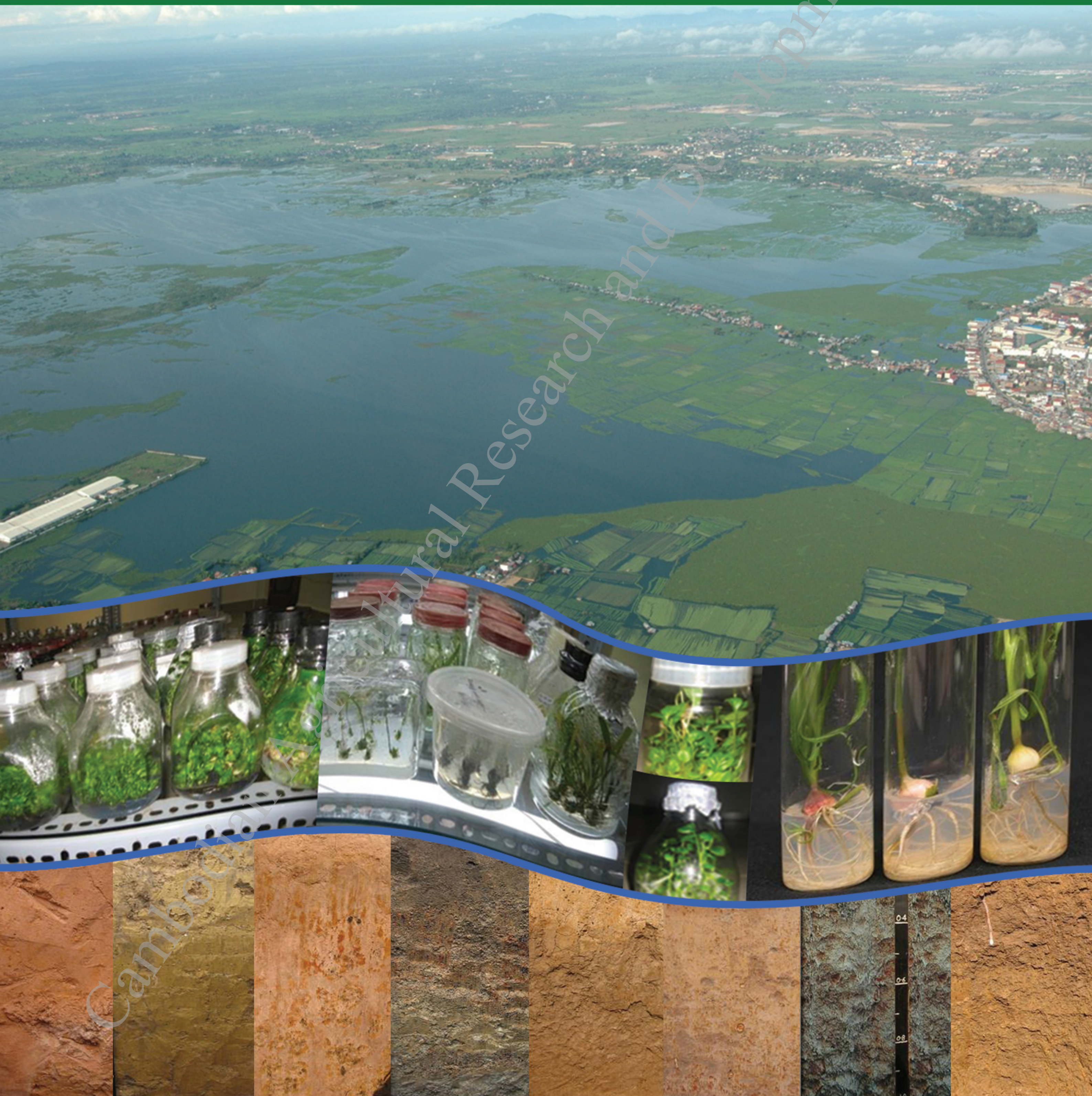
ទស្សនាវដ្ដីកសិកម្មកម្ពុជា

Cambodian Journal of Agriculture

Volume 10, Number 1-2 January - December 2011



A Publication of the Cambodian Agricultural Research and Development Institute

Published by

Cambodian Agricultural Research and Development Institute (CARDI)
National Road N° 3, Prateah Lang Commune, Dangkor District,
Phnom Penh, Kingdom of Cambodia.
P.O. Box 01, Phnom Penh, Kingdom of Cambodia.
Tel: (855 23) 6319 693 - 4
E-mail: cardi@cardi.org.kh, Website: www.cardi.org.kh

Funding for publication of this issue of the journal is provided by the Australian Centre for International Agricultural Research (ACIAR)

Australian Government
Australian Centre for International Agricultural Research

ISSN 1029-8835

CAMBODIAN AGRICULTURAL RESEARCH AND DEVELOPMENT INSTITUTE

"PARTNERSHIP FOR LIVELIHOOD IMPROVEMENT AND ECONOMIC GROWTH"

CARDI is a leading semi-autonomous public institution working with its stakeholders to improve the living standards of all Cambodian, especially farmers, through agricultural research, training and technology transfer. To meet this mission, CARDI offers:

SERVICES

- ✯ Collaborative research projects
- ✯ Agricultural consultancy
- ✯ Agricultural training courses
- ✯ Training / workshop / seminar...facilities
- ✯ Laboratory facilities
- ✯ Space occupancies

PRODUCTS

- ✯ Quality seed of improved crops varieties
- ✯ Premium fragrant milled Rice
- ✯ Scientific books / publication for agriculture

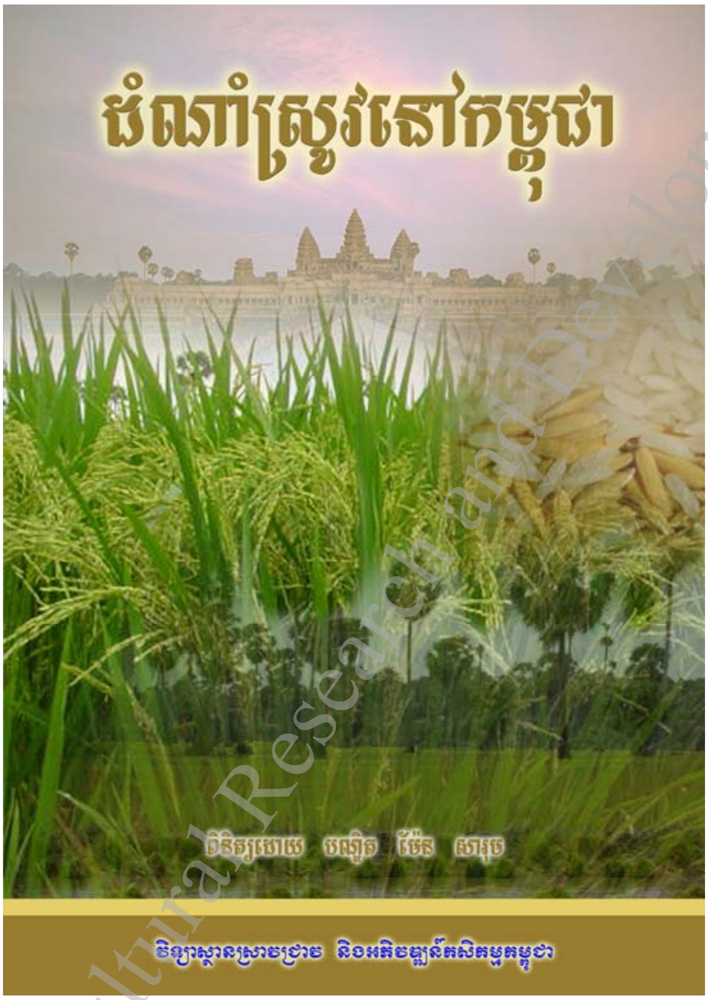
MILLED RICE

BROWN RICE

Contact: Planning Collaboration and Business Office, Cambodian Agricultural Research and Development Institute.
National Road N^0 3, Prateahlang Commune, Dangkor, District, Phnom Penh, Kingdom of Cambodia.
Phone: (855-23) 6319 693 - 4 / Ext. 112
H/P: (855-12) 976 417
P.O. Box 01, Phnom Penh, Kingdom of Cambodia
E-mail: pcb@cardi.org.kh / hunyadana@cardi.org.kh, Website: www.cardi.org.kh

NOW AVAILABLE ON SALE

ដំណាំស្រូវនៅកម្ពុជា



For details,

Mr. Hun Yadana, Head of Planning, Collaboration and Business Office
Cambodian Agricultural Research and Development Institute
Phone: (855-23) 6319 693 - 4 / Ext. 112
H/P:(855-12) 976 417
P.O. Box 01, Phnom Penh, Kingdom of Cambodia
E-mail: hunyadana@cardi.org.kh, Website: www.cardi.org.kh

Or :

Contact : Ms. Srean Kimeap, Assistant to Planning, Collaboration and Business Office
Cambodian Agricultural Research and Development Institute
Phone: (855-23) 6319 693 - 4 / Ext. 224
H/P:(855-89) 612 328
P.O. Box 01, Phnom Penh, Kingdom of Cambodia
E-mail: pcb@cardi.org.kh, Website: www.cardi.org.kh

CONTENTS

ឥទ្ធិពលនៃពន្លឺរស្មីសំយោគ និងសម្ភារៈផ្គត់ផ្គង់ការបណ្តុះទៅលើការដុះលូតលាស់របស់កូនអ័រគីដេ *Dendrobium* sp. ក្នុងដប

Effects of photosynthetic photon flux and supporting material on the growth and development of *Dendrobium* sp. plantlets *in vitro*

*Srean Pao *, Kriengkrai Mosaleeyanon and Chalermpol Kirdmanee*

អត្ថបទសង្ខេប

ឥទ្ធិពលពន្លឺរស្មីសំយោគ (Photosynthetic photon flux) និងសម្ភារៈផ្គត់ផ្គង់ការបណ្តុះ (Supporting materials) ទៅលើការដុះលូតលាស់របស់កូនអ័រគីដេ *Dendrobium* បណ្តុះក្នុងដប (*in vitro*) ត្រូវបានសិក្សា ដើម្បីធ្វើឲ្យមានភាពប្រសើរឡើងនូវគុណភាពលូតលាស់របស់វា ។ កូនអ័រគីដេដែលមានស្លឹក ៣ ទៅ ៤ សន្លឹកត្រូវបានបណ្តុះលើមេជ្រូម Vacin & Went ដោយប្រើហ្វីតាជែល (Phytagel) ចំនួន ២,៤ ក្រាម/លីត្រ ដោយឥតដាក់ស្ករ ឬ វើមីខ័លឡាយ (vermiculite) ចំនួន ១៥ ក្រាម/ដប ប្រើជាសម្ភារៈផ្គត់ផ្គង់ការបណ្តុះ ។ កូនអ័រគីដេដែលបានដាំរួចទាំងនៅលើហ្វីតាជែល និងវើមីខ័លឡាយ ត្រូវបានរក្សាទុកក្នុងទូបណ្តុះរុក្ខជាតិ (Plant growth chamber) នៅក្រោមបរិមាណពន្លឺរស្មីសំយោគ៥០ µmol m^{-2}s^{-1} ឬ ១៥០ µmol m^{-2} s^{-1} អស់រយៈពេល ៣០ ថ្ងៃ ។ បច្ច័យចំនួនពីរផ្សេងទៀតដូចជាៈ កូនអ័រគីដេដែលដាំលើមេជ្រូមដាក់ហ្វីតាជែលចំនួន ២,៤ ក្រាម/លីត្រ ជាមួយសាក់ក្រូស (Sucrose) ចំនួន ២០ ក្រាម/លីត្រ នៅក្រោមពន្លឺរស្មីសំយោគ ៥០ µmol m^{-2} s^{-1} ឬក្រោមពន្លឺរស្មីសំយោគ ១៥០ µmol m^{-2} s^{-1} ។

មេជ្រូមដែលគ្មានស្ករទាំងពីរ ជំរុញការដុះលូតលាស់របស់កូនអ័រគីដេ (ទម្ងន់ស្រស់សរុប ទម្ងន់ស្ងួតសរុប ប្រវែងឫស និងចំនួនស្លឹក) ។ ការដុះលូតលាស់របស់កូនអ័រគីដេអាចពន្លឿនបានតាមរយៈការប្រើ វើមីខ័លឡាយ ឬហ្វីតាជែល ជាសម្ភារៈផ្គត់ផ្គង់ការបណ្តុះ ដោយដាក់ក្នុងមេជ្រូមដែលគ្មានស្ករក្រោមលក្ខខណ្ឌពន្លឺ ១៥០ µmol m^{-2} s^{-1} ។

Srean Pao, Research and Development Center, University of Battambang (UBB), Battambang, Cambodia.
Kriengkrai Mosaleeyanon and **Chalermpol Kirdmanee**, National Center for Genetic Engineering and Biotechnology (BIOTEC), National Science and Technology Development Agency (NSTDA), Klong Luang, Pathumthani, 12120 Thailand.
***Corresponding Author:**
E-mail: paosrean@yahoo.com

ពាក្យគន្លឹះ

កូនអ័រគីដេ ***Dendrobium*** ពន្លឺរស្មីសំយោគ សម្ភារៈផ្គត់ផ្គង់ការបណ្តុះ ***in vitro*** ។

Abstract

In order to improve the quality of *in vitro Dendrobium* plantlets for transplantation, the effect of photosynthetic photon flux (PPF) and supporting material on growth and development were studied. The *in vitro* derived shoots each with 3-4 expanded leaves were cultured on Vacin and Went medium without sucrose using 2.4 g l^{-1} phytagel or 15 g per bottle vermiculite as supporting material. The shoots cultured using phytagel and vermiculite were then incubated in plant growth chambers under 50 µmol m^{-2}s^{-1} or 150 µmol m^{-2} s^{-1} PPF for 30 days. The other two treatments were provided as follows: the shoot cultured in the medium supplemented with 2.4 g l^{-1} phytagel with 20 g l^{-1} sucrose under 50 µmol m^{-2} s^{-1}PPF or under 150 µmol m^{-2} s^{-1} PPF.

Sugar free media significantly promoted the growth and development of plantlets (total fresh and dry weight, root length, number of leaves). The plantlet growth could be improved by using vermiculite or phytagel as a supporting material in sugar free medium under 150 µmol m^{-2} s^{-1} PPF.

Keywords

Dendrobium plantlet, photosynthetic photon flux, supporting material, *in vitro*.

Introduction

Dendrobium sp. is the most popular cut flower and potted plant for the Thai orchid industry. *Dendrobium* sp. and their hybrids are generally propagated through division, cutting single pseudolbulbs or by tissue culture techniques of axillaries buds and shoot meristems. Millions of tissue-cultured plants are raised per year for domestic and export in Thailand (Khentry *et al*, 2006). Micropropagation is an important tool for mass production of uniform plants because of its high efficiency, with good phytosanitary status and quality control. Plantlets grown in small airtight vessels at high air humidity and relatively low photosynthetic photon flux (PPF) are frequently fragile and show low gas exchange with limited development of epicular wax. These plantlets have low growth potential due to limited photosynthetic performance (Jeon *et al*, 2005). To improve phenotype of *in vitro* plantlets, many environmental conditions have been modified: reduction in relative humidity, increase in light intensities, CO_2 enrichment, use of CO_2 concentration inside the vessel, reduction of sugar in the medium and/or use of non agar substrate (Kirdmanee *et al*, 1995). Several aspects such as wavelength (quality) intensity (quantity) and duration of light are important factors affecting plant growth. High light intensity substantially increased the total number of expanded leaves, dry matter, sugar content and nitrogen absorbed in *Phalenopsis* (Soontornchainaksaeng *et al*, 2001). However, high light intensity with high violet and ultra -violet radiations may cause the production of excess phenolic compound as in *Zosteria marina* (Soontornchainaksaeng *et al*, 2001). At low light intensity, an increase in photosynthetic rate (carbon fixation) has occurred, which varies depending on growth and light intensity, susceptibilities to photoinhibition. However, above a certain threshold, carbon fixation becomes saturated and photosynthesis is incapable of using all of the energy absorbed by the plants (Ali *et al*, 2004). Terrestrial orchids naturally need stronger light than epiphytic orchids. Although light is an important factor in micropropagation, reports on the effect of artificial light intensities on plant growth, particularly orchids, are rather scarce (Soontornchainaksaeng *et al*, 2001).

No reports are available on the effects of photosynthetic photon flux and supporting material for *Dendrobium* sp. plantlet *in vitro*. Therefore, the objective of this study was to determine how to enhance growth and development of *Dendrobium* sp. plantlets by increasing photosynthetic photon flux (PPF) using different supporting materials.

Materials and methods

Plant material and culture conditions

The *in vitro* derived shoots each with 3-4 expanded leaves were cultured on Vacin and Went medium (Vacin and Went, 1949) without sucrose under four treatment conditions: using 2.4 g l^{-1} phytagel or 15 g per bottle vermiculite as supporting material. The shoots cultured using phytagel or vermiculite were then incubated in plant growth chambers for 30 days under one of two conditions 50 µmol m^{-2} s^{-1} or 150 µmol m^{-2} s^{-1} PPF. The two treatments were provided as follows: Both treatments contained the shoots cultured in the medium supplemented with 2.4 g l^{-1} phytagel with 20 g l^{-1} sucrose. The first treatment was under low light (under 50 µmol m^{-2} s^{-1} PPF) and the second treatment was under 150 µmol m^{-2} s^{-1} PPF. Table 1 shows the six treatment conditions. The pH of the medium was adjusted to 5.7 ± 1 with 1 N KOH or HCL before autoclaving for 15 minutes at 121 ^{0}C. All six treatments were kept in culture room 4 days then transferred into plant growth chamber (Sanyo) at 24 ± 1 ^{0}C, and at 16h d^{-1} photoperiod at 60% relative humidity.

Growth characteristics

At day 30 of culture, 72 plantlets were sampled from each treatment to determine the number of leaves, root length, fresh weights and leaves area. Then the plantlets were dried at 110 ^{o}C in a hot air oven (Model 500; Memmert, Buchenbach, Germany) for 48 h and then incubated in desiccator before measurement of dry weight (Cha-um *et al*, 2006). The leaf area of *Dendrobium* plantlets was measured by a Leaf Area Meter LIA32 software [LIA32 ver. 0.377e, Copyright: Kazukiyo Yamamoto (Nagoya University).

Experimental design

The experiment used a completely randomized design. Four replicates were raised for each of the six treatments. Three plantlets were in each replicate. The mean values of different treatments such as number of leaves, root length, leaf area, fresh and dry weights of plantlets were compared by Duncan's new multiple ranges test (DMRT) at 5% level, and analyzed by using the Statistical Package for the Social Sciences software (SPSS) (SPSS for Windows; SPSS inc., Chicago, Illinois, USA).

Results and Discussion

Growth characteristics

Total fresh weight of plantlets grown on sugar free media with vermiculite under both lighting condi-

Table 1. Detail of conditions treatments and their combinations

Treatments	µmol m^{-2} s^{-1}PPF	Supporting materials	Sucrose (g l^{-1})
LPS	50	Phytagel	20
LV	50	Vermiculite	0
LP	50	Phytagel	0
HPS	150	Phytagel	20
HV	150	Vermiculite	0
HP	150	Phytagel	0

LPS = Phytagel with sucrose in medium under low light condition; LV = Vermiculite without sucrose in medium under low light condition; LP = Phytagel without sucrose in medium under low light condition; HPS = Phytagel with sucrose in medium under high light condition; HV = Vermiculite without sucrose in medium under high light condition; and HP = Phytagel without sucrose in medium under high light condition.

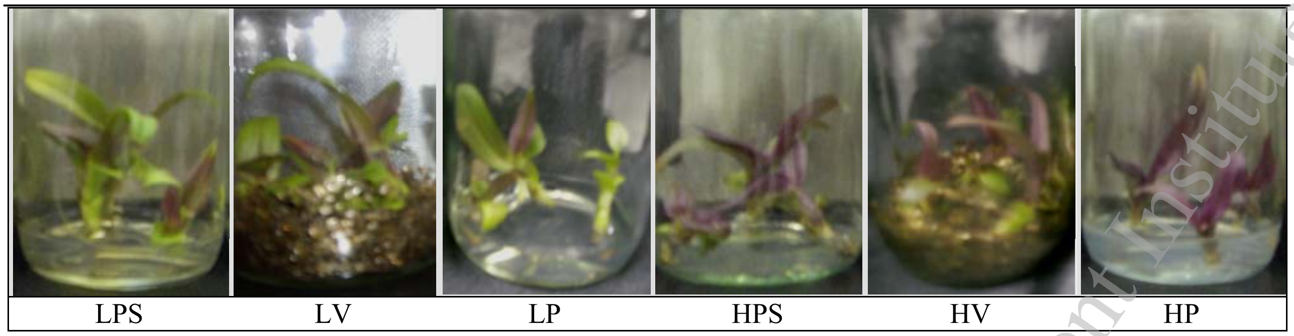


Figure 1. Dendrobium plantlets in vitro after 30 days of culture.

tions was significantly higher than on phytagel with or without sucrose. Light was not the crucial variable but maybe the vermiculite and non-sucrose (Fig.2A). Also Kirdmanee *et al* (1995) concluded that vermiculite gave better growth of *Eucalyptus* plantlets *in vitro* than agar, Gelrite and liquid media without sugar. In addition, total dry weight of plantlets grown on sugar free media with vermiculite or phytagel under high photosynthetic photon flux was significantly higher than other four treatments (Fig.2B). These results are similar to the observations of Soontornchainaksaeng *et al*. (2001). They found total fresh and dry weight in plantlets of *Phaius tankervilliae* and *Vanda coerulea* grown on sugar free media with 100 g per liter of raw banana under increasing light intensity was higher than low light intensity. Kitaya *et al* (1995) reported similar results that fresh and dry weight increased with increasing photosynthetic photon flux density from 30 to 90 µmol m^{-2} s^{-1} and leveled off at photosynthetic photon flux density above 100 µmol m^{-2} s^{-1} for potato plantlets grown on sugar free media.

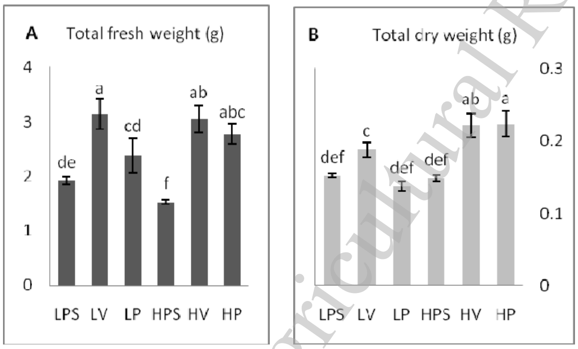


Figure 2. Effects of PPF and supporting material on total fresh (A) and dry (B) weight of *Dendrobium* plantlets after culturing for 30 days. Different letters (a, b, c, d, e or f) above bars indicate a significant difference (P <0.05) according to the DMRT test. The bars present standard error.

Leaf number per plantlets was significantly higher on vermiculite without sucrose under both lighting conditions as compared to the other four conditions (Fig.3). Soontornchainaksaeng *et al*. (2001) found leaf number in *Phaius tankervilliae* and *Vanda coerulea* plantlets grown on sugar free media with 100 g per liter of raw banana exposed to light intensities ranging from 37 to 74 µmol m^{-2} s^{-1} was not significantly different, but at 28 µmol m^{-2} s^{-1} of light intensity, *Vanda coerulea* gave a leaf number less than the others.

Root length was significant higher on both vermiculite and phytagel without sucrose media under high photosynthetic photon flux as compared to those under low light but only on phytagel without sucrose under low photosynthetic photon flux (Fig.3). Also Kirdmanee *et al* (1995) found the primary root length and root percentage of *Eucalyptus* plantlets grown on vermiculite without sucrose were increased.

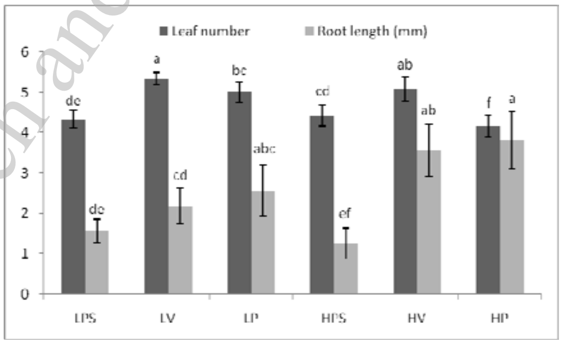


Figure 3. Effects of PPF and supporting material on number of leaves and root length of *Dendrobium* plantlets after culturing for 30 days. Different letters (a, b, c, d, e or f) above bars indicate a significant difference (P <0.05) according to the DMRT test. The bars present standard error.

Leaf area of plantlets grown on phytagel with sucrose under low photosynthetic photon flux was increased (fig.3). The plantlets grown on phytagel with sucrose under low light intensity maybe more developed leaf area than under high light intensity for photosynthesis. Also Soontornchainaksaeng *et al* (2001) found that the leaf area of *Vanda Coerulea* plantlets grown under 74 µmol m^{-2} s^{-1} PPF developed larger than under 93 µmol m^{-2} s^{-1} PPF.

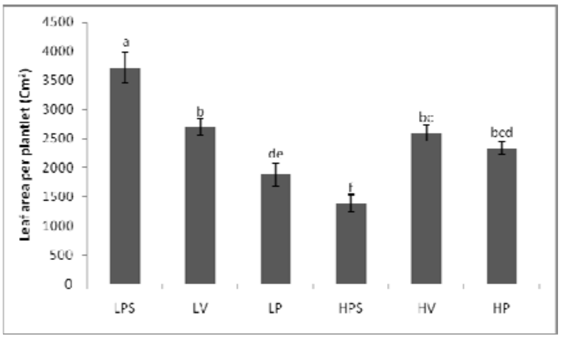


Figure 4. Effects of PPF and supporting material on leaf area of *Dendrobium* plantlets after culturing for 30 days. Different letters (a, b, c, d, e or f) above bars indicate a significant difference (P <0.05) according to the DMRT test. The bars present standard error.

Conclusion

The plantlet growth of *Dendrobium* sp. could be improved by using vermiculite or phytagel as a supporting material in sugar free medium under high photosynthetic photon flux. It was also observed that growth of plantlets cultured on vermiculite or phytagel without sucrose under high photosynthetic photon flux was significantly improved as compared to vermiculite or phytagel with or without sucrose under low light intensity and phytagel with sucrose under high light intensity *In vitro* plantlets with a high growth, increased number of leaves and root length of plantlets were responsive to the photosynthetic photon flux and use of supporting material. Further research should look at the cost-benefit ratio of using higher light intensities.

Acknowledgement

This work was supported by BIOTEC and ASEAN foundation.

References

Ali, B.M., Hahn, J.E., Paek, Y.K. (2004) Effect of light intensity on antioxidant enzymes and malondialdehyde content during short acclimatization on micropropagation *Phalaenopsis* plantlet. *Environmental and Experimental Botany* 54: 109-120.

Black, C.C. and Osmond. C.B. (2003) Crassulacean acid metabolism photosynthesis: 'Working the night shift'. *Photosynthesis Research* 76: 329-341.

Cha-um, S., Supaibulwatana, K., and Kirdmanee, C. (2006) Water relation, photosynthetic ability, and growth of Thai Jasmine rice (*Oryza sativa* L. ssp. *indica* cv. KDML105) to salt stress by application of exogenous glycinebetaine and choline. *J. Agron. Crop Sci.*, 192: 25-36.

Jeon, W.M., Ali, B.M., Hahn, J.E. and Paek, Y.K. (2005) Effect of photon flux density on the morphology, photosynthesis growth of a CAM orchid, *Doritaenopsis* during post-micropropagation acclimazation. *Plant Growth Regulation* 45: 139–147.

Khentry, A.Y., Paradornuwat, T., S. Phansiri, S., and Thaveechai, N. (2006) Incidence of *Cymbidium mosaic virus* and *Odotoglossum ringspot viruss* in *Dendrobium* spp. Thailand. *Crop Protection* 25: 926-932.

Kitaya, Y., Mohapatra, C.S., Kubota, C., and Kozai, T. (1995) Advantages of Photoautotrophic Micropropagation for Space Agriculture. Plants in Space Biology, 235-244, *Review Article. Institute of Genetic Ecology*, Tohuko University, Japan.

Kirdmanee, C. Kitaya, Y., and Kozai, T. (1995) Effect of CO_2 enrichment and supporting material *in vitro* on photoautotrophic growth of Eucalyptus plantlets *in vitro* and *ex vitro*. *In vitro cell. Biol-Plant* 31: 144–149.

Soontornchainaksaeng, P., Chaicharoen, S., Sirijuntarut, M., and Krutrach-ue, M. (2001) *In vitro* studies on the effect of light intensity on plant Growth of *Phaius tankerviliae* (Banks ex L' Herit.) Bl. and *Vanda coerulea* Griff. *ScienceAsia* 27: 233-237.

Vacin, E.F., and Went, F.W. (1949) Some pH changes in nutrient solutions. *Bot. Gaz.* 110: 605-613.

សណ្ឋានដីបាសាល់នៅភាគខាងកើតនៃប្រទេសកម្ពុជា បានផ្តល់នូវកាលានុវត្តភាពយ៉ាងច្រើន សម្រាប់បង្កើននូវផលិតកម្មដំណាំចម្ការ

Field Crop Productivity in Relation to Soil Properties in Basaltic Soils of Eastern Cambodia

Seng Vang[1], R.W. Bell[2], Hin Sarith[1,2], and Touch Veasna[1],

អត្ថបទសង្ខេប

សណ្ឋានដីបាសាល់ នៅភាគខាងកើតនៃប្រទេសកម្ពុជា បានផ្តល់នូវកាលានុវត្តភាពយ៉ាងច្រើន សម្រាប់បង្កើននូវផលិតកម្មដំណាំចម្ការ ប៉ុន្តែទិន្នន័យនៃការពិសោធន៍ស្រាវជ្រាវទាក់ទងទៅនឹងពេលវេលាដាំដុះ និងប្រភេទដីលើដំណាំចម្ការនៅតំបន់នេះ នៅមានកម្រិតនៅឡើយ។ ការសិក្សាស្រាវជ្រាវនេះ មានគោលបំណងដើម្បីកំណត់នូវដំណុះការលូតលាស់ និងទិន្នផលនៃដំណាំពោត សណ្តែកបាយ សណ្តែកដី ល្ង និងសណ្តែកសៀងនៅលើដីស្រែចម្ការកសិករ ដែលទាក់ទងទៅនឹងពេលវេលានៃការដាំដុះ (ដើមរដូវវស្សា ឬពាក់កណ្តាលរដូវវស្សា) ប្រភេទ និងលក្ខណៈសម្បត្តិរបស់ដី នៅលើសណ្ឋានដីបាសាល់ភាគខាងកើតនៃប្រទេសកម្ពុជា។ ពិសោធន៍ជាច្រើនបានធ្វើនៅក្នុងស្រុកអូរាំងឪ ក្នុងរយៈពេលពីរឆ្នាំដែលមានរបបទឹកភ្លៀងប្រចាំឆ្នាំខុសគ្នា។ សណ្តែកដីជាដំណាំដែលមានភាពសមស្របជាងគេបំផុតដោយសារមានដំណុះល្អទាំងនៅដើមរដូវ និងពាក់កណ្តាលរដូវវស្សា និងអាចទទួលបានទិន្នផលនៅលើទីតាំង៨០% នៃទីកន្លែងពិសោធន៍ទាំងអស់។ ទិន្នផលខ្ពស់ជាប់ៗគ្នានៃសណ្តែកដីទទួលបាននៅលើក្រុមដីកំពង់សៀម (២,១-៣,៤ ត/ហត) ប៉ុន្តែទិន្នផលនៅពាក់កណ្តាលរដូវវស្សា មានការធ្លាក់ចុះជាមធ្យម ០,៥ ត/ហត ដែលអាចបណ្តាលមកពីការជាំទឹកខ្លាំង។ នៅលើក្រុមដីអូរាំងឪ និងឡាបានសៀកទិន្នផលសណ្តែកដីមានការប្រែប្រួលទៅតាមទីកន្លែងពិសោធន៍ និងរដូវកាល ប៉ុន្តែជាទូទៅនៅឆ្នាំ២០០៥ ទទួលបានទិន្នផលខ្ពស់ជាងឆ្នាំ២០០៤។ ការនេះប្រហែលជានៅក្នុងឆ្នាំ២០០៥ មានភាពជាំទឹកតិចជាង។ ផ្ទុយពីនេះសណ្តែកសៀង បានទទួលបរាជ័យបើដាំក្នុងដើមរដូវវស្សា ដោយសារមានដំណុះខ្សោយ និងទិន្នផលទាប។ នៅពាក់កណ្តាលរដូវវស្សា ទិន្នផលនៃសណ្តែកសៀងនៅលើក្រុមដីកំពង់សៀម ទទួលបានរហូតដល់ ៣,៣ ត/ហត។ ទិន្នផលសណ្តែកសៀងនៅពាក់កណ្តាលរដូវវស្សាដូចគ្នាទៅនឹងសណ្តែកដីដែរ គឺមិនមានស្ថេរភាពទេនៅលើក្រុមដីអូរាំងឪ និងឡាបានសៀក។ សណ្តែកបាយមិនទទួលបានទិន្នផលទេ នៅលើទីតាំង ៦៣% នៃទីកន្លែងពិសោធន៍ដើមរដូវវស្សា ប៉ុន្តែនៅលើក្រុមដីកំពង់សៀម និងអូរាំងឪ បើសិនដំណាំមានដំណុះល្អ វាអាចផ្តល់ទិន្នផលពី០,៩-១,៣ ត/ហត។ នៅលើដីដូចគ្នានេះដែរ នៅពាក់កណ្តាលរដូវវស្សា សណ្តែកបាយផ្តល់ទិន្នផលពី០,២-១,៥ ត/ហត។ ការបរាជ័យនៃសណ្តែកបាយ នៅលើក្រុមដីឡាបានសៀក ទាំងដើមរដូវ និងពាក់កណ្តាលរដូវវស្សាក្នុងឆ្នាំ២០០៤ និងឆ្នាំ២០០៥ គឺមួយផ្នែកបណ្តាលមកពីភាពអាស៊ីតនៃដី។ ការលូតលាស់នៃដំណាំពោតក៏មិនមានស្ថេរភាពដែរ។ ជាង៥០% នៃដំណាំដែលបានដាំដុះក្នុងឆ្នាំ២០០៥ ត្រូវទទួលបរាជ័យដោយសារមានការរាំងស្ងួតដែលធ្វើឱ្យមានដំណុះគ្រាប់ និងការចាប់ផ្តើមលូតលាស់ខ្សោយ។ ទិន្នផលសណ្តែកបាយទទួលបានរហូតដល់ ៤,៥ ត/ហត នៅលើដីឡាបានសៀក ក្នុងឆ្នាំ២០០៤ ប៉ុន្តែមិនទទួលបានទិន្នផលទេ នៅលើក្រុមដីដូចគ្នាក្នុងឆ្នាំ២០០៥។ ភាពរាំងស្ងួត ភាពអាស៊ីតនៃដី និងកង្វះជីអាសូតត្រូវបានគិតថាជាកត្តាចម្បង ដែលធ្វើឱ្យការលូតលាស់របស់ដំណាំពោតមិនបានល្អ។ ទិន្នផលខ្ពស់នៃដំណាំទាំងអស់លើកលែងតែដំណាំល្ងអាចសម្រេចបាន ប៉ុន្តែវាមានការប្រែប្រួលក្នុងចំណោម ប្រភេទដី ទីកន្លែង និងរដូវកាល។ ការធ្វើឱ្យបានជោគជ័យលើភាពមិនសមស្របនៃការលូតលាស់របស់ដំណាំ គឺ

[1]Soil and Water Sciences Division, CARDI, National Road No. 3, Sangkat Prateah Lang, Khan Dangkor, Phnom Penh, Cambodia

[2]School of Environmental Science, Murdoch University, Murdoch, Perth, WA 6150.

***Corresponding Author:**
E-mail: vseng@cardi.org.kh

Cambodian JA, 10 (1-2): 5 - 19 (2011)

ជាគន្លឹះ ដើម្បីកាត់បន្ថយហានិភ័យទាក់ទងទៅនឹងផលិតកម្ម ដំណាំចម្ការនៅលើដីបាសាល់ ។

Abstract

The basaltic landscapes of eastern Cambodia offer opportunities for increased production of non-rice crops but there is limited experimental data on the performance of these crops in relation to sowing season and soil types. The objective of the present study was to determine the emergence, growth and yield of maize, mungbean, peanut, sesame and soybean in farmers' fields in relation to time of sowing (early wet season, EWS or main wet season, MWS), soil types and soil properties in the basaltic landscapes of eastern Cambodia. Experiments were conducted in Ou Reang Ov district during two years with contrasting rainfall. Peanut was the most reliable crop with successful establishment in both EWS and MWS, and harvestable yield at 80% of sites. Consistently high peanut yields were obtained on Kompong Siem soils (2.1-3.4 t/ha), but MWS yields were depressed on average by 0.5 t/ha, possibly due to greater waterlogging. On Ou Reang Ov and Labansiek soils, peanut yields varied with site and season, but were generally higher in 2005 than 2004, again possibly due to lower waterlogging prevalence. By contrast, soybean failed on all occasions in the EWS either due to lack of crop establishment or yields that were too low to justify growing this crop. In the MWS, soybean yields of up to 3.3 t/ha were attained on Kompong Siem soils. Like peanut, soybean yields in the MWS were inconsistent on the Ou Reang Ov and Labansiek soils. Mungbean failed to produce harvestable yield on 63% of EWS sites, but on Kompong Siem and Ou Reang Ov soil, if establishment was successful, mungbean produced grain yield of 0.9-1.3 t/ha. On the same soils in the MWS, mungbean yields were 0.2-1.5 t/ha. Mungbean failure on Labansiek soils, in both EWS and MWS in 2004 and 2005 was attributed to soil acidity. Maize was inconsistent in its performance. Over 50% of sowings in 2005 failed due to drought which caused poor crop emergence and establishment. Yields up to 4.5 t/ha were obtained on Labansiek soils in 2004, but no yield was obtained in the same soil type in 2005. Drought, soil acidity and inadequate N fertilizer are suggested to be the main factors accounting for the unreliable performance of maize. High yields of all crops except sesame were achievable but actual yields were variable among soils, sites and season. Overcoming the unreliable performance of crops is the key to decreasing the risk associated with non-rice crop production on the basaltic soils.

Introduction

In Cambodia, there is considerable scope for developing upland crops and cropping technologies. Upland areas are widespread throughout the Kingdom and generally under utilized. In 2004-5, non-rice field crops represented only about 13% of the total cropped area in Cambodia (MAFF 2005). With improved security and road access in rural Cambodia, opportunities for crop diversification and increased household income of farmers exist through rainfed cropping in the uplands, in both the EWS and MWS.

Basaltic geology of mid-Pleistocene age is prevalent in Cambodia covering large areas in Kampong Cham, Kampong Thom, Kratie, Mondulkiri, and there are significant occurrences of it in Battambang, Prey Vihear, and Ratankiri (Workman 1972). The soils associated with these occurrences of basalt have not been comprehensively mapped and described. However, Hin et al. (2006, 2007) described the basaltic soils of Ou Reang Ov and Ponhea Krek districts in Kampong Cham province and developed a soil-landscape model for predicting soil types associated with basaltic plateaux. On the gently undulating landform elements on top of the plateau, the Labansiek Soil Group (White et al. 1997) was prevalent. The majority of these soils in Ou Reang Ov district, as in other parts of Kampong Cham, are occupied by rubber. The deep friable nature of these soils provides adequate soil water storage for rubber to survive over the long dry season, and rubber being acid tolerant (Dierolf et al. 2001) is able to grow productively on Labansiek soils. On the slopes of the basaltic plateau are brown gravelly loam soils, not previously described among the rice soil groups of Cambodia (White et al. 1997). The soils of this landform element, which are now called the Ou Reang Ov Soil group, are unsuitable for rice on account of slope, and free drainage (Seng et al. 2007). Similar occurrences of the brown gravelly soil group on the slopes of basaltic plateaux have been observed elsewhere in Kampong Cham, and in Kampong Thom. The Ou Reang Ov Soil group is shallow compared to Labansiek, and this combined with the high gravel content of the sub-soil makes it unsuited to rubber production. On the gentle lower slopes of the basaltic plateau and the adjacent colluvial-alluvial plains, dark clay soils belonging to the Kompong Siem Soil group dominate. In the lower lying portions of this plain, the risk of inundation and waterlogging are so great that rice production is the dominant land use. On the slightly higher elevations close to the slopes of the basaltic plateau, the Kompong Siem soil is better drained and capable of producing field crops apart from rice.

Kampong Cham province already has a relatively diversified crop production, and is a leading province in production of many non-rice crops in Cambodia such as soybean, mungbean, rubber, cassava, peanut, sesame and sugarcane (MAFF 2005). Nevertheless there is limited experimental data on the performance of non-rice crops on the prominent soils of this province. The objective of the present study was to determine the emergence, growth and yield of maize, mungbean, peanut, sesame and soybean in farmers' fields in relation to time of sowing (EWS or MWS), soil types and soil properties in the basaltic landscapes of eastern Cambodia. Experiments were conducted in Ou Reang Ov district of Kampong Cham province for two years (2004, 2005).

Materials and Methods

Sites and soil types

There were 3-4 sites per season located in Ou Reang Ov district, Kampong Cham province (Table 1). Soil profiles were inspected and described in detail at most sites and soil chemical characterization was carried out on at least one site of each Soil group (Hin et al. 2006). If the experiments were repeated on the same soils in both seasons, different sites were used, but usually on an adjacent or close-by location.

Land preparation and sowing

The experimental fields were ploughed (20-30 cm deep) and leveled to control water movement. Drains were constructed around the experiment to remove excess water from the field. After harrowing, beds 10 m long x 1.5 m wide x 0.15 m high were installed. In the MWS, a drain of 15 cm depth was dug around each bed and the soil material heaped on the bed to raise its level for improved drainage. In the EWS, only a shallow 10 cm drain around the bed was set up.

All crop varieties received the following rates of fertilizer nutrients in 2004 and 2005 (as modified from Dierolf et al. 2001; and CIAP 1999): N, 115 (as urea); P, 29 (as di-ammonium phosphate); 28 K (as KCl); 13 S (as 16-16-8-13); Zn, 5 (as $ZnSO_4$); Cu, 1.25 (as $CuSO_4$); Mo, 0.3 (as MoO_3); B, 0.82 (as H_3BO_3). All numbers are expressed in kg/ha of nutrient element.

After installing seeding beds, 50% of N and K and all of the remaining fertilizers were applied by spreading evenly, and then incorporated by hoeing (0-10 cm) into soil. These fertilizers were applied 48 hours before sowing seed. The remaining 50% of N (as urea) and K (as KCl) were top-dressed within 3-4 weeks after sowing. Top-dressing of fertilizer was carried out after weeds had been removed.

The experiment plots were arranged in a randomized complete block design with 5 crop varieties and 4 replications making a total of 20 plots at each location. Trials were sown in the EWS (May-August) and in the MWS (July-October), in 2004 and 2005 (Table 1). Since there was no access to supplementary irrigation at the sites, crops relied completely on rainfall. This necessitated variations in time of sowing among sites (Table 1).

Maintenance of crops

All experimental fields were kept free of weeds and insects during crop growth. No herbicide was used to control weeds. Weeds were removed by hand, especially during early establishment of crops. Pesticide was used to control insect pests as required.

Inter-row tillage was carried out 3-4 weeks after sowing by hand for weed control, and at the same time, plants were thinned to leave only 1 plant per hill.

Data collection

At each site in 2004, soil samples were taken from 0-15 cm and 15-30 cm depth before fertilizer application and after harvesting of crops. Soil samples were air dried, crushed to remove any plant residue, and sieved to pass through a 2-mm sieve. Soil analysis was con-

Table 1. Site details for on-farm trials in the early wet (EWS) and main wet season (MWS) of 2004 and 2005 in Ou Reang Ov district, Kampong Cham province

Seasons	Soil survey site[A]	Soil group	Date of sowing	Location
		2004		
EWS	Site 13	Kompong Siem	23 May 2004	Toul Thkov village, Preah Thiet commune
EWS	Site 14	Ou Reang Ov	23 May 2004	Stung village, Toul Sophy commune
EWS	Site 18	Ou Reang Ov	23 May 2004	Chamcar Kor village, Chork commune
EWS	Site 15	Labansiek	23 May 2004	Toul Sophy village, Damnak Keo commune
MWS	Site 10/13	Kompong Siem	18 July 2004	Toul Phnov village, Ampel Tapopk commune
MWS	Site 11	Ou Reang Ov	19 July 2004	Preah Tiet commune
MWS	Site 17	Ou Reang Ov	30 July 2004	Chamcar Kor village, Chork commune
MWS	Site 16	Labansiek	18 July 2004	Sre Spey village, Kong Chey commune

2005				
EWS	Site 13	Kampong Siem (non-gravelly)	31 May 2005	Ul Sieng, Toul Thkov village, Preah Tiet commune
EWS	Site 14	Ou Reang Ov	29 April 2005	Linh Lon, Stung village, Toul Sophy commune
EWS	Site 17	Ou Reang Ov	26 May 2005	Ear Ben, Chamcar Kor village, Chork commune
EWS	Site 15	Labansiek	04 June 2005	Tbong Khmum district
MWS	Site 13	Kampong Siem (non-gravelly)	23 July 2005	Ul Sieng, Toul Thkov village, Preah Tiet commune
MWS	Site 11	Ou Reang Ov	23 July 2005	Long Chhem, Preah Tiet commune
MWS	Site 17	Ou Reang Ov	28 July 2005	Ear Ben, Chamcar Kor village, Chork commune
MWS	Site 16	Labansiek	3 Aug 2005	Tbong Khmum district

[A] Site numbers refer to Hin et al. (2006).

ducted according to Rayment and Higginson (1991) for: pH ($CaCl_2$); organic C; N (total and inorganic forms); Colwell P; KCl-40 extractable S; DTPA extractable Cu, Zn, Mn, Fe; hot water soluble B; exchangeable Ca, Mg, Na, K, and Al.

Before sowing, seed of all crops was checked for high germination percentage in the laboratory. One week after sowing in the field, seed emergence was determined by randomly selecting 5 hills per plot/bed and the number of established plants counted. These sampling hills were also used to determine plant density (number/m^2) at harvest.

Time of 50 % flowering and 50 % podding were noted and scoring of insect pest damage, weeds, disease (data not shown), and nodulation were recorded at flowering.

Dry matter of shoots at harvest and yield of pods and seeds were determined by randomly sampling 15 plants per plot. Total seed yield per plot (pod yield for peanut) was also determined at maturity by harvesting all plants in the net plot. After seed weight was recorded, seed samples were taken to assess 1000-seed weight, except for sesame.

Daily rainfall data were recorded at several trial sites in 2004 and 2005, using rain gauges at the experimental sites.

Results

Rainfall analysis

Rainfall was recorded throughout the growing season in 2004 for Sites 13, 14 in the EWS, and Sites 11, 16 in the MWS (Fig. 1). The earliest maturing crop, mungbean, received 400-800 mm rainfall from sowing to harvest which was generally below the optimum amount of 750 mm, but above 400 mm, the threshold rainfall which causes severe yield inhibition (Sys et al. 1993). By contrast, for peanut which had a growth

Crops were sown with the following methods:

Crop	Spacing (cm)	Depth of seeding (cm)	Number of seed per hole
Mungbean	30 x 10	2	3
Soybean	30 x 10	3	3
Maize	60 x 20	3	3
Peanut	30 x 10	5	3
Sesame	60 x 10	1	3

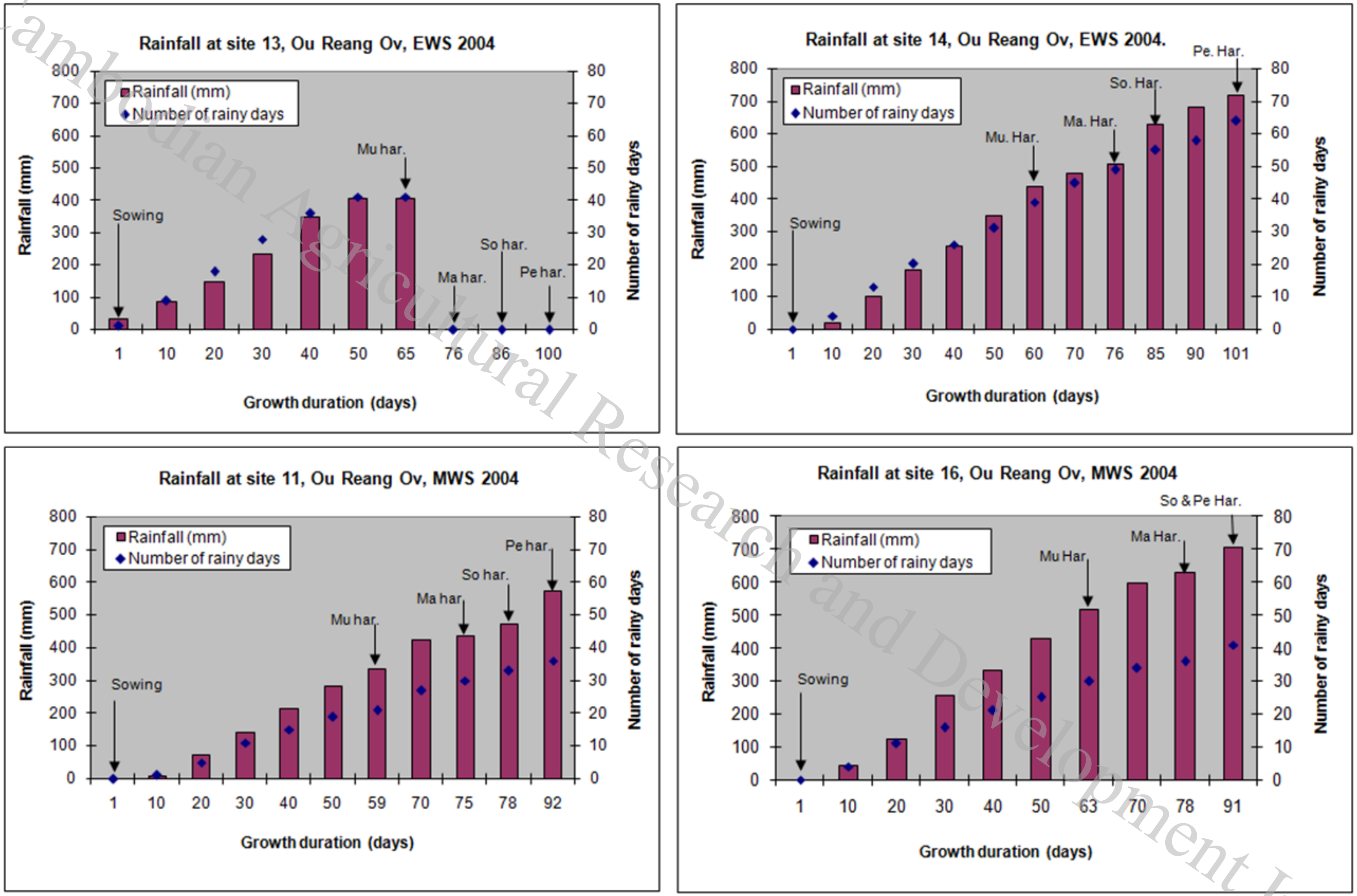


Figure 1. Seasonal rainfall (mm and number of rainy days) for mungbean (Mu), maize (Ma), peanut (Pe), sesame (Se) and soybean (So) in 2004 trials in Ou Reang Ov district in the early wet (EWS) and main wet seasons (MWS). Note there were no rainfall records at Site 13 after day 65.

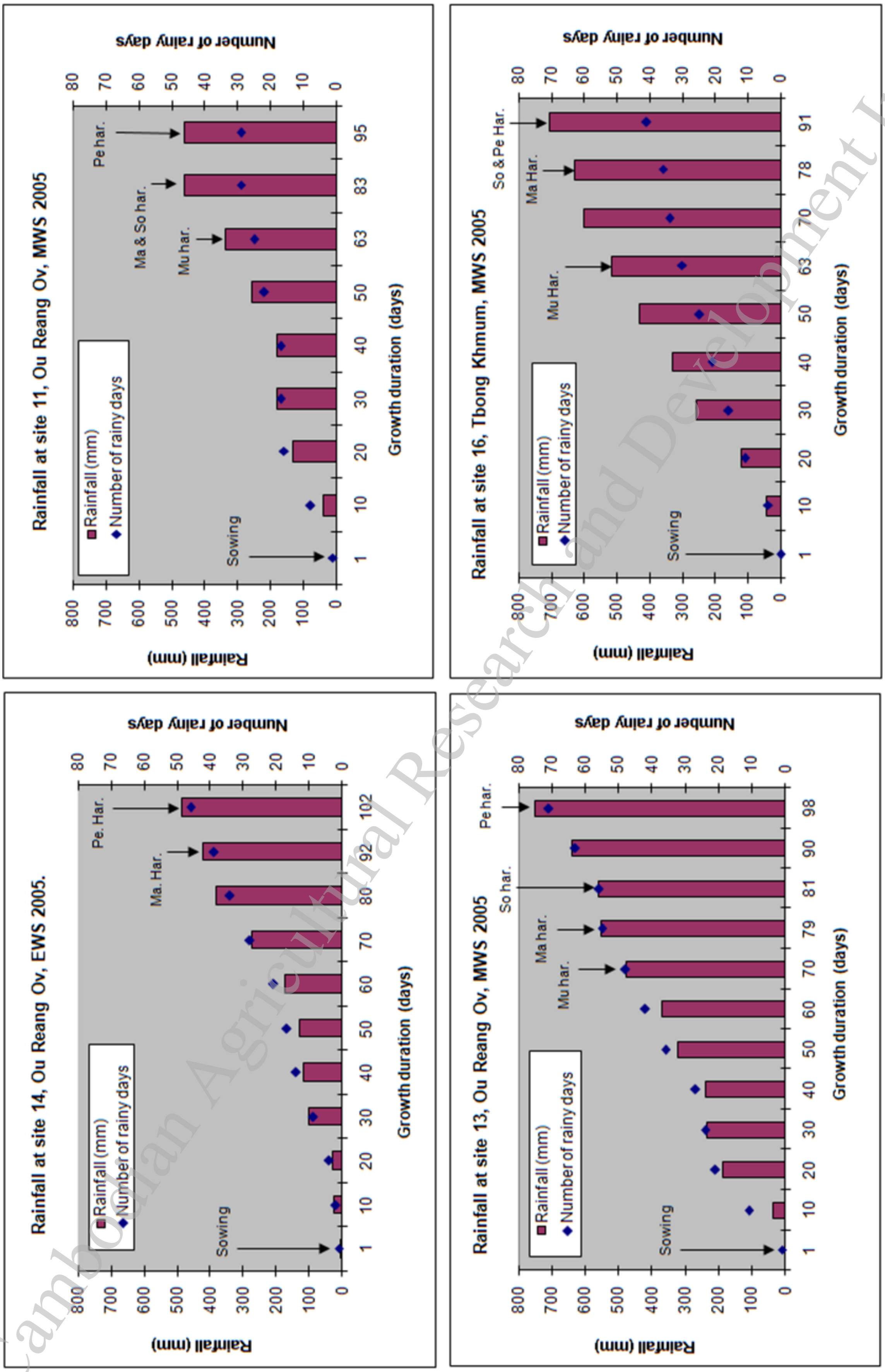


Figure 2. Seasonal rainfall (mm and number of rainy days) for mungbean (Mu), maize (Ma), peanut (Pe), sesame (Se) and soybean (So) in 2005 trials in Ou Reang Ov district in the early wet (EWS) and main wet seasons (MWS).

Table 2. Soil analysis from sites of on-farm trials in 2004. Samples taken before sowing (B) and after harvesting (A)

Season	Soil Group	Site No.	Depth (cm)	Sampling	NO_3-N mg/kg	NH_4-N mg/kg	P mg/kg	Exch K cmol/kg	KCl40-S mg/kg	Org C %	Total N %	pH $CaCl_2$	DTPA Mn mg/kg	DTPA Zn mg/kg	B H_2O mg/kg
EWS	Ou Reang Ov	14	0-15	B	15	16	151	0.78	10.6	2.07	0.17	5.7	106	4.53	0.3
EWS	Ou Reang Ov	14	0-15	A	8	13	141	0.46	9	2.21	0.19	5.5	107	5.29	0.4
MWS	Ou Reang Ov	11	0-15	B	2	14	57	0.45	10	1.62	0.14	4.9	110	10	0.3
MWS	Ou Reang Ov	11	0-15	A	3	18	134	1.42	11	1.82	0.16	5.9	111	5.33	0.3
MWS	Ou Reang Ov	17	0-15	B	7	12	76	0.21	8.5	1.32	0.13	5.1	121	4.63	0.3
MWS	Ou Reang Ov	17	0-15	A	2	10	83	0.11	5.8	1.14	0.11	5.3	49	3.57	0.2
EWS	Ou Reang Ov	14	15-30	B	1	10	79	0.11	5.1	0.85	0.08	5.8	22	0.9	0.2
EWS	Ou Reang Ov	14	15-30	A	4	11	83	0.2	14.2	1.22	0.12	5.3	65	1.99	0.3
MWS	Ou Reang Ov	11	15-30	B	1	12	84	0.23	7.3	1.49	0.11	4.5	136	5.3	0.3
MWS	Ou Reang Ov	11	15-30	A	1	13	62	0.37	10.1	0.91	0.1	4.8	62	1.2	0.2
MWS	Ou Reang Ov	17	15-30	B	5	11	109	0.12	6.7	1.06	0.11	5.2	66	1.37	0.3
MWS	Ou Reang Ov	17	15-30	A	6	10	112	0.12	5.5	0.95	0.10	5.2	52	1.18	0.3
EWS	Kompong Siem	13	0-15	B	1	11	12	0.09	4.9	1.02	0.09	5.7	70	0.7	0.2
EWS	Kompong Siem	13	0-15	A	1	10	18	0.16	6.8	1.15	0.09	5.5	105	1.93	0.3
MWS	Kompong Siem	13	0-15	B	1	16	19	0.16	7.4	1.2	0.12	5.8	82	1.03	0.3
MWS	Kompong Siem	13	0-15	A	1	12	3	0.08	6.6	1.13	0.10	5.5	100	1.61	0.3
EWS	Kompong Siem	13	15-30	B	1	9	9	0.04	3.5	0.71	0.07	6.0	32	0.37	0.2
EWS	Kompong Siem	13	15-30	A	2	9	8	0.07	6	0.77	0.07	6.7	39	0.63	0.3

MWS	Kompong Siem	13	15-30	B	1	5	6	0.07	4.9	0.44	0.04	5.8	127	0.33	0.1
MWS	Kompong Siem	13	15-30	A	2	9	8	0.05	5.9	0.71	0.07	6.5	40	0.48	0.2
EWS	Labansiek	15	0-15	B	21	13	43	0.22	13.2	1.34	0.13	4.7	179	1.63	0.3
EWS	Labansiek	15	0-15	A	5	16	39	0.21	11.4	1.32	0.14	4.7	216	1.61	0.7
MWS	Labansiek	16	0-15	B	2	17	45	0.36	6.7	1.46	0.14	5.3	169	3.48	0.4
MWS	Labansiek	16	0-15	A	3	12	49	0.25	15	1.48	0.14	4.5	156	2.37	0.6
EWS	Labansiek	15	15-30	B	14	12	49	0.12	12.9	0.88	0.1	4.7	98	0.47	0.3
EWS	Labansiek	15	15-30	A	20	14	28	0.14	13.7	1.04	0.12	4.5	113	0.89	0.4
MWS	Labansiek	16	15-30	B	3	14	39	0.22	14.3	1.09	0.11	5.1	133	1.94	0.4
MWS	Labansiek	16	15-30	A	23	8	48	0.12	11.2	0.88	0.10	4.9	92	0.42	0.3

Seed of the following species and varieties were used for the on-farm trials:

Species	Variety	Seed source
Mungbean (*Vigna radiata*)	Cardi Chey	CARDI
Soybean (*Glycine max*)	DT84	Kbal Koh Research Station
Maize (*Zea mays*)	Composit	Kbal Koh Research Station
Peanut (*Arachis hypogaea* L.)	Local variety	Local market
Sesame (*Sesamum indicum* L.)	Local variety (white)	Local market

duration of 92-103 days, cumulative rainfall received was 700-800 mm except at Site 16 where only 450 mm was recorded. All these amounts of rainfall are considered optimal for peanut (Sys et al. 1993). Soybean received adequate rainfall at Sites 13 and 14 in the EWS, but had less than optimal rainfall in the MWS at Site 16.

In general the number of rainfall-days and total in-season rainfall for crops was less in the 2005 season than 2004, especially in the early part of the season (Fig. 2).

Soil analysis

Soil analysis was only conducted on soils from the 2004 experimental sites. In general, this will reflect the properties of the 2005 trial sites since they were located nearby, except for Site 15 which was in a different district and was more severely acid than Site 15 used in 2004.

Organic carbon levels were highest in Ou Reang Ov soils and lowest in Kompong Siem soils. Total N levels followed the same pattern. Ou Reang Ov and Labansiek soils had reasonable amounts of NH_4-N available before sowing (equivalent to about 30-40 kg N/ha), but Kompong Siem had lower levels especially in the 15-30 cm layer. In general, the NO_3-N levels were much lower than for NH_4-N, except on Sites 15 and 16 of Labansiek and Site 14 of Ou Reang Ov soils.

Lowest pH ($CaCl_2$) values were obtained on Labansiek soils: the most acid values, at Site 15, were, about 4.7. Site 11, classified as Ou Reang Ov soil also had low pH ($CaCl_2$), especially at 15-30 cm. Low pH ($CaCl_2$) was associated with high extractable Mn (Table 2) (Hazelton and Murphy 2007), but none of the acid soils contained significant levels of exchangeable Al (data not shown). Kompong Siem soil was only moderately acid (pH ($CaCl_2$) > 5.5).

Exceptionally high extractable P levels were found in the Ou Reang Ov soils, even before fertilizer was applied. The levels in Labansiek soils were > 30 mg P/kg and hence probably adequate for crop growth. By contrast, the Kompong Siem had low extractable P levels (Peverill et al. 1999).

Kompong Siem soils had low and potentially deficient exchangeable K levels (Peverill et al. 1999). Exchangeable K levels in Ou Reang Ov soil were more than adequate for plant growth at Sites 14 and 17, but marginal at Site 11. Labansiek soils had marginal exchangeable K levels in the topsoil and lower levels in the 15-30 cm layer.

Table 3. Field emergence (% of sown seeds) at 2-3 weeks after sowing of crops in the early (EWS) and main wet seasons (MWS). Values are means of four replicates

Sites	Soil group	Maize		Mungbean		Soybean		Peanut		Sesame	
		2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
	EWS										
13	Kompong Siem	72	0	67	89	68	0	62	97	0	0
17	Ou Reang Ov	0	62	0	0	0	0	0	98	0	0
14	Ou Reang Ov	74	60	80	0	48	0	89	93	0	0
15	Labansiek	67	0	0	0	0	0	0	90	0	0
LSD (p<0.05)		*11.1*	*9.0*	*11.3*	*13.4*	*9.9*	*5.3*	*8.9*	*5.1*	-	-
	MWS										
13	Kompong Siem	82	97	85	97	75	98	87	75	0	0
11	Ou Reang Ov	79	88	73	88	72	95	73	73	0	0
17	Ou Reang Ov	85	0	79	77	75	72	78	65	0	0
15	Labansiek	0	0	0	0	0	0	0	97	0	68
16	Labansiek	85	0	75	0	75	0	80	0	0	0
LSD (p<0.05)		*11.5*	*7.6*	*10.5*	*11.7*	*13.1*	*12.6*	*11.5*	*10.7*	-	*10.1*

Levels of extractable S were low enough on Kompong Siem soil to induce deficiency without S fertilizer (Peverill et al. 1999). Ou Reang Ov soils at Sites 14 and 11 had adequate extractable S levels, by contrast with the low levels at Site 17. Those on Labansiek were generally adequate for plant growth even before S fertilizer addition.

Extractable Zn was adequate on all soils, but sub-soil levels < 0.6 mg/kg were found in Kompong Siem soils. Kompong Siem soils also had the lowest extractable B levels, with 15-30 cm again having the lower values. However, even on Ou Reang Ov soils extractable B levels were generally less than or equal to 0.3 mg/kg.

Emergence

In the EWS 2004, the trial at site 18 completely failed due to drought but other trials produced harvestable yield of at least some crops (Tables 3, 6). Peanut was the most successful crop, especially when grown in the MWS with emergence in 88 % of sowings. Peanut emergence was consistently high across soils in the EWS, apart from the lower values on Kompong Siem in 2004. In the MWS, emergence was generally decreased in peanut but still sufficient to establish adequate plant density. Two thirds of maize sowings emerged in both seasons. Only 25-38 % of soybean and mungbean crops emerged from EWS sowings, but 78 % emerged in the MWS (Table 3). For soybean and mungbean, a lower proportion of sown crops emerged in the 2005 EWS than in 2004. Overall, sesame was the least successful crop with no establishment when grown in the EWS and only one harvested crop out of nine sown in the MWS (Table 3).

Maize crop failed to emerge on each soil type, but the level of failures was most prevalent on Labansiek. Considering all soils, emergence was most reliable on Kompong Siem and least so on Labansiek. Emergence at Site 15 in the MWS 2005 failed completely except for peanut. Failure of emergence occurred on Ou Reang Ov and Labansiek soils in the MWS especially in 2005, but not on Kompong Siem.

Plant density

Plant density was relatively uniform at about 30 plants/m^2 for peanut at sites where emergence occurred (Table 4). Maize density was relatively uniform on Kompong Siem and Labansiek soils at 6-10 plants/m^2, but varied considerably from site to site and with season on Ou Reang Ov soil. Soybean density in the MWS was relatively uniform but decreased by 10-30 % on Ou Reang Ov soil at Site 17. In the EWS only 2 out of 8 sowings of soybean had successful emergence and of these the density of plants at Site 14 (Ou Reang Ov soil) was very low. Mungbean densities responded to soil type and season in much the same way as soybean.

Nodulation

At sites where legumes emerged and established successfully, plants were generally nodulated. Nodulation of the legumes was most reliable and satisfactory on Kompong Siem soils. Only one mungbean and one soybean crop, both on Ou Reang Ov soils, failed to form nodules. On Ou Reang Ov soil, nodulation varied from poor to adequate depending on site and season.

Table 4. Number of plants per square meter counted at 2-3 weeks after sowing of crops in the early (EWS) and main wet seasons (MWS). Values are means of four replicates

Sites	Soil group	Maize		Mungbean		Soybean		Peanut		Sesame	
		2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
				EWS							
13	Kompong Siem	6	-[A]	24	25	27	-[A]	29	32	-	-
17	Ou Reang Ov	-	5	-	-	-	-	-	33	-	-
14	Ou Reang Ov	6	2	14	-	4	-	18	32	-	-
15	Labansiek	8	-	-	-	-	-	-	30	-	-
LSD (p<0.05)		*1.4*	*1.2*	*1.8*	*5*	*3.3*	*1.5*	*4.5*	*1.3*		-
				MWS							
13	Kompong Siem	5	10	31	32	31	31	33	26	-	-
11	Ou Reang Ov	8	7	28	22	30	31	32	33	-	-
17	Ou Reang Ov	4	-	20	18	21	27	29	31	-	-
15	Labansiek	-	-	-	-	-	-	-	25	-	3
16	Labansiek	9	-	33	-	33	-	32	-	-	-
LSD (p<0.05)		*10.5*	*0.7*	*3.4*	*4*	*0.8*	*3.0*	*1.6*	*4.3*	-	*2.2*

[A] Crop failed to emerge or survive until maturity.

Table 5. Nodulation of legumes in the early wet and main wet seasons of 2004 and 2005. In 2004, nodulation was rated on a 0-10 scale (0- no nodules; 10 was the best) whereas in 2005, values represent number of nodules per plant

Sites	Soil group	Mungbean		Soybean		Peanut	
		2004	2005	2004	2005	2004	2005
EWS							
13	Kompong Siem	6.6	18	6.3	- [A]	5	21
14	Ou Reang Ov	5.4	-	7.1	-	6	9
17	Ou Reang Ov	-	-	-	-	-	12
15	Labansiek	-	-	-	-	-	7
LSD (p<0.05)		*1.9*	*3.0*	*1.4*	*1.3*	*1.8*	*7.3*
MWS							
13	Kompong Siem	8.1	9	9.0	12	8	35
11	Ou Reang Ov	7.4	4	8.0	0	7	46
17	Ou Reang Ov	3.9	0	4.0	2	3	14
15	Labansiek	-	-	-	-	-	25
16	Labansiek	8.1	-	8.0	-	9	-
LSD (p<0.05)		*1.0*	*6.0*	*1.1*	*3.3*	*1.4*	*12.6*

On Labansiek soil nodulation was satisfactory except for Site 15 in the EWS where poor nodule formation of peanut was obtained. However, few mungbean and soybean crops established successfully on Labansiek soil.

Crop yields

Peanut produced 0-3.4 t of pods/ha (Table 6). Consistently high yields were obtained on Kompong Siem soil, although the levels were about 0.6 t/ha higher in the EWS than the MWS. On Ou Reang Ov and Labansiek soils, large variations were obtaining in yield among sites and seasons. Of the crops that produced a harvestable pod yield, the minimum level was 1 t/ha on Ou Reang Ov soil in the MWS, but 6 out 14 peanut crops had 1.5 t of pods/ha or less.

Maize yields varied substantially with seasons and years so that they ranged from 0 to 4.5 t/ha (Table 6). Highest yields were obtained on Labansiek and Kompong Siem soils, but not consistently so. In general, yields in 2004 were higher than 2005, in both seasons. Soybean only produced yield in 25 % of EWS crops, but the two crops that produced seed had < 0.4 t/ha.

Table 6. Grain yield (t/ha) of field crops in on-farm trials (pod yield for peanut and seed yield for other species) in early wet (EWS) and main wet (MWS) seasons. Values are means of four replicates

Sites	Soil group	Maize		Mungbean		Soybean		Peanut		Sesame	
		2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
EWS											
13	Kompong Siem	1.75	- [A]	0.06	0.92	0.09	-	2.75	3.37	0	-
17	Ou Reang Ov	-	0.44	-	-	-	-	-	1.19	-	-
14	Ou Reang Ov	3.00	0.89	1.32	-	0.36	-	1.50	2.73	0	-
15	Labansiek	4.50	-	0	-	0	-	0	1.49	0	-
	LSD (p<0.05)	*0.94*	*0.35*	*0.28*	*0.38*	*0.16*	0.27	*0.86*	*0.48*	*0.10*	-
MWS											
13	Kompong Siem	4.09	2.09	1.53	0.90	3.32	1.46	2.09	2.73	0	0
11	Ou Reang Ov	2.64	1.78	0.81	0.72	0.89	1.24	1.60	2.98	0	0
17	Ou Reang Ov	1.07	-	0.51	0.24	1.91	0.30	1.36	1.03	0	-
15	Labansiek		-	-	-	-	-	-	1.15	-	0.07
16	Labansiek	4.29	-	0.42	-	2.19	-	2.02	-	0	-
	LSD (p<0.05)	*0.25*	*0.39*	*0.17*	*0.22*	*0.30*	*0.24*	*0.21*	*0.21*	*0.09*	0.09

Main wet season yield of soybean was up to 3.3 t/ha on Kompong Siem soil in 2004. Mungbean produced yields up to 1.3 t/ha in the EWS and 1.5 t/ha in MWS, but most crops had less than 1 t/ha.

In general, yields on Ou Reang Ov were lower than the other soils in the MWS, and prone to large variations with site and year of sowing.

Discussion

Peanut was the most reliable crop grown in both EWS and MWS. It failed to produce harvestable yield in 4 out 18 sowings, only one of which was in the MWS. While most crops of peanut produced < 1.5 t pods/ha, yields > 2.5 t/ha were obtained in 5 out 18 sowings with a highest overall yield of 3.4 t/ha. Peanut appeared to establish more reliably than other crops tested. This may be attributed to its drought tolerance once established, and also to the deeper sowing which may have ensured greater access to soil water availability for reliable germination and emergence. The large vigorous seed of peanut may thus reduce risk of poor establishment compared to other crops for sowing in the EWS. The extent to which more reliable emergence of other crops could be achieved by deeper sowing may warrant examination. Deeper sowing may come at the cost of increased loss of soil water due to more extensive tillage. If deeper sowing does not improve establishment of other crops, mulching, stubble retention or minimum tillage systems may conserve more water in the seed bed and hence enhance germination seed and success (Som Bunna et al. 2011).

Soil constraints

Crop management including the rates of fertilizers applied was designed to ensure that growth of cropped plants in the present study was limited only by rainfall and non-nutritional soil constraints. However, there were still occurrences of N deficiency symptoms during crop growth at Site 14 on the Ou Reang Ov soil in 2005. The fertilizer rates applied were modified from Dierolf et al. (2001), based on experience elsewhere but have not been validated by prior research in Cambodia. Further refinement in the fertilizer rates and/or time of application is required to avoid nutrient disorders especially of those elements prone to leaching, especially of N, K, S (Fox et al. 1985). Nitrogen deficiency in non-legume crops appeared to be widespread in all soil types suggesting that either greater rates are required or a different splitting of applications is needed to minimize N losses before crop uptake occurs (Sittiphanit et al. 2009). In preliminary DSSAT modeling of maize yield on Kompong Siem soils, N stress developed at 28-60 days despite the application of 115 kg N/ha (Wendy Vance, personal communication).

Soil analysis suggests that fertilizer will be necessary to achieve high yields on the three basaltic soils, although the nutrients required vary among soils. Kompong Siem soils have low extractable P, K, S and B and these nutrients may limit crop growth when fertilizer is not used (Peverill et al. 1999). By contrast, Ou Reang Ov soils had such high levels of extractable P, that it is unlikely that P fertilizer is needed for crops on this soil apart from a small starter rate to promote early root growth. Generally K and S levels on Ou Reang Ov soils appeared to be sufficient for crop growth (Peverill et al. 1999), but on the more oxidized, shallow profile forms, as represented by Site 17, deficiencies of both elements may occur and require appropriate fertiliser added. Boron levels were also marginal, and may be deficient for B-sensitive crops like mungbean and peanut (Bell 1999). However, no confirmation of B responses has yet been reported for these soils in Cambodia.

Labansiek soils were the most acid of those studied. Analysis of other profiles of Labansiek soils by Hin et al. (2006) suggested they can be more severely acid than found at the 2004 trial sites. Soil pH reported by Hin et al. (2005) was strongly acidic (pH $CaCl_2$ 4.2-5.5) in Labansiek. Indeed Site 15 for 2005 was more acid than the other sites in 2004 and 2005 and severe failure of crop growth occurred at this site for all species except peanut. Acute Mn toxicity symptoms were observed in soybean, mungbean and peanut. These results suggest that soil acidity was a factor responsible for the poor growth and yield of crops on the Labansiek soils. While lime may be an effective treatment for topsoil acidity (Fox et al. 1985), a ready supply of lime has not yet been developed in Cambodia. Moreover, lime may not be effective in ameliorating sub-soil acidity. For sub-soil acidity constraints, the most practical solution may be to select crop species and cultivars that tolerate acidity. Peanut is an obvious choice of acid tolerant legume crop, while cassava is a highly tolerant crop also (Dierolf et al. 2001).

Maize, mungbean, and soybean crops are quite sensitive to soil acidity (Dierolf et al. 2001). Their growth and yield can be depressed when Al saturation in the soil exceeds 40 %, but peanut can tolerate up to 70 % Al saturation (Dierolf et al. 2001). No pH amendments were used in this study. However, in the recent pot experiments conducted at CARDI, on Labansiek soil, when soil was limed at 3.52 g $CaCO_3$/kg to increase soil pH to about 6.0 (Seng 2000; Seng et al. 2006, the symptoms of Mn toxicity disappeared, and mungbean growth improved markedly. For maize, mungbean and soybean, a programme of selection for acid tolerance traits may be needed if these species are to play a significant future role in crop production on the acid basaltic soils.

While all legumes nodulated without inoculation on most sites there were notable cases of failure on Ou Reang Ov soil by mungbean and soybean. The cause is not clear since this soil was not the most acid and both species did nodulate on the Ou Reang Ov soil on other occasions. The fact that Ou Reang Ov soils tended to have highest mineral N at sowing may have suppressed early nodulation but is not likely to cause total nodulation failure. The failure of nodulation may have been more prevalent in mungbean and soybean had more of those crops emerged and successfully established. Indeed failure of nodulation cannot be ruled out as a factor in crop failure of mungbean and soybean. Peanut nodule numbers were also low on Ou Reang Ov soil in some cases. However, it is noteworthy that the poorest nodulation of peanut was on the very acid Lanabansiek soil with the highest extractable levels of NO_3-N and NH_4-N at Site 15 in 2005.

Apart from mineral nutrition, other soil factors such as physical properties and high soil temperatures may control the growth and yield of crops (Sys et al. 1993). High temperature may be a factor in the poor establishment of EWS crops. No soil temperature data was recorded during planting but at harvest in 2005, early afternoon surface soil temperatures were recorded as high as 38 ^oC. Mulching and stubble retention practices may be important in alleviating high temperature stress for seed germination and crop establishment in the EWS, especially for the early sowings. Ou Reang Ov soil is prone to crusting and hardsetting at the surface (Hin et al. 2006; Bell et al. 2006; Bell et al. 2007). High soil strength limits root penetration for adsorption of moisture and nutrients available in a deeper profile. No specific evidence of high soil strength was obtained from the experiment, but root profile investigations at the end of the experiment on Ou Reang Ov Soil showed a very poor and shallow root growth, generally <30 cm deep. Subsequent investigations on bulk density indicated that values declined with depth from 1.67 to 1.50 g/cm^3 in Kompong Siem (site 13) soil, increased with depth in Ou Reang Ov (site 11) from 1.41 to 1.77 g/cm^3 and were uniformly low (1.1 g/cm^3) in Labansiek soil.

Soil moisture regimes appear to be limiting factors in most soils. Kompong Siem and Labansiek soils used in the experiment had clay and clay loam textures to varying depth. In Thailand, red basaltic soils typically contain low available soil water content (Tawornpruek et al. 2005). This is offset by their depth if roots are able to exploit sub-soil moisture. Aluminium toxicity may limit root exploration into the sub-soil and hence limit crop production by making acid sensitive crops drought-prone. By contrast, acid tolerant species with deep roots such as rubber can have high productivity on Labansiek soils. In Kompong Siem, the available water content is high, but the limitation to root growth on this soil is the common episodes of waterlogging that may cause root pruning.

Seasonal rainfall and growing conditions

Crop performance was generally better in the MWS when rainfall is greater and more reliable than in the EWS. The only exception was peanut where yields were either similar to or lower than in the MWS than EWS. On the Kompong Siem soils, MWS yield of peanut was depressed by 0.5 t/ha. Peanut is not as waterlogging tolerant as soybean and maize, and hence tentatively the better yield of peanut on the Kompong Siem soil in the EWS may be attributed to less waterlogging. Soybean was most severely affected by the EWS conditions with few crops emerging and surviving to produce yield. The maximum yield of soybean obtained, 0.36 t/ha, was too low to justify planting this crop. Sesame failed to emerge or survive in 17 out 18 trials, with no effect of season in its lack of success.

The optimum growing season rainfall ranges for crops used in the experiment are reported as being: mungbean 750-875 mm, maize 500-1200 mm, soybean 500-1100 mm, peanut 400-1100 mm, and sesame 350-800 (Sys et al. 1993). In 2004 amounts of rainfall were generally sufficient for peanut, sesame and maize, but not for mungbean, and soybean. However, most sites experienced inadequate rainfall during the early vegetative stage which was reflected in failure of crops to establish completely at Site 18. In 2005, amounts of rainfalls during the growing season were generally inadequate especially for mungbean, maize and soybean.

Crops vary significantly in their temperature requirement for germination and growth. The optimum temperature ranges for crops used in the study are reported as being: maize 18-32 ^oC, mungbean 21-31 ^oC, peanut 18-30 ^oC, sesame 20-28 ^oC, and soybean 20-30 ^oC (Sys et al. 1993). Unfortunately, there was no temperature data recorded during the trials. However, in the EWS maximum day time temperatures in excess of 35 ^oC are common (Pheav et al. 2003). Hence high air temperature may be a factor in the poor establishment of EWS crops. The extent to which high air temperature has limited crop growth in the present study is unclear.

Soybean and mungbean varieties used in the experiment performed well in the main wet season but not in the early wet season. It was noted that most of the pods at Site 13 were empty and/or dropping from the plants in the early wet season. These crops at Site 13 only were sown in May and hence for the first 8 weeks of growth experienced maximum day lengths of the year. However, the mungbean and soybean sown nearby at site 14 at the same time did not experience the same problem with poor pod and seed set. Day lengths exceeding photoperiod requirements for seed set are not believed to the responsible for poor seed set in soybean DT84 (Andrew James *personal communication*). The poor pod and seed set at Site 13 were consistent with thrip damage.

Success and failure of trials in both seasons indicate that crops responded differently to time of sowing. Experiences from the 2004 and 2005 on-farm trials show that if crops are sown in late May, the success of establishment of sesame was 0%, followed by soybean (25%), mungbean (38%) maize (63%) and peanut (75%). If crops are sown in July-August, success for sesame was still only 20% across 10 sites, the success of mungbean, maize and soybean increased to 70%, whereas peanut had 80 % success in producing a harvestable yield. According to farmers' practice, sesame, mungbean, maize and peanut are to be sown between late March and early April when there had been a two or more significant rain events; and soybean in July (Chea et al., 2006). Our early wet season trials were sown in May (>20th), 5-6 weeks later than farmers, resulting in many crops failing to yield especially sesame. A greater success was obtained in the main wet season, when crops were sown between mid July and August. In rainfed conditions where rainfall is not reliable, it would be useful to carry out supplementary irrigation at critical times such as the time of sowing to allow timely crop establishment and reduce the risk of failure. Supplementary irrigation may also increase stored soil moisture deeper in the soil profile for use during a period of succeeding drought assuming that no physical or chemical impediment to deep root growth exists.

Other factors

Variety selection for the crops used in the present study is still at an early stage in Cambodia. Hence it is possible that with improved varieties, better crop performance could be expected. Higher yield can also be pursued using varieties tolerant to specific soil and climatic conditions. In the case of the legume crops, it is not yet clear whether conditions were suitable for optimal nitrogen fixation.

Good quality seed produces healthy, vigorous plants and together with proper water and pest management will produce higher crop yield. While efforts were made to select good quality seed for the present experiment, poor quality seed may increase the risk of failure to emerge and establish. Hence under farmers' conditions the riskiness of the EWS crops may be greater than reported here.

Conclusions

From two years of on-farm experiments with contrasting rainfall (wet- 2004; dry-2005) to assess productivity of crops on basaltic soils in eastern Cambodia, we draw the following conclusions:

1. Peanut was most reliable in establishment and in producing harvestable yield in both EWS and MWS. It was productive on Kompong Siem soil producing yields comparable to its potential yield (2-3 t/ha). More work needs to be conducted to achieve higher yield on the well-drained Labansiek soils possibly be treating soil acidity (Al saturation and Ca supply). Overall peanut have widest adaption to soils and seasons. Peanut was the most reliable of the crops based on present crop management technologies.
2. Maize and mungbean grew on all soil types, but they produced yields only 35-40% of the potential yield levels (6-9 t/ha for maize, 2-3 t/ha for mungbean). More efforts are needed to achieve the potential yield including improved soil nutrient and acidity management, cultivar suitable for soil and climatic conditions, and better water and pest management.
3. Soybean was fairly suitable on Kompong Siem soils producing yields of 66-81 % of the potential yield (1.5-2.5 t/ha). More work is needed to achieve higher yield on the well-drained Labansiek soils due to soil acidity (Al saturation, P supply). Yield of soybean overall was poor in the EWS, which is consistent with farmers' reluctance to sow it before July, and its reputation for being more drought sensitive than the other crops grown.
4. Sesame when sown in mid- to late-May or in July was not promising on any of the soil types. Factors such as time of sowing, seed quality, water availability, insects and weeds, and fertilizer application techniques must be carefully considered if sesame is to be grown on any of the studied soils.
5. High yields of all crops except sesame were achievable but yields were variable among soils, sites and season. Overcoming the unreliable performance of crops is the key to decreasing the risk associated with non-rice crop production.

Acknowledgements

The authors gratefully acknowledge ACIAR for funding, The Cambodia Agriculture Research and Development Institute for support, the Provincial Department of Agriculture Forestry and Fisheries, Kampong Cham for coordinating trials, and farmers for proving land for the trials and for carrying out land preparation and crop maintenance operations.

References

Bell, R.W. (1999). Boron. Chapter 22. In Soil Analysis An Interpretation Manual. Eds K. Peverill, L. Sparrow and D.J. Reuter. pp.309-317. CSIRO Publishing, Melbourne.

Bell, R.W., Seng, V., Schoknecht, N., Vance, W. and Hin, S. (2006). Assessing land suitability for crop diversification in Cambodia. In: Proceedings of the Land Resource Assessment Forum for Cambodia, held at CARDI, Cambodia 23-26 September 2004. Eds R.W. Bell, K. Coughlan, G. Hunter, R. McNaughton, and V. Seng, pp. 40-58. CARDI, Cambodia.

Bell, R.W., Seng, V., Schoknecht, N., Hin, S., Vance, W. and White, P.F. (2007). Land capability classification for non-rice crops in basaltic soils in eastern Cambodia. CARDI Soil and Water Science Technical Note No. 8.

Cambodia-IRRI-Australia Project (1999). Annual Report for 1998. (CIAP: Phnom Penh, Cambodia).

Chea Sareth, Chapho Samrang Chittra, Wendy Vance, Seng Vang, and Richard Bell (2007). Farmers' perspectives on land capability for upland crops in Battambang, Kampong Cham and Takeo Provinces, Cambodia, 2004. Report for ACIAR Project LWR/2001/051 (ACIAR03).

Dierolf, T., Fairhurst T., and Mutert E. (2001). Soil Fertility Kit. GTZ-GmbH, FAO, PT Jasa Katom, and PPI and PPIC. Oxford Graphic Printer.

Fox, R. L., Yost, R. S., Saidy, N. A., and Kang, B. T. (1985). Nutritional complexities associated with pH variables in humid tropical soils. Soil Science Society of America Journal 49, 1475-1480.

Hazelton, P., and Murphy, B. (2007) Interpreting soil test results. NSW Department of Natural Resources. (CSIRO Publishing: Victory).

Hin, S., Schoknecht, N., Vance, W., Bell, R.W. and Seng, V. (2006). Soil and Landscapes of Basaltic Terrain in Ou Reang Ov District, Kampong Cham Province, Kingdom of Cambodia. CARDI Soil and Water Science Technical Note No. 3.

Hin, S., Bell, R.W., Seng V., Schoknecht, N. and Vance, W.H. (2007). Soil and Landscapes of Basaltic Terrain in Ponhea Krek District, Kampong Cham Province, Kingdom of Cambodia CARDI Soil and Water Science Technical Note No. 14.

Ministry of Agriculture Forestry and Fisheries, MAFF (2005). Agricultural Statistics 2004-2005. Statistics Office, Department of Planning, Statistics, and International Cooperation. MAFF, Phnom Penh, Cambodia.

Peverill, K., Sparrow, L. and Reuter, D.J. Eds (1999). Soil Analysis An Interpretation Manual. CSIRO Publishing, Melbourne.

Pheav, S., Bell, R. W., White, P. F. and Kirk, G. J. D. (2003). Fate of applied P in an highly weathered sandy soil under lowland rice, and its residual effect. Field Crops Research 81, 1-16.

Rayment, G.E. and Higginson, F.R. (1992). Australian Laboratory Handbook of Soil and Water Chemical Methods. Inkata Press, Melbourne. 330 p.

Seng Vang (2000). Edaphic factors restricting rice yields in rainfed lowland soils of southeast Cambodia. Ph D Thesis. Murdoch University, Perth, Western Australia.

Seng, V., Bell. R. W. and Willett, I. R. (2006). Effect of lime and flooding on phosphorus availability and rice growth on two acidic lowland soils. Communications in Soil Science and Plant Analysis 37, 313-336.

Seng, V., Bell, R.W., Schoknecht, N., Hin, S., Vance, W. and White P. F. (2007). Ou Reang Ov: A new Soil Group for the Cambodian Agronomic Soil Classification. Cambodian Journal of Agriculture Vol. 8, No. 1, 2007, 5-12.

Sitthaphanit, S. Limpinuntana, V., Toomsan, B., Panchaban, S. and Bell, R.W. (2009). Fertiliser strategies for sandy soils in a high rainfall regime. Nutrient Cycling Agro-ecosystems 85, 123-139.

Som Bunna, Pao Sinath, Ouk Makara, Jaquie Mitchell, Shu Fukai (2011). Effects of straw mulch on mungbean yield in rice fields with strongly compacted soils. Field Crops Research 124 (2011), 295-301.

Sys, C., Van Ranst, E., Debaveye, J. and Beernaert, F. (1993). Land Evaluation Part III Crop Requirements. Agric Publ. No 7. General Administration for Development Cooperation, Brussels.

Tawornpruek, S., Kheoruenromne, I., Suddhiprakarn, A. and Gilkes, R.J. (2005). Microstructure and water retention of Oxisols in Thailand. Aust. J. Soil Res. 43, 973-986.

White, P.F., Oberthür, T. and Pheav, S. (1997). The Soils Used for Rice Production in Cambodia. Cambodia-IRRI-Australia Project Phnom Penh, Cambodia.

Workman, D.R. (1972). Geology of Laos, Cambodia, South Vietnam and the Eastern part of Thailand. A Review. London, Institute of Geological Sciences.

សារៈសំខាន់របស់បឹងជើងឯករបស់ប្រទេសកម្ពុជាៈ ផលវិជ្ជមាន និងតម្លៃសេដ្ឋកិច្ចសង្គម

The importance of Cheung Ek Lake, Cambodia: socioeconomic value and negative impacts

Seila Sar, Cristy M Warrender, Garry W Warrender and Robert G Gilbert

អត្ថបទសង្ខេប

បឹងជើងឯក មានទីតាំងក្បែររាជធានីភ្នំពេញជាកន្លែងស្តុកកាកសំណល់នៃទីក្រុង និងរោងចក្រឧស្សាហកម្មមកពីជាយក្រុងភាគនិរតី និងភូមិជាច្រើនស្ថិតនៅតំបន់បឹងនេះ (ច្រើនជាងមួយពាន់ហិកតា)។ កាកសំណល់ទាំងនេះមិនត្រូវបានចម្រោះ និងបានដាក់បញ្ចូលគ្នាជាមួយការអនុវត្តន៍កសិដ្ឋានដែលស្ថិតនៅជុំវិញមាត់បឹង ហើយកំពុងតែគំរាមកំហែងដល់សុខុមាលភាពមនុស្ស និងសេដ្ឋកិច្ចនៃតំបន់នេះ។ ទោះបីសកម្មភាពកសិកម្មផ្តល់នូវសារៈសំខាន់នៃសេដ្ឋកិច្ច ដោយភ្ជាប់ទៅនឹងទីផ្សារ និងស្បៀង ក៏ប៉ុន្តែកំពុងតែបង្កើននូវការព្រួយបារម្ភសម្រាប់សុខុមាលភាពជាប់ទាក់ទិននឹងការអនុវត្តន៍ទាំងនេះ។ កាកសំណល់រួមមាន លោហធាតុកម្រិតធ្ងន់សរីរាង្គកខ្វក់ សារធាតុចិញ្ចឹមរលាយក្នុងទឹក និងកាកសំណល់ជីវសាស្ត្រសកម្មដែលកំពុងតែហូរចូលទៅក្នុងបឹងជារៀងរាល់ឆ្នាំ ជាមួយការបន្សាបជាកត្តាតែមួយគត់ក្នុងការជួយបន្ធូរបន្ថយ។ ទឹកកខ្វក់នេះ បានបង្កស្ថានភាពដ៏មានគ្រោះថ្នាក់សម្រាប់សង្គមសេដ្ឋកិច្ចនៃបឹងជើងឯកដូចជា ផលប៉ះពាល់អវិជ្ជមានលើសុខភាពមនុស្ស និងស្ថានភាពសេដ្ឋកិច្ចនៃការអនុវត្តន៍កសិកម្មដែលទើបតែចាប់ផ្តើម។ ការជាប់ទាក់ទងមានពីរ (i) សម្រាប់បុគ្គលផ្ទាល់-ការចំណាយខ្ពស់លើតម្លៃព្យាបាល (ii) សម្រាប់សហគមន៍-ការជួយបន្ធូរបន្ថយនូវសុខភាពខ្សោយ ជំងឺឆ្លង បានផ្សារភ្ជាប់ជាមួយចំនួនច្រើនកំលាំងពលកម្ម ដែលមានសុខភាពមិនល្អសម្រាប់រួមចំណែកទៅលើវិស័យសេដ្ឋកិច្ច។ យើងស្នើសុំលើកនូវវិធីសាស្ត្រសាមញ្ញ ដោយដាំរុក្ខជាតិជួយបន្សាបទឹកកខ្វក់ដែលគួរតែចាប់ផ្តើមឱ្យបានឆាប់ដើម្បីកាត់បន្ថយ សារធាតុបង្កជម្ងឺ និងភ្នាក់ងារចម្លងរោគ នៅក្នុងទឹកកខ្វក់ដែលហូរចូលទៅក្នុងបឹងជើងឯក ជាមួយការបន្ថែម និងការពង្រីកសម្រាប់ប៉ុន្មានឆ្នាំចុងក្រោយនេះ។ ប្រសិនបញ្ហាទាំងពីរនេះត្រូវបានដោះស្រាយ និងគោលនយោបាយរឹតបន្តឹងលើកាកសំណល់សម្រាប់រោងចក្រឧស្សាហកម្ម កសិកម្ម និងសហគមន៍ទីប្រជុំជននោះនឹងបានទទួលនូវផលវិជ្ជមាន លើសុខភាពសេដ្ឋកិច្ចសង្គម និងភាពរីកចម្រើននៃតំបន់នេះ។

Abstract

Cheung Ek Lake, near Phnom Penh, receives a considerable volume of industrial and municipal waste from the southern suburbs and villages in the lake region (more than a thousand hectares). This waste is not treated, and combined with the farming practices conducted on the lake margins, is threatening the human and economic health of the area. Although the agricultural activities provide a vital economic link to food markets, there is growing concern for the health implications of this practice. Waste, including heavy metals, organic pollutants, dissolved nutrients, and biologically active agents are entering the lake throughout the year, with dilution as the only mitigating factor. This wastewater constitutes a dangerous situation for the socio-economic importance of Cheung Ek Lake, as negative effects on human health and economic viability of agricultural practices begin to appear. The implications are two-fold: (i) for the individual - the high cost medical bills and (ii) for the community - the mitigating problems of poor health and disease epidemics, compounded by a workforce containing significant numbers of people too unwell to contribute to the economy. We propose a simple wastewater treatment plant that will immediately start to reduce the pathogens and contaminants in the wastewater entering Cheung Ek Lake, with additions and expansions for later years. If coupled with clear and stricter policies on waste for industries, agriculture and urban communities will see a positive impact on the socio-economic health and wealth of this region.

Seila Sar, Cristy M Warrender, Garry W Warrender and Robert G Gilbert

The University of Queensland, CNAFS (Centre for Nutrition and Food Sciences) 83-S434, Qld 4072, Australia.

***Corresponding Author:**
E-mail: b.gilbert@uq.edu.au

Introduction

General information about Cheung Ek Lake

In Phnom Penh, about 90% of all untreated urban wastewater is discharged to wetland areas and lakes, where it is estimated that 20% of vegetables consumed in Phnom Penh are grown. (Muong,2004). Cheung Ek Lake, a seasonally inundated lake located about 5 km to the south of Phnom Penh, receives large amounts of untreated wastewater from urban development (~500,000 inhabitants). Water from the lake eventually flows into the Tonle Sap River. The total surface of the lake is about 1400 ha in the dry season. Cheung Ek Lake is bordered by two districts in Phnom Penh and one district in Kandal province and supports 36 village communities. There are 31 villages located in five Sangkats of Meanchey and Dangkor district, and another five villages are located in four communes of Takmao district. In 2008, there were about 14,380 households living around this lake.

In Phnom Penh, Beoung Cheung Ek is a large water body that receives 80% of the wastewater from Phnom Penh's urban population and from industrial factories (garment and various other factories); moreover, rainfall run-off discharges into the lake (Seyha and Tuan Anh 2004). The lake also receives wastewater from two Boeng Tompun and Boeng Trabek canals. Boeng Trabek pumping station was constructed in 1986 and Boeng Tompun was constructed in 2004 by **Japan International Cooperation Agency** (**JICA**). Cheung Ek Lake is an important area for growing aquatic plants and fish production, and harvesting is undertaken throughout the year.

Methods

This work was done using both all the available secondary data on Cheung Ek and its related information and direct observation with semi-structured interviews of the key people working on the lake. This was in order to understand the overall situation the lake and to propose suitable solutions to overcome the long-term negative impact received from the lake if people keep continuing draining the lake and taking no action on this. This review also serves as a basic reference for policy decision-makers in implementing future development plans on this lake region.

Results of the study

Socio-economic value of Cheung Ek Lake

Cheung Ek Lake represents not only a source of income for more than 400 households living directly around the lake (Kuong *et al*. 2005), but also the 'end point' for Phnom Penh's wastewater. Water spinach (*Ipomoea aquatica*) is the major crop grown in the lake. People also plant water mimosa (*Neptunia oleracea*), water dropwort (*Oenanthe aquatica*), and

Figure 1. Aerial photo of Cheung Ek Lake taken in 2009 (Source: Prof. Puy Lim).

dry season rice (*Oryza sativa*). Aquatic plants, especially water spinach and water mimosa, occupy about a half of the total surface of the lake in the dry season.

The cultivated vegetable (water spinach) is used for human food and also for animal feed. The upper part of the stem and the upper leaves with leaf stalks are used for human consumption, whereas the lower part of the plant with leaf, stem and root may be used as pig feed (Anh *et al*. 2004). The socio-economic activities on the surface of Cheung Ek Lake represent an important source of income for many households around the lake (Balmisse and Sylvain 2003). Moreover, these aquatic vegetable production systems in peri-urban Phnom Penh provides many benefits, not just incomes for producers and low cost wastewater treatment, but also the employment and earning opportunities for many seasonally hired labourers engaged in setting up, maintenance and harvesting of plants. It is also known that the aquatic plant cultivation and fishing activity are performed directly on the lake with waste polluted water; thus human health and economic value of the products may be influenced negatively by these activities.

The farmers usually sell their products at roadside stalls or sell them to wholesalers or collectors. Various middlemen are important links in this market chain. They can collect aquatic products from farmers, transport and then sell them to the wholesalers in both suburban and peri-urban areas. Wholesalers are a key component in the relationship between the collectors and retailers, whilst retailers provide a vital link between wholesalers/collectors and the consumers. Wholesalers are the main customers of collectors and they mainly sell the product to retailers. From survey results conducted by the authors (Sar et al., 2010), there were three main markets for water spinach and water mimosa production: Deumkor, Chbar Ampov and Neak Meas markets. The producer can either sell the product to middlemen or sell it directly at the market. The product is transported by the middleman or producer to the wholesalers in some main markets in Phnom Penh. Then, the wholesalers sell the product to retailers from other markets in Phnom Penh and also to other traders from provinces such as Koh Kong, Sihanukville, and Kampong Cham. Finally, the product is sold to consumers for their daily household diet. The transaction cost of water spinach from producer to consumer is on average 900 riels per bunch whilst it is on average 1,600 riels per kilogram for water mimosa. The prices of both water spinach and water mimosa are higher in the dry season than in the wet season. The farmer receives the highest price between November and December, the period when water spinach and water mimosa can be seriously damaged by insects and diseases and the supply of water spinach is very low. Within the dry season, the direct-use value of Cheung Ek Lake was estimated at more than 1 million USD, of which water spinach production contributed 65%, fishing 20%, water mimosa production 13%, duck raising 1%, and dry season rice production 0.7%. Cheung Ek Lake thus provides economic returns to both (i) the direct beneficiaries (the households who work on the lake) and (ii) the indirect beneficiaries (such as wholesalers, retailers, and middlemen), whilst providing members of the general public with a variety of sources for food security.

In a survey of households that work on Cheung Ek Lake (a case study conducted by Production in Aquatic Peri-Urban Systems in Southeast Asia (PAPUSSA)) found that farmers were concerned about the future water spinach farming in peri-urban areas, especially Beoung Cheung Ek, because the government may decide to develop the lake area for other urban growth purposes (Kuong *et al*. 2005). The farmers fear that this might lead to a number of detrimental effects.

Negative Impacts of Cheung Ek Lake

Cheung Ek Lake water quality may be the source of negative economic and public health impacts for the people living around, and eating the products, from the lake. Untreated wastewater draining into the lake and the direct application of fertilizers and chemical pesticides on the lake for water spinach cultivation all may have negative impacts on water quality.

Wastewater compositions

Wastewater is characteristically grey in appearance, with a musty odour, and solids content of about 0.1%. The solids can be suspended (about 30%) as well as dissolved (about 70%) (FAO 1992). Dissolved solids can be precipitated by chemical and biological processes; however, the suspended solids can lead to the development of sludge deposits and anaerobic conditions when discharged into the receiving waters.

Chemically, wastewater is composed of organic and inorganic compounds, as well as, various gases. Organic components may consist of carbohydrates, proteins, fats and greases, surfactants, oils, pesticides and phenols. Inorganic components may consist of heavy metals, nitrogen, phosphorus, sulfur, chlorides, toxic compounds, etc., and may have an excessively low or high pH. Gases commonly dissolved in wastewater are hydrogen sulfide, methane, ammonia, oxygen, carbon dioxide and nitrogen (FAO 1992).

Biologically, wastewater contains various microorganisms but the ones that are of most concern to plants and animals are those classified as protista. The category of protista includes bacteria, fungi, protozoa, and algae. Wastewater also contains many pathogenic organisms which generally originate from humans who are infected with disease or who are carriers of a particular disease (FAO 1992).

Human health problems from wastewater

Humans "contract" diseases from wastewater in a variety of ways. Pathogens in wastewater may be transmitted by direct contact with sewage, by eating food or drinking water contaminated with sewage and/ or in which contaminants such as heavy metals may have accumulated. Another important pathogen vector is through contact with other human, animal, or insect carriers. Faeces and urine from both humans and animals carry many disease-causing organisms. Wastewater also may contain harmful chemicals and heavy metals known to cause a variety of environmental and health problems.

Bacteria, viruses, and parasites (including worms and protozoans) found in wastewater are the main types of pathogens that can be directly hazardous to humans. Fungi that cause skin, eye, and respiratory infections and water-borne diseases (i.e. cholera, typhoid, shigella, polio, meningitis, and hepatitis A and E) are also found in sewage and sewage sludge. Animals (including humans) can act as hosts to the bacterial, viral, or protozoal organisms that cause these diseases. (Khan 1997; UN 1997; Warner 1998; WHO 1997). *Escherichia coli* are the most frequent pathogenic agent of urinary tract infections, causing a wide spectrum of clinical syndromes from asymptomatic cystitis to pyelonephritis or sepsis (Sobel and Kaye 1995). Depending on the virulence factors they possess, virulent *E. coli* strains can cause either non-inflammatory diarrhoea (watery diarrhoea) or inflammatory diarrhoea (dysentery with stools usually containing blood, mucus and leukocytes).

E. coli diarrheal disease is contracted orally by ingestion of food or water contaminated with a pathogenic strain shed by an infected person. ETEC diarrhoea occurs in all age groups, but mortality is most common in infants, particularly in the most undernourished or malnourished infants in developing nations (Doyle and Dolores 1997).

Low cadmium exposure level may cause adverse health effects, primarily in the form of kidney damage but possibly also bone effects and fractures. Similar levels of exposure to mercury via food contamination, may increase blood levels and increase the risk of neurological damage to adults and to the unborn foetus of pregnant women (Jarup 2003). Children are also more susceptible to lead exposure due to high gastrointestinal uptake and the permeable blood-brain barrier. Long-term exposure to arsenic in drinking water has been linked to increased risk of skin cancer and some other cancers, as well as other skin lesions such as hyperkeratosis and pigmentation changes. Occupational exposure to arsenic, primarily by inhalation (e.g. of dust resulting from the drying of mid), is causally associated with lung cancer (Jarup, 2003).

Human health problems from consumption and contact with wastewater

In Phnom Penh, about 20% of vegetables consumed are grown in wastewater-fed wetland areas (Muong 2004). Water spinach (*I. aquatica*) is the main crop grown in these wetlands, the Boeng Cheung Ek lake area being the largest. To sustain wastewater use in such peri-urban aquatic food production systems, adverse health implications should be addressed and alleviated. Health risks of wastewater use in agriculture and aquaculture have been reported in many countries like Morocco, Mexico and Pakistan, where wastewater is commonly used for irrigation (Shuval *et al*. 1989; Habbari *et al*. 1999; Cifuentes *et al*. 2000; Blumenthal *et al*. 2001). Outbreaks of cholera, typhoid and shigellosis have been associated with the use of untreated wastewater to irrigate vegetables (WHO 2006). As wastewater-irrigated vegetables passively accumulate faecal contaminants on their surfaces, they may pose a health risk to consumers when the produce is cooked or eaten raw. Increased risk of diarrhoeal disease is associated with the consumption of uncooked vegetables irrigated with wastewater (Blumenthal *et al*. 2003). Water spinach is highly contaminated with faecal pathogens, with more than half the plants being contaminated with Giardia and some plants with *Cryptosporidium spp*. and *Cyclospora spp*. (Anh *et al*. 2007). These findings are the first report from Cambodia on protozoan parasites in vegetables. Pathogens may also be taken up by plant roots and be incorporated into the plant tissue (Guo *et al*. 2002; Solomon *et al*. 2002). Recent results of a study of Cheung Ek Lake on skin diseases suggest that exposure to wastewater is an important risk factor for skin diseases, especially dermatitis (eczema) of the hands and legs (Dalsgaard *et al*. 2005).

Human health problems from crop cultivation

The application of fertilizers and chemical pesticides to Cheung Ek Lake may impact negatively on human health. Increasingly, agricultural chemicals, fertilizers, pesticides, and industrial wastes (including heavy metals) are being found in freshwater supplies. Such chemicals, even in low concentrations, can build up over time and, eventually, can cause chronic diseases such as cancers among people who use the water (Silfverberg 1994).

Health problems from nitrates in water sources are becoming a serious problem; in more than 150 countries nitrates from fertilizers have seeped into water wells, fouling the drinking water (Maywald *et al*. 1998) causing blood disorders (i.e. from excessive concentrations of nitrates) (Bowman 1994). Consistently elevated levels of nitrates and phosphates in water encourage growth of blue-green algae, leading to deoxygenation (eutrophication). Pesticides such as DDT and heptachlor, which are used in agriculture, often contaminate irrigation water. Their presence in water and food products has alarming implications for human health because they are known to cause cancer and neurological diseases and reduce sperm counts (Bowman 1994).

The results from a survey by Teang (2009), water spinach and water mimosa producers in Cheung Ek

Lake apply chemical fertilizers and chemical pesticides on a weekly basis to fight against diseases and insects. The commonly used chemicals and pesticides are:
- DDVP-50 from Thailand (called "Holding-Hand Brand" by farmers) used for prevention of worms and white rust lesions (Kra) (Active Ingredients: 2, 2-dichlorovinyl dimethyl phosphate 50%W/V EC).
- Visher 25 ND from Viet Nam (called "One-Worm Logo" by farmers) used for prevention of worms, grasshoppers and white rust lesions.
- V 80 (known as "Carrying-Pumpkin Brand") from Thailand, used for prevention of white rust lesions (Kra) and conditioning plant bud (Active Ingredients: Zinc ethylenebis (dithiocarbanate) (polymeric) 80% W.P).
- BIOBIT 32B FC from Viet Nam ("One Worm Logo" powder) used as pesticide and for bud conditioning.
- Bao 30 from Thailand (called "Golden Comb Brand" by farmers) used to stimulate new growth of buds.

Based on the results of the survey by the author in 2010, working in the lake without protective gloves and bathing in the lake were the two common reasons resulting in skin problems for the farmers. More fisherman, water-mimosa, and water-spinach cultivators than rice cultivators and duck raisers reported skin problems because they spent longer lengths of time on the lake. Most of the water spinach and water mimosa cultivators realized that their health had worsened because of contact with wastewater chemicals. Furthermore, the fishermen perceived that they had difficulty in breathing, as they had spent an average of 10 hours a day on the lake for fishing activities. The suspected diseases which are mostly encountered by the farmers working in Cheung Ek Lake during the survey are: cough, cholera, typhoid and diarrhoea, which are mostly diseases associated with wastewater. Another case study on Cheung Ek lake by Dalsgaard et al. (2005) also mentioned that the exposure to wastewater is an important risk factor for skin diseases, especially dermatitis (eczema) of the hands and legs.

Human health problems arising from accumulated heavy metals

The contamination of aquatic ecosystems by heavy metals has gained increasing attention in recent decades. Heavy metals represent a significant ecological and public health concern due to their toxicity and ability to accumulate in plants and animals (Alloway and Ayres 1993 and Langston 1998). In natural environments, there exist background levels of heavy metal components in soil and water. However in contaminated areas, plants and animals may begin to accumulate heavy metals. When impacted plants and animals are subsequently used for human food, heavy metal contaminants are often incorporated into the food chain. Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues. Toxic levels of heavy metals have a negative effect on the quality of cultivated plants and animals and later on health of local inhabitants. Heavy metals may enter the human body through food, water, air, or absorption through the skin.

A common heavy-metal contaminant is mercury, which can be used in various industrial processes, as well as being emitted from coal-fired power plants. This metal has a significant vapour pressure under ambient conditions, and thus, apart from mainly infiltrating the human body through food and water, it may also enter through respiration. Moreover, in contact with various organisms, it readily forms compounds such as dimethyl mercury, an highly toxic form, easily passed through the food chain to humans [e.g. the disaster at Minamata Bay, Japan reported by Lui David (1999)]. Mercury is particularly potent because once in the body it cannot be excreted but accumulates in the body tissue and, significantly, in mother's milk (Lui David 1999).

Together with respiration, food can be considered as the greatest vector for toxic chemicals to the human body. Local inhabitants of Cheung Ek Lake consume local fish and sell farm produce which is collected from the contaminated lake. The increased concentrations of metals in fish, such as mercury, lead and cadmium, may pose a threat to human health through consumption (Chen and Chen 1999), although some metals (zinc and copper) are essential trace minerals for metabolic regulation at cellular and tissue levels (Vallee and Faclchul 1993). Aquatic plants often accumulate metals from their environment (Outridge and Noller 1991; Ali and Soltan 1999). Fish is the most common meal for the people living around Cheung Ek Lake. Thus, humans can be affected by bio-accumulation process of heavy metal through the plant/fish life. Chronic exposure to and accumulation of heavy metal by aquatic biota can result in tissue concentrations that will have adverse effects on exposed organisms (Bolognesi *et al.* 1999).

For the general Cambodian population, any effects from accumulated heavy metals caused by untreated industrial effluent impacting Cheung Ek Lake will be widespread as a consequence of the market distribution of water spinach being sold to three main markets in Phnom Penh and transported to other provinces throughout Cambodia. The accumulated heavy metals could result in serious chronic illnesses such as cancer, and neurological diseases as well as an increase in birth defects. In Karachi, Pakistan, for example, a study found that poor people living in areas without any water treatment plants spent six times more on medical care than people who had lived in areas with access to appropriate sanitation and who had a basic knowledge of household hygiene (Khan 1997).

Long-term effects of doing nothing or draining the lake

Doing nothing about pollution problems, and the continuous urban and industrial activity draining into the lake will result in the deterioration of the regional economy and the health of people living around and eating products from the lake. Negative effects of lake water pollution result from untreated wastewater draining into the lake and the direct application of the fertilizers and chemical pesticides on the lake for water spinach and water mimosa cultivation. The raw wastewater will lead to many kinds of widespread water-borne diseases among the population. Moreover, the toxic substances from agricultural and industrial waste practices will build up over time through bio-accumulation process and may cause chronic diseases such as cancer, birth defects and blood disorders. These kinds of diseases require expensive and continuing medical treatment and if a significant fraction of the population suffers from them, this will have a deleterious effect on the national budget, not the least of which arises from lack of productivity of the diseased or ill population. Furthermore, the negative cost factors of effectively doing nothing about pollution of the lake will result in the removal of residents, no land development around the lake, loss of current and future industry such as fishing and cropping practices, tourism and recreation. The loss of future tourist income would be considerable: for example, Ho Tay Lake in Hanoi is a major tourist attraction, adding greatly to the beauty of the city and hence resulting in considerable earnings from domestic and international travellers. Moreover, it is very important to note the dangers of contaminated sediments from the bottom of the lake being exposed to air. The resulting contaminated dust, heavy metals mostly, will spread contamination much further than is possible by just draining wastewater into the lake. The primary source of air contamination at lake sites is the dust from the dry surfaces of sediments, if they are exposed to the environment. Often, in the dry season sediments in Cheung Ek Lake are not completely covered by water, thus the dusts from dry sediments, heavy metals in particular, are commonly available for wind-blown transport. Deposition of wind-blown tailings provides exposure routes for contamination of ground water, surface water, and soil which is a great concern to public health.

Converting the land reclaimed as a result of draining and filling in the lake to commercial and housing uses will put heavy socio-economic pressure on both the local people who live and work dependent on the lake, and on the Cambodian government. Thousands of poor people who live around the lake will lose their livelihood as producers of aquatic plants, fishermen, dry season rice cultivators and duck producers cease operation. Moreover, there will be a decrease in food production if this lake is filled for urbanisation. As it is already known, the products from Cheung Ek Lake, water spinach and water mimosa in particular, supply not only the consumers in the capital city of Phnom Penh but also to the other main provinces including Sihanouk Ville, Koh Kong and Kampong Cham. If the geographical locality now used for producing this kind of vegetable is converted for modern buildings, how should the displaced people earn their livelihoods? How can we get enough food products reaching the demands of consumers? On the other hand, to where should the waste water be drained? These main critical questions need to be answered before Cheung Ek Lake can be considered as a site for urbanisation.

Proposed solutions for solving negative impacts from lake contamination

Finding solutions for the security of Cheung Ek Lake and its surrounding environments must be a high priority in the short and intermediate terms. If the changes are not implemented quickly serious problems will inherited by future generations. Establishing strict policies and laws relating to municipal and industrial waste practices, crop cultivation on the lake and the building water treatment facilities should be implemented as soon as possible. As a preliminary step, the government should establish strict regulations for water spinach cultivation on the lake. Direct application of fertilizers and chemical pesticides on the lake should be minimised and municipal and industrial waste disposal practices must be closely monitored. The proper disposal of wastewater is crucial to the health of the community. The overriding advantage of proper wastewater disposal is the prevention of the spread of diseases. Human waste products contain bacteria and other micro-organisms that cause serious and costly long term diseases such as typhoid fever and hepatitis. If the disposal of wastewater containing disease-causing micro-organisms continues to be unregulated, deadly diseases have the potential of being transmitted throughout the local community. Another benefit of proper wastewater disposal is the protection of the lake from pollution, which can negatively affect fish populations and can promote the growth of weeds and algae destroying the productivity of the lake. In the long-term, industrial wastewater should be treated separately from domestic wastewater, by enforcing the requirement for each industry to obey discharge limits (maximum levels of heavy metals, etc.), as is done in developed countries.

It is recommended that a wastewater treatment plant should be established to reduce pollutants flowing unchecked into the lake. A basic wastewater treatment plants could treat and remove dangerous, disease causing bacteria and suspended solids before allowing remaining water, called effluent, to be discharged into the environment. By combining strict regulations and with the establishment of a wastewater treatment plant, the Cambodian Government can begin to be effective in reducing problems already occurring in this lake area and work towards an environment that is productive and healthy.

Proposed waste water treatment plant

An effective wastewater treatment plant has three stag-

Table1. Comparison in terms of cost-benefit effectiveness between doing nothing or draining the lake and setting up waste-water treatment plant

Option	Advantage	Disadvantage
Doing nothing/draining the lake	– No cost to set up the plant – Industry does not need to pay the cost to sustain the water treatment plants for their waste – No space needed for the wastewater treatment plant – No infrastructure need be built	– Long-term health effects on local people living in Cheung Ek Lake communities – Unhealthy food products from the lake – The lake will contain more chemical waste and polluted substances – Cost more for local people for medical bills – More wastewater-borne diseases – Need for removal of residents at some stage
Setting up wastewater treatment plant	– Positive health benefits for local community – More healthy food will be produced – Clean water can be re-used for agricultural purposes and more agricultural production activities – The lake can be a tourist attraction site after the water is treated	– Require a large amount of money for the plant – Build infrastructure for the plant set up – Industry in the city will need to pay for draining their waste, and then passing costs on to their customers – Large space is required to set up the plant

es of processing (see Figure 1).

Stage 1: the primary treatment starts with the mechanical agitation (Macerator) without aeration. The waste elements are broken into small pieces which results in faster and more complete breakdown in subsequent biological processes. Organic waste is removed at this stage but not other sorts of pollution such as nutrients or pathogens, leaving a material containing only water-soluble compounds, pathogens, small solid particles and liquid droplets.

Stage 2: a coagulant is added to the treated material from Stage 1; the coagulant, comprising a polymeric flocculant, causes the solid particles to stick together to form an aggregate. The mechanism for this is complex, but the simplest description is that the polymer acts like a long rope which attaches itself to many particles and thus causes these bound particles to collide with and stick to other collections of bound particles. The result is a macroscopic solid which can settle out of suspension or which can be filtered off. The polymers (which are typically added at the parts per million, ppm, level) produce no significant additional solids and reduce waste sludge volume. It can also result in higher-quality water for re-use.

With polymeric flocculants, the effluent produced is essentially free of bacteria and solid pollutants; although the volume of the recovery water will be lower than the inflow volume. An aerator is used to improve formation of the sludge treatment and removal of common pollutants through biological processes. An aerobic process is used to avoid odours and digested sludge coming to the water surface, while floating solids are retained by a scum board in the inlet area. With an aeration process, the effluent produced has significantly better water quality, and the final discharge may contain dissolved oxygen which reduces the immediate oxygen demand on the receiving water. The aerobic environment can also eliminate many pathogens present in agricultural wastes.

Stage 3: settling ponds are used to produce high-quality treated water. The processed water is allowed to stand temporarily in the ponds. The sludge will then sink to the bottom of the ponds and the higher-quality water will be at the surface. Then, the recovery water is drained back into the lake with a much higher quali-

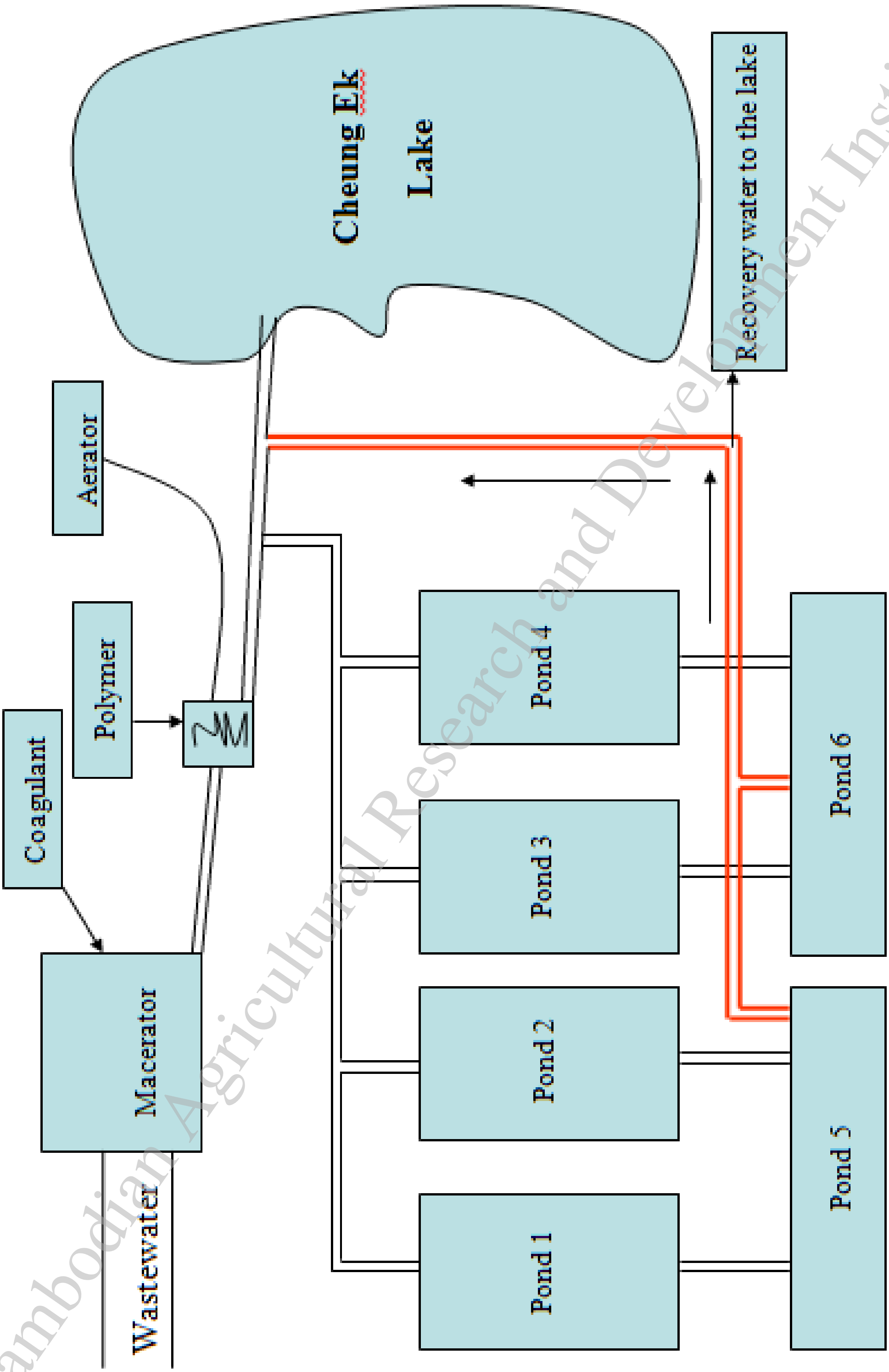


Figure 2. Proposed model of water treatment plants for Cheung Ek Lake region.

ty. Although this whole process requires significant nation-building investment, including the specialists needed to set up the treatment system and the settling ponds, the benefits for sustainable waste management will be enormous.

Positive impact of wastewater treatment

The economic question then becomes the quantification of the cost of:

1. Setting up a water treatment/purification process (high short-term costs) and running this over the years (relatively small intermediate- and long-term costs),
2. Doing nothing (no short-term costs, extremely high intermediate- and long-term costs),
3. Draining the lake and using the land for commercial and housing purposes, which will have short-term profit and enormous intermediate and long-term costs.

An appropriate treatment plants need to be implemented because it is the most effective solution to treat the wastewater from both commercial and domestic waste. Initially, if there is a high cost investment to set up this kind of system for just a single lake. However, it is very cost effective if it is offset against the negative impacts on public and environmental health from doing nothing. This enormous expense from negative cost factors will put more pressure on the government and also on the households who live and work on the lake and the people who consume the products from the lake. If the pollution continues, remediation of these problems will require a longer clean-up period and huge expense. Thus, operations on wastewater treatment should be implemented immediately so the situation is still at a stage where it can be solved with relatively small negative impacts. While the cost of building water treatment plants is high, the costs of *not* doing so can become staggering.

Conclusions

Cheung Ek Lake is a vital economic resource on the urban margin of Phnom Penh. For the about 500 families directly living on the lake it is their home and represents their livelihood. The agricultural activities provide a vital fresh food source for markets in Phnom Penh and surrounding economic hubs. This rural economy also involves growers, wholesalers, distributors and local customers, and provides a valuable trade network in essential commodities such as foodstuffs and animal fodder. However, if the large peri-urban water body of Cheung Ek Lake is to remain viable, a rapid response to the problem of wastewater must be initiated. The considerable volumes of untreated industrial and municipal waste water that currently flow into the lake will, in time, cause irreversible contamination of this resource. Contaminates, such as heavy metals and organic wastes from industrial sources, disease-causing agents from untreated human and animal wastes and excess nutrients, can cause chronic and debilitating health issues in the population around the lake. Although the first signs of health problems are likely to appear in the local community, with an established trade in contaminated goods and population movement, the illness and disease will spread more widely. This constitutes a massive future medical bill for the Cambodian Government compounded by rising employment difficulties when people are unable to work or take sick leave.

To reverse this bleak picture a relatively simple process of wastewater treatment should be implemented as soon as possible. Treating municipal and industrial waste at the most basic level is the first step. This basic plant can then be extended and expanded until waste water is being treated to a high quality. Swift implementation of this proposal, coupled with more strict regulations on industries and municipal groups that produce waste as well as controlling farming practices on the lake, will allow Cheung Ek Lake to regain its place in the economics of this region and vastly improve the health and well being of people who live and work there.

References

Ali, M. and Soltan, M. E. (1999). Heavy metals in aquatic macrophysics, water and hydro soils from the river Nile. Egypt. *Journal of Union of Arab Biology*. Cairo, **9**: 99-115

Alloway, B. J. and Ayres D. C., (1993). 'Chemical principles of environmental pollution'. London: Chapman and Hall. 1993.

Anh, V. T., Cam, P. D., Phuong, P. T., Hoek, W., Chan, V., and Dalsgaard, A. (2004). A study on skin problems among people engaged in wastewater-fed culture of water spinach in Phnom Penh, Cambodia. PAPUSSA Annual report 2004.

Anh, V. T., Tram, N. T. , Klank, L. T., Cam, P. D. and Dalsgaard, A. (2007). Faecal and protozoan parasite contamination of water spinach (*Ipomoea aquatica*) cultivated in urban wastewater in Phnom Penh, Cambodia. *Tropical Medicine and International Health,* **12**, 73–81.

Balmisse, A.L. and Sylvain, M. (2005). Traitement par language des eaux esées de la ville de Phnom Penh. Raport intermédiare N^{o}1 : Caractérisation des eaux usées de Phnom Penh et du Boeung Cheung Ek. Phnom Penh, septembre. Edit. Project FSP d'appui à l Municipalité de Phnom Penh. 76p.

Blumenthal, U. J., Cifuentes, E., Bennette, S., Quiqley, M. and Ruize-Palacios, G. (2001). The risk of enteric infections associated with wastewater reuse: the effect of season and degree of storage of wastewater. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **95**, 131–137.

Blumenthal U. J., Peasey, A., Quigley, M. and Ruiz-Palacios, G. (2003). Risk of Enteric Infections through Consumption of Vegetables with Contaminated River Water. London School of Hygiene and Tropical Medicine, London.

Bolognesi C., Landini, E., Roggieri, P., and Viarengo, A. (1999). Genotoxicity biomarkers in assessment of heavy metals effects in mussels. *Environmental and Molecular Mutagenesis*, **33**, 287-292.

Bowman, J. (1994). 'Water is best': Would Pindar still think so? In: Cartledge, B., ed. 'Health and the environment: The Linacre lectures 1992-3'. Oxford, Oxford University Press. p. 85-125.

Chen, M. -H. and Chen, C. -Y. (1999). Bioaccumulation of sediment-bound heavy metals in grey mullet, *Liza macrolepis*. *Marine Pollution Bulletin*, **39**(1-12), 239-244.

Cifuentes, E. (1998). The epidemiology of enteric infections in agricultural communities exposed to wastewater irrigation: perspectives for risk control. *International Journal of Environmental Health Research* **8**, 203–213.

Dalsgaard, A.,Anh, V.T., Phoung, D. C., Wim V. D. H., and Chan, V., (2005). Skin Diseases Among People Using Urban Wastewater in Phnom Penh. *Urban Aquaculture Magazine* **14**, 30-31

Doyle J. E. Jr., and Dolores G. E. (1997). *Escherichia Coli* in Diarrheal Disease. *J. Clin. Invest.* **92**,141, 1993

FAO (1992). Wastewater Treatment and Use in Agriculture. FAO Irrigation and Drainage Papers-47

Guo, X., van Iersel M. W., Chen, J., Brackette, R. E. and Beuchat, L. R. (2002). Evidence of association of Salmonellae with tomato plants grown hydroponically in inoculated nutrient solution. *Applied and Environmental Microbiology* **68**, 3639–3643.

Habbari, K., Tifnouti, A., Bitton, G. and Mandil, A. (1999). Raw waste water agricultural reuse and risk of protozoan infection in Beni-Mellal, Morocco. *Journal of Egyptian Public Health Association* 74, 353–369

Jarup, L. (2003). 'Hazards of heavy metal contamination'. Department of Epidemiology and Public Health, Imperial College, London, UK.

Khan, A.H. (1997). The sanitation gap: Development's deadly menace. In: 'The progress of nations'. New York, UNICEF. p. 5-13.

Kuong, K., Daream, S., Borin, C. (2005). Peri-urban aquatic food production systems in Phnom Penh. *Urban Aquaculture Magazine* **14**, 13–15

Langston, W. J. (1998). Toxic effects of metals and the incidence of metal of marine ecosystems: In: Furness R. W., Rainbow, P. S., editors. 'Heavy metals in the marine environment'. Bocaraton: CRC Press, 1998. p. 101-122

Liu David H. F., Bela G. Liptak (1999). 'Environmental Engineer's handbook'. *Vol. 3.*

Maywald, A., Zeschmar-lahl, B., and Lahl, U. (1998). Water fit to drink? In: Goldsmith, E. and Hildyard, N., eds. 'The earth report: Monitoring the battle for our environment'. London, Mitchell Beazley. p. 79-88.

Muong, S. (2004). Avoiding Adverse Health Impacts for Contaminated Vegetables: Options for Three Wetlands in Phnom Penh, Cambodia. Economy & Environment Program for South East Asia (EEPSEA). Available on: www.eepsea.org

Outridge , P. M., Noller B.N. (1991).Accumulation of toxic trace elements by fresh water vascular plants. *Rev. Environ. Contam. Toxicology* **121**, 2-63

Sar, S., Chervier, C., Lim, P., Warrender, C., Warrender, G. W., Gilbert, R. G. (2010). Seasonal Direct-Use Value of Cheung Ek Peri-Urban Lake, Phnom Penh, Cambodia. *International Journal of Environmental and Rural Development* **1**, 113-118

Seyha, S and Tuan Anh, V. (2004). Case study of Skin problems of a farmer engaged in water morning glory in Boeung Cheung Ek, Phnom Penh, Cambodia. Royal University of Agriculture, Phnom Penh, Cambodia, National Institute of Hygiene and Epidemiology, Hanoi, Vietnam, pp 1-6.

Shuval, H. I., Wax, Y., Yekutiel, P. and Fattal, B. (1989). Transmission of enteric disease associated with wastewater irrigation: a prospective epidemiological study.

American Journal of Public Health **79**, 850–852.

Silfverberg, P. (1994). Environmental health hazards. In: Lankinen, K.S., Berström, S., Mäkelä, P.H., and Peltomaa, M., eds. 'Health and disease in developing countries'. London, Macmillan Press. p. 67-78.

Sobel, J. D., Kaye, D. (1995). Urinary tract infections. In: Mandell G. L., Bennett J. E., Dolin R (eds): 'Principles and practice of infectious diseases'. Churchill Livingstone, New York, pp 662–690

Solomon, E. B., Yaron, S. and Matthews, K. R., (2002). Transmission of *Escherichia coli* O157:H7 from contaminated manure and irrigation water to lettuce plant tissue and its subsequent internalization. *Applied and Environmental Microbiology* 68, 397–400.

Teang, P. (2009). Spatial Occupation by Human Activity in Cheung Ek Inundated Lake. Master Thesis, Graduate School of Agricultural Sciences, Royal University of Agriculture, Phnom Penh, Cambodia, pp86.

United Nations, (1997). Department for Policy Coordination and Sustainable Development. Critical trends—Global change and sustainable development. New York, UN. p. 43-56.

Vallee, B. L. and Falchuk, K. H., (1993). The biochemical basis of zinc physiology. *Physiological Reviews* **73**, 79-118.

WHO, (2006). Guidelines for the Safe Use of Wastewater, Excreta and Grey water: *Wastewater Use in Agriculture*, Vol. 2. World Health Organisation, Geneva, Switzerland.

Warner, D., (1998). Drinking water supply and environmental sanitation for health. Presented at the International Conference of Water and Sustainable Development, Paris, Mar. 19-21. p.1-

World Health Organisation, (1997). Health and environment in sustainable development five years after the earth summit. Geneva, WHO. p. 19-133.

Author Index

Cambodian Journal of Agriculture
Volume 10, January-December 2011

NAME OF REVIEWER IN YEAR 2011

Nº	Name	Institution	Contact Address
01	Dr. Dule Zhao	IRRI Representative in Cambodia	d.zhao@cgiar.org
02	Dr. Duncan A. Vaughan	FAO Regional office for the Asia and Pacific	Duncan.Vaughan@fao.org
03	Dr. El Sotheary	Socio-Economic Division of CARDI	esotheary@cardi.org.kh
04	Dr. Pheav Sovuthy	General Directorate of Agriculture (GDA)	sovuthypheav@yahoo.com

សេចក្ដីជូនដំណឹង

វិទ្យាស្ថានស្រាវជ្រាវ និងអភិវឌ្ឍន៏កសិកម្មកម្ពុជា មានកិត្តិយសសូមជម្រាបជូនដំណឹងដល់ លោក លោកស្រី អ្នកនាងកញ្ញា ជាអ្នកស្រាវជ្រាវទាំងអស់ ឱ្យបានជ្រាបថា ដោយយល់ឃើញពីគុណសម្បត្តិ និងសារប្រយោជន៏នៃទស្សនាវដ្ដីកសិកម្មកម្ពុជា ក្នុងការផ្ដល់លទ្ធភាពជូនអ្នកស្រាវជ្រាវខ្មែរ ទាំងឡាយឱ្យមានឱកាសបង្កើនសមត្ថភាពស្រាវជ្រាវរបស់ខ្លួនតាមរយៈការសរសេរ ការបកស្រាយ និងចូលរួមពិភាក្សានូវរាល់គំហើញវិទ្យាសាស្ត្រផ្សេងៗ ដែលជាកត្តាចាំបាច់មិនអាចខ្វះបានសម្រាប់អ្នកស្រាវជ្រាវ ដើម្បីជាការពង្រឹងវិស័យស្រាវជ្រាវជាតិ ហើយក៏ដើម្បីជាកិត្តិយសដ៏ខ្ពង់ខ្ពស់សម្រាប់ប្រទេសជាតិយើងដែរនោះ វិទ្យាស្ថានស្រាវជ្រាវ និងអភិវឌ្ឍន៏កសិកម្មកម្ពុជា បានខិតខំព្យាយាមជំរុញឱ្យមានការបង្កើតឡើងនូវទស្សនាវដ្ដីកសិកម្មកម្ពុជានេះ និងធ្វើយ៉ាងណាឱ្យទស្សនាវដ្ដីនេះបានរស់រានជីវិតឡើងវិញក្រោយពីត្រូវអាក់ខានមួយរយៈ។

នាពេលបច្ចុប្បន្ន ក្រោយពីមានការបង្កើតឡើងជាថ្មីនូវក្រុមប្រឹក្សាពិនិត្យ (Editorial Board) របស់ទស្សនាវដ្ដី ដែលមានការចូលរួមពីអង្គភាពពាក់ពន្ធ័ជាច្រើន វិទ្យាស្ថានបាននិងកំពុងរៀបចំដំណើរការបោះពុម្ពទស្សនាវដ្ដីកសិកម្មកម្ពុជា (Cambodian Journal of Agriculture) នេះឱ្យមានជាប្រក្រតីភាពឡើងវិញ ដូចដែលវិទ្យាស្ថានធ្លាប់បានធ្វើការរៀបចំ និងបោះពុម្ពផ្សាយជាហូរហែរកន្លងមកដើម្បីជាការផ្សព្វផ្សាយទាំងក្នុង និងក្រៅប្រទេស។

អាស្រ័យហេតុនេះ ដើម្បីឱ្យទស្សនាវដ្ដីនេះអាចមានសកម្មភាព និងដំណើរការទៅមុខបាន វិទ្យាស្ថានស្រាវជ្រាវ និងអភិវឌ្ឍន៏កសិកម្មកម្ពុជា ក៏ដូចជាក្រុមប្រឹក្សាពិនិត្យនៃទស្សនាវដ្ដីកសិកម្មកម្ពុជា មានក្ដីសង្ឃឹមយ៉ាងមុតមាំ និងជឿជាក់ចំពោះការចូលរួមគាំទ្រពីសំណាក់ លោក លោកស្រី អ្នកនាងកញ្ញា ទាំងឡាយដែលមានបំណងចង់បង្ហាញពីការរកឃើញវិទ្យាសាស្ត្រផ្សេងៗ ក៏ដូចជាបទពិសោធន៏ល្អៗជូនដល់អ្នកស្រាវជ្រាវដទៃៗទៀត និងក៏ដូចជាចង់ជួយពង្រឹងវិស័យស្រាវជ្រាវជាតិយើងផងដែរក្នុងការផ្ដល់នូវអត្ថបទស្រាវជ្រាវផ្សេងៗសម្រាប់ជាការបោះពុម្ពក្នុងទស្សនាវដ្ដី។

សូមអរគុណ

ព័ត៌មានបន្ថែមសូមទំនាក់ទំនង:

វិទ្យាស្ថានស្រាវជ្រាវ និងអភិវឌ្ឍន៏កសិកម្មកម្ពុជា

ផ្លូវជាតិលេខ ៣ សង្កាត់ប្រទះឡាង ខណ្ឌដង្កោ រាជធានីភ្នំពេញ

ប្រអប់សំបុត្រលេខ ០១ ភ្នំពេញ

ទូរស័ព្ទលេខ: (៨៥៥-២៣) ៦៣១៩ ៦៩២ / ០១១ ៨១៨ ៧៩៨

ទូរអក្ខរ: ou.makara@cardi.org.kh / cc: tchanna@cardi.org.kh / cja@cardi.org.kh

ការណែនាំសម្រាប់អ្នកនិពន្ធ

គម្រូវការទូទៅ

ការបោះពុម្ពផ្សាយនៅក្នុងទស្សនាវដ្ដីកសិកម្មកម្ពុជា (CJA) អាចជារបាយការណ៍ដើមនៃលទ្ធផលស្រាវជ្រាវ (អត្ថបទ ឬ កំណត់ត្រាខ្លីៗ) អាចជាលិខិតដែលបញ្ជូនទៅអ្នកត្រួតពិនិត្យ ជាការផ្សព្វផ្សាយពាណិជ្ជកម្ម ឬការប្រកាសនូវដំណឹងនានា។ កំណត់ត្រាស្រាវជ្រាវមិនត្រូវសរសេរលើសពី ២ ទំព័រ ទេ ឯការផ្សព្វផ្សាយវិញក៏មិនត្រូវឱ្យលើសពីកន្លះទំព័រដែរ។

តួអត្ថបទ ឬកំណត់ត្រា

អត្ថបទដែលបានរៀបចំត្រូវផ្ញើរមកអ្នកពិនិត្យដោយប្រព័ន្ធអេឡិចត្រូនិក (តាមរយៈទូរអក្ខរ ឬ តាមរយៈថាស) ក្នុងនោះត្រូវមាន តារាង និងក្រាហ្វិក ឯកសារយោង ចំណងជើងតារាង និងចំណងជើងក្រាហ្វិក។ រូបភាពត្រូវតែជារូបដើម ឬថតចំលង (Scan) ឱ្យច្បាស់ដើម្បីធានានូវគុណភាពរបស់រូបសម្រាប់ទស្សនាវដ្ដី។ អត្ថបទដែលផ្ញើរមកកាន់ទស្សនាវដ្ដីកសិកម្មកម្ពុជា (CJA) អាចជាភាសាអង់គ្លេស ឬភាសាខ្មែរ។ ក្នុងករណីដែលអត្ថបទជាភាសាអង់គ្លេសត្រូវប្រើប្រភេទអក្សរ Time New Roman ដោយមានការបកប្រែជាភាសាខ្មែរនូវចំណងជើង និងសង្ខេបដោយប្រើប្រភេទអក្សរ Limon។ ចំពោះអត្ថបទជាភាសាខ្មែរត្រូវប្រើប្រភេទអក្សរ Limon ដោយមានការបកប្រែជាភាសាអង់គ្លេសនូវចំណងជើង និងសេចក្ដីសង្ខេបដោយប្រើប្រភេទអក្សរ Times New Roman ។

រចនាសម្ព័ន្ធ

ចំណងជើង : ត្រូវនៅទំព័រទី១ នៃអត្ថបទ ឬ កំណត់ត្រា។ ចំណងជើងត្រូវសរសេឱ្យបានខ្លី ប៉ុន្តែច្បាស់លាស់ និងឆ្លើយតបទៅនឹងអត្ថបទ។

អ្នកនិពន្ធ : នៅខាងក្រោមចំណងជើង ត្រូវដាក់ឈ្មោះអ្នកនិពន្ធទាំងអស់ដែលពាក់ព័ន្ធក្នុងការងារស្រាវជ្រាវ។ ដកឃ្លាពីឈ្មោះអ្នកនិពន្ធមួយទៅឈ្មោះ អ្នកនិពន្ធមួយដោយប្រើសញ្ញា Comma (,) ហើយឈ្មោះអ្នកនិពន្ធចុងក្រោយគេត្រូវដាក់ឈ្នាប់ " និង " "and" នៅពីមុខ។ ឈ្មោះអ្នកនិពន្ធ/អត្ថបទនានា គួរតែមាននៅក្នុង Footnote នៃទំព័រទី១។ គួររៀបចំជាបញ្ជីនូវឈ្មោះអ្នកនិពន្ធ និងបញ្ជាក់ពីអាស័យដ្ឋាន និងឯកសារពាក់ព័ន្ធផ្សេងៗនៅក្នុងឃ្លាទី១នៃ Footnote ហើយក្នុងឃ្លាទី២ គួរដាក់បញ្ចូលនូវ ប្រភពមូលនិធិ ប្រសិនបើពុំទាន់បានបង្ហាញនៅក្នុងសេចក្ដីថ្លែងអំណរគុណ។

សេចក្ដីសង្ខេប : អត្ថបទនិមួយៗត្រូវមានសេចក្ដីសង្ខេបជាពីរភាសា គឺភាសាខ្មែរ និងភាសាអង់គ្លេស។ សេចក្ដីសង្ខេបត្រូវឱ្យខ្លីតែច្បាស់លាស់ហើយត្រូវសរសេរមិនលើសពី ២៥០ ពាក្យ សម្រាប់អត្ថបទ និង ១៥០ ពាក្យ សម្រាប់កំណត់ត្រា។ ត្រូវរៀបរាប់អំពីសនិទានភាព ទិសដៅ វិធីសាស្ត្រ លទ្ធផលគន្លឹះ និងសារៈសំខាន់របស់វា ពិសេសសម្រាប់កសិកម្មកម្ពុជា។ បន្ទាប់ពីរៀបសេចក្ដីសង្ខេបត្រូវរៀបចំតាមលំដាប់លំដោយ សេចក្ដីផ្ដើម ដែលរួមបញ្ចូលនូវការវិភាគទៅលើបណ្ណាល័យសាស្ត្រ ពាក់ព័ន្ធហើយបន្តដោយខ្លីៗ សម្ភារៈ វិធីសាស្ត្រ លទ្ធផល ការពិភាក្សា សេចក្ដីសន្និដ្ឋាន (អាស្រ័យលើអ្នកនិពន្ធ) សេចក្ដីថ្លែងអំណរគុណ (អាស្រ័យលើអ្នកនិពន្ធ) និងឯកសារយោង។ លទ្ធផល និងការពិភាក្សាអាចបញ្ចូលគ្នា ហើយសេចក្ដីសន្និដ្ឋានអាចមាននៅក្នុងផ្នែកពិភាក្សា។

តារាង : តារាងទាំងអស់ត្រូវដាក់លេខរៀង ហើយត្រូវមានចំណងជើង។ Headnote ដែលមានព័ត៌មានផ្សេងៗពាក់ព័ន្ធទៅនឹងតារាងទាំងមូល គួរចាប់ផ្ដើមនៅបន្ទាត់ថ្មីមួយ។ តារាងគួររៀបចំទៅតាមទំហំកូឡោនគំរូរបស់ទស្សនាវដ្ដី (ទំហំ ៨ ស.ម ទៅ ២១ ស.ម) ហើយចំនួនកូឡោននៅក្នុងតារាងគួរឱ្យមានចំនួនតិច។ ការបំបែកចំណងជើងតូចៗ ពីចំណងជើងកូឡោនមេច្រើនពេកគឺមិនល្អទេ ហើយចំណងជើងវែងពេកក៏គួរជៀសវាងដែរ ដោយប្រើការសរសេរពន្យល់ខ្លីៗជំនួសវិញ ដែលការសរសេរទាំងនោះមានលក្ខណៈស៊ីគ្នាទៅនឹង Head note។ តួអក្សរទី១ នៅខាងដើមគួរសរសេរជាអក្សរធំ។

និម្មិតសញ្ញា នៃខ្នាតរង្វាស់ផ្សេងៗ គួរដាក់ក្នុងរង្វង់ក្រចកខាងក្រោមចំណងជើងកូឡោន។ បុព្វបទសម្រាប់ឯកតាគួរជ្រើសរើសយ៉ាងណាមិនឱ្យមានចំនួនលេខច្រើនពេក។ ក្នុងករណីមិនអាចជៀសវាងបានគួរដាក់ចំនួននោះដោយមេគុណ ១០ នូវរាល់តំលៃទាំងឡាយក្នុងតារាង។ កំណត់សំគាល់ខាងក្នុងតារាងគួរតែរក្សាទំហំអក្សរឱ្យតូច និងត្រូវរក្សាទុកសម្រាប់ការបរិយាយជាក់លាក់ផ្សេងៗក្នុងកូឡោន។

បន្ទាត់ផ្ដេកអាចដាក់ខាងលើ និងខាងក្រោមចំណងជើងក្រឡោន និងនៅខាងក្រោមបង្អស់នៃតារាងតែប៉ុណ្ណោះ។ ចំពោះបន្ទាត់បញ្ឈរវិញមិនគួរប្រើទេ។ រាល់តារាងនិមួយៗត្រូវឆ្លើយតបនៅក្នុងអត្ថបទ ហើយចំណុចសំគាល់តូចមួយនៅក្នុងគែមទំព័រ (Margin) គួរសរសេរបង្ហាញពីទីតាំងពិតប្រាកដរបស់តារាងនៅក្នុងអត្ថបទ។ តារាងខ្លីៗអាចដាក់បញ្ចូលទៅក្នុងអត្ថបទក្នុងលក្ខណៈជាប្រយោគ និងមិនចាំបាច់មានចំណងជើងទេ។ លើកលែងតែក្នុងករណីពិសេសប៉ុណ្ណោះដែលទិន្នន័យអាចត្រូវបានបង្ហាញទាំងក្នុងតារាង និងក្នុងក្រាហ្វិក។ បើពុំនោះទេគួរប្រើក្រាហ្វិកវិញក្នុងករណីចាំបាច់។

ក្រាហ្វិក ៖ ក្រាហ្វិកទាំងឡាយណាដែលមិនល្អ (ឧ. ក្រាហ្វិក ស្ថិតក្នុងទ្រង់ទ្រាយពិបាកអាន/យល់) នឹងត្រូវបញ្ជូនឱ្យយកទៅពិនិត្យដើម្បីកែសម្រួលឡើងវិញ។ ចំពោះអ្នកនិពន្ធដែលមិនអាចរៀបចំជាក្រាហ្វិកផ្សេងៗបាន គួរទំនាក់ទំនងជាមួយអ្នកត្រួតពិនិត្យ។ សញ្ញា បូក (+) រឺ គុណ (x) គួរជៀសវាង។ ការពន្យល់ពីនិម្មិតសញ្ញាផ្សេងៗគួរតែដាក់នៅក្រោមចំណងជើងនៃក្រាហ្វិក ហើយអក្សរដែលដាក់ក្នុងក្រាហ្វិក គួរមានជាអប្បបរិមា។ អក្សរទាំងពីរនៃក្រាហ្វិក ត្រូវបញ្ជាក់ពីបរិមាណដែលបានវាស់ថ្មីៗ ឬរាប់ហើយត្រូវដាក់ឯកតា SI ក្នុងរង្វង់ក្រចក។

រូបថត ៖ រូបថតត្រូវមានគុណភាពច្បាស់ល្អ។ លក្ខណៈសំខាន់ៗនៃរូបថតដែលត្រូវបានបញ្ជាក់គឺច្បាស់លាស់នៅក្នុងអត្ថបទ ត្រូវតែបង្ហាញឱ្យបានច្បាស់ (ឧ. ដាក់លេខកូដនៅពីលើអក្សរ / ដាក់សញ្ញាព្រួញ)។ រូបថតពណ៌ធម្មជាតិ នឹងត្រូវទទួលយក ប្រសិនបើវាមានសារៈសំខាន់ក្នុងការជួយឱ្យងាយយល់ពីលទ្ធផលផ្សេងៗ។

នាមវល្លិ ៖ ចំពោះរុក្ខជាតិ, ភ្នាក់ងារចំលងជំងឺ និងកត្តាចង្រៃផ្សេងៗ ត្រូវសរសេរជាអក្សរឡាតាំងក្នុងទំរង់ទ្រេត និងអ្នកដែលបានប្រើប្រាស់/បរិយាយមុនគេ (ឧ. rice, *Oryza sativa* L.)។

ខ្នាតរង្វាស់ ៖ ប្រព័ន្ធខ្នាតរង្វាស់អន្តរជាតិ (SI) ត្រូវយកមកប្រើប្រាស់ក្នុងរាល់អត្ថបទដែលត្រូវផ្ញើរមកទស្សនាវដ្តីកសិកម្មកម្ពុជា។ ខ្នាតរង្វាស់ផ្សេងទៀតអាចបង្ហាញនៅក្នុងរង្វង់ក្រចកខាងក្រោយខ្នាតរង្វាស់ SI បើសិនជាខ្នាតរង្វាស់ទាំងនេះអាចជួយសម្រួលឱ្យកាន់តែងាយយល់អំពីការងារដែលបានរៀបរាប់ពីខាងដើម។ ខ្នាតរង្វាស់ដែលត្រួតភ្ជាប់គ្នាពីរដង មិនត្រូវប្រើប្រាស់ទាំងនៅក្នុងទំរង់ជាឯកតាស្មុគស្មាញពេកទេ (ឧ.គួរប្រើ mg/sheep. day, មិនគួរប្រើ mg/sheep/day or mg^{-1} $sheep^{-1}$ day^{-1})។ ទស្សនាវដ្តីកសិកម្មកម្ពុជា ត្រូវប្រើអក្សរកាត់ "L" សម្រាប់ឯកតាគិតជា លីត្រ "mL" សម្រាប់ឯកតាគិតជា មីលីលីត្រ។ ខ្នាតរង្វាស់សម្រាប់ប្រើប្រាស់ក្នុងបណ្តូរអ៊ីយ៉ុង (mmol/kg) គួរប្រើចំពោះប្រភេទបណ្តូរ អ៊ីយ៉ុងទោល ឧ. Na^{+}, K^{+}, $CaO.5^{+}$។ ឯកតាដែលណែនាំឱ្យប្រើសម្រាប់បណ្តូរអ៊ីយ៉ុង និងសម្រាប់សមត្ថភាពបណ្តូរអ៊ីយ៉ុង គឺ cmol(+)/kg [ឬ cmol(-)/kg] កន្លែងដែលមានបញ្ញា (+) រឺ (-) គឺសំដៅលើអាយ៉ុង និងការចុង (បន្ទុកអគ្គីសនី)។ ឯកតាដែលណែនាំឱ្យប្រើសម្រាប់ថាមពលកំដៅអគ្គីសនី គឺ dS/m ប៉ុន្តែខ្នាត mS/cm ត្រូវបានគេទទួលស្គាល់ជាង។

ការវាយតម្លៃលើលទ្ធផល

អត្ថបទស្រាវជ្រាវត្រូវមានការពិពណ៌នាដោយសង្ខេប និងច្បាស់លាស់ ស្តីពីវិធីរៀបចំប្លង់ពិសោធន៍ និងលំអិត ក្នុងករណីដែលការវិភាគវ៉ារីយ៉ង់ ឬការវិភាគតាម Regression Models ត្រូវបានប្រើក្នុងការវាយតំលៃដើម្បីឱ្យអ្នកអានអាចយល់ច្បាស់អំពីវិធីគណនារកក៏រិតលំអៀង។ ការវិភាគស្ថិតិ គួរពិពណ៌នា ដោយសង្ខេប ហើយប្រសិនបើចាំបាច់ត្រូវភ្ជាប់ឯកសារយោងជាជំនួយផង។ ចំនួនឯកត្តាតម្លៃមធ្យម និងរង្វាស់អំពីបំរែបំរួលផ្សេងៗគួរត្រូវបានបង្ហាញ។

ឯកសារយោង

ឯកសារយោង ត្រូវបានលើកយកមកសំអាងដោយឈ្មោះអ្នកនិពន្ធ និងមានដាក់កាលបរិច្ឆេទច្បាស់លាស់ (ប្រព័ន្ធរបស់លោក Harvard) ហើយមិនត្រូវសរសេរជាលេខទេ។ រាល់ឯកសារយោងទាំងអស់នៅក្នុងអត្ថបទ ត្រូវដាក់បញ្ចូលទៅក្នុងបញ្ជីនៅទំព័រចុងក្រោយបំផុតនៃទស្សនាវដ្តី ដោយមានបញ្ជាក់ពីឈ្មោះអ្នកនិពន្ធ ដែលត្រូវរៀបរៀងតាមអក្សរក្រម។ រាល់ឯកសារយោងដែលបានបញ្ចូលទៅក្នុងបញ្ជី ត្រូវតែដូចគ្នាទៅនឹងឯកសារយោងនៅក្នុងអត្ថបទ។ នៅក្នុងអត្ថបទ ឈ្មោះរបស់សហអ្នកនិពន្ធពីរនាក់ត្រូវភ្ជាប់ដោយឈ្នាប់ "និង" ប៉ុន្តែបើចាប់ពីបីនាក់ឡើងទៅ ដាក់ឈ្មោះអ្នកនិពន្ធទី១ រួចបន្តដោយ "*et al.*"។ ចំនួនដែលមានឯកសារយោងលើសពីមួយនៅក្នុងអត្ថបទ ឯកសារយោងទាំងនោះត្រូវដាក់តាមកាលប្បវត្តិត្រឹមត្រូវ។ ចំណងជើងឯកសារនិងលេខទំព័រដំបូង និងខាងចុងបំផុតត្រូវបង្ហាញនូវក្នុងរាល់ឯកសារយោងទាំងអស់។ អត្ថបទដែលមិនបានទទួលយកទៅបោះពុម្ពមិនអាចដាក់បញ្ចូលទៅក្នុងបញ្ជីឯកសារ យោងតែអាចបង្ហាញនៅក្នុងអត្ថបទដោយពាក្យថា "ទិន្នន័យមិនបានបោះពុម្ពផ្សាយ" ឬ "ទស្សនៈផ្ទាល់ខ្លួន"។ ប៉ុន្តែការប្រើប្រាស់ឯកសារយោងទាំងនេះគឺមិនត្រូវបានលើកទឹកចិត្តឱ្យប្រើទេ។ អ្នកនិពន្ធទាំងអស់គួរតែយកលំនាំតាមទស្សនាវដ្តី ដែលទើបនឹងចេញផ្សាយថ្មីបំផុតនូវរបៀបបង្ហាញឯកសារយោងផ្សេងៗ ទាំងក្នុងសៀវភៅ និងក្នុងអក្សរសិល្ប៍ផ្សេងៗ។ ចំណងជើងពេញនៃសាមាយិកប័ត្រត្រូវតែដាក់បង្ហាញមកជាមួយដែរ។

ខាងក្រោមនេះនឹងបង្ហាញពីគំរូខ្លះៗ នៃរបៀបដាក់ឯកសារយោងក្នុងអត្ថបទ ៖

Reference Style (Journal article)

Hubick KT, Farquhar GD, Shorter R (1986) Correlation between water-use efficiency and carbon isotope discrimination in diverse peanut *(Arachis)* germplasm. *Australian Journal of Plant Physiology* **13,** 803-816.

Wagner TE (1985) The role of gene transfer in agriculture. *Canadian Journal of Animal Science* **65,** 539-552.

Reference style (Journal article)

Blackmore DJ (1996) Are rural land practices a threat to the environment? In 'Soil science _ raising the profile'. (Ed. N Uren) pp. 22-30. (ASSSI and NZSSS: Melbourne)

Wolanski E, Mazda Y, Ridd P (1992) Mangrove hydrodynamics. In 'Tropical mangrove ecosystems'. (Eds AI Robertson, DM Alongi) pp. 43-62. (American Geophysical Union: Washington DC)

Reference style (book)

Lucas GB (1963) 'Diseases of tobacco.'(University of North Carolina: Raleigh, NC)
Attiwill PM, Adams MA (1996) (Eds) 'Nutrition of eucalypts.' (CSIRO Publishing: Melbourne)
Hogan B, Beddington R, Constantine F, Lacy E (1994) (Eds) 'Manipulating the mouse embryo _ a laboratory manual (2nd edn).' (Cold Spring Harbor Laboratory Press: Cold Spring Harbor, NY)

Reference style (thesis)

Silver MW (1970) An experimental approach to the taxonomy of the genus Enteromorpha (L.) Link. PhD Thesis, University of Liverpool, UK.

Reference style (Report or Bulletin)

Lea HW (1957) Report on a visit to the USA and Canada, April 1 to October 2, 1957. Department of Agriculture, Orange, NSW.
Chippendale GM, Wolf L (1981) The natural distribution of Eucalyptus in Australia. Australian National Parks and Wildlife Service, Special Publication No. 6, Canberra.

Reference style (Conference Proceedings)

Hayman PT, Collett IJ (1996) Estimating soil water: to kick, to core or computer? In 'Proceedings of the 8th Australian agronomy conference'. Toowoomba. (Dd. M Asghar) p. 664. (The Australian Society of Agronomy: Toowoomba, Qld)
Kawasu T, Koi K, Ohta T, Shinohara Y, Ito K (1990) Transformation of eucalypts (Eucalyptus saligna) using electroporation. In 'Proceedings of the VIIthinternational congress on plant tissue and cell culture'. pp. 64-68. (Amsterdam IAPTC: Amsterdam)

ការរក្សាសិទ្ធិ

ដើម្បីផ្តល់អត្ថបទឱ្យមកបោះពុម្ពផ្សាយ ត្រូវធានាថាលទ្ធផលដែលបានធ្វើរបាយការណ៍មិនបាន ឬមិនធ្លាប់បោះពុម្ពផ្សាយ ឬកំពុងត្រៀមបោះពុម្ពផ្សាយនៅកន្លែងណាផ្សេង។ សេចក្តីសង្ខេបលទ្ធផលនៃការរកឃើញនៃសន្និសីទ ឬនៅក្នុងអត្ថបទបោះពុម្ពផ្សាយណាមួយមិនត្រូវបានចាត់ទុកជាការបោះពុម្ពផ្សាយជាមុននោះទេ។ ទោះបីជាយ៉ាងណាក៏ដោយ ប្រសិនបើទិន្នន័យយ៉ាងច្រើនដូចជាតារាង និងក្រាហ្វិក ត្រូវបានបោះពុម្ពផ្សាយមុនហើយនោះ ការបន្ថែមទិន្នន័យខ្លះៗទៀតមិនអាចចាត់ទុកថាអត្ថបទនោះជាអត្ថបទថ្មីឡើយ។ ចំពោះអត្ថបទដែលមានអ្នកនិពន្ធច្រើនការផ្តល់នូវលំដាប់បោះពុម្ពដោយទស្សនាវដ្តី ត្រូវបានចាត់ទុកថាមានការឯកភាពគ្នារវាងអ្នកនិពន្ធទាំងនោះ។ ពេលផ្តល់អត្ថបទដល់ទស្សនាវដ្តីអ្នកនិពន្ធទាំងអស់ត្រូវចុះហត្ថលេខាលើបែបបទ "អាជ្ញាប័ណ្ណបោះពុម្ពផ្សាយ"។

អាសយដ្ឋានទំនាក់ទំនងសម្រាប់ការផ្តល់អត្ថបទ

ទស្សនាវដ្តីកសិកម្មកម្ពុជា (Cambodian Journal of Agriculture)
បណ្ឌិត អ៊ុក ម៉ាការា ប្រធានក្រុមប្រឹក្សាពិនិត្យទស្សនាវដ្តីកសិកម្មកម្ពុជា
ផ្លូវជាតិលេខ ៣ សង្កាត់ប្រទះឡាង ខណ្ឌដង្កោ រាជធានីភ្នំពេញ ព្រះរាជាណាចក្រកម្ពុជា
ប្រអប់សំបុត្រលេខៈ ០១ ភ្នំពេញ ព្រះរាជាណាចក្រកម្ពុជា
ទូរស័ព្ទលេខៈ (៨៥៥-២៣) ៦៣១៩ ៦៩២
ទូអក្ខរាៈ ou.makara@cardi.org.kh / cc: tchanna@cardi.org.kh / cja@cardi.org.kh

រាល់អត្ថបទទាំងអស់ត្រូវត្រួតពិនិត្យដោយអ្នកជំនាញ យ៉ាងតិចណាស់ពី ០២ នាក់ ឡើងទៅ។

SUGGESTIONS FOR CONTRIBUTORS TO THE *CAMBODIAN JOURNAL OF AGRICULTURE*

General requirement

Contributions to the *Cambodian Journal of Agriculture* (CJA) may be original reports of research (paper or note), letters to the editor, advertisements, or announcements. Research notes should not be more than two pages in length, while advertisements or announcements should not be more than ½ pages.

Manuscripts (Papers and notes)

Copies

Manuscripts should be submitted electronically, including any tables and figures, the references, table heads and figure captions. Photos must be original or scanned at magazine quality. The manuscript submitted to CJA can be in English (US) or in Khmer. In case the manuscript is in English, the test should be in Times New Roman font with a Khmer translation of the title and abstract in Limon font. For Khmer manuscript, the test should be in Limon font with an English translation of the title and abstract in Times New Roman.

Organization

Title: On the first page of either papers or notes. The title should be short but must accurately identify and describe the manuscript content. The title is, therefore, a highly condensed abstract with a maximum of 12 words.

Author(s): Below the title, list the names of all authors involved in conducting the research works. Separate the names of authors with comma (,) including before 'and' for the last author. Author/paper documentation should be included as a footnote of the first page. This should list the authors name and their complete current address and affiliation in the first paragraph. In the second footnote paragraph, the source of funding could be included if not already noted in the acknowledgements.

Abstract: Each paper must have abstracts: in both Khmer and English. It is limited in a self explanatory paragraph of not more than 250 words for papers and 150 words for notes. State the rationale, objectives, methods, key results and their significance especially for Cambodian agriculture. After the abstract the order of sections is an introduction, which includes a concise review of the relevant literature followed by materials and methods, results, discussion, conclusions (optional), acknowledgement (optional), and references. Results and discussion can be combined, and conclusions can be incorporated in the discussion section.

Style

Tables: Table must be numbered and each must be accompanied by a title. A head note containing material relevant to the whole Table should start on a new line. Table should be arranged with regard to the dimensions of the Journal columns (8 by 21 cm), and the number of column in the Table should be kept to a minimum. Excessive subdivision of column headings is undesirable and long heading should be avoided by the use of explanatory notes that should be incorporated into the head note. The first letter, only, of headings should be capitalized. Use asterisk (*, **, ***) only to indicate statistical significance at 0.05, 0.01, and 0.001 levels of probability, respectively.

The symbol of unit of measurement should be placed in parentheses beneath the column heading. The prefixes for units should be chosen to avoid an excessive number of digits in the body of the Table or scaling factors in the headings. When scaling factors cannot be avoided, the quantity expressed should be preceded by the power of 10 by which the value has been multiplied. Footnotes should be kept to a minimum and be reserved of specific items in the columns.

Horizontal rule should be inserted only above and below column heading and at the foot of the Table. Vertical rules should not be use. Each table must be referred to in the text, and a note in the margin should be indicate the preferred position of the Table in the text. Short table can frequently be incorporated into the text as a sentence or as a brief untitled tabulation. Only in exceptional circumstance will the presentation of essentially the same data in both a Table and a Figure be permitted where adequate, the Figure should be used.

Figures: Unsatisfactory Figures (i.e. in unreadable file formats) will be returned for correction. The symbols + or x should be avoided. Explanation of symbols should be given in the caption to the figure, and lettering of graphs should be kept to a minimum. Grid marks should point inwards; legends to axes should state the quantity being measured and be followed by the appropriate SI units in parentheses.

Photographs. Photographs must be of the highest quality, with a full range of tones and of good contrast. Important features to which attention has been drawn in the text should be indicated (i.e. by coded upper case letters and/ or arrows). Colour photographs will be accepted if they are essential to understanding the results.

Nomenclature: For plants, pathogens, insects and pests, give the Latin binomial in italics and the authority that first mention in the abstract or text (eg. rice (*Oryza sativa* L.).

Units of measurement: The International system of units (SI) must be used in all manuscripts submitted to the *Cambodian Journal of Agriculture*. Other units may be indicated in parentheses after the SI units if this helps in understanding the work reported. The double solidus must not be used in complex groupings of units (i.e. use mg/sheep. day, not mg/sheep/ day or mg^{-1} $sheep^{-1}$ day^{-1}). The CJA uses the abbreviation 'L' for litre 'mL' for millilitre. The units for exchangeable ions (mmol/kg) should be used for single charged ionic species, eg. N^+,K^+,$CaO.5^+$. The recommended unit for exchangeable ions and ion exchange capacity is cmol(+)/kg [or cmol(-)/kg], where (+)or (-) refers to a unit charge. This recommended unit is numerically equivalent to the non-SI but still widely used mill equivalents per 100g. The recommended unit for electrical conductivity is dS/m, but mS/cm is acceptable.

Evaluation of results

Research paper must contain a clear and concise description of the experimental design used with sufficient detail such that, in the case where analysis of variance or regression models are to be used in the statistical evaluation, the reader is quite clear as to how the error term was estimated. The statistical tests should be briefly described and, if necessary, supported by references. Numbers of individuals, mean values and measures of variability should be stated be made clear whether the standard deviation or the standard error has been given.

Reference

References

References are cited by the author and date (Harvard system); they are not numbered. All reference in the text must be listed at the end of the paper, with the names of authors arranged alphabetically; all entries in this list must correspond to references in the text. In the text, the names of 2 coauthors are linked by ‘and’; for 3 or more, the first author’s name is followed by ‘et al.’.

Where more than one reference is cited in the text, they should be listed chronologically. The titles of papers and the first and last page numbers must be included for all reference. Papers that have not been accepted for publication cannot be included in the list of reference and must be cited in the text as ‘unpublished date’ or ‘personal communication’; the use of such citations is discouraged. Authors should refer to the latest of the Journal for the style used in citing references in books and other literature. Full title of periodicals must be given.

References style (Journal article)

Hubick KT, Farquhar GD, Shorter R (1986) Correlation between water-use efficiency and carbon isotope discriminations in divers peanut (*Archis) germplasm. Australian Journal of Plant physiology* 13, 803-816.

Wagner TE (1985) The role of gene transfer in agriculture. *Cambodian Journal of Animal Science* 65,539-552.

References style (Book chapter)

Blackmore DJ (1996) Are rural land practices a threat to the environment? In ‘Soil science-raising the profile’. (Ed. N Uren) pp. 22-30. (ASSSI and NZSSS: Melbourne)

Wolandski E, Mazda Y, Ridd P (1992) Mangrove hydrodynamics. In ‘Tropical mangrove ecosystem’. (Eds AI Robertson, DM Alongi)pp. 43-62. (American Geophysical Union: Washington DC).

References style (Book)

Lucas GB (1963) ‘Diseases of tobacco.’ (University of North Carolina: Raleigh, NC)

Attiwill PM, Adams MA (1966) (EDs) ‘Nutrition of eucalypts.’ (CSIRO Publishing: Melbourne)

Hogan B. Bedding ton R, Constantine F, Lacy E (1994) (EDs) ‘Manipulating the mouse embryo – a laboratory manual (2^{nd}edn).’ *(*Cold Spring Harbor Laboratory Press: Cold Spring Harbor, NY)

References style (Thesis)

Silver MW (1970) An experimental approach to the taxonomy of the genus Enteromorpha (L.) Link. PhD Thesis, University of Liverpool, UK.

References style (Report or Bulletin)

Lea HW (1957) Report on a visit to the USA and Canada, April 1 to October 2, 1957. Department of Agriculture, Orange, NSW Chippendale GM, Wolf L (1981) The natural distribution of Eucalyptus in Australia. Australian National Parks and Wildlife Serveice. Special Publication No.6, Canberra

References style (Conference Proceedings)

Hayman PT, Collett IJ (1996) Estimating soil water: to kick, to stick, to core or computer? In ‘Proceeding of the 8^{th} Australian agronomy conference’. Toowoomba (Ed. M Asghar) p.664 (The Australian Society of Agronomy: Toowomba, Qld)

Kawasu T, Doi K, Ohta T, Shinohara Y, Ito K(1990) Transformation of eucalypts (Eucalyptus saligna) using electroporatin. In ‘Proceedings of the VIIth international congress on plant tissue and cell culture’. pp. 66-68 (Amsterdam IAPTC: Amsterdam)

Copyright

Submissions of a paper are taken to mean that the results reported have not been published and are not being considered for publication elsewhere. A summary of the finding in the proceeding of a conference or in an extension article is not necessarily regarded as prior publication. However, if substantial parts of the data, such as those in Tables and Figures, have been published before, the inclusion of extra peripheral data does not alter the judgment that the paper is not new. The Editor assumes that all authors of a multi-authored paper have agreed to its submission.

All authors must sign a ‘License to Publish’ from when the paper is submitted to the Journal.

Contact for submission

Cambodia Journal of Agriculture

c/- Dr. Ouk Makara, Care Editor of Cambodian Journal of Agriculture.
National Road 3, Prateah Lang Commune, Dongkor District, Phnom Penh, Cambodia.
P.O. Box 01, Phnom Penh, Cambodia.
Telephone: (855-23) 6319 692
Email: ou.makara@cardi.org.kh / cc: tchanna@cardi.org.kh / cja@cardi.org.kh

All papers are reviewed by at least 2 referees.

WRITING A RESEARCH PAPER - A FRAMEWORK

How to write research papers for publication

You must write for your readership by:
(i) presenting your main message prominently (e.g. title, summary, conclusion)
(ii) guiding the readers through the argument by presenting the information as simply and as briefly as possible (while keeping them adequately informed).
The word 'adequately' is crucial. Readers have neither the time nor the intellectual ability to assimilate all the information you have at your command. They are totally dependent on you the author to distil it for them.

General structure

Research papers have a clearly defined structure that is well known and widely used.
Research Notes or Technical papers are derivatives of this format and are shorter more concise documents.

The standard scientific document has four parts:
A statement of the problem (e.g. Purpose; Aim; or Hypothesis)
What was done?
What was found?
What the author thinks it means

Headings used to define these parts are:
Introduction
Materials and Methods
Results
Discussion

Title

The title is the reader's first contact with your paper. It is also your first chance to lose a reader. An interesting title is your best chance that readers will press on to explore the rest of the paper; an uninteresting one gives you little chance that even an excellent text will be read. Apart from grabbing the reader's attention, a good title should accurately reflect the content of the paper. A good title may have no more than half a dozen words and certainly no more than twenty, but it is worth the effort to get it right.

There are 3 things you can do to maximize the impact of a title:

(i) try to avoid beginning with:
    The effect of…
    The influence of...,
    Aspects of ...,
    Observations on...,'
Titles beginning with these vague phrases are nearly always boring.

(ii) try to put all the keywords in the title. If possible start the title with a keyword, this adds impact and gives the reader useful information right from the start.

(iii) you can even hint at the main result of the experiment by constructing a title of the form 'A increases B' but it is worth skimming the contents page of your preferred Journal before using this option.

Poor title: '*The effects of irrigation on the growth of wheat*'
Improved title: '*Irrigation at flowering increases the yield of dryland wheat*'

Poor title: *'Rooting depth of wheat in southern New South Wales'*
Improved title: *'Root penetration rate – a benchmark to identify soil and plant limitations to rooting depth in wheat'*

Poor title: '*Using a Happy Seeder to sow wheat into a rice cropping system'*
Improved title: *'The Happy Seeder enables direct drilling of wheat into rice stubble'*

The poor title is vague and leaves important questions unanswered.
The improved title shows readers that you have come straight to the point and adds confidence that the rest of the paper is equally well written and worth reading.

Introduction

The Introduction should tell the reader why he would read the paper and placing the experimental work in its scientific context.

The Introduction should answer the question: "*What did you intend to find out, and why*?'

It is usually composed of three parts:
(i) the background to the work giving its relevance and significance
(ii) a brief review of relevant literature (last 5 years) and the logic that led you to do the work
(iii) a clear statement of objectives and/or a hypothesis

A well-crafted Introduction makes the difference between a passive reader waiting to be convinced and an active reader eager to discover more.

Materials & Methods (include only the essential information)

The Materials & methods is usually the easiest part of a paper to write and is often the best place to start.
This section should answer the question: *What did you use and what did you do*?

Use subheadings to help the reader:
Example 1 (crop):
Site description
Treatments and experimental design
Measurements
Statistical analyses

Example 2 (animal):
Animals
Experimental diets and feeding regime
Measurements
Assays
Data analyses

Example 3 (dairy):
Selection of farms
Study design
Grazing management and supplements
Measurements – milk production and composition
Statistical analyses and calculations

The Materials and methods should allow colleagues to repeat the experiment. If you have used well known methods give the names and a reference, but if you made any modifications then these should be explained. Make sure you cite the original source. Avoid trivia. Use simple language.

Description the statistical analyses. Statistical analyses are a tool not an end. For a common procedure such as Chi-square or analysis of variance (ANOVA), it is enough just to name it. For more unusual techniques, give a reference to the source and also a brief description of the technique if the reader would be lost without first reading the reference. Only if the technique is entirely new should you give a detailed description.

Results

The results are the next easiest section to write.
This section should answer the question: *What did you find*?

Aim for the simplest presentation that will keep the reader adequately informed.

The most logical method is to rank the results in order of priority and present only the most important. In practice it is not as easy as this. However this is often because we make the error of treating the results in isolation from the rest of the paper, especially the discussion. If results are not needed to support the points you will make in the discussion, then discard them. Moreover their support must be direct and obvious, presenting irrelevant results can often lead to a discussion containing vague/fuzzy/weak arguments.

If you always aim for simplicity you may be surprised at how often all you need is a single sentence.

Example:
(i) *N fertiliser increased the grain weights by about 13%*
(ii) *N fertiliser increased the grain weights by 10–15%*
(iii) *Grain weight ranged from 10.21 to 14.85 mg when plots were treated with N fertiliser*

All examples may all be sufficient to satisfy the readers. However, if the readers do not need to know the exact value for each treatment combination, don't burden them with it. If nothing happened, never waste a Table or Figure to prove a point, just write: *The grain weight was unaffected by N fertilizer.* (even if it took you 6 months to gather the data!)

Tables and Figures. If it is essential for the reader to have the exact numbers (and strict testing of the results), Tables are your only option. On the hand, Figures are much easier to digest and are the better option if all you need to show is trends or gross changes.

Once you are sure that every Table and Figure is absolutely necessary, the next task is to guide the readers through them to make sure they are aware of the main points on each.

Don't describe everything in a Table or Figure rather point out the most important comparisons and leave the rest for the readers to make for themselves.

Example - describing the tabulated results:
(i) A statement such as:
'N fertiliser increased grain yield of rice by 10–15% depending on year'
This statement may sum up a Table if the differences between years are unimportant or just due to normal error.

(ii) If there is an important exception to the overall pattern, the sentence can be extended to say:
'N fertiliser increased grain yield of rice by 10–15% in all years except 2002. That year was a drought year and the increase was about 2%.'
(iii) This approach is much easier on the reader than writing.
'N fertiliser increased grain yield of rice by 10% in 1999, 13% in 2000, 10% in 2001, 2.1% in 2002, 15% in 2003, 12% in 2004. It should be noted that 2002 was a drought year.'

Tables and Figures should be constructed so they are understood in isolation from the text; so captions and headings must be informative.

Example - Table/Figure caption:
'Changes in rice grain yield with applied N fertiliser' is much less helpful title for a reader than: *'The effect of nitrogen fertiliser on the grain yield (%) of rice, 1999-2004'.*

Statistics. Most papers have some statistics in the results. An experienced writer uses them with discretion. State the levels of probability and only give the essential statistical information (means + standard errors or standard deviation, l.s.d.s, etc.)

Example 1 – including statistics:
'Applied N fertiliser increased grain yield by 1.8 t/ha compared with the control, and by 0.5 t/ha compared with the organic fertiliser (Table 1). The largest significant ($P<0.05$) yield increase was due to the N + organic fertiliser treatment. The grain yield increases were associated with increases in ear numbers but there were small decreases in kernel weight. The harvest index was not significantly ($P>0.05$) different between any of the treatments (average 42%).'

Example 2:
'Grain protein of barley increased from 10.1 to 11.3% with the addition of N, and further increased, although not significantly (P>0.05), to 11.6% with the addition of K and P (Table 2). Grain protein was not influenced by the addition of S.'

Example 3:
In the year after sowing, mean seedling regeneration following 90 mm of rain in February 2002 was lowest (P<0.05) for cultivars A6, B7 and C2 (Table 3) and highest for D3 and N16, although the latter were not significantly different to many of the cultivars/lines studied (Table 3). After 80 mm of rain in May 2003, seedling emergence in June was lower (P<0.01) for 5 of the 7 Indian lines compared with D3 and N16 (>500 seedlings/m^2, Table 3).

Discussion

The discussion must answer the question: *What do my results mean and what are their implications?*

Structure: Strong arguments pave the way for weaker ones, so lead off your discussion with your main message. The following sections can then be devoted to the secondary and tertiary messages. In the last section you can return to the main message to reinforce that point (but it helps if the main message is examined from a different perspective, otherwise it can seem repetitive).

Content: The discussion should interpret the meaning of your results for the reader so that they can understand the implications of your findings. There must be clear relationships drawn to previous work. Here you can discuss why something happened and why things did not. You can also discuss the relevance of the research to the specific field and make recommendations from your work.

Speculation: Speculation in a scientific paper is not only acceptable but also desirable, provided it fits the facts at that time. If it fails to fit the facts, it is not speculation but an error, and should be removed. Provided that you remember that speculation has to meet the same criteria as the hypothesis, you will find it a powerful tool for making your discussion more interesting.

Citing References: You need no reference if a statement is well known and accepted as fact. However, just what constitutes 'well known' and 'accepted as fact' is hard to define, you will often find that you have to rely on your own judgment. There are two reasons to provide a reference:
(i) if you need to justify a contentious statement
(ii) if there is extra information that you think a reader would want to know.

Give more than one reference if it helps the reader to gain a more rounded view, but not if they cover the same ground. How much information should be given in the text and how much should be left to the reference is sometimes difficult to define. One good guide is to aim to provide the reader with just enough information to understand the paper in a single reading (you could test this on a colleague when the paper is being internally reviewed).

Acknowledgments

Most of us cannot claim all the credit for a paper, so acknowledge those who provided significant technical assistance or worth-while advice. Keep it simple. (e.g. fertilizer or seed companies)

Abstract (or summary)

A summary should go hand in hand with the title because the summary both expands the title and condenses the paper. As such it is the first full mention of the main message, the title being only a short version.

A good summary has four clearly defined elements:
What you did?
Why you did it?
What you found?
What it means

Each of these elements deserves only 1 or 2 sentences and this provides a simple formula for writing a good summary. Beware of writing long summaries.

Each section of a paper gives an opportunity to guide readers down the path you have chosen. You owe it to yourself and your readers to guide them as clearly and simply as you can.

Authored by **Dr. Chris Anderson** (**CSIRO** Publishing)
(Adapted from R. Brown (1992). 'Key skills for writing and publishing research')

A FRAMEWORK FOR WRITING A RESEARCH OR TECHNICAL NOTE

Introduction

Communicating results is a crucial aspect of doing research. Through such communication other people can learn about and benefit from the findings. Often a Research Note or Technical Note (also known as a Short Communication) can be the best option when you are reporting on a single experiment and/or reporting part of a long-term experimental program. Brevity is the key to a successful publication.

A Research Note should explain: what you did, why you did it, what you discovered, and what is significant of your findings.
The report should include the following components:

- descriptive title
- author name and affiliation, date
- informative abstract & list of keywords
- body text
- Acknowledgments
- list of references

Length of paper

There is usually a length requirement; however, it can differ with the type of journal. The Notes for Authors should be used as a guide
[e.g. for CJA use ~3000 words, 2 Tables or Figures, ~20 references; i.e. about 2-3 journal A4 pages.]

The standard four-part outline for the body of a research note is: motivation, methods, results, and discussion.

Title

A logical, accurate, descriptive; avoid titles that exceed 17 words.

Abstract

Write an informative abstract of about 150 words.

Your abstract should serve as a substitute for your paper. Briefly summarize your main findings. Immediately get to the point in the first sentence. A good summary has four clearly defined elements:
What you did? Why you did it? What you found? What it means
Each of these elements deserves only 1 or 2 sentences and this provides a simple formula for writing a good summary.
Beware of writing long summaries.
Do not cite any references in the abstract.

Body text – Introduction, Methods, Results & Discussion

Write a clear, informative, and thoughtful description and critique of what you did.

1. Introduction

Clearly identify a focused well-defined topic.
Why am I doing the work?
Are there related publications that can be used as a reference point?
What is the relevance of the work?
State objectives or purpose of the work
Am I testing a hypothesis?

2. Methods

What did you use and what did you do?
Although it is crucial to explain your experimental procedures, be concise and do not bore your reader with lengthy descriptions of routine implementation concerns.
Where appropriate, include carefully drawn tables and figures.

Use subheadings to help the reader:
Example 1 (crop research):
Site description
Treatments and experimental design
Measurements
Statistical analyses
Example 2 (animal research):
Animals

Experimental diets and feeding regime
Measurements
Assays
Data analyses

3. Results & Discussion (usually combined in a Short Note paper)
What did I find?
What do the results mean?
What are the implications?
Analyse and interpret your data, and discuss the significance and limitations of your findings. Do not simply report your data. Concentrate on significant treatment differences rather than trends (refer to Figures & Tables).

Be sure to motivate, present, and interpret your findings.
Focus on the scientific content of the project - your questions and answers. Identify and explain interesting and important phenomena.

4. Conclusion (s)
End each report with a powerful sentence that concisely summarizes the significance of the entire project. What are the implications of the work?

5. Acknowledgements
Acknowledge any help you received, including any use of equipment or cropping land. Be specific.

6. References
Complete and accurate list of all references cited in the Research Note. There are three reasons for citing works:

- to give credit where credit is due
- to be helpful to the reader to identify useful related work, and
- to identify he context and background of your work.

When citing references in the body of the report, always explain why the reference is being cited. For example, do not cite previous work without critically explaining how it relates to your work.

Writing to be read
Write a clear, informative, and thoughtful description and critique of what you did. Where appropriate, include carefully drawn graphs and tables. Be sure to motivate, present, and interpret your findings.
Focus on the scientific content of the project - your questions and answers. Identify and explain interesting and important treatment differences. Emphasize what is new about your results.

Authored by **Dr. Chris Anderson** (**CSIRO** Publishing)

CONTENTS

ISSN 1029-8835

8 846001 190201