contributions in precisely measuring the extent of diversity that exists, its geographic and ecological structure and dynamics. However, support from other sciences for basic understanding of plants and their environment (agronomy, biochemistry, botany, ecology, ecophysiology, evolution and genetics, as well as economics and the social reasons for germplasm conservation), will be essential.

Box 2 Why is genetic diversity important?

Conventional plant breeding teaches that genes associated with low yield potential in landraces can be eliminated through pure line selection. Data from the 1950s from Thai Rice Department supporting this have been cited (Oka 1988). But Oka went on, *"However, the yield data have come from experiments under the same cultural management (optimal condition of experimental stations - BR) for a few years and provide no information on yield stability under changing environments. Gene diversity in populations would bring about population buffering to stabilise yield, as discussed by Allard and Bradshaw (1964)"*. Indeed, a preliminary study at Chiang Mai University suggests that a very high degree of genetic diversity within a local rice variety called *Bue Chamee* (wild fowl rice, in Karenese) may be the reason for its success in highland paddies over a wide area in the mountains of northern Thailand with a highly diverse biophysical and socioeconomic environment. Characterisation of local genetic diversity, with morphological and physiological analysis, aided by modern biotechnology, will enable the true value of genetic diversity to be precisely measured. It may then be possible to select for productivity without sacrificing diversity.

Many consider the erosion of the *Oryza* genetic system in the Mekong Region to have begun with releases of modern varieties which replaced numerous older varieties with only a few new ones. The modern varieties are products of modern plant breeding. They include promising local varieties that have been through pure line selection to make them genetically homogenous; they also include high yielding varieties and hybrid rice. In Thailand high yielding varieties are still grown on a relatively limited scale. However, Thailand has taken to 'improving' local elite varieties since the 1950s. Through pure line selection, a local Thai elite variety from Bangkhla near Bangkok named Khao Dawk Mali became KDML105, which gave rise to RD15 and a glutinous rice RD6 through mutation breeding. These three varieties together account for 60% the country's main season planting, and more than 90% of the rice area in many provinces (OAE 1998). The three are, unfortunately, genetically very close. In the early 1990s a blast epidemic decimated tens of thousand hectares of this presumably homogenous population of the KDML 105 stock in several provinces. This genetic homogenisation of local traditional cultivars continues in Thailand, and is now being repeated with local rice germplasm in Lao PDR (CGIAR website) and possibly Myanmar.

research team from Chiang Mai University has since found other similarly genetically diverse populations in other parts of Thailand.

Gene flow from introduced germplasm into wild populations would have been going on ever since rice varieties were moved around the region (eg. with the different waves of migrations from southern China into Myanmar, Thailand, Lao PDR and Vietnam and various maritime, river and over-land trade traffics that plied the whole of the region, including mountainous areas long before colonial time). The introduction of GM rice and the advent of modern biotechnology, however, add some new and potentially dangerous elements to the local rice-wild rice genetic system.

This involves the process of gene 'transformation' ie. introduction of the 'exotic' or 'trans' genes from other species. The *Bt* gene that confers tolerance to insect damage comes from a bacterium called *Bacillus thuringiensis*. Other GM crops often contain genes transferred from micro-organisms, including viruses. A potential danger lies in the possibility of genetic interactions of these transgenes with other major genetic systems, from the crop species and its wild relatives to pests, pathogens and weeds and beneficial insects, micro-organisms such as nitrogen fixing bacteria and mycorrhizal fungi, and various other life forms down the trophic chain. The simplest scenario for such genetic interactions would be an 'escape' of a gene for resistance to specific herbicides from GM rice into wild rice. The biotechnology method of embryo culture and embryo rescue has also enabled 'wide-crosses' (ie. hybridisation between rice and other species of the *Oryza* genus) to be made. Wild rice is increasingly used as a source of disease resistance and other useful genes (eg. cytoplasmic male sterility for hybrid rice). For example, Pathumthani 1, one of Thailand's new non-photosensitive, aromatic rices, contains some wild rice genes.[5] The genetic barrier between cultivated rice and its wild relatives is likely to be much reduced in cultivated rice varieties that have incorporated wild rice genes. A recent study by the USA National Research Council concluded that gene migration between the transgenic crop and wild populations of squash in the United States could pose an environmental risk (NRC 2000). This risk is associated with introgression of the transgenes (of the transgenic yellow squash, Freedom II, which is resistant to watermelon mosaic virus 2 and zucchini yellow mosaic virus) into wild populations.

Even more recent is a report of definitive evidence of transgenic contamination in local maize germplasm in the remote mountainous region of Sierra Norte de Oxaca, in Mexico (Quist and Chapela 2001). In this native germplasm, the researchers found weak but clear evidence of p-35S, a promoter from the cauliflower mosaic virus, widely used in transgenic crops, presence of the

[5] Songkran Chitrakorn, personal communication.

International and national legal framework

The Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS)[6] has obliged developing countries to enact laws to confer ownership rights to intellectual and tangible property which are products of creativity, invention, and know-how (intellectual property) as well as biological materials and devices (tangible property). Means of protecting such property that have been applied to plant germplasm include patents, trade secrets, trademarks and geographic marks and appellation origin.

The last one allows legal rights to make and market certain kinds of products to certain geographical regions only, eg. Champagne from the region by that name in France, and similarly for Bordeaux, Burgundy, Cognac, Scotch, and so on. This is currently applied to wine and spirits only, but there are signs that agreements are being reached in the World Trade Organisation (WTO) to extend the application to food and other agricultural products as well. On the plus side for the Mekong Region, it will mean that no one else will be allowed to export Thai rice or Yunnan ham. But there will also be a down side, in that the Mekong Region will no longer be able to export Basmati and Japanese rice, or other products claimed by other geographical regions.

The UPOV (International Union for the Protection of New Varieties of Plants) Convention of 1961 established the principle that an improved variety can be legally owned by the breeder. The Convention is concerned with protecting the results of conventional plant breeding, so is generally believed to have the full weight of the seed industry behind it. The *Exceptions of the Breeder's Right (Article 15)* allows plant breeders to use without restriction protected varieties in the production of new varieties. In its 1991 revision the UPOV Convention was brought in line with contemporary technological developments. In particular, it extended protection to 'essentially derived varieties' in an attempt to strengthen protection for plant breeders who initially develop a new and distinct variety against others who merely make derivations from the initial work. Article 14, 5(c) says that *"Essentially derived varieties may be obtained for example by the selection of a natural or induced mutant, or of a somaclonal variant, the selection of a variant individual from plants of the initial variety, backcrossing or transformation by genetic engineering"*.

Many developed countries have enacted legislation to protect plant breeders' rights in new varieties which complies with the UPOV Convention. For example, Australia's *Plant Variety Right Act 1987* broadly followed the criteria for protection agreed under UPOV, and its *Plant Breeders' Rights Act 1994*

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[6] One of the trade agreements made in the General Agreement on Tariffs and Trade (GATT), known as the Uruguay Round, which concluded on December 15, 1993. In specific reference to the protection of plant varieties, the TRIPS Agreement *"requires that protection be provided either by patents or by an effective* sui generis *system or a combination of both"* (Article 273 (b)).

- the protection of intellectual property rights of plant breeders in order to provide incentives for research and development of new plant varieties, based on the principles of biological safety and food security; and
- the protection of the rights of farmers and local communities to share in the benefits from development of new varieties based on 'their' traditional varieties, in order to provide incentives to communities to conserve traditional and local plant varieties.

However, for all its high minded intentions, the law still lacks a mechanism for implementation two years after its enactment. Among the obstacles for the NPVP 2542's streamlined implementation, especially for communities' rights, is genetic variation within populations of local rice varieties. For various biological, ecological and management reasons, local rice varieties are often not genetically uniform, but are mixtures of several genotypes. Variations are sometimes obvious and can be distinguished visually, others are less obvious and can be distinguished only with special tests. Yet, like other laws originally designed to protect plant breeders' rights, the application of NPVP 2542 is based on the plant variety's uniformity and its ability to 'breed true' ie. all primary traits are maintained in succeeding generations. A community or communities can claim ownership to a particular local variety only if they can show that it is genetically uniform and breeds true. The NPVP 2542 law will therefore not allow claims to many local rice varieties in the region. It would be unrealistic, and logistically and financially impossible, to expect public institutions such as the Department of Agriculture to bear the burden of such proof.

The drive to apply the NPVP 2542 to communities' rights to germplasm is often based on the fear of 'biopiracy' by multi-nationals. However, all who champion the property rights of local communities should be made aware of potential conflicts among local communities in the application of the NPVP 2542. Local germplasm has historically been an 'open source' resource, and many have contributed to development and conservation of local varieties. There is also a potential confusion in the use of names for local varieties, which is often the only handle for local recognition of a variety. The same name is sometimes used for different varieties, and one variety may be known by different names in different locations. Again it would be unrealistic and costly to put the burden of proof of ownership on a public institution such as the Department of Agriculture. Neither will it be adequate to simply post property right claims at the district or sub-district office (as is now common practice with land ownership claims) and expect other communities to register their objection.

It is as yet unclear if the objectives of the NPVP 2542 will be realised by the application of the law. But enforcement of the law can help prevent piracy of privately developed crop varieties as well as GM crops such as *Bt* cotton.

Thai Rice Research Institute. Some of this variation may have come from the original farmers' heterozygous population at Bangkla that had not been through pure-line selection.

This genetic variation within the population has apparently not done Thailand's internal high quality rice market and its US$ 300 million a year export any harm. It however complicates the application of NPVP 2542, and weakens the protection of its local germplasm. For a start the Thai Rice Research Institute will have to determine which of its many breeders' versions of KDML105 is the 'real' one that is protected by the law. NPVP 2542 may even encourage a form of biopiracy. A private person or company can simply select any of the numerous forms of local variety that have been grown by some farmers for a long time. Strict enforcement of the law would force these farmers to pay a licensing fee to the owner of the registered 'new variety', who would also be legally empowered to sell the variety or take it out of the country.

Patent and plant breeders rights laws in developed countries (eg. Australia, Europe, Japan and the USA) all empower individuals and corporations to poach at will from the common pool of plant genetic resources, including the part that is being 'held in trust' by CGIAR centres.[8] According to the tradition of germplasm sharing, farmers and communities may not object sharing with others even in far away countries. The problem arises because original users of the common genetic resource can now be 'fenced out' by the new legal owners empowered by the various property right laws.

Yet another aspect of the property right problem is highlighted by the issue of rice quality in Thailand. Like any other rice producing country, Thailand badly needs R&D to improve acceptability to farmers of new 'improved' rice varieties released from its breeding programmes, to make better use of all of the new inventions and improvements in rice genetics, including higher yields, more β-carotene, more iron and zinc etc. Furthermore it will enable rice breeders to explore other definitions of 'quality' to expand the country's market opportunity, and lessen dependence on just the one single quality type of Thai Hom Mali. Apart from reducing the risk in the market, this will also mitigate the risk in the production system which is currently too dependent on a very narrow gene pool of KDML105 and its mutant sisters, RD6 and RD15.

In order to do this, as discussed above, Thailand will need capacity in biochemistry, genetics (the old-fashioned Mendellian kind as well as molecular) and ecophysiology. Skills need to be acquired, tools (gas chromatography, various spectrometry and electron microscopy, and so on) mastered to enable various quality characteristics to be quantified, and screening procedures

[8] As referred to elsewhere, several CGIAR members, including IRRI, have been involved in recent disputes about germplasm ownership.

Harnessing biotechnology for the Mekong Region: the next 30 years

Building local technical capacity

Pre-fabricated GM crops and modern biotechnology alone are definitely not going to be enough to enable the Mekong Region to reap the full benefits of biotechnology. And without some local capacity for understanding the key functions and processes in the region's important plants, animals and microbes, the GM crops that will inevitably arrive will pose a real threat. The question is whether the Mekong Region can develop the necessary local capacity to handle these threats and make the most of what biotechnology has to offer.

My answer to this is *"Why not?"*. If the capacity for agricultural science in the region has been somewhat limited, it was surely not because of any lack of aptitude but more because there has been no real demand for, and so no investment in, good research. Now suddenly Thailand and Yunnan are awash with public money chasing good research, and Vietnam most probably will soon follow. On the evidence of our record, good and useful agricultural science will not simply just happen because of all this money.

The region is as much in need of capacity in agricultural research management as in technical capacity. A number of regional and relatively long term (say, 10 to 15 years) projects on well chosen agricultural problems could explore and teach how this could be done. The next generation of scientists and professors will be part of this process by making graduate programmes, especially already established and well funded ones like Thailand's Royal Golden Jubilee PhD programme, and perhaps the equivalent in China and Vietnam, an integral part of this effort. Provisions for graduate level training in Thailand, Vietnam and Yunnan for individuals from Cambodia, Lao PDR and Myanmar in the first 10 to 15 years would help towards building local capacity for graduate training, and thus perpetuate such capacity in these countries afterwards. Carefully matched collaboration with advanced labs in developed countries can also make valuable contributions. Issues of intellectual property will need to be addressed in any collaboration in general, and on germplasm specifically.

Intellectual and tangible property rights

The current climate of suspicion and mistrust surrounding the property rights relating germplasm and research findings are an obstacle to collaboration and a distraction for working scientists. Some standard air-tight memoranda of agreement for sharing biological materials, information and trade secrets for the purpose of germplasm research would help calm nerves and remove the fears that are now holding up much needed collaboration. However, there is no alternative to researchers in public institutions, including universities, having some basic intellectual property rights capacity. Innovations often simply regional or provincial licensing agreement, along with their efficacy over space and time. Such experimentation could also explore research management capacity that will have to deal with not only the technical agronomic, biological and ecological side of GM crops, but also how to manage conflicting interests of different stakeholders, from farmers, consumers and NGOs who have appointed themselves guardians of public safety.

Looking after native germplasm

Clearly rice needs careful biotechnology management to safeguard the species' native gene pool. This could also teach lessons on the management of gene pools of other native species. Evidence of gene migration in *Oryza* discussed above clearly points to a danger from GM rice. It appears that how a GM rice hybridises with local wild rice and how their progenies behave could be important criteria that must be determined before any GM rice can be released into the field in the Mekong Region. Understanding phylogeography of local cultivated and wild rice populations on the other hand will help with gene pool management at the national level. For example, stringent standards for releasing GM rice might need to be enforced only in regions with genetically unique rice populations and not everywhere.

Concluding remarks

The case of rice and wild rice raises the possibility that the whole gene pool of a native crop species and its wild relatives may become contaminated and decimated through gene migration. Much has been achieved in transfer of biotechnology to Asia in the last 10 years or so. But in the Mekong Region there is still insufficient capacity to adapt biotechnology for local use and to forestall any potential harmful impacts. There are no 'widely adapted' GM crops nor safety protocols that can be simply and safely transferred from elsewhere. The region needs to develop its own regulatory and local scientific capacity to cope with biotechnology. Such technical capacity is, however, dependent on a local capacity for managing agricultural science research that can find the fine balance between understanding and application.

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Social Challenges for the Mekong Region

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Uplands land use

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The uplands of mainland Southeast Asia stretch from Myanmar to Vietnam and include parts of Cambodia, Lao PDR, Thailand and neighbouring Yunnan Province of China. The uplands, defined here as lands more than 600 metres above sea level, encompass about half of the total land area of the Mekong Region. The uplands are home to many diverse ethnic groups and include pockets characterised by rapid population growth and severe poverty. Significant land use changes are taking place, many of which are leading to tensions within and between upland communities, and between 'upstream' and 'downstream' watershed communities. Food security remains one of the major challenges for upland communities and the governments in the region, but the changing socioeconomic landscape has seen other related concerns emerge.

Agricultural production for subsistence, traditionally dominated by shifting cultivation, is rapidly being replaced or added to by other forms of land use. There are still some communities which rely almost totally on the produce from their subsistence agricultural system. However, many more are now involved in some type of commercial production. New enterprises and land uses are providing new opportunities, but also creating tensions and conflicts. These conflicts arise from internal and external pressures, including government policies. In this chapter I discuss some concerns, focusing on: 1) tensions between crop production, commercialisation and ecosystem/biodiversity conservation; 2) relevance and effectiveness of public policies; and 3) conflicts.

Although I do make some reference to all parts of the Mekong Region, I draw most of my examples from northern Thailand, Vietnam and Lao PDR. At the end of the chapter I put forward a series of questions for policy makers and researchers. Interventions aiming to support poor and marginalised people in the uplands should address these questions, and of course others which are beyond the scope of this particular chapter.

Crop production, commercialisation and ecosystem/biodiversity conservation

A number of factors contribute to the tension between crop production and protection of ecosystems and biodiversity at local and watershed levels. These include the complex relationships between internal and external factors such as population levels and growth, migration, state land tenure policies, customary tenure arrangements, commercialisation, social obligations within traditional

Table 1 Ethnic minority groups in the Mekong Region (by country)

Country	*Number of ethnic groups*	*Population (million people)*		*% Total*
		Minorities	*Total*	
Cambodia	36	0.31	9.45	3.3
Lao PDR	47	2.01	4.88	41.2
Myanmar	>12	>6.8	46.55	14.6
Thailand	10	0.79	58.27	1.4
Vietnam	53	9.88	73.81	13.4
Yunnan	25	13	42	31
Total	183	32.79	234.96	14

Sources: Derived from various texts (Ma Yin 1989, World Resources Institute 1994, Kampe 1997). The data include some ethnic minority people not resident in uplands.

Large-scale infrastructure development projects, such as construction of the Nam Ngum dam in Lao PDR or the Hoa Binh dam in Vietnam, have also displaced people and affected land use in surrounding areas. For example, between 50–60,000 people from the Muong and Tai minorities were displaced by the huge Hoa Binh project whose reservoir extends 230 kilometres back from the dam wall on the Song Da (Black) River, flooding about 200 km^2 of forests and farmland (Hirsch 1998).

There has been a large increase in capital intensive and land extensive monocropping in the uplands. In some parts of the region, this is not a new phenomenon. For example, following the end of the civil war in China in 1949, the communist government promoted the transformation of large parts of the Yunnan uplands. Rubber[1], sugarcane, tea trees and other plantation crops were introduced or vastly expanded. Opium cultivation was totally eradicated. Credit, inputs and terracing earthworks were initially subsidised as part of this transformation. Plantations were seen as 'modern' agriculture replacing the 'primitive' shifting agriculture practised by the area's ethnic minorities, such as the Hani, Jino, Lisu and other smaller groups. Masses of Han Chinese were relocated to work in the collective plantations. Many Han migrants settled in the southernmost counties of Xishuangbanna and Simao in the Lancang Jiang valley (Upper Mekong watershed) and the Red River valley, areas bordering on Myanmar, Lao PDR and Vietnam (Chapman 1991, Kanok Rerkasem 1999). Part of the Yunnan transformation also saw many upland communities move to lower elevations, when land was available, to get involved in wet rice cultivation. During this period, the introduction of hybrid rice – via the Green Revolution – promoted large increases in yields. Due to recent decentralisation to increasingly

[1] Rubber plantations are usually located lower than 600 metres above sea level, hence their impact above that height is indirect.

evaluated. There is concern that intensive farming systems, driven by business goals, are linked to increased destruction of natural forests, biodiversity reduction and general land and water degradation associated with soil erosion, soil fertility depletion, water pollution etc..

The commercial production of high value crops, vegetables and fruit trees also requires substantial water in the dry season. Sprinkler-fed irrigation is economically feasible and relatively easy to install. Large expansion of commercial production in the uplands will increase water use in upstream watersheds and reduce water availability downstream. The extent of future impacts of this problem has yet to be quantified but conflicts over upstream water use are increasing, especially in Thailand. Vietnam's upland landscapes are also changing with the advent, for example, of large areas of coffee monocultures and less degrading tree crops such as persimmon, apricot, plum and lychee.

It must be remembered that Thailand uplands are relatively well-connected to markets, aided by large-scale infrastructure development, especially highway networks. Other parts of the region, such as parts of the Vietnam uplands, are far less well-connected which obviously disadvantages producers by giving them fewer practical options. A separate basic issue is that all the commercial systems, reliant on external markets, are vulnerable to unpredictable market prices. At the time of writing, the troubles facing coffee producers dealing with a world-wide glut offer a harsh lesson that getting the agronomy right is only part of the battle. These problems have diminished the potential of the alternative crops to improve the general livelihoods for the upland ethnic minority populations.

It has been recognised for some time that the promotion of cash crops in the Mekong Region, especially subtropical and temperate species of vegetables, fruit and cut flowers, has to be considered in relation to international trade agreements administered by the World Trade Organisation (WTO), and large-scale infrastructure development such as highway networks and international river transport (TDRI 1994). There will be strong market competition for these commodities. For example, China, which is the biggest producer of these crops and boasts a more favourable climate and lower costs of production, could successfully take over the Mekong Region markets and jeopardise development efforts in the promotion of cash crops on a wider scale. Of the Mekong Region countries, Vietnam is next in line to join the WTO. Nevertheless, with or without trade agreements, legal and 'illegal' trade in these crops has already spread throughout the border areas of the region.

There are many proposals for governments in the region to develop collaborative programmes for large scale production of major cash crops and forest plantations. Some private sectors and agribusiness companies have already exploitation for timber production. Each has been used to restrict people's access to forested areas.

In Vietnam, a policy push for 'non-shifting' agriculture was adopted in the 1980s aiming to fundamentally change the dominant type of farming system by an estimated 2.9 million people from 400,000 ethnic minority families in 34 mountainous provinces (Sargent et al. 1991). This has involved a comprehensive socioeconomic development programme for ethnic minorities, as well as for forest protection and restoration. State funds have been directly channelled to projects in the form of cash payments and interest-free loans to households contracted to protect and restore forests. It is claimed that at least 600,000 people in 378 communes have stopped shifting cultivation, with some 140,000 hectares coming under permanent crop production. A mid 1990s study reported an increase in forest cover of 47,000 hectares of newly planted forests and 70,900 ha of tree plantations for industry (Le Duy Hung 1995). Agroforestry development is also promoted with support from government to sustain local livelihoods based on multiple sources of products (Do Dinh Sam et al. 1997). The greatest incentive in this programme was a revised land law providing up to 50 years tenure for land users investing in commercial tree crops. However, no funds were made available for land improvements. Consequently, rehabilitating degraded forest has proven very difficult.

Table 2 Extent of land under shifting cultivation in mountain areas of the Mekong Region

Country	*Area (10^3 ha)*			*% forest used for shifting cultivation*
	Land	*Forest*	*Shifting cultivation*	
Cambodia	17,652	12,163	n.a.	n.a.
Lao PDR	23,080	13,173	400	3.04
Myanmar	65,774	28,856	181	0.63
Thailand	51,177	12,735	400	3.14
- N. Thailand	*16,966*	*7,523*	*400*	*5.32*
Vietnam	32,536	8,312	3,500	42.1
Yunnan/China	39,410	9,533	130	1.36
Total	229,629	84,772	>4,611	5.44

Sources: (Fujisaka 1991, Lovelace 1991, Do Dinh Sam 1994, Banerjee 1995, FAO 1995, TDRI 1997)

The beneficiaries of the programme have turned out to be the lowland majority ie. the ethnic Vietnamese, or Kinh groups. Limited funds and prejudice against ethnic minority cultures have been the major constraints to extending this kind of programme to remote mountain communities. A further weakness of this programme is the lack of community participation and local initiative. As the

Box 1 Understanding traditional land use

There is still much to be learnt about traditional land uses, such as shifting cultivation. Even the terminology and classification of shifting cultivation remain to be clarified as knowledge about shifting cultivation increases. For example, the 'pioneer' form of shifting cultivation was classified as the most destructive form in terms of forests and natural regeneration processes (Grandstaff 1980). Others see it as a system with a very long fallow period (Kunstadter and Chapman 1978, Chunthaboon Sutthi 1996). As productive land for cultivation is diminishing, the so-called 'pioneer' shifting cultivators turn to rotational practice with managed fallow. A practical taxonomy of shifting cultivation may have significant value for the design and development of alternatives to shifting cultivation. Above all, a shifting cultivation community tends to practise a mosaic pattern of land use eg. the Tay of northern Vietnam incorporate wet rice fields, homegardens, fish ponds, livestock, tree gardens, swiddens, managed fallow and forests. The whole production system may be referred to collectively as a composite swidden (Rambo 1996, Rambo and Le Trong Cuc 1998).

Mosaic patterns of land use are quite common in mountain areas of Southeast Asia. This production approach can be found even in a former pioneer shifting cultivation community (TDRI 1994). A study in the Hmong village of Pah Poo Chom in Chiang Mai Province of northern Thailand has shown that after eradication of opium growing, these former pioneer swiddeners have completely turned to alternative cash crops, cabbage and lychee in particular. On the surface, the village land use system is very simple and dominated by a few cash crops, but household subsistence is derived from numerous additional livelihood activities. These include the production of upland rice from small swidden fields and the distribution of harvests from some 52 species of non-rice swidden crops grown along field edges and in homegardens (maize, waxy corn, sweet sorghum as well as many local vegetables and root crops).[4] Another part of the mosaic is the sale of local livestock and collection of minor forest products from community-managed forests or household agroforestry plots. These mosaic patterns of land use are also now being classed as agroforestry landscapes (Thomas 2002).

Forest cover

Forest cover policies are obviously connected to shifting cultivation policies. Governments in Vietnam and Yunnan are hoping to increase forest cover by increasing incentives such as long term land allocation to individual households. These various experiments provide opportunities for the regional exchange of lessons and experiences to improve the situation.

In Vietnam the government has been paying cash to encourage upland farmers to plant and manage forest trees. Public funds have underpinned initiatives such as Programme 327, which was established in 1992 to provide state loans for agricultural and forest development on degraded lands and for forest protection

[4] Urban migration and off-farm employment in general have increasingly been incorporated into the livelihood strategies of upland peoples, but these factors are beyond the scope of this chapter.

population pressure. However, this strategy shifts the pressure to traditional upland populations and the environment. In Vietnam, the government had plans to move five million lowlanders to the uplands in the 1970s and 1980s. In Dak Lak province alone, resettlement policies brought in more than 300,000 people, mostly northerners, between 1976 and 1996. During the same period, however, spontaneous migration brought in about another 350,000 people. The results were deforestation, water scarcity and conflict between resource users (Ahmad 2000). The upland plateau of middle Vietnam may be capable of carrying a greater population, but systems need developing which are more economically and ecologically sustainable. The massive transfer of lowland populations with inappropriate practices of non-traditional shifting cultivation may upset the traditional practices that continue to exist in mountain areas, threatening local livelihoods and environmental well being. For example, land competition would threaten the practice of long fallow in rotational shifting cultivation. Shorter fallows lead to severe land degradation and impede natural forest regeneration.

In Lao PDR, despite a sparse upland population, the government still adopted a policy of relocation from the hills for many reasons eg. forest protection, improved access to government support and services, prevention of illicit crop growing, promoting sedentary settlement and so on. In Palaveck of Muang Hom district near Xieng Khuang, massive numbers of Lao Soung (highland ethnic minorities, in this case principally Hmong) have moved down to the valley floors for wet rice cultivation as an alternative to traditional shifting cultivation with opium. Development of paddy terraces was encouraged with government incentives eg. land tenure, agricultural tax breaks, extension services and infrastructure development (roads, small-scale irrigation etc.). Other government policies, especially large infrastructure development such as dams and national highways, also drove many upland communities to relocate. In the Nam Ngum area, large populations of Lao Thueng (midland ethnic minorities) have resettled along the roadside with the high expectation of earning alternative income. In the case of dam construction, where villagers are moved from the reservoir sites and often receive little support from the government, the settlers resume shifting cultivation in the hills above the reservoir, with consequences for the reservoir's sedimentation load.

In the early 1960s, Thailand also adopted resettlement schemes for hill tribes in the north. The concept of resettlement was to develop the remote upland peoples. A few *Nikhom Chao Kao* (resettlement areas for hill tribes) were established to bring hundreds of thousands of upland people to lowland sites. The Thai experience of resettlement was not successful, however, and most people could not remain in the *nikhom* areas, fleeing instead to join relatives returning to their original villages in the mountains (Chupinit Kesmanee 1987-8). The problems were due to inadequate support for subsistence, unsuitable sites for farming, a lack of necessary infrastructure and so on. But today, resettlement of

Box 3 The effort to reduce opium production in northern Thailand

Thirty years of experience have now been gained from an enormous effort by Thailand's government, with assistance from international donors and agencies, at a cost of more than US$206 million (Renard 2001) to eradicate opium production. The initial emphasis in northern Thailand was on eradicating illicit opium cultivation, promoting border security and pursuing social integration. In 1972, an opium eradication campaign was promoted through a development strategy of crop replacement. A wide range of cash crops (both annuals and perennials) was introduced to replace income from opium. Infrastructure, road construction in particular, was developed extensively to support large scale production of cash crops for external markets. In 1983 the Office of Narcotics Control Board and the United Nations Funds for Drug Abuse Control jointly identified some 72 major opium-producing areas in northern provinces to target large scale highland development projects. This Area Planning Approach helped to target development efforts to about 60% of the entire area of opium growing in the country (ONCB 1983). As a consequence, opium production in northern Thailand declined sharply from over 145 tons in 1965 to about 30 tons in the 1980s and a further drop to the insignificant level of an average of 14.5 tons for the past five years, 1995–2000 (Kanok Rerkasem 1999, ONCB 2001). At the same time the importance of traditional land use has also declined.

Traditional shifting cultivation is now very rare and permanent cropping has become the major type of land use. Long-fallow shifting cultivation is constrained from exceeding a seven-year cycle and many former opium growers have turned to production of cash crops and commercial fruit trees for external markets. Taken together with the population increase and other external forces, competition for land and natural resources is increasing. Sustainability of land use has become a critical problem and social conflict in land use within upland communities and between the upland and the lowland communities has increased.

Throughout the long development effort in the uplands of northern Thailand, the approach evolved from the initial implementation of the crop replacement approach in the early 1970s to integrated rural development from the 1970s to late 1980s and a participatory approach from 1990 up to the present. Despite some of the negative consequences, development in northern Thailand has been offered as an 'Alternative Development Model' for neighbouring countries like Lao PDR, Myanmar and Vietnam for opium eradication projects (UNDCP 2000). Regional collaboration in upland development projects would indeed benefit from careful evaluation of this Thai experience. Many initiatives are being proposed, including the United Nations International Drug Control Programme (UNDCP) Regional Cooperation on the Eradication of Illicit Drug Crops and Alternative Development and the World Agroforestry Centre's Global Project on Alternatives to Slash and Burn (ASB).

Traditional shifting cultivation is becoming rare in the region, especially Yunnan in China, Vietnam and northern Thailand. In Mae Chaem and Mae Sarieng of northern Thailand, for example, the fallow period of the former long-fallow shifting cultivation systems of the Karen and Lua people has now been reduced to five years or less. Without external inputs, the productivity of upland rice of

This issue of land security in Thailand is one of the main areas for concern in highland development and political debates. Thailand is unique in the region for its refusal to grant land rights to ethnic minorities and hence many highlanders reside in areas which are claimed by the state. There are virtually no tenure arrangements. Traditional land tenure arrangements should be taken into account in order to promote sustainable use of land and forest protection. Karen in Thailand, for example, are known to have strong community control over land use and land allocation to member households, following customary rules and regulations (Prasert Trakarnsupakorn 1997). Protected areas such as headwater and utility forests are community owned and managed. Land for shifting cultivation and fallow fields are shared and allocated to individual households in the cropping phase. Only paddy lands are privately owned. Without recognition of the value of these traditional land tenure practices, land disputes and conflict over land resources designated for other uses often arise between the villages and other stakeholders, especially forestry department rangers.

The Thailand situation differs from other countries in the Mekong Region, where local administration and social integration of ethnic minorities is more advanced (Chayan Vaddhanaphuti 1996). With little progress made in the past, there have been many land disputes and conflicts at various scales, including within single communities, between communities, as well as between communities and government agencies. Instead of enabling communities to play a role in forest and watershed protection, intervention has involved increased imposition of state control to maintain the functions of ecosystems and biodiversity through strict nature preservation. This then puts pressure on village land by appropriating it for other uses such as forest conservation and reforestation and aggravates land disputes in local communities. Consistent with the on-going processes of decentralisation and innovation required by the 1997 Constitution, present forestry policies make mention of local participation and the roles of community organisations (eg. *tambon* administration organisations at the subdistrict level). However, it is questionable whether such concepts have been absorbed into the institutional culture of forestry and other departments. In the non-governmental sector, participatory land use and local watershed management are becoming popular approaches to conflict resolution, land use planning, monitoring and evaluation at the local level (Uraivan Tan Kim-yong 1990, Prasong Jantakad and Carson 1998). Over 30 NGOs are using such approaches with almost 500 villages, forming networks in the northern provinces to participate in the process of local and national campaigns for land use rights and a community forestry bill (Table 3).

On the operational side, participatory approaches are being used in Thailand to empower communities to reduce land disputes between villages in local watersheds. The process of public participation in policy is still in the project phase and the state has yet to put it into effect on a large scale. It remains to be economic and political factors (eg. majority and state prejudice against minorities, insurgency concerns, drug-related issues etc). Lowland communities often blame upland people for land and forest degradation, and especially a decline in water volume, which they attribute to both shifting cultivation and extensive cash crop production. Lowlanders also criticise uplanders for chemical pollution in natural streams. While in some instances such claims might be true, the wholesale stereotyping of upland land use practices is unwarranted. Depletion of lowland water may be associated with increasing water use in the uplands due to different types of land use, including state forest plantations with high water requirements, but it is also associated with a dramatic increase in dry season production (and water demand) by lowlanders. Shifting cultivation includes many types of land and forest management and some types are inappropriate. But upland farming also includes a diversity of traditional land and forest management practices that check soil erosion, sustain fertility and crop productivity with biological processes and conserve natural biodiversity in village land use systems. Whatever the roots of the tension, resolving land and forest degradation will mean eliminating misconceptions about land degradation and biodiversity protection with specific reference to upland communities.

Policy intervention questions

Interventions that could support the poor and marginalised people of the uplands are raised here in the form of key questions.

Are there examples within the region of successful cases of upland management where people can make a living while protecting the environment and biodiversity?

Examples of 'best practice' in land management in the Mekong Region uplands are claimed frequently with very little systematic investigation and documentation. Much is known about farmers' management and conservation of biodiversity but good analysis of this indigenous management is much harder to find. That is, the literature is rich in description but poor in critical analysis. I therefore propose that case studies are needed to analyse both successful and unsuccessful land management practices so as to help identify useful strategies and necessary conditions for success. The conditions may focus on biophysical, technical as well as institutional aspects of management systems. The results could then be used in the design and development of alternative upland management policies. It would also be useful to have a utilitarian taxonomy of the traditional land management practices of shifting cultivators across the region.

An interdisciplinary approach would be appropriate for the above field-based study. A range of appropriate tools and methods should also be chosen for field investigation as well as analysing the results. Many tools and methods are now available eg. participatory appraisal (Chambers 1983, Pretty et al. 1995, Lessons learned from the case studies proposed above could be exchanged through community interaction, cross-country visits and regional training sessions.

How can government agencies play a significant role in building, fostering and supporting local capacity and community organisation at the grassroots level, and its effective interaction with other levels?

For future development to be consistent with a 'people's participation' paradigm, government agencies, development workers and other relevant actors will have to shift from implementing a conventional top down approach to more interactive approaches at various levels of administrative structures and social organisation. This will involve:

- Providing effective, transparent and accountable mechanisms linking local (community) resource management to provincial, prefecture and district governments and governmental agencies involved in formulating and implementing policies at national and other relevant levels.
- Increasing technical capacity for appraisal, monitoring and evaluation, including appropriate information 'feedback' mechanisms and channels for two-way flows of information.
- Coordinating the sharing and 'wise use' of common resources, including equitable distribution of costs and benefits among villages sharing watersheds and between upland and lowland villages.
- Incorporating and promoting land management and sustainable livelihood systems of rural communities, taking into account the management of environmental services and biodiversity-rich ecosystems.

Research questions to support sustainable land use

Several critical research questions about sustainable land use in the Mekong Region uplands remain to be answered. The following questions focus on issues related to upland land use in transition. The research area covers a wide spectrum of land use, from traditional shifting cultivation to permanent fields. Various questions will need to deal with institutional aspects, while others may be purely technical.

1. How can the productivity of upland rice and associated crops be maintained with shorter fallow cycles?
2. How can cash crops be grown, especially on acidic steep land, with minimum soil erosion?
3. How can productivity of upland crops be maintained or improved with minimum use of water and agricultural chemicals?

1. How may the six countries learn from each other's developmental lessons in upland management, including successful and unsuccessful experiences?
2. What is the real local cost of 'exporting' cash cropping to marginal land in other countries within the region? There are many proposals for governments in the region to develop collaborative programmes for large-scale production of major cash crops and forest plantations. Some private sectors and agro-industrial companies have already conducted such programmes on a commercial basis. Examples include maize and soybean production for Thailand in Lao PDR and Myanmar, eucalyptus plantations for the Chinese pulp industry in Thailand, rubber plantations for China in the Wa area of Myanmar, and so on.
3. What impact will major Mekong Region infrastructure development (eg. roads, bridges and Mekong River traffic) have on upland land use sustainability?
4. How may the devastating effects of regional trade in minor forest products be minimised, and the extraction process be managed sustainably? Can some of the species be domesticated and properly managed?

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Boron Nutrition of Crops and Genotypic Variation in Boron Efficiency

Boron nutrition of crops

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1. CROP RESPONSES TO LOW BORON

Adverse effects of boron (B) deficiency on physiological processes are associated with both vegetative growth and reproductive growth (Dell and Huang, 1997). The vegetative processes reportedly affected by B deficiency are root and leaf growth, vascular differentiation and assimilate partitioning; reproductive ones include flower and gametes development, fertilisation and fruit growth. Boron responses of crops in farmers' fields, however, can be very different from those that interest plant nutritionists and physiologists. The adverse effect of B deficiency on individual physiological processes is relevant to farmers only when it also affects crop productivity, i.e. its economic return. Such effects may be associated with whole plant responses or directly involved in the formation of the quantity of yield (e.g. fruit and grain set) and/or quality of the product.

1.1 Physiological vs. Field Responses

Field responses to B application have been documented on 132 crops in 80 countries (Shorrocks, 1997). However, not all of the physiological responses to low B documented are encountered in field grown crops on low B soils. Two of the most rapid response to B depletion or deficiency are inhibition or cessation of root (Bohnsack and Albert, 1977; Dugger, 1983;

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Marschner, 1995, Shelp, 1993, Dell and Huang, 1997) and leaf elongation (e.g. Kirk and Loneragan, 1988, Noppakoonwong et al., 1993, Huang et al., 1996). However, reports of such effects of B deficiency from the field are extremely rare. Some of these responses do not lend themselves readily to field observation. Some of the physiological responses are also less relevant to whole plant and crop response than others.

Some of the physiological processes are less sensitive to B deficiency than others. Without detectable effect on vegetative growth, B deficiency may cause yield losses in field grown wheat through grain set failure (Rerkasem and Loneragan, 1994). The B level sufficient in meeting demand for vegetative growth in wheat can be insufficient for its anther and pollen development (Rerkasem et al 1997a). In barley, the level of B that is limiting to grain set may also depress the number of spikelets spike^{-1} (Jamjod and Rerkasem, 1999), while tillering may actually be promoted (Ambak and Tadano, 1991). In oilseed rape reproductive growth has been found to be more sensitive to B deficiency than vegetative growth, with root growth even less sensitive than above ground vegetative plant parts (Asad, 1998). For B deficiency to become limiting to root growth, external B had to drop to about half the level that was limiting to above ground vegetative growth. Thus long before B deficiency can become severe enough to limit above ground vegetative or root growth, field grown crops may have already failed through the adverse effect on reproductive growth and seed yield.

1.2 The B Limiting Step

Differential sensitivity to B deficiency may also be found among individual steps of each developmental stage. The most sensitive, which might be called "the B limiting step(s)", will be the one(s) through which whole plant response and crop performance are limited by B deficiency. Adverse effects of B deficiency on reproductive growth have been reported to be associated with male sterility in many cereal species. Cross pollination experiments have established that male fertility is the B limiting step in wheat (Rerkasem et al., 1993; Rerkasem and Jamjod, 1997a). While B deficiency also causes male sterility in maize, the B limiting step may be pollen germination which is dependent on B concentration in the stigma or silk rather than male fertility (Vaughan, 1977, Agarwala et al., 1981). For barley, it is yet unclear that B deficiency depresses grain set primarily through pollen germination as well as causing male sterility. However, the same level of B deficiency that depresses grain set has also been reported to depress the number of spikelet spike^{-1} at the same time (Jamjod and

Rerkasem, 1999). Thus, barley grain yield may be depressed by B deficiency through its compounding effects on at least two B limiting steps.

The adverse effect of B deficiency on reproductive development may be related to higher demand for B in reproductive tissues or difficulties in supplying B to them, or both. In those crop species in which B is immobilised in older tissues, reproduction may fail due to B deficiency even while large amounts of B is present in the whole plant (Brown and Shelp, 1997). When the old B can be recycled to supply elevated demand for reproduction, plant B could be more efficiently used, as has been demonstrated in a gene transfer experiment in tobacco (Brown et al., 1999). Phloem loading, transport and utilisation of B for reproduction were all enhanced as the result of the sorbitol production activated by the introduced gene. The management of crop B nutrition may be made more efficiently, by means of genetic manipulation or fertiliser management, if the B limiting step can be identified.

1.3 The Timing of Boron Sensitive Events

In addition to their relative sensitivity to B deficiency, the relevance of the B response of certain physiological processes to whole plant response, and thus that of crop productivity, may also be dependent on the chronological order of their occurrence. Boron deficiency during early growth, e.g. adversely affecting germination and seedling growth, may have a direct bearing on final seed yield quite independently of how other physiological processes respond to B. In China, survival of transplanted oilseed rape seedlings may sometimes be depressed by B deficiency, an effect that can closely correlate ($R^2 = 0.77$) with seed yield (Xue et al, 1998). The seed of grain legumes containing insufficient B when sown in low B soils may grow into abnormal seedlings (Rerkasem et al, 1990, Rerkasem et al, 1997a). These abnormalities during early growth, which include the absence of the entire epicotyl, no growth after unifoliate leaves, ragged trifoliate leaves, or arrested apical growth accompanied by premature lateral branching, may have a long lasting effect that is reflected in a depression of seed yield. Sensitivity to B deficiency of male gametogenesis is especially important to yield response to B in cereals, e.g. wheat (Rerkasem et al, 1993) and barley (Jamjod and Rerkasem, 1999). The adverse effect of B on male fertility is less relevant in those species in which B deficiency causes the loss of flower buds or whole flowers before anthesis. A typical symptom of B deficiency in field grown sunflower is the corky and brittle peduncle that develops into a horizontal break that can result in the loss of the whole flower head (Fernandez et al., 1985, Rerkasem, 1986). Similarly, flower buds in B deficient black gram may begin to shed as soon as they are formed (Rerkasem et al., 1987a).

1.4 Boron and Quality

Apart from quantity of yield, the B limiting step in crop production may be associated with the quality and therefore price of the harvested crop, i.e. seed and fruit. A specific symptom of B deficiency that has been known for a long time is the hollow heart in peanut (Harris and Brolmann,1966). Boron deficiency has to be severe enough to cause at least 40 percent of hollow heart to have any effect on seed yield, but in some markets a marked reduction in price can result from only one or two percent of hollow heart. Percentage hollow heart has been found closely correlated to infection by the Aflatoxin causing fungus, *Aspergillus flavus*, (Rerkasem et al., 1988), although it is still unclear if this is a specific association with the low seed B status or a secondary one of damaged seed in general. The adverse effect of low seed B on germination, found at < 10 mg B kg^{-1} in green gram (Bell et al., 1989) and soybean (Rerkasem et al., 1997a), can be expected in other species. The management of B for fruit production is complicated by the different effects of B on yield and various quality characteristics. For example, the B level that has no effect on fruit number or yield may be limiting fruit size and shelf life in avocado (Smith et al., 1997).

The case of apple in Yunnan in south-western China (Dong et al., 1997) illustrates the complex situation of B nutrition in fruit trees for which optimum B levels may be quite different for yield and various quality characteristics, which are also different from those associated with other physiological responses. To manage for optimum apple production in China, orchards with Golden Delicious at 7 x 7 m spacing generally try to keep about 400 fruit per mature tree, thinning excess fruit by hand as necessary. The effect of B deficiency in causing fruit abscission is of no consequence as long as it does not leave fewer than 25% of the total fruit set. The low B that causes about 75% fruit drop, however, is likely to be also limiting to fruit size. Applying B increases fruit size and sugar:acidity ratio, but beyond a certain level this may have adverse effects on other quality characteristics including a loss of fruit firmness and overshooting the market preferred sugar:acidity ratio.

2. OVERCOMING BORON DEFICIENCY IN FARMER'S CROP

On most agricultural soils, it should be possible to correct the problem of B deficiency with an application of 1-2 kg B ha^{-1}. Incidences of B deficiency that continue to occur in farmers' fields throughout the world clearly indicate inaccessibility of this simple and relatively inexpensive solution to many farmers. The on-farm management problem associated with B deficiency is related to the difficulty of diagnosis and the management of B fertilisers.

2.1 Diagnosis

Although various methodologies for diagnosing B deficiency have been available for a long time (Bell, 1997), affected crops in farmers' fields are rarely diagnosed as such. Few farmers in the developing world are aware of soil and plant analyses as a means to determine if crop nutrition is the yield limiting factor. For those who happen to have the knowledge, supporting logistics that would enable samples to be properly collected, analysed and results interpreted and returned in good time are virtually nonexistent. Exceptions are industrial crops such as rubber and large oil palm estates and timber plantations. Quality control of analytical standard is another common problem in labs that are in operation. Furthermore only a few labs in parts of the developing world where B deficiency is a problem are set up to conduct B analyses in soil or plant, although the equipment and other costs involved are relatively inexpensive. Using visual symptoms that are distinctive and specific to B deficiency for diagnosis can be effective and cost very little. The hollow heart symptom in peanut has been successfully used to map areas prone to B deficiency in Thailand, percentage of seed with hollow heart in a crop used to indicate the severity of deficiency (Rerkasem et al 1987b). The major bottleneck is getting such information through to farmers and farm advisors. Booklets or postcards containing distinct and specific symptoms of a few crops common to the area, e.g. peanut, papaya, mango will do for many tropical countries, that can be made widely available may go a long way towards alleviating B deficiency in farmers' crops.

In addition to all the difficulties above, another obstacle to overcoming B deficiency in farmers' crops is related to its highly variable nature. Year to year variation in crop B responses due to climatic conditions is well known, and continues to be reported in the literature (e.g. Xue et al, 1998). Compounding this variability is the wide range of genotypic variation in the response to low B that can be found in many species of the world's major food crops (see below for more detail discussion on the topic). Incidences of B deficiency observed in farmers' field in one year may not be confirmed next year when the weather becomes less dry, less humid or less cold, or farmers switch back to older varieties known to be unaffected in the same way. The final verification of B deficiency diagnosis with fertiliser trials can also be rendered erroneous by B contamination in the basal fertilisers used. Many formulae of compound fertilisers and macro-nutrients in Asia have be found to contain large amounts of B (Bell et al, 1990).

2.2 Management of Boron Fertiliser

Brazil, Bangladesh, China, Nepal and Thailand are some of the countries where B deficiency has been identified on broad national or regional scale. Among these, the only country where B fertiliser is routinely applied to farmers' crops is Brazil. Brazilian farmers on low B soils are required to include B in their fertiliser management package as a condition for securing farm loans. In the other countries, incidences of B deficiency continue to be common among farmer's crops. Boron fertiliser is applied only occasionally, mostly to high valued crops. For example, tobacco fertiliser in Northern Thailand and Yunnan in south-western China have contained B for many decades. In Thailand foliar B application is routine in vegetables production and orchards of tropical fruits, e.g. durian, rambutan and mangosteen, even in areas where B deficiency has never been diagnosed such as near Bangkok and in the South (Sumitra Poovarodom, pers comm). For high value crops, this trend to apply B as a preventive as well as a corrective measure, can also be found in other countries.

For many important field crops, e.g. wheat and pulses, however, the uncertainty of diagnosis combined with the uncertainty of return means that B deficiency may continue to be an important cause of yield loss in many parts of the world. Breeding and selecting for B efficiency may offer a solution. In the next section this paper will examine potential and limitation of genotypic variation in B efficiency as a means for overcoming B deficiency, and also other implications of genotypic variation in B efficiency in crop B nutrition.

3. GENOTYPIC VARIATION IN BORON EFFICIENCY

In many crop species, genotypes growing on the same soil may be found affected differently by B deficiency. Such genotypic variation in the response to low B has been reported in monocotyledons and dicotyledons, herbaceous plants and trees, field crops, vegetables, fruits and timber species (Rerkasem and Jamjod, 1997b). Nutrient efficiency has been defined as the ability of a genotype to grow and yield well in soils too deficient for a standard genotypes (Graham, 1984). The practical interest in B efficiency in crop introduction and breeding program is, however, to eliminate genotypes that are less B efficient than existing materials as well as to identify those that may be even more efficient. Furthermore, for B it is generally the newly introduced germplasm that are adeversely affected by deficiency when older established genotypes are not (Rerkasem and Jamjod, 1997b, Anatawiroon et al., 1997, Srivastava et al., 2000). Many authors have successfully evaluated genotypes for B efficiency based simply on their performance in low B relative to the performance in B sufficiency (e.g. Xue et al., 1998, Stangoulis et al., 2000). It appears that B efficiency could be defined either without reference to standard genotypes, as these authors have done, or with standard genotypes that can be either more B efficient or inefficient, or preferably both.

Genetic diversity of B efficiency can mean a difference between complete crop failure and normal yield in some crop species. In bread wheat the most efficient genotypes will set grain and yield normally in soils in which the most inefficient set no grain at all (Rerkasem and Jamjod, 1997a). Similarly for lentil, Nepalese landraces named 'Simal' and 'Simrik' yielded 1.2 t/ha of grain on a soil in which a very large proportion of introduced germplasm was so adversely affected by B deficiency that they yielded nothing at all (Srivastava et al., 2000). Another crop species with almost as large differences between the most B inefficient and efficient is black gram (Rerkasem, 1991). In other species, e.g. oilseed rape (Xue et al., 1998, Stangoulis et al, 2000), green gram (Rerkasem, 1991), sunflower (Blamey et al., 1984), and barley (Jamjod and Rerkasem, 1999), the differences may not be quite so large. However, even in such species B efficiency can mean a difference between a crop that is an economic failure or success. Selecting for B efficiency therefore offers a simple means by which yield and economic loss due to B deficiency can be prevented, especially in those crops in which B fertiliser application is for some reason not feasible.

4. CROP BREEDING AND IMPROVEMENT FOR LOW BORON SOILS

Yield and economic losses are the obvious outcome for growing B inefficient crop varieties on low B soils. In addition, B inefficiency in introduced germplasm can be a major obstacle to crop improvement. For example, in China the introduction of high quality cultivars of oilseed rape, low in either or both of erucic acid and glucosinolates, have led to severe yield losses due to their extreme B inefficiency (Yang et al., 1993). Similarly, 82% of a lentil germplasm, numbering almost 500 entries, introduced into Nepal for the purpose of improving local lentil production, were found to be extremely inefficient compared with local landraces (Srivastava et al., 2000). Our own evaluation of CIMMYT germplasm also found very high frequencies of B inefficiency in bread wheat, and also durum and triticale that are distributed widely throughout the wheat growing world (Table 1).

Table 1. Frequency distribution (%) of boron inefficiency in bread wheat, durum and triticale genotypes by GSI in sand culture without added B[a]

Nursery or trial[b]	Number of entries	Frequency (%)		
		Inefficient	Moderately efficient	Efficient
29IBWSN	409	97.3	2.2	0.5
4HTWYT	49	61.2	34.7	4.0
17ESWYT	49	87.7	10.2	2.0
28IDYN	49	100.0	0.0	0.0
28ITYN	49	98.0	2.0	0.0
28ITYN	49	98.0	2.0	0.0

a) Inefficient, GSI = 0-70%; Moderately efficient, GSI = 71-85%; Efficient, GSI > 85%, with Fang 60 as B efficient standard.

b) From CIMMYT, Mexico: the 29th International Bread Wheat Screening Nursery; 4th High Temperature Wheat Yield Trial, 17th Elite Selection Wheat Yield Trial, 28th International Durum Yield Nursery, 28th International Triticale Yield Nursery.

Source: Adapted from Rerkasem and Jamjod (2001)

When the soil on which a crop breeding and improvement program is carried out is diagnosed with B deficiency, a common course of action is to apply B fertiliser over the whole station. For lentil in Nepal, it has been suggested that evaluation of introduced germplasm should be conducted on soils in which B is not limiting (Srivastava et al., 2000). However, unless B deficiency as the limiting factor for a particular crop species has also been removed from farmers' fields, screening for B efficiency should be essential at some stage before materials selected for superior agronomic characteristics reach the farmer's field. Evaluating for B efficiency can greatly enhance the cost effectiveness of crop improvement and breeding program serving soils prone to B deficiency, especially in those species in which genotypic variation in the response to low B in the soil is very large as found in wheat and lentil. Such screening would ensure that B inefficient genotypes that are certain to fail in farmers' fields are eliminated before they reach costly yield trials and on-farm evaluation. With all of our knowledge and understanding on the subject, it would indeed be a pity if farmers' crops should fail just because newly released, supposedly "improved", varieties happen to B inefficient.

Where B efficiency already exists, increasing the frequency in germplasm would be a simple matter of including B efficiency as one of the breeding objectives. The parentage of B efficient Fang 60 and Sonora 64 are actually very common among the pedigrees of CIMMYT wheat (Skovmand et al 2000). The relatively high frequency of B efficiency in the 4HTWYT in Table 1 is therefore not surprising. As we have seen in Thailand's wheat improvement program (Rerkasem and Jamjod, 1997), unintended selection pressure can quickly lead to increases in the frequency of B efficiency. A similar selection pressure clearly does not exist for the rest of the germplasm. Boron efficiency is not one of the breeding objectives of this major international breeding program at CIMMYT, and international yield trials and nurseries in Table 1 are intended for a wide range of environments most of which do not have B deficiency as a limiting factor. However, a B inefficiency frequency of 90% to almost 100% would definitely be a constraint to the potential usefulness of the germplasm on low B soils.

5. CONCLUSION

There are numerous observations and reports of physiological responses to B deficiency in plants. Not all of these are equally relevant to whole plant responses in the field and productivity of farmers' crops. The key to understanding crop B nutrition is the B limiting step, through which whole plant response and crop performance are limited by B deficiency. The management of crop B nutrition may be made more efficiently, by means of genetic manipulation or fertiliser management, if the B limiting step can be identified. The evidence of a wide range of genotypic variation in B efficiency in major crop species has two implications to crop production on low B soils. Firstly, economic success and failure for the particular crop that individual farmers grow will depend on the degree of B efficiency of the crop varieties grown. Secondly, a crop breeding and improvement program will have failed if farmers are constrained from adopting newly released, supposedly improved crop varieties because of their B inefficiency. It is encouraging that work on B efficiency now goes on in major crop species such as wheat, lentil and other pulses and oilseed rape on low B soils such as Nepal, Bangladesh, and China. The problem of B deficiency in these and other crops on low B soils will not be overcome unless crop improvement objectives specifically include B efficiency or B fertiliser is applied.

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Boron Efficiency in a Wheat Germplasm from Bangladesh

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1. INTRODUCTION

Wheat production in Bangladesh has grown from about 32,000 tons from 60,000 ha in 1961 to almost 2 million tons from 800,000 ha by the year 2000. Wheat has contributed significantly to the country's food security. Bangladesh wheat crop, however, often suffers from the problem of grain set failure. Boron (B) deficiency has been identified as one major cause of this problem. Soils on which wheat is grown in Bangladesh commonly contain 0.1-0.3 mg hot water soluble B kg^{-1} (HWS B), at which B deficiency has been shown to cause grain set failure through male sterility (Li et al 1978; Rerkasem and Loneragan 1994). On the other hand, wheat genotypes have been shown to respond differently to low B (Rerkasem and Jamjod, 1997). This study evaluated a set of wheat varieties and advanced breeding lines from Bangladesh national breeding program to assess their response to B in two experiments conducted at Chiang Mai University, Thailand.

2. MATERIALS AND METHODS

Experiment 1 compared three Bangladeshi wheat varieties (Gourab, Kanchan, and Sourav) with two B inefficient (SW 41 and E 12) and one B efficient (Fang 60) standard genotypes in a sand culture at 4 levels of added

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B (0, 0.1, 0.3 and 10 μM), in three replicates. Experiment 2 evaluated 37 released varieties and advanced breeding lines of wheat from Bangladesh national wheat programme, in duplicate blocks, in the sand culture with 0 and 10 μM of added B (B0 and B10) and in a low B soil (0.1 mg HWS B kg $^{-1}$) in the field. Also included in the experiment were the three B efficiency checks from experiment 1. In sand culture, plants were grown in freely drained earthenware pots (Ø 30 cm, 30 cm deep) containing washed river quartz sand. The pots were watered twice daily with 1 liter of nutrient solution (1000 μM $CaCl_2$, 250 μM $MgSO_4$, 500 μM KH_2PO_4, 10 μM FeEDTA, 250 μM K_2SO_4, 1 μM $MnSO_4$, 0.5 μM $ZnSO_4$, 0.2 μM $CuSO_4$, 0.1 μM $CoSO_4$, 0.1 μM Na_2MoO_4 and 5 mM KNO_3) with the varying levels of B. The pots were flushed with water once every 4-5 weeks to wash out excess salt. In the field, entries were sown in duplicate blocks, each entry in one meter row with 0.25 m spacing between rows. At maturity the B effect was assessed on grain set and yield components in the main stem from all plants in pots and from ten randomly selected ears from the field.

3. RESULTS AND DISCUSSION

In sand culture without added B, Kanchan and Gourab had similar Grain Set Index (GSI, Rerkasem and Loneragan, 1994) as the B inefficient SW41 and E-12 at about 20% compared with 59 % in Sourav and 89 % in the B efficient Fang 60 (Tab. 1).

Table 1. Effect of boron on grain set (GSI, %) in three major wheat varieties from Bangladesh compared with B efficient (Fang 60) and inefficient (SW 41, E-12) checks

Variety/ Genotype	Boron level (μM) 0	0.1	0.3	10
Kanchan	19.7aA	82.1bcBC	83.1bA	84.0bA
Gourab	22.6aA	86.8bC	91.9bBC	91.1bAB
Sourav	58.8aB	88.6bC	93.9bC	91.4bAB
Fang 60 (E)[a]	89.1aC	92.7aD	88.aAB	93.9aB
SW 41 (I)	20.7aA	67.8bA	84.7cAB	88.1cAB
E-12 (VI)	14.7aA	74.9bAB	84.9cAB	86.8cAB
F-test	Genotype **	Boron **	G x B **	

Differences (by LSD $p < 0.05$) in same row indicated by lowercase letters and in same column by uppercase letters. ** significant at $p < 0.01$
a) E = efficient, I = inefficient, VI = very inefficient

Without added B, the GSI of 37 varieties and advanced breeding lines from Bangladesh ranged from 4% to 55% while it was 82% in Fang 60, 30% in SW 41 and 17% in E-12. Increasing B in the nutrient solution to 10 μM increased GSI to 80% to 90% in most genotypes. The GSI in B0 of the germplasm correlated well with the GSI in B0 relative to B10 (Fig. 1). As previously suggested (Anantawiroon et al 1997), the inclusion of B efficient and inefficient checks enable germplasms to be evaluated for B efficiency in low B in the absence of B sufficiency control. Based on their GSI in sand culture without added B, out of 37 genotypes from Bangladesh, 6 may be considered very inefficient, 28 inefficient and 3 moderately inefficient no genotype was even moderately efficient (Tab. 2). The B inefficiency of the germplasm was confirmed in the field.

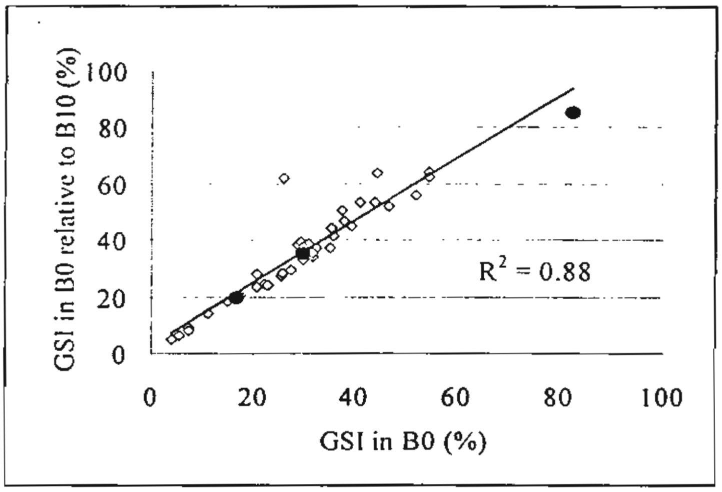

Figure 1. GSI in B0 and GSI in B0 relative to B10 for a wheat germplasm from Bangladesh. Solid circles are, from top, B efficient (Fang 60), and B inefficient (SW 41 and E-12) checks

The two common Bangladeshi varieties, Gourab and Kanchan, were in the same B inefficient class as SW 41. More than 90% of the germplasm tested, which contained released varieties and advanced breeding lines from Bangladesh, was also in this same B inefficient class. The remainders, including the standard variety Sourav were only slightly less inefficient. For an area with widespread low B soils where B fertilizer is still rarely applied in farmers' field, it seems that breeding and selecting for B efficiency would be desirable, especially since genetic sources for B efficiency already exist. It is known that B fertilizer is sometimes applied on station where breeding programs are conducted, to enable germplasm evaluation without the yield potential being limited by B. However, for genotypes destined for low B soils where B fertilizer is not used by farmers, evaluation of B efficiency would be essential some time before advanced breeding lines reach on-farm trials.

Table 2. Frequency distribution of boron efficiency in a wheat germplasm from Bangladesh and their response to boron

Boron Efficiency class[a]	GSI (%) in B0	Number of entries	Mean GSI (%) in each class[b] B0	B10	Field[c]
Very inefficient	0-20	7	9.8	84.5	28.2
Inefficient	21-50	27	31.7	83.5	47.0
Moderately inefficient	51-70	3	53.7	88.4	62.0
Moderate efficient	71-85	0	ne	ne	ne
Efficient	>85	0	ne	ne	ne
Fang 60 (Efficient)			82.5	97.1	84.3
SW 41 (Inefficient)			29.9	85.5	33.8
E-12 (Very Inefficient)			16.8	85.5	38.8

a) Rerkasem and Jamjod (1997) b) ne = no entry c) Soil with 0.1 mg HWS B kg^{-1}

4. CONCLUSION

A wheat germplasm from Bangladesh evaluated for B efficiency has been found to be largely inefficient. Considering the widespread occurrence of low B soils in the country, we suggest that boron efficiency should be included as one of the wheat breeding objectives.

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The Effect of Boron on Pollen Development in Two Wheat Cultivars (*Triticum aestivum* L., cv. 'Fang 60' and 'SW 41')

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1. INTRODUCTION

Boron deficiency causes male sterility in wheat but sensitivity differs among cultivars. In previous studies, a B- inefficient cultivar (cv. SW41) growing in sand culture at low B supply produced pollen that appeared normal at vacuolated young microspore stage, but by anthesis, had become deformed and empty containing no starch (Rerkasem et al., 1997). It has been suggested that the adverse effect of B deficiency may be related to the B requirement during the critical phase of anther development surrounding pollen meiosis: the period from premeiotic interphase through meiosis to late tetrad (Rawson, 1996; Huang et al., 2000). This study was to test the effect of short term B deficiency on pollen quality of B efficient and inefficient wheat cultivars to determine whether different sensitivities to B deficiency during critical stages of pollen microsporogenesis might explain the known cultivar differences in B efficiency.

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2. MATERIALS AND METHODS

Seed of wheat (Fang 60-B efficient and SW 41-inefficient: see Rerkasem et al. 1997) were imbibed in aerated 2 mM $CaSO_4$ solution for 24 hours in the dark at 25°C. Seedlings were then transferred into trays containing 8 L 1/3 strength nutrient solution with 10 µM H_3BO_3 and (give final conc in 8L) MES (2-[N-Morpholino]ethanesulfonic acid) solution and pH was adjusted to 6.0 ± 0.2 everyday with 1 M KOH or 10 % H_2SO_4. Four days after germination, uniform seedlings were transferred to pots containing 5 L of complete nutrient solution with adequate B (10 µM). Nutrient solution was continuously aerated with filtered air and the dry weight increment of extra plants was used to calculate the amount of nutrients for maintaining nutrient supply with programmed nutrient addition (Asher and Blamey, 1987). Seedling roots were rinsed in three changes of 5 mM $CaSO_4$ solution in order to remove B adsorbed on the root surface before transplanting. Two uniform plants per pot were transferred into the B treatments: either low B (0.1 µM B, -B) or adequate B (10 µM B, +B) during the critical stage of pollen development (premeiotic to late tetrad). Pollen developmental stages were identified by dissecting extra plants and staining the microspores with DAPI (4'-6-Diamidino-2-phenylindole·2HCl, Sigma Lot 104F-0542) and examining them under a UV-fluorescence microscope (Vergne et al., 1987). After 5 days of treatment, plants were transferred back to adequate solution B supply (10 µM) and harvested at anthesis. Anthers were collected and fresh pollen examined for viability by the fluorochromatic (FCR) test (Heslop-Harrison et al, 1984) and absence or presence of nuclei by DAPI. Starch accumulation in pollen was assessed by the iodine (KI/I_2) test.

3. RESULTS AND DISCUSSION

Withholding B for 5 days depressed pollen viability at anthesis in the B-inefficient wheat cultivar (cv. SW 41) by 40-70 % (Fig. 1). In contrast to previous reports, starch accumulation in both cultivars was not affected by the temporary B deficiency (Tab. 1). Furthermore, the pollen of SW41 in B- also appeared to differ from SW41 in B+ and Fang 60 in B- and B+ in two other respects. Many of the pollen of SW41 in B- remained attached in pairs and their mitotic nuclei were fewer (Fig. 2).

The cultivar SW41 was more sensitive to B deficiency during the critical stage of microsporogenesis than Fang 60. B deficiency during meiosis has been previously shown to inhibit anther elongation and severely depressed pollen viability (Huang et al., 2000). In SW 41, B deficiency decreased B content in anthers (Rerkasem et al., 1997). It is possible that the adverse effect of pollen development is caused by inadequate supply of B to the ear and anthers. Rerkasem and Loneragan (1994) and Rerkasem et al. (1997) could not detect any difference in flag leaf and whole ear B concentrations between tolerant and susceptible cultivars and Subedi et al. (1999) even found that a tolerant cultivar had lower B in the flag leaf. Therefore, it is unclear whether cultivars differ in B demand or ability to deliver B into the ear. However, B deficient Fang 60 and SW 41 did not differ in their pattern of B partitioning after flag leaf emergence onwards (Subedi et al., 1999). This contradicts a conclusion drawn by Rawson (1996) that the tolerant genotypes can utilise previously stored B when uptake is limited during the critical reproductive stage. Therefore, the mechanism for B efficiency is still unclear.

Unlike in previous reports (e.g. Li et al., 1978 and Da Silva and da Andrade, 1980), this study found the effect of low B on pollen viability without any effect on starch accumulation. Starch accumulation was not sensitive to B withdrawal in the 5 days during premeiotic to late tetrad. In wheat, starch is normally visible about 12 to 24 h after pollen grain mitosis I and the microspore was packed with numerous starch at mitosis II (Bennett et al., 1973). In this study, the B supply would have been restored during starch accumulation. It is unclear what role B plays in starch accumulation, if any. The presence of starch obviously does not indicate viable pollen. On the other hand, it is interesting that inviable pollen can continue to accumulate starch.

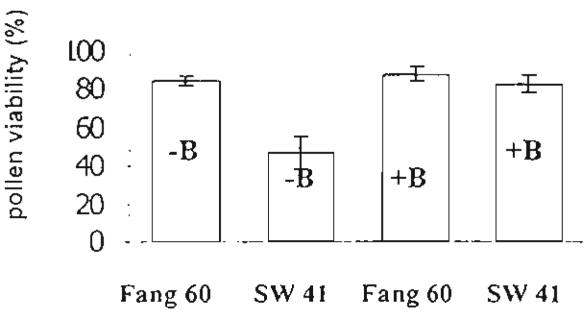

Figure 1. The effect of short term B deficiency on pollen viability (%) in two wheat cultivars by fluorochromatic (FCR) test.

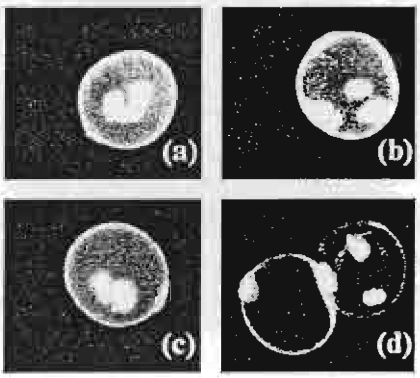

Figure 2. The pollen at anthesis by DAPI test; (a) +B, Fang 60: (b)+B, SW 41; (c) –B, Fang 60; (d)–B, SW 41.

Table 1. Reaction to KI/I_2 staining for starch in the pollen of two wheat cultivars at anthesis.

Cultivar	Boron treatment	
	- B	+ B
Fang 60	+++	+++
SW 41	+++	+++

+++ = most pollen were stained black.

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22 Intensification and diversification of land use in the highlands of northern Thailand[1]

KANOK RERKASEM, CHARAL THONG-NGARN, CHAWALIT KORSAMPHAN, NARIT YIMYAM, BENJAVAN RERKASEM

NORTHERN THAILAND covers an area of approximately 171 000 km^2 and its 17 provinces are characterized by long mountain ridges and narrow valleys. Four major rivers, the Ping, Wang, Yom and Nan, flow southward and are the major tributaries of the country's biggest waterway, the Chao Phraya. The area shares borders with Laos and Myanmar, and contacts with neighbouring countries in the Mekong subregion can be traced back as far as 1050, the *Thai Era of Lan Na* (Penth, 2000). The population is now close to one million, made up of several main ethnic minority groups, including Karen[2], Hmong, Lahu, Lisu, Yao, Akha, H'tin, and other small minority groups such as Lua, Khamu, Shan and Yunnanese (Haw) Chinese (National Security Council and National Economic and Social Development Board, 1993; Department of Public Welfare, 1995). Virtually all of these people make a living by growing rice for subsistence and other crops for cash income, which in the days before the 1970s and 1980s included the opium poppy (*Papaver somniferum*). Originally, crop production activities were based on two broad groups of traditional shifting cultivation land-use systems, termed rotational and pioneer shifting cultivation (Kunstadter et. al., 1978; Grandstaff, 1980). Rotational shifting cultivators typically settled in one place, and grew crops in a rotation involving 1 year of cropping and 5–10 years of fallow. Pioneer shifting cultivators were migratory. Crops were grown on land cleared from mature forests, and the whole village would pick up and move to a new site after a few years of continuous cropping. Traditionally, opium was the major cash crop of the pioneer shifting cultivators. This system, which may or may not have been practised in its classic form, had been particularly severely abused for its destructive impact on biodiversity and the soil.

The land-use systems have undergone marked changes since 1960. In this chapter, we describe these changes in general, and provide examples from four villages to highlight some positive and negative aspects of the new systems.

The highlands in the context of national policy

Development efforts of the Thai government began in the highlands in the 1970s. With support from various international assistance schemes, they were

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directed at eradicating opium poppy cultivation. Central to these efforts were attempts to develop alternative cash crops. The first highland development master plan was initiated in 1983 with assistance from the United Nations Fund for Drug Abuse Control (UNFDAC). It targeted areas and groups involved in opium poppy cultivation (Office of the Narcotic Crops Control Board and UNFDAC, 1983). A second master plan of a similar nature followed in 1988. An important element of these master plans was the coordination of a large number of development activities initiated and supported by several international agencies and bilateral assistance agreements, and implemented as numerous 'highland development projects'.

These largely externally funded projects, which lasted until the late 1990s, helped to direct considerable public investment into the highlands in the form of road building, schools, health services and electrification, as well as the transfer of agricultural technology. Currently public investment for development comes from the Royal Thai Government. There has been a national master plan for highland community development, the environment and narcotic crop control for a period of five years from 1997 to 2001. Apart from this, the highlands receive public investment allocation on the same basis as the rest of the country. Support for development in the highlands is now at a much lower level than in the 30 years before 1990. The exceptions are a handful of villages that continue to receive substantial financial, technical and marketing assistance for their cash cropping through the Royal Project, which is partly funded privately through the Royal Project Foundation and partly publicly from a budget allocation to the Ministry of Agriculture and Cooperatives.

Establishment of permanent villages

Traditionally villages were highly mobile. Pioneer shifting cultivators moved in search of new forests after 5–10 years of continuous cropping. The villages of rotational shifting cultivators also split to establish new settlements when the population grew too large to be accommodated by the existing land. By the mid-1970s, however, movement had virtually stopped. Many Hmong, Lisu, Lahu and Akha villages became permanently settled in the 1960s or earlier. They acknowledged the increasing difficulty of finding new forests to clear. To settle, they frequently bought developed wet-rice land and the associated technology, including the irrigation system, from lowland Thai or Karen farmers. Apparently opium production was sufficiently productive to allow at least some highland farmers to accumulate enough wealth to buy irrigated wet-rice land and invest in commercial crop production.

The trend towards permanent settlement was reinforced by national policies instituted since the 1960s. Originally very few people in the mountains who belonged to any of the ethnic minority groups were recognized as citizens of Thailand.[3] Permanent settlement is still required as a first step towards official recognition and eventually to Thai citizenship. Citizenship has been granted to only about one-third of the population. Provision of health and education services, roads and electricity offered further incentives to settle permanently. There was also pressure through the national conservation and reforestation policy. Although the highlands had always been regarded by law as national property, they had until relatively recently been treated as a free good. In the past 40 years large areas of the highlands have been designated watershed areas, national parks, forest and wildlife reserves, with strict enforcement of conservation laws. All of these factors combined to make village movement and setting up of new settlements virtually impossible.

New cropping systems

New cropping systems have developed with permanent settlement. Thanks to strict enforcement of drug control laws, opium poppy cultivation has almost disappeared. To meet demand for home consumption by older addicts some small areas of cultivation remain, but these are well hidden. Wet-rice is grown by all ethnic groups, often in small highland valleys. Where dry season irrigation is available, rice may be followed by another crop, usually soybean or vegetables. Areas suitable for wet-rice are keenly sought after, but the amount of relatively flat land with sufficient water supply is limited. Cultivation on the slopes is still widespread, and much of it is on very steep gradients. Some land is cropped annually, some with two or three years fallow, and occasionally with the original full cycle of 5–10 years fallow. Upland rice, maize and various other food and cash crops are grown. The very short fallow periods, and sometimes lack of a fallow period, are associated with low yields and heavy weeding requirements. Farmers are reluctant to apply costly fertilizers and pesticides to subsistence-crops, but do use them on high-value cash crops such as cabbages, coffee, tomato, potato, ginger, lettuce and flowers. Furthermore, all of the high-value crops that are grown in the dry season are irrigated by a system of sprinkler irrigation fed gravitationally from mountain streams and springs. These raise another set of problems.

Sustainability problems of cropping intensification

Improved national transportation, rising incomes in Bangkok and other cities, and a temperate environment, combine to create special opportunities for crop production in the highlands. The cooler climate provides an advantage for the production of temperate fruits, vegetables and flowers. During the monsoon season, vegetable production in the highlands has far fewer problems with insect damage than in the lowlands and there is better surface drainage on the slopes. Lychees are harvested much earlier and fetch very high prices. Research to find alternatives to opium and to evaluate new crop species and types began in the 1970s, and has continued with increasing commercial interests and initiatives. The two most recent additions are potato production to supply the fast-growing demand of manufacturers of potato products, and hybrid maize seed production. Commercial seed producers have discovered that the mountains provide the ideal conditions for isolation of populations to prevent unintended cross-fertilization between breeding lines.

All of the new cash crops are subject to wild price fluctuations. Downturns in prices threaten the food security of poor village families who have converted completely to cash cropping. The new crops require heavy fertilizer and pesticide applications. Intensive cultivation with a bare soil surface during the wet season contributes to soil erosion and has led to sedimentation behind dams and weirs and in paddy fields. There are also downstream hydrological consequences. Expansion of irrigated cropping in the highlands has been blamed for many mountain streams and springs running dry in the dry season. Conflicts have erupted between highland and lowland communities on these issues. In the Mae Taeng Irrigation Project of the Royal Irrigation Department, for example, the decline of dry season stream flow during the five months December to April from 1972 to 1991 led to an overall reduction of flow of 60.8 million m^3 over the 19 years, averaged at 3.2 million m^3 per year (Thailand Development Research Institute, 1995). In 1993 an ugly confrontation broke out between an upstream Hmong community in Paklouy village and lowland farmers in Chom Thong district of Chiang Mai valley who had their water supply for irrigation dry up (Benjasilaraks and Silaraks, 1999; Rakyuthitham, 2000). Few of the accusations and counter accusations are substantiated by actual measurements, and it is not certain how the problem of upstream and downstream conflict can be resolved in a near future.

Against this general background, the highlands are nevertheless a place of much diversity in both the environment and how farmers and communities respond to new challenges and opportunities. The case studies below, covering people with diverse ethnic backgrounds and contrasting traditional land-management systems, illustrate local innovation and adaptability. The villages are located in Chiang Mai and Mae Hong Son provinces (Figure 22.1). Two of these, Loh Pah Krai and Pah Poo Chom, are former opium-growing, pioneer shifting cultivator villages. The other two, Mae Rid Pagae and Tee Cha, are Karen, who are traditionally sedentary.

Loh Pah Krai – from opium to wet-rice and home gardens

This Lahu village had been a typical pioneer shifting cultivator village before the villagers settled at Mae Ai, north of Chiang Mai, in the mid-1960s. Within

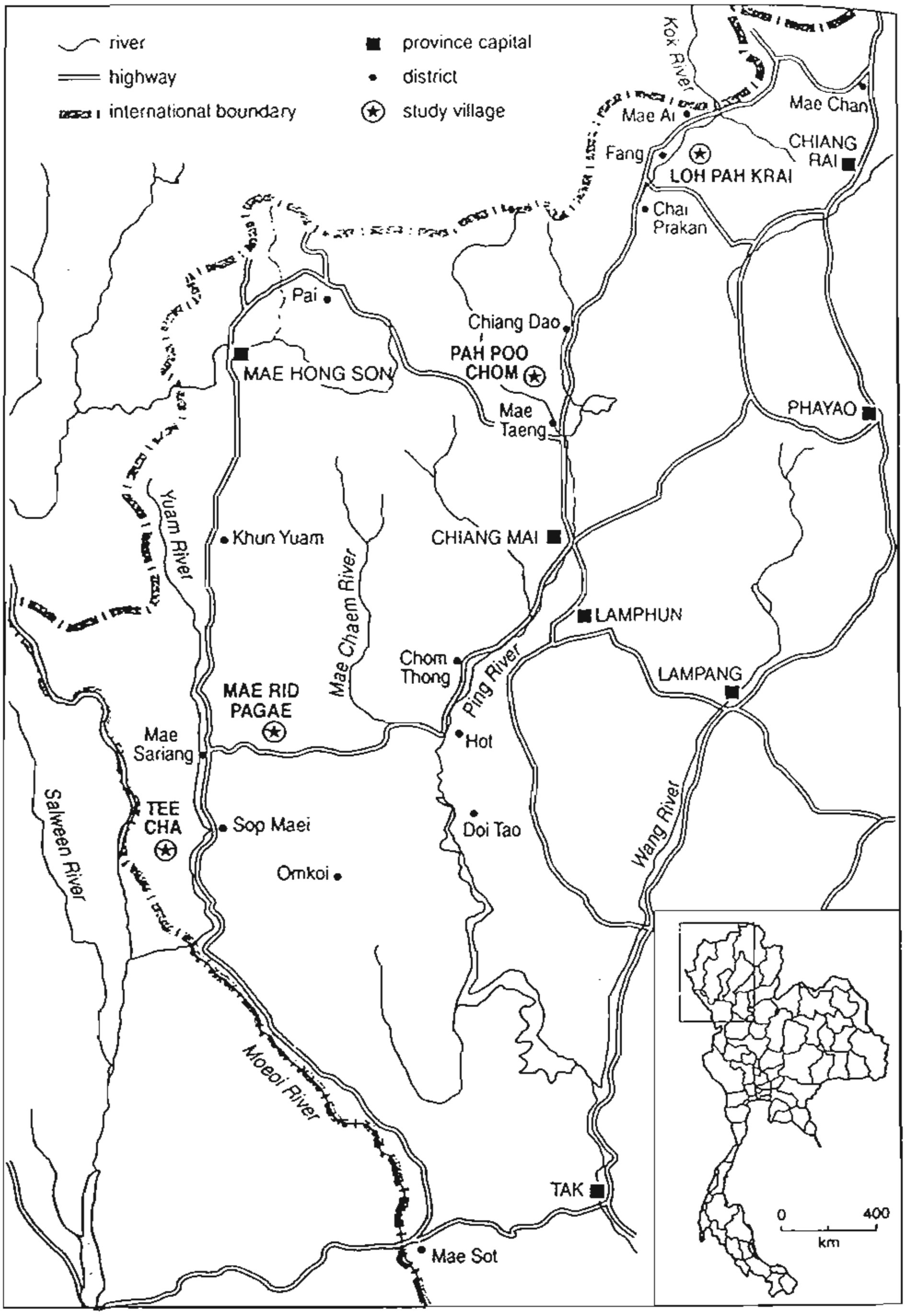

Figure 22.1 *Location of the case study villages in Chiang Mai and Mae Hong Son provinces, Thailand*

the life-time of some of the older members, the village had moved through and, in their own words, 'eaten up several forests' in Chiang Rai and Chiang Mai provinces. To settle permanently, the village bought a sizeable tract of irrigated rice land from some lowland Thais. This was not simply a transfer of land ownership. Along with the land, the Lahu farmers also secured the technological and management skills associated with wet-rice cultivation and the irrigation system. By the mid-1990s they had adopted a double crop system of rice and soybean in the wet-rice fields, and developed an effective scheme for sharing scarce dry season water with downstream villages as well as within the village.

When they first settled, the village was also growing some upland rice and maize on the slopes in short two or three year rotations. By the early 1990s most of the upland fields were cropped every year, often with double-cropping systems of maize or upland rice followed by a grain legume, such as soybean, payee (*Lablab purpureus*) or one of the *Vigna* species. A number of fields within ten minutes walk from the village houses had been developed into home gardens. Some 33 cultivated species were identified in one of the gardens (Table 22.1). Many of the species were grown for sale outside the village, but others provided a year-round supply of food, herbs, spices and animal feed. The food crops were readily shared within the village. Some species were incorporated into vegetative contour conservation strips, for example, lemongrass (*Cymbopogon citratus*), pigeonpea (*Cajanus cajun*) and cha-om (*Acacia pennata* subsp. *insuavis*).

Pah Poo Chom – many ways to biodiversity utilization and conservation

Pah Poo Chom is a Blue Hmong village situated in Mae Taeng watershed, north of Chiang Mai. The villagers settled on a mountain ridge at 940 m above sea level in 1963, and by 1970 most of the surrounding forests had been cleared and cropped with rice, maize and opium. According to the Tribal Research Centre of the Department of Public Welfare, the village was in a stage of extreme poverty, crop yields were low, and opium addicts accounted for 80 per cent of the adult male population and also included some women and even young children (Oughton, 1970; Oughton and Imong, 1970). Based on evidence from this village and many other highland villages, imminent collapse was predicted for highland cropping systems in the 1960s and 1970s (see Keen, 1972; Walker, 1975; Cooper, 1984). Since the early 1990s Pah Poo Chom has been transformed. Cash cropping has been adopted in a major way, but successful management of its biological diversity has also contributed to food security, income generation and conservation of biological diversity.

Table 22.1 Crop species found in a home garden belonging to a farmer from Loh Pa Krai, Mae Ai District, Thailand

Crop type	Common name	Scientific name
Introduced tree crops	Bamboo	*Dendrocalamus asper*
	Lychee	*Litchi chinensis*
	Santol	*Sandoricum koetjape*
	Mango	*Mangifera indica*
	Jackfruit	*Artocarpus heterophyllus*
	Tamarind	*Tamarindus indica*
New crops grown for cash	Adzuki bean	*Vigna angularis*
	Soybean	*Glycine max*
	Payee	*Lablab purpureus*
	Ginger	*Zingiber officinale*
	Green gram	*Vigna radiata*
Local plants	Cha-om	*Acacia pennata* subsp. *insuavis*
	Banana	*Musa sapientum*
	Papaya	*Carica papaya*
	Jujube	*Ziziphus jujuba*
	Upland rice	*Oryza sativa*
	Maize	*Zea mays*
	Sugarcane	*Saccharum officinarum*
	Sweet sorghum	*Sorghum vulgare*
	Ma Kua	*Solanum* spp.
	Chilli pepper	*Capsicum* spp.
	Pineapple	*Ananas comosus*
	Pumpkin	*Cucurbita moschata*
	Wax or white gourd	*Benincasa cerifera*
	Cowpea, several types	*Vigna unguiculata*
	Pigeonpea	*Cajanus cajun*
	Mustard green	*Brassica* spp.
	Taro	*Colocasia* spp.
	Pak Ped	*Vernonia silhetensis*
	Lemongrass	*Cymbopogon citratus*
	Sweet potato	*Ipomoea batatas*
	Tobacco	*Nicotiana tabacum*
	Sesame	*Sesamum indicum*

Source: Rerkasem et al. (1995)

Lychee trees and sprinkler-irrigated vegetables, principally cabbage, have become the main source of cash income. Villagers market most of their vegetables in Chiang Mai, carrying them in their own pick-up trucks. Agricultural land now accounts for only one-quarter of the village land. The balance is made up of natural forests, two parts conservation forest and one part utility forest dominated by bamboos, especially *Dendrocalamus* and *Bambusa* species (Figure 22.2). The largest number of species was found in the conservation forests, followed by the utility forests, the home gardens, agroforest edges between fields and lychee/vegetable intercrops (Table 22.2).[4] A large proportion of the species in each Land-use Stage are used. Harvesting bamboo shoots for sale is an important source of income especially for poorer villagers. Traditional crops that were part of the opium and upland rice swid-

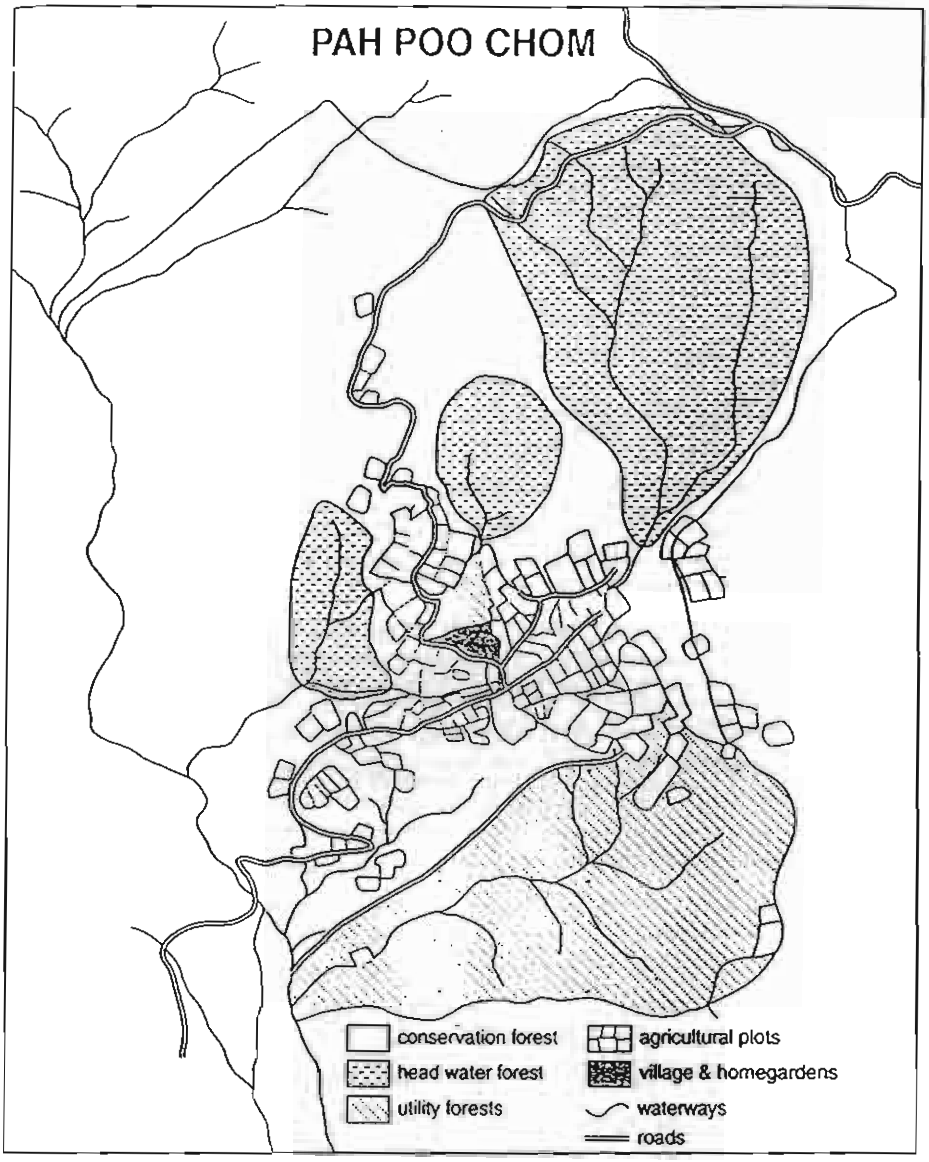

Figure 22.2 *Land-use map of Pah Poo Chom, Thailand*

dens have been conserved and incorporated into new cropping systems. The wild, semi-domesticated and traditional crops and vegetables from Pah Poo Chom (see, for example, Table 22.3) contribute significantly to village food security. They also find ready demand among the urban Hmong community around the Chiang Mai market. A traditional Hmong waxy or glutinous corn is now popular in the city market. Several clumps of a special bamboo are managed by one old man, who crafts them into the Can, a traditional Hmong musical instrument. Sold for 3000–4000 baht[5] each, several of these are made each year and are sometimes exported to Hmong communities in Laos.

Table 22.2 Number of plant species in various Land-use Stages and Field Types of Pah Poo Chom village, Thailand

Land-use Stage/Field Type	*Number of Species**		
	Total	*Used*	*% Used*
Conservation forests (10 × 10 m)	152	133	87.5
Utility forests (10 × 10 m)	135	110	81.5
Bamboo dominant	89	82	92.1
Agroforest edges (total in the 3 sample plots)	89	68	76.4
Wild mango dominated (10 × 10 m)	33	27	81.8
Wetter area (10 × 30 m)	18	14	77.8
Patch close to village, near road (20 × 50 m)	63	46	73.0
Home gardens (total in two gardens)	68	57	83.8
Garden 1 (30 × 30 m)	45	38	84.4
Garden 2 (25 × 30 m.)	45	34	75.6
Lychee/vegetable intercrops (10 × 10 m)	34	12	35.3
Upper slopes	19	12	63.2
Lower slopes	12	5	41.7

*Numbers of species do not add up to the total in each category and grand total because some species occurred in more than one sample.
Source: Field Survey (1999)

Table 22.3 Useful plant species and their numbers in one semi-cultivated field (5 × 10 m) in Pah Poo Chom, Thailand

Species with common or local name			*Number of plants in sample*
Domesticated	*Zea mays*	Waxy corn (Kaopode in Hmong)	300
	Allium ascalonicum	Shallot	1150
	Brassica juncea	Leaf mustard (Pak-kahd in Hmong)	250
	Cucurbita moschata	Pumpkin	4
	Coriandrum sativum	Coriander	5
	Ipomoea batatas	Sweet potato	3
	Litchi chinensis	Lychee seedlings	1
Semi-domesticated	*Momordica* sp.	Wild bitter gourd	20
	Solanum torvum	Susumber	1
Wild herbaceous	*Crassocephalum crepidioides*	Lum Phasi	1
	Amaranthus viridis	Amaranth	1
	Asytasiella neesiana	Edible fern	11
	Phrynium capitatum	Tong Sard for food wrapping	9 clumps
	Musa acuminata	Wild banana	22 hills
	Zingiberaceae sp.	Kong: edible fruit, leaves for lining rice storage container, fibre for rope making	5 hills
	Total 15 species		1783

Source: Field Survey (2000)

Mae Rid Pagae – cash cropping improving food security

Mae Rid Pagae is a Skaw Karen village at 1200 m above sea level, some four hours by road from Chiang Mai. In the past, the limited irrigated wetland and 'sustainable' rotational shifting cultivation provided enough food for the population only in some years. There were sometimes bad years in which production fell short and many had to walk to the nearby town of Mae Sariang to seek work. As the population grew and the national conservation policy limited expansion of crop production into forest land, the problem of food security worsened. The luxury of adequate rice production with long fallow rotation in traditional shifting cultivation was impossible and farmers had to find viable alternatives to support their livelihood.

Cabbage production began in the early 1980s. Currently, visiting traders buy direct from farmers and truck the crop to Bangkok and beyond. However, it is not a monoculture of cabbage that has been adopted by Mae Rid Pagae. Instead, new cropping systems have evolved, incorporating traditional components and the cabbage. In the irrigated fields, cabbage is grown with irrigation in the dry season following the wet-season rice. On the slopes, upland rice and cabbage are grown in alternate years. The problem of sharply fluctuating prices has not eased, but rice yield has been greatly boosted by the incorporation of cabbage. This is probably due to the residual organic and inorganic fertilizers used in cabbage production, and the effect of clean-weeding of the cabbage in reducing weed infestation of rice. Farmers' reports of rice yield having doubled or tripled have since been confirmed in crop-cutting surveys.

The village also has the advantage of a well-structured soil that is less susceptible to erosion than many others. Vegetative contour strips have been adopted, incorporating weed species such as *Chromolaena odorata*, to check water flow down the slopes. However, farmers do acknowledge that they have begun to receive complaints from downstream villages about perceived water contamination with pesticides. In practice, the use of pesticides is limited to the dry season crops that are grown in areas with supplementary irrigation only.

Tee Cha – Pada fallow, a local innovation

In 1999 the population of Tee Cha numbered 148 in 41 households. The Pwo Karen village, established more than 200 years ago, is situated almost on the Myanmar border in Mae Hong Son province. It is one of a few villages where rotational shifting cultivation is still apparently sufficiently productive to meet food security needs (Figure 22.3). A good forest cover, with numerous uses and services, dominates land use. Being relatively isolated, lack of access to the market limits cash cropping. The cropping system in Tee Cha is

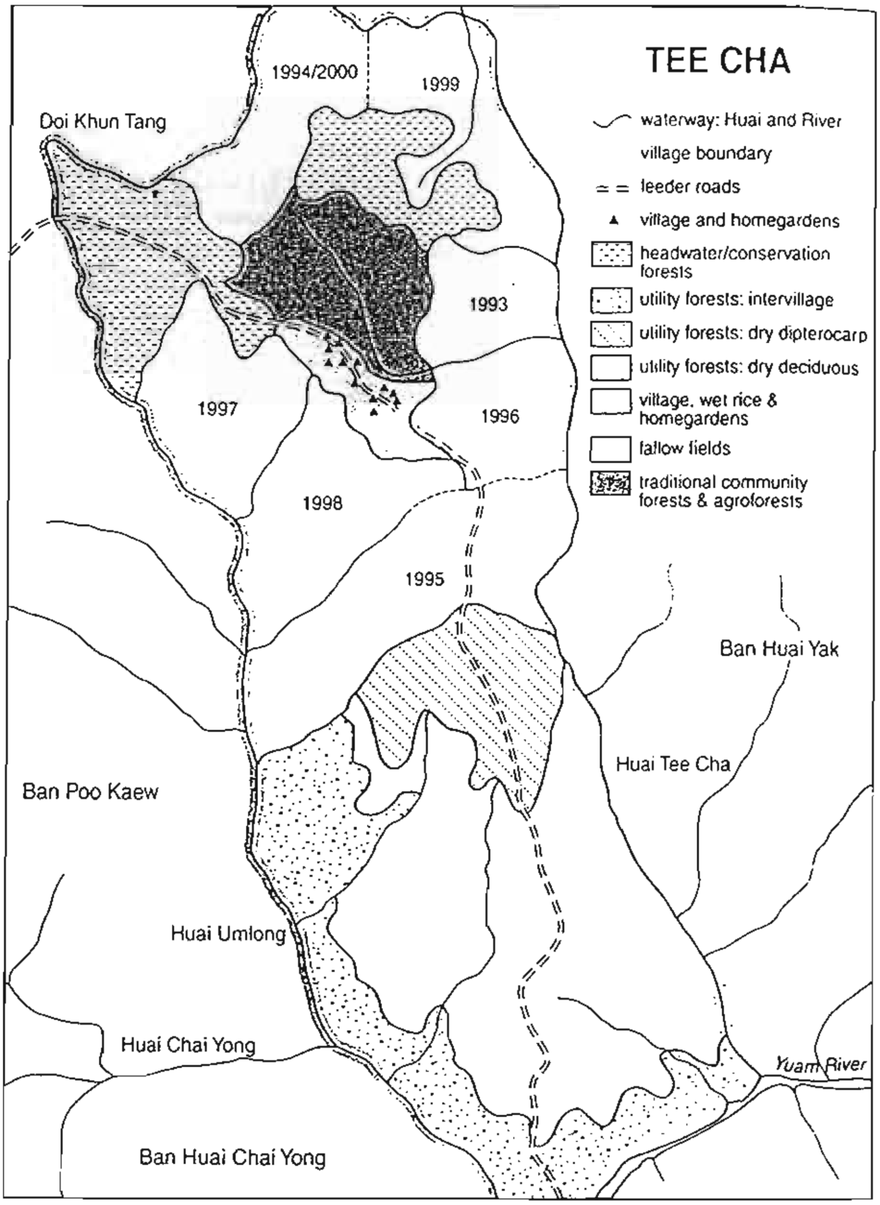

Figure 22.3 *Land-use map of Tee Cha, Thailand*

predominantly subsistence and is managed partly on a communal basis. Upland rice is grown in rotation with six years of fallow. The fallow management, mainly controlling fire and restricting the use of the regenerating forest, felling and burning the mature fallow, and the allocation of land-use rights, are communally organized. Managing the rice crop is an individual enterprise for each farm household, although there is much sharing and exchanging of germplasm and labour.

The seven-year cycle where land is cropped with upland rice every seventh year, is much shorter than the traditional ten-year or more cycle that used to be common in the region. Farmers attribute sustainability of the shorter cropping rotation to the dominance of Pada (*Macaranga denticulata* Muell. Arg.) during the fallow years. The fallow-enriching properties are recognized by other ethnic groups of northern Thailand, the H'tin and Khamu, who call it Teen Tao (Tong Tao in northern lowland Thai), and by forest ecologists (Whitmore, 1982). Pada is a small tree of the Euphorbiaceae family and it begins to flower and produce seed after three years. In the cropping year, Pada seedlings emerge as a thick carpet among the rice, presumably from a seed bank that accumulated during the previous three years. Farmers manage Pada in a number of ways. The seedlings are not considered weeds, so are not destroyed during hand weeding of the rice. However stands may be thinned if they become too dense and seedlings may be transplanted to areas with poor establishment.

The observations of farmers about the tree's value is corroborated by field observations. Preliminary measurements indicate that Pada trees play a major role in nutrient cycling of the cropping system. Nutrients such as nitrogen, phosphorus and potassium have been found to accumulate in the biomass of Pada-dominated fallow after the sixth year in much greater amounts than in Pada-less fallow after ten years (Zinke et al., 1978). A good stand of Pada, which reaches almost over the farmers' head by the time of rice harvest, is associated with an upland rice yield that is about twice the yield with few or no Pada. Attempts to establish Pada in neighbouring villages where it does not occur naturally, however, have so far been unsuccessful.[6]

Adapting to change

Since the 1960s land use in the highlands of Northern Thailand has undergone dramatic change due to external and internal pressures, which have included national conservation and highland development policies, population growth and rising expectations and aspirations of the villagers themselves. Intensive land use has replaced traditional shifting cultivation but some villagers, by using local innovations, have been better able to adjust their land-use systems to cope with the impact of change on food security and the environment.

Many other successful cropping systems and practices can be found in other villages throughout the mountains of northern Thailand. These observations belie the general belief that intensification of agriculture in the mountains is not sustainable and inevitably leads to yield decline and degradation. To understand how some farmers and villages in these difficult environments succeed, however, has required a holistic approach to the study of village land management that recognizes variations in time, space and the management units that exist in the agroecosystem. We conclude this chapter with three characteristic factors that have contributed to these farmers more successfully adapting to change.

First, the mountains are agroecosystems with great diversity. This diversity includes variability in:

- the physical environment, for example, soil properties and microclimates
- the social and economic context of the farming system
- the local management capacity that may range from the different agronomic skills and ability to learn of the individual farmers, to the community's capacity to manage common resources or interact effectively with the market or the provincial and national government.

Second, there is a great diversity of plant genetic resources available in these mountain villages, including domesticated, semi-domesticated and wild species that are little known to outsiders, but that have been incorporated into successful new cropping systems.

Third, the innovations that have given rise to new cropping systems would not have materialized without the farmers' intimate knowledge of the specific sets of physical and socio-economic conditions defining their particular environment and the knowledge of the plant genetic resources available to them.

Innovations and knowledge originating from the outside can become useful only when they happen to fit local conditions. Modern agriculture and its various associated sciences have a great potential to benefit these mountain farmers. The challenge is to identify how they can be made relevant to local needs and conditions. Since it will never be possible to completely characterize the local variability, the best thing is to work closely with farmers.

Chapter 17

1 PLEC began work in Amazonian Brazil in 1992, and work in Amapá, already begun under another project, was then incorporated into PLEC. The task reported here overlaps the period of the two projects.
2 For more complete discussions of the formation of the smallholder timber industry see Pinedo-Vasquez et al. (2001) and Sears et al. (2000).

Chapter 18

1 Translated by Liang Luohui, Managing Coordinator of PLEC.

Chapter 19

1 This was a student paper when it was written in the mid-1990s. Even though there have been some changes in the situation at Baka, and in the market for *Amomum villosum*, since that time, the paper is reprinted without substantial change.
2 55000 mu is approximately 3700 hectares; 1 ha is equivalent to 15 mu.

Chapter 20

1 We thank San Long, and Mi Ba for helping us in the field work. Liang Luohui has given invaluable assistance with finalization of the English version of this paper. Kevin Coffey advised on the use and interpretation of the indices employed.

Chapter 21

1 One hectare is equivalent to 15 mu.

Chapter 22

1 The authors wish to acknowledge support for part of the work reported in this chapter from UNU-PLEC and Thailand Research Fund
2 Karen, Hmong, Lahu, Lisu are some of the most common ethnic minority groups living in the mountainous areas of mainland Southeast Asia.
3 Although some groups, including the Karen, have been in Thailand for several hundred years, others are migrants within the twentieth century.
4 Use of these edges between fields is a particularly distinctive feature of the Pah Poo Chom system. A few are substantial, with natural as well as planted trees. The crops and other products obtained from them are mainly used for self-provisioning, and in this respect they constitute an important diversification of what is otherwise largely a commercial system of land use.
5 At the time of this research US$1 = Bt43.
6 Research into Pada currently being undertaken includes its biology of seed production and dormancy, its contribution to productivity of upland rice in the cropping system, its role in nutrient cycling and relationship with other key fallow species. The role of mycorrhiza and nitrogen-fixing endophytes in the nutrition of Pada is also being investigated. This work is supported by UNU-PLEC and Thailand Research Fund.

การตอบสนองของพันธุ์ข้าวไร่และข้าวนาสวนต่อสภาพดินขังน้ำและดินระบายน้ำดี

Response of upland and lowland rice cultivars to waterlogged and well-drained soil conditions

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Abstract : Rice in Thailand is mostly grown in rainfed lowland ecosystems, where water supply is variable during the growing season. However, there is limited understanding of how Thai rice cultivars adapt to changes in water regime. The objective of this work was to examine the responses of upland and lowland rice cultivars to waterlogged and well-drained soil conditions. Two upland (Sew Mae Jun and Kae Noi) and two lowland (Chainat 1 and KDML105) cultivars were compared in waterlogged (W+, the soil surface was submerged under 10 cm. of water) and well-drained (W0, water the plant everyday but not have water standing in the pot) soil, with three replications. There were separate pots for each harvested at 2, 4, and 8 weeks in which root and shoot length, root and shoot dry weight, total root volume, aerenchyma development and nutrient content were measured. Shoot and root growth of all cultivars grown in waterlogging throughout were higher than in drainage throughout, except Kae Noi. Shoot and root growth of Kae Noi in both of waterlogged and well-drained soil conditions were not different. Aerenchyma development of Sew Mae Jun and KDML 105 were not different in two water soils conditions, while Kae Noi was higher in W+ at 5 cm from the root tips. Nutrient contents of all cultivars were also generally higher in waterlogged soils. Nitrogen contents of upland rice cultivars in well-drained soil were higher than lowland rice cultivars. Moreover, nitrogen contents of upland rice cultivars were equal in both soil water conditions. Whereas, lowland rice cultivars in well-drained soil were 50% less than in waterlogged soil conditions. Phosphorus contents had the same response to soil water conditions as nitrogen contents. Specific nutrient uptake of root, Kae Noi and KDML 105 were equal in both of soil water conditions, while Sew Mae Jun and Chainat 1 in well-drained soil were higher than in waterlogged soil.

บทคัดย่อ : ระบบการปลูกข้าวในประเทศไทยส่วนใหญ่เป็นการปลูกข้าวแบบอาศัยน้ำฝน ซึ่งเป็นสภาพที่มีการเปลี่ยนแปลงของระดับน้ำในระหว่างฤดูเพาะปลูก แต่ความเข้าใจเกี่ยวกับการปรับตัวของพันธุ์ข้าวไทยต่อการเปลี่ยนแปลงของระดับน้ำยังมีอยู่ค่อนข้างจำกัด การศึกษานี้มีวัตถุประสงค์เพื่อตรวจสอบการตอบสนองของพันธุ์ข้าวไร่ และข้าวนาสวนต่อสภาพน้ำขัง ทำการศึกษาพันธุ์ข้าว 4 พันธุ์ คือ ซิวแม่จัน แกน้อย (พันธุ์ข้าวไร่) ชัยนาท 1 และขาวดอกมะลิ 105 (พันธุ์ข้าวนาสวน) ปลูกเปรียบเทียบในสภาพดินขังน้ำ (ขังน้ำสูงจากผิวดิน 10 ซม) และสภาพดินระบายน้ำดี (รดน้ำทุกวัน แต่ไม่มีน้ำขังที่ผิวดิน) ทำ 3 ซ้ำ แยกเก็บข้อมูลแต่ละกระถางที่อายุ 2 4 และ 8 สัปดาห์ โดยเก็บข้อมูลความยาวราก ความสูงต้น น้ำหนักแห้งราก น้ำหนักแห้งต้น ปริมาตรรากรวม การพัฒนาโพรงอากาศ และปริมาณธาตุอาหารในต้นข้าว จากการทดลองพบว่าการเจริญของต้นและรากข้าวทุกพันธุ์ที่ปลูกในสภาพดินขังน้ำเจริญเติบโตดีกว่าในสภาพดินระบายน้ำดี ยกเว้นข้าวพันธุ์แกน้อยมีการเจริญเติบโตในทั้งสองสภาพน้ำที่ไม่แตกต่างกัน สำหรับการพัฒนาโพรงอากาศในรากข้าวของพันธุ์ซิวแม่จันเหมือนกับข้าวพันธุ์ขาวดอกมะลิ 105 ซึ่งมีการสร้างปริมาณโพรงอากาศที่ไม่แตกต่างกันตามสภาพน้ำ ในขณะที่การพัฒนาโพรงอากาศที่ระยะ 5 เซนติเมตรจากปลายรากของพันธุ์แกน้อยสร้างโพรงอากาศมากกว่าพันธุ์อื่นๆที่ปลูกในสภาพเดียวกัน และพบว่าต้นข้าวที่ปลูกในสภาพดินขังน้ำมีปริมาณธาตุอาหารสะสมมากกว่าในดินระบายน้ำดี การสะสมปริมาณ

ไนโตรเจนของพันธุ์ข้าวไรที่ปลูกในสภาพน้ำไม่ขังมากกว่าพันธุ์ข้าวนาสวน โดยพันธุ์ข้าวไร่มีปริมาณไนโตรเจนสะสมเท่ากันทั้งที่ปลูกในสภาพน้ำขังและน้ำไม่ขัง ในขณะที่พันธุ์ข้าวนาสวนที่ปลูกในสภาพน้ำไม่ขังมีปริมาณไนโตรเจน น้อยกว่าถึง 50% ของต้นที่ปลูกในสภาพน้ำขัง ซึ่งปริมาณฟอสฟอรัส และโพแทสเซียมของพันธุ์ต่างๆมีการตอบสนองต่อสภาพน้ำเช่นเดียวกับปริมาณไนโตรเจน ข้าวพันธุ์แกน้อย และขาวดอกมะลิ 105 มีความสามารถจำเพาะของรากในการดูดธาตุอาหารที่เท่ากันไม่ว่าจะปลูกในสภาพน้ำขังหรือน้ำไม่ขังก็ตาม ในขณะที่พันธุ์ซิวแม่จันและชัยนาท 1 ที่ปลูกในสภาพน้ำไม่ขังมีความสามารถจำเพาะของรากในการดูดธาตุอาหารได้ดีกว่าที่ปลูกในสภาพน้ำขัง

คำนำ

การจำแนกพื้นที่ปลูกข้าวโดยใช้สภาพน้ำเป็นตัวแบ่งสามารถแบ่งได้เป็น นาชลประทานและนาอาศัยน้ำฝน พื้นที่ปลูกข้าวในระบบนาอาศัยน้ำฝน เป็นพื้นที่ที่ขาดระบบชลประทานและมักจะขาดการขังน้ำอย่างต่อเนื่องในระหว่างฤดูกาลเพาะปลูก ปริมาณและระยะเวลาในการได้รับน้ำของนาอาศัยน้ำฝน ซึ่งสาเหตุเหล่านี้ทำให้เกิดความเสียหายต่อผลผลิตข้าวได้ (Widawsky and O' Toole, 1990; Zeigler and Puckridge, 1995) ปริมาณฝนและธาตุอาหารมีผลต่อผลผลิตข้าวโดยตรงต่อกระบวนการทางสรีรวิทยาที่เกี่ยวข้องกับระยะการเจริญเติบโตทางลำต้นและใบและการติดเมล็ด สภาพดินที่มีการขังน้ำและดินไม่มีน้ำขังสลับกัน จะลดความเป็นประโยชน์ของธาตุอาหารต่างๆ ที่ข้าวจะดูดใช้ และทำให้มีธาตุอาหารต่ำ ซึ่งเป็นปัจจัยจำกัดศักยภาพการสร้างผลผลิต (Bell et at., 2001) ข้าวนาน้ำฝนปลูกได้ทั้งในสภาพนาสวนและนาไร่ ข้าวนาสวนเป็นการปลูกข้าวโดยใช้เมล็ดโดยตรง หรือ การย้ายกล้าไปปลูกในแปลงที่มีการเตรียมดินและมีน้ำเพียงพอ ข้าวไร่มักจะใช้เมล็ดปลูกโดยตรง และไม่มีการเตรียมแปลง ดินมีการระบายน้ำแบบธรรมชาติ โดยไม่มีน้ำขังที่ผิวหน้าดินเลย ประเทศไทยมีความหลากหลายของพื้นที่ปลูกข้าว และมีพันธุ์ข้าวมากมาย การทราบถึงความสามารถของพันธุ์ข้าวต่างๆมีการปรับตัวต่อสภาพน้ำที่มีการเปลี่ยนแปลงอย่างไรนั้น จะทำให้สามารถจัดการธาตุอาหารและหลักการในการปรับปรุงพันธุ์ข้าวให้มีความสามารถในการให้ผลผลิตที่สูงขึ้น ในนาน้ำฝนที่ควบคุมระดับน้ำไม่ได้

วัตถุประสงค์ของการวิจัย

การทดลองนี้มีวัตถุประสงค์เพื่อตรวจสอบการตอบสนองของการเจริญของต้นและรากข้าว รวมทั้งการสะสมปริมาณธาตุอาหารของพันธุ์ข้าวไร่ และข้าวนาสวนในสภาพดินขังน้ำและดินระบายน้ำดีในระยะ 8 สัปดาห์แรก

อุปกรณ์และวิธีการ

วางแผนการทดลองแบบ Factorial ศึกษา 2 ปัจจัย คือ พันธุ์และสภาพน้ำ โดยศึกษาพันธุ์ข้าว 4 พันธ์ แบ่งเป็นข้าวไร่ 2 พันธุ์ คือ ซิวแม่จัน และแกน้อย ข้าวนาสวน 2 พันธุ์ คือ ชัยนาท 1 และขาวดอกมะลิ 105 ปลูกทดสอบในสองสภาพน้ำ คือ ดินขัง (ขังน้ำสูงจากผิวหน้าดิน 10 เซนติเมตร) และดินที่มีการระบายน้ำดี (รดน้ำทุกวัน แต่ไม่มีน้ำขังที่ผิวดิน) ทำ 3 ซ้ำ ปลูกข้าวในกระถางดินเผาขนาดเส้นผ่านศูนย์กลาง 30 เซนติเมตร ลึก 30 เซนติเมตร ซึ่งบรรจุดินชุดสันทราย 5 กิโลกรัมต่อกระถาง ย้ายปลูกกล้าข้าวอายุ 7 วัน จำนวน 3 ต้นต่อกระถาง ปลูกพันธุ์ละ 24 กระถาง หลังย้ายปลูก 1 สัปดาห์ จึงเริ่มสภาพดินขังน้ำ และดินระบายน้ำดี ใส่ปุ๋ยไนโตรเจน 0.37 กรัมต่อกระถาง ฟอสฟอรัสและโพแทสเซียม 0.26 กรัมต่อกระถาง โดยแบ่งใส่ 2 ครั้ง คือ หลังย้ายปลูก 2 สัปดาห์ และใส่อีกครั้งหลังจากใส่ปุ๋ยครั้งที่ 1แล้ว 4 สัปดาห์ และทำการเก็บข้อมูลแยกแต่ละกระถางที่ระยะ 2 4 และ 8 สัปดาห์ โดยเก็บข้อมูลความยาวราก ความสูงต้น ปริมาตรรากรวม น้ำหนักแห้งราก น้ำหนักแห้งต้น ประเมินการพัฒนาโพรงอากาศ และการสะสมธาตุไนโตรเจน ฟอสฟอรัส และโพแทสเซียม

ผลการทดลอง

พันธุ์ข้าว 4 พันธุ์มีการตอบสนองต่อสภาพน้ำไม่ต่างกันในระยะ 2 สัปดาห์แรก พันธุ์ข้าวที่ปลูกในสภาพน้ำขังและระบายน้ำเริ่มแสดงความแตกต่างในน้ำหนักแห้งรากตั้งแต่สัปดาห์ที่ 4 (ตารางที่ 1) โดยพบว่าเมื่อปลูกในสภาพน้ำขัง ข้าวไร่ซิวแม่จันและแกน้อยมีน้ำหนักแห้งรากต่ำกว่าข้าวนาสวนชัยนาท 1 และขาวดอกมะลิ 105 แต่ในสภาพน้ำไม่ขังข้าวพันธุ์ซิวแม่จัน และข้าวนาสวนทั้ง 2 พันธุ์ มีน้ำหนักแห้งรากต่ำกว่าครึ่งหนึ่งของในสภาพน้ำขัง ที่แปลกไปคือพันธุ์แกน้อยที่มีน้ำหนักแห้งรากไม่ต่างกันตามสภาพน้ำ อิทธิพลของสภาพน้ำต่อพันธุ์ข้าวมีความแตกต่างชัดเจนขึ้นที่สัปดาห์ที่ 8 ในสภาพน้ำไม่ขัง (ตารางที่ 2) พันธุ์ที่มีน้ำหนักแห้งรากสูงสุดคือพันธุ์แกน้อย ปานกลางคือ ซิวแม่จันและขาวดอกมะลิ 105 ที่ต่ำสุดคือชัยนาท 1 เมื่อขังน้ำพันธุ์แกน้อยก็ยังมีน้ำหนักแห้งรากไม่ต่างไปจากไม่ขังน้ำ ในขณะที่น้ำหนักแห้งรากในสภาพน้ำขังในซิวแม่จันและข้าวนาสวน 2 พันธุ์ สูงกว่าในสภาพน้ำไม่ขังถึง 2-4 เท่า

นอกจากนี้ยังพบว่าสภาพน้ำมีอิทธิพลต่อพันธุ์ข้าวต่างกันในความยาวต้นและน้ำหนักแห้งต้น (ตารางที่ 3) และปริมาณธาตุอาหารในต้น (ตารางที่ 4) ที่ 8 สัปดาห์ในสภาพน้ำไม่ขังพันธุ์แกน้อยมีความยาวต้นสูงกว่าข้าวนาสวน 2 พันธุ์กับซิวแม่จัน และเมื่อขังน้ำแกน้อยก็ยังมีความยาวต้นไม่ต่างไปจากไม่ขังน้ำ ในขณะที่ข้าวอีก 3 พันธุ์ในสภาพน้ำขังมีความยาวต้นสูงกว่าในน้ำไม่ขังอย่างมีนัยยะสำคัญ นอกจากนี้ยังได้พบว่าพันธุ์แกน้อยกับชัยนาท 1 ยังรักษาความแตกต่างในการตอบสนองต่อสภาพน้ำในแง่ของน้ำหนักแห้งต้นด้วย กล่าวคือในสภาพน้ำไม่ขังแกน้อยมีน้ำหนักแห้งต้นสูงกว่าชัยนาท 1 และเมื่อชัยนาท 1 มีน้ำแห้งต้นสูงขึ้นอีก 1 เท่าตัวเมื่อขังน้ำ ในขณะที่น้ำหนักแห้งต้นในแกน้อยไม่แสดงการตอบสนองต่อการขังน้ำ เป็นที่น่าสังเกตุว่าสภาพ

น้ำมีผลต่อน้ำหนักแห้งต้นของข้าวไร่อีกพันธุ์หนึ่งคือซิวแม่จันคล้ายกับแกน้อย สำหรับขาวดอกมะลิ 105 มีน้ำหนักแห้งต้นในสภาพน้ำไม่ขังเท่ากับแกน้อย แต่ขาวดอกมะลิ 105 แตกต่างไปจากพันธุ์ข้าวไร่ตรงที่มีน้ำหนักแห้งต้นเพิ่มขึ้นถึงร้อยละ 60 เมื่อขังน้ำ และเมื่อพิจารณาน้ำหนักแห้งรวมทั้งต้นยิ่งทำให้เห็นถึงความแตกต่างระหว่างพันธุ์ที่ตอบสนองต่อสภาพน้ำได้ชัดเจนมากขึ้น โดยจะเห็นได้ว่าพันธุ์แกน้อย และซิวแม่จันมีน้ำหนักแห้งรวมทั้งต้นไม่แตกต่างกันทั้งที่ปลูกในสภาพดินขังน้ำและไม่ขังน้ำ ในขณะที่พันธุ์ข้าวนาสวน คือ ชัยนาท 1 และขาวดอกมะลิ 105 ที่ปลูกในสภาพขังน้ำมีน้ำหนักแห้งรวมทั้งต้นมากกว่าในสภาพไม่ขังน้ำถึงหนึ่งเท่าตัว และเมื่อเปรียบเทียบความสัมพันธ์ต่อสภาพน้ำของน้ำหนักแห้งรวมทั้งต้น จะเห็นได้ว่าพันธุ์แกน้อยที่ปลูกในสภาพน้ำไม่ขังมีความสามารถในการสร้างน้ำหนักแห้งรวมของทั้งต้นได้เท่าหรือดีกว่าในสภาพน้ำขัง ในขณะที่พันธุ์ซิวแม่จันที่ปลูกในสภาพน้ำไม่ขังก็มีความสามารถสร้างน้ำหนักแห้งรวมทั้งต้นได้ถึง 80% ซึ่งใกล้เคียงกับพันธุ์ขาวดอกมะลิ 105 ซึ่งเป็นพันธุ์ข้าวนาสวนที่สร้างน้ำหนักแห้งรวมทั้งต้นได้ 70% ในทางตรงกันข้ามข้าวพันธุ์ชัยนาท 1 ซึ่งเป็นพันธุ์ข้าวนาสวนเช่นเดียวกับพันธุ์ขาวดอกมะลิที่ปลูกในสภาพน้ำไม่ขังมีความสามารถในการสะสมน้ำหนักแห้งรวมทั้งต้นได้เพียงครึ่งหนึ่งของสภาพน้ำขัง (ตารางที่ 6) สำหรับความสามารถในการดูดธาตุอาหารจำเพาะของราก ข้าวพันธุ์แกน้อย และขาวดอกมะลิ 105 มีความสามารถจำเพาะของรากในการดูดธาตุอาหารที่เท่ากันไม่ว่าจะปลูกในสภาพน้ำขังหรือน้ำไม่ขังก็ตาม ในขณะที่พันธุ์ซิวแม่จันและชัยนาท 1 ที่ปลูกในสภาพน้ำไม่ขังมีความสามารถจำเพาะของรากในการดูดธาตุอาหารได้ดีกว่าที่ปลูกในสภาพน้ำขัง (ตารางที่ 5)อีกลักษณะหนึ่งที่สามารถใช้พิจารณาความสามารถของพันธุ์ที่ตอบสนองต่อสภาพน้ำได้ชัดเจน คือ สัดส่วนของรากต่อต้น โดยทุกพันธุ์มีสัดส่วนของรากต่อต้นในสภาพน้ำขังอยู่ระหว่าง 30-40% ยกเว้นพันธุ์ขาวดอกมะลิ 105 ที่มีสัดส่วนรากต่อต้นที่ 20% ทั้งในสภาพน้ำขังและน้ำไม่ขัง เช่นเดียวกับพันธุ์แกน้อยที่มีสัดส่วนรากต่อต้นไม่แตกต่างกันในทั้งสองสภาพน้ำ แต่พันธุ์แกน้อยมีความสามารถในการสร้างรากได้มากกว่าพันธุ์ขาวดอกมะลิ 105 ในขณะที่พันธุ์ซิวแม่จันและชัยนาท 1 ที่ปลูกในสภาพน้ำไม่ขังมีสัดส่วนรากต่อต้นเพียงครึ่งหนึ่งของในสภาพน้ำขัง

การทดลองนี้ยังพบว่า ข้าวทุกพันธุ์สามารถสร้างโพรงอากาศได้ทั้งที่ปลูกในสภาพดินขังน้ำและดินไม่ขังน้ำ ข้าวพันธุ์ซิวแม่จันมีการสร้างโพรงอากาศในปริมาณเท่ากับพันธุ์ขาวดอกมะลิ 105 โดยสามารถสร้างปริมาณโพรงอากาศได้เท่ากันทั้งสองสภาพ เช่นเดียวกับข้าวพันธุ์ชัยนาท 1 ที่ระยะ 8 สัปดาห์ที่มีการสร้างโพรงอากาศในปริมาณที่ไม่แตกต่างกันในทั้งสองสภาพน้ำ นอกจากนี้ที่ระยะ 5 เซนติเมตรจากปลายรากข้าวพันธุ์แกน้อยที่ปลูกในไม่ขังสภาพน้ำสร้างโพรงอากาศได้มากกว่าพันธุ์อื่นๆ และยังสร้างมากขึ้นเมื่อปลูกที่สภาพขังน้ำ (รูปที่ 1) โดยทั่วไปต้นข้าวที่อยู่ในสภาพขังน้ำสะสมธาตุอาหารไนโตรเจน ฟอสฟอรัส และโปแตสเซียมได้มากกว่าในสภาพน้ำไม่ขัง (ตารางที่ 4) แต่นอกจากนี้ยังได้พบว่าสภาพน้ำมีผลต่อการสะสมธาตุไนโตรเจน และฟอสฟอรัสต่างกันในพันธุ์ข้าวไร่และข้าวนาสวน กล่าวคือสภาพน้ำมีผลเพียงเล็กน้อยต่อการสะสมธาตุอาหารในข้าวไร่พันธุ์ซิวแม่จันและแกน้อย ในขณะที่ในสภาพน้ำไม่ขัง ข้าวนาสวนชัยนาท 1 สะสมฟอสฟอรัสในได้เพียงหนึ่งในสาม และขาวดอกมะลิ 105 สะสมได้เพียงครึ่งหนึ่งของเมื่อขังน้ำ

วิจารณ์และสรุปผลการทดลอง

การศึกษานี้ได้แสดงให้เห็นอย่างชัดเจนว่า ในข้าว 4 พันธุ์ที่ทำการศึกษา ไม่มีพันธุ์ใดมีการปรับตัวในสภาพน้ำไม่ขังดีกว่าสภาพน้ำขัง มีแต่บางพันธุ์เจริญเติบโตได้ดีพอกันในสภาพขังน้ำและไม่ขังน้ำ ในขณะที่บางพันธุ์เจริญเติบโตได้ดีกว่าในสภาพน้ำขัง และความแตกต่างระหว่างพันธุ์ข้าวในการตอบสนองต่อสภาพน้ำมิได้จำเพาะอยู่ระหว่างข้าวไร่และข้าวนาสวนเท่านั้น เมื่อพิจารณาจากการเจริญเติบโตของต้นและรากและการสะสมธาตุอาหาร ข้าวไร่พันธุ์แกน้อยนับว่ามีการปรับตัวเข้ากับสภาพน้ำไม่ขังได้ดีที่สุด และข้าวนาสวนพันธุ์ชัยนาท 1 ปรับตัวเข้ากับสภาพน้ำไม่ขังได้ต่ำที่สุด สำหรับข้าวนาสวนขาวดอกมะลิ 105 กับข้าวไร่ซิวแม่จันน่าจะอยู่ตรงกลาง เพราะในสภาพน้ำไม่ขัง สองพันธุ์นี้มีน้ำหนักแห้งรากและต้นสูงกว่าชัยนาท 1 และต่ำกว่าหรือเท่ากับแกน้อย

สภาพน้ำมีผลต่อภาวะธาตุอาหารในต้นข้าวสองทางคือ (1) ปริมาณธาตุอาหารที่เป็นประโยชน์ในสภาพน้ำขังจะสูงกว่าเมื่อน้ำไม่ขัง (Yoshida, 1981) (2) การทำงานดูดอาหารของรากที่อาจต่างกันในสภาพน้ำขังและไม่ขัง เมื่อพิจารณาจากปริมาณธาตุอาหารในต้น พบว่าในสภาพน้ำไม่ขังรากข้าวพันธุ์ไร่แกน้อยมิได้มีความสามารถดูดธาตุอาหารจำเพาะในการสะสมฟอสฟอรัสสูงไปกว่าพันธุ์อื่น (แกน้อย 0.56 mg ซิวแม่จัน 0.74 mg ชัยนาท 1 0.88 mg และ ขาวดอกมะลิ 105 0.80 mg ต่อกรัมน้ำหนักแห้งราก) (ตารางที่ 5) ความแตกต่างในการตอบสนองต่อสภาพน้ำของพันธุ์ข้าวที่วัดได้ จึงน่าจะมาจากความสามารถในการสร้างรากในสภาพไม่ขังน้ำ มากกว่าความสามารถจำเพาะในการดูดธาตุอาหารของรากของแต่ละพันธุ์ นอกจากนี้ความสามารถปรับตัวต่อสภาพน้ำไม่ขังของพันธุ์ข้าวอาจวัดได้จากสัดส่วนราก:ต้น (ROOT:SHOOT RATIO) (ตารางที่ 7) โดยเห็นได้ชัดเจนว่าข้าวไร่พันธุ์แกน้อยรักษาสัดส่วนราก:ต้น ไว้ที่ 0.30 ในสภาพน้ำไม่ขัง เทียบกับ 0.39 ในสภาพน้ำขัง เช่นกันในพันธุ์ขาวมะลิ 105 ที่มีสัดส่วนราก:ต้น ในสภาพน้ำขัง 0.23 ใกล้เคียงกับในสภาพน้ำไม่ขังคือ 0.21 แต่ข้าวนาสวนสำหรับเขตชลประทาน พันธุ์ชัยนาท 1 มีสัดส่วนราก:ต้น 0.36 ในสภาพน้ำขัง แต่ในสภาพน้ำไม่ขังมีเพียง 0.14 เป็นที่น่าสังเกตว่าข้าวพันธุ์ขาวดอกมะลิ 105 แม้จะเป็นข้าวนาสวน แต่ในสภาพน้ำไม่ขัง สามารถสร้างรากได้ดีพอๆกับพันธุ์ข้าวไร่ ความสามารถนี้อาจเป็นเหตุผลสำคัญอันหนึ่งที่ทำให้ข้าวพันธุ์ขาวดอกมะลิ 105 ซึ่งเป็นที่นิยมเพราะเป็นข้าวคุณภาพสูง สามารถปลูกในนาน้ำฝนเกือบทั่วประเทศ นับเป็นร้อยละ 23 ของพื้นที่ปลูกข้าวทั้งประเทศ และเมื่อรวมกับ กข 6 และ กข 15 ซึ่งปรับปรุงพันธุ์มาจากขาวดอกมะลิ 105 ด้วยการกลายพันธุ์โดยวิธีอาบรังสี ด้วยแล้วนับได้ถึงร้อยละ 54 ของพื้นที่ปลูกข้าวทั่วประเทศในปีการเพาะปลูก 2543/44 (OAE, 1998)

โดยสรุปการศึกษานี้ได้แสดงให้เห็นว่าพันธุ์ข้าวไทยมีการตอบสนองต่อสภาพน้ำต่างกัน โดยพันธุ์ที่พบว่าปรับตัวต่อสภาพน้ำไม่ขังได้ดีที่สุดคือข้าวไร่พันธุ์แกน้อย ตามด้วยพันธุ์ซิวแม่จัน ดีปานกลางคือข้าวพันธุ์ขาวดอกมะลิ 105 และได้น้อยที่สุดคือข้าวนาสวนพันธุ์ชัยนาท 1 ความสามารถในการสร้างรากและสัดส่วนราก:ต้น อาจเป็นตัวบ่งชี้ความสามารถปรับตัวของพันธุ์ข้าวต่อสภาพน้ำไม่ขังได้ดี

กิตติกรรมประกาศ

เนตรนภา อินสลุด ได้รับทุนปริญญาเอกกาญจนาภิเษก ขอขอบคุณ สกว. และมูลนิธิ Mc Knight ที่ให้ทุนสนับสนุนงานวิจัย เมล็ดพันธุ์ข้าวที่ใช้ในการวิจัยนี้ได้มาจากคุณปณิตา บุญสิทธ์ และคุณชนากานต์ พรมอุทัย ขอบคุณรองศาสตราจารย์ ดร.ศันศนีย์ จำจด ซึ่งให้คำแนะนำในการทำการทดลองและการเขียนบทความ คุณสิทธิชัย ลอดแก้วและศูนย์วิจัยเพื่อเพิ่มผลผลิตทางการเกษตร ซึ่งให้คำแนะนำและอนุญาติให้ใช้สถานที่ในการวิเคราะห์ธาตุอาหารพืช

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Table 1 Root dry weight of four rice cultivars when grown in waterlogging (W+) and well-drainage (W0) soil conditions at 4 weeks.

Cultivar	Root dry weight (g)	
	W+	W0
Sew Mae Jun	**0.36 Ba**	**0.16 Bb**
Kae Noi	**0.28 Ba**	**0.30 Aa**
Chainat 1	**0.49 Aa**	**0.25 Ab**
KDML 105	**0.50 Aa**	**0.20 Ab**
Mean	***0.41***	***0.23***
	F-test	$LSD_{0.05}$
	G^{ns}	-
	W^{*}	*0.07*
	$G x W^{*}$	*0.13*

ns = non significant (p<0.05), * significant at p < 0.05. The difference between water treatments in the same row is indicated by lower case letters. The difference between cultivars in the same column is indicated by upper case letters.

Table 2 Root dry weight, shoot dry weight and total dry weight of four rice cultivars when grown in waterlogging (W+) and well-drainage (W0) soil conditions at 8 weeks.

Cultivars	RDW (g/plant)		SDW (g/plant)		Total dry weight (g/plant)	
	W+	W0	W+	W0	W+	W0
Sew Mae Jun	**3.86 Ba**	**2.07 Bb**	**13.0Aa**	**11.7Aa**	**16.68 Ba**	**13.77 Aa**
Kae Noi	**3.46 Ba**	**3.32 Aa**	**8.9 Ca**	**11.2 Aa**	**11.36 Ca**	**14.52 Aa**
Chainat 1	**5.53 Aa**	**1.26 Bb**	**15.6 Aa**	**8.9 Bb**	**21.13 Aa**	**10.16 Ab**
KDML 105	**3.92 Ba**	**2.16 Bb**	**17.5 Aa**	**11.1Ab**	**21.42 Aa**	**13.26 Ab**
Mean	***4.19***	***2.20***	***13.76***	***10.73***		
	F-test	$LSD_{0.05}$	*F-test*	$LSD_{0.05}$	*F-test*	$LSD_{0.05}$
	G^{ns}	-	G^{ns}	-	G^{ns}	-
	W^{*}	*0.47*	W^{*}	*2.17*	W^{*}	*3.54*
	GxW^{*}	*0.94*	$G x W^{*}$	*4.34*	GxW^{*}	*5.01*

ns = non significant (p<0.05), * significant at p < 0.05. The difference between water treatments in the same row is indicated by lower case letters. The difference between cultivars in the same column is indicated by upper case letters.

Table 3 **Shoot length of 4 rice cultivars when grown in waterlogging (W+) and well-drainage (W0) soil conditions at 8 weeks.**

Cultivar	Shoot length (cm)	
	W+	W0
Sew Mae Jun	80.6 Ba	68.4 Ab
Kae Noi	73.2 Ca	67.9 Aa
Chainat 1	60.3 Da	51.9 Bb
KDML 105	92.2 Aa	63.3 Ab
Mean	*76.58*	*62.90*
	F-test	$LSD_{0.05}$
	G^{ns}	-
	W^{*}	*2.98*
	$G \times W^{*}$	*5.96*

ns = non significant (p<0.05), * significant at p < 0.05. The difference between water treatments in the same row is indicated by lower case letters. The difference between cultivars in the same column is indicated by upper case letters.

Table 4 **Nitrogen, phosphorus, and potassium contents (mg/plant) of four rice cultivars when grown under waterlogged and well-drained soil conditions for 8 weeks.**

Cultivars	N contents (mg)		P contents (mg)		K contents (mg)	
	W+	W0	W+	W0	W+	W0
Sew Mae Jun	6.04 Aba	5.34 Aba	2.48 BCa	1.54 Aa	2.79	2.54
Kae Noi	5.16 Ba	6.56 Aa	2.28 Ca	1.82 Aa	2.21	2.38
Chainat 1	6.60 Aba	3.38 Bb	3.38 ABa	1.10 Ab	3.14	1.82
KDML 105	8.16 Aa	4.28 ABb	3.52 Aa	1.54 Ab	3.64	2.38
Mean	*6.49*	*4.89*	*2.92*	*1.50*	*2.95 a*	*2.28 b*
	F-test	$LSD_{0.05}$	*F-test*	$LSD_{0.05}$	*F-test*	$LSD_{0.05}$
	G^{ns}	-	G^{ns}	-	G^{ns}	-
	$W*$	*1.14*	W^{*}	*0.48*	W^{*}	*0.53*
	$G \times W^{*}$	*2.29*	$G \times W^{*}$	*0.96*	$G \times W^{ns}$	-

ns = non significant (p<0.05), * significant at p < 0.05. The difference between water treatments in the same row isindicated by lower case letters. The difference between cultivars in the same column is indicated by upper case letters.

Table 5 Nutrient uptake (mg /g root DW) in 4 rice cultivars under waterlogged and well drained soil conditions for 8 weeks.

Cultivars	N uptake (mg/g RDW)		P uptake (mg/g RDW)		K uptake (mg/g RDW)	
	W+	W0	W+	W0	W+	W0
Sew Mae Jun	1.57 Ab	2.57 ABa	0.64	0.74	0.73 Ab	1.22 Aa
Kae Noi	1.49 Aa	2.02 Ba	0.66	0.56	0.65 Aa	0.73 Ba
Chainat 1	1.19 Ab	2.70 Aa	0.61	0.88	0.57 Ab	1.46 Aa
KDML 105	2.05 Aa	2.11 ABa	0.89	0.80	0.92 Aa	1.19 Aa
Mean	*1.58*	*2.35*	*0.70*	*0.75*	*0.72*	*1.15*
	F-test	$LSD_{0.05}$	*F-test*	$LSD_{0.05}$	*F-test*	$LSD_{0.05}$
	G^{ns}	-	G^{ns}	-	G^{ns}	-
	W^{*}	*0.34*	W^{ns}	-	W^{*}	*0.20*
	$G \times W^{*}$	*0.68*	$G \times W^{ns}$	-	$G \times W^{*}$	*0.40*

ns = non significant (p<0.05), * significant at p < 0.05. The difference between water treatments in the same row is indicated by lower case letters. The difference between cultivars in the same column is indicated by upper case letters.

Table 6 Root-shoot ratio and Relative response to water of four rice cultivars when grown in waterlogging (W+) and well-drainage (W0) soil conditions at 8 weeks.

Cultivar	Root-Shoot Ratio		Relative response to water	
	W+	W0	W0/W+	
Sew Mae Jun	0.30 ABa	0.18 Bb	0.82 B	
Kae Noi	0.39 Aa	0.30 Aa	1.17 A	
Chainat 1	0.36 Aa	0.14 Bb	0.48 C	
KDML 105	0.23 Ba	0.21 ABa	0.69 BC	
Mean	*0.32*	*0.21*	*0.79*	
	F-test	$LSD_{0.05}$	*F-test*	$LSD_{0.05}$
	G^{*}	*0.072*	G^{*}	*0.29*
	W^{*}	*0.051*		
	$G x W^{*}$	*0.10*		

ns = non significant (p<0.05), * significant at p < 0.05. The difference between water treatments in the same row is indicated by lower case letters. The difference between cultivars in the same column is indicated by upper case letters.

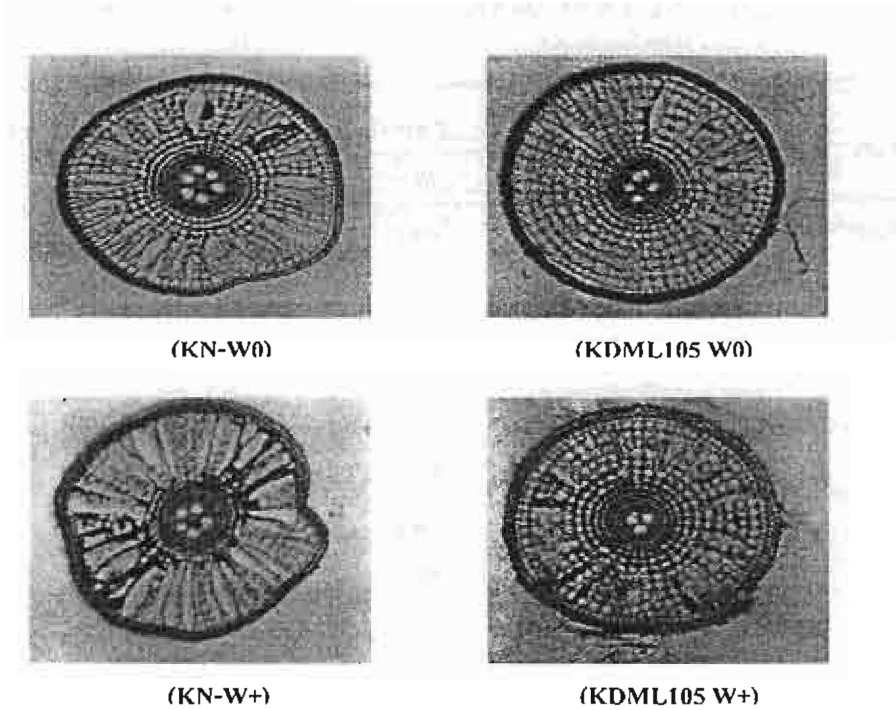

Figure 1 Aerenchyma appearance of Kae Noi (KN) and KDML 105 in waterlogged (W+) and well-drained soil condition at 5 cm from the terminl root.

เปรียบเทียบการตอบสนองต่อการขาดธาตุโบรอนในข้าวบาร์เลย์และข้าวสาลี
Comparative Response to Boron deficiency in Barley and Wheat

Keywords: Barley, Boron deficiency, Boron efficiency, Wheat

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Abstract

To determine if boron (B) deficiency, commonly reported to depress grain set in wheat, has the same effect in barley, two experiments compared three wheat and three barley genotypes at various B levels in sand culture. Plants were grown with varied levels of added B, from 0 to 10 μM. Without added B, the genotypes ranged in Grain Set Index (GSI) from 0 to 93 % for wheat and 0 to 67 % for barley. Boron concentration of the ear and flag leaf at boot stage in wheat and barley correlated ($r = 0.8 - 0.9$, $p < 0.01$) with the effect of B on GSI. Grain set was the only response to low B, also measurable in decreased number of grains ear^{-1} and grains spikelet^{-1}, in wheat. In barley, B deficiency also depressed the number of spikelets ear^{-1} by 23 to 75 % and induced a "rat-tail" symptom of terminal spikelet degeneration. There was a weak correlation between ear and flag leaf B and the effect of B on ear size in barley ($r = 0.47$ and 0.37, respectively, $p < 0.1$). In some barley genotypes, the low B level that depressed grain set sometimes also delayed ear emergence and depressed the number of ears plant^{-1} but sometimes increased tillering. These results demonstrate that the phenotypic response to low B is more complex in barley than wheat. Different strategies may be required for managing B nutrition and different approaches for selecting B efficient genotypes in the two species.

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บทคัดย่อ

รายงานการขาดโบรอนของข้าวบาร์เลย์มีความขัดแย้งกันอยู่ บางรายงานพบว่าเมื่อขาดโบรอนข้าวบาร์เลย์มีน้ำหนักแห้งฟางลดลง ในขณะที่บางรายงานพบว่าน้ำหนักแห้งฟางเพิ่มขึ้น เพื่อยืนยันให้เห็นผลกระทบจากการขาดโบรอนทั้งการเจริญเติบโตทางลำต้นใบและการแพร่ขยายพันธุ์ที่แตกต่างกัน จึงเปรียบเทียบการตอบสนองต่อระดับโบรอนในข้าวสาลีและข้าวบาร์เลย์ โดยทำการทดลองในกระถางทราย ในฤดูปลูก 2541/2542 ที่ภาควิชาพืชไร่ คณะเกษตรศาสตร์ มหาวิทยาลัยเชียงใหม่ ผลจากการขาดโบรอนทำให้ข้าวบาร์เลย์และข้าวสาลีติดเมล็ดลดลง ข้าวบาร์เลย์ยังได้รับผลกระทบจากการขาดโบรอนในการเจริญเติบโตทางลำต้นและใบด้วย โดยข้าวบาร์เลย์จะมีขนาดรวงลดลง การออกรวงช้า มีจำนวนหน่อและน้ำหนักแห้งสูง ต่างจากข้าวสาลีที่ไม่พบอิทธิพลจากการขาดโบรอนในลักษณะดังกล่าว ดังนั้นอาการขาดโบรอนของข้าวบาร์เลย์อาจมีกลไกของการขาดที่มีความซับซ้อนมากกว่าข้าวสาลี ความแตกต่างระหว่างข้าวบาร์เลย์และข้าวสาลีรวมทั้งความแตกต่างในระหว่างพันธุ์ต่อการตอบสนองต่อการขาดโบรอน ทำให้การจัดการเกี่ยวกับธาตุโบรอนเป็นไปได้อย่างเหมาะสม รวมทั้งใช้เป็นแนวทางในงานปรับปรุงพันธุ์ เพื่อคัดเลือกหาพันธุ์ที่ทนทานต่อการขาดโบรอนต่อไป

คำนำ

โบรอนเป็นจุลธาตุที่มีความจำเป็นสำหรับการเจริญเติบโตและการพัฒนาของพืช Shorrock (1997) รายงานว่า มีพื้นที่ที่มีปัญหาดินขาดโบรอนแพร่กระจายอยู่ทั่วโลก และพื้นที่ในประเทศไทยก็มีรายงานการขาดโบรอนด้วยเช่นกัน (เบญจวรรณ และคณะ, 1989; เพิ่มพูน, 2540) เนื่องจากโบรอนเป็นโมเลกุลที่ไม่มีขั้ว ดังนั้นจึงเกิดการชะล้างได้โดยง่ายโดยเฉพาะในบริเวณพื้นที่ที่มีโครงสร้างของเนื้อดินหยาบ (Wilson *et al.*, 1951) และมีฝนตกชุก (Gupta, 1979) การปลูกพืชในพื้นที่ซ้ำๆ กันเป็นเวลานานก็เป็นสาเหตุหนึ่งที่ทำให้ดินขาดโบรอนได้ (Rerkasem & Rerkasem, 1991) ดังนั้นปัญหาดินขาดโบรอนจึงเป็นสาเหตุสำคัญประการหนึ่งที่ทำให้ผลผลิตของพืชลดลง ความต้องการโบรอนเพื่อการเจริญเติบโตและการพัฒนาของพืชแต่ละชนิดแตกต่างกัน ทำให้ปริมาณโบรอนในพืชแต่ละชนิดมีความแตกต่างกัน (Bergmann, 1992) ในพืชใบเลี้ยงคู่จะต้องการโบรอนในปริมาณที่สูงกว่าพืชใบเลี้ยงเดี่ยว อย่างไรก็ตามถึงแม้ว่าในธัญพืชซึ่งเป็นพืชใบเลี้ยงเดี่ยวจะมีความต้องการโบรอนต่ำ แต่ก็มีรายงานการขาดโบรอนด้วย (เบญจวรรณ และศันสนีย์, 2532; Simojoki, 1972; Li *et al.*, 1978 da Silva and de Andrade, 1983; Sthapit, 1988; Amak and Tadano, 1991) เช่นใน ข้าวสาลี (*Triticum aestivum* L.) และข้าวบาร์เลย์ (*Hordeum vulgare* L.) แต่ในรายงานการขาดโบรอนที่ผ่านมา พบว่าในข้าวบาร์เลย์ยังมีความขัดแย้งกันอยู่ โดย Ambak and Tadano (1991) พบว่า การขาดโบรอนทำให้การเจริญเติบโตทางลำต้นเพิ่มสูงขึ้นในขณะที่ Jamjod and