sites further inland. This could be attributed to winds of the southwest monsoons that are of lesser intensity and which tend to shed rain closer to the coast than does the northeast monsoon. Rainfall data at sites in the north and central transects on the west coast support this reasoning. Na:S ratios were low, indicating high S accessions from anthropogenic sources. The fact that S accessions for sites in the central and south transects on the west coast were comparable during the southwest and northeast monsoons could indicate that anthropogenic S sources are dominant over marine sources. Sites in all transects on the east coast had lower Na depositions during the southwest than during the northeast monsoon. S deposition in the north transect on the east coast was similar for both seasons, whilst deposition in the central

and south transects showed the influence of anthropogenic sources, possibly from industries located in the south region.

CONCLUSION

Sulphur accessions at sites monitored in Peninsular Malaysia were of anthropogenic and marine origins. The influence of the strong monsoon winds on Na deposition was recognised; however the pattern of S deposition was less affected. Sites in the central and south transects on the west coast and south transect on the east coast had S accessions which were influenced more by the presence of S-emitting industries. The Na:S ratio was high at sites exposed to the particular monsoon, with the northeast monsoon resulting in a higher ratio. S depositions at sites in the north transect of Peninsular Malaysia were lowest, while central and south transect sites had the highest deposition.

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Selection of Broodstock of Tiger Prawn, *Penaeus monodon* Fabricius, on the Basis of Morphometric Traits

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Keywords: broodstock selection, tiger prawn, *Penaeus monodon*, morphometric traits

ABSTRAK

Penaeus monodon *matang dipungut dari perairan Kedah, Perak, Terengganu, Johor dan Sabah. Ciri morfometrik terpilih dan berat badan bagi setiap ekor udang disukat. Udang betina didapati lebih besar (P<0.05) berbanding dengan udang jantan bagi semua lokasi. Analisis regresi langkah demi langkah menunjukkan bahawa panjang karapas sahaja mencukupi untuk menerangkan varians dalam berat badan bagi udang jantan dan betina. Panjang karapas boleh memberikan anggaran yang lebih tepat bagi berat badan dan oleh itu ia boleh dijadikan sebagai satu kriteria dalam pemilihan induk. Hubungan logaritma antara berat badan dan panjang penuh, berat badan dan panjang karapas, dan antara panjang karapas dan panjang penuh bagi kedua-dua seks juga dikira.*

ABSTRACT

Mature Penaeus monodon *were collected from Kedah, Perak, Terengganu, Johore and Sabah waters in Malaysia. Selected morphometric characters and body weight were measured individually. The results showed that the females were significantly larger (P<0.05) than the males in all locations. Stepwise regression analysis indicated that carapace length alone is sufficient to explain the variance in body weight for male and female prawns and can thus be used as a criterion for the selection of broodstock. The logarithmic relationships between body weight and total length, body weight and carapace length, and between carapace length and total length for both sexes were also calculated.*

INTRODUCTION

Penaeus monodon Fabricius, commonly known as tiger prawn, is the main cultured prawn species in Malaysia. Despite the establishment of hatchery and rearing techniques for this species, prawn broodstocks used for seed production and selective breeding are still being collected from natural populations.

Morphometric traits can easily be used as a criterion for the selection of prawn broodstock (Lester 1983; Huang *et al.* 1990) without killing or damaging them. Total length and carapace length are commonly used to estimate the size composition of prawn species (Ramamurthy and Manickaraja 1978). In addition, some morphometric characters can give a more accurate estimate of body weight and can be used for selecting broodstock on the basis of weight. Relationships between total length and carapace length, and total length and weight have been described for *P. monodon* and other prawn species (Hall 1962; Kirkegaard *et al.* 1970; Ramamurthy and Manickaraja 1978; Horton and Lester 1982; Lester 1983; Goswami *et al.* 1986; Huner *et al.* 1988).

The objectives of this study were to estimate the variability of selected morphometric traits and to determine the relationships among the characters in tiger prawns from different localities.

MATERIALS AND METHODS

Samples of wild and mature *Penaeus monodon* were purchased alive from fishermen in five

different areas, Kedah, Perak, Terengganu, Johore and Sabah waters.

Individual prawns were weighed in the laboratory to the nearest 0.001 g. Total length and carapace length were measured using vernier calipers to the nearest 0.01 cm. All parameters were based on Chua (1978), Grey *et al.* (1983), and Ahmad and Mahyam (1986). The proportion of carapace length to total length or carapace length index (%) was calculated by (carapace length/total length) x 100. Differences in carapace length indices among localities and between sexes were tested by one-way analysis of variance. Tukey test analysis was used to measure differences in carapace length index mean values among locations. The characters were log transformed to reduce the correlation of means and variances (Sokal and Rohlf 1981).

The morphometric characters were analysed by stepwise variable selection regression method using Statgraphics statistical graphics system (STSC, Inc. and Statistical Graphics Corporation, USA). Body weight was used as a dependent variable while total length and carapace length were independent variables. The relationships between total length and weight, and between carapace length and weight are described by the allometric equation, i.e. $Y = aX^b$, where X and Y are independent and dependent variables, respectively, and a and b are two constants. Non-linear regression analysis (Sokal and Rohlf 1981) was performed to determine these relationships for both sexes from different locations. Linear regression analysis was also used to describe the relationship between carapace length and total length. Data were pooled for males and females to provide a common regression equation describing the relationships between the two variables.

RESULTS AND DISCUSSION

The range, mean and coefficient of variation values for adult male and adult female shrimps collected from the five locations are presented in Table 1. Females were significantly larger ($P<0.05$) than the males, with average body weights of 113.54 g and 74.88 g, respectively. This characteristic was also noted in *Penaeus longistylus* (Penn 1980), *P. latisulcatus* and *P. esculentus* Haswell (Penn and Hall 1974). Male shrimps, however, had less variable and greater carapace length indices than the females, indicating that carapace length increases more rapidly than the total length in males but less rapidly in females. The coefficient of variation of the carapace length indices ranged between 5 and 18% in males and 5 to 21% in females. Among the various locations, males from Sabah had the highest average carapace length index (36.46%) and males from Kedah the lowest (22.65%). Similarly to males, the carapace length index (%) of females from Sabah was the largest (36.43%) and females from Kedah were also the smallest (23.17%). The Tukey test shows that the carapace length indices of females were significantly different ($P<0.05$) among locations, except between those from Johore and Perak. The prawns from Johore and Perak could be derived from the same population. The difference in size of carapace within sexes among different locations may be due to different stocks and different environments (Goswami *et al.* 1986; Huang *et al.* 1990).

The results of stepwise variable selection regression analysis for male and female prawns from five locations are shown in Table 2. In males, the carapace length was the first variable in stepwise regression analysis in Perak and Kedah populations, accounting for 79.4% and 72.4%, respectively, of the variation in body weight. Total length became the first entered variable in the regression analysis in Sabah, Terengganu and Johore male shrimp populations, explaining 77.8%, 61.8% and 61.0% of the variation in body weight, respectively. Conversely, among females, carapace length was the first variable to enter the regression step in Perak and Johore populations, explaining 95.6% and 79.7% of the variations in body weight, respectively. The total length was the first entered variable in stepwise regressions of Sabah, Kedah and Terengganu female populations that explained 82.88%, 80.6% and 74.7%, respectively, of the variance in body weight.

This study indicates that carapace length alone is sufficient to explain the variance in body weight for male (65.4%) and female (73.8%) prawns although a combination of two or three variables at a time gives a more accurate estimation of body weight.

From the analysis of variance, there were significant differences ($P<0.05$) in length between sexes for all locations. Therefore, the regression analyses for males and females were done separately.

Table 3 describes the logarithmic relationships between body weight (W) and total length

TABLE 1

Range, mean and coefficient of variation (CV) of total length (TL), carapace length (CL), body weight (WT) and carapace length index (CL. I.) for male (M) and female (F) *Penaeus monodon* collected from different regions in Malaysia

Variable	Sex	Kedah			Perak			Terengganu			Johore			Sabah		
		Range M (N=46) F (N=33)	Mean	CV	Range M (N=95) F (N=6)	Mean	CV	Range M (N=89) F (N=65)	Mean	CV	Range M (N=85) F (N=10)	Mean	CV	Range M (N=68) F (N=33)	Mean	CV
TL	Male	16.2-25.8	20.73	0.12	18.2-28.9	23.34	0.10	15.3-36.0	24.42	0.12	18.8-26.2	22.84	0.07	18.1-26.3	22.48	0.07
(cm)	Female	15.6-27.7	23.20	0.13	23.5-27.5	20.73	0.06	17.3-36.8	28.37	0.14	22.3-26.1	23.89	0.05	20.5-27.0	23.63	0.07
CL	Male	3.5-5.6	4.68	0.10	6.7-10.1	8.09	0.08	4.0-9.5	7.02	0.20	6.1-8.8	7.41	0.07	6.6-10.0	8.18	0.09
(cm)	Female	4.0-6.8	5.36	0.12	7.3-8..7	8.27	0.07	3.7-10.9	7.41	0.18	6.7-8.5	7.67	0.07	6.3-10.3	8.59	0.09
WT	Male	29.5-104.1	57.01	0.28	47.9-130.4	72.70	0.23	37.5-261.2	79.80	0.40	41.7-90.7	62.12	0.17	52.6-137.8	8648	0.23
(g)	Female	41.5-132.4	81.92	0.26	55.2-101.4	85.05	0.40	49.1-265.1	133.74	0.40	52.9-83.8	65.94	0.15	62.2-143.5	99.57	0.21
CL. I.	Male	19.2-27.9	22.57	0.09	27.8-40.1	34.65	0.06	20.1-39.2	28.76	0.18	29.0-37.0	32.43	0.05	32.1-41.1	36.40	0.06
(5)	Female	19.9-27.9	23.10	0.08	27.0-34.0	31.64	0.08	12.2-35.9	26.13	0.21	28.6-35.0	32.11	0.05	30.7-40.7	36.38	0.05

TABLE 2

Range, mean and coefficient of variation (CV) of total length (TL), carapace length (CL), body weight (WT) and carapace length index (CL. I.) for male (M) and female (F) *Penaeus monodon* collected from different regions in Malaysia

Variable	Sex	Kedah		Perak		Terengganu		Johore		Sabah	
		b	R	b	R^2	b	R^2	b	R^2	b	R^2
log CL	Male	2.422	0.724	2.511	0.794	1.575	0.501	1.748	0.584	1.941	0.584
	Female	1.833	0.771	3.356	0.956	2.028	0.660	1.756	0.797	1.775	0.673
	Combined	2.260	0.798	2.568	0.794	1.931	0.628	1.748	0.604	1.937	0.632
log TL	Male	1.948	0.691	1.643	0.573	1.986	0.618	1.849	0.610	2.987	0.778
	Female	1.781	0.806	0.409	0.011	2.799	0.747	1.139	0.623	2.738	0.828
	Combined	2.090	0.768	1.604	0.547	2.434	0.689	1.846	0.613	2.891	0.809

TABLE 3
Relations of log body weight (W) to log total length (L) in male and female of *Penaeus monodon* from different locations

Location	Sex	log W = log a + b log L	Correlation coefficient (r)
Kedah	Male	log W = -0.809 + 1.948 log L	0.83
	Female	log W = -0.518 + 1.781 log L	0.90
Perak	Male	log W = -0.418 + 2.511 log L	0.89
	Female	log W = -1.149 + 3.356 log L	0.98
Terengganu	Male	log W = -0.869 + 1.986 log L	0.79
	Female	log W = -1.959 + 2.799 log L	0.86
Johore	Male	log W = -0.719 + 1.849 log L	0.78
	Female	log W = -1.128 + 2.139 log L	0.79
Sabah	Male	log W = -2.101 + 2.987 log L	0.90
	Female	log W = -1.763 + 2.738 log L	0.91
Combined	Male	log W = -0.671 + 1.899 log L	0.62
	Female	log W = -0.513 + 1.741 log L	0.64

(L) in male and female prawns. Non-linear regression equations of log W = log a + b log L are shown for each location (Table 3). The relationships between body weight and total length for males and females in all locations were estimated as log W = -0.513 + 1.741 log L and log W = -0.671 + 1.899 log L, respectively. The values of coefficient "b" of the weight-total length relationships show considerable variation, ranging from 1.899 to 2.987 in males and from 1.741 to 3.356 in females. The "b" value was significantly smaller ($P<0.05$) than 3.0 for males. In contrast, "b" value in *P. duorarum* was significantly greater than 3.0 for both sexes as reported by Kutkuhn (1962). However, Fontaine and Neal (1971) found that the "b" value for *P. duorarum* males was not different from 3.0 ($P>0.05$).

The logarithmic relationships between body weight (W) and carapace length (L_{car}) for both males and females from each location are also described by the non-linear regression equation of log W = log a + b log L_{car} (Table 4). For all locations, the relationships between body weight and carapace length for males and females were estimated as log W = -0.019 + 2.10 log L_{car} and log W = -0.083 + 2.213 log Lcar, respectively.

Table 5 shows the logarithmic relationships between carapace length (L_{car}) and total length (L) for male and female prawns from each location as log L_{car} = log a + b log L. For all locations, the linear relationships between carapace length and total length for males and females were described as L_{car} = -0.561 + 1.042 log L, respectively.

The results show that carapace length increased linearly with the total length although carapace length does not grow allometrically with body weight. However, body weight is correlated more with carapace length for both male and female prawns, r = 0.81 and r = 0.86, respectively (Table 4) compared with total length with r = 0.64 and r = 0.62 for males and females, respectively (Table 3). Carapace length is a considerably more stable size reference dimension (Rhodes and Holdich 1984) and this may contribute to its good correlation with body weight. Total length measurement is rather varied according to the length of the rostrum, which is easily damaged, thus affecting the accuracy of this measurement.

This study indicates that carapace length can be used as a single variable to explain a large proportion of the variance in body weight. This is in accordance with the measurement used by Hall (1962). Thus this variable can be regarded as an important criterion for choosing

TABLE 4
Relationship of log body weight (W) to log carapace length (L_{car}) in male and female of *Penaeus monodon* from different locations

Location	Sex	log W = log a + b log L	Correlation coefficient (r)
Kedah	Male	$\log W = 0.133 + 2.422 \log L_{car}$	0.85
	Female	$\log W = 0.577 + 1.833 \log L_{car}$	0.88
Perak	Male	$\log W = 0.418 + 2.511 \log L_{car}$	0.89
	Female	$\log W = 1.149 + 3.356 \log L_{car}$	0.98
Terengganu	Male	$\log W = 0.471 + 1.575 \log L_{car}$	0.71
	Female	$\log W = 0.101 + 2.028 \log L_{car}$	0.81
Johore	Male	$\log W = 0.273 + 1.748 \log L_{car}$	0.76
	Female	$\log W = 0.265 + 1.756 \log L_{car}$	0.89
Sabah	Male	$\log W = 0.165 + 1.941 \log L_{car}$	0.76
	Female	$\log W = 0.340 + 1.775 \log L_{car}$	0.82
Combined	Male	$\log W = 0.083 + 2.213 \log L_{car}$	0.86
	Female	$\log W = 0.019 + 2.100 \log L_{car}$	0.81

TABLE 5
Relationship of log carapace length (L_{car}) to log total length (L) in male and female of *Penaeus monodon* from different lacations

Location	Sex	$\log L_{car} = \log a + b \log L$	Correlation coefficient (r)
Kedah	Male	$\log L_{car} = -0.110 + 0.593 \log L$	0.72
	Female	$\log L_{car} = -0.329 + 0.775 \log L$	0.82
Perak	Male	$\log L_{car} = 0.111 + 0.583 \log L$	0.76
	Female	$\log L_{car} = 0.741 + 0.124 \log L$	0.11
Terengganu	Male	$\log L_{car} = -0.476 + 0.953 \log L$	0.51
	Female	$\log L_{car} = 0.101 + 2.029 \log L$	0.81
Johore	Male	$\log L_{car} = -0.164 + 0.761 \log L$	0.74
	Female	$\log L_{car} = -0.388 + 0.924 \log L$	0.67
Sabah	Male	$\log L_{car} = 0.486 + 1.035 \log L$	0.78
	Female	$\log L_{car} = -0.700 + 1.190 \log L$	0.86
Combined	Male	$\log L_{car} = 0.084 + 0.548 \log L$	0.37
	Female	$\log L_{car} = -0.561 + 1.042 \log L$	0.53

broodstock in selective breeding programmes of *P. monodon*.

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Weed Populations and their Buried Seeds in Rice Fields of the Muda Area, Kedah, Malaysia.

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ABSTRAK

Sejumlah 25 spesies rumpai dari 15 famili ditemui dalam sawah di Kampung Tandop, Skim Pengairan Muda, Kedah, Malaysia. Rumpai yang paling dominan di dalam sawah tabur-terus kering ialah Utricularia aurea *Lour.,* Fimbristylis miliacea, *(L.) Vahl* Echinochloa crus-galli *(L.) Beauv.,* Monochoria vaginalis *(Burm. f.) Presl. dan* Najas graminea *(Del.) Ridl.. Dalam sawah tabur-terus basah, spesies dominan ialah* N. graminea, Lemna minor *L.,* Sphenoclea zeylanica *Gaertn.,* Utricularia aurea *dan* Sagittaria guayanensis *H.B.K., sementara dalam sawah padi batat, spesies yang dominan ialah* Echinochloa colonum *(L.) Link* Fimbristylis alboviridis *C.B. Clarke,* F. miliacea, Cyperus babakan *Steud. dan* Fuirena umbellata *Rottb.. Di sawah tabur-terus kering terdapat bilangan biji rumpai yang tertinggi (930,910/m² pada kedalaman 15 cm); padi batat 793,162/m² dan tabur-terus basah 712,228/m². Pada amnya biji rumpai berkurangan apabila kedalaman bertambah. Biji* U. aurea *dan* S. zeylanica *sangat dominan dalam tanah di sawah tabur-terus basah dan kering. Sebaliknya, biji* Scirpus juncoides *Roxb. dan* F. miliacea *dominan di sawah padi batat.*

ABSTRACT

Twenty-five weed species belonging to 15 families were found in rice fields near Kampung Tandop, in the Muda Irrigation Scheme, Kedah, Malaysia. The dominant weeds in dry-seeded rice were Utricularia aurea *Lour.,* Fimbristylis miliacea *(L.) Vahl.,* Echinochloa crus-galli *(L.) Beauv.,* Monochoria vaginalis *(Burm. f.) Presl. and* Najas graminea *(Del.) Ridl.. In the wet-seeded rice, the dominant species were* N. graminea, Lemna minor *L.,* Sphenoclea zeylanica *Gaertn.,* U. aurea, *and* Sagittaria guayanensis *H.B.K. while in volunteer seedling rice fields, the dominant species were* Echinochloa colonum *(L.) Link.,* Fimbristylis alboviridis *C.B. Clarke,* F. miliacea, Cyperus babakan *Steud. and* Fuirena umbellata *Rottb.. Dry-seeded rice fields contained the highest number of weed seeds (930,910/m² in the top 15 cm of soil); volunteer seedling rice fields contained 793,162/m² and wet-seeded rice fields 712,228/m². In general, seed number declined with increasing soil depth. At 10-15 cm depth, seeds of* U. aurea *and* S. zeylanica *were the most abundant in dry- and wet-seeded rice fields, whilst seeds of* Scirpus juncoides *Roxb. and* F. miliacea *were most abundant in volunteer seedling fields.*

INTRODUCTION

The size and species composition of populations of seeds present in arable soils reflect the extent to which past management has permitted seed production by weeds. More importantly, they also determine (at least in part) the nature and extent of weed problems in future cropping. Surveys conducted in many different countries have shown that the number of seeds present in arable soils is usually high (Roberts and Neilson 1981).

Reports on weed seed populations in Malaysian soils are limited. There is one report on soil weed seed populations in pineapple-growing areas in Johore (Wee 1974). On the other hand, many studies report weed

populations growing above ground (Azmi and Supaad 1987). In the Muda Irrigation Area, extensive work has been carried out on above-ground weed populations, covering nearly all parts of the area (Ho and Itoh 1991; Itoh 1991). No information is available on buried weed seeds in rice fields in the area.

At present, direct seeding culture is the predominant practice (about 75%) in the Muda area; 51% of farmers practise wet-seeding, 30% dry-seeding and 19% volunteer seedling (Ho and Md Zuki 1988). The change in weed flora from transplanted to direct-seeded rice culture is well-documented (Ho and Md Zuki 1988). Weed populations may also vary with the three types of direct-seeded rice fields, *viz.* wet-seeded, dry-seeded and volunteer seedling. No study has been conducted on the differences in weed composition and buried seed populations in rice fields seeded by these three methods.

The purpose of the present investigation was to examine emerging weed populations and their soil seed bank in the direct-seeded rice fields employing the three different seeding methods, *viz.* wet-seeding, dry-seeding and volunteer seedling.

MATERIALS AND METHODS

Study Sites

The study was carried out at the Muda Irrigation Project near Kampung Tandop, District BIV, Kedah. The farmers in this area practise direct seeding with one of three seeding methods, dry-seeding, wet-seeding and volunteer seedling. In wet-seeded and volunteer seedling rice fields, the soil was ploughed twice, two weeks and one week before seeding, while in dry-seeded fields, the soil was ploughed once, about one week before seeding. Adequate water was supplied through irrigation canals to the wet-seeded and dry-seeded rice fields. In volunteer seedling rice fields, however, rain served as the main source of water in addition to the supply from the canals. The survey was conducted during the first cropping season (Aug - Dec) in 1992.

Evaluation of Weed Composition

Thirty plots, ten of each of the three seeding methods, with an average plot size of 0.25 to 0.3 ha were randomly selected and assessed for weed composition. At the time of the survey, the paddy plants were 4 $^1/_2$ months old in wet-seeded and volunteer seedling rice fields and 2 $^1/_2$ months old in dry-seeded rice fields.

All weeds from each of ten 1-m^2 quadrats in each plot were sampled and counted by species. Weed species were identified using the keys of Anwar and Azmi (1986) and Itoh (1991). Summed dominance ratio (SDR) of each weed species was determined from the sum of relative density, relative frequency and relative dominance (Numata 1982).

Estimation of Soil Weed Seed Populations

Total weed seed populations were estimated in the three different seeding methods. Soil was sampled from the same locations where samples were taken for weed composition evaluation. Soil samples 7 cm in diameter were taken to a depth of 15 cm. Approximately 3 kg soil was collected from five quadrats in each plot. The soil cores were divided into three different depths, 0-5 cm, 5-10 cm and 10-15 cm. Soil samples of the same depth for each particular seeding method were pooled, mixed thoroughly and air-dried.

The method of seed separation was similar to the method described by Wilson *et al.* (1985). About 400 gm of soil was passed through a descending series of five sieves containing screens of the following sizes: 4 mm (5 mesh), 2 mm (10 mesh), 850 µm (20 mesh), 425 µm (40 mesh) and 250 µm (60 mesh). Water was run through the sieves to enhance sample movement through the screens. The contents collected in each screen were removed, oven-dried (30°C), and seeds were removed under a luminated magnifier. Seeds from entire samples were sorted using a dissecting microscope and counted according to species. The total number of buried seeds found in soil at different depths were expressed in numbers per m^2.

RESULTS

Weed Composition

Twenty-five weed species belonging to 15 families were found in the three areas with different seeding method (Table 1). Cyperaceae was the family with the highest number of species (9). In general, broadleaf weeds were the most dominant (13 species), compared with sedges (9) and grasses (3). The broadleaf weeds included two ferns, namely *Marsilea crenata* Presl. and *Ceratopteris thalictroides* (L.) Brongn.

In general, the weed composition of the three areas with different seeding methods was

TABLE 1
Summed dominance ratio values of weeds in wet-seeded, dry-seeded and volunteer seedling rice fields at Kampung Tandop, District IV, Kedah

Family/species	Wet-seeded	Dry-seeded	Volunteer seedling
Alismataceae			
Sagittaria guayanensis	6.82	-	0.12
Cyperaceae			
Cyperus babakan	1.28	0.18	5.62
Cyperus difformis	1.64	0.10	0.12
Cyperus digitatus	0.40	0.22	1.69
Cyperus iria	-	2.90	0.94
Fimbrisylis miliacea	5.08	11.12	9.34
Fimbristylis alboviridis	-	0.74	9.43
Fuirena umbellata	0.36	1.32	5.04
Scirpus grossus	0.66	-	-
Scirpus juncoides	2.40	1.24	0.36
Lemnaceae			
Lemna minor	9.68	1.22	-
Lentibulariaceae			
Utricularia aurea	7.01	14.69	4.18
Lythraceae			
Rotala indica	0.92	1.78	-
Marsiliaceae			
Marsilea crenata	1.71	0.84	-
Najadaceae			
Najas graminea	12.78	7.58	0.72
Onagraceae			
Ludwigia hyssopifolia	0.96	0.94	3.02
Parkeriaceae			
Ceratopteris thalictroides	0.37	1.35	1.68
Poaceae			
Echinochloa colonum	2.41	5.50	12.58
Echinochloa crus-galli	6.60	10.06	0.47
Leptochloa chinensis	1.64	0.49	0.14
Pontederiaceae			
Monochoria vaginalis	6.57	7.68	2.47
Rubiaceae			
Hedyotis diffusa	-	-	4.63
Scrophulariaceae			
Bacopa monnieri	-	-	4.69
Spenocleaceae			
Sphenoclea zeylanica	7.10	3.06	0.57
Sterculiaceae			
Melochia corchorifolia	-	-	4.14
Crop plant			
Oryza sativa	24.98	22.53	28.40

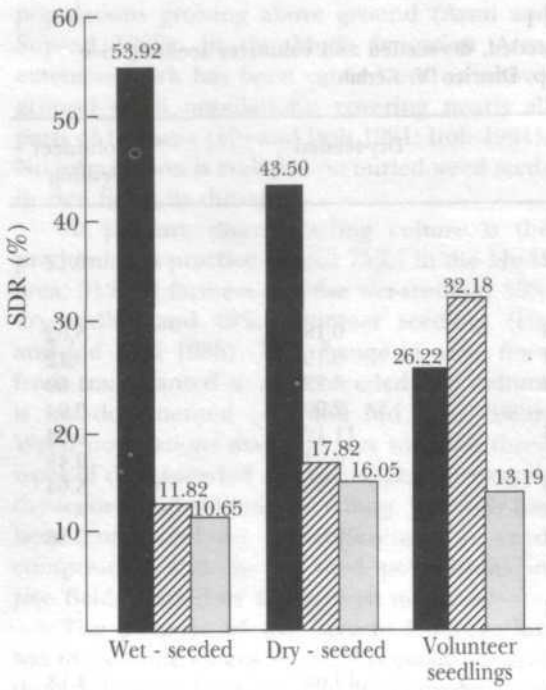

Fig. 1: SDR values of broadleaves (■), sedges (▨) and grasses (□) in wet-seeded, dry-seeded and volunteer seedling rice fields.

quite similar. Twenty-one weed species were found growing in wet- and dry-seding fields while there were 22 in volunteer seedling rice fields. Three species, *Hedyotis diffusa* (Willd.) Roxb., *Bacopa monnieri* (L.) Pennell and *Melochia corchorifolia* L. were not found in wet-seeded rice fields, while *H. diffusa, B. monnieri, M. corchorifolia* and *S. guayanensis* were not observed in the dry-seeded fields. *Lemna minor, Rotala indica* (Willd.) Koehne and *Marsilea crenata* Presl. were absent from volunteer seedling rice fields. In wet- and dry-seeded rice fields, broadleaf weeds were the most dominant (based on the SDR values), followed by sedges and grasses (*Fig. 1*). The SDR values for broadleaf weeds in wet- and dry-seeded fields were 54 and 44%, respectively. On the other hand, sedges were dominant in volunteer seedling rice fields. The SDR value for each species of broadleaf weeds in the volunteer seedling rice fields was found to be lower than 5%. *N. graminea, L. minor, S. zeylanica, U. aurea* and *S. guayanensis* were the most dominant weeds in wet-seeded rice fields (Table 1). The SDR value for *N. graminea, L. minor* and *S. zeylanica* in wet-seeded rice fields was 12.78, 9.68 and 7.1%, respectively. The hierarchical list of dominance (SDR value above 5%) was: *Najas graminea* > *L. minor* > *S. zeylanica* > *U. aurea* > *S. guayanensis* > *E. crus-galli* > *M. vaginalis* > *F. miliacea*. There were six species with SDR values of more than 5% in dry-seeded rice fields. The hierarchical order of those weeds was *U. aurea* > *F. miliacea* > *E. crus-galli* > *M. vaginalis* > *N. graminea* > *E. colonum*. However, in volunteer seedling rice fields, only five species had SDR more than 5%, with the hierarchical order *E. colonum* > *F. alboviridis* > *F. miliacea* > *C. babakan* > *F. umbellata*.

Weed Seed Populations in Soil

Total weed seed populations in the top 15 cm of soil were higher in dry-seeded fields (930,910/m^2) than wet-seeded (712,228/m^2) and volunteer seedling fields (793,162/m^2) (Table 2). In wet- and dry-seeded fields, seeds of *S. zeylanica* and *U. aurea* had the highest single percentages of total seeds found in the soil. In wet-seeded fields, *U. aurea* and *S. zeylanica* represented 39 and 24% of the total weed seed population, while in dry-seeded fields, the percentages of *U. aurea* and *S. zeylanica* seeds were 52 and 18%, respectively. However, in volunteer seedling fields, the number of *S. juncoides* and *F. miliacea* seeds were respectively 39 and 18% of the total weed seed population. Twelve weed species in the wet- and dry-seeded rice fields and 13 in the volunteer seedling fields contributed less than 1% each to the total seed population in the respective soils. They represented 5.1, 3.3, and 5.9% of the total seeds found in wet-seeded, dry-seeded and volunteer seedling fields, respectively. The total number of weed seeds declined with increasing depth, i.e. was lower at 10-15 cm than at 0-5 cm. However, the highest numbers of seeds were buried at depths of 0-10 cm. Seventy-seven per cent of weed seeds in volunteer seedling fields, 69% in wet-seeded fields and 72% in dry-seeded fields were found in the top 10 cm of soil.

DISCUSSION

Ahmed and Moody (1982) reported that the composition of rice weed communities is strongly influenced by water management and cropping system. This was supported by De Datta (1988), who reported that in a given environment, the weed vegetation is at least partly affected by such cultural practices as water management, the cultivar grown and the weed control strategies adopted by farmers. Clearly, the transformation in crop establishment technique from transplanting to direct-seeding rice culture, which involves

TABLE 2
Estimation of the total weed seed population in soil of wet-seeded, dry-seeded and volunteer seedling rice fields

Species	Depth (cm)				% of the total seeds
	0 - 5	5 - 10	10 - 15	0 - 15	
	seeds/m²				
Wet-seeded					
Utricularia aurea	106,796	88,477	85,619	280,892	39.4
Sphenoclea zeylanica	55,217	56,906	61,453	173,576	24.4
Fimbristylis miliacea	32,351	11,173	17,020	60,544	8.5
Monochoria vaginalis	21,567	15,331	14,032	50,930	7.2
Najas graminea	10,394	14,551	7,406	32,351	4.5
Ischaemum sp.	15,201	5,327	7,406	27,934	3.9
Unidentified	-	12,472	10,394	22,934	3.2
Ludwigia hyssopifolia	4,547	5,327	2,079	11,953	1.7
Scirpus juncoides	4,158	2,458	1,169	7,785	1.1
Rotala indica	-	2,858	4,547	7,405	1.0
Seed < 1% (12 species)	18,710	10,394	6,888	35,992	5.1
Total	268,941	225,274	218,013	712,228	
Dry-seeded					
Utricularia aurea	179,942	167,860	138,757	486,559	52.1
Sphenoclea zeylanica	63,142	53,528	48,980	165,650	17.7
Fimbristylis miliacea	33,260	27,042	18,709	79,011	8.5
Unidentified	20,788	14,941	12,472	48,201	5.2
Cyperus iria	13,252	9,874	9,874	33,000	3.5
Ischaemum sp.	14,941	4,937	9,874	29,752	3.2
Monochoria vaginalis	8,315	7,795	3,638	19,748	2.1
Najas graminea	6,626	4,937	4,937	16,500	1.8
Echinochloa crus-galli	3,248	6,626	1,169	11,043	1.5
Scirpus juncoides	3,248	3,248	3,638	10,134	1.1
Seed < 1% (12 species)	12,472	11,174	7,666	31,312	3.3
Total	359,234	311,962	259,714	930,910	
Volunteer seedling					
Scirpus juncoides	103,028	119,658	84,320	307,006	38.6
Fimbristylis miliacea	62,363	56,126	26,114	144,603	18.2
F. alboviridis	33,260	41,055	4,547	78,862	9.9
Utricularia aurea	23,256	26,114	19,488	68,858	8.7
Echinochloa colonum	23,646	19,358	7,016	50,020	6.3
Fuirena umbellata	10,784	17,799	6,626	35,209	4.4
Echinochloa crus-galli	11,953	9,874	4,158	25,985	3.3
Cyperus haspan	7,016	2,858	2,468	12,342	1.6
Cyperus babakan	2,468	390	9,484	12,342	1.6
Cyperus iria	4,158	4,158	2,468	10,784	1.5
Seed < 1% (13 species)	15,201	17,619	14,331	47,151	5.9
Total	297,133	315,009	181,020	793,162	

different water management and cropping systems, has resulted in dramatic changes in the type and distribution of weeds in the Muda area (Ho and Md Zuki 1988).

However, the areas with these three methods of seeding showed no marked variation in weed species composition even though their SDR values were different. The dominance of

certain species in specific areas could be related to management factors which favour the establishment of that species. Generally, species of Poaceae and Cyperaceae are more numerous than those of other families, which are represented by only one species per family in all three seeding methods. This is due to moist or saturated soil conditions favouring the emergence and growth of grasses and sedges which, once established, are difficult to control by flooding (De Datta 1981). The results of this survey showed that grasses and sedges are more problematic than broadleaved weeds in direct-seeded rice fields irrespective of seeding method.

According to Drost and Moody (1982), the soil moisture after planting is the major factor influencing the composition of the weed flora and the dominance patterns of the major weed species in the community. Water supplied to wet and dry rice fields as early as 2-4 days after seeding hinders the establishment of sedges and grasses. The SDR values reflect this as the value for broadleaf weeds is more than double those of sedges and grasses. Flooding has a major suppressive effect on stand establishment and growth when applied at early growth stages of *C. iria* and *E. colonum* (Civico and Moody 1979) and *E. crus-galli* (Smith and Fox 1973); at field capacity, satisfactory stands of *E. crus-galli* developed (Smith and Fox 1973). On the other hand, flooding favoured the growth of broadleaf weeds over grasses and sedges (Ho and Itoh 1991). Submerged weeds such as *U. aurea* and *N. graminea* are dominant under flooding conditions. In volunteer seedling fields, where water is introduced into the field gradually as the seeds begin to germinate and grow, weed problems are more troublesome. Under these conditions, grasses, especially *E. colonum* and sedges, grow simultanuously with the rice plants. Thus, sedges and grasses are more dominant in volunteer seedling fields, where SDR values of broadleaf species are less than 5%.

Twenty-five out of the 55 weed species recorded by Itoh (1991) in the Muda area were found in the direct-seeded fields at Kampung Tandop. However, five species (*B. monnieri, Cyperus digitatus* Roxb., *F. alboviridis, H. diffusa* and *S. juncoides*) were not recorded ealier by Itoh (1991). In some cases their SDR values were considerably higher than those previously reported. Farm machinery can easily transport weed seeds, rhizomes and stolons from one place to another (Klingman *et al.* 1975). In addition, weed seeds can be transported in surface runoff, streams and rivers, and irrigation and drainage canals (Wilson 1980). It is probable that these previously unrecorded weed species were introduced from other weed-infested rice fields outside the Muda area by tractors and combine harvesters. Field inspections revealed that cultivation equipment and tractor tyres often carry dirt and soil contaminated with weed seeds, rhizomes and stolons from infested rice fields. Besides, the recycling of 12-14% of the total water requirement in the Muda area, could further contribute to weed dissemination.

The total numbers of buried seeds reported here are extremely high compared with 16,000/m^2 from an arable soil in Scotland (Warwick 1984), 48,700/m^2 from a vegetable field in Indonesia (Satroutomo and Yusron 1987), or 80,400/m^2 in rice fields in the Philippines (Vega and Sierra 1970). However, the numbers reported here are total numbers, including both viable and non-viable seeds.

Degree of tillage appears to affect not only weed populations but also the number of seeds in the soil. The type and frequency of cultivation influences the composition and density of the weed flora. Typically, the rate of seed decline is lower in uncultivated than in cultivated soil (Roberts and Dawkins 1967). According to Zorner *et al.* (1984), deep ploughing buries seeds deep in the soil, reducing their rate of emergence. Seeds at or just below the soil surface often have a higher germination rate than seeds buried deeper (Herr and Stroube 1970). In the study area, ploughing was done to a depth of about 10 cm. The soil was ploughed twice before seeding in the wet-seeded and volunteer seedling fields, but only once in the dry-seeded rice fields. Tillage increases germination of seeds in the soil seed bank, reducing the seed reservoir in the soil (Roberts 1968).

General observation indicated that weeds were more serious and problematic in dry-seeded rice fields than in fields cultivated by other methods. Weeds in the area, especially *U. aurea*, contributed more seeds to the soil of dry-seeded rice fields. Moody (1980) reported a much wider range and intensity of weed problems in rice sown in dry soil, since the dry-seeded crop emerges at the same time as the weeds.

The higher number of *U. aurea* seeds in wet- and dry-seeded rice fields was expected because

this species was the most dominant weed in dry-seeded as well as in wet-seeded fields. This species is fast-growing and produces many seeds. In volunteer seedling rice fields, seeds of *F. miliacea* and *F. alboviridis* were dominant. Although, seeds of *S. juncoides* were the dominant species in the volunteer seedling field, the SDR value was small (Table 1). This may be due to the water supply to the area containing a large number of these seeds or be due to a build-up of the soil seedbank over seasons coupled with low germination rate. However, further studies are required to verify this observation.

The presence of submerged species such as *U. aurea* and *N. graminea* should be taken into account in the weed control programmes in the Muda area. These weed species were consistently found to be more abundant in all three types of rice culture studied. Also, the abundance of their seeds buried in soil may make them especially difficult to control.

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The Efficacy of Palm Oil Mill Effluent as a Soil Ameliorant

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Keywords: acidity, aluminium, effluent, groundnut, maize, soil solution

ABSTRAK

Satu kajian ladang telah dijalankan untuk menilai keberkesanan efluen kilang kelapa sawit (EKKS) sebagai pembaik tanah untuk pengeluaran jagung. EKKS telah diletakkan di dalam tanah Batang Merbau (Typic Kandiudult) pada kedalaman 0-30 cm sebelum jagung ditanam. Kacang tanah ditanam selepas jagung dituai. Kadar rawatan EKKS ialah 0, 5, 10, 20 dan 40 t ha^{-1}, dengan atau tanpa kehadiran 2 t batu kapur berdolomit ha^{-1}. Kalsium, Mg dan Al bertukar ganti, dan pH (0.01 M $CaCl_2$) di dalam tanah atas sebelum rawatan ialah masing-masing 0.36, 0.19, 1.50 cmol$_c$ kg^{-1} dan 4.1. Hasil tongkol basah tidak bertambah dengan kadar rawatan EKKS sehingga 10 t ha^{-1}; purata hasil ialah 1.7 t ha^{-1} dan menambahkan kadar rawatan EKKS kepada 20 dan 40 ha^{-1} mengakibatkan hasil basah > 2.2 t ha^{-1}. Kenaikan hasil disebabkan oleh kebaikan keadaan untuk pertumbuhan tanaman. Hasil tongkol basah kesemua kadar rawatan EKKS dengan kehadiran kapur ialah > 2.2 t ha^{-1}. Terdapat korelasi bererti diantara hasil jagung dengan Al dan Ca di dalam tanah. Purata hasil kacang tanah tanaman pertama ialah 3 t ha^{-1}. Tidak terdapat sebarang kolerasi diantara hasil kacang tanah dengan Al, Ca atau Mg bertukar ganti di dalam tanah.

ABSTRACT

A field experiment was conducted to assess the effectiveness of palm oil mill effluent (POME) as a soil ameliorant for the production of food crops. The POME was incorporated into the top 0-30 cm of Batang Merbau soil (Typic Kandiudult) prior to seeding with maize. Following maize, groundnut was grown. POME was applied at 0, 5, 10, 20 and 40 t ha^{-1}, both in the presence and absence of 2 t dolomitic limestone ha^{-1}. Exchangeable Ca, Mg and Al, and pH (0.01 M $CaCl_2$) in the topsoil prior to application of the treatments were 0.36, 0.19, 1.50 cmol$_c$ kg^{-1} and 4.1, respectively. The average fresh cob yield of maize was 1.7 t ha^{-1}, and did not increase with application of POME at rates of up to 10 t ha^{-1}. Increasing the rate of POME to 20 and 40 t ha^{-1} resulted in fresh cob yield > 2.2 t ha^{-1}. The increase in yield was attributed to improvement in the soil conditions for plant growth. Fresh cob yields in the presence of lime were > 2.2 t ha^{-1} at all rates of application of POME. Maize yield was significantly correlated with the exchangeable Al and Ca in the soil. Average pod yield for the first crop of groundnut was 3 t ha^{-1}. Groundnut yield was not correlated with exchangeable Al, Ca or Mg in the soil.

INTRODUCTION

Rubber, cocoa and palm oil, the main agricultural exports of Malaysia, are mainly grown on acid and highly weathered soils. These soils are classified as Ultisols and Oxisols and occupy about 72% of the land area of Malaysia (IBSRAM 1985). The clay fractions of the soils are dominated by variable-charge minerals such as kaolinite, goethite and gibbsite (Tessens and Shamshuddin 1983). Charges on the mineral surfaces depend on soil pH and/or ionic strength (Uehara and Gillman 1981) and are, therefore, affected by application of lime or organic matter.

During the early replanting phase of rubber and oil palm plantations, the interrow areas are sometimes used for cash crop production such as maize and groundnut. Low pH, high Al activity in the soil solution, and Ca and/or Mg

TABLE 1
Selected chemical and physical properties of the soil before treatment

Depth (cm)	pH (1:1) ($CaCl_2$)	Exchangeable Cations					Al Sat^n	Texture		
		Ca	Mg	K	Na	Al		Clay	Silt	Sand
		cmol$_c$ kg^{-1}					(%)	g kg^{-1}		
0-15	4.11	0.36	0.19	0.22	0.09	1.50	64	392	26	581
15-30	3.82	0.19	0.10	0.13	0.06	1.48	76	423	13	557
30-45	3.63	0.13	0.06	0.13	0.04	1.38	79	417	45	537

deficiency are major factors reducing the yields of the crops in these soils (Shamshuddin *et al.* 1991; Ismail *et al.* 1993). These constraints are also known to lower cocoa production on Ultisols and Oxisols in Malaysia. Liming the plough layer is a standard practice to overcome these problems, but Ca remains mainly in the zone of lime incorporation (Pavan *et al.* 1984; Gillman *et al.* 1989).

Malaysia produces large amounts of palm oil mill effluent (POME) annually (Chan *et al.* 1983); for every tonne of palm oil produced, about 3 tonnes of POME are generated. At the current rate of palm oil production (> 7 million tonnes in 1993) about 18 million tonnes of POME are produced annually as a processing waste product. POME is an organic-rich waste water with the capacity to detoxify Al when it is incorporated into acid soil (Shamshuddin *et al.* 1992a, b). The POME contains large amounts of plant nutrients, notably N (4.4%), P (1.0%), K (1.5%), Mg (1.0%) and Ca (1.3%) (Hishamuddin *et al.* 1985). Application of POME to the soil is known to increase soil pH which, in turn, reduces exchangeable Al in the soil (Shamshuddin *et al.* 1987) and is suitable for application to the soil in oil palm plantations. Since there is minimal groundwater pollution (Zin *et al.* 1983), POME can be used as an acid soil ameliorant for sustained food crop production. The objective of this study was to determine the effectiveness of POME to alleviate soil acidity for annual crop production.

MATERIALS AND METHODS

Experimental Procedures

A field experiment was established on Batang Merbau soil within a rubber replanting scheme at Kampung Jimah Baru, Port Dickson, Malaysia. The soil was a clayey, kaolinitic, isohyperthermic type (Typic Kandiudult) soil with 5° slope, low CEC and low pH (Table 1). Digested POME at 0, 5, 10, 20 and 40 t ha^{-1} with or without 2.0 t ground magnesium limestone (GML) ha^{-1} was incorporated into the soil to a depth of 30 cm. A randomized complete block design with four replications was adopted. The elemental composition of the POME is given in Table 2. The POME used in the experiment was obtained from an anaerobic ponding treatment system of a palm oil mill. The slurry effluent was then further treated in a flocculative pond to reduce the biochemical oxygen demand (BOD) to < 50 mg L^{-1}. At the time of application, the POME solid was moist, having a moisture content of about 50%. The GML used in the study contained 6.7% Mg and 18.5% Ca.

Maize (*Zea mays* var. Mas Madu) was planted 30 d after the treatments were applied; groundnut (*Arachis hypogaea* var. Matjam) was planted

TABLE 2
Elemental composition of the POME*

Major Element		Trace Element	
Element	Amount (%)	Element	Amount (mg kg^{-1})
N	2.20	Cu	72
P	0.96	Fe	2
Ca	0.64	Mn	296
K	0.93	Zn	122

* The POME contained 20% C_{org}. The chemical composition may vary from factory to factory, depending on the extraction process and the time of digestion.

TABLE 3
The pH and the chemical composition* of the topsoil solutions for selected treatments at the maize harvest

POME (t ha^{-1})	pH	Al	Ca	Mg	K	S	Ca/Al	Mg/Al
				μM				
0	4.73	108	1069	482	1262	311	9.9	4.5
20	5.10	77	1854	914	1566	773	24.1	11.9
40	4.55	72	1445	624	973	631	20.1	8.7
0+GML	5.20	16	938	992	528	717	58.6	620
20+GML	5.20	32	2016	1791	1012	820	63.0	60
40+GML	5.13	38	2142	1558	1415	1313	56.4	41
LSD (0.05)	0.87	109	1533	1194	739	685		

* As the soil solution P concentration was very low, the data are not presented in this table.

immediately after the maize harvest. Fertilizers at the rate of 120 kg N, 100 kg P and 150 kg K ha^{-1} for maize and 45 kg N, 28 kg P and 60 kg K ha^{-1} for groundnut were applied prior to the planting of each crop. A composite sample of five cores was taken from each of the experimental plots (6 x 6 m) before treatment and subsequent to the maize and groundnut harvests at depths of 0-15, 15-30, 30-45 and 45-60 cm. Maize and groundnut were harvested after 70 and 120 d, respectively.

Chemical Analysis

Soil

pH in 0.01 M $CaCl_2$ (w/v 1:1) and in H_2O (w/v 1:1) was determined after 1 h of intermittent shaking and overnight standing. Basic exchangeable cations were extracted by 1 M NH_4OAc buffered at pH7; Ca and Mg were determined by atomic absorption spectrophotometry; K and Na were determined by flame photometry. Aluminium was extracted by 1 M KCl and determined colorimetrically (Barnhisel and Bertsch 1982). Organic C_{org} was determined by the modified Mebius procedure (Nelson and Somners 1982). Particle-size analysis was carried out by the method of Day (1965).

Soil Solution

The air-dried soils (< 2 mm) from the experimental plots were rewetted at a matric suction of 10 kPa and incubated for 1 day (Menzies and Bell 1988). Soil solutions was extracted by centrifugation at 2000 rpm for 1 h and filtered through 0.45-m filter. pH and EC were determined immediately on 2 ml subsamples. The rest of the solutions were stored at 5°C for determination of Al, Ca, Mg, K, Na, Mn, Fe and S by inductively coupled plasma atomic emission spectroscopy. Only topsoil solutions of selected samples were analysed as the others were not expected to give any significant result, and hence, unable to contribute towards the attainment of the set objective.

RESULTS

Effects on Soil Solution

The topsoil solution pH at the harvest of maize (Table 3) and groundnut (Table 4) was not significantly affected by the POME and/or GML treatments, although it tended to be higher where lime was applied. In an earlier pot experiment, POME treatment was found to increase soil solution pH significantly (Shamshuddin *et al.* 1992b). The subsoil solution pH was not determined as a previous study by Ng (1994) showed that subsoil was not affected significantly by POME or GML treatment. The concentrations of Ca, Mg and S in the soil solutions were higher in the POME than in the no-POME control plots, with and without GML (Table 3). On the other hand, soil solution Al concentra-

TABLE 4
The pH and the chemical composition* of the topsoil solutions for selected treatments at the groundnut harvest

POME (t ha^{-1})	pH	Al	Ca	Mg	K	S	Ca/Al	Mg/Al
				µM				
0	4.37	52	548	250	785	279	10.5	4.8
20	5.03	50	1311	515	1161	510	26.2	10.3
40	4.55	75	810	366	958	409	10.8	4.9
0+GML	4.98	30	1009	655	954	577	33.6	21.8
20+GML	5.28	29	749	855	695	716	25.8	29.5
40+GML	4.88	31	1096	641	1003	540	35.4	20.7
LSD (0.05)	1.15	54	595	400	476	338		

* As the soil solution P concentration was very low; the data are not presented in this table.

tion tended to decrease with POME application in the absence of GML but increased in its presence. There was less change with solution pH and Al, Ca, Mg and S concentrations after groundnut harvest (Table 4).

Effects on Solid Phase

POME treatment alone did not significantly decrease the amount of exchangeable Al in the soil (Tables 5 and 6). On the contrary, a pot experiment indicated a significant reduction in exchangeable Al as a result of POME application (Shamshuddin *et al.* 1992a). However, when both POME and limestone were incorporated together into the soil, the minimum level of exchangeable Al was observed with 5 t POME ha^{-1} + GML at the maize harvest (Table 5). Exchangeable Ca and Mg were not significantly affected by POME application alone, but were increased in those treatments which received GML, which contains Ca and Mg.

Effects on Maize and Groundnut Yields

The fresh weight yield of maize cobs was < 2 t ha^{-1} at POME application rates < 10 t ha^{-1} (Table 5). The highest yield of 4.15 t ha^{-1} was obtained with application of 20 t POME ha^{-1}. The higher yield of maize in the 20 t POME ha^{-1} is attributable to the higher soil pH (Table 5). Yields > 3t ha^{-1} were also obtained when 20 and 40 t POME ha^{-1} were added together with 2 t GML ha^{-1}.

Treatment with 2 t GML ha^{-1} gave the highest groundnut yield of 4.16 t ha^{-1} (Table 6). However, this yield was not significantly different from the yield of the other treatments, except where 40 t POME ha^{-1} was applied. On average, the groundnut yield for the whole experiment was about 3 t ha^{-1}.

DISCUSSION

The soil pH ($CaCl_2$) and pH (H_2O) were correlated with the soil solution pH but the pH ($CaCl_2$) had the higher (r = 0.69) correlation and was selected to explain the variation in the maize and groundnut yields due to POME application (Tables 5 and 6). The soil solution pH was not used to explain the variation in yield as its value appeared to be unaffected by the POME and/or GML treatment.

In an earlier study, Shamshuddin *et al.* (1989) reported that critical soil pH values for groundnut and maize grown on Ultisols in Malaysia were 4.3 and 4.6, respectively. This means that a 90% relative maize yield was obtained when soil pH was around 4.6. Data in Table 5 show that the soil pH was in general < 4.6. Thus, it would appear that the pH condition was not conducive for maize.

The maize yield in the control treatment was 1.75 t ha^{-1}. However, maize yield was significantly increased by the application of 20 t POME ha^{-1} alone. The yield also increased to > 3 t ha^{-1}

TABLE 5
The pH, exchangeable Al, Ca and Mg in the topsoil, and maize yield (fresh cob weight)

POME (t ha^{-1})	pH ($CaCl_2$)	Exchangeable Cation			Yield (t ha^{-1})
		Al	Ca	Mg	
		cmol$_c$ kg^{-1}			
0 (T1)	4.09 ba	1.46 bdac	0.80 ba	0.29 b	1.75 b
5 (T2)	3.92 b	1.65 ba	0.55 ba	0.27 b	1.59 b
10 (T3)	3.88 b	1.79 a	0.32 b	0.30b	1.85 b
20 (T4)	4.40 ba	1.37 bdac	0.28 b	0.21b	4.15 a
40 (T5)	3.85 b	1.55 bac	0.49 ba	0.21 b	2.21 ba
0+GML (T6)	4.45 ba	0.62 ed	0.95 ba	0.69 ba	2.21 ba
5+GML (T7)	4.62 a	0.33 e	1.38 a	1.03 a	2.73 ba
10+GML (T8)	4.35 ba	0.95 ebdac	1.02 ba	0.73 ba	2.39 ba
20+GML (T9)	4.33 ba	0.78 edc	1.17 a	0.48 ba	3.35 ba
40+GML (T10)	4.37 ba	0.90 ebdc	1.32 a	0.81 ba	3.22 ba

TABLE 6
The pH, exchangeable Al, Ca and Mg in the topsoil, and groundnut yield (fresh pod weight)

Treatment	pH $CaCl_2$	Exchangeable Cations			Yield (t ha^{-1})
		Al	Ca	Mg	
		cmol$_c$ kg^{-1}			
T1	3.78 ba	1.42 ba	0.54 bc	0.22 c	2.97 ba
T2	3.83 ba	1.50 a	0.49 bc	0.19 c	2.74 ba
T3	3.62 b	1.64 a	0.40 c	0.17 c	3.51 ba
T4	4.07 a	1.16 ba	1.61 ba	0.65 ba	3.28 ba
T5	3.75 ba	1.65 a	0.35 bc	0.25 cb	2.55 b
T6	4.02 a	1.34 ba	0.82 bac	0.55 bac	4.16 a
T7	4.06 a	0.98 ba	1.13 bac	0.59 bac	3.23 ba
T8	3.71 ba	1.26 ba	0.75 bac	0.52 bac	3.10 ba
T9	3.89 ba	1.08 ba	1.42 ba	0.68 a	3.52 ba
T10	3.93 ba	0.74 b	1.71 a	0.70 a	3.36 ba

when the soil was treated with $\geq$ 20 t POME together with 2 t GML ha^{-1}. The increase in yield, although not significant, was due in part to better soil conditions (lower Al) and/or increase in plant nutrient contents (Ca and Mg) of the soils as a result of the treatment (Tables 3 and 5). The POME used in the current experiment contained moderate amounts of N, P, K and Ca (Table 2).

Data in Table 6 also show that the soil pH at the groundnut harvest was about 4, and therefore, the pH condition in the soil was good enough for groundnut production. Thus, groundnut did not respond to the POME appli-

cation. However, groundnut growth responded favourably to GML application alone, giving the highest yield of 4.16 t ha^{-1} when the soil was treated with 2 t GML ha^{-1}.

There was an indication that the maize yield increased with increasing soil solution Ca/Al concentration ratio, but this trend was not observed for the Mg/Al ratio (Tables 3 and 5). However, in the subsequent crop of groundnut, the yield was indicated to increase with increasing soil solution Ca/Al and Mg/Al concentrations ratios (Tables 4 and 6). As indicated in Table 3 and 5, maize yield appeared to increase with an increase in soil solution Mg concentration. This is consistent with the finding of an earlier study by Shamshuddin *et al.* (1991) where magnesium application was required to improve maize yield. The observed yield increase as a result of the POME and/or GML treatment for both crops was due to an increase in Ca, Mg and/or reduction in Al in the soil solution.

There was no significant correlation between the maize or groundnut yield and the exchangeable Al and Ca. However, when the 20 t POME ha^{-1} treatment was not taken into consideration in the regression analysis, the maize yield was significantly correlated with the exchangeable Al. The relationship is given by the equation:

$$Y = 3.31 - 0.84\ Al, \quad r = 0.69,\ P < 0.05.$$

Likewise, the maize yield (without the 20 t POME ha^{-1}) was significantly correlated with the exchangeable Ca. The relationship is given by this equation:

$$Y = 1.20 + 1.36\ Ca, \quad r = 0.79,\ p < 0.05$$

The above results showed that the maize yield was increased by reduction in the exchangeable Al and/or by increase in the exchangeable Ca. The reduction in exchangeable Al and the increase in the exchangeable Ca can be achieved by POME and/or GML application. There was also the possibility of the soil acidity being alleviated via complexation of Al by organic acids in the POME, as the POME used in the current study contained 20% C_{org} (Table 2). However, the maize or groundnut yield was not significantly correlated with Al or Ca concentration in the soil solution.

Maize yield appeared to be unaffected by the exchangeable Mg. This is contrary to the findings of Ismail *et al.* (1993) who observed in a pot experiment that relative top maize weight increased with increasing exchangeable Mg. More research is needed to prove conclusively the need of extra Mg by maize grown on acid soils to alleviate Al toxicity.

CONCLUSION

Palm oil mill effluent is available in large quantities in Malaysia. Due to its high plant nutrient content it can be used to ameliorate acid soil infertilities for maize production. Maize yield appears to increase with an increase in exchangeable Ca and/or decrease in exchangeable Al. However, these trends were not observed in the groundnut yield. In this study, the POME required to ameliorate acid soil infertilities for maize production was about 20 t ha^{-1}.

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Kesan Baja Nitrogen dan Kepadatan Penanaman ke atas Hasil Biji Foxtail Millet

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Kata kunci: foxtail millet, baja nitrogen, kepadatan penanaman, hasil biji

ABSTRAK

*Tujuan kajian ini ialah untuk menentukan kesan baja N dan kepadatan tanaman ke atas pengeluaran hasil biji foxtail millet (*Setaria italica *(Linn.) Beauv.). Empat populasi foxtail millet telah ditanam pada empat paras kepadatan (1, 5, 9 dan 17 pokok/pasu) dan dibekalkan dengan empat paras N (0, 50, 100 dan 150 kg/ha), dalam kombinasi faktorial rawak lengkap dengan tiga replikasi. Keputusan kajian mendapati bahawa semua empat populasi yang dikaji menunjukkan gerakbalas yang positif terhadap bekalan baja N. Kepadatan penanaman telah menyebabkan pengurangan hasil biji/pokok bagi semua empat populasi foxtail millet yang dikaji. Walau bagaimanapun, kesan kepadatan ke atas hasil biji/pasu adalah berbeza-beza di antara populasi.*

ABSTRACT

*The objective of this study was to determine the effects of N fertilizer and plant density on grain yield production of foxtail millet (*Setaria italica *(Linn.) Beauv.). Four populations of foxtail millet were planted at four plant densities (1, 5, 9 and 17 plant(s)/pot) and supplied with four levels of N fertilizer (0, 50, 100 and 150 kg/ha), in a completely randomized factorial combination with three replications. The results showed that the four foxtail millet populations had positive response to N fertilizer. Plant density reduced the grain yield production per plant basis. However, the effect of plant density on grain yield/pot varied among the populations.*

PENDAHULUAN

Pembiakbakaan tanaman ialah kaedah pembaikan baka atau genetik tanaman bagi memperbaiki ciri-ciri morfologi dan agronomi dengan matlamat untuk meningkatkan pengeluaran hasil. Walau bagaimanapun pada hakikatnya diketahui bahawa genotip tanaman akan hanya dapat diekspres/tonjolkan jika keadaan persekitaran untuk tumbesaran tanaman adalah sesuai. Faktor seperti bekalan air, baja, cahaya matahari, jenis tanah dan kepadatan tanaman adalah penting untuk menentukan proses tumbesaran yang sempurna.

Bagi bekalan baja, Makino dan Osmond (1991) menyatakan nitrogen adalah unsur dan terpenting kepada tanaman. Biasanya kesan nitrogen ke atas tanaman dikaitkan dengan peningkatan hasil biji seperti yang dilaporkan pada gandum (*Triticum aestivum* L.) (Boquet dan Johnson 1987), jagung (*Zea mays L.*) (Touchton & Rodriquez 1985; Narimah *et al.* 1994) dan pearl millet (*Pennisetum americanum* (L.) Leeke) (Kaushik dan Gautam 1985). Keupayaan pengambilan nitrogen oleh tanaman adalah juga bergantung kepada genotip tanaman. Misalnya, FAO (1980) melaporkan di India kultivar pearl millet tempatan menunjukkan gerakbalas positif terhadap bekalan nitrogen hingga ke tahap 80 kg/ha berbanding dengan 160 kg/ha bagi varieti hibrid.

Kepadatan penanaman pula selalu dikaitkan dengan peningkatan pengeluaran hasil per luas kawasan seperti yang dilaporkan bagi tanaman-tanaman seperti padi (*Oryza sativa* L.) (Srivinasa dan Rao 1984; Rao 1989), sekoi (*Sorghum bicolor* (L.) Moench.) dan finger millet (*Eleusine coracana*

Gaert.) (Ssekabembe 1991). Walau bagaimanapun dari segi tumbesaran tanaman, kepadatan yang terlalu tinggi boleh menyebabkan persaingan yang tinggi terhadap bekalan nutrien dan cahaya matahari dan menghadkan pertumbuhan akar yang seterusnya boleh menyebabkan kepayahan air (Karlan dan Camp 1985). Kepadatan yang tinggi juga boleh mengurangkan kadar tumbesaran (Weiner *et al.* 1990) dan mengurangkan hasil biji akibat dari pengurangan kesuburan bunga (Mishra & Mohapatra 1987; Yu *et al.* 1988).

Di dalam kajian ini empat populasi foxtail millet diguna untuk menentukan kesan pembajaan nitrogen dan kepadatan tanaman ke atas ciri hasil biji.

BAHAN DAN KAEDAH

Biji benih

Biji benih foxtail millet yang ditanam di dalam kajian ini terdiri dari satu populasi tempatan (yang diperoleh dari Sipitang, Sabah) dan tiga populasi (Ise.160, Ise.1057 dan Ise.1378) dari International Crop Research Institute for the Semi-Arid Tropics (ICRISAT).

Baja

Baja yang digunakan ialah urea (46% N) sebagai sumber N, muriate (60% K_20) sebagai sumber K dan batuan berfosforus (46% P_20_4) sebagai sumber P.

Kaedah

Kajian dijalankan di Rumah Hijau, Jabatan Biologi, UKM Kampus Sabah dan penanaman dilakukan di dalam pasu (garispusat = 27 cm dan tinggi = 21 cm). Rekabentuk eksperimen ialah faktorial rawak lengkap dengan tiga replikasi. Empat populasi foxtail millet (Ise.160, Ise.1057, Ise.1378 dan Sipitang) ditanam pada empat paras kepadatan (1, 5, 9 dan 17 pokok/pasu) dan dibekalkan dengan empat paras N (0, 50, 100 dan 150 kg/ha). Paras P dan K adalah 45 kg/ha.

Penanaman dilakukan pada 25 Julai 1993; 5 - 10 biji benih ditanam pada setiap lubang pada kedalaman 2 - 3 cm dan permukaan tanah di atas biji benih dipadatkan. Apabila anak benih mencapai peringkat 4 - 5 helai daun, pengurangan dilakukan kepada satu pokok bagi setiap lubang.

Pembajaan permulaan dilakukan sehari sebelum penanaman. Pada peringkat ini, separuh dari N dan semua P dan K ditaburkan di atas permukaan tanah di dalam pasu. Pembajaan berikutnya dilakukan 30 hari selepas penanaman dengan menabur kuantiti N yang selebihnya untuk pengambilan yang lebih cekap. Penyiraman dilakukan setiap hari. Kawalan rumpai dan perosak dilakukan apabila perlu.

Cerapan

Hasil biji/pokok

Semua panikel yang telah matang dari setiap pokok dituai dan dikeringkan di bawah cahaya matahari. Spikelet (biji) dileraikan dari panikel dan ditimbang. Bagi kepadatan 5, 9 dan 17 pokok/pasu pengukuran dilakukan pada setiap pokok di dalam setiap pasu, kemudian dipuratakan untuk direkodkan sebagai hasil biji/pokok bagi setiap pasu.

Hasil biji/pasu

Hasil biji/pasu ialah jumlah berat keseluruhan spikelet dari semua pokok pada setiap pasu. Ciri hasil biji/pasu diukur untuk mendapatkan anggaran pengeluaran hasil/luas kawasan.

Analisis data

Data bagi ciri-ciri yang dicerap dianalisis dengan model statistik berikut:

$$Yijkl = U + \alpha i + \beta j + \gamma k + (\alpha\beta)ij + (\alpha\gamma)ik + (\beta\gamma)jk + (\alpha\beta\gamma)ijk + eijkl$$

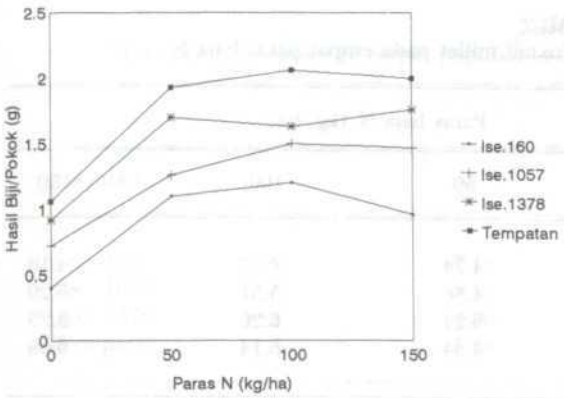
di mana

- Yijkl = cerapan pada pasu ke-*l* dari populasi ke-*i* pada paras N ke-*j* dan kepadatan ke-*k*
- U = min keseluruhan
- αi = kesan populasi
- βj = kesan paras N
- γk = kesan kepadatan
- $(\alpha\beta)ij$ = kesan interaksi di antara populasi dan N
- $(\alpha\gamma)ik$ = kesan interaksi di antara populasi dan kepadatan
- $(\beta\gamma)jk$ = kesan interaksi di antara N dan kepadatan
- $(\alpha\beta\gamma)ijk$ = kesan interaksi di antara populasi, N dan kepadatan
- eijkl = ralat.

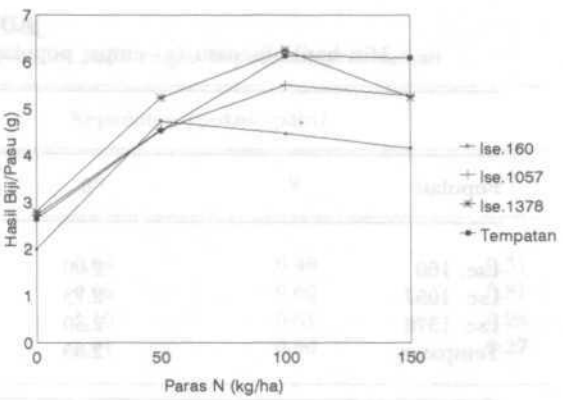
KEPUTUSAN

Kesan nitrogen

Keputusan kajian ini mendapati populasi-



Rajah 1: Kesan baja N ke atas hasil biji/pokok empat populasi foxtail millet



Rajah 2: Kesan baja N ke atas hasil biji/pasu empat populasi foxtail millet

JADUAL 1
Min hasil biji-pokok (g) empat populasi foxtail millet pada empat paras baja N

	Paras baja N (kg/ha)			
Populasi	0	50	100	150
Lse. 160	0.40	1.10	1.20	0.96
Lse. 1057	0.72	1.26	1.50	1.47
Lse. 1378	0.92	1.70	1.63	1.76
Tempatan	1.06	1.93	2.06	2.00

Lsd = 0.73
0.05

populasi foxtail millet menunjukkan gerakbalas yang positif terhadap bekalan baja N *(Rajah 1 dan 2)*. Semua empat populasi yang dikaji mempunyai min hasil biji/pokok dan hasil biji/pasu yang minimum pada paras N=0 kg/ha.

Populasi Ise.160 dari ICRISAT mempunyai min hasil biji/pokok 0.40 g pada keadaan tanpa bekalan baja N. Bekalan baja N pada kadar 50, 100 dan 150 kg/ha didapati telah meningkatkan hasil biji/pokok masing-masing 1.10 g, 1.20 g dan 0.96 g (Jadual 1). Walau bagaimanapun, perbezaan yang bererti ialah di antara min pada N=0 kg/ha dengan min pada N=100 kg/ha. Pengukuran ke atas hasil biji/pasu, didapati Ise.160 mempunyai min 2.00 g pada N=0 kg/ha. Bekalan baja N pada kadar 50, 100 dan 150 kg/ha telah meningkatkan hasil biji/pasu dengan nilai min masing-masing 4.74 g, 4.47 g dan 4.16 g (Jadual 2).

Perbandingan secara relatif, didapati populasi Ise.1057 menunjukkan prestasi yang lebih baik dari Ise.160 *(Rajah 1 dan 2)*. Pada keadaan tanpa bekalan baja N, min hasil biji/pokok meningkat apabila dibekalkan dengan 50, 100 dan 150 kg/ha N, dengan nilai min masing-masing 1.26 g, 1.50 g dan 1.47 g (Jadual 1). Perbezaan yang bererti ialah di antara nilai min pada N=0 kg/ha dengan N=100 dan 150 kg/ha. Pengukuran hasil biji/pasu pula didapati populasi Ise.1057 mempunyai nilai min 2.73 g. Hasil biji/pasu juga menunjukkan peningkatan yang bererti dengan bekalan baja N, iaitu dengan nilai min 4.56 g, 5.51 g dan 5.29 g masing-masing, pada N=50, 100 dan 150 kg/ha (Jadual 2). Walau bagaimanapun min hasil biji/pasu tidak berbeza secara bererti di antara tiga paras N yang berbeza.

Populasi Ise.1378 yang juga dibekalkan oleh ICRISAT mempunyai nilai min hasil biji/pokok yang rendah secara bererti pada N=0 kg/ha, iaitu 0.92 g. Bekalan baja N telah meningkatkan hasil biji/pokok dengan min 1.70 g, 1.63 g dan

JADUAL 2
Min hasil biji/pasu (g) empat populasi foxtail millet pada empat paras baja N

Populasi	Paras baja N (kg/ha)			
	0	50	100	150
Lse. 160	2.00	4.74	4.47	4.16
Lse. 1057	2.73	4.56	5.51	5.29
Lse. 1378	2.80	5.24	6.26	5.25
Tempatan	2.65	4.54	6.14	6.09

Lsd = 1.45
0.05

1.76 g, masing-masing pada paras N=50, 100 dan 150 kg/ha (Jadual 1). Corak yang serupa juga dicerap bagi hasil biji/pasu, di mana pada keadaan tanpa N, min adalah paling rendah iaitu 2.80 g. Bekalan baja N pada kadar 50, 100 dan 150 kg/ha telah meningkatkan hasil biji/pasu dengan nilai min masing-masing 5.24 g, 6.26 g dan 5.25 g (Jadual 2).

Populasi tempatan juga menunjukkan corak yang sama seperti populasi-populasi dari ICRISAT *(Rajah 1 dan 2)*. Pada N=0 kg/ha, min hasil biji/pokok ialah 1.06 g dan min meningkat secara bererti dengan bekalan baja N pada kadar 50, 100 dan 150 kg/ha, iaitu masing-masing 1.93 g, 2.06 g dan 2.00 g (Jadual 1). Hasil biji/pasu menunjukkan peningkatan yang bererti dengan bekalan N pada kadar 50 kg/ha. Selanjutnya, bekalan N pada kadar 100 dan 150 kg/ha menunjukkan peningkatan hasil biji/pasu yang bererti iaitu dengan min 6.14 g dan 6.09 g (Jadual 2).

Kesan kepadatan

Rajah 3 menunjukkan kepadatan penanaman menyebabkan pengurangan hasil biji/pokok dalam foxtail millet. Kesemua empat populasi yang dikaji mempunyai min hasil biji/pokok yang maksimum pada penanaman 1 pokok/pasu. Populasi-populasi juga berbeza secara bererti bagi ciri hasil biji/pokok pada penanaman 1 pokok/pasu, dengan min populasi tempatan yang paling tinggi (5.38 g), dan diikuti dengan populasi Ise.1378 (4.00 g), Ise.1057 (3.10 g) dan Ise.160 (2.18 g) (Jadual 3).

Penanaman pada kepadatan 5, 9 dan 17 pokok/pasu telah menyebabkan pengurangan yang bererti ke atas hasil biji/pokok. Pada kepadatan 5 pokok/pasu, didapati min hasil biji/pokok ialah di antara 0.69 - 1.10 g (Jadual 3). Selanjutnya, pada kepadatan 9 dan 17 pokok/pasu, masing-masing mempunyai julat min hasil biji/pokok di antara 0.46 - 0.61 g dan 0.25 - 0.31 g (Jadual 3). Hanya populasi Ise.1378 yang menunjukkan perbezaan yang bererti bagi hasil biji/pokok di antara paras kepadatan 5 pokok/pasu dengan 17 pokok/pasu. Bagi lain-lain populasi, perbezaan paras kepadatan di antara 5, 9 dan 17 pokok/pasu, tidak memberi kesan yang bererti ke atas hasil biji/pokok (Jadual 3).

Kesan kepadatan penanaman ke atas hasil biji/pasu adalah berbeza-beza mengikut populasi *(Rajah 4)*. Populasi Ise.160 menunjukkan peningkatan hasil biji/pasu dengan peningkatan bilangan pokok/pasu *(Rajah 4)*, iaitu dengan min 2.18 g, 3.44 g, 4.17 g dan 5.57 g, masing-masing pada kepadatan 1, 5, 9 dan 17 pokok/pasu (Jadual 4). Walau bagaimanapun, perbezaan min yang bererti hanya dicerap di antara kepadatan 1 pokok/pasu dengan min-min pada kepadatan 9 dan 17 pokok/pasu.

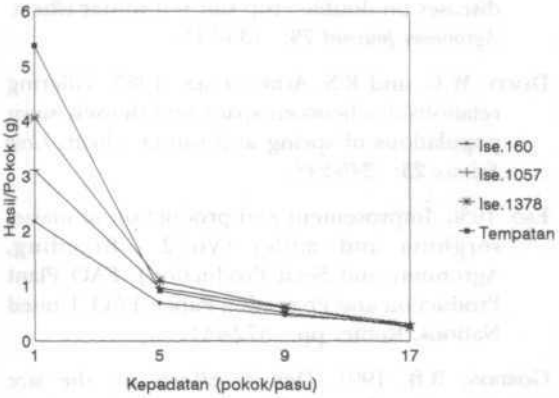
Populasi Ise.1057 pula mempunyai min hasil biji/pasu 2.75 g pada kepadatan 1 pokok/pasu dan berbeza secara bererti dengan min-min pada kepadatan 5, 9 dan 17 pokok/pasu dengan nilai masing-masing 4.81 g, 5.28 g dan 5.24 g (Jadual 4).

Pada kepadatan 1 pokok/pasu populasi Ise.1378 yang mempunyai min hasil biji/pasu 4.06 g, adalah lebih tinggi berbanding dengan populasi-populasi Ise.160 dan Ise.1057 (Jadual 4). Peningkatan kepadatan kepada 5 pokok/pasu menyebabkan peningkatan hasil biji/pasu

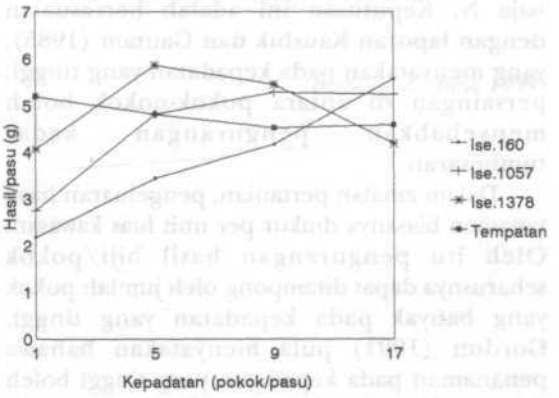
JADUAL 3
Min hasil biji-pokok (g) empat populasi foxtail millet pada empat kepadatan penanaman

Populasi	Kepadatan (pokok/pasu)			
	1	5	9	17
Lse. 160	2.18	0.69	0.46	0.31
Lse. 1057	3.10	0.96	0.60	0.31
Lse. 1378	4.06	1.10	0.61	0.25
Tempatan	5.38	0.91	0.50	0.27

Lsd = 0.73
0.05



Rajah 3: Kesan kepadatan ke atas hasil biji/pokok empat populasi foxtail millet



Rajah 4: Kesan kepadatan ke atas hasil biji/pasu empat populasi foxtail millet

yang bererti iaitu dengan nilai min 5.87 g *(Rajah 4* dan Jadual 4). Pada kepadatan 9 pokok/pasu, min hasil biji/pasu Ise.1378 ialah 5.45 g dan tidak berbeza secara bererti dengan min-min pada lain-lain paras kepadatan. Pada kepadatan 17 pokok/pasu, min hasil biji/pasu ialah 4.18 g dan berbeza secara bererti dengan min hasil biji/pasu pada kepadatan 5 pokok/pasu.

Keupayaan pengeluaran hasil biji/pasu bagi populasi tempatan tidak dipengaruhi oleh jumlah pokok/pasu. Penanaman 1, 5, 9 dan 17 pokok/pasu mempunyai min-min hasil biji/pasu yang tidak berbeza secara bererti, iaitu dengan nilai masing-masing 5.20 g, 4.81 g, 4.82 g dan 4.58 g (Jadual 4). Pada penanaman 1 pokok/pasu populasi foxtail millet tempatan ini mengeluarkan tiller-tiller yang produktif. Manakala, pada kepadatan 5, 9 dan 17 pokok/pasu didapati pokok-pokok tidak mengeluarkan tiller. Oleh itu, bagi populasi tempatan hasil biji daripada tiller pada kepadatan 1 pokok/pasu telah memberikan jumlah hasil biji yang sama dengan pokok-pokok pada kepadatan 5, 9 dan 17 pokok/pasu.

PERBINCANGAN

Foxtail millet selalunya dianggap sebagai jenis tanaman yang berupaya hidup pada tanah yang kurang subur (Rachie 1975). Walau bagaimanapun, keputusan kajian ini membuktikan bahawa prestasi pengeluaran hasil biji foxtail millet dapat dipertingkatkan dengan bekalan baja N. Kadar baja N yang dapat membantu meningkatkan hasil biji ialah di antara 50-100 kg/ha.

Selanjutnya, kesan bekalan baja N ke atas pengeluaran hasil biji foxtail millet adalah bergantung kepada kepadatan penanaman. Hasil biji/pokok didapati berkurangan apabila kepadatan penanaman adalah tinggi, walaupun pokok-pokok dibekalkan dengan

JADUAL 4
Min hasil biji/pasu (g) empat populasi foxtail millet pada empat kepadatan penanaman

Populasi	Kepadatan (pokok/pasu)			
	1	5	9	17
Lse. 160	2.18	3.44	4.17	5.57
Lse. 1057	2.75	4.81	5.28	5.24
Lse. 1378	4.06	5.87	5.45	4.18
Tempatan	5.20	4.81	4.52	4.58

Lsd = 1.45
0.05

baja N. Keputusan ini adalah bersesuaian dengan laporan Kaushik dan Gautam (1985), yang menyatakan pada kepadatan yang tinggi, persaingan di antara pokok-pokok boleh menyebabkan pengurangan kadar tumbesaran.

Dalam amalan pertanian, pengeluaran hasil tanaman biasanya diukur per unit luas kawasan. Oleh itu pengurangan hasil biji/pokok seharusnya dapat ditampong oleh jumlah pokok yang banyak pada kepadatan yang tinggi. Gordon (1991) pula menyatakan bahawa penanaman pada kepadatan yang tinggi boleh menyebabkan kepelbagaian dalam saiz pokok dan ini boleh menimbulkan masalah untuk proses penuaian. Bagi jenis tanaman yang mengeluarkan tiller seperti padi (Rao 1989) dan gandum (Dewey & Albrechtsen 1985), kepadatan yang rendah merangsangkan pengeluaran tiller. Hasil biji daripada tiller seharusnya dapat meningkatkan pengeluaran hasil per luas kawasan, iaitu seperti yang dicerap dalam populasi tempatan. Walau bagaimanapun, masa matang biji pada tiller adalah lewat berbanding dengan panikel utama, dan ini juga boleh menimbulkan masalah untuk proses penuaian.

Secara amnya, keputusan kajian ini mencadangkan bahawa untuk pengeluaran hasil biji foxtail millet yang optimum, penanaman harus dilakukan dengan kepadatan 100,000 pokok/ha (5 pokok/pasu) dan bekalan baja N di antara 50 - 100 kg/ha.

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The Mineralogy and Chemical Properties of Soils on Granite Gneiss in Three Climatic Zones in Sri Lanka

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Keywords : agro-ecological zone, granite gneiss, mineralogy, soil solution

ABSTRAK

Granit gneis dijumpai wujud di merata-rata di Sri Lanka. Bergantung kepada keadaan iklim dan topografi kawasan, bahan ini mengalami luluhawa kimia yang berbeza-beza. Satu kajian mineralogi dan sifat kimia keatas sifat tanah granit gneis daripada tiga zon agro-ekologi di Sri Lanka telah dijalankan. Tanah dalam zon lembab didapati rendah pH dan kation bertukar ganti, manakala tanah dalam zon kering pula mempunyai pH dan kation bertukar ganti yang tinggi. Warna tanah bertukar daripada coklat kekuningan kepada merah apabila tanah bertambah kering mungkin disebabkan oleh kehadiran hematit dan/atau goethit. Kaolinit, haloisit dan smektit wujud di dalam semua tanah tanpa mengira iklim; amaun haloisit berkurangan menghala ke permukaan tanah. Boitit wujud dengan banyaknya di dalam tanah zon perantaraan dan kering, tetapi tidak wujud dalam tanah zon lembab. kepekatan Ca dalam larutan tanah bergantung kepada amaun Ca yang wujud dalam bentuk bertukar ganti. Tambahan lagi, kepekatan Ca larutan berkolerasi secara bererti dengan EKPK dan nisbah EKPK/KPK tanah.

ABSTRACT

Granite gneiss occurs sporadically throughout Sri Lanka. Depending on the climatic conditions and topography of the area, the rock undergoes different degrees of chemical weathering. The mineralogy and chemical properties of four common granite gneiss soils occurring in three agro-ecological zones in Sri Lanka were studied. The soil in the wet zone is low in pH and basic exchangeable cations, while the soils in the wet zone are high in pH and basic exchangeable cations. The colour of the soils changes from yellowish-brown to red as the soils get drier, presumably due to the presence of haematite and/or goethite. Kaolinite, halloysite and smectite are present in all the soils irrespective of the climatic conditions; the amount of halloysite decreases towards the surface. Biotite is abundant in the soil of the intermediate and dry zones, but is absent in the soil of the wet zone. Gibbsite is present in the highly weathered soil of the wet zone.The concentration of Ca in soil solution is dependent on the amount in the soils existing in the form of exchangeable Ca. Additionally, the solution Ca concentration is significantly correlated with the soil ECEC and the ECEC/CEC ratio.

INTRODUCTION

Sri Lanka, located near the Equator, is agro-ecologically divided into wet, intermediate and dry zones (Anon 1979). The wet zone occurs in the southwest, while the dry zone occurs in the north *(Fig. 1)*. The middle part of the country receives intermediate rainfall. Soil physico-chemical properties and agricultural production in the country are closely related to the rainfall patterns in the different agro-ecological zones.

The southern part of Sri Lanka is dominated by red yellow podzolic and latosolic soils (Anon

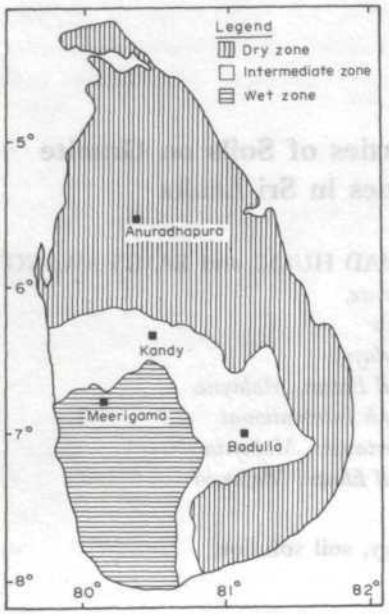

Fig. 1: A map of Sri Lanka showing agro-ecological zones (Anon. 1979) and the sites of soil sampling

1979). Besides red yellow podzolic soils, reddish brown earth occurs in the intermediate zone. These soils can either be classified as Ultisols or Alfisols in soil taxonomy (Soil Survey Staff 1992). The soils in the middle and northern parts of the country are different from those of the south due to differences in the rate of leaching and chemical weathering; the rainfall in the north is much lower than in the south. The colour of these soils is determined primarily by the type of Fe mineral rather than the absolute amount of Fe oxide present in the soils. According to Schwertmann (1993), haematite-containing soils have mostly hues between 5YR and 10R, whereas goethite-containing soils with no haematite have hues between 7.5YR and 2.5Y.

Granite gneiss is an important rock type in Sri Lanka, and many soils earmarked for agricultural and/or forestry purposes are derived from it. The granite gneiss occurs sporadically throughout the three agro-ecological zones of Sri Lanka. Biotite (iron magnesium mica) is one of the major minerals in the granite gneiss (Paramananthan 1977). According to Eswaran and Heng (1976), biotite transformed to halloysite, kaolinite or goethite depends on the position of the mineral in a weathering profile. Due to differences in the climate and topography, the granite gneiss soils in Sri Lanka that have undergone different degrees of weathering are differentiated into Ultisols and Alfisols. Mineralogical transformation and soil solution chemical composition in the different agro-ecological zones have not bean investigated and documented in Sri Lanka. The objective of this paper is to characterize the mineralogy and soil solution chemical composition of some of the common granite gneiss soils in the three agro-ecological zones in Sri Lanka.

MATERIALS AND METHODS

Soils

The soil profiles for this study were examined during a field tour in Sri Lanka in October 1991 (Shamshuddin and Ahmad Husni 1992). The soils, derived from granite gneiss, were sampled at four localities, representing the three agro-ecological zones in Sri Lanka *(Fig. 1)*. The soils

TABLE 1
Location, annual rainfull, agro-ecological zone and colour classification of the soils under investigation

Location	Rainfall mm/year	Agro-ecological zone	Subsoil colour	Subgroup
Meerigama	4008	Wet	Yellowish brown	Typic Hapludults
Badulla	1800	Intermediate	Red	Typic Hapludults
Kandy	1563	Intermediate	Red	Typic Rhodustalfs
Anuradhapura	1329	Dry	Red	Typic Rhodustalfs

TABLE 2
Relevant chemical properties of the soils under investigation

Location	Depth (cm)	Horizon	pH(1:1)		Exchangeable Cations					ECEC	CEC	Fe_2O_3	Teture (mm)		
			H_2O	$CaCl_2$	Ca	Mg	K	Na	Al				<2	2-50	>50
					cmol$_c$/kg								%		
Meerigama	0-9	Ap	5.4	4.8	1.52	0.55	0.04	0.13	0.20	2.44	3.99	0.4	4.8	8.3	86.6
	9-34	Bw	5.2	4.1	0.49	0.40	0.04	0.03	0.20	1.16	3.26	0.4	9.8	8.6	81.2
	34-65	Bt_1	5.2	3.9	0.53	0.55	0.04	0.05	0.10	1.27	4.43	0.6	14.3	4.8	80.8
	65–85	Bt_2	5.3	3.8	0.08	0.75	0.04	0.08	4.00	5.67	8.98	1.2	31.1	6.2	62.1
	85-120	Bt_3	5.1	3.8	1.12	0.54	0.04	0.09	5.10	6.89	11.92	1.2	30.1	12.8	56.8
Badulla	0-26	Ap	5.5	5.0	3.00	1.43	0.45	0.08	0.10	5.78	16.48	9.4	14.0	56.7	28.8
	26-63	Bw	5.3	5.1	3.01	4.09	0.38	0.52	0.30	8.30	10.50	8.5	60.5	14.1	25.1
	63-98/104	Bt_1	5.9	5.6	3.03	6.72	0.09	0.19	0.10	13.13	17.21	10.4	64.1	17.4	18.2
	98/104-135	C_1	5.2	4.9	4.25	51.21	0.18	0.32	0.010	56.06	34.83	3.4	34.7	18.0	46.5
	135+	C_2	6.4	5.7	4.00	52.60	0.27	0.54	0.10	57.51	13.24	2.5	14.5	12.9	72.2
Kandy	0-14	Ap	6.4	6.2	12.00	0.58	0.29	0.57	0.10	13.54	14.71	3.0	27.8	5.6	66.5
	14-49	Bt_1	6.0	5.5	10.10	2.43	0.31	0.27	0.10	13.22	14.12	3.4	34.7	6.2	58.8
	49-97	Bt_2	6.3	5.7	11.70	3.38	0.16	1.31	0.10	15.65	16.77	4.0	44.8	5.8	49.1
	97-130	Bt_3	6.3	5.7	10.85	5.52	0.27	0.48	0.20	17.22	17.50	4.3	46.0	5.7	48.0
	130+	Bt_4	7.0	6.1	9.40	5.45	0.13	0.22	0.10	15.40	16.63	4.0	40.4	7.9	51.7
Anuradhapura	0-9	A_1	6.4	6.1	10.69	1.61	0.54	0.95	0.10	13.89	9.57	1.8	16.2	5.8	77.7
	9-24	Bt_1	6.1	5.6	6.28	1.65	0.32	0.48	0.10	8.83	9.72	2.5	24.3	9.1	66.2
	24-65	Bt_2	6.3	5.4	7.23	2.07	0.18	0.32	0.10	9.90	10.74	2.9	32.3	8.4	58.9
	65-120	Bt_3	6.2	5.3	7.69	2.11	0.13	0.24	0.10	10.27	12.51	3.1	35.9	9.3	54.3
	120-140/150	Bt_4	6.3	5.2	8.25	0.32	0.22	0.20	0.20	9.15	12.65	2.7	34.9	8.1	56.7

are classified either as Hapludults, Haplustalfs or Rhodustalfs (Table 1), based on their chemical properties (Table 2) or on profile morphology (data not shown).

Methods

pH in water and 0.01 M $CaCl_2$ was determined after 1 h of intermittent shaking and an overnight stand. CEC was determined by 1 M NH_4OAc buffered at pH7. Basic exchangeable cations were extracted by 1 M NH_4OAc; Ca and Mg were determined by atomic absorption spectrophotometry, while K and Na were determined by flame photometry. Exchangeable Al was extracted by 1 M KCl and determined colorimetrically (Barnhisel and Bertsch 1982). ECEC was calculated as the sum of basic exchangeable cations and exchangeable Al. Free iron oxide was determined by the method of Mehra and Jackson (1960). Texture of the soils was determined by the pipette method of Day (1965). The mineralogy of the clay fraction from the topsoil and the subsoil was determined by XRD analysis and TEM. The XRD analysis was conducted using a Philips diffractometer equipped with a graphite monochromator, operated from 3 to 50 degrees 2 - theta at a scanning speed of $^1/_2$ degree per minute. Selected samples were subjected to further tests in order to confirm the presence of smectite and chlorite.

Distilled water was added to the air-dried soils and subsequently incubated for 1 day at a matric suction of 10 kPa (Menzies and Bell 1988). This study assumes that a state of equilibrium is reached between the liquid and solid phase of the soils during the incubation period. Soil solutions were extracted by centrifugation at 2000 rpm for 1 h. pH and EC were determined immediately from 2-ml subsamples. The rest of the solutions were stored at 5°C for determination of Ca, Mg, Na, K, Al, Mn, Fe, P and S by inductively coupled plasma atomic emission spectroscopy (ICPAES). Nitrate in the soil solutions was determined by an autoanalyser.

RESULTS AND DISCUSSION

Soil General Properties

Rainfall distribution pattern in the areas covered by granite gneiss in Sri Lanka is variable, having values ranging from 4008 mm p.a. in Meerigama to 1329 mm p.a. in Anuradhapura (Table 1). The effects of rainfall on the soils are manifested clearly by soil pH and the amounts of basic exchangeable cations present. Where rainfall is high (Meerigama), basic exchangeable cations are low and the basic cations are lost via leaching. pH ($CaCl_2$) is < 5, thus the soil is acidic in reaction (Table 2). The topsoil from the intermediate agro-ecological zone (Badulla) contains reasonable amounts of basic exchangeable cations. Here the soil pH is higher than that at Meerigama. The basic exchangeable cations and the soil pH increase further as the rainfall decreases. This is shown clearly by the high pH value in the soil at Anuradhapura, where topsoil pH ($CaCl_2$) is higher than 6.

The exchangeable basic cations in the soils subjected to high rainfall (Meerigama) are low (Table 2) and exchangeable Al in the topsoil is also low, but at depths below 65 cm, the exchangeable Al is > 4 $cmol_c$/kg soil. However, in drier areas (Kandy and Anuradhapura), the basic exchangeable cations are very high, especially the exchangeable Ca. As pH in these soils is high, exchangeable Al is only present in trace amounts. Aluminium in the soil solution precipitates as $Al(OH)_3$ as pH approaches 5.5.

Exchangeable Mg in the C horizons of the soil at Badulla is extremely high, having values exceeding 50 $cmol_c$/kg soil (Table 2) which is presumably related to the presence of weathered ferromagnesium minerals in the granite gneiss. The typical Mg-bearing minerals in granite gneiss are biotite, pyroxene and amphibole, which on weathering become smectite if conditions are favourable for its formation. The high CEC (in terms of $cmol_c$/kg clay) observed in the C horizons points to the presence of this mineral.

The colour of the soils in the B horizon changes from yellowish brown (10YR 5/6) to red (2.5YR 4/6) and is presumably attributed partly to the presence of goethite and/or haematite which, in turn, depends on the availability of moisture in the soil profiles. The red soils occurring in the intermediate and dry zones, which are classified as Rhodustalfs, are normally associated with the presence of these Fe minerals. Haematite is coloured 5R to 2.5 YR (Bigham *et al.* 1978), while goethite is 7.5 YR to 10 YR (Kitagawa 1983). Goethite tends to impart yellowish brown to brown colours to soils (Allen and Hajek 1989). The soils studied are very deep, except the soil at Badulla site, which is seriously eroded. The Badulla site is located at

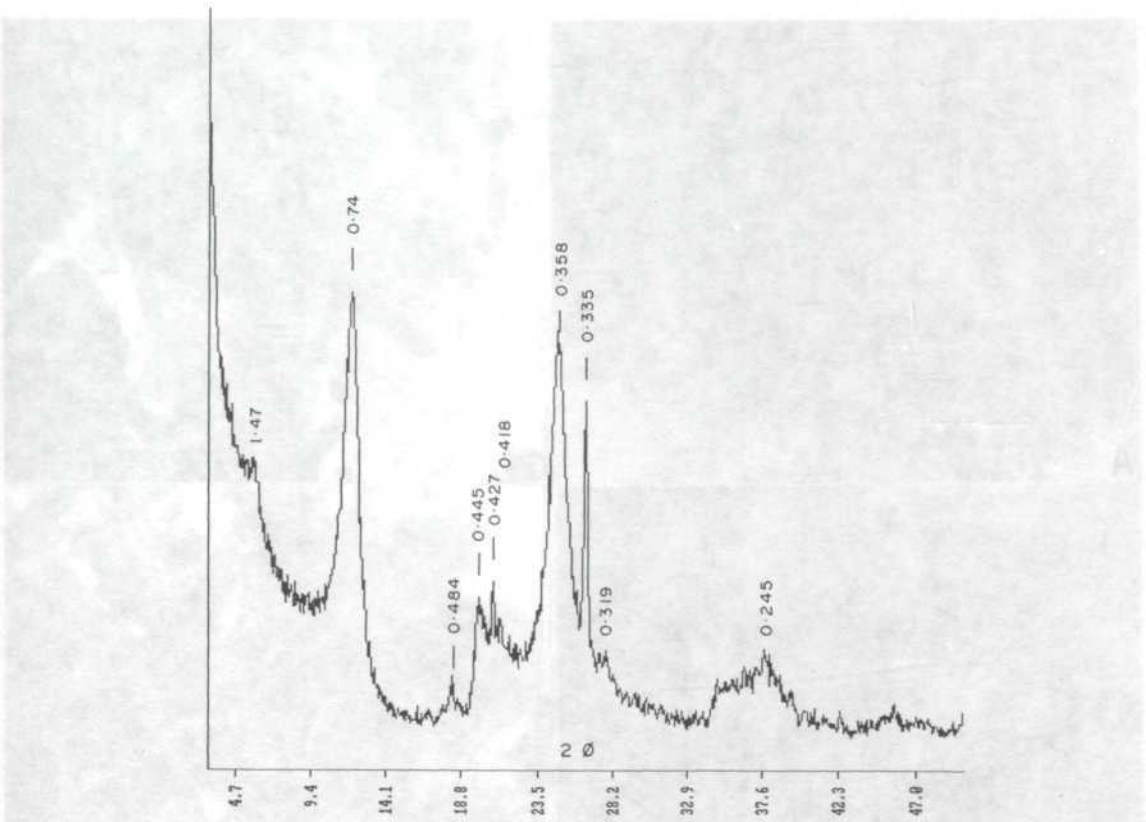

Fig. 2: X-ray diffraction pattern of Mg-saturated clay fraction from the Ap horizon of the soil at Meerigama

659 m k.a.s.l., on rugged topography having a slope of 100%. The topsoil is constantly removed by geological erosion during rainy months. Morphologically, the soil is not highly weathered as rock fragments containing weatherable minerals were observed in the B horizon.

Overall, the four soils under study are sandy in nature, an inherent physical property of the soils derived from granite gneiss, which is essentially composed of quartz, feldspar and biotite (black mica), with minor amounts of ferromagnesium minerals. The CEC (on the basis of 1 kg clay) is high, suggesting that some of the soils contain some smectite or mica-smectite mixed-layers. These minerals are the alteration products of biotite weathering under impeded drainage conditions (Velde 1992).

Mineralogy

The XRD analysis of the clay fraction from the Ap horizon of the soil at Meerigama shows the presence of smectite (1.47 nm), halloysite (0.74, 0.445 nm) kaolinite (0.358 nm) and quartz (0.427, 0.335 nm), with minor amounts of gibbsite (0.484 nm), feldspar (0.319 nm) and goethite (0.418, 0.245 nm) (*Fig. 2*). The subsoil showed similar mineralogy. Though present in minor amounts, goethite imparts yellowish brown 10 YR 5/6 colours to the soil (Kitagawa 1983; Allen and Hajek 1989). There are no biotite reflections in the diffractogram. The biotite present in the original rock could have been transformed completely to halloysite (Paramananthan 1977) and/or goethite under the strongly leaching environment (Eswaran and Heng 1976). In the humid tropics, biotite can also be transformed to kaolinite (Eswaran and Heng 1976). The halloysite and quartz XRD peaks are sharp and intense, showing their dominance in the clay fraction. The presence of smectite is also reflected in the high CEC (calculated on the basis of 1 kg clay), but the smectite is not clearly manifested in the TEM micrographs as smectite crystals are very small (Plate 1A, B).

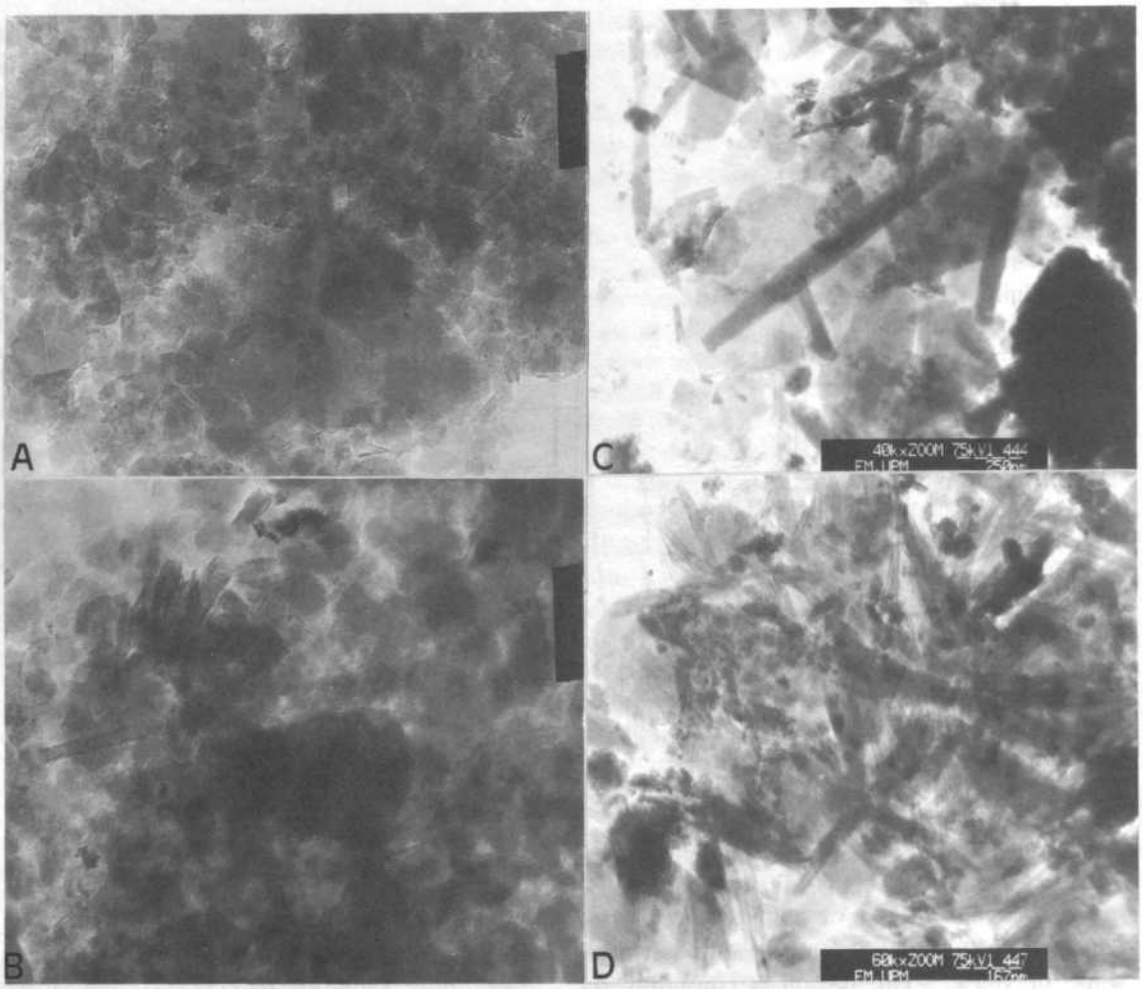

Plate 1. TEM micrograph of the clay fraction from the Ap (A) and Bt_3 (B) horizon of the soils at Meerigama and from the A_1 (C) and C_1 (D) horizons of the soils at Badulla

The TEM micrographs show clearly the presence of a mixture of halloysite and kaolinite in the clay fraction of the soil; the halloysite crystal is tubular while the kaolinite crystal is hexagonal in shape. The amount of halloysite decreases towards the soil surface, while kaolinite increases, which is similar to the observation of Paramananthan (1977) in the granite gneiss soil of Malaysia. This is an indication that halloysite changes to kaolinite in the course of soil weathering. X-ray diffraction pattern of the clay fraction from the Bt_3 horizon is similar to that of the Ap, showing a similar type of mineralogy in the soil of both horizons.

The topsoil at the Badulla site has sharp XRD reflections at 0.72 and 0.356 nm, suggesting the presence of large amounts of kaolinite (*Fig. 3*). Biotite is absent in this horizon although the XRD pattern of the clay fraction from the C_1 horizon indicates the presence of some biotite, shown by a weak reflection at 1.0 nm (data not shown). The biotite in the topsoil could have been transformed completely to goethite, halloysite or kaolinite as shown in the earlier studies (Eswaran and Heng 1976; Paramananthan 1977). The presence of goethite is shown by the reflections at 0.416, 0.269 and 0.242 nm (*Fig. 3*). Some smectite is present in the topsoil as is shown by a weak 1.43 nm reflection. However, the amount of smectite in the C_1 horizon is very high; the XRD reflection at 1.43 nm is very strong and intense (data not shown). Halloysite is present in small amounts in the topsoil; the amount increases in the subsoil (Plate 1C, D). This phenomenon is similar to the earlier observa-

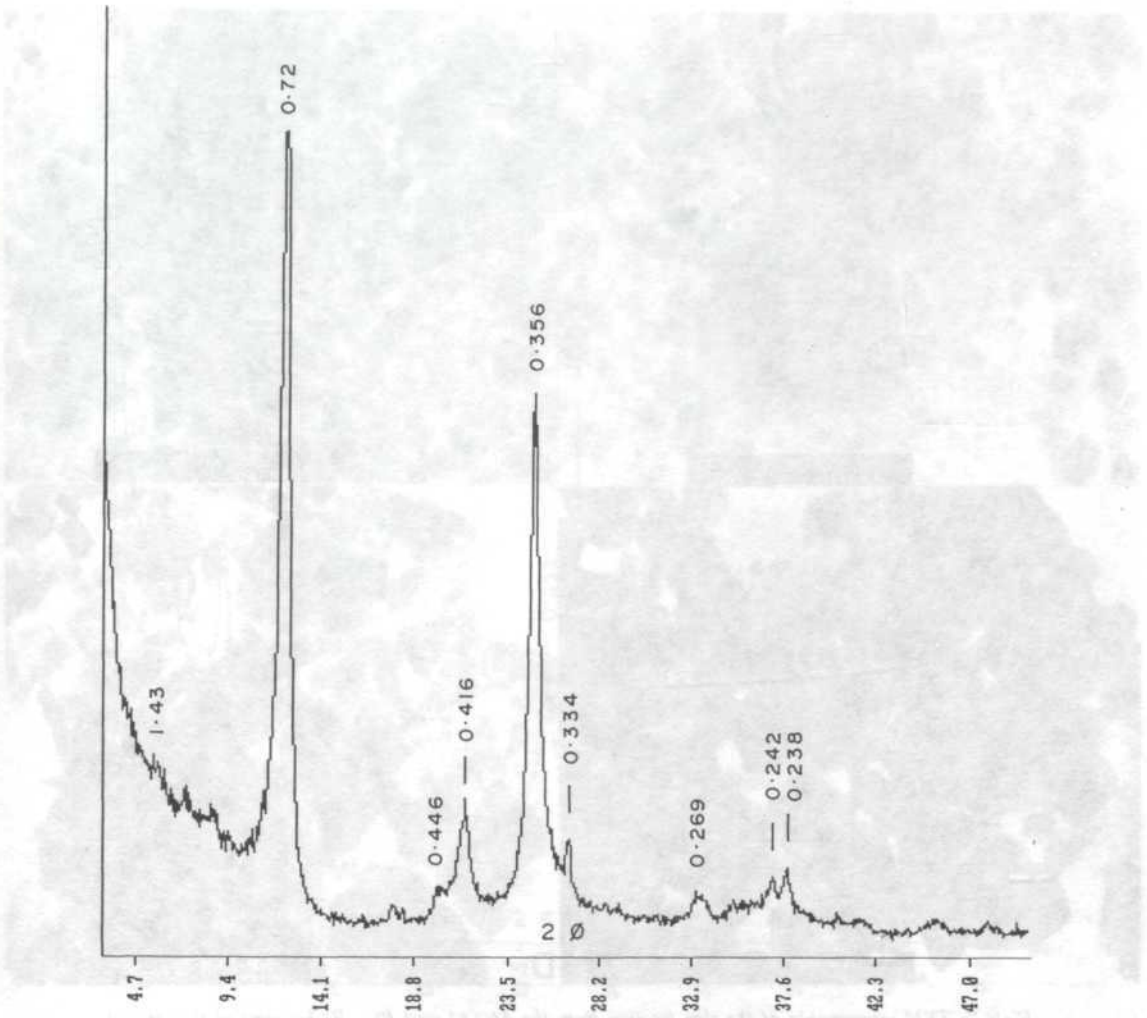

Fig. 3: X-ray diffraction pattern of Mg-saturated clay fraction from the Ap horizon of the soil at Badulla

tion in the TEM micrographs of the soil at the Meerigama site.

Smectite (1.53 nm), biotite (1.01, 0.499, 0.334 nm), quartz (0.425, 0.334 nm) and kaolinite (0.72, 0.355 nm) are the dominant minerals in the topsoil at the Kandy site (*Fig. 4*). Halloysite (0.445 nm) is present in minor amounts. The dominance of kaolinite is further confirmed by TEM observation (Plate 2A). The clay minerals in the subsoil are coated with Fe oxides (Plate 2B) as the amount of Fe_2O_3 in the soil is moderately high (Table 2). They are mostly present in the form of haematite (0.270, 0.251 nm) and goethite (0.270, 0.245 nm). The dominance of smectite in the soil is reflected by the high CEC; the CEC values throughout the profile are > 37 $cmol_c$/kg clay. The amount of halloysite in the subsoil is higher than in the topsoil, as is shown by the appearance of 0.74 nm reflection in the XRD diffractogram from the Bt_4 horizon (data not shown). Some of this halloysite, which is tubular in morphology, can be seen in the TEM micrograph in Plate 2B.

The A_1 horizon of the soil at Anuradhapura is dominated by biotite (1.02, 0.335 nm), quartz (0.426, 0.335 nm), halloysite (0.73, 0.446 nm), smectite (1.57 nm) and kaolinite (0.357 nm), with some feldspar (0.324 nm) and haematite (0.270, 0.251 nm) (*Fig. 5*). Plates 2C and D show the presence of some of these minerals in the clay fraction of the soil. The morphology of the halloysite and kaolinite is not clearly mani-

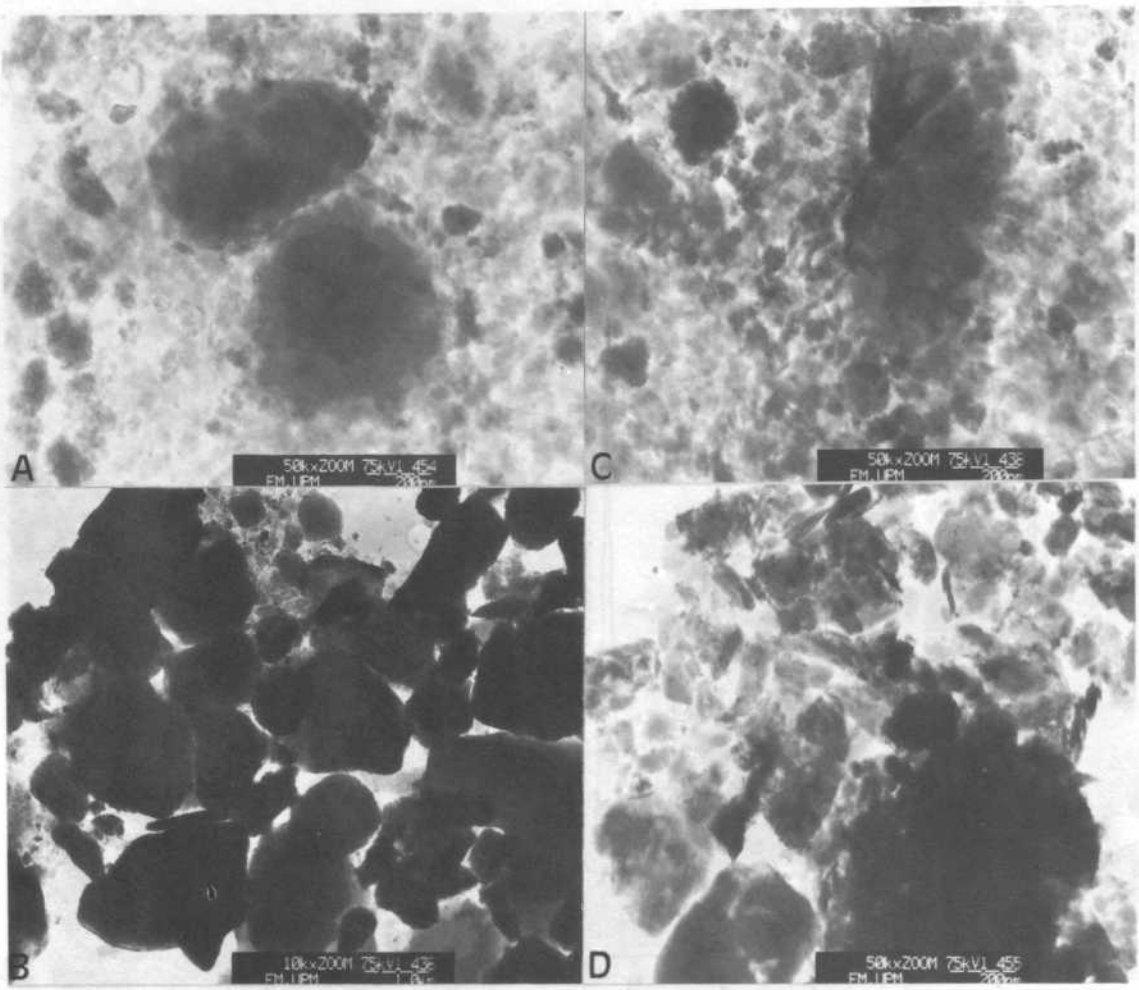

Plate 2: TEM micrographs of the clay fraction from the Ap (A) and Bt_4 (B) horizons of the soils at Kandy and from the A_1 (C) and Bt_4 (D) horizons of the soils at Anuradhapura

fested because the minerals are coated with Fe oxides, similar in nature to that of the soil at Kandy. The iron minerals are haematite, as is shown by the very clear XRD reflections at 0.270 and 0.251 nm. For this reason, the soil at Anuradhapura is red (2.5YR 4/6), and hence classified as Rhodustalf (Table 1). There is no evidence of the presence of goethite in the top-soil. The soil colour would have been yellowish brown to yellow if goethite is the dominant form of Fe mineral in the soil (Schwertmann 1993). In the Bt_4 horizon, however, some goethite was present together with haematite (data not shown). Other minerals in the clay fraction are similar to those found in the A_1 horizon.

The 0.270 and 0.251 nm reflections are more intense in the diffractogram of soil at Anuradhapura compared with that at Kandy, indicating that the amount of haematite is higher in the soil at Anuradhapura. According to Bigham *et al.* (1978) haematite is transformed to goethite as soil moisture increases. Therefore, the soils in the intermediate and wet zones do not have haematite and the form of Fe minerals is goethite. The presence of goethite in the Bt_4 horizon of the soil at Anuradhapura is a clear manifestation of the availability of some moisture in that horizon.

Gibbsite is absent in the soils at Kandy and Anuradhapura, but present in the soil of the wet zone. This suggests that gibbsite, which is an alteration product of feldspar, can only be formed if the moisture and temperature are sufficiently high. Gibbsite is a common mineral in the soil at an advanced stage of weathering.

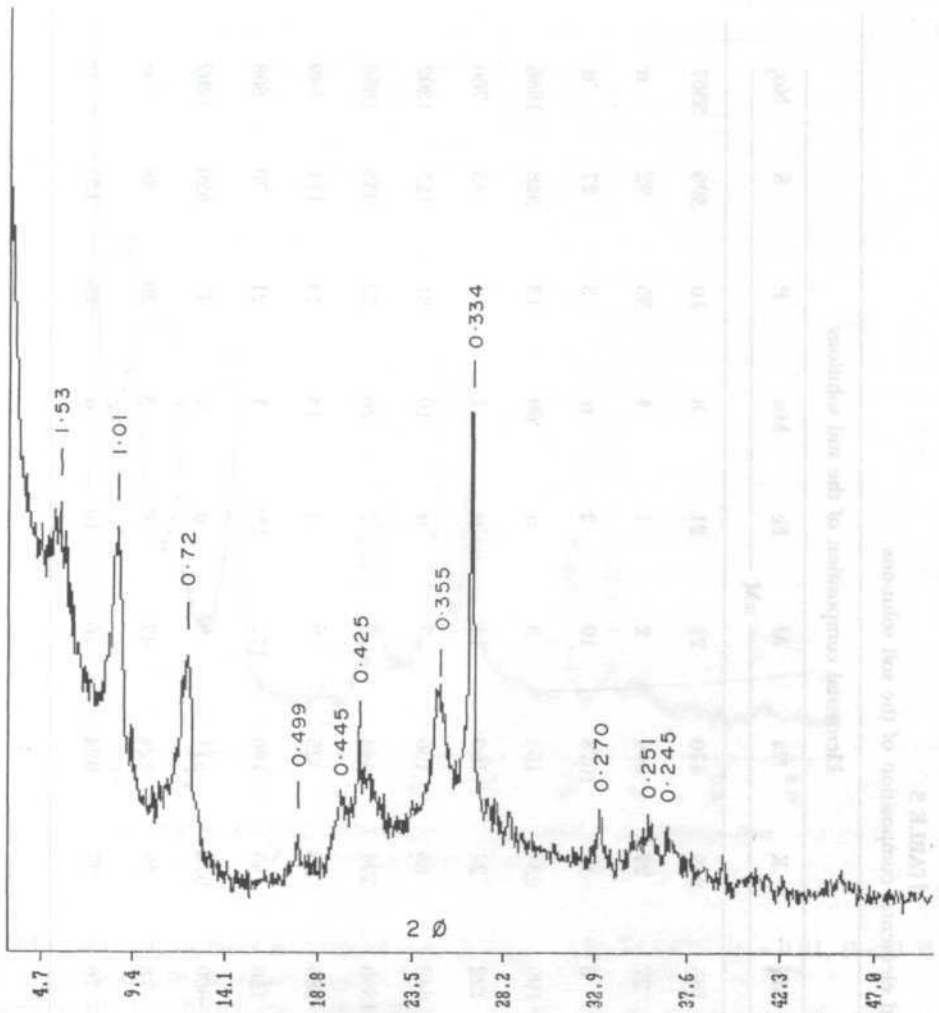

Fig. 4: X-ray diffraction pattern of Mg-saturated clay fraction from the Ap horizon of the soil at Kandy.

The Chemical Properties of Soil Solution

Generally, the soil solution Al concentration is low. High values are only observed in the Bt_4 horizon of the soils at Kandy and Anuradhapura, having values of 177 and 76 µM, respectively (Table 3). More Al is present in the soil solution of the drier area. Al is expected to exist as $Al(OH)_3$ which is the normal Al species stable at high pH. Mineralogical investigation reveals that the soils are dominated by kaolinite, halloysite and oxides of Fe, which are termed variable-charge minerals. This means that the negative charge on the soil surfaces increases with increasing pH (Uehara and Gillman 1981). Negative charge is, therefore, high at high pH, when Al is held tightly by the soil surfaces. Consequently, the soil solution Al concentration is low.

The soil solution pH (Table 3) is comparatively higher than the soil pH (Table 2). Lower pH_{CaCl2} value compared to pH_{sol} is due to greater hydrolysis of Al in solution of the former; $CaCl_2$ solution can extract more Al than water. The soil solution pH is related to the pHC_{CaCl2} by the following equation:

$$pH_{sol} = 4.56 + 0.52\ pH_{CaCl2}\ (r = 0.68,\ p < 0.05)$$

Although the basic exchangeable cations in the soils are high, their concentrations in the soil solution are low, except in soil solution Na concentration. It is believed that the cations are

TABLE 3
pH, EC and elemental composition of the soil solutions

Location	Horizon	pH	Elemental composition of the soil solutions										
			EC (mS/cm)	Ca	Mg	K	Na	Al	Fe	Mn	P	S	No_3
				mM									
Meerigama	Ap	6.9	63	250	185	249	470	23	21	8	10	396	3507
	Bt_1	6.9	53	37	27	27	669	2	1	4	35	92	tr
	Bt_3	6.2	59	18	6	18	1078	10	2	tr	3	27	tr
Badulla	Ap	7.0	44	152	199	234	154	3	tr	69	13	328	1856
	Bt_1	7.2	20	84	122	27	160	11	tr	1	16	43	766
	C_1	7.6	74	207	643	63	166	7	tr	10	81	125	1202
Kandy	Ap	8.4	207	2478	1393	324	444	2	2	26	52	933	1856
	Bt_1	8.2	179	964	385	55	325	2	1	14	13	111	549
	Bt_4	7.3	50	170	158	55	160	177	22	1	21	70	608
Anuradhapura	A_1	7.5	175	1946	860	976	511	9	tr	tr	41	520	1202
	Bt_1	7.0	71	170	78	39	224	47	6	3	39	88	tr
	Bt_4	6.9	35	132	76	37	624	76	10	tr	26	135	tr

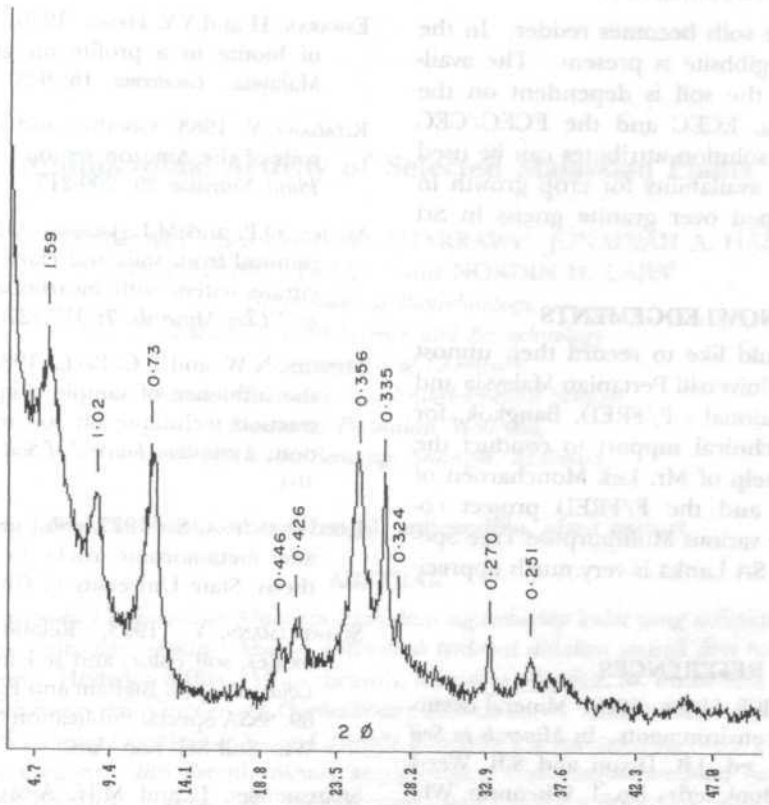

Fig. 4: X-ray diffraction pattern of Mg-saturated clay fraction from the A_1 horizon of the soil at Anuradhapura

strongly held to the soil surfaces because of the high CEC, contributed by smectite and/or being produced by the variable-charge minerals as a result of high pH. Nevertheless, the soil solution Ca concentration is highly correlated with the exchangeable Ca, and the relationship is represented by this equation:

$$Ca_{sol} = 311 + 147\ Ca_{exch}\ (r = 0.74,\ P < 0.01)$$

The exchangeable Ca in the Ap and A_1 horizons of the soils at Kandy and Anuradhapura are 12.00 and 10.69 $cmol_c/kg$, respectively (Table 2). The corresponding soil solution Ca concentrations are 2478 and 1946 µM (Table 3). The soil solution Ca concentration is higher in the dry than in the wet zone (Table 3). The Ca concentrations of soil solutions at the Meerigama, Kandy and Anuradhapura sites increase with depth. The soil solution Ca concentration is also highly correlated with the ECEC (calculated on the basis of 1 kg clay). The relationship is given by the following equation:

$$Ca_{sol} = 1.28\ ECEC^{1.47}\ (r = 0.91,\ P < 0.01)$$

In addition, the soil solution Ca concentration is related to the ECEC/CEC ratio by the equation:

$$Ca_{sol} = 342\ ECEC/CEC^{1.74}\ (r = 0.59,\ P < 0.05)$$

In contrast, the soil solution Mg and Al concentrations are not significantly correlated with any of the above-mentioned parameters.

CONCLUSION

The mineralogy and chemical properties of the soils in the three agro-ecological zones in Sri Lanka are different. Where the annual rainfall is high, soil pH and basic exchangeable cations are low. In the drier areas where leaching is restricted the pH and basic exchangeable cations are high. Kaolinite, halloysite and smectite are the major minerals in all the soils irrespective of the climatic conditions. While the amount of haematite increases as the soil get drier, the amount of goethite decreases, and consequently

the colour of the soils becomes redder. In the wet zone, some gibbsite is present. The availability of Ca in the soil is dependent on the exchangeable Ca, ECEC and the ECEC/CEC ratio. These soil solution attributes can be used as indices of Ca availability for crop growth in the soils developed over granite gneiss in Sri Lanka.

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Antimicrobial Activity of Selected Malaysian Plants

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ABSTRAK

Ekstrak metanol daripada 17 tumbuhan Malaysia telah disaring terhadap kulat yang meliputi yis dan kandida serta bakteria gram positif dan negatif. Aktiviti antimikrob terdapat didalam ekstrak dari tumbuhan Borreria latifolia, B. setidens, Hedyotis diffusa, H. nudicaulis, Morinda elliptica, M. umbellata *(Rubiaceae),* Sida rhombifolia *(Malvaceae) dan* Vitex ovata *(Verbenaceae). Ekstrak dari* S. rhombifolia *dan* B. latifolia *telah menunjukkan aktiviti yang luar biasa terhadap* Candida albicans, Ca. intermedia, Aspergillus ochraceous, Cunninghamella elegans *dan* Pseudomonas aeruginosa. *Walaubagaimanapun, hanya aktiviti yang serdehana melawan* Bacillus cereus, B. megaterium *dan* Candida lipolytica *yang diperhati. Aktiviti antimikrob tidak terdapat daripada ekstrak tumbuhan* Calophyllum inophyllum *(Guttiferae),* Entada *sp. (Leguminosae),* Eclipta alba *(Compositae),* Dendrotrophe umbellata *(Santalaceae),* Cardiospermum halicacabum *(Sapindaceae),* Glochidion lutescens, *dan* Euphorbia prunifolia *(Euphorbiaceae).*

ABSTRACT

Methanolic extracts of seventeen Malaysian plants were screened against fungi, including yeast and candida, as well as gram negative and gram positive bacteria. Antimicrobial activities were present in extracts prepared from Borreria latifolia, B. setidens, Hedyotis diffusa, H. nudicaulis, Morinda elliptica, M. umbellata *(Rubiaceae),* Sida rhombifolia *(Malvaceae) and* Vitex ovata *(Verbenaceae). Extracts from* S. rhombifolia *and* B. latifolia *showed exceptionally high activity against* Candida albicans, Ca. intermedia, Aspergillus ochraceous, Cunninghamella elegans *and* Pseudomonas aeruginosa. *However, only moderate activity was observed against* Bacillus cereus, Ba. megaterium *and* Ca. lipolytica. *Extracts from* Calophyllum inophyllum *(Guttiferae),* Entada *sp. (Leguminosae),* Eclipta alba *(Compositae),* Dendrotrophe umbellata (Santalaceae), Cardiospermum halicacabum *(Sapindaceae),* Glochidion lutescens *and* Euphorbia prunifolia *(Euphorbiaceae) gave negative results.*

INTRODUCTION

The tropical forest of Malaysia is blessed with more than 10,000 species of medicinal plants (Burkill 1930; Gimlette and Burkill 1930; Perry and Metzger 1980; Taylor and Wong 1987). Nakashini *et al.* (1965) reported the first screening of biological activity of indigenous Malaysian plants. Recently, Universiti Pertanian Malaysia has embarked on a systematic screening of medicinal plants for antimicrobial, cytotoxic and antiviral activities. This paper reports. the results of the screening of some Malaysian plants for antimicrobial activity. Filter paper disc diffusion and tube dilution methods were used for qualitative and quantitative evaluations of the antimicrobial activity against bacteria, fungi and candida.

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MATERIALS AND METHODS

Plants

Plant material was collected from the state of Selangor and identified by R. Kiew and S. Anthonysamy, Department of Biology, Universiti Pertanian Malaysia. Voucher specimens are deposited in the herbarium of the Biology Department. The plants included:

Compositae:	*Eclipta alba*
Euphorbiaceae:	*Euphorbia prunifolia, Glochidion lutescens*
Guttiferae:	*Calophyllum inophyllum*
Leguminosae:	*Entada* sp.
Malvaceae:	*Sida rhombifolia*
Rubiaceae:	*Borreria latifolia, B. setidens, Hedyotis diffusa, H. nudicaulis, H. verticillata, Morinda citrifolia, M. elliptica, M. umbellata*
Santalaceae:	*Dendrotrophe umbellata*
Sapindaceae:	*Cardiospermum halicacabum*
Verbenaceae:	*Vitex ovata*

Plant Extracts

Approximately 200 g of plant material was soaked overnight in methanol. The extracts were decanted and transferred into the rotary evaporator where evaporation occurred under reduced pressure. This extraction procedure was repeated three times for each plant sample. The dark residues obtained were used for the screening programme.

Chemicals

Standard streptomycin sulphate antimicrobial discs (30 µg/disc), nystatin powder from which 50 µg/ml solution was prepared for disc impregnation and nutrient broth were used.

Microorganisms

The microorganisms were obtained from the culture collection of the Department of Pharmacognosy, University of Mansoura, Egypt (which had originally come from the American Type Culture Collection, ATCC or Northern Regional Research Laboratories, NRRL), and the College of Pharmacy, University of Iowa, USA. The stock cultures were grown on Sabouraud-Dextrose Broth (SDB) for 24 hours at 28°C at which time the cells were harvested by centrifugation (4°C, 2000 rpm, 3 min.). The cells were washed and suspended in sterile 0.9 % saline solution to give a final concentration of between 10^5-10^6 CFU/ml (Colony Forming Unit) using a haemocytometer.

The microbial strains were: **Bacteria**: *Bacillus cereus* NRRL 14591B (UI-1447), *Ba. megaterium* ATCC 14581, *Pseudomonas aeruginosa* UI-60690; **Fungi**: *Aspergillus ochraceus* NRRL 398, *A. niger* ATCC 11394, *Cunninghamella elegans* ATCC 9244; **Candida and Yeast:** *Candida lipolytica* ATCC 2075, *Ca. albicans* ATCC 10231, *Ca. intermedia* ATCC 5159 and *Sacchromyces cerevisiae* NRRL 2034.

Assay for Antibacterial Activity

Disc Diffusion Method

Antibacterial activity of the plant extracts was tested using disc diffusion method according to Bauer *et al.* (1966). The discs were prepared by impregnating them with ethanolic solution of each extract (50 mg/ml). They were then evenly spaced on the agar surface previously inoculated with the suspension of each microorganism (10^5 - 10^6 CFU/ml) to be tested. Standard discs of nystatin (50 µg/disc) and streptomycin sulphate (30 µg/disc) were used as positive controls. The plates were incubated at 37°C for 24 hours and the antimicrobial activity was recorded by measuring the width of the clear inhibition zones around each disc.

Minimum Inhibition Concentration

The effectiveness of antibacterial activity of the plant extracts was quantified using the tube dilution method according to Hufford *et al.* (1975). Plant extracts at different concentrations (30-1000 mg/ml) were added into 5 ml broth. Cultures containing between 105-10^6 CFU were inoculated in 5 ml broth tubes and incubated for 24 hours at 37°C. Nystatin (50 mg/ml) and streptomycin sulphate (30 mg/ml) were used as standard antibiotics for comparison with the activities of the plant extracts against microbial species. For antifungal and anticandida activities, the SDB was used. Minimum inhibitory concentration (MIC, mg/ml) was recorded at the highest dilution which was free from microbial growth.

RESULTS AND DISCUSSION

The filter paper disc diffusion method is a very convenient and rapid method for screening of antimicrobial activity from plant extracts (Bauer *et al.* 1966). The formation of inhibition zone is observed as a result of the diffusion of antimi-

TABLE 1
Inhibition zone (mm) of the impregnated disc against bacteria, fungi and candida

Microbes	G_1 (w)	G_2 (w)	G_9 (l-t)	G_{10} (l-s)	G_{12} (w)	G_{13} (l-t)	G_{20} (r)	G_{21} (r)	S	N
A	18	13	13	14	20	19	12	11	25	n
B	21	22	20	20	-	20	20	17	30	n
C	-	-	15	16	18	-	-	-	25	n
D	-	-	25	25	8	9	8	12	n	28
E	19	20	8	8	12	11	13	16	13	22
F	8	-	25	24	15	14	21	15	29	22
G	10	-	12	13	8	11	-	-	n	20
H	17	8	20	20	13	17	13	12	n	26
I	18	19	21	19	9	11	19	13	n	25

Bacteria : A *Bacillus cereus* UI-1477 (NRRL 14591B), **B**. *Pseudomonas aeruginosa* UI 60690, and **C**. *Ba. megaterium* ATCC 14581. Fungi : **D** *Aspergillus ochraceous* NRRL398, **E.** *A. niger* ATCC11391, and **F.** *Cunninghamella elegans* ATCC 9244. Candida: **G.** *Candida lipolytica* ATCC 2075, **H.** *Ca. albicans* ATCC 10231, and **I.** *Ca. intermedia* ATCC 5159.

Plant extract: G_1 = *Hedyotis nudicaulis*, G_2 = *H. diffusa*, G_9 = *Sida rhombifolia*, G_{10} = *Borreria latifolia*, G_{12} = *B. setidens*, G_{13} = *Vitex ovata*, G_{20} = *Morinda elliptica*, G_{21} = *M. umbellata*.

Plant part: (w) = whole plant, (l) = leaf, (t) = twig, (r) root, (s) = stem.

Antibiotic: S= Streptomycin sulphate (30 µg/ml), N = Nystatin (50 µg/ml).

- : no activity

n: not tested

TABLE 2
Minimum inhibition concentration (MIC, µg/ml) of plant extract inhibiting the growth of bacteria, fungi and candida

Microbes	G_1 (w)	G_2 (w)	G_9 (l-t)	G_{10} (l-s)	G_{12} (w)	G_{13} (l-t)	G_{20} (r)	G_{21} (r)	S	N
A	62	125	125	125	62	62	250	250	31	n
B	62	62	62	62	500	125	62	125	31	n
C	500	250	125	125	125	-	-	-	31	n
D	500	500	62	62	250	250	250	125	n	31
E	62	62	250	250	125	125	125	125	n	31
F	500	500	62	62	250	250	125	250	n	62
G	250	500	125	125	250	250	500	500	n	31
H	125	500	62	62	125	125	125	125	n	31
I	62	62	62	62	250	250	62	125	n	31

Bacteria : A *Bacillus cereus* UI-1477 (NRRL 14591B), **B**. *Pseudomonas aeruginosa* UI 60690, and **C**. *Ba. megaterium* ATCC 14581. Fungi : **D** *Aspergillus ochraceous* NRRL398, **E.** *A. niger* ATCC11391, and **F.** *Cunninghamella elegans* ATCC 9244. Candida: **G.** *Candida lipolytica* ATCC 2075, **H.** *Ca. albicans* ATCC 10231, and **I.** *Ca. intermedia* ATCC 5159.

Plant extract: G_1 = *Hedyotis nudicaulis*, G_2 = *H. diffusa*, G_9 = *Sida rhombifolia*, G_{10} = *Borreria latifolia*, G_{12} = *B. setidens*, G_{13} = *Vitex ovata*, G_{20} = *Morinda elliptica*, G_{21} = *M. umbellata*.

Plant part: (w) = whole plant, (l) = leaf, (t) = twig, (r) root, (s) = stem.

Antibiotic: S= Streptomycin sulphate (30 µg/ml), N = Nystatin (50 µg/ml).

- : no activity

n: not tested

crobial compounds from the filter paper. The effectiveness of compounds found in the extract was quantified further by measuring the minimum inhibition concentration that inhibited the growth of microbes compared with the standard antibiotics (Hufford *et al.* 1975). Table 1 shows the size of the inhibition zone of streptomycin to be between 25 and 30 mm where the MIC value was 31 µg/ml when tested against *Bacillus cereus, Ba. megaterium* and *Pseudomonas aeruginosa.* In the case of fungi and candida, an inhibition zone of 22-28 mm was measured with MIC value of 31 µg/ml when nystatin was used. However, the MIC value for *Candida elegans* was 62 µg/ml (Table 1 and 2). In this study, the highest antimicrobial activity was observed at 50% level of the standard antibiotics (62 mg/ml for plant extracts and 31 µg/ml for standards). Plant extracts which gave MIC values of between 125 and 250 µg/ml were considered to possess moderate activity while those with MIC value of more than 250 µg/ml were considered to possess a weak activity.

Out of the seventeen extracts screened, only eight exhibited pronounced antimicrobial activities against the tested microbes (Table 1). Extracts from *Sida rhombifolia* and *Borreria latifolia* produced an inhibition zone in all the microbes and possessed exceptionally high activity against *P. aeruginosa, Aspergillus ochraceous, Cunninghamella elegans, Candida intermedia* and *Ca. albicans* (MIC value of 62 µg/ml), moderate activity against *Ba. cereus, Ba. megaterium* and *Ca. lipolytica* and weak activity against *A. niger.*

Hedyotis nudicaulis and *H. diffusa* showed high activity against *P. aeruginosa, Ba. cereus, Ca. albicans* and *A. niger* but only moderate activity against yeast (Table 1 and 2), the MIC values for both extracts being 62 µg/ml with the *H. diffusa* extract possessing MIC value of 125 µg/ml against *Ba. careus.* The MIC value of streptomycin and nystatin against these microbes was 31 µg/ml. Unfortunately these two plant extracts failed to inhibit *Ba. megaterium* and *A. orchraceous.* Extract of *H. diffusa* also failed to inhibit *Ca. elegans* and *Ca. lipolytica.* Higher concentrations of *H. diffusa* and *H. nudicaulis* extracts were required to inhibit these two microbes (MIC value of 500 µg/ml).

Except for *Ba. megaterium,* all tested microbes were inhibited by the B. *setidens* extracts. The extract was highly active against *Ba. cereus* and moderately active against *Ba. megaterium, A. niger* and *Ca. albicans.* Petroleum ether extract of *Vitex ovata* showed good antimicrobial activity against all tested species with the exception of *Ba. megaterium.*

Among the Rubiaceae species, *Morinda elliptica* exhibited high activity against fungi especially *A. niger, A. ochraceous, Ca. elegans:* moderate activity was observed against *Ca. intermedia.* Moderate antibacterial activity was shown by the extracts of *M. elliptica* and *M. umbellata* but the former was only active against *A. niger.*

Several of these plant extracts have potential as new antibiotics, in particular those from *S. rhombifolia* and *B. latifolia* which displayed inhibition against all the microbes tested.

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Genetic Variability, Correlations and Path Coefficient Analysis of Components of Seed Yield in Cowpea (*Vigna unguiculata*)

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Keywords: *Vigna unguiculata*, **cowpea, genetic diversity, correlations, path analysis**

ABSTRAK

*26 varieti kacang duduk (*Vigna unguiculata *L. Walp) telah dinilai di medan untuk mengkaji kebolehubahan genetik, hubungan antara-ciri dan juga analisa laluan komponen hasil biji benih. Hasil biji benih adalah ciri paling banyak berubah dengan pekali variasi genotip (gcv) dan pekali variasi penotip (pcv) masing-masing 22.11 dan 35.25 peratus. Hari-hari pengeluaran bunga adalah paling kurang berubah dengan gcv dan pcv masing-masing 1.93 dan 2.30 peratus. Berat bagi 100 biji benih mempunyai anggaran keterwarisan tertinggi 29.33 peratus, sementara bilangan peduksi bagi setiap tanaman menunjukkan anggaran ketewarisan terendah 30.11 peratus. Bilangan pedunkel dan cabang setiap tanaman serta bilangan pod pedunkel menunjukkan signifikan dan genotip positif korelasi dengan hasil biji benih. Hanya bilangan pedunkel dan bilangan cabang setiap tanaman menunjukkan penotip positif korelasi dengan hasil biji biji benih. Analisis pekali laluan menunjukkan hasil biji benih dipengaruhi oleh berat 100 biji benih, bilangan biji benih setiap pod, bilangan cabang setiap tanaman dan jumlah pod bagi setiap pedunkel.*

ABSTRACT

*Twenty-six varieties of cowpea (*Vigna unguiculata *L. Walp.) were evaluated in the field to study genetic variability, inter-character relationships as well as the path analysis of components of seed yield. Seed yield was the most variable character with genotypic coefficient of variation (gvc) and phenotypic coefficient of variation (pvc) of 22.11 and 35.25%, respectively. Days to flowering was the least variable with gvc and pvc of 1.93 and 2.30%, respectively. Weight of 100 seeds had the highest heritability estimate of 92.33% while number of peduncles per plant exhibited the lowest heritability estimate of 30.11%. Number of peduncles per plant, number of branches per plant and number of branches per peduncle showed signficant and positive phenotypic correlation with seed yield. Only number of peduncles per plant and number of branches per plant showed positive phenotypic correlation with seed yield. Path coefficient analysis revealed that seed yield was affected by weight of 100 seeds, number of seeds per pod, number of branches per plant and number of pods per peduncle.*

INTRODUCTION

Cowpea (*Vigna unguiculata*) is a grain legume which constitutes a major dietary protein in the humid and subhumid tropics. The protein content is about 24% (Elias *et al.* 1964) and the quantity is a function of the genotype and the environment (Bliss 1975).

Phenotypic variability and the heritability of character determine, to a large extent, the rate of genetic advance. Hence, it is essential to partition the overall variability into its heritable and non-heritable components in order to determine the most effective breeding procedures. The response of correlated characters can be predicted if the genetic correlations and heritabilities of the characters can be predicted if the genetic correlations and heritabilities of the characters are known. But as more charac-

ters are involved in correlation studies, the indirect associations between characters become more complex. In such a situation, path-coefficient analysis has been of great value in identifying direct and indirect associations (Dewey and Lu 1959).

Several investigations have shown that number of seeds per pod, pod length and weight of 100 seeds were moderately to highly heritable (Singh and Mehndiratta, 1969; Leleji 1975; Tikka *et al.* 1977; Erskine and Khan 1978). Erskine and Khan (1978) also reported moderate and low heritabilities for seed yield and number of seeds per pod, respectively. Kheradnam and Niknejad (1974) observed significant positive phenotypic correlations of seed yield with the number of pods per plant and number of seeds per pod.

The objectives of this study were to determine (a) genetic variability, (b) inter-character associations, and (c) the components of pod yield in cowpea.

MATERIALS AND METHODS

Twenty-six cowpea varieties were utilized for this study; 25 of these were obtained from the Grain Legume Improvement Programme of the International Institute of Tropical Agriculture, Ibadan, Nigeria.

The varieties were grown at the University of Agriculture Teaching and Research Farm, Abeokuta, during the late rainy season (September) of 1991. The varieties were grown in randomized complete block design with three replications. Each variety was grown in 2 x 2 m plots, each containing 44 plants. The plants were spaced 50 cm between rows and 20 cm apart within the row to give 11 plants per row. With the exception of the varieties at the borders, which had five rows to offset the border effect, each variety had four rows. Plants were sprayed with Cymbush (Cypermethrin) at the rate of 1.5ml/l every 2 weeks to control insect pests, while weeding was done when necessary.

From the competitive plants in the harvest area of $4m^2$ data were collected on the following characters: seed yield per square met, weight of 100 seeds, number of seeds per pod, pod length, number of pods per peduncle, number of branches per plant, number of peduncles per plant and number of days to flowering.

The plot means were subjected to analysis of variance and covariance according to the procedures outlined by Snedecor and Cochran (1967) and Kemphorne (1973).

A random model was assumed. Genotypic and phenotypic coefficients of variation were estimated using the formula suggested by Burton (1952). Broad-sense heritability estimates were calculated according to the formula suggested by Allard (1960). Genotypic and phenotypic coefficients of correlation were also calculated from the genotypic and phenotypic variances and covariances and of the characters. Environmental correlations were calculated as outlined by Falconer (1960).

Path-coefficients were calculated using the genotypic coefficients of correlations as outlined by Dewey and Lu (1959). The nature of the causal scheme, including characters and seed yield, is presented in *Fig. 1.*

RESULTS

Table 1 shows the analysis of variance and the range of the eight characters evaluted. The varieties were different from each other for all the characters evaluated except for number of branches per plant.

Table 2 presents the means, genotypic and phenotypic coefficients of variation and heritability estimates for the eight characters. Seed yield was the most variable character with genotypic coefficient of variation (gvc) and phenotypic coefficient of variation (pvc) of 22.11 and 35.25%, respectively. Number of days to flowering was the least variable exhibiting gcv and pcv of 1.93 and 2.30%, respectively. The other characters showed intermediate variation.

Weight of 100 seeds, which had intermediate gcv and pcv had the highest heritability estimate of 92.23%, followed by pod length, which had the heritability estimate of 82.12%. Number of pods per peduncle and number of days to flowering also exhibited high heritability estimates of 80.00 and 70.62%, respectively. Other characters showed low to intermediate heritability estimates.

Table 3 shows the genotypic, phenotypic and environmental correlation coefficients among the eight characters. Significant genotypic, phenotypic and environmental correlation coefficients were observed between number of peduncles per plant and number of branches per plant, number of pods per plant and days to flowering and between weight of 100 seeds and

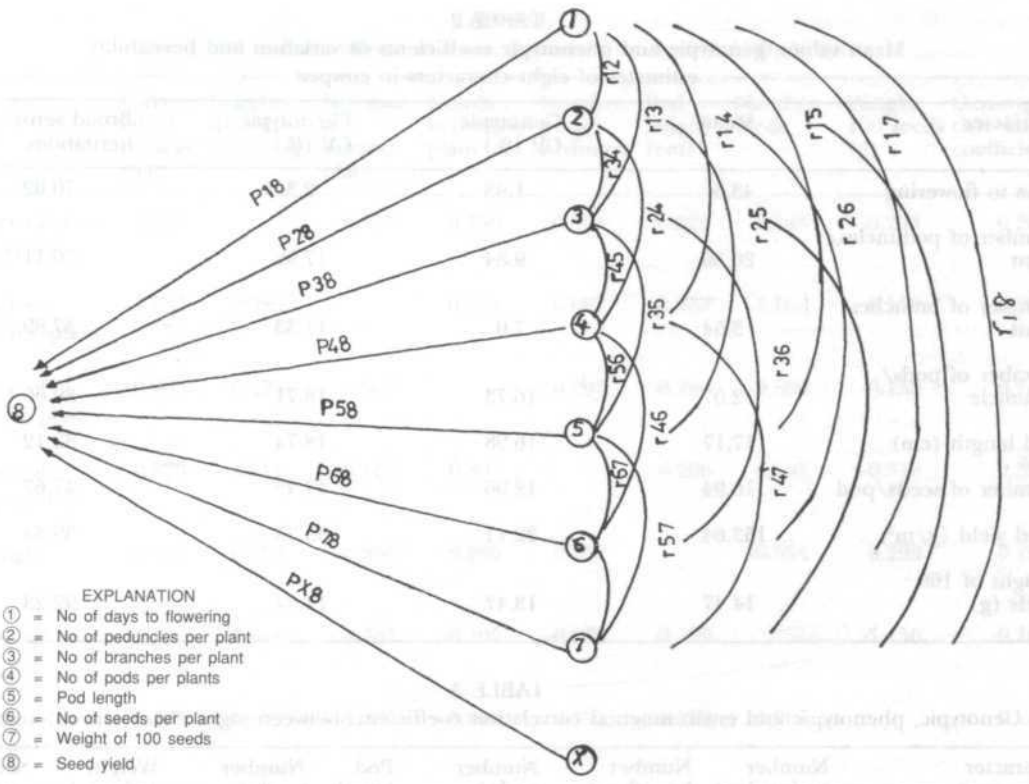

Fig 1: Path diagram of factors influencing pod yield in cowpea (source : Dewey & Lu 1959)

TABLE 1
Mean squares in the analysis of variance of characters in cowpea

Source of Variation	D.F.	Days to flowering	Number peduncles/ plant	Number branches	Number pods/ peduncle	Pod length (cm)	Number seeds/ pod	Weight 100 seeds (g)	Seed yield (g/m^2)
Block	2	0.17	5.88	0.52*	0.06	3.78	3.78	2.13	5879.66**
Genotype	25	2.44**	21.35**	0.35	0.40**	27.36*	7.12**	11.73**	5240.82**

*, ** = Significant at 5 and 1% levels of probability respectiely

number of seeds per pod. Similarly, all three correlation coefficients were signficant for the relationship between number of peduncles per plant, number of branches per plant and seed yield. Only genotypic correlation coefficients were signficant for the relationship between number of branches per plant, number of seeds per pod and days to flowering: between pod length, number of seeds per pod and number of peduncles per plant and between number of pods per peduncle and seed yield. Only environmental correlation was signficant for pod length and number of days to flowering, number of pods per peduncle and seed yield, and between pod length and weight of 100 seeds. Phenotypic and environmental correlations were signficant for pod length and number of pods per plant.

Table 4 gives the direct and indirect effects of seven characters on seed yield as well as the residual factors. Number of seeds per pod and weight of 100 seeds had the largest direct effects

TABLE 2
Mean values, genotypic and phenotypic coefficients of variation and heritability estimates of eight characters in cowpea

Character	Mean	Genotypic CV (%)	Phenotypic CV (%)	Broad sense (%) heritability
Days to flowering	43.6	1.93	2.30	70.62
Number of peduncles/ plant	20.36	9.84	17.92	30.11
Number of branches/ plant	3.54	7.0	11.33	37.89
Number of pods/ peduncle	2.07	16.73	18.71	80.00
Pod length (cm)	17.17	16.98	18.74	82.12
Number of seeds/pod	10.94	12.06	17.45	47.67
Seed yield (g/m^2)	153.64	22.11	35.35	39.34
Weight of 100 seeds (g)	14.47	13.47	14.47	92.23

TABLE 3
Genotypic, phenotypic and environmental correlation coefficients between eight characters in cowpea

Character		Number peduncles/ plant	Number branches/ plant	Number pods/ plant	Pod length (cm)	Number seeds/ pod	Weight 100 seeds (g)	Seed yield/m^2 (g)
Number of days to flowering	G	0.07	0.39*	0.42*	-0.29	0.45*	-0.17	0.20
	P	-0.03	0.09	0.40*	-0.05	0.27	-0.11	0.02
	E	-0.10	-0.03	0.66*	0.51**	0.30		-0.08
Number of peduncle/plant	G		0.58**	0.10	-0.51**	-0.46*	0.10	0.73**
	P		0.41*	0.01	-0.26	-0.26	0.11	0.39*
	E		0.52	-0.04	0.37	-0.31	0.11	0.46**
Number of branches/plant	G			0.34	-0.31	-0.22	-0.08	0.71**
	P			0.16	-0.19	-0.23	-0.03	0.43*
	E			0.17	-0.28	-0.34	-0.01	0.53*
Number of pods/ peduncle	G				-0.29	0.08	-0.22	0.39*
	P				-0.39*	0.01	-0.20	0.28
	E				-1.05**	-0.06	-0.13	0.37*
Pod length (cm)	G					-0.13	0.17	-0.15
	P					-0.11	0.18	-0.01
	E					-0.22	0.43*	0.12
Number of seeds/pod	G						-0.67**	-0.18
	P						-0.40*	0.06
	E						-0.50**	0.06
Weight of 100 seeds (g)	G							0.29
	P							0.16
	E							0.25

*, ** = Significant at 5 and 1% levels of probability respectively

G, P and E are genotypic, phenotypic and environmental correlation coefficients respectively

TABLE 4
Direct and indirect effects of some characters on seed yield in cowpea

Character	Direct effect on seed yield	Number days to flowering	Number peduncles/ plant	Number branches/ plant	Number pods/ peduncle	Pod length (cm)	Number seeds	Weight 100 seeds (g)	Genotypic correlation coefficient
Number of days to flowering	-1.218		0.117	0.350	0.365	-0.324	1.143	-0.293	0.20
Number of peduncles/plant	1.667	-0.085		0.524	0.087	-0.467	-1.168	0.173	0.73**
Number of branches/plant	0.903	-0.475	-0.967		0.296	-0.284	-0.559	-0.138	0.71**
Number of pods/peduncle	0.870	-0.511	0.167	0.307		-0.266	0.203	-0.378	0.39*
Pod length (cm)	0.916	0.353	-0.850	-0.280	0.252		-0.534	0.293	-0.15
Number of seeds/pod	2.539	-0.548	-0.767	-0.199	0.070	-0.199		-1.156	-0.18
Weight of 100 seeds (g)	1.725	0.207	0.167	-0.072	0.191	0.156	-1.701		0.29

*, ** = Significant at 5 and 1% levels respectively.
Residual Factors = -0.579.

on seed yield in spite of their low correlations. Only number of days to flowering had negative direct effect on seed yield.

Although number of seeds per pod had the largest direct effect on seed yield, it also had a large indirect effect through reduction in weight of 100 seeds. Similarly, weight of 100 seeds had a large indirect effect through the reduction in the number of seeds per pod. Although the direct effect of number of days to flowering was negative, it had a large indirect effect through increase in the number of seeds per pod.

The residual factors accounted for -0.579.

DISCUSSION

The wide range of variability observed for the eight characters evaluated may be attributed to the diverse genetic background of the varieties studied.

Heritability estimates alone indicate the effectiveness with which selection of genotypes can be based on phenotypic performance. However, heritability in conjuction with genetic coefficient of variation provides a more dependable measure of amount of genetic advance to be expected from selection (Burton 1952). The medium gcv and high heritability estimates observed for days to flowering and the relatively high gcv and low heritablility estimate for seed yield suggest limited scope for further improvement for these characters through selection.

Phenotypic correlation is a composite of genotypic and environmental correlations but it was observed that the genotypic correlation coefficients were, in most cases, higher than their corresponding phenotypic correlation coefficients. This has been ascribed to negative environmental correlations between the corresponding characters (Searle 1961).

Seed yield was genotypically correlated with number of peduncles per plant, number of branches per plant and number of pods per peduncle, indicating the reliability of these characters in selecting for yield. However, only number of peduncle per plant were phenotypically correlated with seed yield. Char-

acters which are phenotypically correlated but not genotypically correlated will not produce repeatable estimates of inter-character associations and any selection based on the relationship is likely to result in little, if any, genetic gain. This is true of the relationship between number of pods per peduncle and pod length. Also, characters that are genotypically correlated but not phenotypically correlated will not be of practical value in selection since selection is often based on the phenotypic performance of the characters. This is true of the relationship between number of days to flowering and number of branches per plant, between pod length and number of peduncles per plant, between number of peduncles per plant and number of seeds per pod, and between number of pods per peduncle and seed yield.

The positive correlation between seed yield and number of branches per plant may be related to greater photosynthetic capacity provided by more leaves since the branches bear most of the leaves. Also, more branches imply more pod-bearing peduncles and hence number of days to flowering, and number of branches per plant suggests that early-flowering varieties produce fewer branches and thus yield less than varieties that flower late.

Negative correlation between pod length and number of peduncles per plant indicated that the varieties with long pods produced lower numbers of peduncles. Unless the length of the pod can compensate for the low number of peduncles, such varieties are likely to yield less. However, since the number of seeds per pod and the number of peduncles per plant were negatively correlated, it appears that selecting for high number of peduncles will result in a low number of seeds per pod. The fact that weight of 100 seeds and number of seeds per pod were negatively correlated indicates that by selecting for a high number of seeds per pod, one is indirectly selecting for light seeds. Since there was significant association between number of peduncles per plant, number of branches per plant, number of pods per peduncle and seed yield, such characters should be selected for whenever high seed yield is the objective.

Generally, low environmental correlation indicates that phenotypic correlation will be a good index of genotypic correlation (Falconer 1960). The signficant environmental correlation observed between number of peduncles per plant, number of branches per plant, number of pods per plant and seed yield indicates that selection for yield on the basis of the phenotypic performances of these characters will not be effective. However, the high environmental correlation and low genotypic correlation between weight of 100 seeds, number of pods per plant and pod length suggests that environmental correlation would be a more reliable index of phenotypic correlation.

Correlation measures mutual association with no regard to causation, whereas path analysis specifies causes and measures their relative importance (Dewey and Lu 1959). That the number of seeds per pod and weight of 100 seeds had the largest direct effects on seed yield in spite of their low correlation with it, indicates the defects of selecting on the basis of inter-character correlations alone. The path coefficient analysis revealed that the poor association between number of seed per pod, weight of 100 seeds and seed yield was largely due to indirect effects through reduction of weight of 100 seeds and number of seeds per pod respectively. The fact that number of peduncles per plant, number of branches per plant and number of pods per peduncles were positively correlated with seed yield, with relatively large direct effects on seed yield, indicates that these characters are also important when selecting for high seed yield.

On the basis of path analysis, it is established that seed yield in cowpea is affected by weight of 100 seeds, number of seeds per pod, pod length, number of branches per plant and number of pods per peduncle. For selection purposes, however, emphasis should be placed on those characters with high heritability in order to produce repeatable results. Therefore weight of 100 seeds, number of seeds per pod and number of pods per peduncle should be selected for whenever high yield is the objective.

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Grain-size Distribution of Sediment in the Vicinity of Setiu Lagoon-estuary System

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ABSTRAK

Enapan di sistem lagun-muara di Setiu, pantai timur Malaysia kebanyakkannya adalah terdiri dari puin kasar hingga ke sangat halus dengan nilai kepencongan yang kebanyakkannya negatif. Kawasan muara sungai adalah dipengaruhi oleh daya pengangkut dan hakisan. Tiada terdapat kelodak dan tanah liat di muara sungai ini adalah kerana kurang terdapatnya faktor pemendapan yang dipengaruhi oleh arus yang kuat berbanding dengan kawasan lagun. Enapan di kawasan pantai adalah pasir kasar ke halus. Saiz butiran min berkurang ke arah barat-laut pantai itu. Nilai kepencongan pasir pantai kebanyakkannya negatif yang mana menunjukkan kawasan kajian dipengaruhi oleh ombak dan arus yang agak kuat.

ABSTRACT

The sediments in the Setiu Lagoon-estuary system on the east coast of Malaysia consist mostly of coarse to very fine particles. The major portions of the sediment are negatively skewed. The estuary area is under the influence of transportative and erosive forces. The lack of silt and clay in the estuary is attributable to less depositional factor under the influence of stronger currents than in the lagoon area. The beach sediment ranges from coarse to fine sand. Generally, the mean grain-size decreases towards the north-west sector. The skewness value of the beach sand area is mostly negative, indicating that the study area is under the influence of rather strong wave and current action.

INTRODUCTION

An understanding of the distribution pattern of sediments is fundamental to the successful design and operation of coastal structures such as jetties, breakwaters and groins and to effective management of coastal zones. The estuary and lagoon areas are constantly undergoing physical changes. The causative factors of sediment distribution are cyclic in nature, and include wind, wave, tide and current (Pethick 1984). Man-induced activities are equally important factors affecting sediment distribution. In the past, especially in Malaysia, the major interest in estuaries and lagoons has been primarily biological, resulting in a notable lack of literature on specific coastal, physical and geological processes. No study of physical and sedimentation processes on Setiu Lagoon-estuary system exists. The Malaysian Drainage and Irrigation Department (Jabatan Parit dan Taliair Malaysia 1977) conducted river discharge measurements for a few selected points on the Setiu and Chalok rivers but did not describe physical processes within the estuary. Salleh and Hussain (1986) collected temperature and salinity data for a feasibility study for a mariculture project in the Setiu estuary but did not explain the circulation or other physical processes. The purpose of this study is to describe the general distribution of the beach and estuarine sediment along the coastline of a Setiu Lagoon-estuary system.

STUDY AREA

The lagoon-estuary system investigated extends from latitude 5° 35'N to 5° 45'N and from longitude 102° 40'E to 102° 49'E and is located on the east coast of Peninsular Malaysia about 60 km north-west of Kuala Terengganu (*Fig.1*). The system forms one of the principal water resources of north-west Terengganu. The Setiu lagoon-estuary is of primary oceanographic interest since it is one of the large estuaries on the Terengganu coast into which two major river systems empty. The major sources of freshwater are the Setiu and Chalok rivers that drain the southern-eastern part of the study area. The estuary area is the region along the south-eastern side of the study area from the bridge at Kampung Penarik to Kampung Payang (Stations 1-13). The lagoon area is the section from Kampung Che Buis to Kampung Benting Lintang (Stations 14-25). One striking topographical feature within the estuary and lagoon area is a series of small islands that act as sediment traps and prevent migration of sediment. In general, the estuary area is deeper than the lagoon area.

High rainfall is recorded during the monsoon season. The north-east monsoon prevails between November and March, and the rest of the year is the transition and south-west monsoon periods. The mean annual temperature lies in the range of 25.6 °C to 27.8 °C. The temperature of surface water is typical of tropical waters, being 27 °C to 28 °C and belongs to the surface type with warm temperatures of more than 25 °C (Leong 1974) and low salinity of less than 34 ppt. Phillips (1985) described the tides along the Terengganu coast as having mean spring tide in the range of 1.8 m. The tidal ranges in the study area nowhere exceeded 2m and the area conforms to the low mesotidal coastal type (Hayes 1979). The coastal current usually flows parallel to the coastline in a southerly direction during the north-east monsoon but is reversed for the rest of the year (Dale 1956). Current in the south-eastern region of the estuary (i.e. near the head of the estuary) is mainly a combination of tide and river outflow. In the lagoon area, tides seem to be the major force in the water movement. The current speed is greater at the estuary area, indicating that it is more active in terms of hydraulic energy level than the lagoon area (Rosnan 1988). NNE-NE waves predominate during NE monsoon seasons whereas NE-SEE waves predominate during the other seasons. The most frequent wave height is between 1.0 to 1.5m. The most prominant winds come from N-NE and SE-S direction. Winds stronger than 20 km/h are mainly from NE-ENE directions. NE-E wind occupies about 70% of the wind frequency from the sea. Raj (1982) stated that there are two net directions of present-day beach sediment transport by littoral drift along the Terengganu coastline, a north-westward transport, to the northwest and a southward transport, south of Kuala Terengganu. The average annual rates of sediment transport for the Setiu area are 30 to 75 m/year and are considered moderate. The

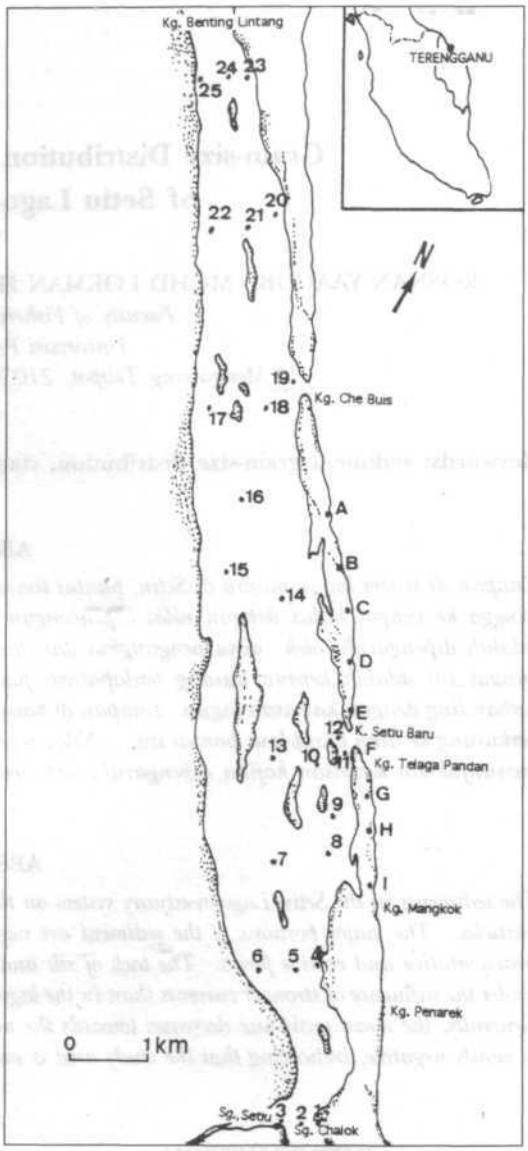

Fig 1: Location of the sampling stations

longshore drift in both directions probably contributes the quartz sand making up the beach.

MATERIALS AND METHODS

Sampling Technique

Thirty-four samples were collected with an Ekman grab sampler in May 1990 in the estuary and lagoon areas (*Fig. 1*). At every sampling station sediment sub-samples were taken from the centre of the grab with a plastic corer (diameter 4.6 cm and length 25 cm). The physical appearance of the sediment (such as colour and observed textural classes) were recorded on site. The beach samples were collected in plastic bags from the foreshore area at each station in October 1990.

Analytical Technique

The sediment samples were air dried and quartered by hand (Krumbein and Pettijohn 1938). A small portion of the samples (50 - 100 g) was used for textural analysis by the wet sieving and pipette method as described by Buller and McManus (1979). The coarse fraction (particles with diameter greater than 4 phi or 63 μn) were analysed using the dry sieving technique. Based on the data obtained, statistical measures were calculated according to the graphical measures of Folk and Ward (1957) as follows:-

$$\text{Mean } (M_z) = \frac{\text{Ø16} + \text{Ø50} + \text{Ø84}}{3}$$

$$\text{Sorting Coefficient } (\sigma_1) = \frac{\text{Ø 84} - \text{Ø16}}{4} + \frac{\text{Ø95} - \text{Ø5}}{6.1}$$

$$\text{Skewness } (S_k) = \frac{\text{Ø16} + 2\,\text{Ø84} - 2\text{Ø50}}{2(\text{Ø 84} - \text{Ø 16})} + \frac{\text{Ø5} + \text{Ø95} - 2\text{Ø50}}{2(\text{Ø 95} - \text{Ø 5})}$$

RESULTS AND DISCUSSION

The sediments at the sampling sites ranged from sand to sandy loam. The sample colour was mostly yellowish brown in the estuary area and dark grey in the lagoon area. In the estuary region all the samples were found to have a range in the sand classes. Visual examination of the coarse fraction (larger than two millimetres) shows that it is composed almost exclusively of carbonate detritus, mostly shell fragments. Sand percentages within the sampling sites range from 93.6 to 97.80%, silt between 0 and 22.36% and clay between zero and 9.30% (Table 1). Results showed higher percentages of sand in the estuary area, especially at the inlet. At the outer inlet of lagoon and adjacent beach, the sediment consisted of 100% sand. Silt content was higher at the central part and lower in the mid-channel of the lagoon. The silt percentage generally decreased toward the inlet and there is lower clay content in the area away from the inlet. There is little mixing of gravel and mud.

Plots of the graphic mean, sorting and skewness values show estuary-lagoon sediment populations which can be related to spatial variation. The range of mean grain size is 0.15 - 1.58 phi. The mean diameter also indicates that most of the sediment in the system consists of coarse to very fine sand, with greater prevalence of very fine sand size according to the classification of Wentworth (1922). The few samples with a mean grain-size coarser than sand are unequally distributed but always occur at the inlet area. However mean grain-size values at Stations 11 and 12 are in the medium to coarse sand range and showed great variation in space and time.

Sediments in the lagoon-estuary system have a range of sorting coefficient of 0.82 - 2.11 phi. There was a large group of samples with a sorting coefficient between 1 - 2 phi (poorly sorted). Most of the remaining samples showed sorting coefficient near 0.90 phi (moderately sorted). The sediments for the most part are poorly sorted, but a significant portion of the area is influenced by moderately sorted sediment. The lowest values (best sorting) were confined to the region at Stations 1 and 6, near the head of the estuary and lagoon respectively. The highest value (poorest sorting) occurred at Station 12. In general, sorting of sediment improves as grain size decreases.

Skewness values in the estuary and lagoon system range from -0.46 to -0.22. Positive values of skewness indicate that the normal size distribution is influenced by finer sizes. Most of the sediments were negatively skewed and these

TABLE 1
Particle size distribution and the statistical parameters of sediments in the estuary-lagoon area.

Station No.	Gravel %	Sand %	Silt %	Clay %	Mean M_z	Sorting Coefficient	Skewness S_k
	> - 1 Phi	-1 to 4 Phi	8 - 4 Phi	< 8 Phi			
1	8.10	91.9	None	None	0.25	1.38	0.07
2	16.20	93.8	None	None	0.59	1.04	-0.04
3	17.10	82.9	None	None	0.26	1.39	0.07
4	3.70	96.3	None	None	0.48	0.93	-0.01
5	10.00	90.0	None	None	0.63	1.21	-0.18
6	18.90	81.1	None	None	0.20	1.17	-0.09
7	3.20	96.8	None	None	2.27	2.00	0.24
8	2.90	97.1	None	None	1.27	1.40	0.06
9	4.40	95.6	None	None	0.70	1.00	-0.11
10	3.50	96.5	None	None	0.96	0.82	-0.21
11	2.20	97.8	None	None	0.31	0.85	0.22
12	3.70	96.3	None	None	1.58	2.11	0.19
13	8.60	91.4	None	None	1.40	0.83	-0.11
14	1.50	97.3	None	None	1.48	1.09	0.05
15	6.10	93.3	None	None	0.70	1.07	-0.13
16	1.10	97.5	None	None	0.32	0.70	-0.46
17	-	86.7	8.40	5.60	0.52	1.08	-0.09
18	-	88.3	7.12	7.12	0.98	1.02	-0.11
19	-	73.6	19.10	7.30	0.60	1.01	0.01
20	-	94.6	5.37	0.03	0.58	1.15	0.04
21	-	95.3	4.61	0.03	0.27	1.96	-0.34
22	-	93.5	4.00	3.00	0.17	1.93	-0.23
23	-	94.1	1.40	4.40	0.15	1.87	-0.20
24	-	82.0	14.90	3.10	0.80	1.98	-0.29
25	-	94.2	1.30	4.60	0.90	1.45	-0.31

Estuary (Stations 1-13)
Lagoon (Stations 14-25)

areas are probably associated with sediments deposited in an environment dominated by strong current action or might be due to the accumulation of coarse grains at these areas (Buller and McManus, 1979). Skewness values decrease as the grain size increases. Following Visher (1969), it is suspected that the coarser sediment (less than 1 phi) transport mechanism is by means of bedload, while the remaining fraction in the size range of 2 to 1 phi is by saltation and fraction of sizes beyond 2 phi is by means of suspension.

TABLE 2
The statistical parameters of the sediment at the Setiu beach

Station No.	Mean M_z	Sorting Coefficient (C_1)	Skewness S_k	Type of Sorting
A	0.49	0.59	-0.06	Moderately well sorted
B	0.19	0.63	-0.34	Moderately well sorted
C	0.58	0.84	-0.26	Moderately sorted
D	1.13	0.88	-0.04	Moderately sorted
E	0.88	0.67	-0.16	Moderately well sorted
F	0.32	0.69	-0.08	Moderately well sorted
G	0.87	0.84	-0.10	Moderately sorted
H	0.90	0.63	-0.24	Moderately sorted
I	0.98	0.78	0.11	Moderately sorted

The data obtained by the dry sieving technique for all the composite beach sand are summarized in Table 2. Mean diameter ranged from 0.19 to 1.13 phi. It was found that Station D had the smallest grain size of all stations. The mean diameters also indicate that most of the beach sand consists of medium and fine-grained sand. Beach sand generally increased towards the South. In areas near the river inlet, the sediment had a relatively coarser grain size with coarser sand found to the south-west of the river mouth.

The sorting coefficient ranged from 0.59 to 0.88. All stations had either moderately well-sorted or moderately sorted sediment. Stations A and B at the extremity away from the river mouth had moderately well-sorted sediment. The skewness value was highest at Station I. Most of the beach sand was negatively skewed. This indicates that the beach sand has excess coarse fraction and the area is subjected to high wave energy or is under the influence of strong currents.

CONCLUSION

The estuary area is composed of poorly sorted coarse sediment and the lagoon area is of moderately sorted fine sediment. This shows that the estuary area is more active in terms of hydraulic energy level than the lagoon area. Furthermore, lack of silt and clay in the estuary area is attributable to a lack of depositional processes under the influence of relatively stronger currents compared to the lagoon area where depositional processes are active.

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