Chapter 6

General Discussions

6.1 Genotypic variation in Mn efficiency in rice

Genetic differences in Mn acquisition, uptake and utilization efficiency in crop cultivars have been observed in many plant species such as bread wheat, durum wheat, oat, barley and lucerne (Bansal *et al*., 1991; Graham, 1988; Huang and Graham, 1997; Kaur *et al*., 1989; Marcar and Graham, 1987; Nyborg, 1970; Saberi *et al*., 1997; Gherardi and Rengel, 2004; Rengel; 1997) but no information is available in rice. Previous studies suggested that rainfed rice genotypes differed in Fe efficiency (Yanaphan *et al*., 2005). As Fe and Mn deficiency often occur together in upland rice on alkaline and calcareous soils, Mn efficiency of rice genotypes could mirror their Fe efficiency. Besides, Upland rice genotypes grown in calcareous soil may have adaptation ability to Mn deficiency themselves. Rainfed rice genotypes that found to be Fe efficiency and upland rice genotypes from calcareous soil in Northern Thailand have been found to be more Mn efficient (Chapter 2). When grown on the same condition of limited Mn supply, efficient genotypes (KDML105 and Sam Lern) produced more leaves, tillers and YEB-1 chlorophyll content than inefficient PSL1. Relative number of leaves of KDML105 was 15% higher than other genotypes, 20% in relative number of tillers, 40% in relative root dry weight. Besides, Mn treatments were effect on relative Mn uptake (mg Mn plant^{-1}) of KDML105 that was highest (152.58%), whereas Mn inefficient PSL1 was the lowest in all physiology traits. Especially, relative Mn uptake of PSL1 was 68% lower than KDML105. The response to Mn defficiency has been reported that some crops grown without added Mn depressed root dry weight e.g. in wheat (Pearson and Rengel, 1997), Mn uptake in wheat (Jiang and Ireland, 2001; Pearson and Rengel, 1997), in lucerne (Gherardi and Rengel, 2004). Mn deficiency factors, when operating for a long period, can result in inhibited growth and root physiological processes responsible for nutrient uptake with the consequence of an impaired capability for Mn tolerance.

Upland rice genotypes in this study exhibited variation of Mn efficiency, that occurred among individual plants of each seed accession and seed accessions sharing the same name. When compared under the same limited Mn supply number of leaves and tillers are reliable parameters to classify genotypic ranking which showed high correlation with YEB-1 chlorophyll content which also refects response to low Mn. The results showed a range of genotypic variation to Mn efficiency in rice germplasm. In Mn deficiency, the difference among genetically diverser local upland rice genotypes covered a wide range and % CV of YEB-1 chlorophyll content, number of leaves, number of tillers compared with that KDML105 and PSL1, which are pure line. According to Chang (1976), seed of local rice varieties maintained by farmer are high in gentic diversity.

YEB-1 chlorophyll content is able to be a criteria in Mn efficiency genotype, due to chlorophyll content that were affected primary by Mn deficiency that has been observed by Ohki (1985) and Kreidemann *et al*. (1985). The use of chlorophyll content as criteria index was the easy way to indicate and screen for Mn efficiency genotypes with Mn deficiency symptoms of inefficiency genotypes were caused by uptake and utilization in all physiological processes.

Moreover, some local upland rice varieties collected from calcareous soil like Sam Lern and BB tolerant to Al toxicity (Phattarakul, 2008) have been found to be similarly tolerant to Mn deficiency when compared to KDML105 based on relative YEB-1 chlorophyll content, correlated well with their relative shoot and root dry weight and relative Mn uptake efficiency. Therefore, Sam Lern, BB and KDML105 were the most Mn efficiency genotypes.

The mechanisms of Mn efficiency such as Mn acquisition, uptake and utilization efficiency will next be explored.

6.2 Physiological response to Mn deficiency in Mn-efficient and inefficient rice genotypes

Various plant species have developed morphological and/or physiological mechanisms to improve acquisition and use efficiency of mineral nutrients when grown on poor, infertile soils (Römheld, 1998). Nutrient concentration and uptake by different plant genotypes are the most important criteria for identifying the existing genetic specificity of plant nutrition (Saric, 1987). When under Mn stress, wheat genotypes tolerant to Mn deficiency had a greater ratio of Mn-reducers to Mn-oxidizers in the rhizosphere compared to sensitive genotypes. Mn-efficient durum wheat genotypes had greater Mn uptake from Mn deficient soil, produced higher grain yield, relative grain yield and above ground biomass and generally maintained higher seed Mn concentration (Khabaz-Saberi *et al.*, 1997).

Possible mechanisms by which one genotype may better tolerate to Mn deficient than another were proposed by Graham *et al*. (1985) as (a) superior internal Mn use, (b) modified internal redistribution of Mn, (c) faster specific rate of Mn absorption at low soil Mn, (d) improved root geometry, and (e) greater root excretion of substances into the rhizosphere that mobilize insoluble Mn. Additionally, more than one mechanism is often responsible for the level of tolerance to nutrient deficiency in a particular plant genotype (Rengel, 2001).

Therefore, Mn efficiency defined as the ability of rice genotypes to acquire Mn from the rhizosphere solution and/or high uptake and/or to incorporate or most utilization.

<u>*Acquisition efficiency*</u>

The results clearly showed that Mn acquisition efficiency of Mn efficient genotype (KDML105), was the release of root exudates from roots. Root exudates increased the mobility of the reduced Mn in the rhizosphere (Marschner, 1995). This modified improved Mn availability. KDML105 can reduce Mn unavailable (Mn(IV)) to Mn available (Mn(II)) form. Therefore, PSL1 grown together in the same pot with KDML105 can uptake more Mn than their sole growing, contributing to increased chemical availability of Mn from root exudates of KDML105 roots. Besides, KDML105 indeed released root exudate as occurred in low pH in rhizospere solution and reduced MnIV oxide on filter paper when grown in Mn deficiency condition according to chickpea roots that excrete organic acids into the rhizosphere (Ohwaki and Hirata, 1990) and demonstrated by MnIV reduction indicating white zones on the filter paper (Dinkelaker, 1993a, 1993b).

KDML105 succeeded in Mn acquisition efficiency based on relative of YEB-1 chlorophyll content, number of leaves, number of tillers, shoot dry weight, root dry weight, total dry weight and enhanced Mn uptake efficiency in PSL1 that was increased when grown together with KDML105 that this affectively on root exudates of KDML105.

Uptake efficiency

The capacity of the genotype to increase uptake as the supply of the nutrient to the root is increased. These may be quite different from each other in a particular genotype (Blair, 1993). The results showed that KDML105 was the highest Mn content in shoot, root, whole plant, Mn uptake efficiency and relative Mn uptake efficiency. Mn content was higher in plant demonstrated that Mn uptake efficiency in plant such as in wheat that known to be most Mn efficient also absorbed more Mn and had a higher tissue Mn concentration (Gladstones and Loneragan 1970; Graham *et al*. 1983; Marcar and Graham 1987b; Graham 1988; Huang *et al*. 1994; Bansal and Nayyar 1998; Marschner *et al*. 2003). Accordingly, previous research reported that Mn efficient genotypes take up more Mn from soils with Mn deficiency by Rengel (2000) and Rengel (2001). Besides, Mn uptake efficiency trait of KDML105 performed better than PSL1 under Mn deficiency, in leaf chlorophyll content, number of leaves and number of tillers.

Utilization efficiency

For a given genotype, nutrient use efficiency is reflected by the ability to produce a high yield in a soil that is limiting in one or more mineral nutrients for a standard genotype (Graham, 1984). Mn deficiency impaired essential growth functions and TNC production according to wheat (Pearson and Rengel, 1997). Therefore, Mn efficient genotypes should produce more yield and carbohydrate in Mn deficient condition (although limited Mn availability). The concentration of soluble TNC in root of PSL1 and KDML105 decreased when grown in Mn deficiency. Whereas in Mn deficiency, concentration of soluble TNC in shoot of PSL1 decreased but KDML105 was still similar when compared to Mn sufficiency. Relative shoot and root dry weight of KDML105 was higher also.

In most reports, Mn deficiency in plants have an adverse effect on yield. For example, Jiang and Ireland (2005) showed that under low Mn condition, yield of wheat cv. Maris Butler could produce higher yield than inefficient genotype. In Mn deficiency, KDML105 also produced higher yield than inefficient PSL1. Both, however, responded to increased Mn supply. The response of KDML105 and PSL1 are able to be classified into 2 groups modified from Gerloff (1977) that KDML105 is Mn efficient responders and PSL1 is Mn inefficient responders.

The production of carbohydrate and yield are able definition of Mn utilization efficiency from many observes and reports in plant (Pearson and Rengel, 1997; Jiang and Ireland, 2005; Graham *et al*., 1992; McDonald *et al*., 2001). Therefore, KDML105 showed higher Mn utilization efficiency than PSL1.

6.3 General conclusion

A wide range of physiological mechanisms responsible for variations in response to Mn deficiency between genotypes have been found in the present study. Such mechanisms can function either within or outside the plant to affect Mn availability, acquisition, uptake or utilization. Some mechanisms features controlling plant resistance to Mn deficiency are given in YEB-1 chlorophyll content, number of leaves, tillers, Mn uptake efficiency, carbohydrate concentration and grain yield. Thai rice genotypes tolerant to Mn deficiency were KDML105 and Sam Lern (upland rice genotypes from our evaluating). KDML105 displayed a significant better performance in Mn acquisition, Mn uptake and Mn utilization compared with others when subjected to a low Mn supply are referred to as ‘Mn efficient’. Therefore, finding out the rice genotypes that can yield well in conditions that is Mn deficient for other genotypes and understanding genotypic variation in responses to Mn deficiency will facilitate attempts to decrease yield loss from Mn deficiency in rice genotypes. While it appears that variety differences in tolerance to Mn deficiency are under genetic control it could potentially be exploited in plant breeding.

6.4 Further research

The variations in response to Mn deficiency between rice genotypes from this thesis particularly in rainfed and upland rice, a large number of rice germplasm should be done for the further evaluation of rice adapted to calcareous soil region. The Mn efficient genotypes from limestone area should be confirmed for genetic variation within genotype (Sam Lern) by DNA analysis and evaluated mechanism of Mn efficiency in this rice genotype. KDML105 should be confirmed as Mn acquisition efficiency by HPLC and examine the kinetics of $Mn2^{+}$ influx in intact with roots of rice genotypes differing in Mn uptake efficiency.