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CMU Plant Nutrition Lab
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1. CURRENT RESEARCH AREAS

Research activities at the lab covers two main closely connected research areas. In the first area are closely linked physiological and genetic studies attempting to explain mechanisms and controls relating to plant nutrition in two specific subject areas:

- Nutrient efficiency
- Roles of nutrition in grain yield and quality formation processes

In the second area, are those activities aiming to improve nutrient management in agricultural production. The target for this nutrient management research is the agroecosystem, in which the following aspects are explicitly recognized:

- variations within and between fields within one farm and among farms, as well as
- long-term effects and
- possible off-site impacts of nutrient management.

Four main subject areas are covered in the nutrient management research:

- Nutrient cycling and balance in agroecosystems
- Diagnosis/prognosis
- Fertilizer management
- Efficient/inefficient genotypes

2. RESEARCH PROGRAMMES

Research activities are conducted in three specific programmes.

2.1 BORON DEFICIENCY

Many agricultural soils in Asia are low in boron (B), an essential nutrient element. This low B status of the soil has proved to be a limiting factor in the production of many crops, including wheat, barley, mungbean (black and green gram), other pulses as well as tree crops such as mango, papaya, cashew, and temperate fruit trees such as apple. In Thailand, low B soils are widespread in the North and the Northeast. This programme focuses on B efficiency, i.e. ability of genotypes to grow and produce economically acceptable yield in soils in which other genotypes are adversely affected by B deficiency, as a means by which the problem of B deficiency in crop production may be corrected (Rerkasem and Jamjod 1997a). The programme has two sub-programmes

2.1.1 Grain set failure in Triticeae

Boron deficiency causes widespread sterility, i.e. grain set failure, in wheat throughout subtropical Asia, from Nepal through north-eastern India, Bangladesh (possibly Myanmar too), Northern Thailand to South-western China. However, an enormous range of genotypic variation in B efficiency has been established in the wheat germplasm (Rerkasem and Jamjod, 1997b), clearly indicating that B efficiency could offer a simple means by which the problem might be solved cost effectively.

2.1.1.1 Genotypic variations and screening

We have developed the Grain set index as a means by which boron efficiency in wheat (Rerkasem and Loneragan, 1994) and barley (Jamjod and Rerkasem, 1999) genotypes may be assessed. A system for screening has also been developed (Anantawiroon et al 1997). With these tools, we continue to evaluate germplasm (in the form of CIMMYT's various annual nurseries and yield trials) for B efficiency, in barley, durum and triticale, as well as bread wheat.

The CIMMYT wheat germplasm is largely B inefficient, i.e. they are adversely affected by B deficiency which causes grain set to fail in soils in which Fang 60, CMU's standard B efficient check, set grain normally (Table 1).

Table 1. Frequency distribution of B efficiency in the 29th International Bread Wheat Screening Nursery screened at two levels of B deficiency.

Grain Set Index[1]	% of entries	
	Sand culture with no added B	Low[2] B soil with 2 t/ha lime
0-20	19.5	67.3
21-50	28.2	16.5
51-70	26.3	6.9
71-85	13.3	5.3
>85	12.8	4.1
Number of entries	415	419

[1] % grain set in the first two florets of 10 central spikelets (Rerkasem and Loneragan 1994) [2] Hot water soluble boron at 0.1 mg/kg.

However, the germplasm has also been found to contain a number of genotypes, which appear to be highly B efficient, even when the B deficiency pressure was accentuated (low B soil with lime, in Table 1). Finding B efficiency in the CIMMYT germplasm is certainly more advantageous than finding the efficiency among landraces, because the former has already been improved regarding agronomic and other desirable characteristics such as disease resistance. The B efficient CIMMYT genotypes can be directly chosen, after appropriate local testing, for release in areas with potential B deficiency problem, or they can be used as sources for B efficient genes without the need to eliminate unwanted archaic genes. A Boron Efficiency Nursery is being prepared, which will include a range of B efficiency, and can be used as

- reference checks or
- source of B efficiency genes.

As these will include CIMMYT most advanced germplasm, seeds of these lines should be available to breeders from CIMMYT.

2.1.1.2 Mechanisms and genetics

Studies of B efficiency in the four Triticeae species will result in the identification of the range of B efficiency, and therefore susceptibility to sterility problem, for practical purposes. The comparative studies are also expected to provide insights into the genetics of B efficiency because of their chromosomal differences and similarities: bread wheat containing all three genomes, durum has two, and barley only one. Triticale, on the other hand, has the three genomes of bread wheat, but with an additional set of chromosomes from rye, which has been shown to be exceptionally efficient in Zn, Cu and Mn.

Possible mechanisms for B efficiency include (Rerkasem 1995)

- B uptake from soil
- distribution of B among the various plant parts, including a possibility of B recycle via the phloem
- ability of the plant to meet demand for a particular process/function
- actual functional requirement

On the basis of the first mechanism of better B uptake, we are in the process of verifying if there is a possibility that B efficiency genotypes may turn out to be susceptible to toxicity. On-going work on mechanistic explanation of B efficiency includes comparing reproductive and vegetative responses to B. We have so far found that while the effect of B deficiency in wheat is largely through its reproductive process, there are some indications that in barley vegetative growth may be almost as sensitive (Jamjod and Rerkasem, 1999). As anthers/pollen development appears to be the step in reproductive process that is most sensitive to B deficiency, a project is underway to examine how B efficient genotypes such as Fang 60 are better at supplying their anthers and pollen with B than less efficient genotypes. This work employs the use of isotope 10 of B (^{10}B) to trace the movement of B within the plant and into the anthers, and is being conducted in collaboration with Murdoch University in Western Australia.

Studies of genetic control of B efficiency have been initiated by crossing wheat genotypes with varying levels of efficiency. Partial dominance of efficiency genes has been indicated by the response of the F1's to low B in comparison to the parents. Further understanding of the genetics is now being realized through responses to low B of the segregating populations. Similar genetic studies on barley are now underway.

2.1.2 Boron efficiency in Vigna

In Thailand mungbeans (black gram and green gram) are usually grown on the poorest soils with very little fertiliser. B deficiency can cause severe yield losses in both species; through arrested development of the flower buds, flowers and pods, resulting in their untimely senescence. We have, however, discovered a wide range of boron efficiency in the two grain legumes (Rerkasem 1991). Preliminary screening have discovered both efficient and inefficient genotypes among advanced breeding lines from AVRDC that have been tested by the Department of Agriculture and Kasetsart University, as well as among land races (Table 2).

Table 2. Boron efficiency found in green gram (*Vigna radiata*) and black gram (*Vigna mungo*) germplasm in Thailand.

Boron efficiency	Cultivar/line
Boron efficient	
Green gram	Uthong 1, Chainat 36, Kampangsaen 1, Kampangsaen 2, MO1, VC 1163
Black gram	BC48, Phitsanulok Lone
Boron inefficient	
Green gram	DMR1389, DMR1269
Black gram	Uthong 2, Regur, Phitsanulok 2

Screening for B efficiency therefore seems to offer, just as in the case of Triticeae, a simple and cost effective means by which the problem of B deficiency in these two important grain legumes can be overcome. On-going work aims to increase physiological and genetic understanding that may prove useful in improving screening techniques and also where B efficiency is included as a major objective in breeding programmes. Growth of seedlings and plants, especially on low B soils, has been previously shown to be strongly dependent on B content of the seeds that gave rise to them (Rerkasem et al 1990). Currently under investigation are differences among genotypes in their ability to accumulate B in the seed and the effect of this seed B content on growth and B efficiency of the plant that grows from it. The higher B concentration in the youngest fully expanded leaf that was found associated with B efficient genotypes of green gram and black gram (Rerkasem 1991) may be explained by one or both of the following mechanisms:

- ability to better acquire and accumulate B, and/or
- ability to better remobilize B (i.e. phloem transport of B), and so recycle the B that had accumulated in older tissues.

A study is underway to test this hypothesis. Findings on B phloem mobility in the mungbeans should also be useful in determining the efficacy of foliar B application as a means to overcome B deficiency in standing crops. Crossing between B efficient and inefficient genotypes commences in 1999. A comparative study of B efficiency in *V. radiata* and *V. mungo* is underway.

2.2 RICE QUALITY AND YIELD

This group of activities focuses on the role of nutrient in grain yield and quality formation in rice.

2.2.1 Fe in rice grain

An IFPRI survey in the Philippines has shown that cereals provide about half of people’s Fe intake (Senadhira et al 1998). In Thailand, this half of the Fe intake can be expected to come from rice. The current level of Fe intake is, however, inadequate for a very large proportion of the population in Thailand. A survey of the Northeast reported that 40% of pregnant women and 18% of school children were affected by iron deficiency anaemia (Nutrition Division 1991). Increasing Fe content of the rice grain may offer a means to increase daily Fe intake, and hence help to reduce incidences of iron deficiency anaemia.

We have started to evaluate Fe content in the grain of rice genotypes. All of the standard paddy cultivars recommended by the Thai Rice Research Institute such as Khao Dawk Mali 105, RD7, RD 6 have been found with about 10 mg Fe/kg in their grain. However, amongst the Thai rice germplasm some genotypes with very high grain Fe, with close to 30 mg Fe/kg, have been identified. Studies are now underway to evaluate the influence of genetic and environment (G, E, GxE) on grain Fe. Mechanistic explanation of how genotypes achieve different concentration and amount of Fe in the grain may include differential uptake ability, ability to distribute and remobilize Fe. These are being examined. Crossing of genotypes with low and high grain Fe commences in the wet season of 1999. Among the high grain Fe genotypes are IR68144, Xua Bue Nuo and Jalmagna identified and provided by IRRI (Dr Glenn Gregorio). Planned activities includes

- studies on the Fe chemistry of the grain, which is expected to provide basic understanding of bioavailability of the Fe,
- exploring quick screening methods and assays for grain Fe
- examination of the relationship between grain Fe and other quality characteristics
- genetic studies.

2.2.2 Grain quality

Thailand's rice export market is dominated by high quality rice, with the Fragrant Thai Jasmine as the main product. "High Quality Thai Rice" has been defined by the Ministry of Commerce and recognised among rice buyers, mills, traders, exporters and even consumers. At the production end, however, we know only a little how the various characteristics of quality are determined. For example, it is well established that the Fragrant Thai Jasmine can only be produced from specific cultivars (i.e. KDML 105, RD15, Fragrant Supanburi, Fragrant Klong Luang). Unfortunately, simply growing these standard cultivars does not always produce the best quality rice. From these same cultivars, better quality rice is produced only from some locations (e.g. Chiang Rai, Paed Rew, Surin) but not others (e.g. Lampoon, Ratchaburi). This study aims to assess the role nutrients, by themselves and in interaction with other factors (e.g. nutrient X water) in determining grain quality characteristics specific to the "High Quality Thai Rice".

2.2.3 Rice yield potential (MCC yield decline revisited)

The first documentation of the yield decline under intensive cropping systems in Asia was documented by the MCC, from its now world famous long-term experiment (Gypmantasiri et al 1980). The most obvious symptom of this problem was empty glumes in rice, which may account for up to half of the spikelets. The problem remains with us today, especially with new high yielding varieties (HYV's) such as RD7, RD10. An introduction of IRRI's newest advanced lines (provided by Dr Surapong Sakarung and Dr G.S.Khush), has further highlighted the problem. Some 25-50% empty glumes were found in some of these, which includes IRRI's New Plant Type (NPT). Preliminary examination has revealed that most of the empty glumes were not fertilised, indicating that the problem should be related to the process of grain set (male and female gametes, development; fertilisation, i.e. failure at the sink) rather than grain filling (photosynthesis, i.e. limited source capacity). Nutrient deficiency, especially many of the microelements (namely, B, Cu, Mn and Mo), is one of the most prominent factors causing grain set failure in cereals. Based on our experience with grain set failure in Triticeae, this work has been initiated to determine if nutrient has a role in causing empty glumes in HYV and NPT rices, and hopefully to finally solve the old MCC's yield decline problem.

2.3 NUTRIENT MANAGEMENT

Three groups of activities make up this programme, all of which focus on two main issues:

- Nutritional constraint to crop productivity/profitability
- Impact of nutrient management,
    - on long-term productivity of the soil
    - beyond the farm boundary, i.e. off-site impact.

2.3.1 Nutrient cycling and balance in agroecosystems

In collaboration with the agroecology group (see section on Agroecology Group – PLEC, Thailand sub-cluster) we are examining two agroecosystems in the highlands, namely,

- fruit trees and vegetables mixed cropping
- traditional rotational cropping system with upland rice.

This research will examine farmer's practices and innovations in relations to nutrient management, with specific emphasis on

- their effectiveness regarding crop productivity, i.e. if crop productivity is being limited by nutritional disorders,
- nutrient balance with potential implications on long term productivity and off-site impact.

2.3.2 Diagnosis/prognosis

The lab provides occasional services on diagnosis for crop nutrient status with leaf analysis services, for farmers, researchers and extension officers. At this stage critical values which form the basis for this methodology come from the book "*Plant Analysis, an Interpretation Manual"* (Reuter and Robinson 1997). In many cases, however, there are still needs for calibration to take into account variations due to local conditions and genotypes. The work on calibration of tissue analysis is now under way for temperate vegetables, coffee and lychee. We hope that establishing critical values for Thai crops that have not been covered in the book, e.g. longan, tamarind and guava, will be included in our future work-plan. Results from the boron research in both Triticeae and *Vigna spp.* have also established critical values for boron deficiency that have been widely used.

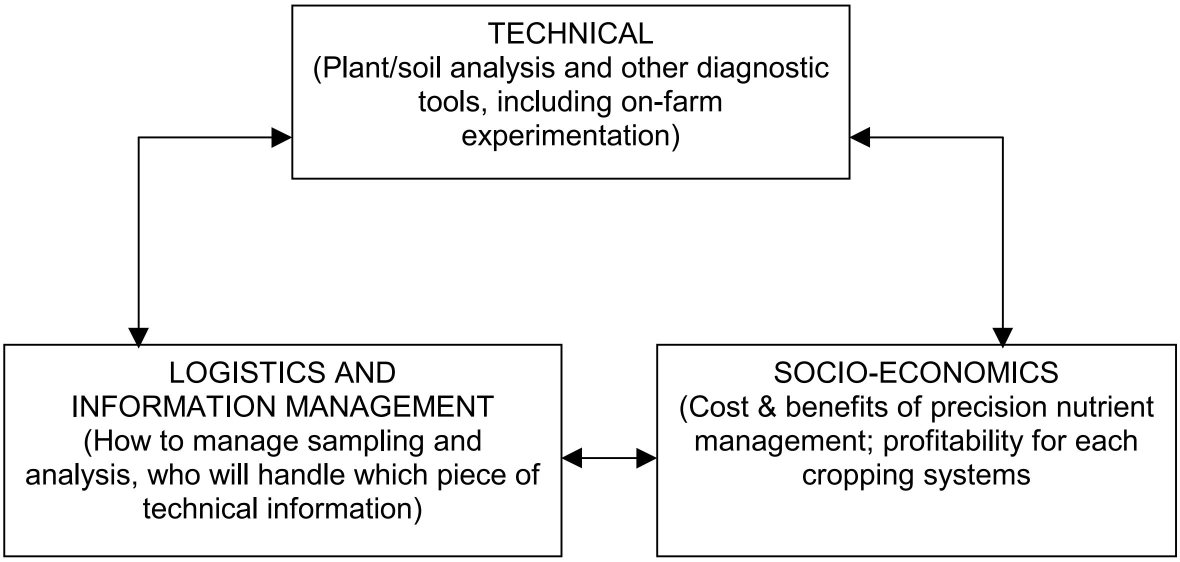
2.3.3 Precision fertilizer management

The above work on boron and Fe focused primarily on efficient genotypes as the means for nutrient management. The other aspect of nutrient management in crop production in Thailand deals with the management of fertilizer involving the big three, namely, nitrogen, phosphorus and potassium (N, P, K), and other nutrient elements that could become limiting as cropping systems are intensified. The use of fertilizer is a relatively new technology for Thai agriculture. In the early 1960's the average of fertilizer use in the country was only 1-2 kg/ha. By 1990's, however, fertilizer use has increased to 76 kg/ha, which are made up of 56% of nitrogenous, 26% of phosphatic and 19% of potassic fertilizers.

Decisions relating to fertilizer use is now one of the most challenging tasks in modern farm management. As cropping systems have become more intensive, fields have gone through highly diverse management and production histories (including removal of nutrients with the harvest), it has become increasingly difficult for "fertilizer recommendations" made by the Department of Agriculture to match crop's need and the soil's supply capacity in each field. Farmers, therefore, must decide on

- which of the nutrient elements need to be applied (at the maximum the list can go up to 16, but generally it would be whether any other elements apart from N are also limiting yield and profitability)
- for the macro-elements, how much (too little yield and/or quality will be limited, too much profit will be sacrificed, also any nutrient that is unused by the crop may leak into the environment).

This research activity on precision fertilizer management has been initiated to develop and adapt the technology for farms in Thailand. In order that such technology would fit on-farm conditions, the research will have three closely linked, mutually defining, elements:



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