Journal of Science & Technology in the Tropics

Volume 7 Number 1 June 2011

JOSTT

DEDICATED TO THE ADVANCEMENT OF SCIENCE AND TECHNOLOGY RELATED TO THE TROPICS

Journal of Science & Technology in the Tropics

AKADEMI SAINS MALAYSIA

COSTAM

Volume 7 Number 1
June 2011
ISSN 1823-5034
9 771823 503009

CONTENTS

Journal of Science & Technology in the Tropics Volume 7 Number 1 April 2011

stream and pond at edge of forest, ca 780-850m, 04° 31.065N, 101° 30.894E.
4. Ringlet area (21.ix): highly disturbed lake, small open pools nearby and a small high gradient forest stream with a mud and rocks substrate, ca 1100m, 04° 25.877N, 101° 23.305E.
5. Pelana Jor area (22.ix) – rocky streams and muddy tributaries in highly disturbed forest, ca 580-710m, 4° 22.090N, 101° 20.028E.
6. Sg. Relong area (23.ix) – rocky high gradient stream in forest, sand bottomed low gradient stream and swamp area in highly disturbed forest, ca 610m, 4° 24.775N, 101°, 30.289E.
7. Kuala Boh area (25.ix) – rocky streams in disturbed forest and in open, ca 670m, 4° 26.032N, 101° 29.623E.
8. Kuala Woh area (27.ix) – large rocky low gradient stream and small tributary in forest, ca 75m, 4° 14.591N, 101° 52.629E
9. Sg. Pauh area (18-27.ix) – forest with a rocky stream and marshy areas, ca 1470m, 4° 28.805N, 101° 23.042E. We were staying at this location, and this area was only sampled incidentally late in the day after the main fieldwork was over.

Sampling and identification

Most of the collecting carried out during the survey was of adult Odonata, and was conducted using handheld nets. Some collecting of larval Odonata, chiefly Anisoptera, was also conducted. Adult specimens were preserved either by treatment with acetone, drying or immersion in ethanol, larvae by preservation in ethanol. In addition a number of larvae were reared in captivity by one of the authors (CYC). The family level taxonomy used below follows that in [1].

The material collected is held in either the Centre for Insect Systematics at Universiti Kebangsaan Malaysia (UKM), collection C.Y. Choong, collection R.A. Dow; specimens in ethanol are in the collection of National Museum of Natural History Naturalis (Leiden, Netherlands) (RMNH). Specimens of adult Odonata were identified to species under a stereomicroscope, by reference to the relevant literature, and direct comparison with material, including type material, held in The Natural History Museum, London (BMNH) and RMNH.

RESULTS

A total of 55 species of Odonata were collected. 301 individual specimens of adult and larval Odonata, belonging to 14 families, were collected. The species collected, locations and number of specimens collected at each location on a given date are listed below, together with notes on species of particular interest. A summary is given in Table 1.

Zygoptera

Amphipterygidae

1. *Devadatta argyoides* Selys, 1859 – 2: 1 m#, RAD, 19.ix; 1 m#, RAD, 24.ix; 3: 1 m#, RAD, 2 m#, CYC, 20.ix; 4: 2 m#, CYC, 21.ix; 5: 1 m#, RAD, 1 m#, CYC, 22.ix; 6: 1 m#, CYC, 23.ix; 7: 1 m#, RAD, 25.ix; 8: 4 m#, RAD, 1 m#, CYC, 27.ix.

Chlorocyphidae

2. *Aristocypha fenestrella* (Rambur, 1842) – 2: 1 m#, RAD, 1 larva, 2 m#, 1 f#, CYC, 19.ix; 3: 2 m#, RAD, 1 m#, CYC, 20.ix; 5: 1 m#, RAD, 2 m#, CYC, 22.ix; 6: 1 m#, CYC, 23.ix; 7: 1 m#, RAD, 25.ix.
3. *Heliocypha biforata* (Selys, 1859) – 8: 1 m#, CYC, 27.ix.
4. *Heliocypha perforata* (Percheron, 1835) – 8: 1 m#, RAD, 1 m#, CYC, 27.ix.

Euphaeidae

5. *Dysphaea dimidiata* (Selys, 1853) – 8: 1 m#, RAD, 27.ix.
6. *Euphaea impar* Selys, 1859 – 8: 1 m#, RAD, 27.ix.
7. *Euphaea ochracea* Selys, 1859 – 5: 2 m#, RAD, 1 m#, CYC, 22.ix; 8: 1 m#, RAD, 1 m#, CYC, 27.ix.

Calopterygidae

8. *Echo modesta* Laidlaw, 1902 – 3: 4 m#, 1 f#, RAD, 3 m#, 1 f#, CYC, 20.ix; 5: 1 m#, RAD, 3 m#, CYC, 22.ix; 6: 1 f#, RAD, 23.ix; 7: 2 m#, RAD, 1 m#, CYC, 25.ix.
9. *Neurobasis chinensis* (Linnaeus, 1758) – 5: 2 m#, RAD, 1 m#, CYC, 22.ix.
10. *Vestalis amethystina* Lieftinck, 1965 – 3: 2 m#, RAD, 20.ix; 5: 4 m#, RAD, 3 m#, CYC, 22.ix; 6: 2 m#, RAD, 3 m#, CYC, 23.ix; 7: 3 m#, CYC, 25.xi; 8: 1 m#, RAD, 1 m#, CYC, 27.ix.
11. *Vestalis amoena* Hagen in Selys, 1853 – 6: 1

Table 1. Species and number of Odonata collected in Cameron Highlands, sites arranged from higher altitude to lower altitude.

No.	Odonata Species	Sampling Site									
		Sg. Burung	Sg. Telom	Sg. Pauh	Ringlet	Sg Terisu	Pelanar jor	Kuala Boh	Sg Relong	Kuala Woh	TOTAL
1	*Devadatta argyoides*		2		2	3	2	1	1	5	16
2	*Aristocypha fenestrella*		5			3	3	1	1		13
3	*Heliocypha biforata*									1	1
4	*Heliocypha perforata*									2	2
5	*Dysphaea dimidiata*									1	1
6	*Euphaea impar*									1	1
7	*Euphaea ochracea*						3			2	5
8	*Echo modesta*					9	4	3	1		17
9	*Neurobasis chinensis*						3				3
10	*Vestalis amethystina*					2	7	3	5	2	19
11	*Vestalis amoena*							2	1	1	4
12	*Indolestes anomalus*		1			2					3
13	*Orolestes wallacei*					1			6		7
14	*Podolestes orientalis*						1				1
15	*Drepanosticta fontinalis*					2				14	16
16	*Prodasineura collaris*						8	2		1	11
17	*Prodasineura humeralis*							4		2	6
18	*Prodasineura laidlawi*								1	2	3
19	*Argiocnemis species*		1			9		2	12		24
20	*Ceriagrion fallax pendleburyi*		1		3	2		1	7		14
21	*Onychargia atrocyana*								6	1	7
22	*Pseudagrion pruinosum*							3	1		4
23	*Calicnemia chaseni*					8	1				9
24	*Calicnemia rectangulata*		6								6
25	*Indocnemis orang*					2					2
26	*Coeliccia albicauda*					3	9	5	1	2	20
27	*Copera vittata*					1		1	2	1	5
28	*Acrogomphus ?malayanus*		1								1
29	*Burmagomphus species*						1				1
30	*Stylogomphus ?malayanus*		1								1
31	*Chlorogomphus ?dyak*	2									2
32	*Anaciaeschna montivagans*		2								2
33	*?Periaeschna laidlawi*	2									2
34	*Indaeschna grubaueri*					1					1
35	*Hemicordulia tenera*							1			1
36	*Macromia* sp. cf. *cupricincta*		2								2
37	*Macromia moorei malayana*							1			1
38	*Agrionoptera insignis*					2			1		3
39	*Lathrecista asiatica*								1		1
40	*Lyriothemis biappendiculata*									2	2
41	*Neurothemis fluctuans*					1	1		2		4
42	*Neurothemis ramburii*								2		2
43	*Onychothemis culminicola*									1	1

44	*Orthetrum chrysis*						1	1			2
45	*Orthetrum glaucum*				4		3			1	8
46	*Orthetrum luzonicum*		1	1	5				1		8
47	*Orthetrum pruinosum schneideri*						1		1		2
48	*Orthetrum testaceum*				1						1
49	*Orthetrum triangulare malaccense*		4			2	4	1			11
50	*Pantala flavescens*				2						2
51	*Tetrathemis platyptera*					3			5		8
52	*Tetrathemis aurora*								1		1
53	*Trithemis festiva*							1			1
54	*Zygonyx ida*					1	3				4
55	*Zygonyx iris malayanus*							3	1	2	6
	Total number of individual	4	27	1	17	57	55	36	60	44	301
	Total number of species	2	12	1	6	19	17	18	22	19	55

m#, RAD, 23.ix; 7: 2 m#, RAD, 25.ix; 8: 1 m#, RAD, 27.ix.

Lestidae

12. Indolestes anomalus Fraser, 1946 – Not previously known from Malaysia, all published records of this species are of material from Thailand [36-38]. There is considerable geographic variation in the extent of the pale markings on the synthorax of males (see Fig. 1). 2: 1 m#, RAD, 24.ix;`3: 1 m#, YFN, 1 m#, CYC, 20.ix.

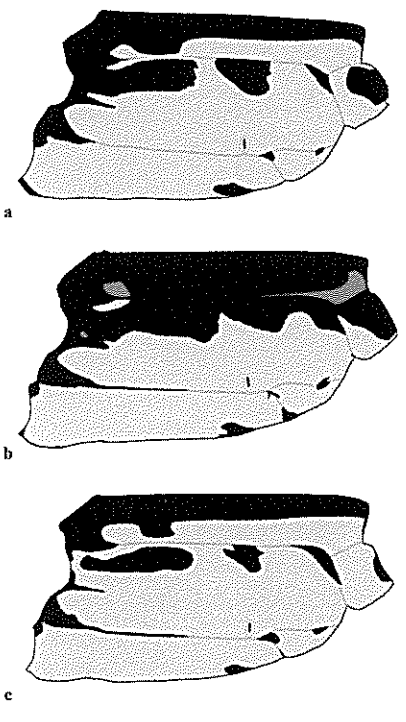


Figure 1. Pattern of male synthorax in different populations of *Indolestes anomalus*: (a) Cameron Highlands, Malaysia; (b) Lampang, Thailand; (c) Tak, Thailand.

13. Orolestes wallacei (Kirby, 1889) – 3: 1 m#, RAD, 20.ix; 6: 3 m#, 1 f#, RAD, 2 m#, CYC, 23.ix.

Megapodagrionidae

14. Podolestes orientalis Selys, 1862 – 5: 1 f#, CYC, 22.ix.

Platystictidae

15. Drepanosticta fontinalis Lieftinck, 1937 – There is considerable variation in body length in this species of Peninsular Malaysia, with the length of the abdomen including the anal appendages ranging from 35 to 43 mm. Specimens collected from Kuala Woh fall within the lower part of the body length spectrum; specimens from the other parts of Cameron Highlands are of longer body length. 3: 1 m#, RAD, 1 m#, CYC, 20.ix; 8: 7 m#, 1 f#, RAD, 6 m#, CYC, 27.ix.

Protoneuridae

16. Prodasineura collaris (Selys, 1860) – 5: 3 m#, RAD, 3 m#, 2 f# (1 pair in tandem), CYC, 22.ix; 7: 1 f#, RAD, 1 m#, CYC, 25.ix; 8: 1 m#, CYC, 27.ix.

17. Prodasineura humeralis (Selys, 1860) – 7: 2 m#, RAD, 2 m#, CYC, 25.ix; 8: 1 m#, RAD, 1 m#, CYC, 27.ix.

18. Prodasineura laidlawi Förster in Laidlaw & Förster, 1907 – 6: 1 m#, RAD, 23.ix; 8: 2 m#, RAD, 27.ix.

Coenagrionidae

19. Argiocnemis species – A problematic taxon, common in peninsular Malaysia and Sarawak; it is certainly not *Argiocnemis rubescens rubeola* Selys, 1877, but it may already have a valid name currently suppressed in the synonymy of that species. 2: 1 m#, RAD, 19.ix; 3: 4 m#, 1 f# (1 pair in tandem), RAD, 3 m#, 1 f# (1 pair in tandem), CYC, 20.ix; 6: 8 m#, 2 f# (1 pair in tandem), RAD, 3 m#, 1 f# (1 pair in tandem), CYC, 23.ix; 7: 1 m#, RAD, 1 m#, CYC, 25.ix.

20. *Ceriagrion fallax pendleburyi* Laidlaw, 1931 – 2: 1 m#, CYC, 24.ix; 3: 1 f#, RAD, 1 m#, CYC, 20.ix; 4: 1 m#, RAD, 2 m#, CYC, 21.ix; 6: 3 m#, 1 f#, RAD, 2 m#, 1 f#, CYC, 23.ix; 7: 1 m#, RAD, 25.ix.
21. *Onychargia atrocyana* (Selys, 1865) – 6: 4 m#, 1 f# (1 pair in tandem), RAD, 1 m#, CYC, 23.ix; 8: 1 m#, CYC, 27.ix.
22. *Pseudagrion pruinosum* (Burmeister, 1839) – 6: 1 m#, RAD, 23.ix; 7: 2 m#, RAD, 1 m#, CYC, 25.ix.

Platycnemididae

23. *Calicnemia chaseni* (Laidlaw in Campion & Laidlaw, 1928) – 3: 4 m#, RAD, 3 m#, 1 f#, CYC, 20.ix; 5: 1 m#, CYC, 22.ix.
24. *Calicnemia rectangulata* Laidlaw, 1933 – Found in the vicinity of a very small rocky high gradient forest stream, also observed in similar habitat above 1800m on Gunung Berinchang. 2: 3 m#, RAD, 1 m#, 1 f# (tandem pair), CYC, 19.ix; 1 m#, RAD, 24.ix.
25. *Indocnemis orang* Förster in Laidlaw & Förster, 1907 – 3: 1 m#, RAD, 1 m#, CYC, 20.ix.
26. *Coeliccia albicauda* (Förster in Laidlaw & Förster, 1907) – 3: 2 m#, RAD, 1 m#, CYC, 20.ix; 5: 4 m#, 1 f# (1 pair in tandem), RAD, 3 m#, 1 f#, CYC, 22.ix; 6: 1 m#, CYC, 23.ix; 7: 3 m#, 1 f#, RAD, 1 m#, CYC, 25.ix; 8: 1 m#, RAD, 1 m#, CYC, 27.ix.
27. *Copera vittata* (Selys, 1863) – Two colour forms have been recorded for this species in Peninsular Malaysia. The typical red-legged form is distributed in the northern part of Peninsular Malaysia whilst a yellow-legged form is confined to southern part of Peninsular Malaysia. Specimens collected from Cameron Highlands areas (except Kuala Woh) are of the red-legged form, but one from Kuala Woh is of the yellow-legged form. 3: 1 m#, CYC, 20.ix; 6: 1 m#, RAD, 1 m#, CYC, 23.ix; 7: 1 m#, CYC, 25.ix; 8: 1 m#, CYC, 27.ix.

ANISOPTERA

Gomphidae

28. *Acrogomphus ?malayanus* Laidlaw, 1925 – 2: 1 larva, CYC, 19.ix.
29. *Burmagomphus* species – Only a teneral (freshly emerged) female was collected; the condition of the specimen does not permit reliable identification to species. 5: 1 f#, RAD, 22.ix.
30. *Stylogomphus ?malayanus* Sasamoto, 2001 – 2: 1 larva, CYC, 19.ix.

Chlorogomphidae

31. *Chlorogomphus ?dyak* (Laidlaw, 1911) – 1: 2 larvae, CYC, 19.ix.

Aeshnidae

32. *Anaciaeschna montivagans* Lieftinck, 1932 – A montane species, otherwise known from Sumatra and Java [26]. The only previous record from Peninsular Malaysia was also made in the Cameron Highlands [34]. 2: 1 f#, RAD, 1 f#, CYC, 19.ix.
33. ?*Periaeschna laidlawi* (Förster, 1908) – 1: 2 larvae (1 larva emerged on 8.x), CYC, 18.ix.
34. *Indaeschna grubaueri* (Förster, 1904) – 3: 1 m#, CYC, 20.ix.

Corduliidae

35. *Hemicordulia tenera* Lieftinck, 1930 – 7: 1 f# (teneral), RAD, 25.ix.
36. *Macromia* sp. cf. *cupricincta* Faser, 1924 – Although the exact identity of this species cannot be determined from the two reared female specimens, it is certainly close to *M. cupricincta*, a species that occurs from north-east India to Lao PDR, and which has been recorded as far south as Kanchanaburi in Thailand [39]. Whether or not the specimens in question are actually *M. cupricincta*, they certainly represent a new addition to the odonate fauna of Peninsular Malaysia. 2: 2 female larvae (1 emerged on 27.ix, 1 emerged on 5.xii), CYC, 24.ix.
37. *Macromia moorei malayana* Laidlaw, 1982 – 7: 1 m#, CYC, 25.ix.

Libellulidae

38. *Agrionoptera insignis* (Rambur, 1842) – 3: 2 m#, CYC, 20.ix; 6: 1 f#, CYC, 23.ix.
39. *Lathrecista asiatica* (Fabricius, 1798) – 6: 1 m#, CYC, 23.ix.
40. *Lyriothemis biappendiculata* (Selys, 1878) – This species shows considerable variation in

the colouration of the male thorax. Specimens from Peninsular Malaysia and some populations in Borneo have the synthorax red or dark brown, whilst other populations in Borneo develop a white synthorax. 8: 1 f#, RAD, 1 m#, CYC, 27.ix.

41. *Neurothemis fluctuans* (Fabricius, 1793) – 3: 1 m#, RAD, 20.ix; 5: 1 m#, RAD, 22.ix; 6: 1 m#, RAD, 1 m#, CYC, 23.ix.
42. *Neurothemis ramburii* (Brauer, 1866) – 6: 1 m#, RAD, 1 m#, CYC, 23.ix.
43. *Onychothemis culminicola* Förster, 1904 – 8: 1 m#, RAD, 27.ix.
44. *Orthetrum chrysis* (Selys, 1891) – 5: 1 m#, RAD, 22.ix; 7: 1 m#, RAD, 25.ix.
45. *Orthetrum glaucum* (Brauer, 1865) – 4: 2 m#, RAD, 1 m#, 1 f#, CYC, 21.ix; 5: 1 m#, RAD, 2 m#, CYC, 22.ix; 8: 1 m#, CYC, 27.ix.
46. *Orthetrum luzonicum* (Brauer, 1868) – 2: 1 m#, YFN, 19.ix; 4: 1 m#, RAD, 3 m#, 1 f#, CYC, 21.ix; 6: 1 m#, RAD, 23.ix; 7: 1 m#, RAD, 25.ix; 9: 1 m#, CYC, 18.ix.
47. *Orthetrum pruinosum schneideri* Förster, 1903 – It is likely that this taxon is a distinct species rather than a subspecies of *O. pruinosum*. 5: 1 m#, RAD, 22.ix; 6: 1 m#, CYC. 23.ix.
48. *Orthetrum testaceum* (Burmeister, 1839) – 4: 1 m#, RAD, 21.ix
49. *Orthetrum triangulare malaccense* Förster, 1903 – 2: 1 m#, RAD, 1 m#, CYC, 19.ix; 1 m#, 1 f# (in tandem), RAD, 24.ix; 3: 1 m#, RAD, 1 m#, CYC, 20.ix; 5: 1 m#, RAD, 2 m#, 1 f# (1 pair in tandem), CYC, 22.ix; 7: 1 m#, CYC, 25.ix.
50. *Pantala flavescens* (Fabricius, 1798) – 4: 2 m#, CYC, 21.ix.
51. *Tetrathemis platyptera* (Selys, 1878) – 3: 1 m#, RAD, 2 m#, CYC, 20.ix; 6: 4 m#, RAD, 1 m#, CYC, 23.ix.
52. *Trithemis aurora* (Burmeister, 1839) – 6: 1 f#, CYC, 23.ix.
53. *Trithemis festiva* (Rambur, 1842) – 7: 1 m#, RAD, 25.ix.
54. *Zygonyx ida* Selys, 1869 – 3: 1 m#, RAD, 20.ix; 5: 1 m#, RAD, 1 m#, 1 f# (tandem pair), CYC, 22.ix.
55. *Zygonyx iris malayanus* Laidlaw, 1902 – 6: 1 m#, RAD, 23.ix; 7: 1 m#, RAD, 2 m#, CYC, 25.ix; 8: 1 m#, 1 f# (tandem pair), CYC, 27.ix.

DISCUSSION

As noted in the introduction, although the Cameron Highlands are regarded as a high importance highland ecosystem, the natural habitats of the area are under considerable pressure from human activities. Therefore it is important to determine the sites of highest diversity, and sites where specialist high altitude species occur, sooner rather than later. This study makes a contribution to this process; the information presented here should be useful to the local authorities in the implementation of any biodiversity conservation program. It is clear from the results and the discussion below that the preservation of low and mid altitude sites in the area, as well as high altitude sites, is essential if the full diversity of Odonata in the area is to be maintained.

Insufficient sampling was performed during this short study to allow for a meaningful statistical analysis to be performed, however one general trend is clear. The sites sampled range from ca 75m to ca 1600m in altitude. The abundance and species diversity of Odonata collected was relatively high in the habitats below 1000m, and lower in the habitats above 1000m. This trend is clearly visible in Table 1 where the sampling locations have been arranged in order of decreasing altitude. In total 18 species were collected at the four sites above 1000m, whilst 46 species were collected at the sites below 1000m; four full days were spent collecting above 1000m, and five full days below 1000m. Nine species were only collected above 1000m, but in the case of at least two of these (*Orthetrum testaceum* and *Pantala flavescens*) this is clearly due to under-sampling, as both of these species are common in the lowlands of Malaysia. Very few adults of stream breeding Odonata were collected above 1000m, but larvae were found for a number of species, suggesting that there may be a seasonal factor in occurrence of adults at higher altitudes in the Cameron Highlands.

Of the higher altitude sites, the Sg. Telom area yielded the highest number of species (12). This is probably partly due to the fact that this are included some of the least disturbed habitat sampled, but this area also received more sampling effort than the other sites above 1000m. The number of species collected at each of the sites below 1000m is fairly similar, ranging from 17–22. The total from all sites sampled would undoubtedly rise with further collecting.

The fall in odonate diversity at higher altitudes is not a surprising result; it is well known that species diversity of Odonata falls with increasing altitude [4, 40]. Similar results were also found by NYF's BSc. students for Coleoptera [41] and Lepidoptera [42] in the Cameron Highlands. More generally, altitudinal gradients in biodiversity have been studied by many ecologists, and insect diversity typically decreases from low to high altitude.

The fact that two new records for Malaysia were made in just nine days of fieldwork suggest that the odonate fauna of both the Cameron Highlands and the whole of Peninsular Malaysia is still far from completely known; this conclusion is supported by the recent discovery of two new species of *Amphicnemis* Selys in Pahang [43]. Moreover at least 16 of the other records made (*Vestalis amoena*, *Orolestes wallacei*, *Prodasineura collaris*, *Drepanosticta fontinalis*, *Ischnura senegalensis*, *Onychargia atrocyana*, *Copera vittata*, *Indaeschna grubaueri*, *Macromia moorei*, *Agrionoptera insignis*, *Lathrecista asiatica*, *Neurothemis ramburii*, *Orthetrum luzonicum*, *Orthetrum testaceum*, *Tetrathemis platyptera* and *Trithemis festiva*) do not appear to have been recorded in the Cameron Highlands or immediately adjacent regions previously. Some of these species are very common in Peninsular Malaysia.

Acknowledgments–The authors wish to thank the Forestry Department of Pahang and Perak for granting permission for sampling of Odonata in the Cameron Highlands. This study was funded by Universiti Kebangsaan Malaysia (UKM) via research grant UKM-GUP-ASPL-07-04-048.

REFERENCES

1. Orr A.G. (2005) *Dragonflies of Peninsular Malaysia and Singapore*. Natural History Publications (Borneo), Kota Kinabalu.
2. Clausnitzer V., Kalkman V.J., Ram M., Collen B., Baillie J.E.M., Bedjanic M., Darwall W.R.T, Dijkstra K-D.B., Dow R., Hawking J., Karube H., Malikova E., Paulson D., Schutte K., Suhling F., Villanueva R., von Ellenrieder N. and Wilson K. (2009) Odonata enter the biodiversity crisis debate: the first global assessment of an insect group. *Biological Conservation* **142**: 1864-1869.
3. Corbet P.S. (1999) *Dragonflies: Behaviour and Ecology of Odonata*. Harley Books, England.
4. Orr A.G. (2003) *Dragonflies of Borneo*. Natural History Publications, Kota Kinabalu.
5. Wilson K.D.P. (2004) *Field Guide to the Dragonflies of Hong Kong*. Second Edition. Cosmos Books Ltd, Hong Kong.
6. Tang H.B., Wang L.K. and Hämäläinen M. (2010) *A photographic guide to the dragonflies of Singapore*. Raffles Museum of Biodiversity Research.
7. David J.M., Hans G.P.J. and Robert G.D. (1996) Soil erosion and environmental impact of vegetable production in the Cameron Highlands, Malaysia. *Agriculture, Ecosystem and Environment* **60**: 29-46.
8. Norida M. and John M. (2005) Insecticide use in cabbage pest management in the Cameron Highlands, Malaysia. *Crop Protection* **24**: 31-39.
9. Asahina S. (1966) Malayan dragonflies taken by Mr. E. Kawase in 1960/1962. *Kontyû* **34**: 18-21.
10. Asahina S. (1967) A revision of the Asiatic species of the damselflies of the genus *Ceriagrion* (Odonata, Agrionidae). *Japanese Journal of Zoology* **15**(3): 255-334Campion H. and Laidlaw F.F. (1928) Notes on oriental dragonflies (Odonata) with descriptions of new species. *Proceedings of the Zoological Society of London* (1): 129-138.
11. Donnelly T.W. (1998) Back to Thailand and Malaysia – Farangpo 98. *Malangpo* **15**: 137-142.
12. Förster F. (1908) Neue Aeschniden. *Annales de la Société Entomologique de Belgique* **52**: 213-218.
13. Fraser F.C. (1942) Dr. Raymond Wheeler's collection of Odonata from the Federated Malay States, with the descriptions of a new genus and two new species. *The Proceedings of the Royal Entomological Society of London, Series B. Taxonomy* **11**(7): 95-104.
14. Kemp R.G. and Kemp G.S. (1989) Some dragonfly records from the states of Pahang and Perak, West Malaysia. *Notulae odonatologicae* **3**(3): 37-40.
15. Laidlaw F.F. (1903) Odonata, part I. *Fascicule Malayensis Zoology* **1**:189-200.
16. Laidlaw F.F. (1931) Dragonflies of the Malay Peninsula with descriptions of new species. *Journal of the Federated Malay Museums* **16**(3/4): 175-233.
17. Laidlaw F.F. (1932) A revision of the genus *Coeliccia* (order Odonata). *Records of the Indian Museum* **34**(1): 7-42.
18. Laidlaw F.F. (1932) Notes on some Malaysian dragonflies, with descriptions of new species. *Bulletin of the Raffles Museum, Singapore* **7**: 95-98.
19. Laidlaw F.F. (1934) A Note on the dragonfly fauna (Odonata) of Mount Kinabalu and of some other mountain areas of Malaysia, with a description of some new or little known species. *Journal of the*

Federated Malay States Museums **17**(3): 549-561.

20. Laidlaw F.F. and Förster F. (1907) Odonata, part II. *Fascicule Malayensis Zoology* **4**: 1-15.
21. Lieftinck M.A. (1933) Notes on the larvae of two interesting Gomphidae (Odon.) from the Malay peninsula. *Bulletin of the Raffles Museum, Straits Settlements* **7**: 102-115.
22. Lieftinck M.A. (1939) Critical notes on the Malaysian species of *Idionyx*, Hagen (Odon). *Treubia* **17**(3): 199-204.
23. Lieftinck M.A. (1948) Descriptions and records of South-east Asiatic Odonata. *Treubia* **19**: 221-278.
24. Lieftinck M.A. (1950) Further studies on Southeast Asiatic species of *Macromia* Rambur, with notes on their ecology, habits and life history, and with descriptions of larvae and two new species (Odon., Epophthalmiinae). *Treubia* **20**: 657-716.
25. Lieftinck M.A. (1954) Handlist of Malaysian Odonata. A catalogue of the dragonflies of the Malay Peninsula, Sumatra, Java and Borneo, including the adjacent small islands. *Treubia* (Suppl.) **22**: i-xiii + 1-202.
26. Lieftinck M.A. (1964) Some Gomphidae and their larvae, cheifly from the Malay peninsula (Odonata). *Zoologische Verhandelingen* **69**: 1-38.
27. Lieftnck M.A. (1965) Some Odonata of the genus Drepanosticta Laidlaw, chiefly from the Malay peninsula (Platystictidae). *Zoologische Mededelingen* **40**(21): 171-186.
28. Lieftinck M.A. (1965) The species-group of *Vestalis amoena* Selys, 1853, in Sundaland (Odonata, Calopteryiidae). *Tijdschrift voor Entomologie* **108**(11): 325-364.
29. Lieftinck M.A. (1984) Further notes on the specific characters of *Calicnemia* Strand, with a key to the males and remarks on some larval forms (Zygoptera: Platycnemididae). *Odonatologica* **13**(3): 351-375.
30. Norma-Rashid Y. (1995) Preliminary odonate survey of Perak, Peninsular Malaysia. *Notulae odonatologicae* **4**(5): 77-92.
31. Norma-Rashid Y. and Van Tol J. (1995) New records of Odonata for West Malaysia. *Notulae odonatologicae* **4**(6): 101-103.
32. Sasamoto A. (2001) Description of a new subspecies of *Stylogomphus lawrenceae* Yang et Davies, 1996 from the Malay Peninsula (Anisoptera: Gomphidae). *Tombo* **43**: 14-18.
33. Sasamoto A. (2007) Records of the rare dragonflies from Peninsular Malaysia. *Aeschna* **43**: 9-11.
34. Vick G.S. (1993) A visit to Malaysia in July 1993. *Kimminsia* **4**(2): 16-17.
35. Fraser F.C. (1946) One rare and two new species of Odonata from tropical Africa and Asia. *Proceedings of the Royal Entomological Society of London (Series B)* **15**(3/4): 41-45.
36. Asahina S. (1985) A list of the Odonata recorded from Thailand, Part VIII. Lestidae. *Chô Chô* **8**(8): 2-13.
37. Hämäläinen M. and Pinratana A. (1999) *Atlas of the dragonflies of Thailand – distribution maps by provinces*. Brothers of St. Gabriel in Thailand, Bangkok.
38. Kitagawa K. and Katatani N. (2005) Notes on Thai Odonata, Part 4. The Odonata from Kanchanaburi. *Aeschna* **42**: 23-30.
39. Samways M.J. (1989) Taxon turnover in Odonata across a 3000 m altitudinal gradient in southern Africa. *Odonatologica* **18**(3): 263-274.
40. Gan B.H. (2009) *The diversity and abundance of bettles (Coleoptera) at different altitudes in Cameron Highlands, Pahang.* Bachelor of Science (Hon.) thesis, Universiti Kebngsaan Malaysia (UKM), Bangi.
41. Ong S.S. (2009) *A comparison on composition and abundance of butterflies (Lepidoptera) at different altitudes in Cameron Highlands, Pahang.* Bachelor of Science (Hon.) thesis, Universiti Kebngsaan Malaysia (UKM), Bangi.
42. Dow R.A., Choong C.Y. and Ng, Y.F. (2010) A review of the genus *Amphicnemis* in Peninsular Malaysia and Singapore, with descriptions of two new species (Odonata: Zygoptera: Coenagrionidae). *Zootaxa* **2605**: 45-55.

Journal of Science and Technology in the Tropics (2011) 7: 17-24

Genetic breeding programmes for tropical ornamental fishes in South-East Asia

Violet P. E. Phang[1] and Gideon Khoo[2*]
[1]Department of Biological Sciences, National University of Singapore, Kent Ridge, Singapore 117543
[2]Faculty of Science, Universiti Tunku Abdul Rahman, 31900 Kampar, Perak, Malaysia
(*E-mail: gideonkhoo@utar.edu.my)

Received 11-01-2011; accepted 25-01-2011

Abstract Fish breeders aim to produce fish that are healthy, fast growing and viable. Ornamental fish breeders, however, face an additional challenge of providing diversity to capture and stimulate the interests of fish hobbyists. Traditional genetic methods to produce phenotypic variation include rigorous selection for rare spontaneous mutations, close inbreeding to fix desirable genes, selective breeding and hybridization. Although successful, these methods have taken decades, even centuries. Advances in molecular technology have resulted in the unravelling and engineering of DNA. The challenge, therefore, is to determine if the ornamental fish industry can harness biotechnological advancements, such as transgenesis or induced mutagenesis, and collaborate with researchers and scientists to develop diversity within a shorter time frame. Furthermore, ornamental fish breeders need to select new criteria, for example, adaptability to transportation conditions, and urban environments such as indoor aquaria and small ponds. Since tropical ornamental fish farms are almost entirely small family run businesses, the fish stocks are invariably kept as small, closed populations to preserve the purity of the lines. The result is erosion of genetic variability and inbreeding depression despite outcrosses to introduce new genetic variation. With the advent of DNA technology, distant outcrosses between stocks could be planned based on DNA fingerprinting profiles. With the growing awareness of biodiversity, conservation problems of overfishing and continued destruction of the environment, there is an urgent need to take remedial measures. Captive breeding of wild-caught fishes need to be stepped up and global alliance is required to designate more protected areas, reserves and sanctuaries. International gene banks can provide for *ex-situ* conservation of the valuable genetic diversity of domesticated and wild-caught ornamental fishes.

Keywords breeding – ornamental fishes – genetic variability – conservation

INTRODUCTION

The culture and keeping of fish as pets have their roots in Asia. Goldfish (*Carassius auratus*) have been kept as pets during the Southern Song Dynasty in China prior to 1000 A.D. [1]. The Japanese Koi carp is another long-time favourite. The development of ornamental Koi from the common carp (*Cyprinus carpio*), which was introduced into Japan from Eurasia some 2000 years ago, can be traced back to the Tokugawa period in the 17th century [2].

Breeders of food and ornamental fishes share the common goal of improving the reproductive fitness of fish in terms of faster growth, higher fecundity, greater disease resistance and adaptability to fluctuating environmental conditions, by using selective breeding. Ornamental fish breeders face another challenge. Whereas consumers are notoriously conservative in their choice of food fish, the reverse is true for ornamental fish enthusiasts, who have an insatiable craving for 'novel fish'. Hence, the ornamental fish industry is compelled to continually provide diversity to captivate, sustain and enhance the interests of hobbyists. Diversity is achieved by developing new strains of cultured fish species through genetic methodology and the introduction of previously unknown species.

TRADITIONAL METHODS

Traditional methods used to develop novel strains involve continual rigorous and tedious screening of thousands of fish stocks for rare spontaneous mutants. The desired mutant characteristics that appeal to and selected by fish hobbyists include: new and enhanced coloration and colour patterns; improvement of body and fin shapes; unique body or fin shapes and sizes; and bizarre morphological structures. This is followed by several generations of close inbreeding of the selected fish in order to fix the desired characters and genes, and to develop a pure breeding line (Fig. 1). Subsequently, the population size increases. Using carefully chosen parents, selective breeding is performed on each generation to improve the quality of the stock, desired phenotypic characteristics, fitness and viability [3]. Hybridization between different strains is also practiced to create new variations, and this is followed by generations of intense selection to develop a new line.

These traditional methods have been successful as evidenced by three perennial favourites: goldfish, Koi and guppy. The selected characteristics are, however, very specific for each species. Goldfish are famous for the numerous varieties showing various colours. The goldfish body has been selected for short spherical or egg-shaped form with dorsal and tail fins of different shapes (Fig. 2). Goldfish are particularly noted for varieties with bizarre morphological structures on the head such as Shubunkin, Ryukin, Ranchu, Oranda, Lionhead, Telescope Eye, Bubble Eye, Pearl Scale, Comet and others. On the other hand, Japanese Koi or Nishikigoi are selected for a streamlined body showing different pure colours of white, silvery-white, gold, orange, red or black, as well as strategically placed colour patterns (Fig. 3). Selective breeding of the Koi has given rise to the "Gosanke" strains, a term which is used to describe the three main patterns and

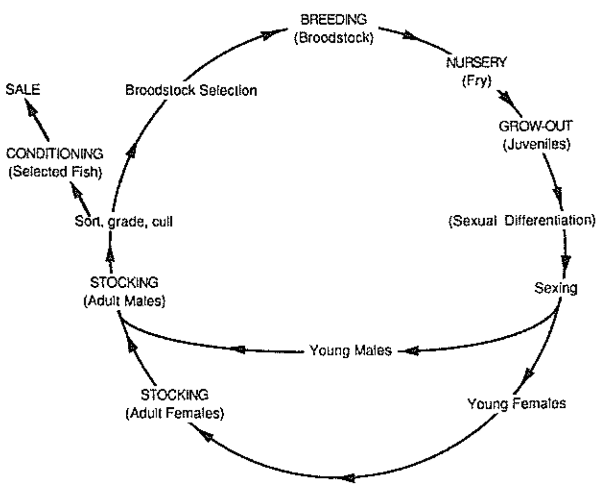


Figure 1. Conventional breeding programme of the guppy (*Poecilia reticulata*), molly (*Poecilia latipinna* and *P. sphenops*), platyfish (*Xiphophorus maculatus*) and swordtail (*Xiphophorus helleri*) to fix the desired traits and genes, and to develop pure breeding lines [30].

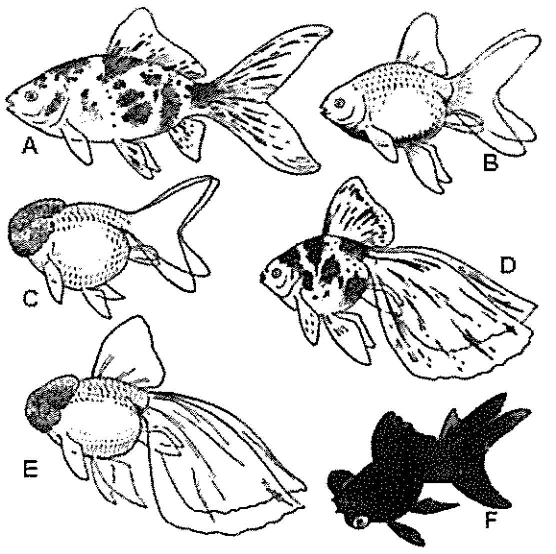


Figure 2. Examples of goldfish (*Carassius auratus*) varieties selected for spherical form with dorsal and tail fins of different shapes, and bizarre morphological structures on the head: (A) Shubunkin, (B) Fantail, (C) Lionhead, (D) Veiltail, (E) Oranda, and (F) Moor.

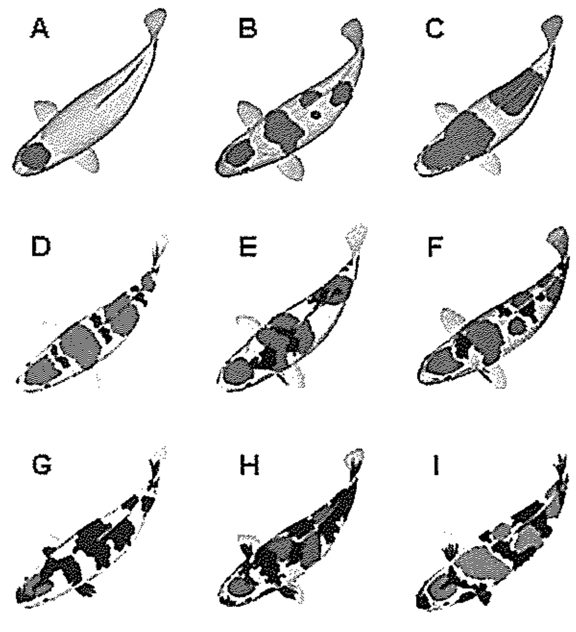


Figure 3. Examples of the Kohaku, Sanke and Showa strains of the Japanese Koi (*Cyprinus carpio*), which have arisen as a result of selective breeding for specific coloration and colour patterns. (A) Tancho-Kohaku, (B) Doitsu-Kohaku, (C) Nidan-Kohaku, (D) Subo Sumi-Sanke, (E) Maruten-Sanke, (F) Doitsu-Sanke, (G) Tancho-Showa, (H) Maruten-Showa and (I) Doitsu-Showa.

varieties, namely, Kohaku, Sanke and Showa. Other Koi varieties include Kin Gin Rin, Goshiki, Utsuri, Hikarimoyo, Hikari Mujimono, Kawarimono, Asagi, Koromo and Bekko. The guppy, *Poecilia reticulata*, is sexually dimorphic, with males of the different strains displaying striking coloration on their bodies and large dorsal and caudal fins of varied shapes and sizes (Fig. 4).

The ornamental fish industry has, and will continue, to depend on traditional selection methods to provide novel forms that are essential for the trade. Nevertheless, these methods are slow and laborious, often taking decades or even a century to produce results as they are highly dependent on rare and chance occurrences of suitable spontaneous mutations. Research on gene control have been conducted on the different strains of the goldfish [4], Japanese Koi [5, 6], and guppy [7-14]. When the genes involved have been elucidated, crossing between different strains can be planned on a scientific basis rather than in a haphazard manner to produce new variations for the commercial market.

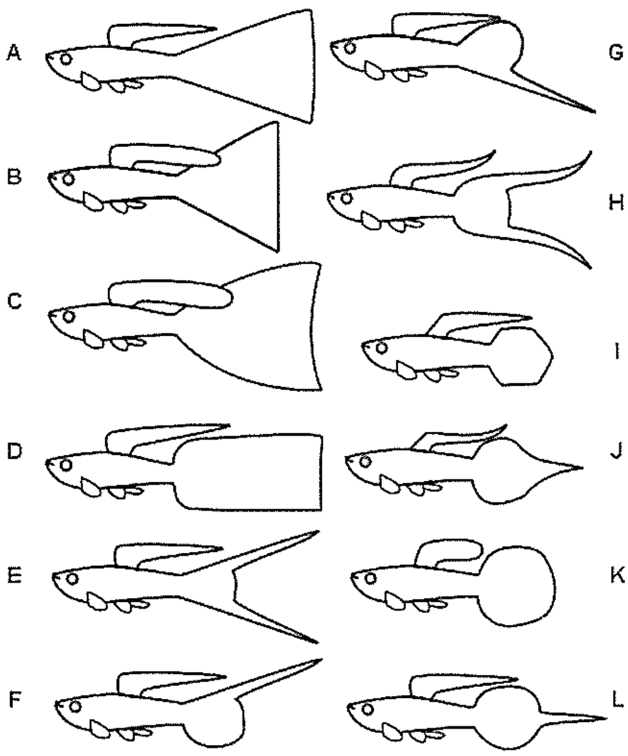


Figure 4. Caudal fin shapes of the guppy, *Poecilia reticulata*: (A) fan tail, (B) triangle or delta tail, (C) veil tail, (D) flag tail, (E) double sword, (F) top sword, (G) bottom sword, (H) lyre tail, (I) spade tail, (J) spear tail, (K) round tail and (L) pin tail.

NEW TECHNOLOGY

Today, all sectors of the aquaculture industry must utilize new technology to survive and progress in the 21st century. The ornamental fish sector is no exception. But, what are the new technologies that are available for the industry to harness? There has been rapid development of molecular techniques and DNA methodology, especially in the last three decades. In the late 1990s, application of molecular technology has become increasingly important in the field of agriculture. Conversely, the aquaculture and fisheries communities have advanced very little in comparison [15, 16]. The ornamental fish industry comprises mainly backyard farms, small farms and family-run farms that, unlike multinational corporations, do not have the capacity or the financial means to maintain their own research and development programmes. Thus, in order to latch on to new technologies, these farms have to work with researchers and scientists in public and private institutions and universities.

One challenge is whether it is possible to induce mutations rather than waiting for them to occur infrequently and randomly. Pioneering work on induced mutagenesis has been conducted on the zebrafish, *Brachydanio rerio*, using X-rays [17, 18]. Shima and Shimada [19] used irradiation and chemicals to induce mutations in the Japanese medaka fish, *Oryzias latipes*. Induced mutagenesis will yield a higher frequency of mutations from which to carry out selection of specific traits for breeding.

Production of transgenic fish could also be a useful method of genetic manipulation. Work on the zebrafish, Japanese medaka and other species have shown that fish is an excellent model organism for gene transfer because thousands of eggs can be laid by a single female, fertilization is external, and development is also external and relatively short [20, 21]. Genetic engineering of freeze-resistant Atlantic salmon (*Salmo salar*) has been carried out by microinjecting the antifreeze gene of the winter flounder (*Pseudopleuronectes americanus*) into salmon eggs [22]. Studies by Zhu [23] indicated that the human growth hormone gene accelerated the growth rates of transgenic mud loach (*Misgurnus mizolepis*), goldfish (*C. auratus*), crucian carp (*Carassius carassius*) and common carp (*C. carpio*).

Cloning of useful genes in ornamental fish, like those that control colour and morphological aberrations, are important and entail application

JOURNAL OF SCIENCE AND TECHNOLOGY IN THE TROPICS

INSTRUCTIONS TO CONTRIBUTORS

JOSTT is a multi-disciplinary journal. It publishes original research articles and reviews on all aspects of science and technology relating to the tropics. All manuscripts are reviewed by at least two referees, and the editorial decision is based on their evaluations.

Manuscripts are considered on the understanding that their contents have not been previously published, and they are not being considered for publication elsewhere. The authors are presumed to have obtained approval from the responsible authorities, and agreement from all parties involved, for the work to be published.

Submission of a manuscript to JOSTT carries with it the assignment of rights to publish the work. Upon publication, the Publishers (COSTAM and ASM) retain the copyright of the paper.

Manuscript preparation
Manuscripts must be in English, normally not exceeding 3500 words. Type double spaced, using MS Word, on one side only of A4 size with at least 2.5 cm margins all round. Number the pages consecutively and arrange the items in the following order: title page, abstract, key words, text, acknowledgements, references, tables, figure legends.

Title page
Include (i) title, (ii) names, affiliations and addresses of all authors, (iii) running title not exceeding five words, and (iv) email of corresponding author.

Abstract and key words
The abstract, not more than 250 words, should be concise and informative of the contents and conclusions of the work. A list of not more than five key words must immediately follow the abstract.

Text
Original research articles should be organized as follows: Introduction, Materials and Methods, Results, Discussion, Acknowledgement, References. The International System of Units (SI) should be used. Scientific names and mathematical parameters should be in italics.

References
References should be cited in the text as numbers enclosed with square [ ] brackets. The use of names in the text is discouraged. In the reference section, the following examples should be followed:

1. Yong H.S., Dhaliwal S.S. and Teh K.L. (1989) A female Norway rat, *Rattus norvegicus*, with XO sex chromosome constitution. *Naturwissenschaften* **76**: 387-388.
2. Beveridge W.I.B. (1961) *The Art of Scientific Investigation*. Mercury Book, London.
3. Berryman A.A. (1987) The theory and classification of outbreaks. In Barbosa P. and Schultz J.C. (eds.) *Insect outbreaks* pp. 3-30. Academic Press, San Diego.

Tables
Tables should be typed on separate sheets with short, informative captions, double spacing, numbered consecutively with Arabic numerals, and do not contain any vertical lines. A table should be set up to fit into the text area of at most the entire page of the Journal.

Illustrations
Black-and-white figures (line drawings, graphs and photographs) must be suitable for high-quality reproduction. They must be no bigger than the printed page, kept to a minimum, and numbered consecutively with Arabic numerals. Legends to figures must be typed on a separate sheet. Colour illustrations can only be included at the author's expense.

Proofs and reprints
Authors will receive proofs of their papers before publication. Order for reprints must be made when returning the proofs.

Submission
Manuscripts (including all figures but not original artwork), together with a CD version of the text, should be submitted to:

The Editorial Office
Journal of Science and Technology
in the Tropics
Academy of Sciences Malaysia
902-4 Jalan Tun Ismail
50480 Kuala Lumpur, Malaysia

E-mail: jostt@akademisains.gov.my

JOSTT is listed in Scopus

of gene transfer technology. Examples of these are the insertion of the green fluorescent protein (GFP) gene from a jellyfish into a zebrafish embryo, which caused the fish to become brightly fluorescent under both natural white light and ultraviolet light [24, 25], the development of fluorescent transgenic medaka fish based on regulating upstream sequences of *myf-5*, rhodopsin, troponin, and actin genes [26, 27], and cloning and expression of the prolactin receptor of the discus fish (*Symphysodon aequifasciata*) [28].

Germ-line chimeras have been produced in the zebrafish by cell transplants from unhatched embryos of pigmented wild type to those of the albino [29]. A high percentage of chimeras (85%), with each fish having its own pigmentation pattern, was obtained. When fully developed, such techniques promise to be invaluable in the production of ornamental fish variations. In the near future, it may be possible for the aquaculture industry to cater to the demands of fish hobbyists by providing novel varieties of fishes that have been genetically engineered using molecular techniques, which require less time compared to conventional breeding methods.

SPECIAL CONSIDERATIONS WHEN BREEDING ORNAMENTALS

Farmers raising food fish most often concentrate on producing one or a few species. Ornamental fish farmers, out of necessity to provide diversity for fish fanciers, have to practice monoculture of a number of strains of a single species, as in the case of goldfish [1, 3, 4], Japanese Koi [2, 5, 6], guppies [7-14, 30], arowana (*Scleropages* spp. and *Osteoglossum* spp.) and discus fish (*Symphysodon* spp.) [31], Siamese fighting fish (*Betta splendens*), or polyculture of several less established fish species.

Ornamental fish farms characteristically have numerous small aquaria, small ponds and net cages suspended in large ponds [30]. Due to financial, labour and physical constraints, they can only maintain a small effective population size (N_e) for each of the stocks. Restriction of population size and genetic drift result in the loss of genetic diversity and fixation of undesirable genes within stocks, thus leading to increased inbreeding levels. The main symptoms of inbreeding depression are: susceptibility to disease, slow growth, low fecundity, high sterility, slow or no response to selection, and an increase in morphological and structural abnormalities. Inbreeding depression may even result in complete loss of lines.

DESIGNING BREEDING PROGRAMMES FOR ORNAMENTALS

To improve the gene pool and minimize the undesirable effects of inbreeding, fish farmers must understand the importance of practicing genetic broodstock management. The N_e for each stock must be kept as large as possible, while taking into account the limiting factors. N_e depends on the total number of breeding individuals, sex ratio, mating system and variance of family size. The necessity to provide for species diversity does not allow the farmer to maintain a large N_e or stocking density within the farm (Table 1). This problem is exacerbated in the case of large ornamentals such as Koi carp, arowana and discus fish, and less for small-sized species like guppies, Siamese fighting fish and tiger barb (*Barbus tetrazona*).

What would be a reasonable guide as to the number of male and female broodstock? Recommended numbers range from 50-1000 per farm [32, 33]. Unfortunately, there is no recommended magic number to guarantee prevention of inbreeding and genetic drift. Since the founder population determines how much genetic variability exists, it is important for the farmer to avoid using only a few individuals, or a large number of individuals, from a single spawn [3, 30, 32-34]. With ornamental fish, however, there is a need to use highly selected broodstock to maintain and improve the quality of the stock. Thus, there is a trade-off between selection intensity and N_e.

Alternative ways to increase N_e are to control the sex ratio and variance of family size. A 1:1 male to female sex ratio maximises N_e while a skewed ratio reduces N_e. A survey of guppy farms in Singapore and Malaysia showed that the sex ratio is usually 1:3, 1:4 or even 1:10 [30, 34]. There is more stringent selection on males for vivid coloration and large well-shaped tails and fins. Using equal sex ratio for the guppy means lowering the selection intensity of males [34].

One recommendation is to spawn more fish than the farmer actually needs and to keep a sample from each spawn for the brood stock [30]. From a short-term perspective, this is a waste of effort, but from

Table 1. Sizes of tanks and cage nets, and their stocking densities at 10 guppy farms in Singapore and Malaysia [30].

Aquaria	Size (m) Length × Width × Height	Vol. of water / tank (m^3/tank)	Stocking density (no. of fish/m^3 water per tank)	Total no. of fish/ tank
Breeding	2.13 × 1.83 × 0.46	1.17	145–170	170–200
	1.83 × 1.22 × 0.46	0.67	120–180	80–120
	1.52 × 1.52 × 0.46	0.69	115–145	80–100
	1.22 × 1.07 × 0.46	0.39	130–180	50–70
	1.22 × 0.91 × 0.46	0.33	120–150	40–50
Nursery	3.05 × 3.05 × 0.46	2.79	280–300	500–650
	2.74 × 1.83 × 0.46	1.50	180–230	270–350
	2.44 × 1.83 × 0.46	1.34	200–260	270–350
	1.83 × 1.52 × 0.61	1.28	140–170	180–220
	1.83 × 1.22 × 0.46	0.67	150–220	100–150
	1.22 × 0.91 × 0.46	0.33	180–240	60–80
Cage-nets	3.05 × 0.91 × 0.91	2.11	250–400	120–180
	2.74 × 1.83 × 1.22	4.56	400–550	70–120
	2.44 × 1.83 × 1.83	5.45	400–600	70–110
Grow-out	3.66 × 2.13 × 0.46	2.34	280–300	400–550
	3.05 × 1.83 × 0.46	1.67	200–320	330–530
	2.74 × 1.83 × 0.46	1.50	200–300	300–450
	2.44 × 1.83 × 0.46	1.34	200–300	270–400
	2.13 × 1.83 × 0.46	1.17	160–180	190–210
	2.13 × 1.37 × 0.46	0.88	160–180	140–145
Stocking	0.91 × 0.46 × 0.30	0.08	140–200	20–30
	0.61 × 0.46 × 0.30	0.06	100–150	15–20
Conditioning	1.07 × 0.61 × 0.46	0.20	340–500	70–100
	0.91 × 0.61 × 0.46	0.17	300–400	50–70
	0.91 × 0.46 × 0.46	0.13	220–320	30–40

the long-term genetic viewpoint, it is worthwhile because it preserves the genetic variability of the stock. Another tried and tested method to increase genetic variability in fish stocks is to outcross fish of the same species or strain with fish from other sources [34]. This leads to an immediate increase in genetic variability. However, if this is again followed by restriction of population size, the stock will deteriorate after a number of generations through erosion of genetic variability.

FUTURE CONSIDERATIONS

DNA fingerprinting has assumed an important role in aquaculture. It has become an important technique for monitoring population and inbreeding levels, pedigree studies and genetic broodstock management [15, 34-37]. The use of arbitrarily primed polymerase chain reaction (AP-PCR), also known as random amplified polymorphic DNA (RAPD) fingerprinting, which is a simpler, faster and less costly method of separating amplified DNA fragments, has been developed [38, 39] (Fig. 5). This technique allows the screening of large numbers of samples within a short period of time compared to the conventional restriction fragment length polymorphism (RFLP) assay [34-39]. Genetic outcrossing programmes can then be drawn up based on the DNA profiles (Fig. 6). For example, in the case of guppies, where a number of farms culture 10-15 different colour strains, the RAPD fingerprints would allow recommendations as to the most genetically distant sources of fish the farmer should acquire for outcrossing his own stocks [34].

The setting up of gene repositories is recommended as a means of conserving the tremendous amount of *ex situ* genetic diversity of both wild-caught and cultured ornamental fishes. Recent advances in the cryopreservation of sperm and oocytes have allowed the conservation of fish germplasm [40, 41]. Androgenesis and gynogenesis could also prove to be useful techniques for reconstituting the organism from male and female gametes, respectively, in the near future.

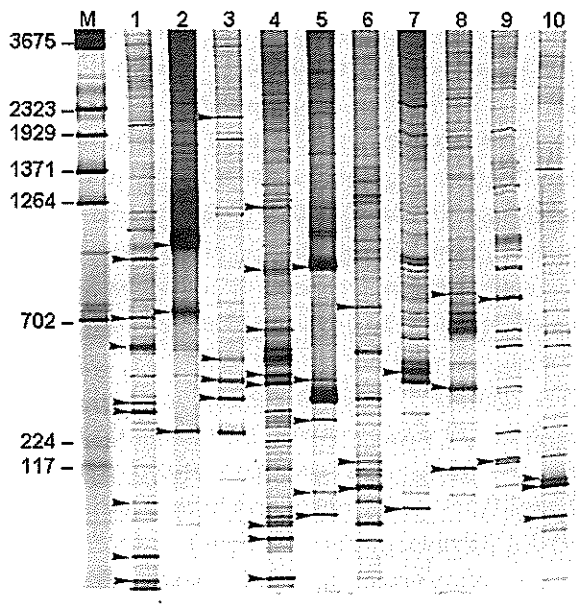


Figure 5. AP-PCR fingerprints of 10 species of tropical fishes generated by a 9-mer primer, 5'-GGTAACGCC-3' [35]. Lanes M: λDNA/*Bst*EII Digest marker (Sigma), 1: *Betta splendens*, 2: *Colisa lalia*, 3: *Trichogaster microlepis*, 4: *Cyprinus carpio*, 5: *Barbus tetrazona*, 6: *Brachydanio rerio*, 7: *Poecilia reticulata*, 8: *Xiphophorus maculatus*, 9: *Oreochromis niloticus* and 10: *Hyphessobrycon innesi*. Arrowheads indicate polymorphic bands among the different species.

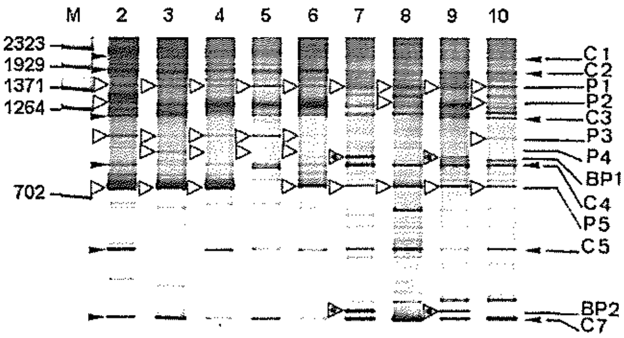


Figure 6. AP-PCR fingerprints of five Green Snakeskin (GSS) guppy males (Lanes 2-6) and four 3/4 Black (3/4 B) guppy males (Lanes 7-10) generated by a 10-mer primer, 5'-AATCGGGTCG-3' [37]. Lane M = λDNA/*Bst*EII Digest marker (Sigma). At least six distinct common bands, C1-C5 and C7 (arrowhead) are present in GSS and 3/4 B individuals. The P1 band (open triangle) is also present in all individuals. P2-P5 (triangle) are the four polymorphic bands in GSS and 3/4 B. The BP1 and BP2 bands (triangle with dot), which are polymorphic in 3/4 B, are absent in GSS.

Ornamental fish breeders should also focus on conditions hitherto not considered before. The first is tolerance to transportation conditions which include low pH and oxygen, high ammonia, nitrite and carbon dioxide, and sharp drops in temperatures when the air carrier is flying at high altitudes [42]. This will reduce mortality rates during transportation. Another is tolerance to urban environments provided by consumers, such as indoor aquaria, artificial lighting, non-optimal temperatures, lack of water exchange, accumulation of metabolic waste products, and indoor or outdoor ponds of restricted sizes.

Almost all ornamental fishes are produced or wild-caught in tropical countries and air-freighted to temperate countries such as United Kingdom, Netherlands, France, Germany, Japan and the United States of America where the main commercial markets exist. Freshwater species originate mainly from the Amazon basin, with the tetras, rasboras, barbs and live-bearing toothed carps (poeciliids) accounting for at least 80% of the millions of fishes exported from this region. Marine ornamentals comprise almost entirely of tropical coral reef fishes, most of which do not survive very well outside their natural marine environment.

Overfishing, pollution and environmental destruction are the major causes of diminishing biodiversity and possible extinction of rare ornamental species. According to McNeely [43], the main cause of overexploitation of biodiversity in tropical countries is the inequity between rich countries (consumers) and poor countries (producers). The global trade in ornamental fishes undervalues the natural resources of the latter, thus resulting in poor countries remaining in poverty.

In conclusion, there is an urgent need for global cooperation where the aquaculture industry, governments, fishermen, fish breeders and hobbyists work together. Measures such as the designation of national conservation parks, sanctuaries, controlled fishing and protection of endangered species should be implemented. Captive breeding of ornamental fishes that are presently caught from the wild should be stepped up. What is required is the conservation of biodiversity for sustainable use. This means controlled harvesting without depleting the overall diversity of the freshwater and marine ecosystems.

Acknowledgements – This work was supported by research grants from the National University of Singapore and European Commission.

REFERENCES

1. Li Z. (1990) *Chinese Goldfish*. Tetra Press, New Jersey, USA.
2. Tamadachi M. (1990) *The Cult of the Koi*. T.F.H. Publications, New Jersey, USA.
3. Kirpichnikov V.S. (1981) *Genetic Bases of Fish Selection*. Translated by G.G. Gause. Springer-Verlag, Germany.
4. Kajishima T. (1977) Genetics and developmental analysis of some new colour mutants in the goldfish, *Carassius auratus*. *Genetics* **86:** 161-174.
5. Katosonov V.Ya. (1978) Colour in hybrids of common ornamental (Japanese) carp. III. Inheritance of blue and orange colour types. *Genetika (Moscow)* **14:** 2184-2192.
6. Cherfas N.B., Peretz Y. and Ben-Dom N. (1992) Inheritance of the orange type pigmentation in Japanese carp (koi) in the Israeli stock. *Israeli Journal of Aquaculture (Bamidgeh)* **44:** 32-34.
7. Phang V.P.E., Ng L.N. and Fernando A.A. (1989) Inheritance of the snakeskin colour pattern in the guppy, *Poecilia reticulata*. *Journal of Heredity* **80:** 393-399.
8. Fernando A.A. and Phang V.P.E. (1990) Inheritance of red and blue caudal fin colourations in two domesticated varieties of the guppy, *Poecilia reticulata*. *Journal of Aquaculture in the Tropics* **5:** 209-217.
9. Phang V.P.E., Fernando A.A. and Chia E.W.K. (1990) Inheritance of the colour patterns of the blue snakeskin and red snakeskin varieties of the guppy, *Poecilia reticulata*. *Zoological Science* **7:** 419-425.
10. Phang V.P.E. and Fernando A.A. (1991) Linkage analysis of the X-linked green tail and blue tail colour genes in the guppy, *Poecilia reticulata*. *Zoological Science* **8:** 975-981.
11. Khoo G., Lim T.M., Chan W.K. and Phang V.P.E. (1999) Genetic basis of the variegated tail pattern in the guppy, *Poecilia reticulata*. *Zoological Science* **16:** 431-437.
12. Khoo G., Lim T.M., Chan W.K. and Phang V.P.E. (1999) Sex-linkage of the black caudal-peduncle and red tail genes in the Tuxedo strain of the guppy, *Poecilia reticulata*. *Zoological Science* **16:** 629-638.
13. Khoo G., Lim T.M., Chan W.K. and Phang V.P.E. (1999) Linkage analysis and mapping of three sex-linked colour pattern genes in the guppy, *Poecilia reticulata*. *Zoological Science* **16:** 893-903.
14. Phang V.P.E., Khoo G. and Ang S.P. (1999) Interaction between the autosomal recessive *bar* gene and the Y-linked snakeskin body (*Ssb*) pattern gene in the guppy, *Poecilia reticulata*. *Zoological Science* **16:** 905-908.
15. Hallerman E.M. and Beckmann J.S. (1988) DNA-level polymorphism as a tool for fisheries science. *Canadian Journal of Fisheries and Aquatic Sciences* **45:** 1075-1087.
16. Hadrys H., Balick M. and Schierwater B. (1992) Application of random amplified polymorphic DNA (RAPD) in molecular ecology. *Molecular Ecology* **1:** 55-63.
17. Streisinger G., Walker C., Dower N., Knauber D. and Singer F. (1981) Production of homozygous diploid zebrafish (*Brachydanio rerio*). *Nature* **291:** 293-296.
18. Walker C. and Streisinger G. (1983) Induction of mutations by X-rays in pregonial germ cells of zebrafish embryos. *Genetics* **103:** 125-136.
19. Shima A. and Shimada A. (1981) Development of a possible non-mammalian test system for radiation induced germ-cell mutagenesis using a fish, the Japanese medaka (*Oryzias latipes*). *Proceedings of the National Academy of Sciences USA* **88:** 2545-2549.
20. Kimmel C.B. (1989) Genetics and early development in the zebrafish. *Trends in Genetics* **5:** 283-288.
21. Vielkind J.R. (1992) Medaka and zebrafish: ideal as transient and sable transgenic systems. In Hew C.L. and Fletcher G.L. (eds.) *Transgenic Fish* pp. 72-91. World Scientific Publishers, Singapore.
22. Fletcher G.L., Davies P.L. and Hew C.L. (1992) Genetic engineering of freeze-resistant Atlantic salmon. In Hew C.L. and Fletcher G.L. (eds.) *Transgenic Fish* pp. 190-208. World Scientific Publishers, Singapore.
23. Zhu Z. (1992) Generation of fast growing transgenic fish: methods and mechanisms. In Hew C.L. and Fletcher G.L. (eds.) *Transgenic Fish* pp. 91-119. World Scientific Publishers, Singapore.
24. Ju B., Xu Y., He J., Liao J., Yan T., Hew C.L., Lam T.J. and Gong Z. (1999) Faithful expression of green fluorescent protein (GFP) in transgenic zebrafish embryos under control of zebrafish gene promoters. *Developmental Genetics* **25:** 158-167.
25. Gong Z., Wan H., Tay T.L., Wang H., Chen M. and Yan T. (2003) Development of transgenic fish for ornamental and bioreactor by strong expression of fluorescent proteins in the skeletal muscle. *Biochemical and Biophysical Research Communications* **15:** 58-63.
26. Chou C.Y., Horng L.S. and Tsai H.J. (2001) Uniform GFP-expression in transgenic medaka (*Oryzias latipes*) at the F0 generation. *Transgenic Research* **10:** 303-315.
27. Kinoshita M. (2004) Transgenic medaka with brilliant fluorescence in skeletal muscle under normal light. *Fisheries Science* **70:** 645-649.
28. Khong H.K. (2009) *Cloning and expression profiling of discus fish (*Symphysodon aequifasciata*) prolactin receptor*. MSc Thesis, Universiti Sains Malaysia, Malaysia.
29. Lin S., Long W., Chen J. and Hopkins N. (1992)

Production of germ-line chimeras in zebrafish by cell transplants from genetically pigmented to albino embryos. *Proceedings of the National Academy of Sciences USA* **89:** 4519-4523.

30. Fernando A.A. and Phang V.P.E. (1985) Culture of the guppy, *Poecilia reticulata*, in Singapore. *Aquaculture* **51:** 49-63.
31. Koh T.L., Khoo G., Fan L.Q. and Phang V.P.E. (1999) Genetic diversity among wild forms and cultivated varieties of Discus (*Symphysodon* spp.) as revealed by random amplified polymorphic DNA (RAPD) fingerprinting. *Aquaculture* **173:** 485-497.
32. Ryman N. and Utter F. (eds.) (1986) *Population Genetics and Fishery Management*. University of Washington Press, Seattle, USA.
33. Tave D. (1993) *Genetics for Fish Hatchery Managers*. AVI Publishing Co., Westport, USA.
34. Khoo G. (2001) *Genetic Markers and Linkage Mapping by RAPD Fingerprinting in the Guppy (*Poecilia reticulata*)*. PhD Thesis, National University of Singapore, Singapore.
35. Dinesh K.R., Lim T.M., Chua K.L., Chan W.K. and Phang V.P.E. (1993) RAPD analysis: an efficient method of DNA fingerprinting in fishes. *Zoological Science* **10:** 849-854.
36. Dinesh K.R., Lim T.M., Chan W.K. and Phang V.P.E. (1995) Genetic variation inferred from RAPD fingerprinting in three species of tilapia. *Aquaculture International* **4:** 19-30.
37. Foo C.L., Dinesh K.R., Lim T.M., Chan W.K. and Phang V.P.E. (1995) Inheritance of RAPD markers in the guppy fish, *Poecilia reticulata. Zoological Science* **12:** 535-541.
38. Welsh J. and McClelland M. (1990) Fingerprinting genomes using PCR with arbitrary primers. *Nucleic Acids Research* **18:** 7213-7218.
39. Williams J.G.K., Kubelik A.R., Livak K.J., Rafalski J.A. and Tingey S.V. (1990) DNA polymorphisms amplified by arbitrary primers are useful as genetic markers. *Nucleic Acids Research* **18:** 6531-6535.
40. Cabrita E., Robles V. and Herraez P. (eds.) (2009) *Methods in Reproductive Aquaculture: Marine and Freshwater Species*. CRC Press, Boca Raton, USA.
41. Babin P.J., Cerdà K. and Lubzens E. (eds.) (2007) *The Fish Oocyte: From Basic Studies to Biotechnological Applications*. Springer, Dordrecht, Netherlands.
42. Teo L.H., Chen T.W. and Lee B.H. (1989) Packaging of the guppy, *Poecilia reticulata*, for air transport in a closed system. *Aquaculture* **78:** 321-332.
43. McNeely J.A. (1992) The biodiversity crises: challenges for research and development. In Sandlund D.T., Hindar K. and Brown A.H.D. (eds.) *Conservation of Biodiversity for Sustainable Development* pp 15-32. Scandinavian University Press.

Journal of Science and Technology in the Tropics (2011) 7: 25-30

Evaluation of straight fertilizer, urea (Agrenas) and ammonium sulphate on *Hevea brasiliensis* (RRIM2000)

Shafar Jefri Mokhatar and Noordin Wan Daud[1]
Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia,
43400 Selangor, Malaysia
([1]E-mail: wnordin@agri.upm.edu.my)

Abstract Demand for natural rubber is expected to increase once more. Due to the increase in demand and price, interest towards rubber will also increase and many people will need quality scions for the rubber nursery and industry. A fertilizer evaluation study was conducted to compare the new urea fertilizer Agrenas from PETRONAS, with the oldest synthetic nitrogen fertilizer, ammonium sulphate, on rubber at the nursery stage. Through this study, it was found that urea performs equally as well when compared to ammonium sulphate at the equivalent of 10g N. However, in terms of cost per unit nitrogen, urea is very much cheaper; the cost of urea is around USD350-500 per ton, compared to the cost of ammonium sulphate which is USD 5670-6190 per ton. The dosage of urea used should be controlled because it can cause adverse effects on the plant if over applied. The leaves of plant will scorch, the soil will crust, and the plants will be vulnerable to infection. The study provides information for further improvement in rubber nursery management.

Keywords rubber – fertilizer – urea – ammonium sulphate – *Hevea brasiliensis*

INTRODUCTION

Rubber has been grown commercially in Malaysia since 1903, when the first rubber estate was established in Melaka. Malaysia is the biggest consumer of pure latex and fifth in the consumption of natural rubber in the world. Asia is the biggest producer of natural rubber in the world, led by Thailand, Indonesia, Malaysia and Vietnam. Surgical latex gloves, catheters and condoms from Malaysia are known for their high quality and are the most famous in the world. Currently, Malaysia is the largest exporter of these products [1, 2]. The export earnings from rubber in 2009 were worth RM 25 billion. Demand for natural rubber is expected to increase once more and it is projected that there will be a shortage of natural rubber. The price of SMR 20 was RM2.30 in 2003 and RM 10.55 in October 2010 [3]. Rubber prices reached their highest price in decades, fuelled by strong demand from China's auto industry and tight supply in Southeast Asian producing nations [4].

Clones in the case of rubber refer to rubber plants produced from the selection and breeding process, and which have been field-tested. There are several selection criteria in rubber breeding. These include vigour, resistance to diseases, resistance to wind, fewer and higher branches, bark thickness and yield [5, 6]. The clones are produced to improve the yield of the rubber tree. In recent times, yield is not only the latex, but also the timber from the tree which has a high demand as well. To satisfy the demand for latex and timber, the Malaysian Rubber Board (MRB) has conducted research to produce rubber trees which can give high yields of latex and timber; and the result is the RRIM 2000 series of clones. All these clones also have a high growth rate and can be tapped to produce latex yield within a shorter period of time [6, 7].

A fertilizer can be defined as a mined, refined or manufactured product containing one or more essential plant nutrients in available or potentially available forms [8]. Nitrogen is absolutely essential to plant growth. Plants grown in soil with sufficient amounts of available N make for vigorous, rapid growth with leaves having a healthy deep green colour [9]. Nitrogen deficiency symptoms in rubber are seldom reported in Malaysia; this is probably due to the widespread use of nitrogenous fertilizers, and also to the general use of leguminous cover crops when replanting rubber [10]. Plants suffering from N deficiency mature earlier and the vegetative growth stage is often shortened [11]. Urea is classified chemically as an organic compound and contains 46 %

Journal of Science and Technology in the Tropics (2011) 7: 25-30

N by weight. It can be used as a nitrogenous fertilizer which can be applied as a solid or as a solution [12]. Ammonium sulphate (21%N), a white crystalline chemical synthesized from ammonia and sulphuric acid, is largely used for rubber grown on inland soils of Malaysia [13]. The fertilizer consumption in the country has increased tremendously and is likely to continue to do so, while at the same time, the costs of fertilizers are ever increasing. There is an urgent need to know the types of fertilizers, their characteristics and quality suitable for rubber. Fertilizers are important especially in the nursery stage. In establishing rubber nurseries the focus now will be on the latest clones with the right fertilizers for the growth of the scions. This is to ensure maximization of profits. A local company, PETRONAS has launched its own brand of urea fertilizer, Agrenas, which is expected to give higher yield, and to support the growth of Malaysia's agriculture sector.

MATERIALS AND METHODS

The study was carried out in the nursery. Four treatments with four replicates which contain three plants for each treatment were carried out using the completely randomized design (CRD): scions fertilized with the nitrogenous fertilizer Agrenas 1 (21.74 g/plant, equivalent to 10.87 kg/ha), Agrenas 2 (43.48 g/plant = 21.74 kg/ha), ammonium sulphate (47.62 g/plant = 23.81 kg/ha), and unfertilized scions. Agrenas is a commercial brand of urea. The unfertilized scion was used as the control in this study. The respective treatments had the equivalent of 10g N (T1), 20g N (T2), and 10g N (T3) and zero N (T4). The rates were chosen according to current practice, as recommended by the Rubber Industry Smallholders Development Authority (RISDA). The scions used were the RRIM 2000 series clone at the six-month stage in 15cm x 33cm polybags filled with Rengam series soil as the medium. Fertilizer application was done every six weeks at the same rates. The fertilizer was incorporated into the soil around the plant to prevent loss of nitrogen through volatilization. The study duration was 24 weeks, and data on plant height and girth were collected over the duration of the study, while data on leaf N content and dry weight of leaves were collected at the end of the study. Plant height was measured from the soil surface to the shoot tip. The girth was measured at 10cm from the soil. Leaf sampling was done according to foliar sampling method adopted by the Malaysian Rubber Board (MRB). Four basal leaves from the first sub-terminal whorl were collected as a leaf sample [14]. The sampled leaves were cut from stems and placed in the forced draft oven at 60°C for 48 hours. After that, the weights were determined using a weighing machine. The leaf samples were used for (N) analysis by an atomic absorption spectrophotometer (AAS).

RESULTS AND DISCUSSION

The results show that urea (Agrenas) performed equally well as ammonium sulphate in both efficiency and growth. This was shown by treatment T1 (urea, 10g N) which gave an almost similar response to ammonium sulphate (T3) as reflected by leaf dry weight, leaf N content, height and girth increment measurements. ANOVA for height and girth at 24 weeks and the LSD Test showed that at

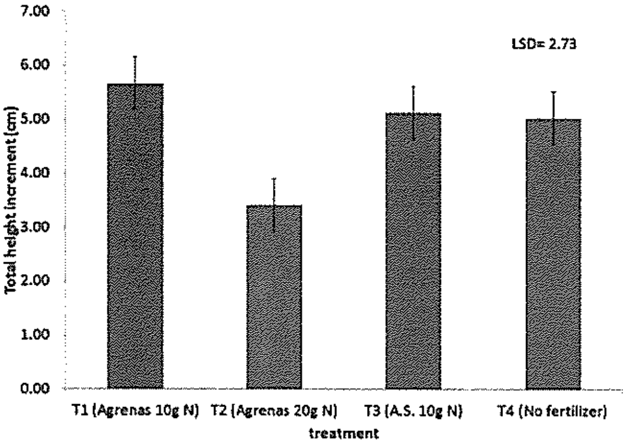


Figure 1. Comparison of total plant height due to different fertilizer treatments after 24 weeks.

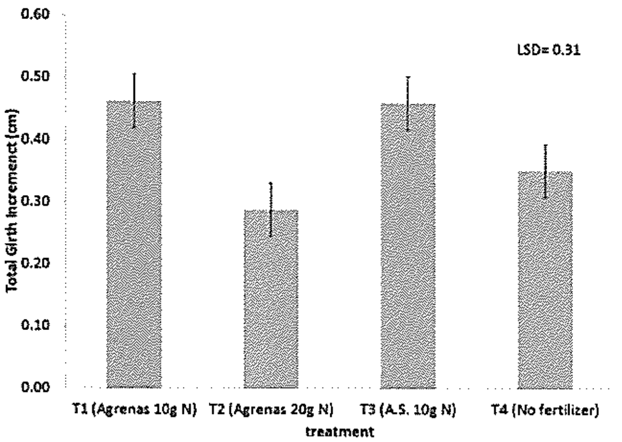


Figure 2. Comparison of total girth circumference due to different fertilizer treatments after 24 weeks.

the probability level of ($P<0.05$) T2 had a lower height and girth compared to the other treatments (Figs. 1, 2). This may have been because the dosage in T2 was too high for rubber plants at this stage of growth. Most of leaves of the plants in T2 were scorched and some had abscised from the plant. Plants recovering from defoliation showed bursts in new vegetative buds. Nutrients, especially N, were utilized to produce new leaves. Consequently, the plants from T2 were lower in girth and height.

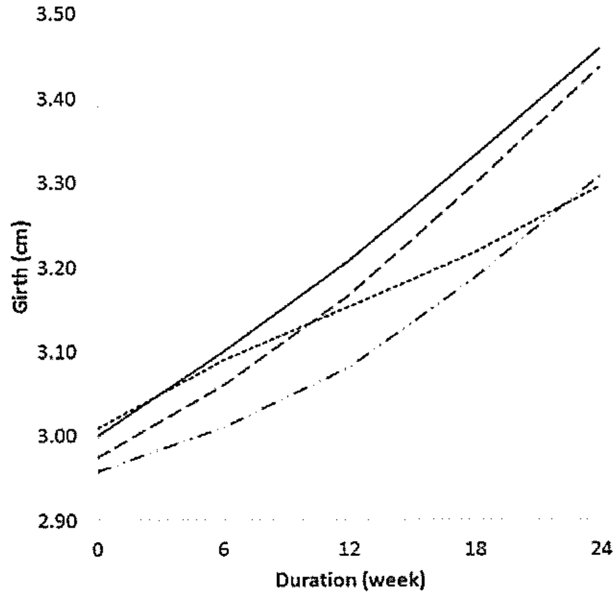


Figure 3. Comparison of girth due to different fertilizer treatments over 24 weeks. -- -- - T1 (Agrenas 10g N); - - - - T2 (Agrenas 20g N); — T3 (ammonium sulphate 10g N); – - - - T4 (no fertilizer).

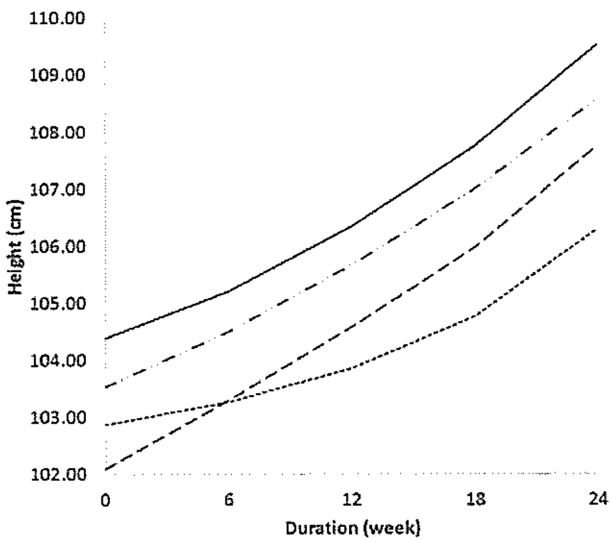


Figure 4. Comparison of plant height due to different fertilizer treatments over 24 weeks. -- -- - T1 (Agrenas 10g N); - - - - T2 (Agrenas 20g N); — T3 (ammonium sulphate 10g N); – - - - T4 (no fertilizer).

Figures 3 and 4 show the trend of girth and height increments at six weekly intervals. All treatments, except T2, showed that the girth and height increased steadily over time. T2 showed slower girth and height increments, probably because of the scorching of the leaves, which interrupted plant growth.

The treatment with ammonium sulphate (T3) produced the highest mean leaf dry weight at 5.26g, followed by urea at 10g N (T1) with 4.53g; urea at 20g N (T2) with 1.96g and the lastly the control (T4) with 1.80g. There was no significant difference between T3 and T1 and between T2 and T4 according to the LSD test.

For leaf N content (Fig. 5), T1 (4.54%) and T3 (4.54%) were not significantly different, but significant from the other treatments, T2 (4.26%) and T4 (2.4%). The leaf N content in T2 was less than T1 and T3. Over-fertilization may have harmed the plant roots, thus interfering with nutrient (including N) uptake in T2.

The observed scorching effect mentioned above due to excessive application of fertilizer in T2 resulted in the leaves of the plants turning yellow and dying (Fig. 6). In the first week after applying fertilizer, all the plants in treatment T2 showed leaf scorch. Too much nitrogen had desiccated or damaged the roots, producing these foliar symptoms in *Hevea brasiliensis*. Consequently the plants were more vulnerable to fungal (Fig. 7) and bacterial infections [15, 16]. The soil in the polybags to which

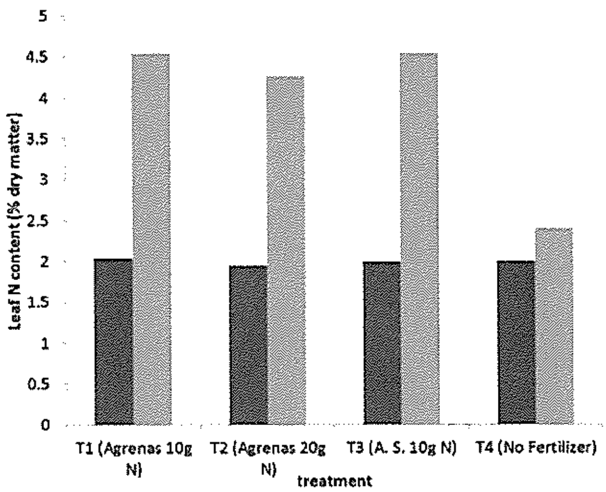


Figure 5. Comparison of leaf nitrogen content due to different fertilizer treatments. ■ initial; ▒ after 24 weeks.

Figure 6. Different stages of scorching of *Hevea brasiliensis* leaves due to excessive fertilizer.

Figure 7. Infection by *Oidium* occurred on the leaves of *Hevea brasiliensis* due to high dosage of urea (T2).

Figure 8. Crusting of soil due to high dosage of urea (T2).

a high dosage of urea had been applied also showed evidence of crusting. This soil crusting (Fig. 8) resulted in impeding the percolation of water through the soil, and water was therefore not readily available to the roots; hence, plant growth was affected. Other studies on over dosage of fertilizer in other crops indicate that a crusting layer developed from excess fertilizer even when the fertilizer was incorporated into the soil during application [17, 18, 19].

CONCLUSION

The findings indicate that urea (Agrenas) was as good as ammonium sulphate for the parameters leaf dry weight, leaf nitrogen content, height and girth increment at the same level of N application. The cost of urea (USD350-500 per ton) [20] being very much cheaper compared to ammonium sulphate (USD 5670-6190 per ton) [21], hence the use of urea (Agrenas) is more economical in providing nitrogen compared to ammonium sulphate. From the results, it can be concluded that the best fertilizer treatment for raising RRIM 2000 series rubber scions was applying urea or ammonium sulphate at a rate equivalent to 10g N. This study suggests that in future urea can be used as a nitrogen source for young rubber instead of ammonium sulphate.

Acknowledgements – The authors would like to thank all the people involved in completion of this study. Grateful acknowledgement is made to Encik Mohd Khoiri Bin Kandar and Encik Mat Yusof for making available the facilities in the Atomic Absorption Spectrophotometer (AAS) laboratory and to all the laboratory assistants in Department of Crop Science. Special thanks are extended to Puan Salmi Yaacob, staff of Department of Crop Science, and also, thanks to the staff of the Crop Section, Agriculture Park, Universiti Putra Malaysia.

REFERENCES

1. Wan Noordin Daud (1993) Getah: Daripada Pertanian Ke Industri. *Isu-isu semasa Sains dan Teknologi*, pp 19-33. Publication of the Ministry of Science, Technology and Environment.
2. Malaysian Rubber Export Promotion Council (2010) http://www.mrepc.com/industry/. Accessed on 30 Jun 2010.
3. Malaysian Rubber Board (2010) Prices of SMR 20 by Malaysian Rubber Board. http://www3.lgm.gov.my/mre/YearlyChart.aspx . Accessed on 15 November. 2010.
4. New Strait Times (2010) Rubber Hits Record on China Demand. October 16, 2010.
5. Wan Noordin Daud (2008) Plantation Crop-Rubber and Oil Palm. Lecture Notes 5, 6,9,11 and 12. Universiti Putra Malaysia, Serdang.
6. Malaysian Rubber Board (2009) *Rubber Plantation and Processing Technologies*. First Edition, Malaysian Rubber Board, Kuala Lumpur, Malaysia.
7. Malaysian Rubber Board (2007) *Klon-Klon Siri RRIM 2000 untuk Lateks dan Balak*. MRB, Kuala Lumpur.
8. Roy R.N, Finck A., Blair G.J. and Tandon H.L.S. (2006). *Plant Nutrition for Food Security*. FAO.
9. Martin J.H., Waldren R.P. and Stamp D.L. (2006) *Principles of Field Crop Production*, 4th edition, Pearson Prentice Hall.
10. Shorrocks V.M. (1964) *Mineral Deficiencies in Hevea and Associated Cover Plants*. RRIM, Kuala Lumpur, Malaysia.
11. Mengel K. and Kirkby E.K. (1987) *Principles of Plant Nutrition*, 4th edition, Plant Nutrition, International Potash Institute, Bern, Switzerland.
12. PETRONAS (1988) *Urea in Perspective*. Petronas, Kuala Lumpur.
13. Tajuddin Ismail (1979) Composition and characteristic of inorganic fertilizers. *RRIM training manual on rubber planting and nursery techniques*. RRIM, Kuala Lumpur.
14. Rubber Research Institute of Malaysia (1990) *Manual for Diagnosing Nutritional Requirements for* Hevea. Vinlin Press Sdn Bhd, Kuala Lumpur.
15. Diane R., Alan M.D. and Steve D. (2002) Fertilizing the Vegetable Garden. *Virginia Cooperative Extension. Publication* 426-323. http://pubs.ext.vt.edu/426/426-323/426-323.html. Accessed on 7 September 2009.
16. Williams S. (2008) *Garden Line, Fertilizer: The Basics. Department of Horticulture Science.* University of Saskatchewan. http://gardenline.usask.ca/misc/fertiliz.html. Accessed on 7 September 2009.
17. North Carolina University (2010) Fertilizing House Plants. Retrieved from http://www.ces.ncsu.edu/depts/hort/consumer/quickref/houseplants/fertilizing.html on 21 October 2010.
18. Mary N.L. (2009) Caring for Over Fertilized. Retrieved from http://www.associatedcontent.com/article/1727902/caring_for_an_over_fertilized_indoor.html?cat=32.
19. Arizona University (1998). *Arizona Master Gardener*

Journal of Science and Technology in the Tropics (2011) 7: 3

EDITORIAL

Promotion of Science and Technology

The world around us abounds with science and science affects our everyday lives from the time we wake up to the time we sleep. Science in fact influences our lives truly "from cradle to grave" and consequently the national development. Yet, the awareness of the critical importance of Science and Technology (S&T) in our everyday lives is still inadequate. At best people take S&T for granted. This is particularly serious when the lack or apparent lack of awareness is amongst our political leaders. When that awareness is lacking, it is usually translated to a lower funding for S&T and for Research and Development (R&D). When this happens, the implications are very serious. While Malaysia aspires to be an innovative society, it must be realized that support for R&D is critical in order to promote innovation.

With the establishment of the National Research and Development Council and the National Innovation Council, supported by the National Science Policy, it is hoped that the top level of administrative and policy infrastructure and mandate are in place. What needs to follow are the other two "M's" after the first "M" of "Mandate" and that is "Money" and "Manpower". Political recognition of the importance of Science and Technology must come along with appropriate budgetary allocations. Thus it is important that funding for R&D should be increased to be at least 2% of the national Gross National Product.

The second level of lack of awareness of the importance of S&T is by the public and this is reflected by the percentage of students opting for the Arts is higher than those opting to study Science. A well-educated and sustainable workforce with relevant S&T training will be crucial in Nation building and to drive the knowledge-based economy. The government aspiration to have 60% school going children studying in the science stream has yet to be achieved. In this regard, science laboratories should be supported with up-to-date equipment and facilities. More importantly, science teachers must be adequately trained and fully aware of the development of S&T that goes around us. We need to keep up-to-date with the development of S&T and these developments must be reflected in the teaching of S&T at schools. In this regard, the teaching of science and mathematics must be in English in the interest of the development of science in the country. Moreover teaching of S&T must not be limited to the classroom only but exposure to real life situations on the ground is equally important.

The final level of lack of awareness of the importance of S&T is amongst the younger generations. The role of parents and teachers are critical but others such as NGOs have an important role. For example, the programme "PUSAT" or "Promotion of Understanding of Science and Technology" as undertaken jointly by The Malaysian Scientific Association and the Academy of Sciences Malaysia, must be supported by all NGOs, the Government, in particular, the Ministry of Education.

Awareness of the importance of S&T is a long term investment that is critical if Malaysia is to achieve a developed country status by 2020. Without the critical mass, the research funding and the commitment by the private and public sectors, the aspiration for Malaysia to produce a Nobel laureate in S&T will never materialize. Science and technology are dynamic and progressing all the time. The Government must likewise, continue to evaluate the impact of S&T policies, financial incentives, and the funding system in order to achieve the desired outcomes of economic change. Perhaps what we need is the creation and implementation of a New S&T Policy Transformation Programme to complement the New Economic Transformation Programme.

Dr Salleh Mohd. Nor and Dr Ong Eng Long
Co-Chairman JOSTT

Manual. Cooperative Extension, College of Agriculture, University of Arizona.

20. Alibaba.com (2010). Nitrogen Fertilizer, Urea N46. http://www.alibaba.com/product-free/105941273/UREA_N46.html. Accessed on 6 September 2010.

21. Alibaba.com (2010) Nitrogen Fertilizer, Ammonium Sulphate. http://www.aliexpress.com/product-gs/314918673-Ammonium-sulfate-wholesalers.html. Accessed on 6 September 2010.

Journal of Science and Technology in the Tropics (2011) **7**: 31-39

Mechanical and physical properties of three-layer cement-bonded particleboards from *Leucaena leucocephala* (Petai Belalang)

A. R. Marzuki[1], O. Megawati[2], M. S. Hamidah[3]*, and M. R. Ahmad Ruslan[3]
[1]Faculty of Civil Engineering, Universiti Teknologi MARA, Jengka Campus, Pahang, Malaysia
[2]Research Management Institute, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia
[3]Faculty of Civil Engineering, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia
(*E-mail: hamid929@salam.uitm.edu.my)

Received 23-12-2010; accepted 28-02-2011

Abstract This study used *Leucaena leucocephala* (*LL*) to determine the compatibility and suitability of using *LL* as wood particles to manufacture cement bonded particleboard (CBP) of three layers. Two types of *LL* tree trunks, 8 and 16-year old were used as three-layer *LL*-CBP specimens of four series of *LL* wood particles to cement ratios, 1:2.5, 1:2.25, 1:2.0 and 1:1.75. After 28 days, the mechanical and physical properties of the *LL*-CBP boards were investigated. The tested *LL*-CBPs of the 8-year old *LL* trees showed better mechanical strength than those of the 16-year old. The results also showed that the modulus of rupture (MOR), modulus of elasticity (MOE), internal bond (IB), thickness swelling (TS_w) and water absorption (WA) of these CBPs passed the values stipulated in the codes of MS 544:2001. The *LL* is feasible to be used as the particle raw materials to build CBP.

Keywords cement bonded particleboard (CBP) – *Leucaena leucocephala*

INTRODUCTION

The demand of particleboards has increased which induces research on the feasibility of using fast growing trees as raw materials to build particleboards. Researching to exploit fast growing trees to build cement bonded particleboard (CBP) is essential to attain comparable, if not better, materials than the present sources of wood particles, and to counter lack of source of wood particles and deforestation. The CBP, crucial in construction, is constructed from wood particles, Portland cement and water, which are chemically treated. It must be noted that partly, the superiority of CBP is subject to the compatibility of wood particles to maintain elasticity, less tendency to crack, a strong internal bond and good dimensional stability.

With increasing demand of particleboards, many types of woods like athel, black locust, southern pine and red pine are used. In Malaysia, the production of CBP, which began in 1982, used rubber wood as wood particles [1]. However, Malaysia is facing depletion of rubber wood as a source of raw material as the area planted with rubber trees has been drastically reduced to make way for development. In 2004 alone, Malaysia exported particleboard and medium density fibreboard (MDF) worth RM 608 million and a large part of them were made of rubber wood [2] but the Malaysian rubber area was reduced from almost 2.0 million hectares in 1980 to only 1.25 million hectares in 2005 [3]. Continuous exploitation of rubber by many types of industries may affect the production of latex, which in turn may harm the income of rubber planters and rubber tapers. In addition, it is anticipated that if the price of rubber wood soars, the price of CBP production may increase.

Leucaena leucocephala, locally known as Petai Belalang, is a tropical fast growing tree, grown widely in Southeast Asia. It can be found almost everywhere in Malaysia such as by the roadside, empty fields and jungles. Its density is from about 600 to 1000 kg/m^3 [4]. In addition to fast-growing, it can reach 20 m tall and has a girth 5 to 50 cm bole diameter [5]. *LL* trees can breed very fast and need no intensive care. At present, it is only used as shading trees and the leaves are used as cattle feeds. Once they reach maturity the *LL* trees are just burned or left to decay.

For making CBP, *LL* has another advantage that its light yellow hue and the yellow brown heartwood [5-7] are almost similar to the colour of the rubber wood, unlike the darker *Acacia*. Economically, using fast growing trees to make CBP could make a crucial contribution to enhance the construction, environment and economic needs of the country, other than offering an immediate constant supply to the manufacturers of CBP.

Little study has been conducted to explore the use of *LL* in manufacturing cement board. This study investigated the feasibility of *LL* for the production of particleboards. The objectives of this research were to (1) test the chemical composition, the physical properties of the *LL* particles, and the hydration of the *LL*-cement mixtures, (2) characterize the mechanical properties and physical properties of the particleboards having the *LL* wood particles, and (3) determine the influence of wood/cement ratio on the two ages (8 years and 16 years old) of the *LL* wood particles on the properties of the particleboards.

MATERIALS AND METHODS

Materials

The 8 years and 16 years old *LL* wood was obtained from the Malaysian Agriculture Research and Development Institute (MARDI) farm in Kelantan, Malaysia. The plots of the two ages of these *LL* trees were adjacent to each other, planted and documented by the said organisation. They were marked 8Y for *LL* trees of 8 years old and 16Y for the *LL* trees of 16 years old. The two ages were sampled to determine the effect of the tree maturity on the quality of CBP of three layers. The age of *LL* trees, like other species, can be distinguished by looking at the size of the heartwood when the trunk is cross-sectioned. The cross section of 8 and 16-year old *LL* is shown in Figure 1.

To prepare the *LL* particles, the *LL* tree trunks were chipped with a drum chipper, flaked with a knife ring flaker and then crushed into particles. The particles were retained in the 3.35 mm sieve size and then were fed once again into the flakers to produce smaller particles suitable to build CBP. Then, the *LL* particles were air dried for about two weeks to achieve the moisture content of between 15 % to 18 % range, adopted from Rahim and Asma [9].

Testing on the *LL* wood particles

(a) Chemical composition test on the LL wood particles The chemical composition of the *LL* was conducted by a standard method in pulp and paper industry, the Technical Association of the Pulp and Paper Industry USA (TAPPI) [11-15], which tests on cold water solubility, hot water solubility, NaOH solubility, alcohol-benzene solubility, lignin, holocellulose, ash and sugar content. Two identical samples of the *LL* wood particles were tested for the chemical composition.

(b) Physical properties test on the LL wood particles The physical properties of *LL* wood particles tested were bulk density and particle size distribution. The bulk density of *LL* particles was determined by the weight of the particles in a 1-litre cylindrical flask. The laboratory method of measuring the bulk density (loose) of wood particles is given in TAPPI UM 23:

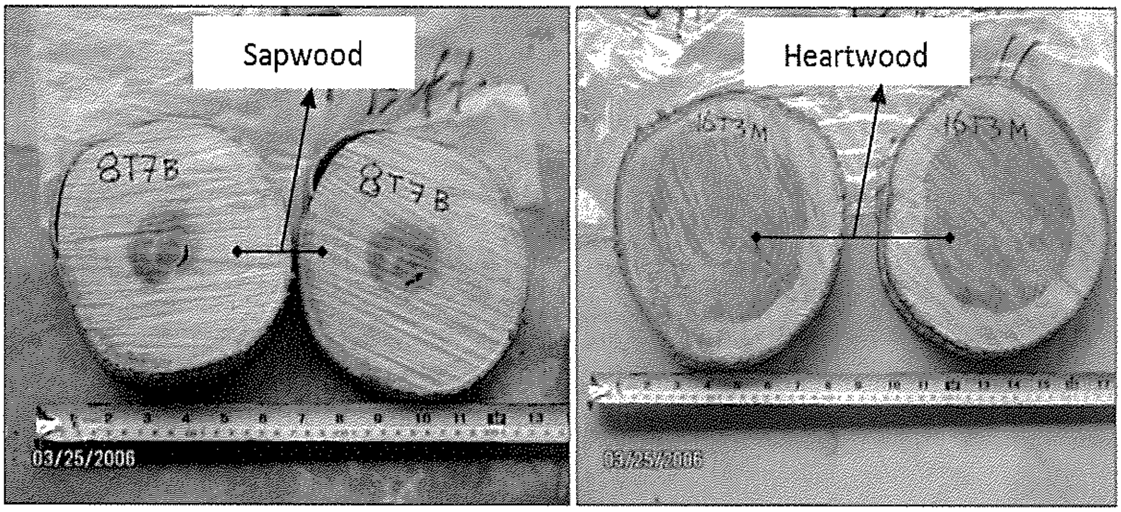


Figure 1. Cross sections of the 8-year old (left) and 16-year old (right) disk of the *LL* trunks.

Bulk density of wood chips [16]. The particle size distribution was analyzed by a method established by Bahre [17]. Six sets of the *LL* wood particles samples were tested for the bulk density while two sets of samples were tested for its particle size distribution.

(c) Hydration test A series of neat cement and *LL*-cement mixtures were run to determine the influence of *LL* particles on the maximum temperature (T_{max}) and time to reach the maximum temperature (t_{max}) in the Portland cement matrix. The test was conducted based on the method prescribed in ASTM C 186-83 [18] by using a Shinko Thermal Recorder. For hydration test, two sets for each series of the *LL*-cement mixtures were adopted.

A sample consisted of 200 g of cement, mixed with 87 mL of distilled water and 10 g of *LL* wood particles in a polythene bag (Table 1). After a manual full mixing for 5 minutes, 1 cm of iron-constant thermocouple wire was inserted into the mixture in the centre of the polythene bag. The polythene bag was secured with an adhesive tape and placed in a 1-litre capacity thermos flask. The process was carried out in one turn and recorded by a thermal recorder, conducted in a controlled temperature room maintained at 22 ± 1°C. A cement hydration temperature and time curve in each sample was observed and plotted for 24 hours. This is because ambient temperature at the time of mixing and setting would affect cement hydration, strength and wood cement compatibility test [19].

Preparation of cement binder

To prepare the cement binder, ordinary Portland cement (OPC) was used. Aluminum sulphate and sodium silicate were mixed as a cement accelerator at 1.5% and 3% of dosage respectively. The percentage was prepared for each ratio series.

Preparation of cement particleboard (CBP) specimens

For comparison purposes, four ratios of wood/cement were used: 1:1.75, 1:2.0, and 1:2.25 and 1:2.5 based on the air-dried weight of wood particles. A panel board of 450 mm x 450 mm x 10 mm, at target density of 1300 kg/m³ was prepared for each ratio series. Five replicates of panel boards were prepared for each ratio (Table 2).

Table 1. Proportions of cement, water and wood in *LL*-cement mixture for compatibility test.

Sample	Cement (g)	Water (mL)	Wood (*LL*) (g)
Control	200	80	-
LL-cement	200	87	10

The *LL*-CBP panels were made into three-layer sandwich boards to test the different ranges of *LL* particles size. A combination of 1 mm and 0.5 mm particles was used for the outer layers of the boards; the wood particles of 2 mm sieve size were used for the middle or core layer. For each series, five identical board panels were prepared. For a piece of board panel production, half of the wood particles were from the fine particles (1 mm and 0.5 mm particles) and another half of the weight was from coarse particles (2 mm). The fine particles were divided into two, top and bottom layers. Hence, the weight ratio of both outer layers to the core layer was 1:1. Forty pieces of three-layer *LL*-CBP were made from the 8-year old and 16-year old *LL*. Table 2 shows the details of the series and the number of CBP panels prepared.

Aluminium sulphate and sodium silicate accounting for 1.5% and 3% by the weight of cement were prepared and placed in the cement mixer with the fine wood particles. Water was added and the mixture was thoroughly mixed. OPC was then added and the mixing was continued to obtain uniformity.

The blending was repeated when mixing the coarse *LL* particles for the core (interior) layer of the boards. The wood particle mixtures were spread by hand and consolidated into boards of 10 mm thick in the mould. Pressure was then applied to these boards. The boards were clamped for 24 hours and hardened under a controlled condition at 65°± 3°C in a hardening chamber. The boards then were removed from the moulds and placed on the rack, which was placed 15 mm above water. The water level below the rack was kept constant in the entire curing period of 28 days. The purpose of having the water below the rack was to control its relative humidity within the range of 83% to 96% and the rack was left for 28 days to ensure full hydration of cement. After 28 days, the cured panels were trimmed and cut into

Table 2. Details of the series and number of CBP panels.

Target density (kg/m³)	Wood/cement ratio	Three-layered CBP (unit of panel)	
		8Y	16Y
1300	1:1.175	5	5
1300	1:2.00	5	5
1300	1:2.25	5	5
1300	1:2.50	5	5

pieces of various sizes for testing their mechanical and physical properties.

Testing of *LL*-CBP boards

(a) Mechanical properties The mechanical properties – modulus of rupture (MOR), modulus of elasticity (MOE) and internal bond (IB) – of the boards were tested in accordance with the Malaysian Standard MS 934: Specification for Wood Cement Board [20] and MS 544: A specification for cement bonded particleboard [21].

(b) Physical properties The physical properties tested were thickness swelling (TSw) and water absorption (WA). The dimension for thickness swelling and the weight for water absorption of the panels were measured respectively after the boards were soaked completely in water for 24 hours. For each testing, 15 identical board specimens were used.

Statistical analysis

The statistical analysis to determine if there was any significant influence between the different wood/ cement ratio and the two ages of *LL* particles used was conducted by an Independent Sample *t*-test of Analysis of Variance (ANOVA) and Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Chemical composition of *LL* particles

Table 3 shows the chemical compositions of the 8 and 16-year old *LL* particles. The *LL* particles had a lignin content of 29-34% and holocellulose content of 81-83%. These lignin and holocellulose contents were about similar to hazelnut husk, kiwi stalk and other types of wood [10, 22].

The sugar content of 0.79% and 0.54% in the 8-year and 16-year old particles respectively, was lower than that in rubber wood (1-1.7%) and oil palm (11-33 %) [23]. The sugar content above 0.5-0.8% would inhibit cement setting [23, 24]. Thus the sugar content in the *LL* particles of both the 8- and 16-year old trees was acceptable for the CBP preparation. This low sugar content is believed to cause minimal delay in the setting of cement.

The test also showed that *LL* had lower solubility values than the solubility values in the kiwi stalk [10], hardwood and softwood species [22] and coconut coir [25]. Having lower solubility values indicate that the boards having the *LL* particles have dimensional stability when immersed in water.

Bulk density test of the *LL* particles

The bulk density of the *LL* fine particles was higher than the coarse particles, and the bulk density of the 8-year old particles was lighter than that of the 16-year old (Table 4). According to Savastano *et al.* [26], the bulk density in the wood is an important factor to explain the compaction ratio of wood/cement ratio. Hence the CBP made of 8-year old *LL* having more wood particles, thus denser with less voids, possesses properties that are believed to produce higher

Table 3. Chemical composition of *Leucaena leucocephala* (*LL*) particle.

Chemical component	Chemical content (%)	
	8Y	16Y
Cold water solubility	5.01	2.01
Hot water solubility	1.65	1.42
1% NaOH soluble	11.97	15.33
Alcohol-benzene solubility	1.51	3.29
Lignin	29.34	33.68
Holocellulose	83.37	81.55
Ash	0.88	0.63
Sugar content	0.79±0.028	0.54±0.035

Table 4. Mean ± SD and range of the bulk density (g/1000 cm^3) of air-dried *LL* wood particles with moisture content of 15-18%.

	8Y		16Y	
	Fine	Coarse	Fine	Coarse
Mean± SD	137.5± 4.51	103.7±1.87	154.1±3.52	118.2±4.63
Range	130.5-143.3	102.0-106.5	149.9-159.3	112.2-122.3

strength, making them suitable to be built into wall for external application.

Particle size

Most of the *LL* particles were retained at the sieve (screen) size of 0.5-2.0 mm which was almost 72% of the total weight. Based on 100 samples, the average thickness and length of the 8-year old and 16-year old flakes were within 0.4-9.58 mm and 0.39-9.42 mm respectively (Fig. 2). Ideally, a higher ratio of length to thickness of wood particle is normally preferred for wood composites products for better internal bonding between particles and the binder. This might be due to the manner the *LL* particles were cut, that they were first chipped and later flaked. As such the length to thickness ratio increased as the shape of the particle was flat and elongated. This could have contributed to a better internal bonding.

Hydration

The maximum temperature (T_{max}) and time to reach maximum temperature (t_{max}) of the two ages of *LL* wood particle are shown in Table 5. The hydration of neat cement attained maximum hydration of 70.5°C with a hydration time of 8 hours. The presence of 10 g oven-dried weight of *LL* particles in the mixtures reduces the T_{max} and delayed the t_{max} to 9 to 10 hours for both ages (Fig. 3). This indicates that there is some retardation effect on the hydration of *LL*-cement mixtures. However, this retardation effect was low as compared to that of oil palm trunk with T_{max} of 57-58°C and t_{max} delayed to 14 hours [27]. There is not much difference in terms of T_{max} and t_{max} for mixtures containing 8-year old or 16-year old *LL* particles.

Table 5. Maximum temperature (T_{max}) and time to reach maximum temperatre (t_{max}) of two ages of *LL*.

	Control (Neat cement)	8Y *LL*-cement	16Y *LL*-cement
Max. Temperature (°C)	70.5	65	65
Time to reach max (hours)	8	10	9

Mechanical and physical properties of the *LL*-CBP

Table 6 shows the mean ± SD values of MOR of the *LL*-CBP. The mean MOR (7.68 MPa to 11.22 MPa) showed a decrease in elasticity and internal bond properties as the wood/cement ratio increased and vice versa.

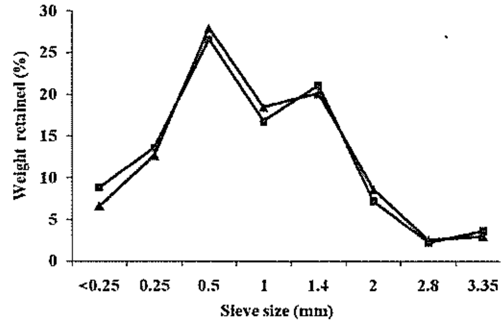


Figure 2. Particle size distribution of 8Y and 16Y *LL* trees. ---▲---, 8Y; ---■---, 16Y.

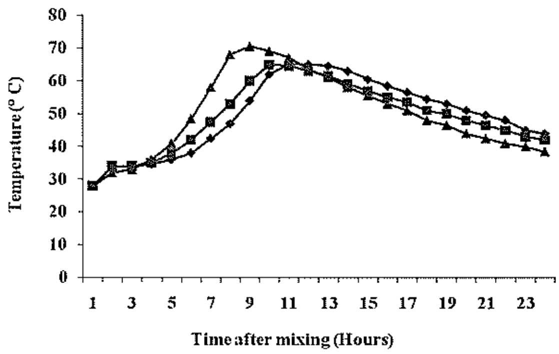


Figure 3. The hydration temperature for the mixture of Portland cement and *Leucaena leucocephala* particles. ---◆---, neat cement; ---▲---, 8Y; ---■---, 16Y.

Table 6. Mechanical and physical properties of 8Y and 16Y *LL* boards (n = 15).

Wood/Cement Ratio	Age	Density (kg/m³)	MOR (MPa)	MOE (MPa)	IB (MPa)	WA (%)	TS_w (%)
1:1.75	8Y	1246±33	11.22±1.33	3453±477	0.840±0.135	12.42±2.73	0.67±0.20
	16Y	1263±44	10.21±1.47	2941±477	0.706±0.102	14.00±1.81	0.70±0.14
1:2.00	8Y	1267±37	10.47±0.87	3604±470	0.902±0.094	14.58±1.14	0.66±0.16
	16Y	1273±40	9.40±1.10	3524±428	0.737±0.128	15.68±1.59	0.64±0.11
1:2.25	8Y	1271±53	9.65±1.49	3558±489	0.790±0.132	15.50±2.09	0.66±0.08
	16Y	1297±44	9.31±1.34	3427±583	0.702±0.096	16.81±1.32	0.56±0.14
1:2.50	8Y	1265±30	8.95±1.27	4002±477	0.729±0.111	19.04±1.49	0.65±0.19
	16Y	1286±71	7.68±1.20	3308±543	0.593±0.097	15.93±1.33	0.38±0.10
MS 544: 2001			>9.0	>3000	>0.5	<30	<2.0

The *LL*-CBP of 1:2.50 wood/cement ratio appeared to attain the best elasticity properties. Similar findings were observed for the CBP specimens investigated by Savastano *et al.* [26], in which the rigidity of the boards decreased with an increasing wood content (lower wood/cement ratio), and as more cement was used, the higher the rigidity. Nevertheless, in this study, the elasticity values, regardless of any wood/cement ratio, were almost equivalent to or well above the MS minimum requirement of 3000 MPa [21]. This shows that the *LL*-CBP achieved adequate rigidity although having wood/cement ratio as low as 1:1.75. In short, the *LL* is able to contribute sufficient bending strength to the boards.

A similar study, using maple particles [28], also found that the rigidity and other properties of the boards increased linearly with a greater cement/wood ratio. However, contradictory findings were reported by Nemli *et al.* [10] where all strength properties were affected similarly as the kiwi wood particle content increased. Almieda *et al.* [29] reported that having lower cement content, the compaction ratio of mat to board thickness increased and led to enhanced bending strength (MOR). In fact, at the same wood/cement ratio, the 8-year old *LL*-CBP specimens gave a higher volume of wood particles in the mixture due to the lightness of the 8-year old wood particles, thus improving the board properties. The higher amount of wood particle would cause even tighter structure on the particleboard, which offers more bonding capacity within the board [10]. Besides bulk density, roughness of the particles also plays a role in the compactness ratio, and affects the properties of the particleboard [30].

The high content of cement might cause brittleness to CBP and at the same time increases the cost of materials. Table 7 shows the differences between the *LL*-CBP boards and the boards made of other wood particles.

In the present study, the bonding between the *LL* wood particles and the binder (cement) had a similar trend in rupture behaviour; decreases as the cement content increases. The positive influence of increasing the cement on the bonding was also not observed by Nemli *et al.* [10]. However, Nemli's opinions contradicted Savastano *et al.*'s [26] and Papadopoulos's [28] that increasing the content of cement would increase brittleness while insufficient cement would reduce the binding effect.

Conversely, in the *LL* case, despite having low cement content, its internal bonding was still much higher than what is stipulated in the MS 544: 2001 (minimum IB is 0.5) [21]. This shows that the CBP having *LL* particles has little effect on the bonding structure between its particle and the binder.

Effect of the *LL* wood/cement ratio

The Duncan Multiple Regression Test (DMRT)

Table 7. Differences between the present findings and those of other CBP made of different types of wood particles.

Properties	Rubberwood CBP*	8Y-LL CBP#	16Y-LL CBP#	Coconut Coir CBP**	Oil Palm Trunk CBP *	Rubberwood CBP***
Density (kg/m^3)	1252-1280	1246-1271	1263-1297	1125	1258-1320	1197-1220
MOR (N/mm^2)	11.67-12.1	9.0-11.2	7.7-10.2	19.94	11.3-12.6	6.4
MOE (N/mm^2)	4318-4696	3453-4002	2941-3524	5315	3394-3815	4090
Internal Bond/IB (N/mm^2)	0.99-1.07	0.73-.90	0.59-0.74	0.73	0.87	0.34
TSw (%)	0.66-0.69	0.65-0.67	0.38-0.70	3.64	0.88-1.23	1.8
Water abs. (%)	9.83-13.96	12.4-19.0	14.0-16.8	19.65	22.2-17.6	15.2

Present study; * [27]; ** boiled and washed coir [25]; *** [31]

Table 8. ANOVA values of Duncan Multiple Regression Test (DMRT) for effect of wood/cement ratio on mechanical properties of 8Y *LL*-CBP specimens. Means with the same letter in the same group indicate not significantly different.

Wood/cement	MOR	DMRT	MOE	DMRT	IB	DMRT
1:1.75	11.22	a	3453	b	0.840	ab
1:2.0	10.47	ab	3604	b	0.902	a
1:2.25	9.65	bc	3558	b	0.790	bc
1:2.5	8.95	c	4002	a	0.729	c

Table 9. ANOVA values of Duncan Multiple Regression Test (DMRT) for effect of wood/cement ratio on mechanical properties of 16Y *LL*-CBP specimens. Means with the same letter in the same group indicate not significantly different.

Wood/cement	MOR	DMRT	MOE	DMRT	IB	DMRT
1:1.75	10.21	a	2941	b	0.706	a
1:2.0	9.40	a	3524	a	0.737	a
1:2.25	9.31	a	3427	a	0.702	a
1:2.5	7.68	b	3308	ab	0.593	b

Table 10. ANOVA values of Duncan Multiple Regression Test (DMRT) for effect of wood/cement ratio on physical properties of 8Y *LL* boards. Means with the same letter in the same group indicate not significantly different.

Wood/cement	TS_w	DMRT	WA	DMRT
1:1.75	0.67	a	12.42	c
1:2.0	0.67	a	14.58	b
1:2.25	0.66	a	15.50	b
1:2.50	0.65	a	19.04	a

Table 11. ANOVA values of Duncan Multiple Regression Test (DMRT) for effect of wood/cement ratio on physical properties of 16Y *LL* boards. Means with the same letter in the same group indicate not significantly different.

Wood/cement	TS_w	DMRT	WA	DMRT
1:1.75	0.70	a	14.00	b
1:2.0	0.65	ab	15.68	a
1:2.25	0.57	b	16.81	a
1:2.50	0.38	c	15.93	a

indicated that the wood/cement ratio had a significant effect on the MOR, MOE and IB of the *LL*-CBP at 5% level of significance (Tables 8, 9). The mechanical properties of the 8-year old *LL*-CBP were significantly influenced by the wood/cement ratio. Therefore, it implies that the *LL*-CBPs behave similarly like those of other woods [26, 28, 31].

The swelling of the *LL*-CBP produced by 8-year old *LL* (Table 10) was not influenced by the wood/cement ratio as those of 16-year old. This indicates that younger *LL* does not have effect on the swelling as the wood/cement ratio changed. Not having effect on swelling is an additional advantage to the boards made of low cement content. These results contradicted the finding of reduced cement content causing poor internal bonding and high springback [31]. In addition, the presence of accelerator could improve the dimensional stability as it improves the compatibility of the particles with cement [29, 32]. However, the results from the 16-year old *LL* on the swelling due to water absorption are significant when there was an increase in wood/cement ratio (Table 11).

The wood/cement ratio influenced significantly the water absorption (WA) of the boards after a 24-hour soak in water for boards of 8-year old but not for 16-year old *LL* (Tables 10, 11). The boards with the highest cement content recorded the highest water absorption.

The most suitable wood/cement ratio to produce the finest *LL*-CBPs is 1:1.75. As concluded by other researchers [31], the CBP incorporating 2.5 to 3.0 parts of Portland cement to 1.0 part of wood particles (by weight) attain acceptable mechanical and physical properties. In one study [31], the CBP made of wastepaper and sawdust with low cement/particle ratio (2.0:1 on weight basis) was the most economical. The present investigation recorded that the *LL*-CBP boards with a ratio as low as 1:1.75 attained the mechanical and physical properties which fulfil the requirement of MS 544: 2001 [21]. Thus at a wood/cement ratio of 1:1.75, the *LL* has the potential to produce more economical particleboards as cement which is expensive._

Effect of the *LL* age

In the *LL*-CBP specimens, with a ratio of 1:1.75, the maximum strength of rigidity was obtained from the 8-year old *LL* trees (Table 12). Thus the *LL*-CBPs manufactured from the 8-year old trees had a better bending strength compared to the boards of the 16-year old trees.

The Independent Sample *t*-test shows that the MOE of the 8-year old *LL* boards had a higher value compared to those of 16-year old (Table 12). Similarly, the IB of the 8-year old *LL*-CBP specimens was significantly higher than those of 16-year old. Therefore, the 8-year old *LL* wood particles could

Table 12. Independent Sample *t*-test for effect of age of *LL* on physical properties of the three-layer *LL-CBP*.

Properties	Age of *LL* (years)	Number of specimens tested	Mean ± SD	P value
MOR	8	60	10.07 ± 1.50	0.001
	16	60	9.15 ± 1.56	
MOE	8	60	3654 ± 511	0.000
	16	60	3310 ± 539	
IB	8	60	0.82 ± 0.13	0.000
	16	60	0.69 ± 0.12	
TS_w	8	60	0.66 ± 0.16	0.003
	16	60	0.57 ± 0.17	
WA	8	60	15.39 ± 3.07	0.637
	16	60	15.60 ± 1.81	
Density	8	60	1262 ± 40	0.043
	16	60	1280 ± 52	

offer more elasticity, flexural strength and stronger internal bond than the 16-year old. The low density of wood particles obtained from the younger tree (Table 4) required more content of wood particles to be accommodated in the board to maintain the same volume. Thus, the CBP made of 8-year old *LL* having higher bulk density, hence denser with less voids, are able to produce higher strength of boards.

The mechanical properties of *LL*-CBP made of young *LL* trees were statistically superior over those made of the mature *LL* trees. The lower bulk density of the 8-year old *LL* trees allows higher volume of *LL* particles to be consolidated. Having lower bulk density produces a higher board compaction ratio and less void spaces inside the board panel [27]. On the other hand, there is not much difference between the swelling and water absorption values of the 8-year old *LL* and 16-year old boards though Çöpür *et al.* [22] claimed that the higher density of particleboard would produce higher dimensional stability after 24-hour soaking. In sum, having similar or much lower thickness swelling and water absorption to the other types of wood (Table 7), the CBP manufacturers still stand to gain if they use *LL*, that is in terms of the waiting period for the supply of 8-year old *LL* raw materials, which is shorter by 17 years than that of the rubber trees, whose use as particles is only feasible after 25 years (due to other economic reasons).

Acknowledgement – The authors would like to express greatest appreciation and gratitude to the Forest Research Institute of Malaysia and Universiti Teknologi MARA of Malaysia for assisting and funding this study. Thanks are also rendered to the Malaysian Agriculture Research and Development Institute for supplying *Leucaena leucocephala*.

REFERENCES

1. Gan H. and Rahim S. (1992) The cement bonded particleboard industry in Malaysia. *Proceedings of National Seminar on Wood Based Panel Products*. Kuala Lumpur 23-24 Nov 1992 pp. 124-128.
2. Malaysia Timber Industry Board (MTIB). Supply and demand of rubber wood in Peninsular Malaysia. Retrieved April 8, 2007. http://www.mtib.gov.my/rubberwood.php.
3. Dahlan T. (2006) Optimising forest and mill residues. *Proceedings of the 8th Pacific Bio-Based Composites Symposium* pp. 29-49.
4. Oey D.S. (1951) *Specific gravity of Indonesian woods and its significance for practical use*. FRPDC, Forestry Department, Bogor, Indonesia.
5. Collin E.H. (1998) *Leucaena* - A Genetic Resources Handbook. Department of Plant Sciences, University of Oxford, Oxford, United Kingdom, pp. 124-125.
6. James A.D. (1983) *Leucaena leucocephala*: *Handbook of Energy Crops*. Centre for New Crops and Plants Products, Purdue University.
7. Kumar B.M., Kumar, S.S. and Fisher R.F. (1998) Intercropping teak with *Leucaena* tree growth and modifies soil characteristic. *Agroforestry System* **42**: 81-89.
8. Eusebio D.A., Florence P.S., Rico J.C. and Evans P.D. (2002) Manufacture of low-cost wood-cement composites in the Phillipines using plantation grown Australia species: *Eucalypts*. *Proceedings of Wood Cement Composites in the Asia Pacific Region* pp. 115-122.
9. Rahim S. and Wan Asma I. (1990) Cement bonded particleboard from *Acacia mangium* – A preliminary study. *Journal of Tropical Forest Science* **2**: 267-273.
10. Nemli G., Kirci H., Serdar B. and Ay N. (2003) Suitability of kiwi (*Actinidia sinensis* Planch.) prunings for particleboard manufacturing. *Industrial Crops and Products* **17**: 39-46.
11. TAPPI T 204 (1996) *Sampling and preparing wood for analysis*. Technical Association of the Pulp and Paper Industry (TAPPI) Standard for Fibrous Materials and Pulp Testing, Norcross, USA.
12. TAPPI T 212 (1996) *1% caustic soda solubility of woods*. Technical Association of the Pulp and Paper

Industry (TAPPI) Standard for Fibrous Materials and Pulp Testing, Norcross, USA.
13. TAPPI T 257 (1996) *Alcohol-benzene solubility of wood.* Technical Association of the Pulp and Paper Industry (TAPPI) Standard for Fibrous Materials and Pulp Testing, Norcross, USA.
14. TAPPI T 222 (1996) *Acid insoluble lignin in wood and Pulp.* Technical Association of the Pulp and Paper Industry (TAPPI) Standard for Fibrous Materials and Pulp Testing, Norcross, USA.
15. TAPPI T 222 (1996) *Alpha-, Beta and Gamma-Cellulose in Pulp.* Technical Association of the Pulp and Paper Industry (TAPPI) Standard for Fibrous Materials and Pulp Testing, Norcross, USA.
16. TAPPI UM 23 (1996) *Bulk density of wood chips.* Technical Association of the Pulp and Paper Industry (TAPPI) Standard for Fibrous Materials and Pulp Testing, Norcross, USA.
17. Bahre B.W. (1985) *Physical determinations for the control of quality of the chip boards, fiber boards and OSB boards.* Bison Werke, Bahre and Greten GmbH, Weinheim, Germany.
18. ASTM C186-83 (1983) *Heat of hydration of hydraulic cement.*
19. Wei Y.M., Zhou Y.G. and Tomita B. (2000) Hydration behavior of wood cement-based composites I: Evaluation of wood species effects on compatibility and strength with ordinary Portland cement. *Journal of Wood Science* **46**: 296-302.
20. MS 934 (1986) *Malaysian Standard Specification for Wood Cement Board.* Standards & Industrial Research Institute of Malaysia (SIRIM).
21. MS 544 (2001) *Malaysian Standard Specification for cement bonded particleboard, Part 4, Section 3.* Standards and Industrial Research Institute of Malaysia (SIRIM).
22. Cöpür Y., Güler C., Akgül M. and Taşçioğlu C. (2007) Some chemical properties of hazelnut husk and its suitability for particleboard production. *Building and Environment* **42**: 2568-2572.
23. Simatupang M.H. (1985) Wood cement boards. In Bever M.B (ed.) *Encylopedia of Materials Science and Engineering* pp. 5399-5402. Pergamon Press Ltd.
24. Weber H. (1985) International construction system. *Handbook of Element Construction with Cement Boards and other Types of Board* pp. 95-98. Bison Werke, Bahre and Greten GmbH, Weinheim, Germany.
25. Asasutjarit C., Hirunlabh J., Khedari J., Charoenvai S., Zeghmati B. and Cheul Shin U. (2007) Development of coconut coir-based lightweight cement board. *Construction and Building Materials* **21**: 277-288.
26. Savastano H. Jr., Warden P.G. and Coutts R.S.P. (2000) Brazilian Waste Fibres as reinforcement for cement-based composites. *Cement and Concrete Composites* **22**: 379-384.
27. Rahim S. (1996) *Development, Properties and Durability of Oil Palm Fibre Cement Composite.* PhD Thesis, University of Sheffield, UK.
28. Papadopoulos A.N. (2008) Performance of cement bonded boards made from maple particles. *Holz Roh Werkst* **66**: 385-387.
29. Almeida RR, Menezi C.H.S.D. and Teixeira D.E. (2002) Utilization of the coconut shell of *babacu* (*Orbignya sp.*) to produce cement-bonded particleboard. *Bioresource Technology* **85**: 159-163.
30. Barboutis J.A. and Philippou J. L. (2007) Evergreen Mediterranean hardwoods as particleboard raw material. *Building and Environment* **42**: 1183-1187.
31. Fuwape J.A., Fabiyi J. S. and Osuntuyi E.O. (2007) Technical assessment of three layered cement-bonded boards produced from wastepaper and sawdust. *Waste Management* **27**: 1611-1616.
32. Halvarsson S., Edlund H. and Norgren M. (2009) Manufacture of non-resin wheat straw fibreboards. *Industrial Crops and Products* **29**: 437-445.
33. Zheng Y., Pan Z., Zhang R., Jenkins B. M. and Blunk S. (2006). Properties of medium-density particleboard from saline Athel wood. *Industrial Crops and Products* **23**: 318-326.

Journal of Science and Technology in the Tropics (2011) 7: 40-48

Improving productivity and economic development in agriculture

C. Devendra
Consulting Tropical Animal Production Systems Specialist, 130A Jalan Awan Jawa,
58200 Kuala Lumpur, Malaysia
(E-mail: cdev@pc.jaring.my)

Abstract Improving productivity and development in agriculture is discussed in the context of its multifunctional role and as an important determinant of economic growth. The former involves both food and non-food products, linking the system components (land, crops, animals and water), small farmers and the landless. Technologically driven transformation and development spur agricultural growth, reflected in the success through the Green Revolution. Economic growth and transformation follows with resultant expansion of the manufacturing and service sectors. In Malaysia, the development of the oil palm sector contributed further to economic growth. Agriculture became secondary with slow growth, due to a combination of structural and policy constraints, inadequate R&D, and the liberalisation of trade. Waning agriculture and its neglect is evident in the declining share of agriculture in GDP between 1965 and 2004: East and North East Asia – from 53 to 9%; South and South West Asia – from 35 to 17%; and South East Asia – from 30 to 11%. Self-sufficiency levels in Malaysia are impressive for fisheries (103%), fruits (106 %), poultry products and pork (115-132%), with much lower levels for other food commodities. Priority development strategies include inter alia focus on rainfed areas, oil palm-based silvopastoral systems and ruminant production, vigorous application of productivity-enhancing technologies, and development of adaptation and mitigation approaches to cope with the threats and effects of climate change. Revitalising agriculture must come from policy and institutional support, backed by increased investments and private sector participation in the immediate tomorrow.

Keywords Agriculture – development pathways – economic transformation – self-sufficiency – food commodities – silvopastoral systems – climate change – R&D investments

INTRODUCTION

Asian agriculture is an important determinant of economic growth, and the technologically driven transformation and development through the Green Revolution of the 1960s and beyond is testimony of this fact. Together with forestry and fisheries, agriculture provides the primary source of food , nutritional and food security for the welfare of the people [1]. Its multifunctionality concerns the efficient use of natural resources, and preservation of the ecosystems in a manner that it can sustain the needs of human welfare in the future.

The agriculture sector also produces non-food products like biofuels and rubber which are of much economic importance and a variety of important services:

- Links system components (land, crops, animals and water) ,small farmers and the landless
- Agricultural growth provides for pro-poor initiatives and environmental sustainability
- Links to several component industries like food processing and feed milling
- Promotion of nutritional and food security
- Foreign exchange savings from exports e.g. of staples and imports, and
- Research and development (R&D) and innovation link science and society, resolution of problems of farmers, and scale-neutral technology application and adoption.

Despite the importance of agriculture, the sector is one of general neglect and does not appear to be high on the priority for national development compared to other sectors such as information and communication technology. This is reflected in lower growth in production of rice, wheat and staples, and inability of the production resources to match the expanding human requirements such as in foods of animal origin due to rapid population growth rates. Slow growth is apparent for the following reasons [2]:

- *Structural constraints*: inequality of land ownership, lack of human capital development due to access to health and education, and inadequate rural infrastructure
- *Policy constraints*: anti-agriculture macroeconomic policies, failure in agricultural credit policies, and lack of promotion of R&D and external services
- *External factors*: progress in liberalisation of agricultural trade, agricultural price instability and declining official development assistance.

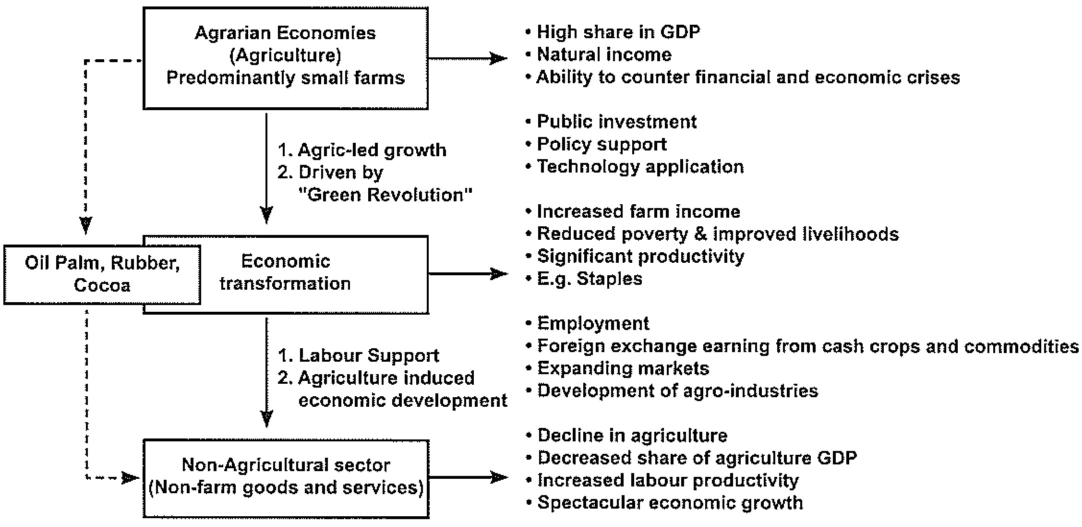
The intent in this paper is to briefly describe the importance of agriculture, its development trends in economic transformation in Asia in general, and Malaysia in particular, and current contribution. More particularly, the paper will highlight emerging development opportunities to improve agricultural productivity, emphasise the challenges for R&D in the context of emerging constraints and the quest to revitalise agricultural growth.

DEVELOPMENT PATHWAYS IN ECONOMIC TRANSFORMATION

Agriculture was the primary driver of economic development. Most countries in Asia including Malaysia started as agrarian economies with emphasis on rural development in which the thrust in agriculture was on crop cultivation and especially crops with export potential (e.g. cassava, cocoa, oil palm and rubber). Historically, agriculture invariably contributed to the largest share of the gross domestic product (GDP). Agricultural growth was led by the technology and supply driven Green Revolution which brought with it much affluence for farmers and significant increased productivity. The pace of agriculture-induced economic development was then followed by the growth of the non-agricultural sector, especially the manufacturing and service sectors. The resulting effect was a secondary role for agriculture that was associated with variable outputs, declining agriculture and decreased share in the GDP, increased labour productivity, and spectacular economic growth.

Figure 1 illustrates the development pathways in the process of economic transformation. In Malaysia, support for the development of agriculture has been minimal, but the sector has continued to make significant contributions in many ways. A combination of diversification of agriculture, and the finding that tree crops, notably oil palm, rubber and cocoa were well suited to the Malaysian environment led to a rapid shift and expansion to tree crop-based agriculture. The strategy emphasised the following:

- Pursue the comparative advantage of diversification of natural resource-based commodity exports in which oil palm, rubber and cocoa were prominent
- Intensively invest substantially in R&D on commodities to remain competitive in tandem with the private sector
- Influence of government and markets on resource allocation and the dynamics of growth, and



Figures 1. Development pathways and economic transformation in agrarian economies in general and Malaysia in particular.

- The emerging sequential phases were: commodity exports, import substitution, and export manufacturing.

This development had three important effects. Firstly, natural resource-based commodity exports enabled the generation of significant foreign exchange earnings and helped the country to leap frog from an agriculture base to a strong industrialised non-agriculture setting. Secondly, less emphasis and development attention was given for promoting higher value foods like fruits, meat and milk. Lastly, increased affluence and *per capita* incomes began to fuel diet diversification and increasing imports of higher value.

The leap frog from the agriculture base to resource-based industrialisation, while greatly beneficial to Malaysia, did little to balance with the development of agriculture. Rice fields gave way to export processing zones and electronic factories, together with rice production having no competitive margin over Thailand, which successfully exports rice. The result was a concurrent trend for import substitution. This is unlike the situation with Indonesia, which in addition to the export crops also invested heavily on food crops to increase their productivity at lower costs, as also on non-food products like wood for home consumption.

The relationship between the growth in the agriculture sector and the combined manufacturing and services sector indicate that countries with higher agricultural growth also recorded higher growth in non-agricultural activities. During 197-1995 Indonesia and Malaysia for example fall almost directly on the fitted line to reflect this relationship, with the annual *per capita* average growth in agriculture of 1.70% and 1.26% respectively, pushing growth in the manufacturing and service sectors of 6.23/year and 5.34/year.

DECREASING GROWTH AND WANING AGRICULTURE

Throughout most of Asia, investments and the development of agriculture are on the decline, and the reasons for these are of concern. It has recently been reported [2] that the sector involves a large proportion of the region's surface, provides jobs for 60 % of the working population in the Asia-Pacific region, and generates a quarter of the regions's total GDP. Associated with these, the reliance on agriculture is especially significant as it provides a number of services to mankind. Low product prices, high input prices and higher value addition in industry and services have also made agriculture less attractive. Low productivity and resulting slow growth are apparent. Between the 1980s and 2000-2003, growth in agricultural output in South Asia dropped from 3.6% in the 1980s to 3.0%, and in East Asia and the Pacific from 3.0% in the 1980s to a mere 0.1 %. It was clear that further progress was limited without necessary intervention and infusions of new technologies. Interestingly in Malaysia, value addition in the agriculture and agro-based industry enabled growth at 8.2% in 2005 and 14.2% in 2010 over the Ninth Malaysia Plan period [3].

Waning agriculture and its neglect is evident, in which the share of agriculture in GDP has declined significantly. The fall in agriculture's share in GDP between 1965 and 2004 is reflected in the following data [2]: East and North East Asia: from 53 to 9%; South and South West Asia: from 35 to 17%; and South East Asia: from 30 to 11%.

Associated with waning agriculture and decreasing productivity is the impact on poverty. It has also been reported [2] that while poverty is declining, this has slowed since the 1980s. It is estimated that agriculture alone can lift an estimated 641 million people out of poverty [2], and that a 1% increase in agricultural productivity would lead to a 0.37% drop in poverty in the Asia-Pacific region. In recent years there has been increasing evidence to underline this important relationship. For the region as a whole, and using Thailand as the benchmark for productivity gains, it has been further calculated that about 218 million people can be free of poverty.

INADEQUATE AND DECLINING INVESTMENTS IN AGRICULTURE R&D

Investing in agriculture R&D is the key determinant of productivity growth. Unfortunately, such investments, associated with waning agriculture are inadequate in agriculture R&D. This has been further exacerbated by reduced donor funding for agriculture. Reversing declining agricultural growth calls therefore for increasing the level of R&D support and investments in the future. It is relevant to note that estimated returns to agricultural R&D are high, and high enough to justify an even greater investment of public funds [4], reflected by the massive investments and policies that resulted in the success of the Green Revolution in India.

In Malaysia, R&D expenditure as a percentage of GDP is relatively small, and ranged from 0.2% in the Second Malaysia Plan to 0.68% in the Ninth Malaysia Plan. Within the funding, there is the allocation to the Intensification of Research in Priority Areas project (IRPA) fund, whose allocation has been increasing [5].

It is not clear however, what exactly was the contribution to agriculture, but is probably small. A significantly increased R&D allocation for agriculture is necessary in the country to push productivity increases in agriculture, and progress from here to buoyant commercialisation and entrepreneurship. The need for more innovation in R&D has been emphasised [6].

LAND USE FOR AGRICULTURE

Crop production in Asia is mainly found in the 'high potential' lands, but available arable land in most countries is utilised to the maximum, and in some cases has led to degradation. Irrigated agriculture is well developed in high potential areas, but most countries are still heavily dependent on rainfed production systems. The importance of rainfed agriculture is illustrated in Table 1.

In South East Asia, the total rainfed area is 99 million ha and in South Asia 116 million ha. In South East Asia the rainfed area as a proportion of total land available ranges from 63% in Indonesia to 68.5% in Malaysia and 97% in Cambodia. In South Asia, the corresponding values are from 27% in Pakistan to 84% in Nepal. Only in Pakistan and Sri Lanka does the percentage of irrigated land exceed that of the rainfed area. In absolute terms however, the largest irrigated land area of 43.8 million ha is found in India. The contributions of rainfed production, excluding Pakistan, to agricultural gross domestic product ranges from16% in Malaysia to 61% in Myanmar. Most of the resource-poor farmers in rainfed areas are small farmers or smallholders and the landless, with very small farm sizes [1]. Out of an estimated

Table 1. Human populations, food demand and land use in the priority agroecological zones of Asia [7].

Parameters	Arid/ Semi-arid zones		Sub-humid zone		Humid zone		% of Asia in agro-ecological zones
	Amount/ number	% of Asia	Amount/ number	% of Asia	Amount/ number	% of Asia	
Human populations in 2010 (10^6)	1311.4	35.7	588.8	16.0	1264.5	34.4	86.1
Food demand in 2020 (10^6 tGE)*	358.6	33.4	175.5	16.3	383.9	35.8	85.5
Production of food crops (10^6 tGE)	230.9	31.5	123.6	16.9	262.7	35.9	84.3
Production of cash crops (10^6 tGE)	79.6	33.6	62.8	26.5	89.7	37.9	98.0
Land area (10^6 ha)	327.6	16.1	237.7	11.7	534.1	26.2	54.0
Arable land (10^6 ha)	191.9	41.5	73.0	15.8	123.4	26.7	84.0
Rain-fed arable land (10^6 ha)	126.8	38.8	55.2	16.9	86.1	26.3	82.0
Irrigated arable land (10^6 ha)	65.2	48.8	17.8	13.1	37.3	27.5	88.6

* tGE- tones of grain equivalent. Excludes cool tropics

Table 2. Agricultural land use in Malaysia (10 3 ha; 2000-2010) [9].

Crop	2000	2005	2010	Annual growth rate (%)*
Oil palm	3377	4049	4555	2.4
Rubber	1431	1250	1179	-1.2
Rice	479	452	450	-0.1
Fruits	304	330	375	2.6
Coconut	159	180	180	0.0
Cocoa	76	33	45	6.2
Vegetable	40	64	86	6.1
Tobacco	15	11	7	7.4
Pepper	13	13	14	0.6
Total	5893	6383	6891	1.5

*9th Malaysia Plan (2006-2010) target

Table 3. Self-sufficiency levels in food commodities in Malaysia (2000-2010) [11].

Commodity	2000	2005	2007	2010	Revised 2010
Rice	70	72	72	90	86
Fruits	94	117	105	138	106
Vegetables	95	74	89	108	91
Fisheries	86	91	97	104	103
Beef	15	23	25	28	28
Mutton	6	8	9	10	10
Poultry	113	121	121	122	122
Eggs	116	113	114	115	115
Pork	100	107	116	132	132
Milk	3	5	n.a	5	n.a

470 million small farms worldwide of less than two hectares of land, 85% are small farmers of which 87% are found in Asia [8], excluding several million landless farmers and agricultural labourers.

In Malaysia rice, fruit, pepper and vegetable production is important, and the tree crops (oil palm, rubber and cocoa) dominate agriculture, involving both large plantations and small farmers (Table 2). The tree crops occupy more than 86% of the total agricultural area and involve most of the fertile alluvial coastal plains and undulating foothills. Oil palm alone uses about 63.4% of the total agricultural area, which is expected to expand by about 2% by 2010.

SELF- SUFFICIENCY IN FOOD COMMODITIES

Table 3 presents current self-sufficiency levels in Malaysia between 2000 and 2010. Among crops, the country is 100% self-sufficient in fruits, 86% for rice and 91% for vegetables. The fishery sector was 103% self - sufficient. Among animal products, self-sufficiency levels were the highest with poultry meat, eggs and pork (115-132%). In comparison, the contribution form ruminants to beef, milk, goat meat and mutton are very minor and emphasise the huge potential for their development. Goat meat for example, is in very short supply, and together with the considerable demand has resulted in the highest price among the available meats [10]. The high levels of self-sufficiency in the non-ruminant commodities are consistent with their ex-farm value which in 2008 was 9 million RM and accounting for 91.4% of the total ex-farm value of livestock products in Malaysia [11].

INTAKE OF ANIMAL PROTEINS

Based on calculations of data on dressed meat, and conversion to *per capita* intake of animal proteins, the *per capita* consumption patterns and trends between 1990 and 2010 indicate that *per capita* intakes are increasing, and compared to the intake in 2005, the projected consumption in 2010 of 97.1 g/day represents an increase of about 378%. The increasing *per capita* consumption and requirement is influenced by two primary complementary reasons. Firstly, it is correlated to increasing affluence and disposal income with intake tapering off at higher levels due to saturation. Secondly, affluence also drives diversification of food habits in which some of the energy in carbohydrates is substituted by energy from dietary proteins [12]. The data on foods of animal origin and intakes emphasise an urgent priority need to increase ruminant animal numbers and also productivity.

DEVELOPMENT STRATEGIES AND OPPORTUNITIES

There exist a number of important and potentially rewarding development opportunities that involve biological, policy and institutional considerations.

Focus on rainfed areas

Priority attention needs to be given to the development of rainfed areas. The justification for targeting the rainfed areas is related to the twin reasons of inadequate availability of arable land and the need to increase agricultural productivity to meet the projected human needs. Inadequacy of arable land is associated with the following reasons *inter alia*: demand for agricultural land to meet human needs, e.g. housing, recreation and industrialisation; expansion of crop production to ceiling levels; in Malaysia, expansion of oil palm areas into high potential arable land; and increased urbanisation and use of arable land.

The extent of the rainfed areas in Asia is considerable [13]. The rainfed areas involve marginal/less favoured + arid lands + forests and woodlands, and accounted for 83.1% of agricultural lands compared to 16.6% favoured land. Marginal and arid lands alone constituted 48.5% of the total area. Additionally, about 63% of the rural population was found in the former compared to only 37% in the favoured areas (Table 1). Malaysia has an estimated rainfed land area including the oil palm, which can be developed.

It is relevant to note that in studies in India [14] and China [15], the returns to investments are very much higher in these areas in comparison to areas that have benefited from the Green Revolution.

Oil palm-based silvopastoral systems: stratification and ruminant production

While agroforestry offers the use of various trees as intervention options, silvopastoral systems provide the link between trees and animals as system components:

land, crops and animals, small farmers and the landless. In this context, there exits a huge potential for developing integrated oil palm-based ruminant production in Malaysia which is presently underestimated. The oil palm environment favors stratification, potential economic impacts, and offers a number of production options that can significantly contribute to improve NRM, increased productivity and enhanced food security in Malaysia. Unfortunately, wider adoption of the system is slow, and may require government intervention with appropriate incentives.

Only 2.2 % of the land area under oil palm is currently being used. Given that the land areas are projected to further increase to about 8-8.5 million hectares by about 2010, the opportunity to emphasise the development of integrated systems is enormous. The methodologies and the results of advances that have been made hitherto have relevance and application in West Africa, Central and Latin America [16].

Benefits of integrated systems

The benefits of crop-animal-soil interactions are many [17], and the various interactions often result in very positive benefits. The role of livestock in silvopastoral systems provides a means to intensify resource use with various types of livestock-trees interactions. The economic benefits are especially significant [18], and recent information suggest the following results with reference to the use of cattle: (a) Increased animal production and income – this arises from increased productivity and meat offtakes; (b) Increased yield of FFB and income – by about 30% with measures of between 0.49-3.52 mt/ha/yr; (c) Savings in weeding costs – by about 47-60%, equivalent to 21-62 RM/ha/yr; and (d) Internal rate of return – the IRR of cattle under integration was 19% based on actual field data. Several theoretical calculations approximate to this value.

Promoting vigorous application of productivity-enhancing technologies

There is an urgent need to apply vigorously proven and potentially important productivity-enhancing technologies. Two examples serve to illustrate this point. One concerns the food- feed system which has much relevance in cropping systems in both irrigated and lowland areas. An ideal food-feed system is one that maintains, if not increases the yield of the food crop, sustains soil fertility and provides dietary nutrients for animals [10]. Good examples of food-feed systems in Asia are as follows:

- *Bangladesh* – *Lathyrus setivus* has been introduced into rice cropping systems which has resulted in increased forage yields and improved soil conditions
- *India* – Fodders grown in the summer include pearl millet, maize, sorghum and cowpea, and in winter berseem and lucerne
- *Pakistan* – Inter-cropping maize with cowpea increased both crude protein and dry matter yields
- *Thailand* – Cowpea has been successfully inter-cropped with cassava to increase forage yield for ruminants in the semi-arid environment in the North East region

The other example is intensive use of the by-products from oil palm which are currently underutilised, and have potential in the future [20]. Both the examples also highlight the need for concurrent attention to push progress in productivity growth through interdisciplinary research and farming systems perspectives; and strengthening research-extension-farmer linkages and technology transfer.

EFFECTS OF CLIMATE CHANGE

The effects of climate change are now becoming increasingly serious. The core issue is uncertainty of climate and the biophysical environment. Such uncertainties have also been considered and emphasised for climate change scenarios for Malaysia between 2001 and 2009 [21]. Examples of areas that will be especially prone to the effects of climate change are the northern parts of South Asia, northern China and in parts of the Mekong countries like Thailand, Cambodia and Vietnam. In China for example, temperatures are projected to be between 1.21^{oC} and 2^{oC} above 1961-1990 levels which will be associated with more droughts, spreading deserts and reduced water supplies. In the more arid environments, there is also the likelihood of landlessness.

IPPC [22] projections on climate change suggest that for South East Asia a mean surface temperature increase of 3.77oC is anticipated by the turn of this century, and drier weather conditions in the next two to three decades. A recent study by the Asian Development Bank [23] on the effect of climate change on South East Asia with reference to Indonesia,

Table 4. Effects of climate change on land use and livelihood systems of the poor.

Land use systems	Livelihood systems of the poor *
• Reduce soil moisture	• Reduced income
• Expansion of semi-arid and arid AEZs	• Increased poverty
• Increased droughts	• Increased vulnerability
• Increased rangelands	• Inability to adapt to heat stress
• Woody encroachment	• Increased food and nutritional
• Desertification	• Insecurity
• Increased overstocking of heat tolerant animals e.g. Goats specially in the rangelands with resultant soil degradation	• Increased susceptibility to diseases
• Increased salinisation	• Reduced self-reliance
• Reduced biodiversity	• Increased urban migration
• Effects on the systems	
• Reduced systems services	
• Shift out of agriculture	

* Includes the landless

Philippines, Thailand and Vietnam has indicated that the agricultural dependent economies will contract by as much as 6.7% annually. The economic cost according to the report would be 2.2% of GDP by 2010 if only the impact on markets is considered, 5.7% if health costs and biodiversity losses are factored in, and 6.7% if losses from climate-related disasters are also included. The latter far exceeds the projected cost globally of climate change, estimated at 2.6% of GDP each year to the end of the century. Additionally, climate change is expected to put 49 million additional people at risk of hunger by 2020, and 132 million by 2050 [24].

Table 4 summarises the effects of climate change on land use and livelihood systems. The effects are serious and wide ranging, and cause *inter alia* reduced soil moisture, expansion of semi-arid and arid AEZs, increased droughts, increased rangelands, increased woody encroachment, desertification, increased overstocking of heat tolerant animals, e.g. goats especially in the rangelands with resultant soil degradation, reduced biodiversity and effects on the ecosystems. The resultant trend will be a shift out of agriculture.

Crop production will be seriously affected by climate change involving both annual and perennial crops. Cash crops, which are so important for income and the stability of households, will either have reduced yields or not grown at all as is already happening with successive droughts. It has been reported [25] that rice yields decreased by 10% for every 1oC increase in temperature. The ADB [23] also reviewed the effects of temperature rise on crop yields and has projected in South East Asia (Indonesia, Philippines, Thailand and Vietnam), there will be rice yield falls by about 50% in 2100 relative to the 1990 level.

With animals, the effects of climate change on productivity will depend on the resilience of animal production systems. The extent of adaptation will be especially important in the future. Tropical climates with their high temperatures and humidity inflict behavioural and metabolic changes that result in reduced feed intake and therefore lower productivity. The two key concerns are (i) heat stress and (ii) the quantitative and qualitative availability of feed resources [26]. The R&D opportunities and policy aspects on the effects of climate change are enormous. The strategies for coping with climate change have to address a combination of mitigation and adaptation options simultaneously.

WATER AVAILABILITY AS A CONSTRAINT

Agriculture uses a very high proportion of accessible fresh water to produce food. This is often inadequately appreciated as a key biophysical constraint in agricultural development in the future. The problem is anticipated to be much more pronounced in the rainfed environments and drought-prone areas, with grave possibilities that these same areas will become even drier with the threat of global warming. In these situations, crop growth will be increasingly exacerbated by decreasing rainfall, reduced length of the growing period, and increased food insecurity and poverty. Mismanagement of the available freshwater resources can have serious consequences, which *inter alia* include: (1) shortfalls in food production will affect requirements – exacerbated by climate change vulnerability; (2) food self-sufficiency is put to risk; (3) agricultural growth is likely to be stifled due to competition for water; and (4) at stake – changing ecological and agricultural landscape.

CONCLUSION

Agriculture is an important determinant of economic growth, and is reflected in the technologically driven transformation and development through the Green Revolution. Multifunctionality is an important feature of agriculture, enabling the efficient and sustainable use of the natural resources. Economic growth and transformation led to significant expansion of the manufacturing and service sectors, and also the development of the oil palm sector. These resulted in agriculture becoming secondary in terms of development attention. Nevertheless, major opportunities exist to revitalise agriculture in the context of food security. This involves an assessment of the contribution from crops and animals, improving productivity through concerted yield-enhancing technology applications backed by increased investments in inter-disciplinary R&D, and promoting increased private sector participation: these constitute the challenges for the immediate future.

REFERENCES

1. Devendra C. (2010) *Small farms in Asia. Revitalising Agricultural Production, Food Security and Rural Prosperity.* Academy of Sciences Malaysia, Kuala Lumpur.
2. ESCAP (2008) *Economic and social survey of Asia and the Pacific 2008. Sustaining growth and sharing prosperity.* ESCAP, Bangkok,Thailand.
3. Economic Planning Unit (2006) *The Ninth Malaysia Plan (2006-2010).* Prime Minister`s Department, Putra Jaya, Malaysia.
4. Pardey P.G. and Beintema N.W. (2001) *Slow magic. Agricultural R and D: a century after Mendel.* International Food Policy Research Institute Food Policy Report, Washington D.C., USA.
5. Ministry of Science, Technology and Innovation (2008) *Facts and Figures.* Putrajaya, Malaysia.
6. Thiruchelvam K. (2004) Towards a dynamic national system of innovation in Malaysia: enhancing the management of R and D in public research institutions and universities. *Journal of Technolology and Innovation* **12**: 122-150.
7. Technical Advisory Committee (1992) *Review of CGIAR of Priorities and Strategies. Part 1.* TAC Secretariat, FAO, Rome.
8. Nagayets O. (2005) Small farms: current status and key trends. *Proceeding of The Future of Small Farms* pp. 355-356. International Food Policy Research Institute, Washington DC, USA.
9. Ministry of Plantation Industries and Commodities, Malaysia (2006) *Statistics and Commodities.* Kuala Lumpur, Malaysia.
10. Devendra C. (2007) *Goats: biology, production and development in Asia.* Academy of Sciences Malaysia, Kuala Lumpur.
11. Department of Veterinary Services (2010) *Livestock Statistics.* Ministry of Agriculture and Agro-based Industries, Putrajaya,Malaysia.
12. Devendra C. (2010) Food production from animals in Asia: priority for expanding the development frontiers. *ASM Science Journal* **4**: 173-184.
13. Consultative Group on International Agricultural Research/Technical Advisory Committee (2000) *CGIAR priorities for marginal lands.* CGIAR, Washington, USA.
14. Fan S., Hazell P. and Thorat S. (2000) Targeting public investments by agroecological zone to achieve growth and poverty alleviation goals in rural India. *Food Policy* **20**: 411-428.
15. Fan S., Zhang L. and Zhang X. (2000) Growth and poverty in rural China: The role of public investments. *Environment and Production Technology Division Discussion Paper No. 66.* International Food Policy Research Institute, Washington DC, USA.
16. Devendra C. and Pezo D. (2004) Crop-animal systems in Asia and Latin America: Characteristics, trends and emerging challenges. Comparison with West Africa. In Williams T.O., Tarawali S.A., Hiernaux P. and Fernandez-Rivera S. (eds) *Proceedings International Conference on Sustainable crop-livestock production for improved livelihoods and natural resource management* pp. 123-159. International Livestock Research Institute (ILRI), Nairobi,Kenya.
17. Devendra C. and Thomas D. (2001) Crop – animal interactions in mixed farming systems in Asia. *Agricultural Systems* **71**: 27-40.
18. Devendra C. (2007) Integrated tree-crops ruminant systems: expanding the research and development frontiers in the oil palm. In Devendra C., Shanmugavelu S. and Wong H.K. (eds) *Proceedings Workshop on integrated tree crops-ruminant systems (ITCRS)/ Assessment of status and opportunities in Malaysia* pp. 5-23. Academy of Sciences Malaysia, Kuala Lumpur.
19. Devendra C., Sevilla C. and Pezo D. (2001) Food

-feed systems in Asia. *Asian-Australian Journal of Animal Science* **14**: 733-745.

20. Devendra C. (2009) Intensification of integrated oil palm-ruminant systems: enhancing productivity and sustainability in South East Asia. *Outlook on Agriculture* **38**: 71-81.
21. Malaysian Meteorological Department (2009) *Climate change scenarios for Malaysia*. Ministry of Science Technology and Innovation, Kuala Lumpur, Malaysia
22. IPPC (2007) *Climate change 2007: Contribution of working groups I, II and III to the Fourth Assessment Report, of the Intergovernmental Panel on Climate Change*. Cambrige University Press, Cambridge, United Kingdom and New York.
23. ADB (2009) *The economics of climate change in South East Asia: a regional review*. Asian Development Bank, Manila, Philippines.
24. IFAD (2009) New thinking to solve old problem. http://www.ipsnews.net/africa/nota.asp?idnews=45905. (Accessed on 26 Mar 2009).
25. Peng S.B., Huang J.E., Sheehy J.E., Laza R.C., Vispera K.H., Zhong X.H., Centeno S., Khush G.S. and Cassman K.G. (2004) Rice yields decline with higher night temperatures from global warming. *Proceeding of National Academy of Science* **101**: 9971-9975.
26. Devendra C. and Sevilla C.C. (2002) Availability and use of feed resources in crop-animal systems in Asia. *Agricultural Systems* **71**: 59-74.

Journal of Science and Technology in the Tropics (2011) 7: 49-56

Wetting of low and high surface energy solids by mixed surfactant solutions

D. P. Subedi[1*], U.M. Joshi[1], T. Manandhar[2], N. Shrestha[2]
[1] Department of Natural Sciences, Kathmandu University, Dhulikhel, Kavre, Nepal
[2] Department of Pharmacy, Kathmandu University, Dhulikhel, Kavre, Nepal
(*E-mail: dsubedi@ku.edu.np)

Received 21-01-2011; accepted 03-03-2011

Abstract Wetting of glass and polycarbonate surface by aqueous surfactant solutions of binary mixtures of lauric acid, capric acid and myristic acid were studied in the range of overall concentrations C = 10^{-8}–10^{-2} M. Measurement of surface tension of the solution and contact angle of the solution with the two substrates were employed for this purpose. The main objective of the work was to determine the critical vesicle concentration (CVC) and critical micelle concentration (CMC) for the binary mixtures of the surfactant solutions from the contact angle measurement with surfaces of low and high surface free energy. Contact angle measurement on polycarbonate showed that a synergistic effect appears in all the three types of binary mixture producing a perfect wetting of the polymer substrate of low surface energy. Results obtained from contact angle measurement were compared with the results from the analysis of surface tension. The values of CMC and CVC of the three mixtures obtained from the two approaches were found to be consistent in all experiments.

Keywords contact angle – critical vesicle concentration – critical micelle concentration – fatty acids – amphiphilic component

INTRODUCTION

The wetting of solid surfaces by liquids has great practical importance in many industrial processes, such as cleaning, printing, painting and pesticide applications. Modification of wettability is an essential technological application of surfactant science. The ability of surfactant to modify the wetting or contact angle on an aqueous solution on a variety of solid surfaces is well known [1, 2]. Addition of surfactants to water reduce the surface tension of water as well as the solid-water interfacial tension resulting a better wetting ability of the aqueous solution to spread over the surface of the solid. When a surfactant is added to water, it will diffuse throughout its volume. The shorter the hydrocarbon chain, the more readily the molecule can diffuse to the surface. Once at the surface a bond can be made between water surface and solid surface, with the solid acting as the interface, effectively reducing the surface tension.

Many material processing involve wetting of solids by liquids. Prediction of wetting as well as adhesion usually involves measurement of contact angle of liquids on a solid surface. If a solid is not completely wettable it is considered to be water repellent and vice versa. In other words, the contact angle is a specific measure of water repellency by a solid substrate. It is an inherent surface property and is believed to be shown by substrates having low surface free energy, with the consequence that such a solid shows a very weak attraction to the liquid phase with which it is in contact. Adsorption of surfactant onto a solid is a primary cause of solid/liquid interfacial tension reduction, and hence decrease in contact angle [3]. Contact angle measurement is very useful in determining CMC of a solution.

CMC is the concentration of an amphiphilic component in solution at which the formation of aggregates (micelles, round rods, lamellar structures etc.) in the solution is initiated. Amphiphilic molecules contain two distinct components, differing in their affinity for solutes. The hydrophilic part of the molecule has an affinity for polar solutes, such as water, and the hydrophobic part of the molecule has an affinity for non-polar solutes, such as hydrocarbons. Amphihilic molecules display distinct behaviour when interacting with water. An amphiphilic molecule can arrange itself at the surface of the water

Journal of Science and Technology in the Tropics (2010) 7: 5-8

Colour variation and polymorphism in the Giant orb-weaving spider *Nephila vitiana* (Araneae: Nephilidae) from Lombok, Indonesia

I. Wayan Suana[1*], H. Sunarpi[2], Mohd Sofian-Azirun[3], Rosli Hashim[3], Phaik Eem Lim[3,4] and Hoi Sen Yong[3,#]

[1]Faculty of Science and Mathematics, Mataram University, Jalan Majapahit 62, Mataram 83125, Indonesia

[2]Rector, Mataram University, Jalan Majapahit 62, Mataram 83125, Indonesia

[3]Institute of Biological Sciences, University of Malaya, 50603 Kuala Lumpur, Malaysia

[4]Institute of Ocean and Earth Science, University of Malaya, 50603 Kuala Lumpur, Malaysia

(*E-mail: swansurya@yahoo.com; #E-mail: yong@um.edu.my)

Received 09-07-2010; accepted 23-07-2010

Abstract The Giant orb-weaving spider *Nephila vitiana* occurred in large number in a patch of mangrove vegetation in Gili Meno, Lombok, Indonesia. Two abdominal (opisthosomal) colour morphs – yellow and greenish-yellow – were present in adult female spiders. They were equally abundant. A single female of the yellow morph was found in Sekotong on the main Lombok Island. The dorsum of the abdomen in the yellow morph was decorated with five pairs of sigillae. In the greenish morph, the dorsum was marked with five pairs of white-spotted sigillae or yellow spots. The present observation does not show unequivocally the association of colouration with habitat usage. Whether yellow colour in *N. vitiana* confers a selective advantage remains to be verified. The juvenile female spiders have different colour pattern from the adults.

Keywords *Nephila vitiana* – colour polymorphism – spider – colour variation – new record – West Nusa Tenggara

INTRODUCTION

The Giant orb-weaving spider *Nephila vitiana* (Walckenaer, 1847) has been recorded to occur in Indonesia, Sulawesi, to Fiji, Tonga [1]. It has been suggested that this spider is not present in the Australasian region, including Fiji and Tonga [2]. In the collections of 30 museums in Europe, USA, Australia and New Zealand, specimens clearly referable to *N. vitiana* were from Bali (in Western Australian Museum, Perth, Australia) and Sulawesi and Timor (in Zoologischen Museum, Berlin, Germany) [2]. Excepting Bali with 8 specimens, the number was very small for Sulawesi (2 specimens) and Timor (1 specimen).

Nephila vitiana was originally described as *Epeira vitiana* Walckenaer, 1847. It now includes as synonyms the taxa *Nephila pipersii* Thorell, 1877 and *Nephila wallacei* Thorell, 1877 [1]. It is noteworthy that there appear very little published records of this spider. We report here the finding of *N. vitiana*, and the occurrence of abodominal colour variation, in Lombok, West Nusa Tenggara, Indonesia.

MATERIALS AND METHODS

During the occasion of the signing of Memorandum of Understanding (June 2010) between Mataram University and University of Malaya in Mataram, Lombok, Indonesia, the Malaysian delegates were accompanied by some Indonesian counterparts for three field excursions – to Kerandangan, Gili Meno and Sekotong. Kerandangan is a forested area, Gili Meno is a small island, and Sekotong is a coastal area with mangrove vegetation.

On Gili Meno (9 June 2010), we witnessed a large number (over 20) of *N. vitiana* in a patch of mangrove vegetation (a study site of I. Wayan Suana). The general appearance and the abodominal (opithosomal) colour of the female spiders were noted and photographed. In addition to the female spiders, other life stages (egg cocoon, spiderlings, such that the polar part interacts with the water and the non-polar part is held above the surface (either in the air or in a non-polar liquid). The presence of these molecules on the surface disrupts the cohesive energy at the surface and thus lowers the surface tension.

The present work is focused on the wetting of glass and polycarbonate by the aqueous solutions of two surfactants and their binary mixture with the objective of determining CVC and CMC.

EXPERIMENTAL PROCEDURE

Materials

Capric acid (batch no: 100125) and Lauric acid (batch no: V0680032) were purchased from Loba Chemie. Myristic acid (batch no: 3163298) was purchased from Spectrochem Private Limited, India. Disodium tetraborate (Borax) [batch no: NL2513 5906S], sodium hydroxide pellets (batch no: NL5879/16208S) and potassium dihydrogen orthophosphate (batch no: NL63576209S) were purchased from Qualigens Fine Chemicals, India. Hydrochloric acid (batch no: S008B05) was purchased from Rankem Fine Chemicals Limited, India. Propanol (Iso–propyl alcohol) [batch no: 0790/88612] was from S.D. Fine Chem. Limited, Bojsar. Chemical name and the molecular formula of the fatty acids used in our study are presented in Table 1.

Preparation of solutions

The stock solution for mixed capric and myristic acid was prepared by mixing 0.1 M capric acid and 0.00023 M myristic acid in 0.125 M sodium hydroxide solutions. This gave capric acid to myristic acid ratio of 20:1.5 mL of stock solution which was taken in 25 mL volumetric flask with different volume of 0.5 M hydrochloric acid and volume was adjusted to 25 mL with 0.125 M sodium hydroxide solutions. This gave a series of mixed capric acid and myristic acid solutions with varying acidic strength. Similarly, the stock solution for mixed capric acid and lauric acid was prepared by mixing 0.1 M capric acid and 0.01 M lauric acid in 0.135 M sodium hydroxide solutions. In the same way, the stock solution for 20:1 mixed lauric acid and myristic solution was prepared by mixing 0.01 M lauric acid and 0.00626 M myristic acid in 0.1 M sodium hydroxide solutions. The temperature of these solutions was maintained at 50^{0}C to avoid phase separation and aggregation.

Measurement of surface tension

Surface tension of the sample liquid was measured using capillary rise method. In this method, the surface tension is related to the height of liquid supported by gravity, the tube radius, the contact angle of the liquid meniscus and the density difference between liquid and vapor. So the surface tension is given by $\gamma = Rh\rho g/2cos\theta$ (1), where γ = surface tension of sample solution, R = radius of the capillary tube, ρ = density of sample solution, g = acceleration due to gravity, θ = contact angle.

A traveling microscope having horizontal and vertical transverse was used for the measurement of height of the liquid column in the capillary and the diameter of the capillary. The microscope is provided with a Ramsden eye-piece having fine cross-wires in it.

Contact angle analysis

The most common method of quantifying wetting is the contact angle measurement. Furthermore, the measurement of contact angle on a solid surface is the most practical way to obtain information about surface energy: solid-vapour and solid-liquid surface tension [4]. The contact angle θ is defined as the angle between the solid surface and the tangent to the surface of the drop at the point of contact of the two as shown in (Fig. 1). The contact angle of a liquid drop on a solid substrate is related to interfacial tensions, which is given by Young's equation [5, 6] as: $\gamma_l\, cos\theta = \gamma_s - \gamma_{sl}$ (2), where, γ_{sv} is the surface free energy of the solid substrate, γ_{sl} is the interfacial tension between

Table 1. Chemical names and structures of fatty acids used in our study.

Number of carbon atoms	Common name	Chemical name	Structure
10	Capric acid	Decanoic acid	$CH_3(CH_2)_8COOH$
12	Lauric acid	Dodecanoic	$CH_3(CH_2)_{10}COOH$
14	Myristic acid	Tetradecanoic	$CH_3(CH_2)_{12}COOH$

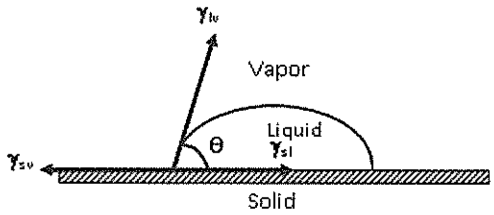


Figure 1. Schematic diagram of the contact angle and interfacial tensions of the three surfaces at the three-phase boundary

the solid and the liquid and γ_{lv} is the surface tension of the liquid. This equation shows that a perfect wetting, i.e. cosθ tending to unity, is favoured by a high energy surface solid, low interfacial free energy and low liquid surface free energy.

The contact angle of a liquid on solid is strongly influenced by a number of factors such as surface roughness, chemical heterogeneity, sorption layers, molecular orientation and swelling. These effects have to be considered when contact angle measurements are used to calculate the solid surface tension.

In this study the contact angle of drops with the surface of the flat plate of glass and polycarbonate was measured using a rame'-hart Contact Angle Goniometer model 200. This unit is equipped with standard software to analyze the drop image for the calculation of surface energy. The system offers a high level of computer aided precision in measuring contact angle and therewith facilitating the calculation of surface energy using different model equation.

RESULTS AND DISCUSSION

Determination of CMC from surface tension

Figures 2-4 show the graphs of surface tension as a function of concentration of the three types of binary mixtures. The CMC values obtained from the surface tension measurement for the three binary mixtures were 0.06479, 0.02 and 0.02 respectively. The results presented in the figures show that surface tension decreased as the concentration of the surfactant increased till the cut-off point. After this cut-off point, the surface tension became constant with increasing concentration.

The CMC of capric acid:myristic acid (20:1), capric acid:lauric acid (8.5:1), and lauric acid:myristic acid (20:1) sample solutions were determined at concentration 0.06479 M, 0.02 M, and 0.02 M respectively. Mixed lauric acid and myristic acid shows the CMC at low surface tension than in capric acid and lauric acid mixed solution and capric acid and myristic acid mixed solution. It shows sharp decrease in the surface tension at CMC than in the case of capric acid and lauric acid mixed solution and capric acid and myristic acid mixed solution. In the case of capric acid and myristic acid, the large unequal carbon chain of C_{10} and C_{14} results in improper mixing. Therefore, there was no sharp decrease in surface tension.

In the case of capric acid and lauric acid mixed solution, the mixture of C_{10} and C_{12} carbon chain and lauric acid and myristic acid, the mixture solution of C_{12} and C_{14} carbon chain results in sharp decrease in surface tension.

In aqueous solution, mixed anionic surfactants aggregate into a spherical structure called micelles, where hydrophobic portions of the molecules are

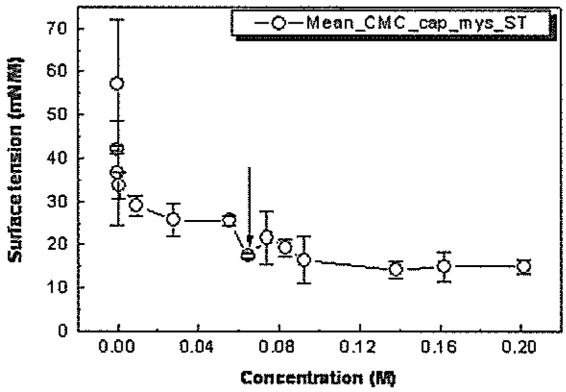


Figure 2. CMC determination of mixed capric acid and myristic acid (20:1) solution by surface tension. Arrow indicates concentration corresponding to the CMC

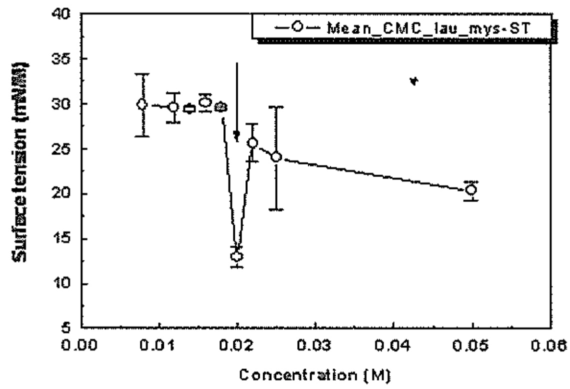


Figure 3. CMC determination of mixed lauric acid and myristic acid (20:1) solution by surface tension.

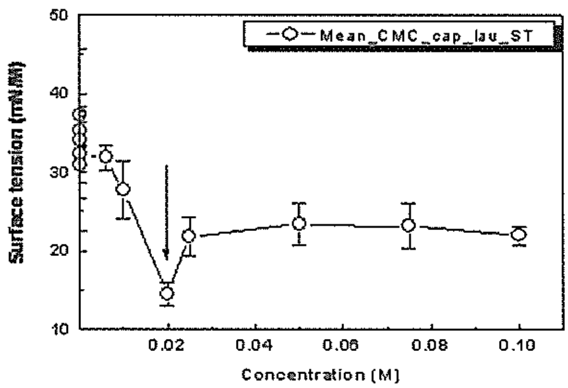


Figure 4. CMC determination of mixed capric acid and lauric acid (8.5:1) solution by surface tension.

protected from contact with water. The surfactant molecules aggregate in order to minimize free energy of the solution. As a result, they are dynamic (but equilibrium) structures, able to rearrange in response to changing environmental conditions such as temperature and pH.

The micelle can be well described by a core-shell structure where the core is comprised of the hydrophobic tail of the surfactants. The micelle core is then separated from water by the hydrophilic (charged) head groups, arranged at the surface of the micelle. If there are repulsive interactions between micelles, each micelle will tend to have nearest neighbours in a somewhat well defined location. The presence of stronger interaction between neighbouring micelles can have significant impact on the diffusion of micelles [7].

Surfactant mixtures often exhibit features deviating significantly from the individual component (i.e., they exhibit substantial synergism). Mixed surfactant systems are also of significant theoretical interest because their propensity to form micelles in solution can differ substantially as compared to individual surfactant system. The addition of co-surfactant will decrease the surface tension significantly compared to its individual component because of the excessive interaction between the molecules/ions of the components of the mixture. For the excessive attraction, synergism is observed (i.e., some property in a mixture is observed at lower surfactant concentration than their individual component). However, as the concentration is increased above CMC, the surfactant replaces the co-surfactant in the micelles so that the surface tension increases and become constant when the interface becomes completely loaded with further surfactants [8].

Determination of CMC from contact angle

Figures 5-7 show CMC determination of aqueous solutions of three types of binary mixtures by contact angle in glass substrate.

Surface energy is quantified in terms of the force acting on a unit length at the solid-air or solid-liquid interface. Surface energy is the energy possessed by atoms at the surface of the solid, whereas surface tension is the result of the attraction between molecules at the liquid surface. For a liquid to wet a solid, the surface energy of that solid must be able to overcome the surface tension of the liquid, thus breaking the surface tension and forming a permanent film that will bond to the surface.

In high-energy surface (glass), surface is made up of a complex mixture of molecules made from carbon, hydrogen and oxygen and (unlike hydrocarbons) there will be a significant proportion of polar groups (e.g. O-H) present. The force of attraction between polar molecules is stronger than those between non-polar hydrophobic molecules, and they are sufficiently strong to overcome the surface tension forces of

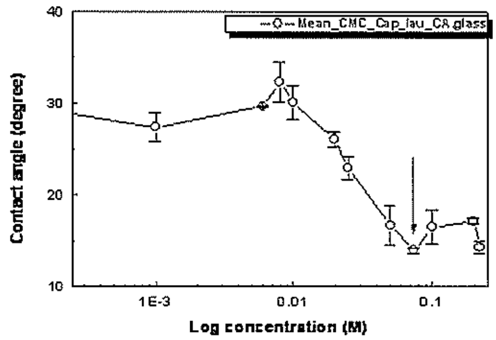


Figure 5. CMC determination of mixed capric acid and lauric acid (8.5:1) solution by contact angle in glass substrate.

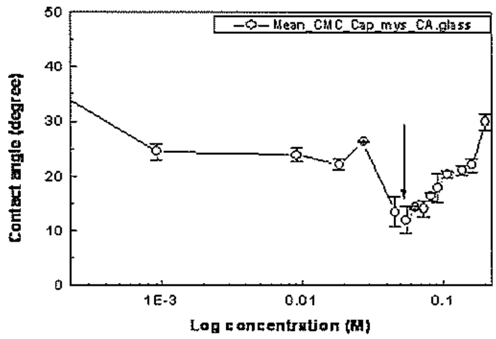


Figure 6. CMC determination of mixed capric acid and myristic acid (20:1) solution by contact angle in glass substrate

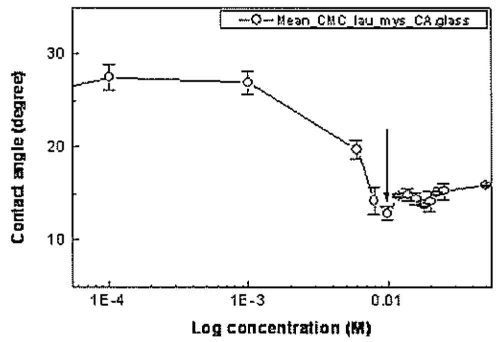


Figure 7. CMC determination of mixed lauric acid and myristic acid (20:1) solution by contact angle in glass substrate.

water, causing the droplet to spread out as a film. The molecular model accounts for micellar mixture resulting from electrostatic and steric interactions between the hydrophilic heads of the surfactant and from packing of surfactant hydrophobic tails of unequal lengths in the micellar core.

Figures 8-10 show CMC determination of aqueous solutions of three types of binary mixtures by contact angle in PC substrate. In low energy

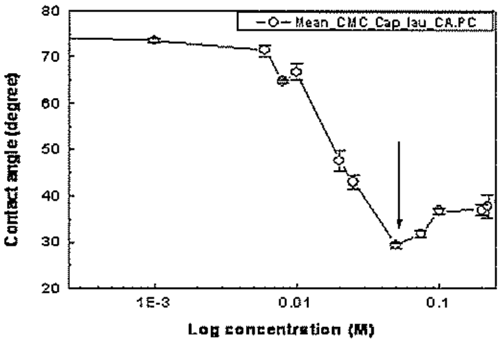


Figure 8. CMC determination of mixed capric acid and lauric acid (8.5:1) solution by contact angle in polycarbonate substrate.

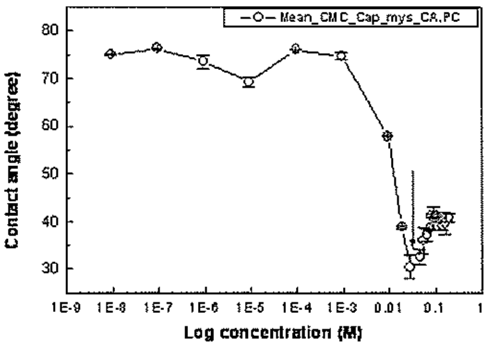


Figure 9. CMC determination of mixed capric acid and myristic acid (20:1) solution by contact angle in polycarbonate substrate

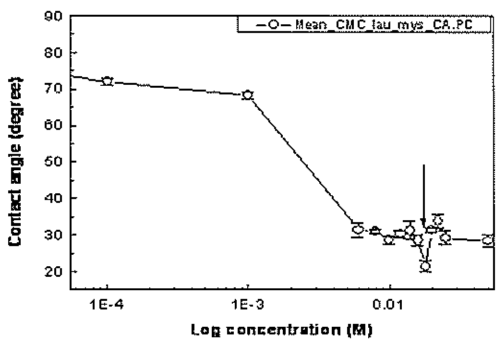


Figure 10. CMC determination of mixed lauric acid and myristic acid (20:1) solution by contact angle in polycarbonate substrate.

surface (polycarbonate), the surface force that hold hydrocarbon molecules together are much weaker and consequently polar liquid tend to form droplets on the surface rather than spread out. In this kind of surface, the surfactant contacts the surface through its hydrophobic tail, forming a progressively more compact monolayer on the surface as the amount of adsorbed surfactant increases. In such monolayers, the surfactant head groups are oriented toward water. The surface becomes saturated at a bulk surfactant concentration slightly below the CMC. At saturation it turns into discrete aggregates, hemi-micelles or bi-layer structures (vesicles). In the case of polycarbonate, the strong electrostatic interaction between the surfactant molecules and the solid substrate are absent. For low energy surface γ_{sv} = constant. Therefore, it should be expected that the wetting action of ionic and anionic mixture solution at low concentration vary strongly with variation of γ_{sl} and γ_{lv}. Synergism is an interaction of two or more factors such that the effect, when combined, is greater than the predicted effect based on the response to each factor applied separately. The synergistic effect in wetting of polycarbonate is caused by synergism at the liquid/vapor interface and the synergism in adsorption of anionic/anionic mixture surfactant at polycarbonate surface [9]. The difference between contact angles of mixed surfactant solutions on glass surface points out the different adsorption behaviour on the surface. In the case of carboxylate anionic/anionic mixture, electrostatic interaction between the negatively charged glass surface and the anionic mixed surfactant takes place. The maximum in surfactant contact value corresponds to formation of a monolayer of ions at the solution-glass interface [10]. The contact angle profiles of the mixed surfactant show three characteristic regions. At low concentration, the contact angle is independent of surfactant concentration. At and in the neighbourhood of CMC, the contact angle decreases dramatically as a function of surfactant concentration. At concentration higher than CMC, the contact angle remains unchanged [8].

The mixed monolayer is expected to form at lower concentration. The effect decreases as the surfactant concentration increases. Probably the synergism in glass wetting by mixed solution is due to synergism in adsorption of mixed surfactant at the glass surface.

A surfactant (surface active agent) when added to a liquid will reduce the surface tension of the liquid, thus improving its wetting abilities. When the surfactant is added to water, it will diffuse throughout its volume. The shorter the hydrocarbon chain is, the more readily the molecule can diffuses to the surface. Once at the surface a bond can be made between the water surface and solid surface, with the surfactant acting as the interface, effectively reducing the surface tension of the liquid.

Determination CVC by surface tension

Figures 11-13 show the graphs of surface tension

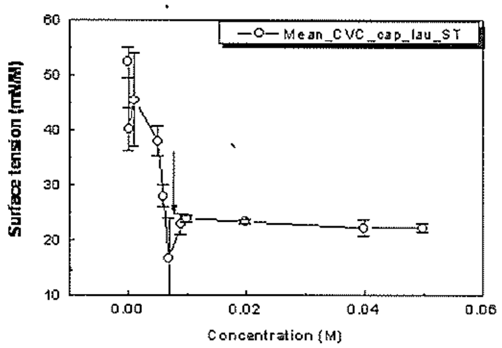


Figure 11. CVC determination of mixed capric and lauric acid (8.5:1) solution by surface tension. Arrow indicates concentration corresponding to the CMC.

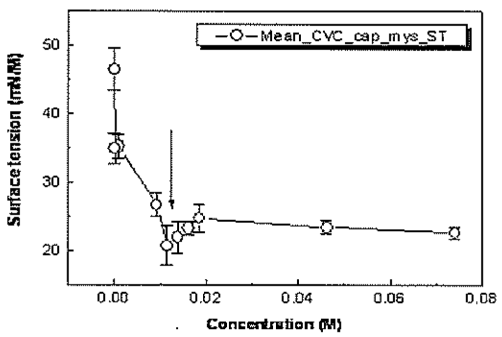


Figure 12. CVC determination of mixed capric acid and myristic acid (8.5:1) solution by surface tension. Arrow indicates concentration corresponding to the CMC.

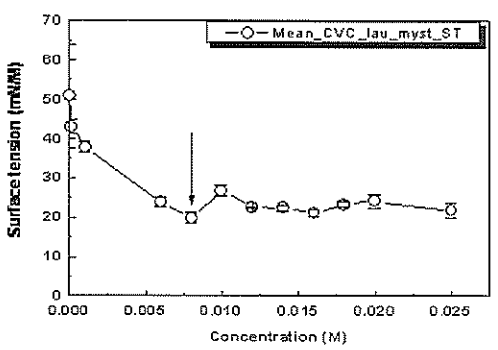


Figure 13. CVC determination of mixed lauric acid and myristic acid (8.5:1) solution by surface tension. Arrow indicates concentration corresponding to the CMC.

as a function of concentration of the three types of binary mixtures. The surface tension decreases as the concentration of the surfactant increases till the cut-off point. After this cut-off point, the surface tension becomes constant with increasing concentration. The critical vesicle concentration of capric acid:myristic acid sample solution was 0.0115 M. The critical vesicle concentration of capric acid:lauric acid sample solution was 0.007 M. The critical vesicle concentration of lauric acid:myristic acid sample solution was 0.008 M.

Surfactant mixtures often exhibit synergism features deviating significantly from the individual surfactant. Mixed surfactant systems have tendency to form vesicles in solution, which differ substantially as compared to individual surfactant system. The addition of co-surfactant will decrease the surface tension significantly than from the individual surfactant because of the excessive interaction between molecules or ions of the components of the mixture. However, as the concentration is increased above CVC, the surfactant replaces the co-surfactant in the vesicles so that the surface tension increases and becomes constant when the surface becomes completely loaded with further surfactant.

CVC determination by contact angle

Plots of contact angle on glass against surfactant concentration are shown in Figures 14-16. The contact angle of surfactant mixture components has three characteristic regions. The region of lower concentration exhibits an insignificant decrease in the contact angle. The contact angle decreases with an increase in the concentration and at concentration higher than the critical vesicle concentration (CVC), the contact angle remains unchanged. CVC was achieved at lower surfactant concentration than in solution of individual component. This is due to synergistic effect of the binary solutions of anionic and anionic surfactants.

Plots of contact angle on PC against surfactant concentration are shown in Figures 17-19. In the case of low energy surface (polycarbonate), the contact angle decreases with an increase in concentration and at concentration higher than critical vesicle concentration (CVC), the contact angle remains unchanged (i.e. zero). The contact angle becomes zero due to the complete spreading of the mixed sample solution in the low energy surface.

Journal of Science and Technology in the Tropics (2011) 7: 49-56

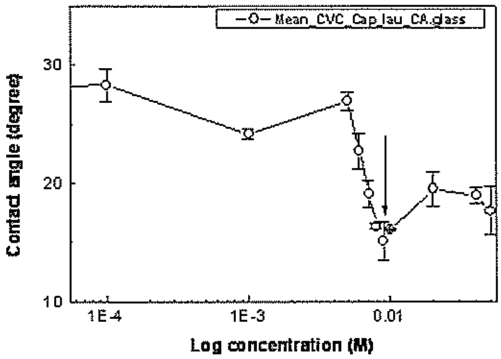


Figure 14. CVC determination of mixed capric acid and lauric acid (8.5:1) solution by contact angle in glass substrate

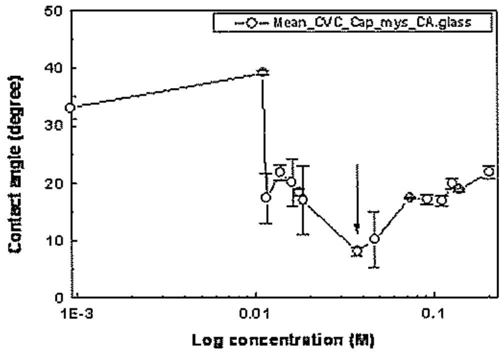


Figure 15. CVC determination of mixed capric acid and myristic acid (20:1) solution by contact angle in glass substrate.

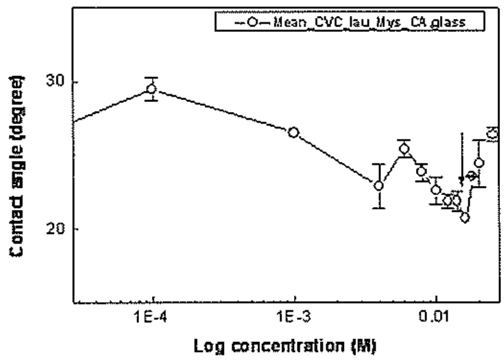


Figure 16. CVC determination of mixed lauric acid and myristic acid (20:1) solution by contact angle in glass substrate

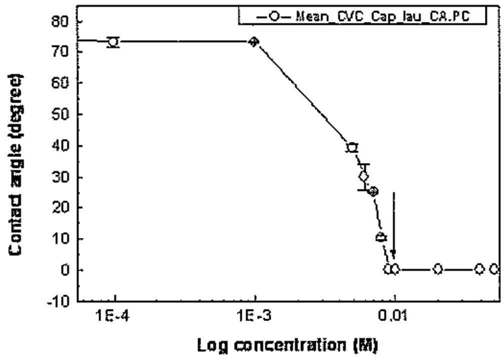


Figure 17. CVC determination of mixed capric acid and lauric acid (20:1) solution by contact angle in polycarbonate substrate.

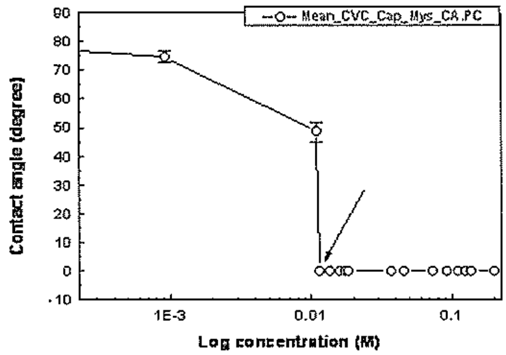


Figure 18. CVC determination of mixed capric acid and myristic acid (20:1) solution by contact angle in polycarbonate substrate.

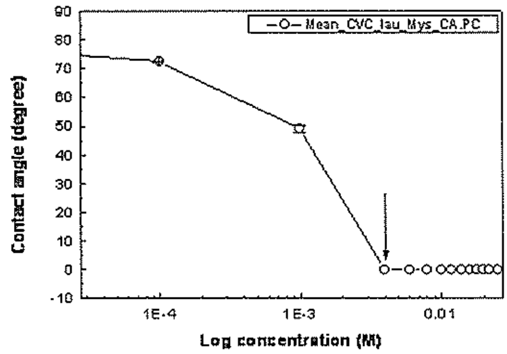


Figure 19. CVC determination of mixed lauric acid and myristic acid (20:1) solution by contact angle in polycarbonate substrate.

The results of CMC and CVC analysis by different techniques are summarized in Table2.

CONCLUSION

CMC and CVC of mixed fatty acids were studied for characterization of fatty acids by the method of surface tension and contact angle measurement. The values of CMC and CVC were consistent in all experiments for each approach. Since the present study is focused on characterization of micellar and vesicular mixed fatty acid for encapsulation of drugs, further studies may be carried out to encapsulate various drugs (hydrophilic and lipophilic) in vesicles formed from mixed fatty acids and calculate the encapsulation percentage.

Table 2. Results of CMC and CVC by different techniques of mixed fatty acids.

Fatty acid	Method	Critical micelle concentration	Critical vesicle concentration
Capric acid and myristic acid	Surface tension	0.06479	0.0115
	Contact angle	0.0277	0.0115
Capric acid and lauric acid	Surface tension	0.02	0.007
	Contact angle	0.05	0.009
Lauric acid and myristic acid	Surface tension	0.02	0.008
	Contact angle	0.018	0.004

Acknowledgement – The authors would like to thank Prof. Panna Thapa and Dr. Boris Niraula for their valuable suggestion during the entire work. We are also grateful to Mr. Ajaya Kumar, GE Plastics India for kindly providing the polycarbonate samples for our study.

REFERENCES

1. BLuepakdeesakoon B., Saiwan C. and Scamehorn J.F. (2006) Contact angle of surfactant solutions on precipitated surfactant surfaces III. Effects of subsaturated anionic and nonionic surfactants and NaCl". *Journal of Surfactant and Detergent* **9**: 126-136.
2. Luangpirom N., Dechabumphen N., Saiwan C. and Scamehorn J.F. (2001) Contact angle of surfactant solutions on precipitated surfactant surfaces *Journal of Surfactant and Detergents* **4**: 367-373.
3. Kiss E., Erdelyi K., Szendro I. and Vargha-Butler E.I. (2004) Adsorption and wetting properties of pluronic block copolymers on hydrophobic surfaces studied by optical waveguide lightmode spectroscopy and dynamic tensiometric method *The Journal of Adhesion* **80**: 815-829.
4. Kwok D.Y., Geitzelt T., Grundke K., Jacobasch H.J. and Neumann A.W. (1997) Contact angle measurement and contact angle interpretation. *Lanmuir* **13**: 2880-2894.
5. Good R.J. and Stromberg R.R. (1979) *Surface and colloid science – Experimental methods*, vol. 11. Plenum Press, New York.
6. Young T. (1805), An essay on the cohesion of fluids. *Transactions of the Royal Society London* **95**: 65-87.
7. NIST Center for Neutron Research (Access on 5 Aug 2006). Diffusion of surfactant micelles. www.ncnr.nist.gov/sumerschool.ss01/SS01micelles.
8. Bogdanova Y.G. (2003) Wetting effect of aqueous binary mixture solution of cationic and non-ionic surfactants. *Russian Chemica Bulletin International Edition* **52**: 2352-2359.
9. Bogdanova Y.G. (2003) Wetting of solids by aqueous solution of surfactant binary mixtures. 2. Wetting of high energy surface. *Colloid Journal* **65**: 323-327.
10. Mittal K.L. (Access on 5 Aug 2006) Contact angle, wettability and adhesion. www.thattechnicalbookstore.com/b9067643912.htm

Journal of Science and Technology in the Tropics (2011) 7: 57-64

Development of calcia stabilized zirconia (CSZ) thermal barrier coatings (TBC): Characterization and improvement of CSZ powder for optimization in coating properties

Amir Azam Khan[1], Muhammad Asim[2], Muhammad Farooq Zafar[3]
[1]Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, University Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia
(E-mail: akamir@feng.unimas.my)
[2]School of Chemical and Materials Engineering, National University of Sciences and Technology, Sector H-12, 44000, Islamabad, Pakistan
[3]Mechanical Engineering Workshops, Plot # 174, Sector I -10/3, 44000 Islamabad, Pakistan

Abstract Thermal barrier coatings (TBCs) are thermally insulating, refractory, wear resistant coatings having dual layered structure for optimum insulation, wear and corrosion resistance. Zirconia is considered an appropriate material for the top coat, because of its intrinsic thermal, chemical and wear resistant properties. Having very high melting point and low thermal conductivity, zirconia (ZrO_2) based materials are the most utilized for ceramic top coat in TBCs. One problem in pure zirconia is that it undergoes phase transformation from tetragonal to monoclinic at about 1170°C. This phase transformation is accompanied with induced stress in the coating which can produce coating detachment and cracking during use. The phase transformation in zirconia can be avoided by adding some phase stabilizers such as yittria, calcia or magnesia. During this study coatings were produced through thermal plasma spraying using zirconia added with 4 wt% CaO powder. The particle size distribution of the irregular shaped powder was approximately mono modal with D_{90} = 40.302 μm, and the spread was 0.3-80 μm. The work demonstrated that improvement in powder quality through leaching could reduce the porosity and greatly improve the quality of the coatings. Characterization techniques used during this work are X-ray diffraction (XRD), optical microscopy, laser particle size analysis and scanning electron microscopy (SEM).

Keywords plasma spraying – thermal barrier coatings – partially stabilized zirconia – CaO – particle size distribution

INTRODUCTION

The increase in operating temperature of gas turbine engines during the last 50 years has seen developments in high temperature engineering alloys. Nickel based superalloys were developed because of required combination of strength and toughness at high temperatures (>1000°C). The maximum operating temperature of these alloys was enhanced by composition refinement, directional grain growth and single crystal development. This resulted in dramatic improvements in both power and efficiency of the turbine engines [1].

Further improvements are impeded by a slowing in the development of materials with even higher temperature capabilities. The efficiency of gas turbine engines are directly linked with materials used in the hot sections of gas turbine engines. The components of hot sections like combustion chamber, turbine blades, bearing and seals, must endure extremely hot engine gases, an oxidizing and hot corrosive environment, large centrifugal loads and high velocity dust/silt particle impacts [2]. New turbine engine materials must therefore possess a balance of high temperature strength, toughness and oxidation and corrosion resistance. Further improvements in nickel base superalloys appear unlikely since they now operate in environments where the temperature approaches 90% of their melting point [3].

Thermal barrier coatings (TBCs) enable the gas turbines to operate at a gas temperature above the workable temperature of the substrate. In addition to the above mentioned application, the automotive industry also uses these coatings to protect components such as pistons, valves, intake and exhaust ports against wear and corrosion [3, 4]. The benefit of these coatings results from their ability to sustain high temperature gradients (~200°C) under non-equilibrium conditions as well as extreme wear conditions. The main function of TBCs is to enhance the component efficiency by increasing its working temperature and to lower the temperature of the metal substrate in order to enhance the performance of component. These coatings are specifically designed for components submitted to degradation at high temperatures, to erosive wear resulting from the impact of solid particles, to high temperature corrosive attacks, etc. [4-6].

Zirconia is a material of choice for TBCs because of its intrinsic properties such as very low thermal conductivity and high temperature stability. It reduces heat influx to the underneath metallic components and prevents hot corrosion. ZrO_2 top coat can be applied by a variety of deposition techniques – plasma spraying (PS) and electron beam physical vapour deposition (EBPVD) are the two most commonly used techniques. EBPVD produces columnar structure which is more strain tolerant and exhibit longer life compared to plasma sprayed coatings which show a lamellar structure [6, 7]. The lamellar structure exhibited by the plasma sprayed coatings is also recognized by a higher porosity compared to EBPVD technique. If properly controlled with a defined structure, this porosity enhances the thermal insulation. On the other hand, absence of columnar structure also prevents penetration of hot gases towards the coating-substrate interface, thus preventing any hot corrosion to take place at the interface. Another advantage of plasma sprayed coatings is in the process itself as it is very quick with acceptable coating cost. On the other hand due to its high speed, the process parameters are also difficult to control [7].

Atmospheric plasma spraying (APS) technique is industrially the most common and technically the most suitable one to produce ceramic coatings. Vacuum or low pressure plasma spraying (VPPS or LPPS) is expected to give dense coatings but this is achieved at a higher cost [8]. They are widely applied as easy fixes and are considered a low-cost deposition technique. The bonding mechanism of these coatings is largely mechanical. The structure of APS coatings consists of pores and defects that are parallel to the interface. These pores give APS coatings a lower thermal conductivity and they have a greater effect in reducing heat flux to the underneath substrate. The other advantages associated with APS coatings are process flexibility, low equipment cost and less operational expenses involved. In general, the APS process can be optimized more easily for large parts [9-11].

Conventional plasma-sprayed coatings are characterized by their coarse grain structure, significant open porosity, generally in the range of 8 to 20 volume%, and pancake-like morphology, i.e. splats. The coarse microstructures are a result of spraying relatively coarse (>20 μm) powders. Small particles generally less than 2 μm, when sprayed under conventional plasma spray conditions are likely to either vaporize in the plasma or fail to enter the plasma, resulting in poor deposition efficiencies [11, 12]. This makes the pretreatment of plasma grade powders an important area of research. Properly treated and sized (agglomerated) powders penetrate the plasma plume as desired, improving the efficiency of the spraying process as well as helping to obtain the required coating structure [12].

The limitation in the use of pure zirconia powder is attributed to displacive tetragonal (t) to monoclinic (m) phase transformation. This transformation occurs at 950°C. This phase change accompanied by a shear strain and a volume expansion of 4%, results in cracks within the coating and at the interface. Eventual detachment of the coating takes place in longer use. This phase transformation can be controlled by adding some suitable bivalent or trivalent oxides of calcium, magnesium, scandium and yttrium. Calcia addition compared to other oxides makes the cubic phase stable with small additions, whereas the yttria-stabilization also is very common [13-16]. Yttria, although more expensive, is a more popular choice as it gives stability to the tetragonal phase to a much lower temperature and thus helps improve the resistance against thermal cycling conditions. On the other hand, a larger quantity of Y_2O_3 is required to achieve the same stabilization effect compared to CaO [12, 17].

The objective of current work is to study phase transformation in calcia stabilized zirconia within the plasma sprayed coatings, using inexpensive commercially available powder. Improvement in the powder characteristics is expected to improve the quality of the coating in a way to develop an acceptable thermal barrier coating (TBC), which is less expensive as compared to yttria stabilized zirconia (YSZ). This may be utilized for strategic applications where thermal cycling is not a critical parameter.

MATERIALS AND METHODS

The starting powder was a commercially available zirconia for use as sintered pellets or small injection molded implants. The powder has small quantities of CaO (about 4% wt) as stabilizer, the quantity of which was also verified experimentally. The true density of the powder was measured using gas pycnometry. Particle size distribution of this powder was analyzed using laser particle size distribution analyzer (HORIBA LA910). Powder morphology was studied using optical and scanning electron microscopes. Energy dispersive X-ray analysis (EDAX) studies revealed the elemental constituents of powder under study. For phase analysis X-ray diffraction (XRD) of powder was performed.

The powder was applied on substrates using a hand controlled Metco plasma spray system. The substrate used in this study was INCONEL-718, a superalloy (75 mm × 50 mm and 5 mm in thickness). Plasma spraying conditions are shown in Table 1. Prior to plasma spraying, surface of the substrate was roughened using grit blasting, surface roughness tester and optical microscope was employed to observe surface conditions and morphology.

The plasma gun (3MB, Metco) moved left and right in the horizontal direction, in each passage depositing a layer of ceramic material on rectangular substrates mounted on a rotating cylindrical sample holder. After deposition process the coated surfaces were air cooled. The porosity of the coatings was determined by measuring the pore and the coating area via image analysis technique on optical microscope. EDAX analysis was performed to determine the elemental variation in the zirconia powder during atmospheric plasma spraying and post deposition. Post deposition X-ray diffraction analyses were carried out to evaluate the phase changes during deposition [16].

Table 1. Plasma spraying process condition

Process variable	Value
Primary gas (Ar)	90 SCFH
Secondary gas (H_2)	15 SCFH
Carrier gas (Ar)	14 SCFH
Powder feeding rate	6.6 lb/hr
Distance b/w gun and substrate	3.5 inch
Angle b/w gun and substrate	90°
Plasma voltage	30V
Plasma current	500A

RESULTS AND DISCUSSION

Characterization of powder

The true density of the powder was 5.80g/cm^3 using helium gas pycnometer, which was less than all the polymorphs (cubic, tetragonal and monoclinic phases) of zirconia. Two possibilities could be the reason: (1) the powder may contain some closed porosity, and (2) there may be some low density additive (CaO in our case), for the particular sample of stabilized zirconia [12, 14]. As the additive quantity of approx. 4 wt% is expected to bring very little change in overall density, it is believed that both possibilities (1) and (2) are jointly responsible for the reduced density.

Laser particle size distribution of powder is shown in Figure 1. It is evident from this distribution curve that the maximum population of particles can be estimated in the 15~40 µm range. Nonetheless, a large size tail in the curve is also observed, representing a non negligible quantity of fine particles in the powder. From light optical microscope (LOM) and scanning electron microscope (SEM) analysis (Fig. 2), the powder had irregular crushed morphology with no surface porosity at least observable at the working magnification levels. The pictures also support the presence of fine particles among the mostly large size particles, as it was also observed through laser particle size distribution of the powder.

EDAX analysis confirmed that the powder was composed of three elements, zirconium, calcium and oxygen (Fig. 3). From relative weight% of these

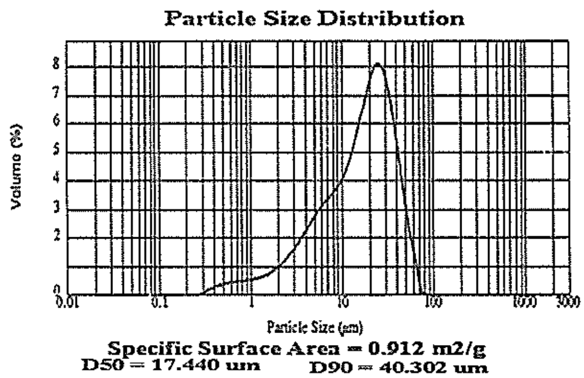


Figure 1. Particle size distribution of zirconia powder.

juveniles, and males) were also noted. Due to limited time, quantitative study was not carried out. I. Wayan Suana made a follow-up trip (26-27 June 2010) to make numerical record of the colour morphs as well as the other life stages.

RESULTS AND DISCUSSION

Female *N. vitiana* can be readily distinguished from other *Nephila* species in the region (e.g. *N. antipodiana*, *N. pilipes* and *N. plumipes*) by the presence of a reddish sternum (Fig. 1) [2, 3]. There are also prominent yellow marks near the joints on the ventral side of all the legs (Fig. 1). A fairly large population of this spider was found confined to a small stretch of mangrove vegetation on Gili Meno. The spiders appeared to prefer this habitat near the water edge than the nearby area with coconut palms. We did not observe any *N. vitiana* in other parts of the island.

Two abdominal colour morphs – yellow (Figs. 2, 3) and greenish-yellow (Figs. 4, 5) – of female *N. vitiana* were present in Gili Meno. A cursory count during our first visit indicated that these two colour morphs occurred in about 1:1 ratio in some 20 individuals observed. On the second visit, the yellow morph accounted for 29 individuals and the greenish-yellow morph 22 individuals. The number of yellow and greenish-yellow females was not significantly different ($\chi^2 = 0.96$; $0.50 > P > 0.30$).

During the first visit, there were few adult male (Fig. 5) and juvenile female (Fig. 6) spiders. Several egg cocoons were present on the branches nearby the web. The silk appeared more orange than yellow in colour. The numerical count on the second visit resulted in six males and 19 juveniles associated with the yellow females; and one male and 13 juveniles associated with the greenish-yellow females. It is noteworthy that there appeared to be significantly more adult males associated with the yellow females. The significance remains to be determined.

The dorsum of the yellow morph was decorated with dark streaks and spots. It possessed five pairs of sigillae/spots arranged longitudinally along the middle part, with the two anterior pairs more prominent and larger in size (Fig. 2). The sigillae had a dark outline and a dark spot at the posterior part.

In the greenish-yellow morph, the dorsum was streaked with yellow base colour (Figs. 4, 5). It was decorated with five main pairs of white-spotted sigillae (Fig. 4) or yellow spots (Fig. 5) arranged longitudinally as in the yellow morph, but without dark outline. Most of the greenish-yellow morph had white-spotted sigillae. In individuals with sigillae, the white colour was marked with a dark spot at the posterior part in the anterior pairs (Fig. 4). In individuals with yellow spots, the two anterior pairs were larger and the posterior spots were irregular in shape.

Colour polymorphism and pattern variation have been recently reported for female *N. antipodiana* in Peninsular Malaysia [4]. Several colour morphs appear to be present. The yellow abdominal colour morph appears to be the common form. In a particular locality, the population appears to be represented by only two colour morphs – yellow and non-yellow (greenish-yellow or reddish brown). In the present Gili Meno population, only two colour morphs (yellow and greenish-yellow) were observed. On the main Lombok Island, a single yellow-morph female spider was found in an inland area of Sekotong among the fruit trees. On Bali Island, over 15 *N. vitiana* adult females in Kedonganan all belonged to the greenish morph – the spiders occurred among mango trees and on electric cables (I. Wayan Suana, unpublished data). It has been suggested that yellow colour is most cryptic in the below-leaf environment and hence selected for [5]. However, as in *N. antipodiana*, the association of colouration and habitat use in *N. vitiana* remains to be elucidated.

The juvenile female *N. vitiana* (Fig. 6), like *N. antipodiana* [4], is very different in colouration and pattern from the adult. These two taxa could provide useful models for the study of the ontogeny of colour and pattern development.

During the three earlier brief field excursions in early June 2010, we did not encounter any *N. antipodiana* and *N. pilipes*. We also did not come across any *Nephila* spider in Kerandangan. More intensive field study will be needed.

As in the case of *N. antipodiana* and *N. pilipes* [6, 7], two species of comb-footed spider (Theridiidae) – *Argyrodes argentatus* Pickard-Cambridge 1880 and *Argyrodes flavescens* (Pickard-Cambridge 1880 – are associated with *N. vitiana*. In Gili Meno, there were significantly more *Argyrodes* spiders associated with the yellow females than the greenish-yellow females – 42 versus 6. The reason and significance need verification.

In sum, it is reasonable to conclude that the dorsal

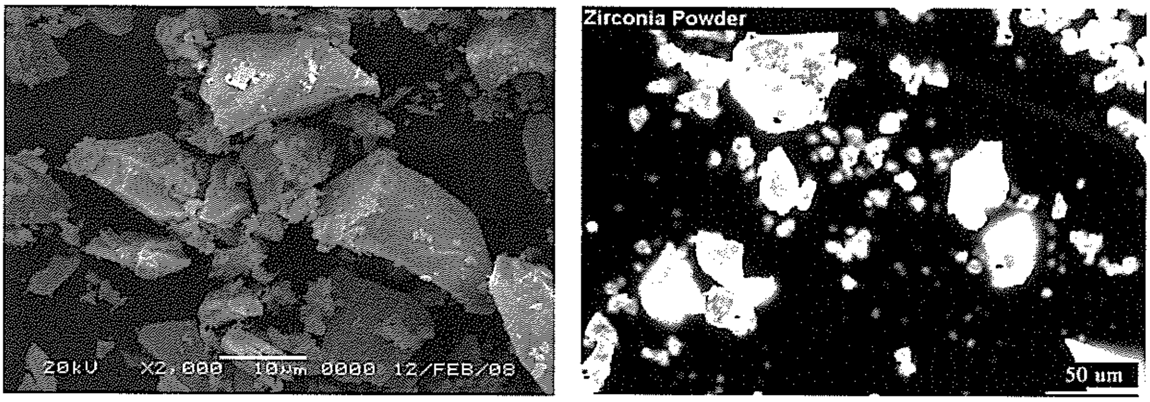


Figure 2. SEM (left) and Optical (right) micrographs of the zirconia powder.

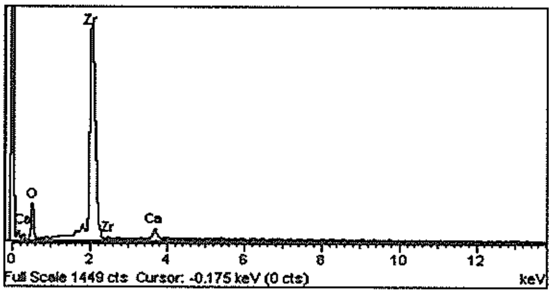


Figure 3. EDAX analysis of zirconia powder.

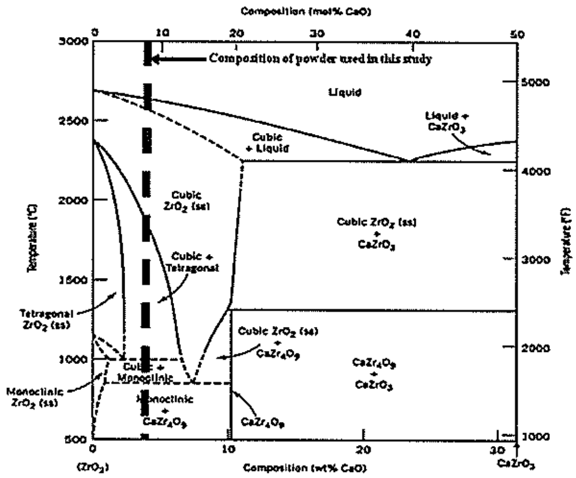


Figure 4. ZrO_2-CaO phase diagram [17].

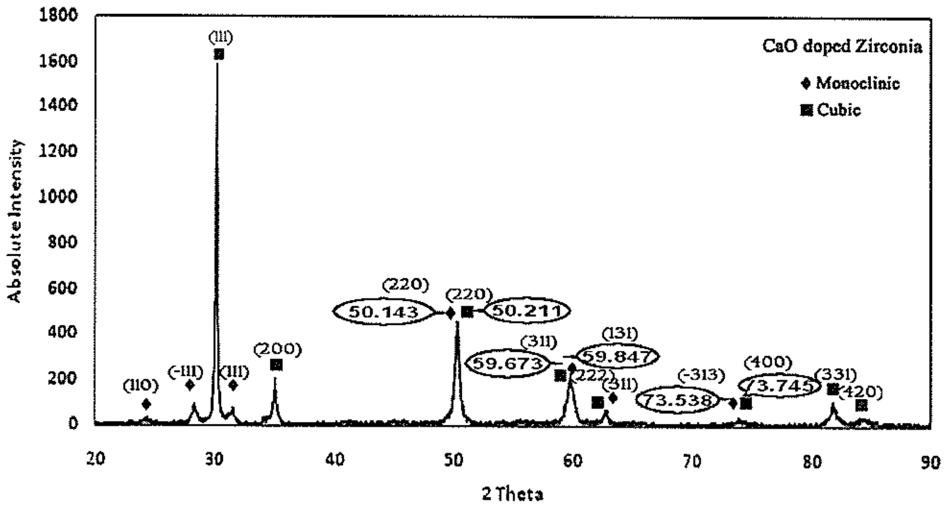


Figure 5. X-Ray diffraction (XRD) pattern of zirconia powder. *ICDD C 01-089-9069, C 01-070-8739.

elements, it could be estimated that the powder contained calcia (CaO) and zirconia (ZrO_2) powders with 4 to 96 (approx) percent by weight. The powder under study can be mapped in ZrO_2-CaO phase diagram (Fig. 4) [17].

XRD pattern of the powder (Fig. 5) confirms that the powder consisted of monoclinic and cubic phases only. It can be said that the powder was CaO-PSZ (because of the presence of both the monoclinic phase and the cubic phase). The powder can be described, looking at the results shown in Figures 2 to 5, as a partially stabilized zirconia with about 4 wt% calcia

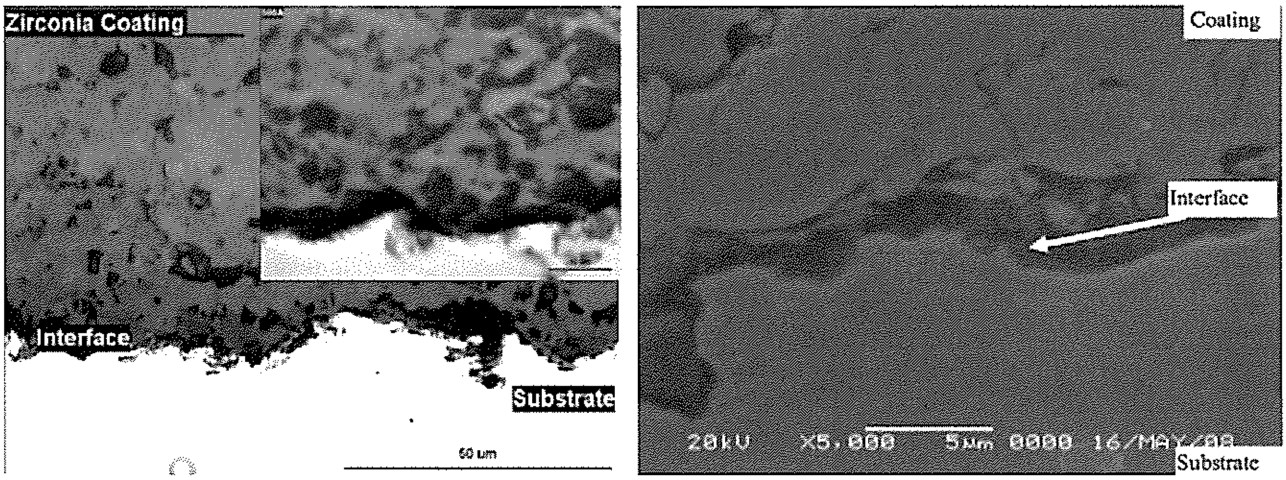


Figure 6. Optical microscope (left) and scanning electron microscope (right) images of the coating.

as stabilizer. It exhibits an irregular shape and has a crushed morphology with a particle size scatter from 0.2 to 80 µm.

Microstructure of deposited coating

The cross-sections of the coated samples were studied on optical microscope and SEM for interface examination and level of porosity (Fig. 6). The lamellar structure, very usual in APS coating, was observable within these coatings, although these lamellae were not regular shaped due to a large particle size distribution of the powder. The porosity observed was mostly interconnected, considered undesirable in thermal barrier systems as a mostly closed porosity provides the best heat insulation effect. The level of porosity was more than 20% which was also on a higher side for a good quality TBC. A relatively important level of porosity was observed at the interface. This porosity can be considered as a defect as it reduces the contact area at the interface, thus reducing the coating adhesion to surface. As mentioned earlier, probably one reason for this is the surface profile obtained through grit blasting prior to the coating. The other reason for large level of porosity may be attributed to the wide particle size distribution with large number of fine particles. The heating rate and temperature of these particles could not be properly controlled during plasma spraying. When these small particles strike with substrate or on the previously deposited particles with different temperature and momentum, i.e. behaving according to their quantity of heat, temperature and mass during deposition process, this gives a very non uniform structure and porosity to the coating. During plasma spraying some fine particles might have even evaporated or not able to enter in plasma jet. This created voids and porosity in the deposited layers (Fig. 6).

XRD of coating

To find out any phase change in zirconia which might take place during or after plasma spraying, XRD of the deposited coating was carried out (Fig. 7). This XRD pattern shows that all monoclinic peaks had disappeared; only cubic peaks were observed. This change could be explained by the fact that during plasma spraying process the powder was in the molten form and all the calcia was completely dissolved in zirconia (Fig. 4). When this molten stream of zirconia powder struck the substrate which was relatively at low temperature, splat formation and quenching of molten powder took place, resulting in rapid solidification of this powder. Because of highly non equilibrium conditions during plasma spraying, there was no time available for the calcia to diffuse out from zirconia lattice to attain equilibrium composition. Such high cooling rates result in preservation of cubic phase stable otherwise only at above 1000 °C for this particular composition and which is a meta-stable phase at room temperature (Fig. 4). This is the function of CaO, i.e. stabilization of cubic phase of ZrO_2 at room temperature. Such a phenomenon is observed during the heat treatment of partially stabilized zirconia. Another notable feature of the pattern shown in Figure 7 compared to Figure 5 is reduction in peak broadening and noise level and an increase in peak intensity, which indicate increase in crystallite size in the coating.

Journal of Science and Technology in the Tropics (2011) 7: 57-64

Energy dispersive X-ray analysis (EDAX) of coating

To observe any composition change in the powder during plasma spraying, EDAX of coating was also carried out after the spraying. The results are shown in Figure 8. Although it was expected that no decomposition of zirconia would take place at high temperatures, the plasma being a highly ionized medium, it was deemed useful to check for any compositional changes after the spraying. From the results it could be inferred that composition of powder was not altered after plasma spraying, i.e. the powder remained stable during its passage through plasma and no detectable decomposition of the powder took place.

The micrographs in Figure 6 show a large amount of porosity within the coating as well as at the interface between the substrate and coating. One should consider two aspects of porosity in a coating. If the porosity is higher than 20% and present specifically at the interface, this may be damaging for the integrity and life of the coating for mechanical operations. Secondly, if this porosity is evenly distributed inside the coating, in small size, mostly closed porosity, this improves the thermal barrier effect of the coating through increase in the insulation ability. To address the above two issues, the term controlled porosity is used for such type of coatings. A controlled or engineered porosity is well within the closed porosity limits and is deemed beneficial for the eventual application as a thermal barrier, without compromising the mechanical properties. This demonstrates how much is the importance to control the spraying parameters of the process as well as to have an adequately sized powder with suitable morphology.

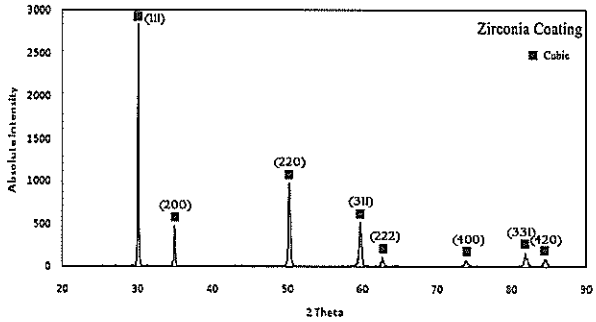


Figure 7. XRD pattern of deposited coating. * ICDD C01-089-9069.

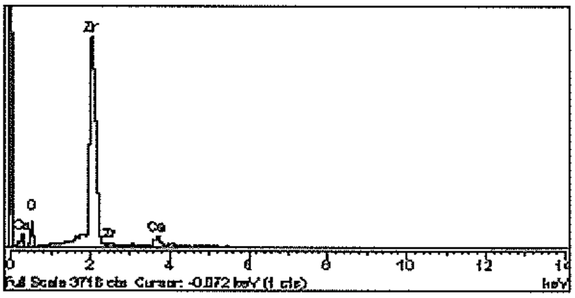


Figure 8. EDAX analysis of zirconia coating.

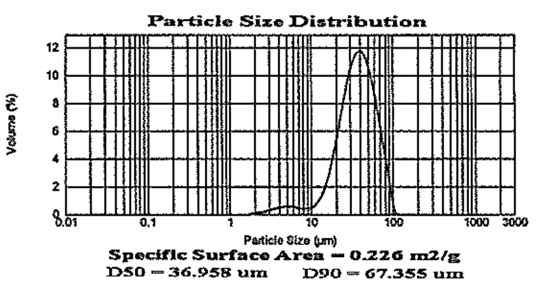


Figure 9. Particle size distribution of the wet sieved and milled powder.

Treatment of zirconia powder

After carefully looking at the structure of the powder (Fig. 2) and the size distribution curve (Fig. 1), one could easily see that the powder was composed of a mixture of large size particles in the range of 10 to 50 µm and fine particles of extremely small size. Such a mixture is not considered to be suitable for plasma spraying as very small size particles have a tendency either to evaporate if they can penetrate the plasma plume, or they simply reside on the surface of highly viscous plume while they are thrown towards the substrate as a solid unmelted particle. Decreasing the amount of fine particles within a large distribution is believed to improve the powder flow in the nozzle and is also supposed to improve the output of the process.

The present powder was treated through a multistage process comprising of liquid phase sieving after proper dispersion of the powder, drying and milling for breakage of soft agglomerates produced during the wet treatment. The particle size distribution of the treated powder was studied through laser particle size analyzer. Figure 9 shows the distribution curve for the treated powder where the tail of the distribution curve, representing the fine particles, had been considerably shortened. This powder was then sprayed under similar conditions to those of the previous one (Fig. 6). Figure 10 gives the microstructure of the coating obtained with the treated powder.

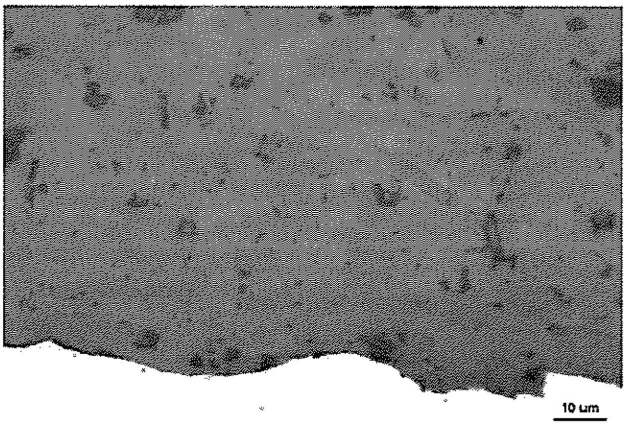


Figure 10. Microstructure of the coating and interface obtained after treating the powder.

The dense microstructure in Figure 10 shows that the porosity levels were reduced, although the porosity still remained between 10 to 15%. This porosity had mainly transformed into closed porosity which is ideal for a thermal barrier. Although it appears that the porosity is largely reduced at the interface and an increased adhesion of the coating is expected, this increase in adhesion remains to be verified. The interface between substrate and coating is still a subject of ongoing research. Special adhesion tests are designed to check the strength of the bond. The interface adhesion in ceramic plasma sprayed coatings is a result of mechanical anchoring. The surface roughness (given by its Ra coefficient) and other parameters like wetting of the substrate surface by the molten splats are all very important in increasing the coating adhesion to the substrate [12].

CONCLUSION

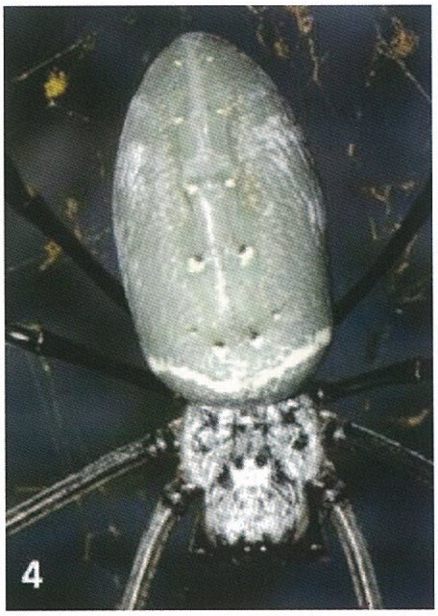
Calcia (CaO) stabilized zirconia coatings can be produced through plasma spraying process with 4 wt% CaO. The particle size distribution plays a very important role in order to improve the quality of the coating. The large particle size distribution of the powder is not desirable as this increases the porosity in the coating and this porosity remains interlinked (open). A correct powder size distribution coupled with suitable spraying parameters can give good quality dense structure, optimal porosity and a stabilized cubic phase at room temperature. The adhesion of the coating is expected to improve as well as porosity at the coating-substrate interface is expected to be reduced. These coatings are produced without a bond coat in case the intended use is for a one time limited duration application. Treatment of the powder is carried out to remove the fine particles and hence to improve the overall powder spraying ability. The coatings obtained through the treated powder are dense, have closed porosity and an intimate contact is achieved at the interface. Such interfaces usually present high adhesion to the substrate. As the adhesion in plasma sprayed coatings is mainly attributed to the mechanical interlocking and not to the diffusion at the interface, the interface strength has to be verified by the Adhesion-Cohesion test conducted on a mechanical testing machine. As for the objectives of the present work, suitable microstructure and density of coatings is achieved using an improved commercial calcia stabilized zirconia powder. This is cost saving specifically when the plasma grade powders are expensive and in some cases difficult to procure.

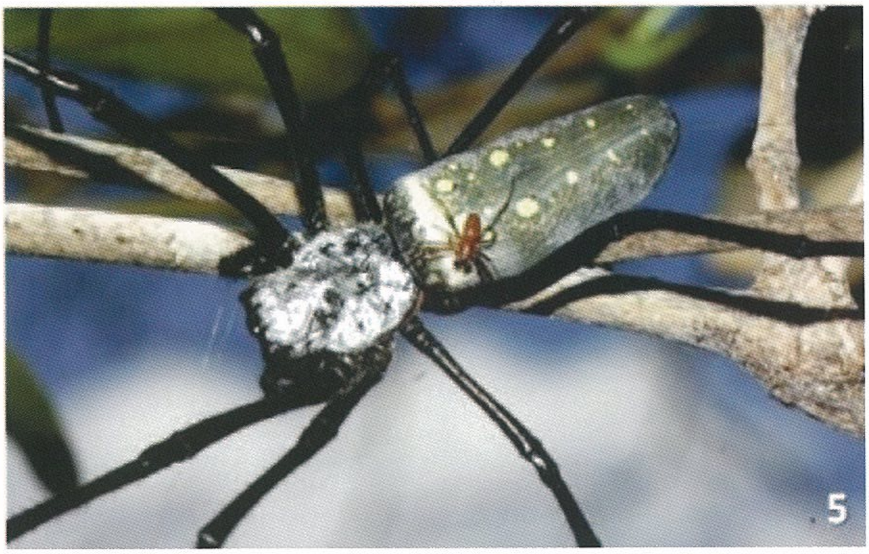
REFERENCES

1. Reed R.C. (2006) *The Superalloys: Fundamentals and Applications*. Cambridge University Press.
2. Fritscher K. M. Peters, H.J. RLtzer-Scheibe, U. Schulzet (1992) *Advanced Aerospace Materials*. Springer-Verlag, Berlin, Germany.
3. Padture N.P., Gell M. and Jordan E.H. (2002) Thermal barrier coatings for gas-turbine engine applications. *Science* 296(5566): 280-284.
4. Sharafat S., Kobayashi A., Chen Y. and Ghoniem N.M. (2002) Plasma spraying of microcomposite thermal barrier coatings. *Vacuum* **65**: 415-425.
5. Antoua G., Montavon G., Hlawka F.B., Cornet A. and Coddet C. (2005) Microstructures of partially stabilized zirconia manufactured via hybrid plasma spray process. *Ceramics International* **31**: 611-619.
6. Guo H., Kuroda S. and Murakami H. (2006) Microstructures and properties of plasma-sprayed segmented thermal barrier coatings. *Journal of American Ceramic Society* **89**(4): 1432-1439.
7. Mauer G., Vaen R., Stöver D., Kirner S., Marqués J.-L., Zimmermann S., Forster G. and Schein J. (2011) Improving powder injection in plasma spraying by optical diagnostics of the plasma and particle characterization. *Journal of Thermal Spray Technology* 20(1-2): 3-11.
8. Khan A.A., Labbe J.C., Grimaud A. and Fauchais P.

(1997) Molybdenum and tungsten coatings for X-Ray targets, obtained through low pressure plasma spraying process. *Journal of Thermal Spray Technology (ASM Int.)* **6**(2): 228-234.

9. Beele W., Marijnissen G. and van Lieshout A. (1999) The evolution of thermal barrier coatings – status and upcoming solutions for today's key issues. *Surface and Coatings Technology* **120-121**: 61-67.
10. Khan N.A. and Lu J. (2007) Thermal cyclic behavior of air plasma sprayed thermal barrier coatings sprayed on stainless steel substrates. *Surface & Coatings Technology* **201**: 4653-4658.
11. Vural M., Zeytin S. and Ucisik A.H. (1997) Plasma-sprayed oxide ceramics on steel substrates. *Surface & Coatings Technology* **97**: 347-354.
12. Fauchais P., Montavon G. and Bertrand G. (2010) From powders to thermally sprayed coatings. *Journal of Thermal Spray Technology* **19**(1-2): 56-80.
13. de Arellano-Lo´pez R. and Faber K.T. (1999) Microstructural characterization of small-particle plasma spray coatings. *Journal of American Ceramic Society* **82**(8): 2204-2208.
14. Hannink R.H.J., Kelly P.M. and Muddle B.C. (2000) Transformation toughening in zirconia-containing ceramics. *Journal of American Ceramic Society* **83**(3): 461-487.
15. Song Y.S., Lee I.G., Lee D.Y., Kim D.J., Kim S. and Lee K. (2002) High-temperature properties of plasma-sprayed coatings of YSZ/NiCrAlY on Inconel substrate. *Materials Science and Engineering* **A332**: 129-133.
16. Stubican V.S. and Hellmann J.R. (1981) Phase equilibria in some zirconia system. *Advances in Ceramics* **3**, *Science and Technology of Zirconia*: 25-37.
17. Stevens R. (1986) *Zirconia and Zirconia Ceramics*. Magnesium Elektron Ltd.





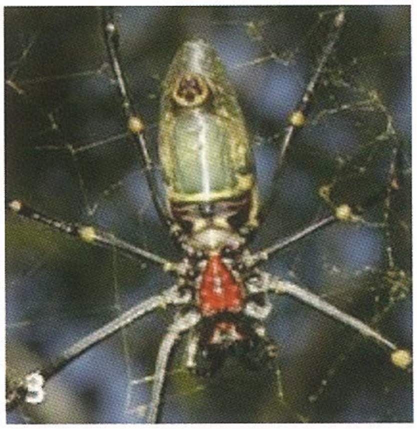


Figure 1. Ventral view of female *Nephila vitiana* in Gili Meno. (photo: H. S. Yong)

Figure 2. Yellow morph of female *N. vitiana* in Gili Meno. (photo: H. S. Yong)

Figure 3. Ventral view of yellow morph of female *N. vitiana* in Gili Meno. (photo: H. S. Yong)

Figure 4. Greenish-yellow morph of female *N. vitiana* with white-spotted sigillae in Gili Meno. (photo: H. S. Yong)

Figure 5. Greenish-yellow morph of female *Nephila vitiana* with yellow spots and a male on its back in Gili Meno. The dorsal view looks very much like *Nephila antipodiana*. (photo: H. S. Yong)

Figure 6. Juvenile *Nephila vitiana* at Gili Meno, Lombok, Indonesia. (photo: H. S. Yong)

abdominal colour in female *N. vitiana* is polymorphic in nature. Whether the yellow morph confers a selective advantage remains to be confirmed. Extensive studies are needed to determine the occurrence of abdominal colour polymorphism in *N. vitiana* in West Nusa Tenggara and other parts of Indonesia.

Acknowledgements – We thank Mataram University and University of Malaya for financial support and research facilities to carry out this study. This is the first publication arising from the collaboration between the two universities.

REFERENCES

1. Platnick N.I. (2010) *The world spider catalog, version 11.0.* American Museum of Natural History, online at http://research.amnh.org/entomology/spiders/catalog/index.html.
2. Harvey M.S., Austin A.D. and Adams M. (2007) The systematic and biology of the spider genus *Nephila* (Araneae: Nephilidae) in the Australasian region. *Invertebrate Systematics* **21**: 407-451.
3. Dahl H. (1912) Seidenspinne und Spinnenseide. Mitteilung aus dem Zoologischen Museum in Berlin **6**: 1-90.
4. Yong H.S., Hashim R., Belabut D. and Lim P.E. (2010) Abdominal colour polymorphism in female Asian Golden Web Spider *Nephila antipodiana* (Araneae: Nephilidae). *Journal of Science and Technology in the Tropics* **6**: 39-42.
5. Oxford G.S. (2009) An exuberant, undescribed colour polymorphism in *Theridion californicum* (Araneae, Theridiidae): implications for a theridiid pattern ground plan and the convergent evolution of visible morphs. *Biological Journal of the Linnean Society* **96**: 23-34. With 2 figures.
6. Koh J.K.H. (1989) *A guide to common Singapore spiders*. Singapore Science Centre, Singapore.
7. Yong H.S. (2009) *Nephila antipodiana* (Araneae: Nephilidae) from Pahang: a new record for Peninsular Malaysia. *Journal of Science and Technology in the Tropics* **5**: 19-21.

Journal of Science and Technology in the Tropics (2011) 7: 9-16

New records of Odonata (Insecta) from the Cameron Highlands, with first records of two species for Malaysia

Y. F. Ng[1], R. A. Dow[2] and C. Y. Choong[1]
[1] Centrè for Insect Systematics, Faculty of Science and Technology,
Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor D.E. Malaysia
(E-mail:ng_yf@ukm.my)
[2] National Museum of Natural History, P.O. Box 9517, 2300 RA Leiden, The Netherlands

Abstract Records of Odonata collected in the Cameron Highlands in September 2008 are presented. Fifty five species from 14 families were collected as either adults or larvae. Two of the species, *Indolestes anomala* and *Macromia* sp. cf. *cupricincta*, have not previously been recorded in Malaysia, whilst another 16 species do not appear to have been recorded in the Cameron Highlands or immediate surrounds before now.

Keywords Odonata – dragonflies – damselflies – new records – Cameron Highlands – conservation

INTRODUCTION

The Odonata (dragonflies and damselflies) of West Malaysia have received increasing attention in recent years, especially following the publication of a field guide for Peninsular Malaysia and Singapore [1]. The bright colours and fascinating behaviour of many odonates makes them an ideal flagship group for invertebrate conservation; they are the first insect group for which a global assessment of conservation status has been undertaken [2]. They are also considered to have considerable potential as indicators of habitat integrity, for instance see [3] and references therein. For general information on Odonata in tropical Asia, see the introductory sections of [1, 4-6].

The Cameron Highlands are an upland district in Pahang state. They have been regarded as the most important highland ecosystem of Peninsular Malaysia. However the suitability of the area for tea growing was realised in the in early 1940s; subsequently the area became an important cultivation site for vegetables and fruits for Malaysia and Singapore. Nearly 100,000 ha of steep mountainous land in Cameron Highlands have been used for agriculture [7]. Use of land for agricultures purposes has led to environmental problems such as loss of forest area, water pollution, soil erosion and the unmanageable solid waste burden of a rising population [7, 8].

The Cameron Highlands are arguably one of the better studied areas for Odonata in peninsular Malaysia, with records from the area or its immediate vicinity [9-35]. It should be noted that there is some doubt about whether or not some locations from these publications are within the Cameron Highlands as defined here, or from adjacent areas. Despite the number of publications listed above, it is clear that there has been a lack of systematic sampling in the area. This paper presents results of a short survey carried out in September 2008; it demonstrates that the inventory of Odonata known from the area, and indeed from peninsular Malaysia, is far from complete, with two new records for Malaysia being made in just nine days of sampling. Some records from Kuala Woh in Perak, just outside of the Cameron Highlands are included; all of these species are already known from, or likely to occur, in the Cameron Highlands.

MATERIAL AND METHODS

Study sites

Sampling was carried out at the locations listed below, from 18-27 September 2008, but no sampling was conducted on 26 September:

1. Sg. Burung area (18.ix) – a forest stream with a rock and gravel substrate, ca 1550m, 4° 29.897N, 101° 23.732E.
2. Sg. Telom area (19.ix and 24.ix) – rock and gravel substrate forest streams and a pond at the margin of forest, ca 1460-1600m, 4° 36.769N, 101° 24.260E.
3. Sg. Pos Terisu area (20.ix) – rocky forest