Managing plant under stress

a challenge for food security

PROFESSOR DR. MOHD RAZI ISMAIL

Managing plant under stress

a challenge for food security

PROFESSOR DR MOHD RAZI ISMAIL
Ph.D (London), B.Sc. Agriculture Science (UPM),

15 JULY 2011

Dewan Taklimat
Universiti Putra Malaysia

Universiti Putra Malaysia Press
Serdang • 2011
http://www.penerbit.upm.edu.my

First Print 2011

UPM Press is a member of the Malaysian Book Publishers Association (MABOPA)
Membership No.: 9802

Perpustakaan Negara Malaysia Cataloguing-in-Publication Data

Mohd Razi Ismail
Managing plant under stress : a challenge for food security /
Mohd Razi Ismail.
Bibilography : p. 57
ISBN 978-967-344-230-0
1. Plants--Effect of stress on. 2. Agriculture--Environmental aspects.
3. Food security. I. Title.
632.1

Reka letak teks : Sahariah Abdol Rahim @ Ibrahim
Reka bentuk kulit : Md Fairus Ahmad

Design, layout and printed by
Penerbit Universiti Putra Malaysia
43400 UPM Serdang
Selangor Darul Ehsan
Tel: 03-8946 8855 / 8854
Fax: 03-8941 6172
http://www.penerbit.upm.edu.my

Dedication

My mother , Puan Hjh Sapiah Hj Abdullah and
father Tn Hj Ismail Mohammad-

رَّبِّ ارْحَمْهُمَا كَمَا رَبَّيَانِي صَغِيرًا

My wife, Puan Hjh Khuzaimah Mohammed Noor,

A beauty and rellief to the eyes, relief to the eyes, a greet to our knowledge.. She is our princess in the house,a friend on the roads..At our tangling time, she is our guider..She keep our eyes still..
Make our heart still faithful.. The knowledge given will be kept always..When we forget she is the remainder"

And daughter Nuurain Amirah, sons, Muhammad Ammar, Muhammad Afwan, Muhammad Ashraf, Muhammad Anas, and Muhammad Muaz and
son-in law Mohd Riduan Wan Deraman

رَبِّ اجْعَلْنِي مُقِيمَ الصَّلَاةِ وَمِن
ذُرِّيَّتِي رَبَّنَا وَتَقَبَّلْ دُعَاء رَبَّنَا اغْفِرْ لِي
وَلِوَالِدَيَّ وَلِلْمُؤْمِنِينَ يَوْمَ يَقُومُ الْحِسَابُ

The beauty of Allah creation for a process the life

سورة الزمر :21

Seest thou not that Allah sends down rain from the sky, and leads it through springs in the earth? Then He causes to grow, therewith, produce of various colours: then it withers; thou wilt see it grow yellow; then He makes it dry up and crumble away. Truly, in this, is a Message of remembrance to men of understanding

سورة الأعراف57

It is He Who sendeth the winds like heralds of glad tidings, going before His mercy: when they have carried the heavy-laden clouds, We drive them to a land that is dead, make rain to descend thereon, and produce every kind of harvest therewith: thus shall We raise up the dead: perchance ye may remember.

But the calamity on earth is because of human hand's perpetrated.

الروم: 41

Evil has become rife on the land and at sea because of men's deeds; this in order that He may cause them to have a taste of some of their deeds; perhaps they will turn back (from evil)

(Meaning that God created this very beautiful, splendid planet. And he gave it to us as a gift. But he asked us not to corrupt it, not to ruin it, not to destroy it. Use it for our benefit.)

Contents

Abstract 1

Introduction 3

Crop Imporvement Strategies Under Stressful Environment 12

The Impact of Environmental Stress on Major Economic Crops in Malaysia 19

- Sustainable Rice Production in Changing Climate 19
- The Impact of Drought Stress in Oil Palm Yield: The Need to Optimize Water Use Efficiency 24
- Sustaining Fruit Production Under Climate Change 26

Manipulation of Growth by Genetic or Agronomic Means for Managing Plant Under Stress 29

- Genetic Manipulation 29
- Agronomic Manipulation 34
- Exploitation of Long Distance Chemical Signalling to Regulate Plant Development and Improve Water use Efficiency 37
- Application of Cultural Practices for Adaptation of Crops to Environmental Stresses 45

Protected Environment Cultivation: Altering Natural Plant Microclimate for Managing Plant Under Stress 49

Enhancing Food Security and Adaptation of Crop to Unfavorable Climate: The Way Forward 57

References 58

Biography 67

Acknowledgement 71

List of Inaugural Lectures 73

ABSTRACT

Allah subhanahuwataala , The Almighty is the Only and Unique Owner of everything including climate. The creation of climate is unchallengeable but Allah provides us the mind to explore adaptation to what has been created. The global climate change causes various environmental stresses that led to major impact on human life. In agriculture, environmental stresses represent the most limiting factors to food productivity. Environmental stress impact not only crops which are presently being cultivated, but also are significant barriers to the introduction of crop plants into areas which are not at this time being used for agriculture. A significant problem for agriculture in the world is the major variation in crop yields from year to year due to variations in environmental stresses such as drought, flooding, salinity and high temperature. Stressful environments are often characterized by the occurrence of more than one stress simultaneously. Thus, drought is often associated with temperature, drought with salinity and flooding with ion toxicity. In urban environments, air pollutants are often associated with high temperature and low intercepted radiation with the occurrence of haze. Managing these environmental stress elements is a major consideration to achieve sustainability in agriculture system. Any contribution that relates understanding of factors and managing environmental stress will be of special interest of many years to come. Rice is fundamental for food security with approximately 3 billion people, about half of the world population, eating rice every day In coming decades, downward pressures on food stocks are expected to intensify. In addition to increased demand from the ever increasing population, the forthcoming climate change can also affect rice production. In Malaysia, national food policy under 10th Malaysia plan projected that 90% SSL (self sufficiency level) will need to be achieved by 2015 while the present SSL is 65%. To

achieve the target, at least two major challenges, (i) low yield of rice, and (ii) climate change should be considered during innovative research formulation on rice. Low average yield of rice (4 t ha^{-1}), features eight granary areas in Malaysia, can be considered a major threat for national food security The ultimate aim is to sustain yield in resources that are increasingly limited under a changing climate. This will led to ensuring food security for present and future generation to come.

INTRODUCTION

In the past many agricultural development projects in Malaysia involving food production had failed due to various factors that include lack of project planning, inadequate crop knowledge, climate change and poor management practices. Large scale commercial food crop based projects often fail to deliver the objectives due to inevitable crop losses that hampered sustainability of the respective project. Large scale cultivation of fruit commodity and lowland production of vegetables utilizing protected environment has shown little success. Figures 1, 2 and 3 are examples of non- sustainable food crop ventures resulting to huge investment losses and failure to deliver the needs of availability for food security. There is currently a major concern to ensure food security by enhancing food productivity of major food crops. Malaysia is still unable to achieve self –sufficiency level in many food items except for fish and chicken meat (Figure 4). In addition to the increased demand for food from the ever increasing population, the forthcoming climate change can also affect production globally in several ways such as salinity, sea-level rise, drought, flooding, increased incidence of pests, diseases, and weeds, increased temperature and CO_2 level. Many resources required for successful crop growth in the tropics are of short supply and this situation will be exacerbated by developing environmental change. Another only option is to increase domestic food production, which is also a major component of national food supply and availability.

Malaysia does not have a clear comparative advantage in paddy and rice industry, but it is a strategic crop in terms of food security, poverty and other social and political concerns. To ensure the sustainability of the industry, since 1960s, Malaysia has embarked on an interventionist regime which has grown deeper despite the call for a more liberalised market by the WTO. Food security objective is translated into self-sufficiency target at 65% under the Ninth Malaysia Plan (2006-2010) and 70% under the Tenth Malaysia Plan (2011-2015), Agro-food Policy (2011-2020) and the inclusion of paddy farming in the Economic Transformation Program (ETP). In a recent development, there is an immediate need that the self-sufficiency level (SSL) is to be hastened from 2020 to 2015. This new development has placed a major impact for rice granary areas to raise productivity by 25-30% in the forthcoming years. Therefore, food security and sustainable domestic rice production can, and should be addressed together. But the low yield of rice (4 t ha^{-1}) is one of the major constraints to national food security and production sustainability in Malaysia as a whole (Figure 5) .

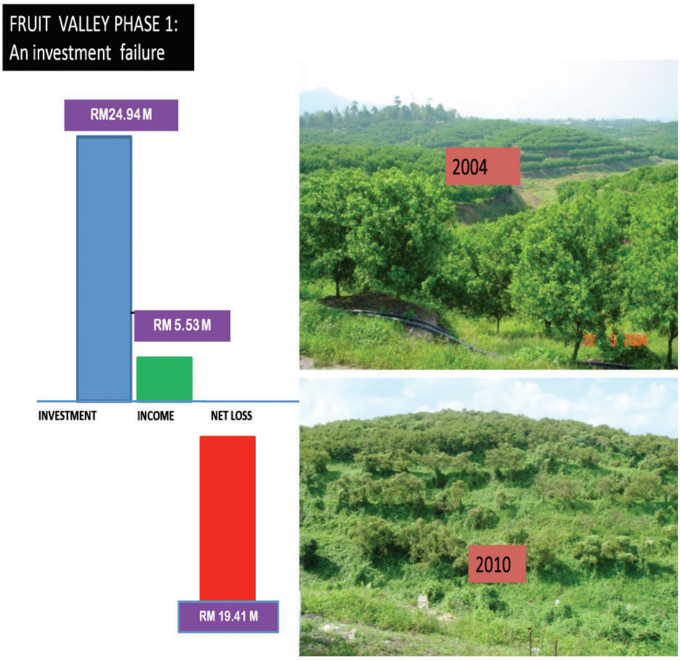


Figure 1 An investment failure for fruit production venture
Source: Mohd Razi Ismail et al. 2010

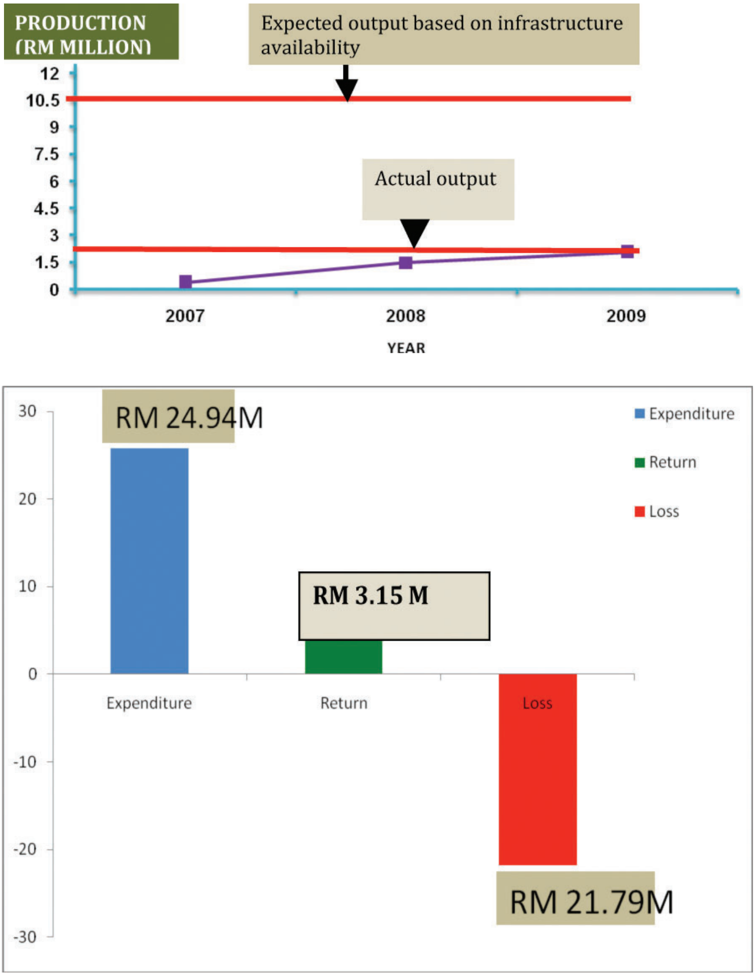


Figure 2 Financial report of food production agricultural project implemented by a government agency
Source: Auditor's General Report 2010

Figure 3 One of the state government agricultural agencies ventures with expertise from Holland involving an investment of approximately RM 4 million. The project was initiated in 2006 and at present was abandoned and failed to meet the objective of increasing food production and to improve farmers' income.

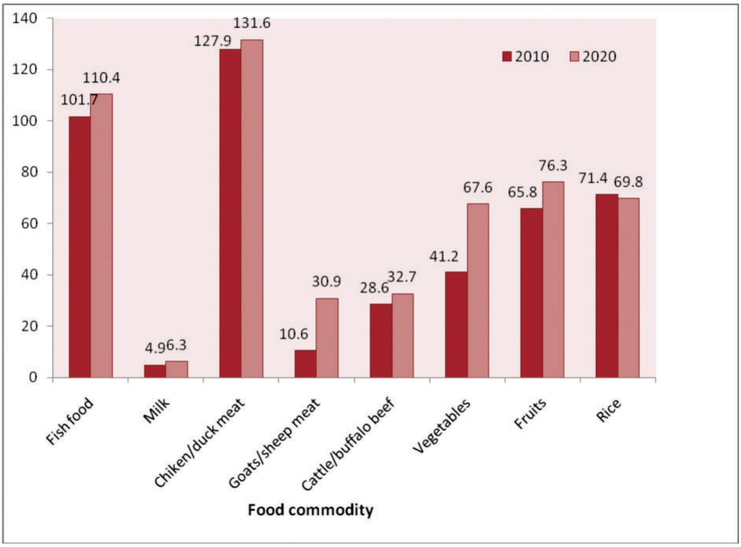


Figure 4 Self- sufficiency level for major food items.
Source: Agro-food Statistics, MOA, 2009

It is well known that average yields in agricultural systems of developed countries rarely exceed 30% of the recorded yields for those countries (Davies, Bacon and Mohd Razi, 2004). The difference between average and record yields is mostly attributable to the effects of abiotic stress (Table 1). Low yield of rice will be a great challenge to achieve self-sufficiency level under the Tenth Malaysia plan (2011-2015). In Malaysia, the most popular and high yielding rice cultivar MR219 developed by MARDI in 2001 possessed the potential yield of between 6.5 to 10.7 tonnes per hectare. In most granary areas , however, the average yield recorded in 2009 was between 2.83 to 5.44 tonnes per hectare well below the yield potential of this particular cultivar (Figure 6).

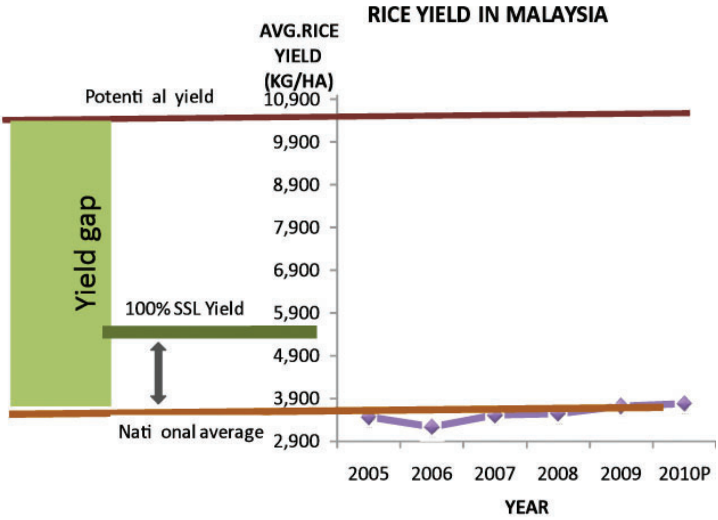


Figure 5 National average rice yield, yield to reach 100% SSL and potential yield

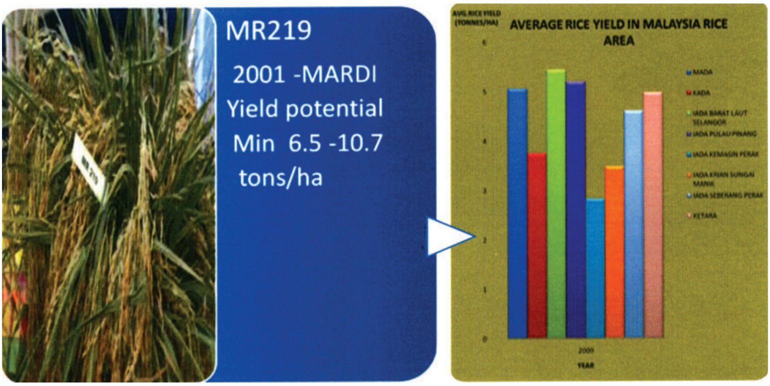


Figure 6 Rice cultivar MR219 developed by MARDI possessed yield potential of 6.5-10.7 tonnes per hectare. In major granary areas, the average yield achieved is between 2.83-5.44 tonnes per hectare.

Table 1 Record yield, average and averge losses in major United State of America (USA) crops. (Boyer, 1982)

Crop	Record[b] Yield	Average[b] Yield	Average Losses[c]			
			Diseases	Insects	Weeds	Pyhsicochemical
Maize	19,300	4,600	836	836	697	12,300
Wheat	14,500	1,880	387	166	332	11,700
Soybean	7,390	1,610	342	73	415	4,950
Sorghum	20,100	2,830	369	369	533	16,000
Oat	10,600	1,720	623	119	504	7,630
Barley	11,400	2,050	416	149	356	8,430
Potato	94,100	28,200	8,370	6,170	1,322	50,000
Sugar beet	121,000	42,600	10,650	7,990	5,330	54,400
Mean Percentage of record yield	100	21.5	5.1	3	3.5	66.9

Note. Values are kilograms per hectare.Record and average yields are as of 1975.

[a] In the original work (Boyer, 1982), weed losses were considered to be physicochemical because the losses were attributable to competition for light, nutrients, and so on. On the other hand, weeds are of biological origin and it may be argued that the losses should be included with insects and diseases. For simplicity, the latter approach is taken here, which slightly alters the values calculated for each loss in comparison with Boyer (1982)

[b] From Wittwer (1975)

[c] Calculated according to the U.S Department of Agriculture (1965)

[d] Physicochemical losses calculated as record yield-(average yield + disease loss + insect loss + weed loss).

Environmental stresses are considered to be major constraints that limit agricultural productivity that hindered the expression of the genetic potential. These are not stresses in the sense in which the word is usually used, i.e. not dehydration stress, which is what seems to pre-occupy many workers in this field. Rather, much limitation in yield may be a function of changes in the regulation by genes of growth and functioning of plants in what may be only marginally sub-optimal environments. This assertion is supported by the view of plant breeders that characteristics are important for yield in stress environments have more to do with growth under conditions that are relatively favourable than with resistance to stress *per se*. This is because there is little growth by plants once stress develops. A definite way to improve productivity in stress environments is to maximise growth during relatively favorable times (Richards, 1993). Davies and Gowing (1999) have highlighted the sensitivity of growth and gas exchange of a range of plants to a degree of soil drying that may be barely measurable by the standard techniques available to us.

Breeding or management can overcome environmental stresses. Although genetic development is considered as a sustainable approach, sometimes it does not meet the short-term requirements of farmers as it requires a considerable investment of resources over a long-period. Although plant biotechnology offers much quicker progress in a crop improvement program under stressful environments, its success has not been widespread to date. Such crop improvement programs may only be adopted in larger-scale industries that are capable of financing a substantial research and development program. Also, such programs are more often used in annual species where the time between investment of research resources and the return via improved cultivars is considerably less. For example, engineering of C_4 rice requires a huge investment. Bill and Melinda Gates foundation donates huge amount to generate C_4 rice, which is expecting to bring 2nd Green revolution and ends the world hunger (IRRI 2011). The roadmap to C_4 rice is shown in the following Figure 7. The C_4 rice project is about using cutting edge science to discover the genes that will supercharge photosynthesis, boost food production and improve the lives of billions of poor people in the developing world. It is important to note that at 25^0C and current atmospheric CO_2, ~ 30% of the carbohydrate formed in C_3 rice is lost via photorespiration and the size of this loss increases with temperature (Zhu *et al.* 2010)

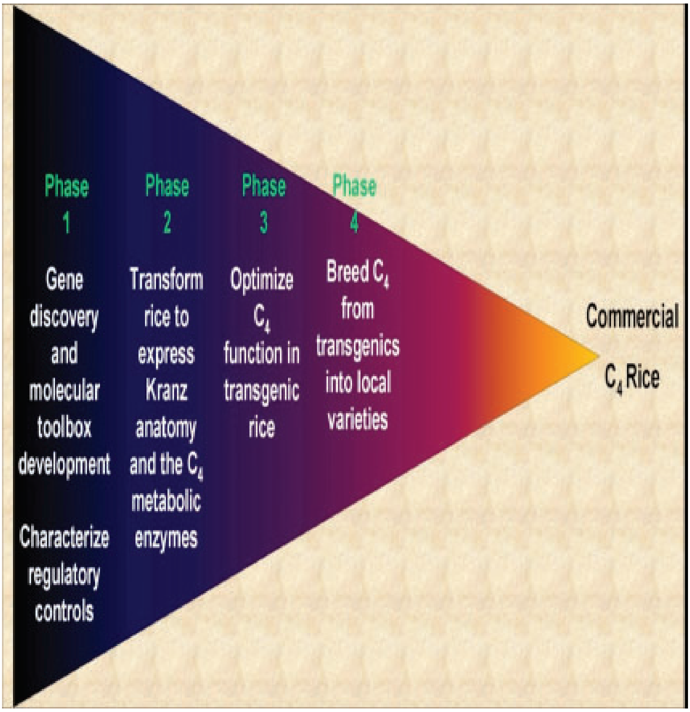


Figure 7 The roadmap for conversion of rice carbondioxide pathway C_3 to C_4 rice (IRRI 2011)

There is often an immediate need by farmers in different parts of the world to obtain simple technology in cultural practices that can be used to alleviate environmental stress conditions. Therefore, the need to develop technology that permits hands on methods which are able to withstand plant growth during period of environmental stresses is essential in ensuring the success of agricultural practices. Therefore, integrated efforts need to be carried out in research. The short and long term approaches need to be considered to achieve a common objective for sustaining plant production in stressful environment. The impact of environmental stresses and managing plant system are of my interest, past and future to pave way of ensuring food security and indirectly, to improve the livelihood of agricultural community especially the poor farmers.

CROP IMPROVEMENT STRATEGIES UNDER STRESSFUL ENVIRONMENT

Sustained production of crops under environmental stresses is possible if appropriate management decision is made. This involves a multidisciplinary approach to identify and providing baseline information for sustainable management of plants. One important application of understanding the physiological and biochemical processes under stress is in crop improvement program. The target of crop improvement program is to develop cultivars with higher harvestable yield during environmental stresses. In drought stress, it is a challenge as the complexity of drought normally interacts with other abiotic stresses. The selection of traits based on the interaction with unfavorable environments is particularly important and sometimes ignored in the breeding program. For example the selection of early vigor which encourages the improvement of crop water use efficiency in a sense that it reduces the loss of water from the soil surface by improving the soil shade and the early vigor is easy to be achieved through genetic and cultural practices. The priority of the breeder to introduce varieties only with high yielding characters has sometimes brought to the instability of the cultivars introduced.

Jones (1986) indicated that an important question in relation to attempts in identifying the environmental factors such as the temperature, water or radiation that limit the yield of any crop and overcoming these constraints by breeding or management. However, most plant breeders assume that breeding for environments where drought (and other stresses) are unpredictable and variable is too slow and difficult. The target is hard to define; and the progress with selection is too low to achieve meaningful results. Therefore, most of breeding for stress environments has been actually conducted using the same approach that been successful in areas where lack of water (and other abiotic stress) is seldom important (Ceccarelli and Grando, 1996). Recently, there is interest among the researchers in this region to emphasise their fundamentals in biotechnology to improve crop growth under stressful environment. The success in breeding for better adapted varieties to these stress conditions depend on the concerted efforts by various expertise including molecular biology, genetics, biotechnology and biochemistry. Conventional breeding though plays an essential role in rice improvement, it is rather a slow process as it is time consuming, the selection process is also slow and identification of the appropriate genotype is difficult. These challenges can be overcame to some extent by applying genetic engineering and molecular breeding approaches. Developing stress-tolerant plants based on our understanding of the biochemical responses of rice plants to varying conditions and identification of genes that are known to be involved in stress response might prove to be a faster track towards improving rice varieties (Amudha and Balalubramani, 2011). These techniques hold great promise for the development of rice cultivars with higher yield potential. Genetic transformation of rice has demonstrated numerous important opportunites resulting in genetic improvement of existing elite rice varieties and production of new plant types.The introduction of alien genes associated with yield determinants allows plant breeeders to achieve breeding objectives faster and more precise. Several techniques are now available for the transformation of rice and are routinely employed. There are several genes which are associated with water- , salinity-tolerant and increased yield. Two of the important ones are genes which are involved in starch and proline synthesis. Starch synthesis genes (SSI and SSII) are known to regulate the starch quality synthesis in rice grains, hence influence yield and quality. Similarly, proline is the foremost organic molecule that accumulates in plants following exposure to water and/or salt stresses. The enzyme δ-1 pyrroline-5-carboxylate synthetase (P5CS) acts as a key role in the biosynthesis of proline and catalyses the major regulatory step (Zhu et al. 1998). Its activity is strongly affected by salinity and low or minimum water availability (Sreenivasulu et al., 2007). Another problem is the submergence of rice field in rain-fed low land ecosystems. Sequencing the Sub1 region in an FR13A-derived line revealed the presence of three genes encoding putative ethylene responsive factors (ERF), Sub1A, Sub1B and Sub1C and Sub1A were subsequently identified as the major determinant of submergence tolerance (Xu et al., 2006). More recently sub-1 gene for submergence tolerance has been successfully introgressed through marker-assisted backcrossing (MAB) into a popular high-yielding variety, Swarna, within a 2-years time frame in India (Neeraja *et al.*, 2007). The selection for yield increase will also be supported through closely linked biochemical and molecular markers. It has been reported that there are alterations in the translatable mRNAs and protein species induced by environmental stresses. In several abiotic stress-inducible genes are controlled by ABA but others are not indicating involvement of both ABA-dependent and ABA-independent (Ahuja et al, 2010). The ABA responsive genes have been named in a variety of ways depending upon the developmental stage or the external stimuli applied. The LEA (late embryogenesis abundant), RAB (responsive to ABA) and dehydrins (dehydration-induced proteins) constitute of a group of small proteins. Synthesis of ABA is a common denominator in the induction of all these proteins. The role of lAE proteins in water deficit stress tolerance has yet to be determined. It is possible that it relates to the involvement of osmotic adjustment tolerance which contributes to dehydration tolerance at low water potential. There are genes that induced reduction in turgor and have designated them as turgor-responsive genes. Limited understanding of osmoregulatory mechanisms at the molecular levels hinders utilization of plant biotechnology to transfer specific drought tolerance genes to plants. Many plants have been shown to accumulate high concentration of proline in responses to osmotic stress (Mohd Razi et al, 1994: Tarmizi and Maziah, 1995). Genes that are responsible for proline biosynthesis has been successfully isolated by many workers. It is an important task for researchers to undertake research in characterization, expression of cDNA encoding, mRNA and water stress proteins (WSP) in wide range of tropical plant species exposed to environmental stress conditions. The benefit of the understanding of the research to be undertaken will contribute towards improving the productivity of plants grown in osmotically stressful environments, and will enable presently unutilized land in semi arid into agricultural production.

In the tropics, crop production is often limited both by period of drought and high temperature during plant development. The Lockhart concept (1963) demonstrated that there is a linear relationship between growth and turgor, with growth rate falling to zero at as finite turgor (the yield threshold). During the last 10 years this concept has been challenged, researchers observed reductions in growth of many crop plants during drought and other environmental stimuli occurred in the absence of any decline in turgor (Gowing *et al.*, 1993). This draws the attention to the cell wall biochemical properties. It is suggested that many stresses can directly influence the activity of wall enzymes but that the effects of stress can also be indirect through a change in xylem sap pH (Bacon *et al.*, 1998). Among putative wall-loosing enzymes, xyloglucan endotransglycosylase activity (XET) showed a general correlation with growth rate in tomato fruit (Thompson *et al.*, 1998) and leaf expansion rates (Bacon *et al.*, 1998). With respect to the termination of fruit growth to environmental stresses, the enzyme most often linked to decrease in wall extensibility is peroxidase. Correlation between peroxidase activity and the cessation of growth have been reported from a variety of plant organs (Sobeih et la, 2004; Mohd Razi and Wahab, 2008). The role of peroxidase during fruit development indicated that an increase in turgor within the parenchyma cells of mesocarp tissue creates tissue pressure and extent of fruit growth may be correlated well with cell wall enzymes in regulation of fruit growth (Figure 8,9,10). Elucidating the mechanism that controls the stiffness of the fruit exocarp may be fundamental in the control of some of the physiological orders that affect fruit growth. If peroxidase mediated stiffening of cell walls is responsible for changes in the mechanical properties of exocarp, identification of peroxidase enzymes present cultivars susceptible to disorder related to the skin may facilitate screening for resistance for commercial cultivation (Andrews et al, 2000).

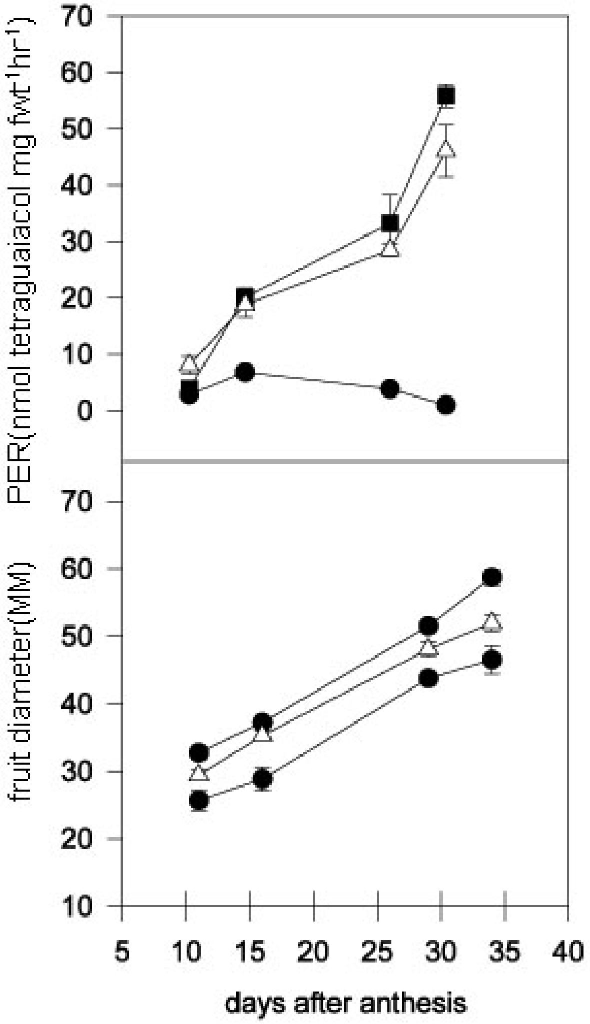


Figure 8 Changes in fruit diameter and peroxidase activities (PER) during exposure to well watered (●), PRD (Δ) and DI(■). Bars represent SE± 4 replicates for PER and fruit diameter , and SE± 3 for RWC

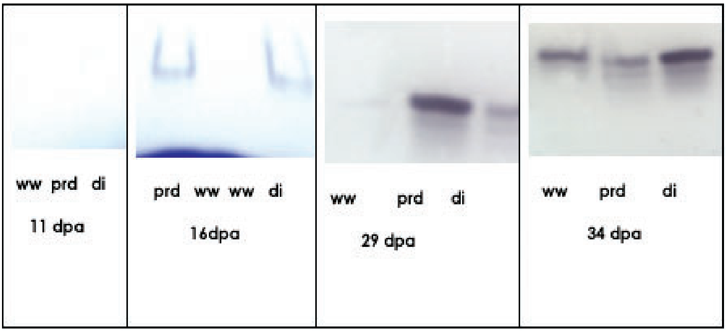


Figure 9 Native PAGE gels stained for peroxidase activity at different fruit age of plants exposed to well watered (ww), partial root drying (prd) and deficit irrigation (di)

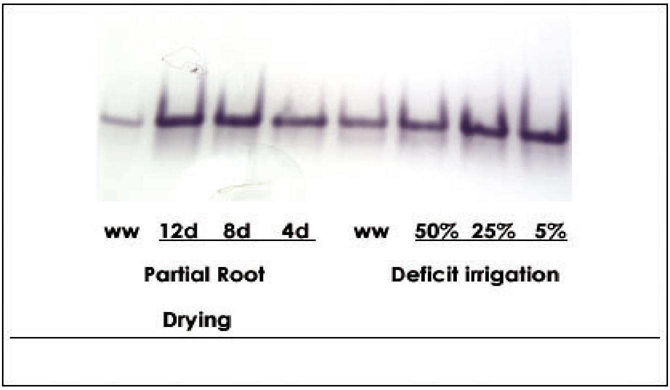


Figure 10 Native PAGE soluble peroxidase isoforms of leaves of tomato when exposed to PRD and Deficit Irrigation treatments.
Source : Mohd Razi and Wahab 2008

Mohd Razi Ismail

THE IMPACT OF ENVIRONMENTAL STRESS ON MAJOR ECONOMIC CROPS IN MALAYSIA

Sustainable Rice Production in Changing Climate

Rice (*Oryza sativa* L.) is one of the major food crops for direct human consumption and accounts 50% of the mankind in the world (FAO 2008). The world's population is expected to surpass 9 billion people by 2050, which will require an estimated 70% increase in global agricultural production. At the same time, climate change is expected to have multiple impacts on agricultural productivity and rural incomes in areas that are already experiencing high levels of food insecurity. The demand for rice will grow faster than for other crops, because population growth is greatest in rice-consuming and rice-producing regions such as in Asia, Africa and the Americas. In 2008, rice stocks have fallen dramatically and the stock to use ratio of rice was at the lowest level in 30 years. For wheat, the stock to use ratio in 2008 was at the lowest level in 50 years (FAO 2008). In coming decades, downward pressures on food stocks are expected to intensify. In addition to increased demand from a ever increasing population, climate change is predicted to reduce food reserves through increased heat and drought inhibition of crop productivity while crop land declines rapidly due to erosion, industrialization, urbanization and the planting of biofuel crops (Easterling *et al. 2007*). Rice yields will decline by 10% for each one degree rise in the minimum night temperature. According to a report by IRRI, between 1979 and 2003, minimum mean night time temperature rose by 1.5^0C , suggesting a reduction of 15% in yield. Globaly, 23 M hectares or 18% of the world's rice area are considered drought-prone. Rice cultivation in Malaysia is not sparred from these production constraints. According to Mon and Chang (2008), the risk of encountering water deficit for rice cultivation in the MADA, one of Malaysian major rice granary areas, cannot be ruled out although several initiatives had been employed to reduce the impact. The impact of drought is highly significant to the rice production and on our national food self-sufficiency. As a consequent to the cancellation of one crop in 1978 due to drought, the potential paddy production of 360,000 tonnes were lost. This can be translated into a loss of RM180 million to the nation in terms of paddy value. The 60,000 farm families lost a potential income of RM3,000 per farm family. Again in 1983, 1987, 1991 and 1992, incidents of low reservoir storage were encountered due to droughts. The consequences of droughts in Muda area from 1977-1992 had resulted in the cancellation of planting of one first season crop, rescheduling of planting schedules, reduction in planting areas and rationing of irrigation supply. All these have caused the overall reduction in paddy production and consequently more rice had to be imported to meet the nation's rice consumption need. These reports in MADA are examples of the impact of the environmental calamity such as drought to food security during the years when Malaysian population demand of rice can still cope with the stock piles deficit by importation. Considering these potential threats, water use efficiency strategies need to be emphasized in national food security. Similarly, in recent years, flooding or full submergence of rice planting has become another important threat in MADA rice growing areas. In the latest incident, 403 hectares of rice planting has been damaged by flooding in MADA rice growing areas during the off season in 2009 (Laporan Penyiasatan Pengeluaran Padi, MADA Luar Musim 2009(1/2009).

Understanding rice physiology and biochemistry will enable further understanding in crop adaptation to climate change. Rice is a tropical plant adaptable to warm temperate crop that utilizes the C_3 photosynthetic pathway. Being a C_3 plant, reductions in photosynthesis by photorespiration can be substantial in its typical growth environment. At current CO_2 levels, photosynthetic reductions in rice due to photorespiration are estimated to be 25–35% at 30–35°C. Recently, Makino (2011) showed that biomass production and relative growth rate (RGR) are the greatest in rice grown at 30/24°C (day/night). The increased level of CO_2 coupled with high temperature is the main features of the forthcoming climatic change, which may have potential impact on rice productivity worldwide. However, increased level of atmospheric CO_2 has a positive effect on rice yield. For every 75 ppm increase in CO_2 concentration, rice yields will increase by 0.5 t ha^{-1}. However, the story of temperature episode is different. That is, the rice yield will decrease by 0.6 t ha^{-1} for every 1°C increase in day and night temperature. Thus an assessment of the potential impacts of interactive changes of CO_2 and temperature is crucial to determine the future agricultural strategies maintaining sustainable rice productivity (Kirschbaum. 2011)

Photosynthetic capacity is strongly influenced by both CO_2 and temperature. Although rice and wheat are both C3 plants, the photosynthetic rate (*A*) at 25°C is higher in wheat than rice, for the same N content. This is mainly because wheat has a greater specific activity of ribulose-1,5-bisphosphate carboxylase/oxygenase (Rubisco)) and a higher content of Cyt *f* (Makino, 2011). Such information is very scanty among rice genotypes although rice genotypes differ tremendously in the levels of grain yield. In addition, yield levels of rice genotypes/varieties are also greatly influenced by the environmental conditions and the field management practices. There are also remarkable interactions between genotypes and environments such that varieties are adapted to specific environmental conditions. These opportunities will not be explored yet. Therefore, varietal/genotypic yield potential studies under different CO_2 and temperature regime may be one of the best options to achieve the target self-sufficiency level (SSL) of rice production in eight granary areas in Malaysia in future. As mentioned, the potential yield of paddy is 10 MT/ha compared to the national average of 4 MT/ha. This gap in production can be narrowed through improved crop and soil management as well as control of pests and diseases. Performance of high yielding varieties can be improved through agronomic manipulation and harnessing the rice genetic diversities to provide key genes that will enable better tolerance towards biotic and abiotic stresses. Interestingly, several researchers achieved 10 t ha^{-1} by using high-yielding *indica* inbred cultivars in the tropical irrigated lowlands, where hybrids rice yield increased by 15% (Peng *et al.* 2003, Yang *et al.* 2007). The high yield of the elite inbred rice is associated with high harvest index (HI) and increased photosynthetic efficiency (Peng *et al.* 2000). It is confirmed that low HI is the main trait for low yield of rice in the tropics. The yield advantage of hybrid rice in the tropics is also attributed by high HI (Lafarge and Bueno 2009, Bueno *et al.* 2010).). Actually, HI is the ratio of harvestable biomass over the total biomass. However, total biomass production and its effective partitioning towards the harvestable materials are associated with plant architectures, many physiological and biochemical processes. So, HI is a complex trait although it looks simple. High HI is associated with high biomass accumulation before anthesis (Peng *et al.* 1998, 2003; Laza *et al.* 2003, Katsura *et al.* 2007). Some researchers argued that high biomass accumulation during grain filling (Yamauchi 1994, Peng *et al.* 1999) is identified as sustaining higher grain yield of hybrid rice over elite *inbreds*. It is disagreed by Laza et al. (2003), who reported that there is a negative relationship between biomass accumulation and biomass remobilization during grain filling stage. The increase in yield potential of many modern *inbred* crops was mainly explained by the increase in HI and the associated increase in grain number per land area rather than that in biomass production (Hay 1995, De Vita *et al.* 2007, Alvaro *et al.* 2008). The processes related to biomass partitioning are some of the main physiological and biochemical attributes, leading to the positive changes in the growth rate of panicles, grains and yield potential as a whole. The main underlying physiological cause of the increase in yield potential over time is claimed to be the greater panicle growth during the second part of the reproductive stage, that is the period before heading (Siddique *et al.* 1989, Horie *et al.* 2003). A higher crop growth rate (CGR) during this period is triggering higher panicle growth and a higher amount of stored assimilate to be available and remobilized during grain filling (Sheehy *et al.* 2001). In Malaysia, about 40% loss in grain yield may be attributed to spikelet sterility of the lodged plants. The lodging of rice plants during the ripening period results not only in a reduction in yield, owing to decreased canopy photosynthesis as a result of self-shading, but also in a decrease in the grain quality.

A major challenge in rice production is to enhance water use efficiency (WUE). Several practices such as post-anthesis controlled soil drying, alternate wetting and moderate soil drying regimes during the whole growing season, and non-flooded straw mulching cultivation, could substantially enhance WUE and maintain or even increase grain yield of rice, mainly via improved canopy structure, source activity and sink strength, as well as enhanced remobilization of pre-stored carbon reserves from vegetative tissues to grains (Yang and Zhang 2010).

Therefore, there is a way to identify promising traits for increasing yield potential by investigating the physiological and biochemical processes responsible for the advantage of hybrids over *inbreds.* It is thought that the identification of the components involved in the higher hybrid performance could be of great interest in order to increase the yield potential of modern *inbred* varieties or MARDI released varieties. Analyzing the phenotypic differences between high-yielding hybrids, the elite indica *inbreds,* local landraces and MARDI released varieties (including farmer's well accepted popular variety MR219 as a check) in their way to build up grain yield could confirm some aspects of the actual breeding strategies and suggest new target breeding traits for future crop improvement. In Malaysia, expanding irrigation and drainage infrastructures ideal for rice cultivation as in the Sekinchan area in IADP Barat Laut, Selangor could be costly for the nation. There is large initial investment to up-scale paddy farming areas. In entry point project EPP10 of the national Economic Transformation Program (ETP), the investment to facilitate commercial paddy cultivation can reach RM 100 millions only in a specified granary area. Facilitating rice biological attributes by physiological, biochemical and molecular processes for the objective to increase yield per unit area can offer an alternative towards a sustainable rice cultivation and the national food security.

The Impact of Drought Stress in Oil Palm Yield: The Need to Optimize Water Use Efficiency

Apart from the problem with availability of skilled foreign labor, persistently bad weather beginning with the yield-sapping El Nino-driven drought and followed by La Nina which brings heavy rain to Southeast Asia–have prompted the industry regulator to make further revision to its estimates. Heavy rain, amid the ongoing annual monsoon in top palm oil producing state of Sabah hindered the progress on oil palm fruit collection since the beginning of December affecting overall palm oil production (Palm Oil News , Dec 14, 2010). Major oil palm producers in Malaysia have been given priority on this issue in particular to the prediction of crude palm oil price (CPO) in the commodity future trading. The degree of the occurrence of climatic impact such as El Nino has been given due consideration in establishing the price for CPO. The interactions between climatic factors such as radiation, temperature and humidity may interpret the oil palm responses to climate. Rainfall is quantitatively found to have a poor correlation with yield, while drought is among the natural climatic factors capable of influencing a yield pattern due to its induction of a high abortion rate (Mohd Haniff, 2000).This has led to a low FFB number and followed by a low yield before a yield peak. In Nigeria, positive significant influences of the combined effects of the four climatic factors i.e. mean temperature, relative humidity, solar radiation and total precipitation are highest on FFB yield variation in palms under rainfed condition (Augustus, 2001). *El Nino* which caused drought and less rainfall with high temperature has resulted a decline in Malaysian FFB yield by more than 2 tonnes/ha/yr the following year after it occurred (Idris, 2002).

Under favorable weather conditions and rainfall distribution as well as constant sunshine throughout the year resulted in excellent pollination and formation of oil palm fruits, the oil extraction rate (OER) improved to 20.15%. Within the oil palm plant system, water deficit affect productivity and growth performance through reductions in photosynthetic rates and light conversion efficiency. In a lysimeter study, Foong and Lee (2000) showed that the annual potential evapotranspiration of oil palm at 22 years after planting could be as high as 6.9 mm/day. Under normal climatic conditions, the annual potential evapotranspiration of mature palm is about 5.5 – 6.0 mm/day. Under severe conditions, the evapotranspiration can reach as high as 10 mm/day. Prolonged water deficits will result in increasing vegetative disorders, such as accumulation of unopened leaves, premature drying out of lower leaves, premature drying out of lower bunches, and toppling of the entire canopy. Studies by Henson *et al*. (1991) showed that oil palm photosynthetic rate decrease with an increase in vapour pressure deficit. Fronds production on a dry site was reduced by 4-12 % as compared to a wet site. In earlier studies, Turner (1976) stated that water stress decreases oil palm yield by increasing inflorescence abortion and by decreasing the sex ratio**.**

In elucidating mechanism of responses to water deficit and WUE, we confirmed that yield of oil palm is highly dependent on water availability. Mohd Roslan and Mohd Razi (2010) reported that a 10 % higher FFB production and 8.37% increased in bunch number can be achieved with irrigation compared to normal rain-fed cultivation. The results suggested that any disturbance of water availability in the root zone will have major impact on oil palm yield where any approaches which could improve WUE are proven to be vital for sustaining oil palm productivity under stressful conditions.

Sustaining Fruit Production Under Climate Change

The fact that Malaysia is still lagging in fruit industry despite of numerous policy dedicated to boost fruit production is due to the lack of tacit knowledge in crop management. The country is still a net importer of many tropical fruits species . As a result of deficit fruit supply, Thailand is capitalizing on our inability to produce sufficient amount of fruit to meet the domestic demand. Figure 11 illustrates the trend of fruit import from Thailand. As an example, the development and special focus are given to mangosteen to be extensively developed and marketed in the global market as flagship of the Malaysian fruit industry (NAP3,1999). These, however, did not materialized as fruits from Thailand are still dominating the world market in this fruit species. In China, durian and mangosteen are the two most popular Thai fruits, accounting for nearly 50% of total fruit sales in the market in 2011.

Mangosteen and durian from Thailand dominating China's market.
Source: Bangkok Post 8/5/2011

Fruit imported from Thailand (FAMA 2008)

NAP3:

1. Special focus for mangosteen to be developed extensively and aggressively marketed for the global market as flagship of Malaysian fruit industry
2. Institutional support provided by the government

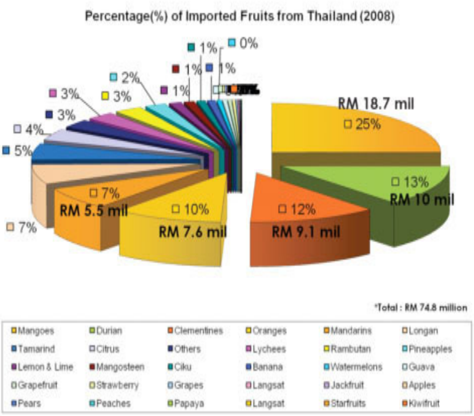


Figure 11 Fruits imported from Thailand in 2008 to cope for domestic demand (FAMA, 2008).

Present unpredictable environmental changes such as inconsistent rainfall pattern have resulted to the non-sustainability in fruit production in Malaysia. A major problem with many tropical fruit tree species is excessive vigour as a result of continuous shoot growth. The use of assimilation in leaf growth restricts fruit set and development while excessive leaf area can lead to significant water loss and the development of damaging internal water deficit. The high level of soil moisture during early stage of growth in fruit trees may be advantageous for raising successful stand with vigorous shoots but such an excessive vegetative growth at later part in the development stage is likely to adversely affect the rate of flowering and seed or fruits setting and delays in physiological maturity in plants. Like the case in some other crops, many tropical fruit trees require a brief but moderate dry period for the initiation of flower buds and to keep the buds dormant before flower induction by a sudden increase in the availability of soil moisture. The absence of this signal often lead to the failure in flower initiation and subsequently fruit production. The temporary soil drying or moderate water stress can reduce vegetative growth and control excessive shoot vigour , but can improve yield and quality of fruit crop. In the field, this climatic variation is beyond mankind ability to control but there are opportunities to establish plant' s adaptation. Various attempts to regulate plant development have been made to establish flowering initation in tropical fruit trees. The cultural practices such as modification of tree architecture, root pruning and restriction and regulated deficit irrigation are potential approaches to establish "pseudo" soil drying to trigger the most important process in fruit production, the flowering process. Plant water relation in physiological processes holds a key role that merit for investigation and exploration to sustain fruit production in Malaysia. Furthermore, a concerted multidisciplinary research approach to establish plant adaptation to climate change is needed for the fruit industry to prosper and sustain. The flowering process needs to be elucidated both by the plant physiologist and molecular biologist. The later examines the molecular biology of fruit development and molecular basis of enhanced flowering under mild water deficit and to examine of the optimization by genetic manipulation. These enablers will be able to establish agronomic manipulation for fruit trees adaptation of the climatic change and, to meet the ultimate goal for self-sufficient and safety for domestic consumption of fruits.

MANIPULATION OF GROWTH BY GENETIC OR AGRONOMIC MEANS FOR MANAGING PLANT UNDER STRESS

Genetic Manipulation

There have been many recent attempts to enhance solute accumulation in plants by inserting transgenes for the accumulation of compatible solutes (e.g. Apse et al., 1999). Many groups have now genetically enhanced the accumulation of such substances at low water potentials with a resulting maintenance of turgor. Resulting transgenic plants generally survive longer when challenged with a soil drying episode but this is not the same as maintenance or promotion of growth and such manipulations are unlikely to have little bearing on yielding of crops in the field.

Recent increases in our understanding of chemical signalling in plants have raised the possibility that artificial manipulation of hormone synthesis and accumulation may change plant performance under drought. Several of the regulating genes in the biosynthetic pathway for ABA have now been identified and high-ABA transgenics have been produced (Ahuja et al, 2010). A wide range of low ABA mutants is also available. Physiological investigations with these transgenics will reveal the importance of this hormone in the drought resistance response of plants. It seems unlikely that high ABA accumulation *per se* will be useful for high yielding under drought. Although the hormone elicits a myriad of responses that are related to water conservation and turgor maintenance under drought, these responses are not always compatible with high yielding as soil dries (see Trewavas and Jones, 1991). Genotypes of many crop species may also vary in their in their capacity to accumulate ABA in leaves and hence show differences in the sensitivity of developmental changes in soil water content (Mohd Razi and Davies, 1997).

Considering that most vulnerable farmers are often confronted with multiple stress factors, researchers have shown promising results in identifying genes for multiple abiotic stresses. This is an area of research that merit investigation to explore possible interactive mechanism of plant adaptation to the climate change. Drought and high temperature are combined abiotic stress factors that affect plant growth and development. Plants have evolved a number of adaptive mechanisms that allow the photochemical and biochemical systems to cope with negative changes in the multiple stress such as drought and high temperature both phenotypic and genotypic. The basic understanding of stomatal responses to combined impact of drought and high temperature has a significant contribution to determining overall plant survival strategies. (Figure 12) This is true as the fact that stomata is responsible for the flow of CO_2 fixed and water lost by the plants and will have implication from modeling energy fluxes to determine the ecosystem responses of individual plant survival to climate change (Ahuja et al., 2010). Much effort has concentrated on the role of stomata characters in breeding for stress tolerance. It is of the general view that stress tolerance is associated with reduced rates of water use and its relationship with the ABA accumulation. These physiological and biochemical attributes are important in relating the adaptation of plants to multiple stress tolerance.

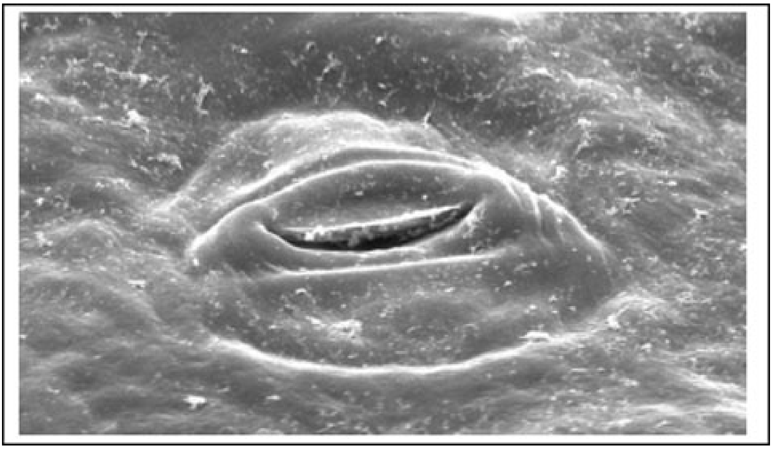


Figure 12 Appearance of mangosteen stomata on well watered condition (X 2000 magnification).

In Malaysia, genetic manipulation focused on the development of cultivar that tolerates water limited water condition. The collaborative research program involving UPM-MINT-MARDI-UMT has successfully established stress tolerant rice cultivar through induced mutation breeding. From this collaborative research program, the mutant rice cultivar MR219-4 has been developed. Mutant MR219-4 (Figure 13) is unique because it performs very well under saturated conditions in irrigated areas and aerobic conditions (sprinkler assisted irrigation) under dryland regime Abdullah et. al., 2010). Plant physiological attributes have also indicated that this new rice cultivar possesses higher stomatal conductance under limited water conditions leading to higher water use efficiency compared to other established cultivars for cultivation in major granary areas in Malaysia (Table 3). This new rice cultivar is also found to be promising for submergence stress (Damanik et al, 2010).

Table 2 Mutant lines showing higher stomatal conductance under limited water conditions compared to the established commercial cultivars MR220.219 and 211 under limited water growing conditions

Rice varieties	Normal flooding conditions	Water limited conditions
220	173	76
219	170	89
211	224	67
219Ai	390	151
219Aii	230	121
219Bi	309	327
219Bii	403	311
211Ci	335	82
211Cii	405	95
211Di	276	109
211Dii	251	18

Field Screening of Mutants (simulated water stress regime in MARDI S.Perai)

Figure 13 Plants under aerobic condition in MARDI S. Perai (MR219-4 at ripening stage)

Mutant MR219-4 is unique because it performs very well under saturated conditions in irrigated areas and aerobic conditions (sprinkler assisted irrigation) under dryland regime. In addition, the mutant can also tolerate submergence and therefore can be planted in flood-prone rainfed areas. The superior adaptation and yield performance of mutant MR219-4 under aerobic condition is obviously a very interesting finding because its parent, MR219 has never been recommended for aerobic soil (Abdullah et al, 2010)

Agronomic Manipulation

Optimizing source and sink relationship for higher yield

Once the plant has expanded its leaves to intercept radiation, dry matter accumulation is dependent upon efficient conversion of radiant energy to chemical energy (photosynthesis). This is more important for a longer period of time during plant development than is the maintenance of leaf growth. Once the ground is covered, leaf expansion is less crucial but the leaves must continue to work as carbon supply during the reproductive development is of crucial importance to the production of yield. A late soil drying episode may completely wipe out yield in a crop where yield is a reproductive plant part (e.g. grain). This can happen even when the canopy has been well developed and functioning. Work by Boyer's group has shown that immediately after anthesis, developing maize grains need a continuous supply of carbohydrate and if this can be maintained, very low water potentials can be endured and some yield can be produced. Practically this may be achieved by enhancing re-mobilisation of resources from the leaves to the developing fruits or grain. The re-mobilisation of resources is vital for the grain filling in rice production. In an attempt to established plant adaptation to minimal water, we establish new irrigation approach adopting controlled water deficit by alternate irrigation (AWD) for rice cultivation (Figure 14). Apart from saving water, this irrigation approach is found to benefit grain filling due to early senescence that resulted in much non-structural carbohydrate being mobilized from the straw to the panicle. A 'stay-green' character as in continuous flooding may result in enhanced photosynthesis and carbon gained later in the season. This may be of benefit for yielding fruit production but only if the carbohydrate product is re-mobilised to the reproductive parts. Experience from the field suggests that this may not be the case when for example photosynthesis is sustained late in the season when excess nitrogen fertiliser is applied or for example where strong stemmed, lodging-resistant varieties of cereals are chosen. Here, delayed senescence results in much non-structural carbohydrate being left in the straw. Enhanced grain filling in both wheat and rice may be achieved by controlled soil drying. This treatment enhances plant senescence and remobilisation of resources from leaves of particular genotypes with a tendency to retain carboydrates and N-rich resources in straw as grain develops. ABA may play an important role in the process (Yang et al., 2001). Soil drying can also enhance grain filling when excess N is applied to crops and one highly beneficial side effect of this treatment can be enhanced N use efficiency (Davies, Bacon and Mohd. Razi, 2004).

WATER SAVER TECHNIQUE IN GRANARY RICE PRODUCTION; THE POSSIBLE USE OF ALTERNATE IRRIGATION FOR IMPROVEMENT OF WATER USE EFFICIENCY IN RICE CULTIVATION

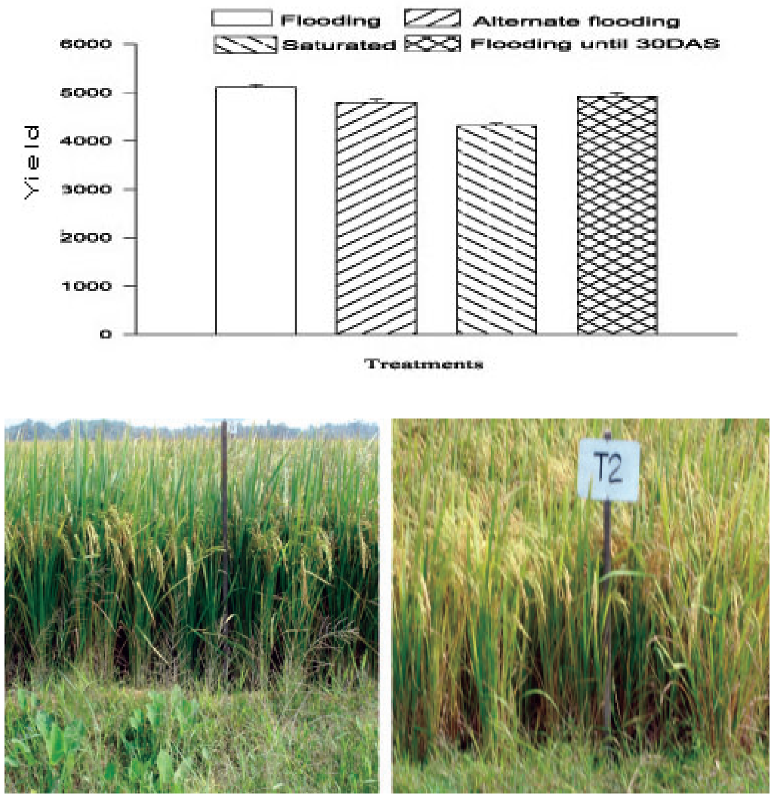


Figure 14 Effect of different water managements and Alternate irriagtion practices on rice yield (kg/ha) at Ladang Merdeka Mulong, in KADA

Exploitation of Long Distance Chemical Signalling to Regulate Plant Development and Improve Water use Efficiency

Chemical signaling can be particularly important in crop production whre plants are often container-grown and restricted roots and the protruding roots can rehydrate substantially. Root growth regulation has caused significant changes in chemical signaling that imposing intentional stress by understanding root shoot communication may have a commercial impact on restricting vegetative growth without adversely affecting subsequent plant development. Enhanced production of chemicals that can restrict leaf growth may be of commercial significance. The exploitation of long distance chemical signalling to regulate vegetative growth by restricting shoot development of over-vigorous crop, while the maintenance of shoot water status would ensure normal reproductive development. (Figure 15, 16)

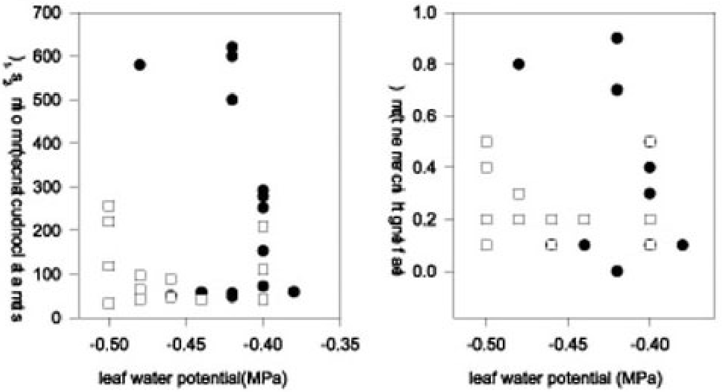


Figure 15 Evident of non-hydraulic factor controlling early stomatal conductance and leaf length of sensitive ● and tolerant □ genotypes

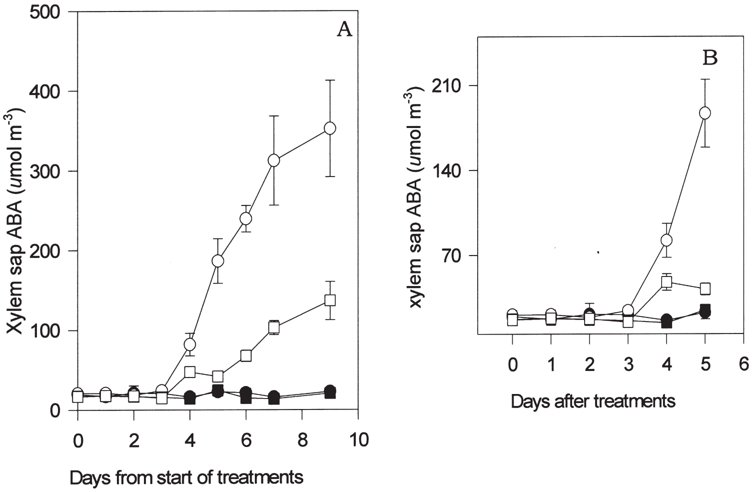
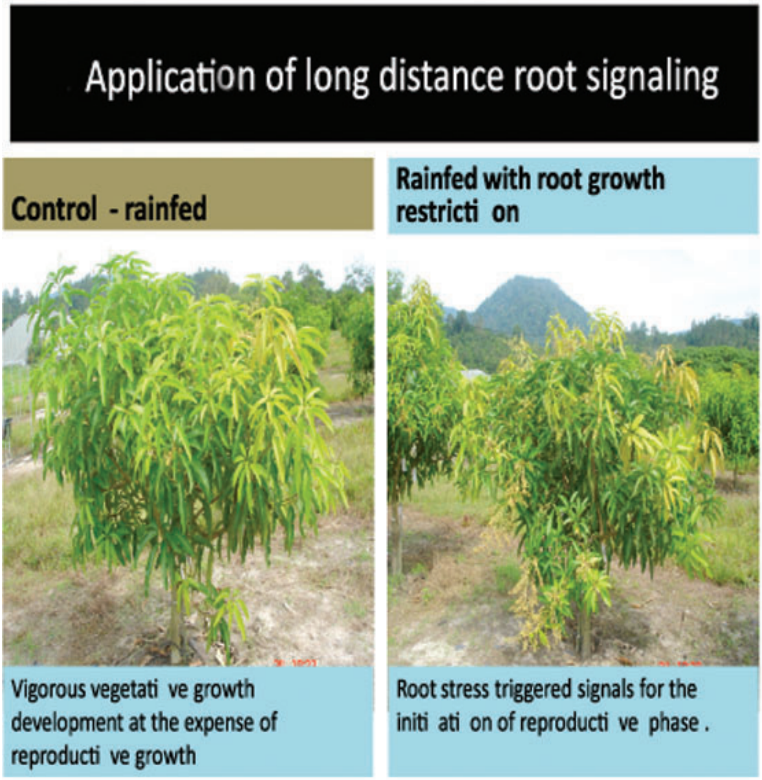


Figure 16 Xylem sap ABA of Bellboy (μ) and Cili Padi (□) that are either well watered (closed symbol) or water stressed (open symbol). Bars represent ± Se of 4 replicates. Figure 16A shows the changes throughout duration of experiment and Figure 16B is magnified showing the changes within the first 5 days of water stress (Mohd Razi, Davies and Hamad, 2002)

Subsequently, Tesfaye et al. (2008) described the results from an experiment where crop vigour is significantly reduced without any yield penalty and at the same time, efficiency of water use and quality of fruit are significantly improved. These results are achieved by employing rhizosphere manipulation to generate root signals that moved to the shoot to modify growth and functioning. The non-hydraulic responses that trigger root signals are evident in many of the species tested, tomatoes, (Ali, et al., (2006). Mohd Razi and Wahab (2008) Mohd Razi Ismail and Phizackerley (2009), coffea (Tesfaye et. al 2008), mango (Zaharah and Mohd Razi, 2009) , potato minituber (Mobini et al, 2009) , rockmelon (Fatahian et al, 2009) , mangosteen (Adiwirman, et al, 2001), oil palm (Mohd Roslan and Mohd Razi, 2009) and rice (Zulkarnain et al, 2009) The working hypothesis is that the rhizosphere regulation will trigger root signals and influence shoot development for proportional assimilate translocation. In regulation of fruit development in tomatoes, cell wall peroxidases seem to play a significant role in chemical signalling although existing restricted hydraulic Iingkages among fruit and vegetative plant parts may be important. Applying root growth restriction as part of root: shoot communication application triggered floral initiation and this is an important feature for manggo production (Figure 17). The non-hydraulic factors that regulate root and growth are evident with the changes in the ABA concentration and stomatal conductance of mango trees (Figure 18). The structural changes under modified root system have also affected shoot development (Figure 19). The overall root modification can lead to a significant changes in shoot development and often benefit crop production under irregular weather patterns as a result of to climate change (Figure 20)



Application of long distance root signaling

Control - rainfed

Rainfed with root growth restriction

Vigorous vegetative growth development at the expense of reproductive growth

Root stress triggered signals for the initiation of reproductive phase.

Figure 17 Applying root growth restriction as part of of root: shoot communication triggered application floral initiation off-season production in mango

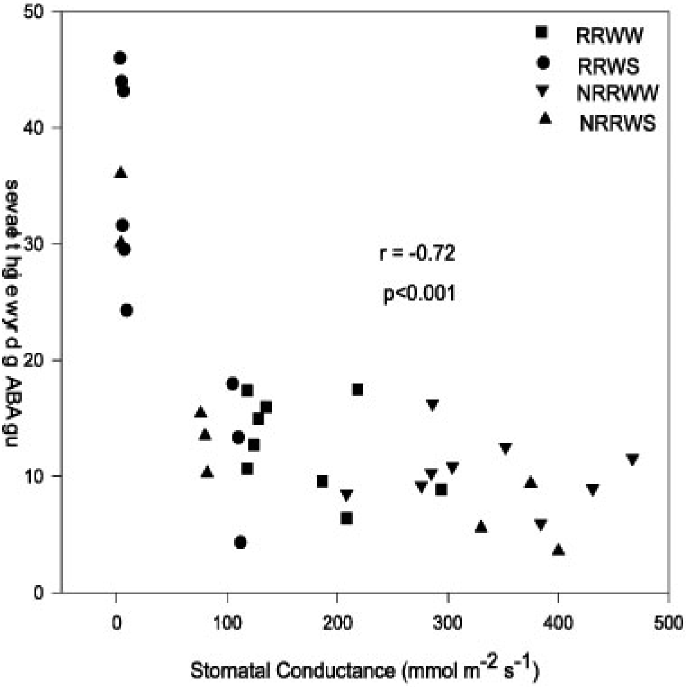


Figure 18 The relationships between leaf abscisic acid accumulation and stomatal conductance as affected by restricted and unrestricted root volumes with well water and water stress conditions and re-watered after symptoms of wilting during the water stress cycle.(Source: Zaharah and Mohd Razi, 2009)

Note:

RRWW = Restricted Root in 2 litres of soil with Well Watered

RRWS = Restricted Root in 2 litres of soil with Water Stressed

NRRWW = Unrestricted Root in 20 litres of soil with Well Watered

NRRWS = Unrestricted Root in 20 litres of soil with Water Stressed

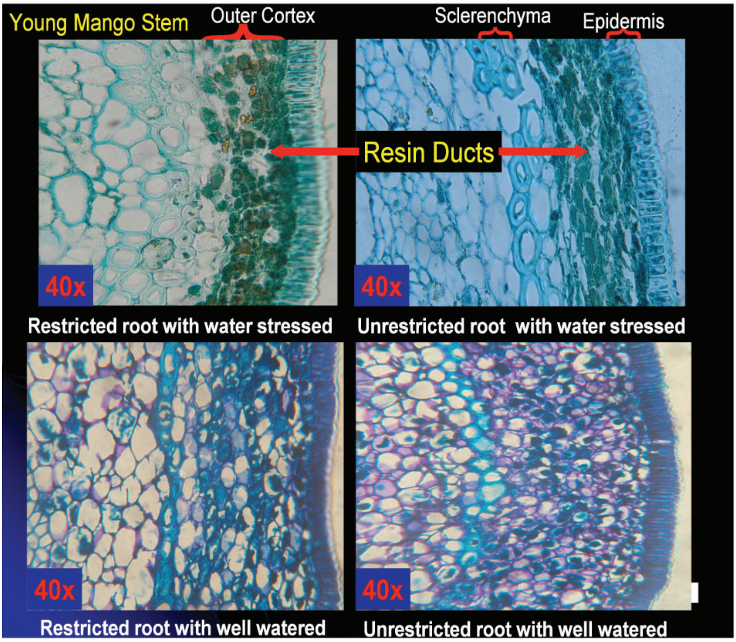


Figure 19 Structural changes in stem of mango trees with root environment manipulation. Source: (Zaharah and Mohd Razi, 2009)

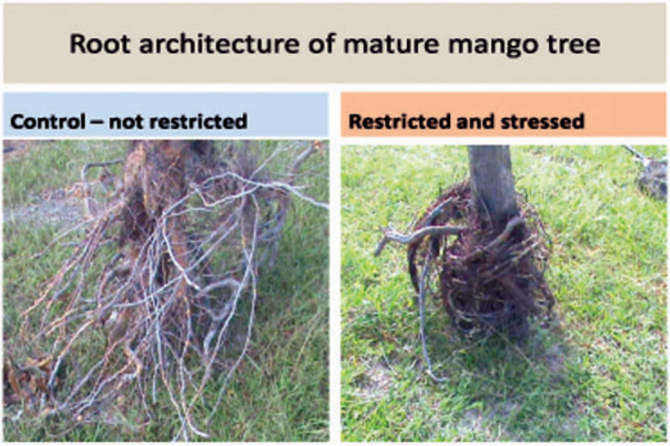
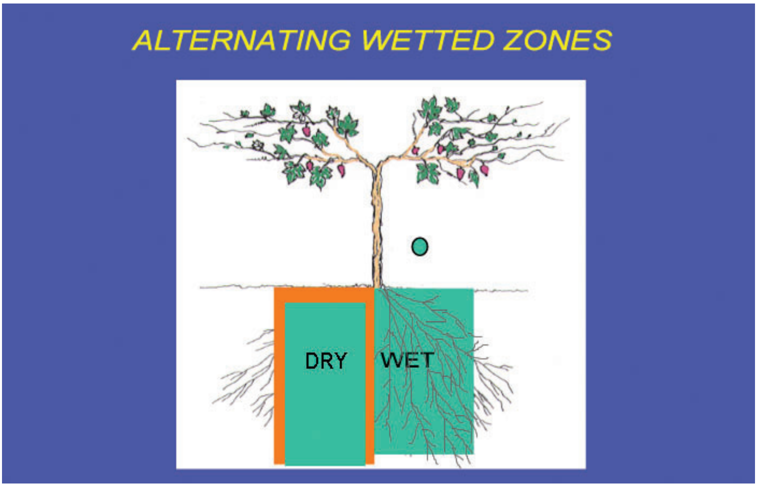
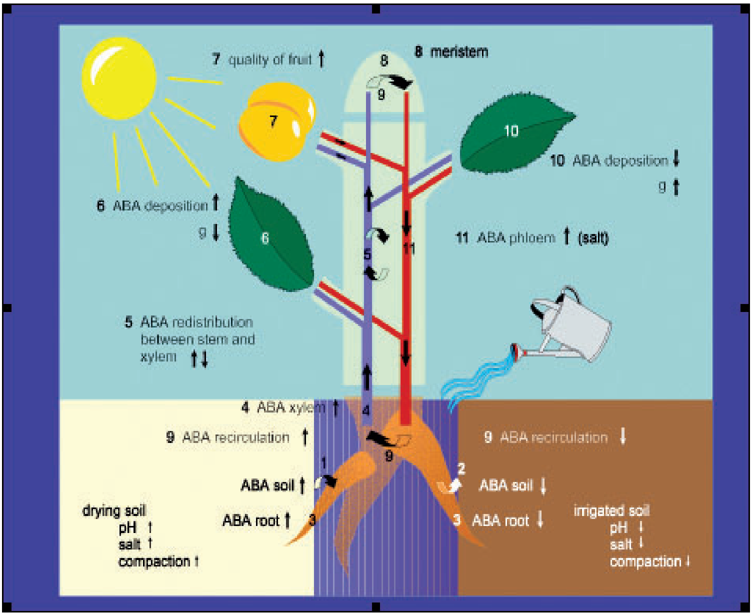


Figure 20 Restricted root architecture of mature mango tree may have potential impact in sustaining mango production due to climate change

The application of partial root drying (PRD) as one of strategies in balancing plant chemical signal is another effective way of modifying the growth and development of plants (Figure 21). PRD tends to save water derived signals produced by the roots and transported to the leaves that alter growth and yield. This and other strategies in manipulating rhizosphere development to generate plant signaling can be tools in regulation of plant growth and development in tropical crop species.



ALTERNATING WETTED ZONES



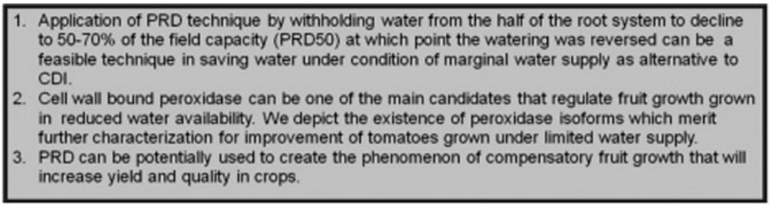

1. Application of PRD technique by withholding water from the half of the root system to decline to 50-70% of the field capacity (PRD50) at which point the watering was reversed can be a feasible technique in saving water under condition of marginal water supply as alternative to CDI.
2. Cell wall bound peroxidase can be one of the main candidates that regulate fruit growth grown in reduced water availability. We depict the existence of peroxidase isoforms which merit further characterization for improvement of tomatoes grown under limited water supply.
3. PRD can be potentially used to create the phenomenon of compensatory fruit growth that will increase yield and quality in crops.

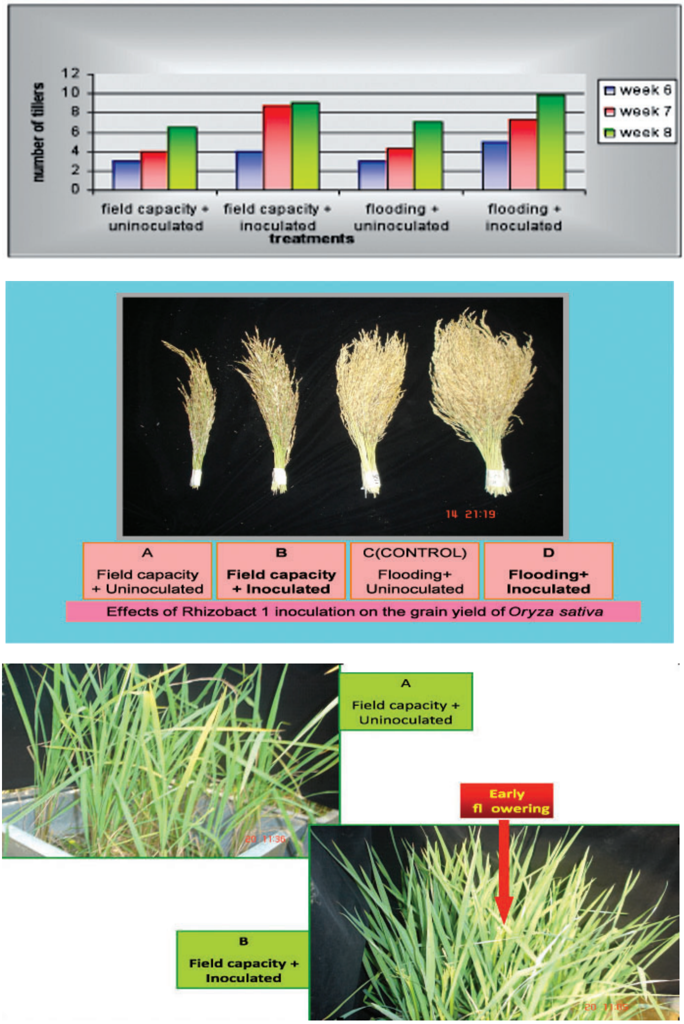
Figure 21 Improve water use efficiency with the application of Partial Root Drying Irrigation in tomatoes.

Application of Cultural Practices for Adaptation of Crops to Environmental Stresses

Selection of crops based on tolerance is vital in the land use planning. In landscape protection and reclamation, trees that can tolerate salinity stress and stresses of occasional waterlogging can be selected from the determination of tolerance characteristics. In situation where there is limited arable land available for cultivation of food crops, the choice of cultivars or species is vital to ensure that available land can be used efficiently and to use the unfavorable land successfully instead of high capital investment for land reclamation.

In a short-term approach to minimise drought stress effects, chemical and cultural practices can be potentially used. These include the use of bioregulatory substances, partial root drying, beneficial microbes, wetting agents and organic matter. The application of bioregulatory substances has been practiced as short-term measures to sustain crop during prevailing stressful environments. There are many bioregulatory substances but prospective compounds are abscicic acid analogs and monoethanolamine. Recently, a lot of interests have emerged on the possibility to improve stress tolerance of crops by transforming the glycine betaine pathway into plant species lacking of it. Others include azethelenacetal analogs, triazole, methanol benzyladenine and gibberilic acid.

The effect of mycorrhiza to enhance growth and yield of variety of crops is well understood. The enhancement of growth is found to be through the increase ability of the host plant to absorb mineral nutrients from the soil or to increase the drought tolerance of some plants e.g. mangosteen (Masri , 1997) , and tomatoes (Edaroyati *et al,* 1999). Roots of inoculated plants have higher hydraulic conductance which enhancing their water uptake under drought conditions. The used of active strain of *Klebsiella* sp. has been shown to increased grain yield of acutely water stressed plants (Razi and Sen, 1996). Rhizo-bacteria that exert beneficial effects on plant growth and development are referred to as plant growth promoting rhizo-bacteria (PGPR). In recent years, the use of PGPR to promote plant growth has increased in various parts of the world. PGPR can affect plant growth by production and release of secondary metabolites (plant growth regulators/ phyto-hormones / biologically active substances), lessening or preventing deleterious effects of phyto-pathogenic organisms in the rhizosphere and/or facilitating the availability and uptake of certain nutrients from the root environment. Selection of effective PGPR is the most critical aspect to have maximum benefits from this technology. In one of our research projects, the use of the promoter was found to be promising for improvement of water use efficiency of rice under limited water growing conditions (Figure 22).



Effects of Rhizobact 1 inoculation on the grain yield of *Oryza sativa*

Figure 22 PGR improves growth and yield of rice plants under limited water conditions

Wetting agents such as hydrogel are hydrophilic chemical material that absorbs water from the surrounding and increases moisture retention of the soil/potting substrate and improves plant survival and development. Water-absorbing synthetic polymers may improve the properties of light textured soils and therefore stimulate plant growth. In addition of the polymers to the soil increase water holding capacity and reduce evapotranspiration losses and can significantly increase water use efficiency (Al-Harbi *et al.,* 1999). It has been used to reduce the frequency of irrigation as a consequence of increased soil water content both in fruit trees and nursery crops under condition of drought or water restrictions.

Organic matters such as agricultural waste and other branches of industry (bark, wood fiber, sawdust, coir products, oil palm empty fruit bunch and rise chaff) are often incorporated in the soil to improve soil characteristics. These materials could be used successfully in agriculture after being naturally decomposed to improve soil physical and chemical properties (Ali et al, 2006). This will help to increase soil moisture content and to provide the plants with needed nutrients for better growth and development.

Other cultural practice also includes proper tillage operation, mulching, windbreaks and adoption of precise irrigation management system. Local farmers as short-term measure to minimise crop losses due to stress effects have practised these approaches. Apart from molecular and biotechnological approaches in improvement program for crop grown in stressful conditions, understanding plant interaction with external factors such as fertilizer application can provide immediate solution to the present farmers. Works by Jianchang Yang and co workers in China on rice and wheat (publications Yang et al., 2002) are applicable to farmers due to simplicity and farmer-friendly approach in improvement of grain fillings in rice and wheat grown under restricted water conditions.

Mohd Razi Ismail

PROTECTED ENVIRONMENT CULTIVATION: ALTERING NATURAL PLANT MICROCLIMATE FOR MANAGING PLANT UNDER STRESS

Environment and health concerns have lead to increasing used of various cultivation systems under protected environment for horticultural crop productions. The agriculture NKEA includes the subsector of fruit and vegetables that need to be expanded to meet the need for domestic and global market. In the strategy for tapping premium markets, the national ETP (Economic Transformation Program) has outlined the upgrading capabilities to produce fruit and vegetable for premium markets as one of the entry point projects (EPP7) that include the utilizing of protected environment for horticultural production. The sustainability feature in horticultural production under protected environment is emphasized due to the fact that open cultivation is generally associated with heavy environmental burden regarding water resource depletion and massive use of pesticides as well as high rates of fertilizer applications, often connected with low efficiency. Additionally, overexploited resources of high quality water, previously available for horticultural production, compete progressively more for human consumption, due to the strong population growth and increasing urbanization in the region. Therefore there is an immediate need to establish a new eco-efficient approach to be adopted in the horticultural sector to ensure sustainability.

The most important natural resource and the most irregular and the least manageable for crop production is the climate. It is the most determinants factor, relating to the constancy and adequacy of vegetable supply that consequently determine the self-sufficiency level (Figure 4). The tropical climate as experienced in Malaysia is characterized by irregular rainfall patterns and an abrupt change in weather pattern. In many horticultural crops, this irregular and abrupt change in weather often result to major crop failure due to the damage to harvestable organs such as fruits and grains. Heavy rainfall has frequently caused flooding and thus affect vegetable and fruit cultivation (Figure 23). In addition, heavy rainfall reduces the effectiveness of fertilizers applied to soil due to soil leaching and surface run-off.

Figure 23 Heavy rainfall at later stage of fruit development causing crop losses in open field cultivation

Cultivated horticultural plant species for protected environment cultivation are mainly selected for their high yield in optimum growing conditions. The yield advantage of plant grown in protected cultivation over the open cultivation has been well acknowledged. While the primary object of cultivation under protected cultivation is the replacement of uncertainty in crop production due to the climatic changes, there may be other considerations such as providing favorable microclimatic conditions, reduced usage of chemicals for pest, disease and weed control and also enable precision crop management that make the adoption of the principle desirable. These enablers are indeed important benefit of crop cultivation under protected cultivation, but economic consideration will usually seen as the over-riding factor. Thus, plants grown under protected cultivation also can be subjected to environmental stresses as a result of a poor design in protected environment structure. This limitation is attributed to the fact that there involves high initial cost for a protected environment structure to be built to meet the need for favorable microclimatic conditions. As a result of cost saving in protected structure, high temperature and low humidity often limit plant productivity under protected cultivation in the lowland of Malaysia (Figure 24). The non-sustain cultivation of horticultural crops under protected cultivation in lowland is partly due to poor crop management under high temperature and low humidity conditions. As shown in Figure 2 , one of the fertigation ventures failed to deliver the expected output involving huge monetary losses. One of the root causes is presumably due to low technical knowledge in water and fertilizer use. There is tendency among growers of using excessive water and fertilizer to ameliorate the adverse effect of high temperature and low humidity on crops grown under protected cultivation.

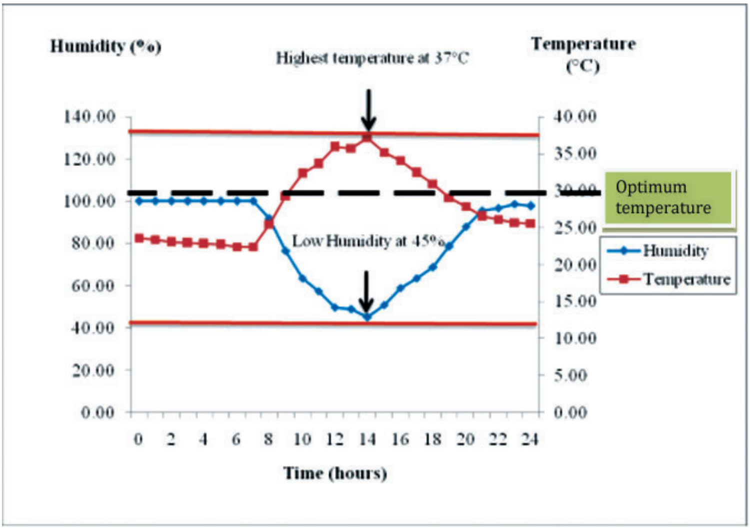


Figure 24 Diurnal changes in air temperature and relative humidity under rainshelter in lowland condition

Fertigation practices will determine volumes of fertilizer and water applied to the plant. Applying fertilizer solution based on plant water relations is shown to be efficient in comparison to growers standard practice. The analysis of of yield-fertilizer use shown in Table 3, reveals that a considerable amount of fertilizer wascgiven in excess to the plant if growers adopted fertilizer application recommended by the extension agency.

Table 4 Recommended standard fertigation practice for lowland cultivation of chillies

Source: Department of Agriculture (DoA)

Week	Volume of nutrient solution (ml)	Electrical Conductivity (dSm^{-1})
1	300-500	1.2
2	400-600	1.3
3	700-800	1.4
4	800-1200	1.5
5	1200-1500	1.6
7	1500-1800	1.8
10	1800-2000	2.0
12	1800	2.0-2.8

Table 5 Volume of fertilizer and yield for one season of cultivation for chilly plant

Irrigation/ Fertigation	Volume of nutrient solution (L/plant)	Yield (kg/plant)
DOA (Table 4)	106.3	0.75
Practice1	30.88	0.29
Practice2	38.66	0.37
Practice3	38.37	0.32
Practice4	48.26	0.37
Practice5	45.94	0.34
Practice6	58.17	0.54
Practice7	60.68	0.46
Practice8	75.27	0.60

Table 3 Analysis of Yield and Fertilizer Use for A Commercial Fertigation Project

Fertigation Practices		Total volume of fertilizer applied for 3 months duration (litre per plant)	Yield (kg per plant)
1	Grower's standard practice	106	0.75
2	Fertigation Check (fertigation based on plant water relations)	75	0.60
	Differences	31	0.15

Analysis on the commercial scale fertigation project carried by one of the agencies in Malaysia consisting of 217 units that accommodate 1000 plant population per unit

	Items	Quantity / Value
1	Plant population	217000
2	Excess fertilizer applied per plant as in Practice 1	31
3	Total fertilizer in excess applied	6.73 million litre
4	Cost per litre of fertlizer	RM 0.07
5	Total cost of fertilizer applied in excess	RM 0.471 Million
6	Yield gained with excess fertilizer applied in Practice 1 over Practice 2	0.15 kg per plant
7	Total yield gained for the project (217000 plant population at 0.15kg/plant)	32.55 tonnes
8	Assuming farm gate price at RM 4000 per tones, total yield gained	RM 0.130 Million
9	Total losses per cultivation season of 3 months	
	Total cost of fertilizer applied in excess	RM 0.471Million
	Total yield gained with excess fertilzer	RM 0.132Million
	Net losses for excess fertilizer applied	RM 0.339Million
10	Total annual loss due to excess fertilizer applied adopting Practice 1 (assuming 3 cropping season)	RM 1.017 Million

Assumption :
i. Other cultivation inputs are similar and no interference with other abiotic and biotic factors
ii. Standard growers practice (Practice 1) adopting fertilizer application based in Table 4

The analysis suggested an inefficient fertilizer use has increased production cost for a commercial chilly cultivation. Indirectly, there is an impact on the socioeconomic aspects in improving poverty and entrepreneur development program. In many agricultural projects, the government provided a significant amount of subsidies including fertilizer at the initial stage of the project venture to the growers. When these subsidies are reduced or withdrawn, they are not able to sustain their venture . These findings are consistent with the outcomes of one of the related projects as reported in the Auditors General Report (2010) when only 16% (41 out of 251) entrepreneurs are able to meet the income target during the four years of project implementation.

In retrospective, the precision management approach for cultivation under protected cultivation has been given the uttermost priority in our research at the university (Figure 25). The physiological and biochemical basis are explored to ascertain the mechanism of plant responses to the microclimatic stresses within the plant canopy. The low technology agronomical manipulations such as foliar enrichment to activate sink strength and such approaches have sustain yield and optimized resource usage. The fundamental of chemical signalling and hydraulic architecture are applied to fine-tune water and nutrient management for crop cultivation under protected cultivation. The new irrigation approaches including adopting deficit fertigation and partial root drying (PRD) have been successful in reducing water and fertilizer usage in soilless cultivation under protected cultivation. Establishment of precise irrigation management using monitoring and control system enables 60% reduction in water and fertilizer use as compared to the standard growers practices. These management approaches have increased resource use efficiency that ultimately, enable growers to sustain crop productions under unfavorable microclimatic conditions.

Figure 25 Research in precision management for plants grown under altered microclimate has been intensified for sustainable crop production.

Mohd Razi Ismail

Enhancing Food Security and Adaptation of Crop to Unfavorable Climate : The Way Forward

Environmental stress is a major force that governed food production in the tropics. By year 2025, 60-70% more food will be needed from resources similar to those available today, causing less suitable land to be brought into. To achieve sustainable crop production for human consumption, strategic measures should be undertaken in management of environmental stress parameters. In the tropics, drought, high temperature and flood are most frequent environmental parameters that determine crop production. At the plant level, restriction of plant growth due to stresses cannot be attributed to one single direct process. When plants are exposed to environmental stresses, there are integrated and regulated physiological and biochemical processes curtailing growth and plant development. Managing environmental stresses require an integrated approach to achieve sustainability. These include understanding of the fundamental and mechanism of plant responses to individual or combined stresses that affect plant metabolism. The aim of the understanding is to develop self-defence within plant organs upon exposure to external stress conditions.

The goal of understanding plant responses to environmental stress is to develop sustainable crop management practices to ensure continuity of food production. The responses of plants to environmental stress had been investigated generation by generation, and yet there still no answer to the problem of famine and death, in particular, due to drought in many parts of the world. To develop a sustainable approach in managing environmental stress, there should be an integrated effort among various disciplines in biology and physical sciences to bring their understanding together for improvement and management of crop in stressful environments. It is important that we understand the basis of the plant's finelytuned sensitivity to environmental stress, for if we can overcome it, using either agronomic or genetic techniques, the advantages for crop growth and food production may be substantial. Later in development, carbohydrate supply to developing reproductive organs can be crucial if yield is to be maximized. Grain filling processes are highly sensitive to environmental stresses and these processes are another substantial target for biotechnologists interested in enhancing crop yield under dryland environments. There is an immediate need for an interdisciplinary research strategy for the future where plant breeders, molecular technologists, physiologists and agronomists to work together to address important crop production issues in the region. Finally, the ways in which enhanced understanding of the physiology of plant growth and development under environmental stresses may be exploited to sustain crop yield and will lead to food security in Malaysia.

REFERENCES

Abdullah , M.Z., Rahim, H, Sariam, O. Maziah , M., and Sayed Zain, S.H. (2010). MR219-4. An efficient water use mutant developed through mutation breeding. Proceedings National Rice Conference 2010; pp253-256

Adiwirman, l; Mohd Razi, I; Mohd Ridzwan, H; Masri, M; Fauzi, R (2001) Increase survival of droughted mangosteen plants by hydrogel polymer incorporation. Transactions of the Malaysian Society of Plant Physiology 10;p79-81

Ahuja, I, de Vos, R.CH, Bones, A, M and Hall, R .D. (2010) Plant molecular stress responses face climate change . Trends in Plant Science 15; 664-676

Ali, I, H., Mohd Razi Ismail, M. Mokhtarudin Manan and H Mohd Saud (2006) . Rice straw compost and water deficit affect yield , quality and Water Use Efficiency of toimatoes in different media. Biological Agriculture and Horticulture- Vol 24 No 3, 301-315

Al-Harbi, A. R., Al-Omran, A. M., Shalaby, A. A. and Choudhary, M. I. (1999). Efficacy of a hydrophilic polymer declines with time in greenhouse experiments. HortScience 34(2):223 - 224.

Alvaro, F. Isidro , J., Villegas, D., Garcia, del Moral, I, F and Royo, C., (2008) Breeding effects on grain filling , biomass partitioning and remobilization in Mediterranean durum wheat. Agronomy Journal 100; 361-270

Amudha J. and Balalubramani G. (2011). Recent molecular advances to combat abiotic stress tolerance in crop plants. Biotechnology , Molecular and Biological Review. 6(2): 31-58

Andrews, J., M. Malone, D.J. Thompson, L.C Ho and K.S. Burton 2000: Peroxidase isoenzyme patterns in the skin of maturing tomato fruit. Plant Cell Environment 23, 415-422

Apse, M.P. Aharon, G.S , Snedden W.A and Blumwald, E. (1999) Salt tolerance conferred by over expression of a vascular Na+/H= antiport in Arabidopsis. Science 285; 1256-1258.

Auditors General Report 2010. Management of Mega Fertigation Project Terengganu. Pg 31-41. Auditors General Report.

Augustus, E.I. 2001. Relations between oil palm yield and climatic factors under differential irrigation regimes. In *Proceedings of the 2001 PIPOC International Palm Oil Congress (Agriculture).* pp568-577

Bacon, M. A., Wilkinson S. A., Davies W. J., (1998). pH regulated leaf cell expansion in droughted plant is ABA-dependent. Plant Physiology, 118: 1507-1515.

Bueno CS, Pasuquin E, Tubana B and Lafarge L. 2010. Improving sink regulation, and searching for promising traits associated with hybrids, as a key avenue to increase yield potential of the rice crop in the tropics. Field Crops Research. 118:199–207

Boyer, J.S. (1982) Plant productivity and environment. Science 218; 443-448

Ceccarelli, S. and Grando, S. (1996). Drought as a challenge for the plant breeder. Plant, Growth Regulator, **20**:149-155.

Damanik, I, Mahmood Maziah,, Mohd Razi Ismail, Syahida Ahmad, Abdullah Mohd Zain. (2010) Responses of the antioxidative enzymes in Malaysian rice (Oryza sativa L.) cultivars under -submergence condition. Acta Physiologia Plantarum. **32** : 739-747

Davies, W.J and Gowing , D.J.G (1999) Plant responses to small perturbation in soil water status. In : Phsyiological Plant Ecology. Eds. M.C. Press et al., Blackwells Oxford, 67-85

Davies, W.J., Bacon, M, Mohd Razi Ismail (2004) Crop growth and environmental stress; genetic targets and agronomic manipulation to sustain yield under drought. In : Environmental Stress Impact on Tropical Crops .(Eds. Mohd Razi Ismail and W.J. Davies) Joffri Publishing House Seri Kembangan ; 1-8

De Vita P, Nicosia OLD, Nigro F, Platani C, Riefolo C, Fonzo ND,Cattivelli L (2007). Breeding progress in morpho-physiological, agronomical and qualitative traits of durum wheat cultivars released in Italy during the 20th century. European. Journal of . Agronomy., 26:39-53

Easterling, W.E., Aggarwal, P.K., Batima, P., Brander, K.M., Erda,L., Howden, S.M., Kirilenko, A., Morton, J., Soussana, J.-F.,Schmidhuber, J., and Tubiello, F.N. (2007). Food, fiber and forestproducts. In Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L.Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson,eds (Cambridge, UK: Cambridge University Press), pp. 273–313.

Edaroyati, P. M. W., Ismail, Mohd Razi., Azizah, H. and Mokhtaruddin, A. (1999). Mycorrhizal in soilless culture: effects on yield of tomato plants (*Lycopersicon esculentum* Mill.). Microbiology Symposium and JSPS-NRCY/DOST/LIPI/VCC Seminar.

FAO (Food and Agricultural Organization of the United Nations). 2008. Food and agriculture statistics global outlook.. http://faostat.fao.org/Portals/_Faostat/documents/pdf/world.pdf

Foong, S.F and Lee, C.H. (2000) Increasing oil palm productivity with irrigation – Felda experience. International Planters Conference, 17-20 May 2000.pp277-301.

Gowing, D. J. G., Davies, W. J., Trejo, C. L. and Jones, H. G. (1993). Xylem transported chemical signals and the regulation of plant growth and physiology. Philos. Transaction of the . Royal Society of . Biological Science **341**:41-47.

Hay R.K.M. (1995). Harvest index: a review of its use in plant breeding and crop physiology. Annals of Applied Biology 126, 197–216.

Henson, I.E . (1991). Limitations to gas exchange, growth and yield of young oil palm by soil water supply and atmospheric humidity. Transactions of Malaysian Society of Plant Physiology, **2**:39-45.

Horie T, Lubis I, Takai T, Ohsumi A, Kuwasaki K, Katsura K and Nii A. (2003). Physiological traits associated with high yield potential in rice. In: Mew, T.W., Brar, D.S., Peng, S., Dawe, D., Hardy, B. (Eds.), Rice Science: Innovations and Impact for Livelihood. Proceedings of the International Rice Research Conference, 16–19 September 2002, Beijing, China, pp. 117–145

Idris, O. 2002. El Nino: langkah-langkah mengurangkan kesannya terhadap pengeluaran hasil sawit. Peladang Sawit **21**:1-5.

International Rice Research Institute (2011), IRRI Bulletin

Jones, H. G. (1986). Plants and Microclimate. Cambridge University Press, 322 pp.

Katsura K, Maeda S, Horie T and Shiraiwa T. (2007). Analysis of yield attributes and crop physiological traits of Liangyoupeijiu, hybrid rice recently bred in China. Field Crops Research. 103, 170–177.

Kirschbaum, M, U.F. (2011). Does enhanced photosynthesis enhanced growth? Lessons learned from CO2 enrichment studies. Plant Physiology 155 ; 117-124

Lafarge T and Bueno CS. 2009. Higher crop performance of rice hybrids than elite inbreds in the tropics. 2. Does sink regulation, rather than sink size, play a major role? Field Crops Research. 114, 434–440.

Laza RC, Peng S, Akita S and Saka H. 2003. Contribution of biomass partitioning and translocation to grain yield under sub-optimum growing conditions in irrigated rice. Plant Production Science 6 (1): 28–35.

Nguyen, H. T. and Burje, J. J. (1987). Genetic diversity of heat shock protein synthesis and its relation to thermal tolerance in wheat leaves. In Key, J. L. and McIntoch (Eds) Plant Gene Systems and Their Biology. AR Liss Inc. New York, pp 109-120.

Makino, A, (2011) Photosynthesis, grain yield and nitrogen utilization in rice and wheat . Plant Physiology 155; 125-129

Masri, M. (1997). Mycorrhiza inoculation from growth enhancement and improvement in water relation in mangosteen seedlings. PhD Thesis, UPM Serdang.

Mobini,H. S, Mohd Razi Ismail and Hossein Aroueei (2009). Influence of ventilation and media on tuberisation and growth characteristics. African Journal of Biotechnology 8; 2232-2341

Mohd Razi Ismail and Khuzaimah Mohd Noor (1996). Growth, Water Relations and Physiological Processes of Starfruit (*Averrhoa carambola* L.) Plants Under Root Growth Restriction. *Scientia Horticulturae*; 65 (4): 229-238 .

Mohd Razi Ismail and W. J. Davies (1997). Water relations of *Capsicum* genotypes under water stress. Biologia Plantarum 39(2):293-297

Mohd. Razi, I., Edaroyati, P. M. W. and Patricia P. (1999). The development of protected environment for horticultural crop improvement in Malaysia. Microbiology Symposium and JSPS-NRCY/DOST/LIPI/VCC Seminar.

Mohd Razi Ismail and W.J. Davies (2002) Growth and stomatal responses of pepper to drought and it relationship to the xylem sap ABA. Scientia Horticulturae 96 (1-4) (2002) pp. 313-327

Mohd Razi, I. Puteri Edaroyati M Wahab (2008) Growth, physiological and biochemical responses of tomato (Lycopersicon esculentum Mill) grown in deficit irrigation. Ecology, Environment and Conservation. **14(4):**169-174

Mohd Razi , I, Zulkfli, O, Kamaruzaman, S, Sariah , M, Anuar, A.R, Mohamad Hanafi, M, Lopez, S, Beattie, A, Rita, M, Zainal Abidin M.A, Zainal Abidin, M, Ismail, L, Amin Mahir, I (2010). A Comprehensive study of citrus cultivation and greening disease in

Durian Mentangau, Terengganu. A consultancy report to *East Coast Economic Region Development Council* (*ECERDC*)

Mohd Roslan MN and Mohd Razi, I (2010) . Crop water use efficiency in under rain fed and irrigated oil palm cultivation. Proceedings of the 2010 PIPOC International Palm Oil Congress (Agriculture).

Mon, K.L and Chang, C.M (2008) The impact of drought and flood on paddy cultivation in Muda Irrigation scheme. Paper presented at teh 13th Conference on Irrigation and Drainage (13th MANCO) , Kota Kinabalu 2-3rd Feb 2008.

Neeraja C, Maghirang-Rodriguez R, Pamplona A, Heuer S, Collard B, Septiningsih E, 1 2007. A marker-assisted backcross approach for developing submergence-tolerant rice cultivars. Theoretical and Applied Genetics 115: 767–776.

Peng S, Yang J, Laza MRC, Sanico AL, Visperas RM and Son TT. 2003. Physiological bases of heterosis and crop management strategies for hybrid rice in the tropics. In: Virmani, S.S., Mao, C.X., Hardy, B. (Eds.), Hybrid Rice for Food Security, Poverty Alleviation, and Environmental Protection: Proceedings of the 4th International Symposium on Hybrid Rice. Hanoi, Vietnam, 14–17, May 2002, IRRI, Los Ba˜nos, Philippines, pp. 153–170.

Razi, S. S. and Sen, S. P. (1996). Amelioration of water stress effects on wetland rice by urea-N, plant growth regulators and foliar spray of a diazotrophic bacterium *Klebsiella sp.* Biology Fertility Soils, **23**:454-458.

Richards, R.J. (1993) Breeding crops with improved stress resistance. In: Plant responses to cellular dehydration (Eds. T.J. Close and E.A. Bray, American Society of Plant Physiology Proceedings ;pp: 211-223)

Sheehy JE, Dionora MJA and Mitchell PL. 2001. Spikelet numbers, sink size and potential yield in rice. Field Crops Research. 71, 77–85.

Siddique KHM, Kirby EJM and Perry MW. 1989. Ear-to-stem ratio in old and modern wheats: relationship with improvement in number of grain per year and yield. Field Crops Research 21, 59–78.

Sreenivasulu, N., Sopory S.K. and Kavi Kishor P.B. (2007). Deciphering the regulatory mechanisms of abiotic stress tolerance in plants by genomic approaches. Gene 388: 1-13.

Sobeih, W. Y., I. C. Dodd, M.A. Bacon, D. Grierson and W.J. Davies 2004: Long-distance signals regulating stomatal conductance and leaf growth in tomato(*Lycopersicon esculentum)* plants subjected to partial root drying. Journal of Experimental Botany . 55, 2353-2363

Tarmizi, A. H. and Marziah, M. (1995). The influence of low temperature treatment on growth and proline accumulation in polyembriogenic cultures of oil palm (*Elaeis guineensis* Jacq.). *Elaeis* **7**:107-117.

Tesfaye, S.G., Mohd **Razi, I**. and Maziah, M.(2008) Effects of deficit irrigation and partial rootzone drying on growth, dry matter partitioning and water use efficiency in young Coffee (Coffea arabica L.) plants. Journal of Food Agriculture and Environment. **6(2)**:132-137

Trewavas, A.J, and Jones, H.G. (1991). In : Abscisic acids , Physiology and Biochemistry. BIOS;pp:169-188

Thompson, D.S. W.J. Davies and L.C. Ho 1998: Regulation of tomato fruit growth by epidermal cell wall enzymes. Plant Cell Environment. 21, 589-599

Turner, P.D. 1976. The effects of drought on oil palm yields in South-east Asia and South Pacific region. In: *International Developments in Oil Palm, 1976. Proc. of the Malaysian Developments in Oil Palm Conf, Kuala Lumpur*, 14-17 Jun 1976: 673-94.

Wan Mohammad Zulkarnain, **Mohd Razi Ismail***, M. Ashrafuzzaman, Halimi Mohd Soud and Ismail C Haroun. (2009) Growth, physiological and biochemical responses of Malaysian rice cultivars to water stress. Pertanika. **32(2)** 323-333

Xu K, Xia X, Fukao T, Canlas P, Maghirang-Rodriguez R, Heuer S, (2006). Sub1A is an ethylene response factor-like gene that confers sub-mergence tolerance to rice. Nature 442: 705–708.

Yamauchi M. 1994. Physiological bases of higher yield potential in F1 hybrids. In: Virmani, S.S. (Ed.), Hybrid Rice Technology: New Developments and Future Prospects. IRRI, pp. 71–80.

Yang, J. Zhang, J, Wang, Z , Zhu, Q and Wang, W. (2001). Hormonal changes in the grains of rice subjected to water stress during grain filling. Plant Physiology 127; 315-323.

Yang W, Peng S, Laza RC, Visperas RM and Dionisio-Sese ML. 2007. Grain yield and yield attributes of new plant type and hybrid rice. Crop Science. 47, 1393–1400.

Yang J and Zhang J. 2010. Crop management techniques to enhance harvest index in rice. Journal of Experimental Botany, 61: 3177–3189

Zaharah, S and Mohd Razi Ismail (2009). Growth, stomata aperture, biochemical changes and branch anatomy in mango cv Chokanan in response to root restriction and water stress. Scientia Horticulturae , 123; 58-67

Zhu B.C., Su J., Chan M.C. Verma D.P.S., Fan Y.L. and Wu. R. (1998). Over expression of a Delta (1) pyrroline-5-carboxylase synthetase gene and analysis of tolerance to water and salt stress in transgenic rice. Plant Science 139: 41-48.

Zhu, X.G, Long, S.P and Ort D.R (2010) Improving photosynthetic efficiency for greater yield . Annual Review Plant Biology 61; 235- 262

BIOGRAPHY

Mohd Razi Ismail was born in Kelantan, Malaysia on 14 May 1961. He obtained his early education at Melor Primary and Secondary School, in Kelantan. He then completed his secondary school education at Technical Secondary School, in Alor Star Kedah in 1978. He then, enrolled as a Diploma in Agriculture undergraduate student at the then Universiti Pertanian Malaysia before being promoted to the Bachelor Agriculture Science in 1980. Graduated with a Bachelor Agriculture Science from Universiti Pertanian Malaysia in 1984, he then pursued his postgraduate study at Wye College, University of London , England in 1986 before he graduated with PhD in Horticulture (Plant Physiology) in 1989.

Dr Mohd Razi started his lectureship in UPM in April 1989, promoted to Associate Professor in June 1997 and was then promoted to Professor in Plant Physiology at the Faculty of Agriculture in 2007. He has more than 20 years experience as an academician in teaching Plant Physiology courses both at undergraduate and postgraduate levels. In program curriculum development at the University, Dr Mohd Razi is one of the committee members who involved in re-structuring of the Bachelor of Agriculture Science (BSP) to replace the Bachelor of BioIndustry at the faculty. He has developed courses - Protected Environment Agriculture and Farm Practice-Controlled Environment for the undergraduate program. He developed the postgraduate course, Physiology of Plant Under Environmental Stress (HRT5301) to cater the understanding of plant physiology for postgraduate levels. He has also served as one of the expert panels in establishing curriculum development for Diploma of Agro-technology students in Malaysian polytechnics under the Ministry of Higher Education.

Dr Mohd Razi has supervised more than 100 undergraduates and more than 50 postgraduates in the field of agriculture and horticulture where many of them have graduated. At present he is supervising 25 postgraduates as the main supervisor. Apart from postgraduate supervision, he also supervises post-doctoral in the field of environmental plant physiology.

His area of research interest is on environmental stress physiology in which he has generated knowledge in the intricacies of plant regulation under stressful environment especially in tropical crops. While many of his research programs are funded by national research awarding bodies such as MOSTE and MOA, he had also been awarded international awards from the British Council and Foreign and Commonwealth Office in 1993 and 2003, respectively. These research grants that were both granted by national and international levels have enabled Dr Mohd Razi to supervised postgraduates , build –up research resources and published more than 200 scientific articles in various publications such as in books, journals , serial publications and proceedings.

Food security has been a very important niche area in agriculture research. In the Eighth Malaysian Plan (RMK 8) , Dr Mohd Razi has led one project under IRPA Top-Down Program with funding amounted to RM 0.65 million to work on sustainable rice production under limited water conditions. Recently, when the Ministry of Higher Education (MOHE) launched the Top-Down Program under Long Term Research Grant (LRGS), Dr Mohd Razi is the program leader who leads the team to secure grant in the niche area of Food Security. Recently, the Ministry of Higher Education has approved a grant of RM 10 million for his team to undertake this research program.

In lieu with his experience in plant eco-physiology of food crops, he has also been invited for advisory and extension services for various agencies both local and international levels. At the international level, he has successfully co-ordinated the academic link under Program P551: The Environmental Stress Impact on Tropical Crops under the auspicious of British Council FICHE –UPM Link Program for several terms. He has led the United Nation Development (UNDP) Training Program for scientist and extension officer in hydroponics and protected cultivation in 2000. At the national level, he involved with many government and private agencies for consultancy purpose. In 2010, he had successfully led a group of consultants to undertake a comprehensive study for the development of a tropical fruit crop in the Eastern Corridor Economic Development Region, ECERDC with a grant amounted to RM 0.65 million. Beside the mentioned administrative duties, he was the UPM Hydroponic Project Manager from 1995-2003 and when Institute of Tropical Agriculture was established in the university , he was appointed and served as the first, Head of Laboratory of Food Crop at the Institute until now.

The University had awarded him at the Majlis Anugerah Gemilang Putra (MGAP) 2010 in the excellence category of consultancy. He received the Excellence Service Award in 1996 and 2007 from the University. The Faculty of Agriculture awarded Dr Mohd Razi 1997 Researcher's Award and the Certificate of Excellence Awards throughout the years of his service at the faculty. His research on saving water in horticultural crops has also won an award in the Water Malaysia Exhibition in 2009.

Despite of the endless task he has to encounter as a daily routine, Dr Mohd Razi is keen in badminton and will join his friends in the badminton court and return home for his family and the community before dusk. For the community, he serves in the Persatuan Penduduk and Surau al-Ikhlas Fasa 4 Tambahan , Bandar Baru Bangi and other organisations in various capacities.

"If death comes and one of you has a small palm tree in his hand, let him plant it before he dies starts if he is able to."

ACKNOWLEDGEMENT

Prof Dr. Mohd Razi Ismail would like to acknowledge Universiti Putra Malaysia, Ministry of Science, Technology and Innovation, Ministry of Higher Education and Ministry of Agriculture and Agro-Industry for the facilities and financial support to carry out various research projects. He is indebted to his colleagues, students of both undergraduates and postgraduates, supporting staff , the university community and many others for their presence, contributions and support throughout his working life at the University.

Allah promises :

Any Muslim who plants a tree, then whatever is eaten from it is sadaqah (charity) on his behalf; what is stolen from it is also sadaqah; what animals eat from it is also sadaqah;what birds eat from it is also sadaqah; whosoever takes anything from the tree, it is sadaqah (for the one who has planted the tree).”

InsyaAllah, we sow the seed of knowledge to nourish mankind with food are liken.

LIST OF INAUGURAL LECTURES

1. Prof. Dr. Sulaiman M. Yassin
   The Challenge to Communication Research in Extension
   22 July 1989

2. Prof. Ir. Abang Abdullah Abang Ali
   Indigenous Materials and Technology for Low Cost Housing
   30 August 1990

3. Prof. Dr. Abdul Rahman Abdul Razak
   Plant Parasitic Nematodes, Lesser Known Pests of Agricultural Crops
   30 January 1993

4. Prof. Dr. Mohamed Suleiman
   Numerical Solution of Ordinary Differential Equations: A Historical Perspective
   11 December 1993

5. Prof. Dr. Mohd. Ariff Hussein
   Changing Roles of Agricultural Economics
   5 March 1994

6. Prof. Dr. Mohd. Ismail Ahmad
   Marketing Management: Prospects and Challenges for Agriculture
   6 April 1994

7. Prof. Dr. Mohamed Mahyuddin Mohd. Dahan
   The Changing Demand for Livestock Products
   20 April 1994

8. Prof. Dr. Ruth Kiew
   Plant Taxonomy, Biodiversity and Conservation
   11 May 1994

9. Prof. Ir. Dr. Mohd. Zohadie Bardaie
   Engineering Technological Developments Propelling Agriculture into the 21st Century
   28 May 1994

10. Prof. Dr. Shamsuddin Jusop
    Rock, Mineral and Soil
    18 June 1994

11. Prof. Dr. Abdul Salam Abdullah
    Natural Toxicants Affecting Animal Health and Production
    29 June 1994

12. Prof. Dr. Mohd. Yusof Hussein
    Pest Control: A Challenge in Applied Ecology
    9 July 1994

13. Prof. Dr. Kapt. Mohd. Ibrahim Haji Mohamed
    Managing Challenges in Fisheries Development through Science and Technology
    23 July 1994

14. Prof. Dr. Hj. Amat Juhari Moain
    Sejarah Keagungan Bahasa Melayu
    6 Ogos 1994

15. Prof. Dr. Law Ah Theem
    Oil Pollution in the Malaysian Seas
    24 September 1994

16. Prof. Dr. Md. Nordin Hj. Lajis
    Fine Chemicals from Biological Resources: The Wealth from Nature
    21 January 1995

17. Prof. Dr. Sheikh Omar Abdul Rahman
    Health, Disease and Death in Creatures Great and Small
    25 February 1995

18. Prof. Dr. Mohamed Shariff Mohamed Din
    Fish Health: An Odyssey through the Asia - Pacific Region
    25 March 1995

19. Prof. Dr. Tengku Azmi Tengku Ibrahim
    Chromosome Distribution and Production Performance of Water Buffaloes
    6 May 1995

20. Prof. Dr. Abdul Hamid Mahmood
    Bahasa Melayu sebagai Bahasa Ilmu- Cabaran dan Harapan
    10 Jun 1995

21. Prof. Dr. Rahim Md. Sail
    Extension Education for Industrialising Malaysia: Trends, Priorities and Emerging Issues
    22 July 1995

22. Prof. Dr. Nik Muhammad Nik Abd. Majid
    The Diminishing Tropical Rain Forest: Causes, Symptoms and Cure
    19 August 1995

23. Prof. Dr. Ang Kok Jee
    The Evolution of an Environmentally Friendly Hatchery Technology for Udang Galah, the King of Freshwater Prawns and a Glimpse into the Future of Aquaculture in the 21st Century
    14 October 1995

24. Prof. Dr. Sharifuddin Haji Abdul Hamid
    Management of Highly Weathered Acid Soils for Sustainable Crop Production
    28 October 1995

25. Prof. Dr. Yu Swee Yean
    Fish Processing and Preservation: Recent Advances and Future Directions
    9 December 1995

26. Prof. Dr. Rosli Mohamad
    Pesticide Usage: Concern and Options
    10 February 1996

27. Prof. Dr. Mohamed Ismail Abdul Karim
    Microbial Fermentation and Utilization of Agricultural Bioresources and Wastes in Malaysia
    2 March 1996

28. Prof. Dr. Wan Sulaiman Wan Harun
    Soil Physics: From Glass Beads to Precision Agriculture
    16 March 1996

29. Prof. Dr. Abdul Aziz Abdul Rahman
    Sustained Growth and Sustainable Development: Is there a Trade-Off 1 or Malaysia
    13 April 1996

30. Prof. Dr. Chew Tek Ann
    Sharecropping in Perfectly Competitive Markets: A Contradiction in Terms
    27 April 1996

31. Prof. Dr. Mohd. Yusuf Sulaiman
    Back to the Future with the Sun
    18 May 1996

32. Prof. Dr. Abu Bakar Salleh
    Enzyme Technology: The Basis for Biotechnological Development
    8 June 1996

33. Prof. Dr. Kamel Ariffin Mohd. Atan
    The Fascinating Numbers
    29 June 1996

34. Prof. Dr. Ho Yin Wan
    Fungi: Friends or Foes
    27 July 1996

35. Prof. Dr. Tan Soon Guan
    Genetic Diversity of Some Southeast Asian Animals: Of Buffaloes and Goats and Fishes Too
    10 August 1996

36. Prof. Dr. Nazaruddin Mohd. Jali
    Will Rural Sociology Remain Relevant in the 21st Century?
    21 September 1996

37. Prof. Dr. Abdul Rani Bahaman
    Leptospirosis-A Model for Epidemiology, Diagnosis and Control of Infectious Diseases
    16 November 1996

38. Prof. Dr. Marziah Mahmood
    Plant Biotechnology - Strategies for Commercialization
    21 December 1996

39. Prof. Dr. Ishak Hj. Omar
    Market Relationships in the Malaysian Fish Trade: Theory and Application
    22 March 1997

40. Prof. Dr. Suhaila Mohamad
Food and Its Healing Power
12 April 1997

41. Prof. Dr. Malay Raj Mukerjee
A Distributed Collaborative Environment for Distance Learning Applications
17 June 1998

42. Prof. Dr. Wong Kai Choo
Advancing the Fruit Industry in Malaysia: A Need to Shift Research Emphasis
15 May 1999

43. Prof. Dr. Aini Ideris
Avian Respiratory and Immunosuppressive Diseases- A Fatal Attraction
10 July 1999

44. Prof. Dr. Sariah Meon
Biological Control of Plant Pathogens: Harnessing the Richness of Microbial Diversity
14 August 1999

45. Prof. Dr. Azizah Hashim
The Endomycorrhiza: A Futile Investment?
23 Oktober 1999

46. Prof. Dr. Noraini Abdul Samad
Molecular Plant Virology: The Way Forward
2 February 2000

47. Prof. Dr. Muhamad Awang
Do We Have Enough Clean Air to Breathe?
7 April 2000

48. Prof. Dr. Lee Chnoong Kheng
Green Environment, Clean Power
24 June 2000

49. Prof. Dr. Mohd. Ghazali Mohayidin
Managing Change in the Agriculture Sector: The Need for Innovative Educational Initiatives
12 January 2002

50. Prof. Dr. Fatimah Mohd. Arshad
Analisis Pemasaran Pertanian di Malaysia: Keperluan Agenda Pembaharuan
26 Januari 2002

51. Prof. Dr. Nik Mustapha R. Abdullah
Fisheries Co-Management: An Institutional Innovation Towards Sustainable Fisheries Industry
28 February 2002

52. Prof. Dr. Gulam Rusul Rahmat Ali
Food Safety: Perspectives and Challenges
23 March 2002

53. Prof. Dr. Zaharah A. Rahman
Nutrient Management Strategies for Sustainable Crop Production in Acid Soils: The Role of Research Using Isotopes
13 April 2002

54. Prof. Dr. Maisom Abdullah
Productivity Driven Growth: Problems & Possibilities
27 April 2002

55. Prof. Dr. Wan Omar Abdullah
Immunodiagnosis and Vaccination for Brugian Filariasis: Direct Rewards from Research Investments
6 June 2002

56. Prof. Dr. Syed Tajuddin Syed Hassan
Agro-ento Bioinformation: Towards the Edge of Reality
22 June 2002

57. Prof. Dr. Dahlan Ismail
Sustainability of Tropical Animal-Agricultural Production Systems: Integration of Dynamic Complex Systems
27 June 2002

58. Prof. Dr. Ahmad Zubaidi Baharumshah
The Economics of Exchange Rates in the East Asian Countries
26 October 2002

59. Prof. Dr. Shaik Md. Noor Alam S.M. Hussain
Contractual Justice in Asean: A Comparative View of Coercion
31 October 2002

60. Prof. Dr. Wan Md. Zin Wan Yunus
    Chemical Modification of Polymers: Current and Future Routes for Synthesizing New Polymeric Compounds
    9 November 2002

61. Prof. Dr. Annuar Md. Nassir
    Is the KLSE Efficient? Efficient Market Hypothesis vs Behavioural Finance
    23 November 2002

62. Prof. Ir. Dr. Radin Umar Radin Sohadi
    Road Safety Interventions in Malaysia: How Effective Are They?
    21 February 2003

63. Prof. Dr. Shamsher Mohamad
    The New Shares Market: Regulatory Intervention, Forecast Errors and Challenges
    26 April 2003

64. Prof. Dr. Han Chun Kwong
    Blueprint for Transformation or Business as Usual? A Structurational Perspective of the Knowledge-Based Economy in Malaysia
    31 May 2003

65. Prof. Dr. Mawardi Rahmani
    Chemical Diversity of Malaysian Flora: Potential Source of Rich Therapeutic Chemicals
    26 July 2003

66. Prof. Dr. Fatimah Md. Yusoff
    An Ecological Approach: A Viable Option for Aquaculture Industry in Malaysia
    9 August 2003

67. Prof. Dr. Mohamed Ali Rajion
    The Essential Fatty Acids-Revisited
    23 August 2003

68. Prof. Dr. Azhar Md. Zain
    Psychotheraphy for Rural Malays - Does it Work?
    13 September 2003

69. Prof. Dr. Mohd. Zamri Saad
Respiratory Tract Infection: Establishment and Control
27 September 2003

70. Prof. Dr. Jinap Selamat
Cocoa-Wonders for Chocolate Lovers
14 February 2004

71. Prof. Dr. Abdul Halim Shaari
High Temperature Superconductivity: Puzzle & Promises
13 March 2004

72. Prof. Dr. Yaakob Che Man
Oils and Fats Analysis - Recent Advances and Future Prospects
27 March 2004

73. Prof. Dr. Kaida Khalid
Microwave Aquametry: A Growing Technology
24 April 2004

74. Prof. Dr. Hasanah Mohd. Ghazali
Tapping the Power of Enzymes- Greening the Food Industry
11 May 2004

75. Prof. Dr. Yusof Ibrahim
The Spider Mite Saga: Quest for Biorational Management Strategies
22 May 2004

76. Prof. Datin Dr. Sharifah Md. Nor
The Education of At-Risk Children: The Challenges Ahead
26 June 2004

77. Prof. Dr. Ir. Wan Ishak Wan Ismail
Agricultural Robot: A New Technology Development for Agro-Based Industry
14 August 2004

78. Prof. Dr. Ahmad Said Sajap
Insect Diseases: Resources for Biopesticide Development
28 August 2004

79. Prof. Dr. Aminah Ahmad
The Interface of Work and Family Roles: A Quest for Balanced Lives
11 March 2005

80. Prof. Dr. Abdul Razak Alimon
Challenges in Feeding Livestock: From Wastes to Feed
23 April 2005

81. Prof. Dr. Haji Azimi Hj. Hamzah
Helping Malaysian Youth Move Forward: Unleashing the Prime Enablers
29 April 2005

82. Prof. Dr. Rasedee Abdullah
In Search of An Early Indicator of Kidney Disease
27 May 2005

83. Prof. Dr. Zulkifli Hj. Shamsuddin
Smart Partnership: Plant-Rhizobacteria Associations
17 June 2005

84. Prof. Dr. Mohd Khanif Yusop
From the Soil to the Table
1 July 2005

85. Prof. Dr. Annuar Kassim
Materials Science and Technology: Past, Present and the Future
8 July 2005

86. Prof. Dr. Othman Mohamed
Enhancing Career Development Counselling and the Beauty of Career Games
12 August 2005

87. Prof. Ir. Dr. Mohd Amin Mohd Soom
Engineering Agricultural Water Management Towards Precision Framing
26 August 2005

88. Prof. Dr. Mohd Arif Syed
Bioremediation-A Hope Yet for the Environment?
9 September 2005

89. Prof. Dr. Abdul Hamid Abdul Rashid
The Wonder of Our Neuromotor System and the Technological Challenges They Pose
23 December 2005

90. Prof. Dr. Norhani Abdullah
Rumen Microbes and Some of Their Biotechnological Applications
27 January 2006

91. Prof. Dr. Abdul Aziz Saharee
Haemorrhagic Septicaemia in Cattle and Buffaloes: Are We Ready for Freedom?
24 February 2006

92. Prof. Dr. Kamariah Abu Bakar
Activating Teachers' Knowledge and Lifelong Journey in Their Professional Development
3 March 2006

93. Prof. Dr. Borhanuddin Mohd. Ali
Internet Unwired
24 March 2006

94. Prof. Dr. Sundararajan Thilagar
Development and Innovation in the Fracture Management of Animals
31 March 2006

95. Prof. Dr. Zainal Aznam Md. Jelan
Strategic Feeding for a Sustainable Ruminant Farming
19 May 2006

96. Prof. Dr. Mahiran Basri
Green Organic Chemistry: Enzyme at Work
14 July 2006

97. Prof. Dr. Malik Hj. Abu Hassan
Towards Large Scale Unconstrained Optimization
20 April 2007

98. Prof. Dr. Khalid Abdul Rahim
Trade and Sustainable Development: Lessons from Malaysia's Experience
22 Jun 2007

99. Prof. Dr. Mad Nasir Shamsudin
Econometric Modelling for Agricultural Policy Analysis and Forecasting: Between Theory and Reality
13 July 2007

100. Prof. Dr. Zainal Abidin Mohamed
Managing Change - The Fads and The Realities: A Look at Process Reengineering, Knowledge Management and Blue Ocean Strategy
9 November 2007

101. Prof. Ir. Dr. Mohamed Daud
Expert Systems for Environmental Impacts and Ecotourism Assessments
23 November 2007

102. Prof. Dr. Saleha Abdul Aziz
Pathogens and Residues; How Safe is Our Meat?
30 November 2007

103. Prof. Dr. Jayum A. Jawan
Hubungan Sesama Manusia
7 Disember 2007

104. Prof. Dr. Zakariah Abdul Rashid
Planning for Equal Income Distribution in Malaysia: A General Equilibrium Approach
28 December 2007

105. Prof. Datin Paduka Dr. Khatijah Yusoff
Newcastle Disease virus: A Journey from Poultry to Cancer
11 January 2008

106. Prof. Dr. Dzulkefly Kuang Abdullah
Palm Oil: Still the Best Choice
1 February 2008

107. Prof. Dr. Elias Saion
Probing the Microscopic Worlds by Lonizing Radiation
22 February 2008

108. Prof. Dr. Mohd Ali Hassan
Waste-to-Wealth Through Biotechnology: For Profit, People and Planet
28 March 2008

109. Prof. Dr. Mohd Maarof H. A. Moksin
Metrology at Nanoscale: Thermal Wave Probe Made It Simple
11 April 2008

110. Prof. Dr. Dzolkhifli Omar
The Future of Pesticides Technology in Agriculture: Maximum Target Kill with Minimum Collateral Damage
25 April 2008

111. Prof. Dr. Mohd. Yazid Abd. Manap
Probiotics: Your Friendly Gut Bacteria
9 May 2008

112. Prof. Dr. Hamami Sahri
Sustainable Supply of Wood and Fibre: Does Malaysia have Enough?
23 May 2008

113. Prof. Dato' Dr. Makhdzir Mardan
Connecting the Bee Dots
20 June 2008

114. Prof. Dr. Maimunah Ismail
Gender & Career: Realities and Challenges
25 July 2008

115. Prof. Dr. Nor Aripin Shamaan
Biochemistry of Xenobiotics: Towards a Healthy Lifestyle and Safe Environment
1 August 2008

116. Prof. Dr. Mohd Yunus Abdullah
Penjagaan Kesihatan Primer di Malaysia: Cabaran Prospek dan Implikasi dalam Latihan dan Penyelidikan Perubatan serta Sains Kesihatan di Universiti Putra Malaysia
8 Ogos 2008

117. Prof. Dr. Musa Abu Hassan
Memanfaatkan Teknologi Maklumat & Komunikasi ICT untuk Semua
15 Ogos 2008

118. Prof. Dr. Md. Salleh Hj. Hassan
Role of Media in Development: Strategies, Issues & Challenges
22 August 2008

119. Prof. Dr. Jariah Masud
Gender in Everyday Life
10 October 2008

120 Prof. Dr. Mohd Shahwahid Haji Othman
Mainstreaming Environment: Incorporating Economic Valuation and Market-Based Instruments in Decision Making
24 October 2008

121. Prof. Dr. Son Radu
Big Questions Small Worlds: Following Diverse Vistas
31 Oktober 2008

122. Prof. Dr. Russly Abdul Rahman
Responding to Changing Lifestyles: Engineering the Convenience Foods
28 November 2008

123. Prof. Dr. Mustafa Kamal Mohd Shariff
Aesthetics in the Environment an Exploration of Environmental: Perception Through Landscape Preference
9 January 2009

124. Prof. Dr. Abu Daud Silong
Leadership Theories, Research & Practices: Farming Future Leadership Thinking
16 January 2009

125. Prof. Dr. Azni Idris
Waste Management, What is the Choice: Land Disposal or Biofuel?
23 January 2009

126. Prof. Dr. Jamilah Bakar
Freshwater Fish: The Overlooked Alternative
30 January 2009

127. Prof. Dr. Mohd. Zobir Hussein
The Chemistry of Nanomaterial and Nanobiomaterial
6 February 2009

128. Prof. Ir. Dr. Lee Teang Shui
Engineering Agricultural: Water Resources
20 February 2009

129. Prof. Dr. Ghizan Saleh
Crop Breeding: Exploiting Genes for Food and Feed
6 March 2009

130. Prof. Dr. Muzafar Shah Habibullah
Money Demand
27 March 2009

131. Prof. Dr. Karen Anne Crouse
In Search of Small Active Molecules
3 April 2009

132. Prof. Dr. Turiman Suandi
Volunteerism: Expanding the Frontiers of Youth Development
17 April 2009

133. Prof. Dr. Arbakariya Ariff
Industrializing Biotechnology: Roles of Fermentation and Bioprocess Technology
8 Mei 2009

134. Prof. Ir. Dr. Desa Ahmad
Mechanics of Tillage Implements
12 Jun 2009

135. Prof. Dr. W. Mahmood Mat Yunus
Photothermal and Photoacoustic: From Basic Research to Industrial Applications
10 Julai 2009

136. Prof. Dr. Taufiq Yap Yun Hin
Catalysis for a Sustainable World
7 August 2009

137 Prof. Dr. Raja Noor Zaliha Raja Abd. Rahman
Microbial Enzymes: From Earth to Space
9 Oktober 2009

138 Prof. Ir. Dr. Barkawi Sahari
Materials, Energy and CNGDI Vehicle Engineering
6 November 2009

139. Prof. Dr. Zulkifli Idrus
Poultry Welfare in Modern Agriculture: Opportunity or Threat?
13 November 2009

140. Prof. Dr. Mohamed Hanafi Musa
Managing Phosphorus: Under Acid Soils Environment
8 January 2010

141. Prof. Dr. Abdul Manan Mat Jais
Haruan Channa striatus a Drug Discovery in an Agro-Industry Setting
12 March 2010

142. Prof. Dr. Bujang bin Kim Huat
Problematic Soils: In Search for Solution
19 March 2010

143. Prof. Dr. Samsinar Md Sidin
Family Purchase Decision Making: Current Issues & Future Challenges
16 April 2010

144. Prof. Dr. Mohd Adzir Mahdi
Lightspeed: Catch Me If You Can
4 June 2010

145. Prof. Dr. Raha Hj. Abdul Rahim
Designer Genes: Fashioning Mission Purposed Microbes
18 June 2010

146. Prof. Dr. Hj. Hamidon Hj. Basri
A Stroke of Hope, A New Beginning
2 July 2010

147. Prof. Dr. Hj. Kamaruzaman Jusoff
Going Hyperspectral: The "Unseen" Captured?
16 July 2010

148. Prof. Dr. Mohd Sapuan Salit
Concurrent Engineering for Composites
30 July 2010

149. Prof. Dr. Shattri Mansor
Google the Earth: What's Next?
15 October 2010

150. Prof. Dr. Mohd Basyaruddin Abdul Rahman
Haute Couture: Molecules & Biocatalysts
29 October 2010

151. Prof. Dr. Mohd. Hair Bejo
Poultry Vaccines: An Innovation for Food Safety and Security
12 November 2010

152. Prof. Dr. Umi Kalsom Yusuf
Fern of Malaysian Rain Forest
3 December 2010

153. Prof. Dr. Ab. Rahim Bakar
Preparing Malaysian Youths for The World of Work: Roles of Technical and Vocational Education and Training (TVET)
14 January 2011

154. Prof. Dr. Seow Heng Fong
Are there "Magic Bullets" for Cancer Therapy?
11 February 2011

155. Prof. Dr. Mohd Azmi Mohd Lila
Biopharmaceuticals: Protection, Cure and the Real Winner
18 February 2011

156. Prof. Dr. Siti Shapor Siraj
Genetic Manipulation in Farmed Fish: Enhancing Aquaculture Production
25 March 2011

157. Prof. Dr. Ahmad Ismail
Coastal Biodiversity and Pollution: A Continuous Conflict
22 April 2011

158. Prof. Ir. Dr. Norman Mariun
Energy Crisis 2050? Global Scenario and Way Forward for Malaysia
10 Jun 2011