CHAPTER V

DISCUSSION

Iron (Fe) toxicity is a constraint that can adversely affect yield of lowland rice in the tropics and subtropics (Audebert, 2001). In Laos, Fe toxicity is suspected to be one reason of the soil infertility in wetland rice**.** A preliminary survey in the Vientiane Plain of Laos found many pieces of evidence supporting this (Panomwan Boonchuay, unpublished data). The survey found rusty color water (of Fe_2O_3) in 72.2% of the rice fields examined, and *Xyris indica* L., an indicator plant for Fe toxic soils, in 38.8% of the fields. Symptoms of Fe toxicity were observed in almost 90% of the rice crops examined, 51.8% with moderate symptom (leaf bronzing but regular panicles) and 37.5% with severe symptoms (leaf bronzing with arrested panicle emergence). Iron toxicity occurs in mineral soils are rich in iron. The appearance of toxicity symptom, of leaf bronzing and reduction in rice yield occur under specific conditions of soil submergence, when microbial reduction of insoluble Fe^{3+} produces soluble and potentially toxic Fe^{2+} (*Ponnamperuma*, 1972).

In this thesis, I conducted experiments aiming to understand and solve the problem of Fe toxicity in farmers' wetland rice in Lao PDR. In experiment 1, I evaluated the effect of excessive Fe on rice growth. In experiment 2, I investigated 9 rice varieties, mostly from Laos PDR, for their response to high iron concentration. Three of the Lao rice varieties identified in experiment 2, two varieties as tolerant and one variety as sensitive were assessed for their performance in an Fe toxic soil in

Vientiane in experiment 3. This last experiment also investigated the possible effect of zinc (Zn) fertilizer in alleviating Fe toxicity.

5.1. **Effects of Fe toxicity on TDK1, a Lao rice variety**

The growth of rice variety (TDK1) was effected by Fe toxicity at F2000 but rice could grow without stress symptom and growth well at Fe1000. This result is similar with the report of Olaleye et al., (2001). These authors found rice plants still grow well with 1000 mg Fe kg^{-1} application, but Fe toxicity was found with application of 3000 mg Fe kg^{-1} soil or higher. The severity of iron-toxicity in rice plant depending on soil factors especially, the content and type of clay minerals, amount of exchangeable soil Fe and soil pH. Das et al., 1997 reported the concentration of soil Fe^{2+} is less in clay than in sandy soils. As a result, high amounts of soluble Fe^{2+} (100–1000 mg L^{-1}) may be found in acid soils (Ponnamperuma, 1972). Fe concentrations can up to 5000 mg kg^{-1} in acid sulfate soils (Harmsen and Van Breemen, 1975). The critical of soluble Fe in lowland rice is 300 mg water-soluble Fe L^{-1} (Lantin and Neue, 1989). Potentially toxic Fe^{2+} has been previously reported in a much wider range, from 20 to 2500 mg kg^{-1}. Such factors that influence Fe toxicity in plants may include the accumulation of hydrogen sulfide, organic acids (Tadano and Yoshida, 1978) and the availability of other nutrient elements (Ottow et al., 1982).

In this experiment Fe toxicity was found to depressed root length, plant height, leaf number and total dry weight. The effect of Fe toxicity on root length, plant height and leaf number strongly correlated with the effect on total dry weight. This means that the effect of Fe toxicity on root length, plant height and leaf number can predict the effect on dry weight. The effects on plant height and leaf number are useful for field studies as they can be measured on the plant standing in the field as they are non-destructive. For studies in solution culture, root length can easily be measured and the plants returned to the nutrient solution to continue to grow.

The strong correlation between the effect of Fe on root growth and dry weight has two implications. Firstly, root growth is a good indicator to evaluate effect of Fe toxicity on biomass production. Secondly, the adverse effect of Fe toxicity on root growth may indirectly affect plant growth by suppressing the ability of the root system to explore the soil and the surface area with which to take up nutrients. The effect of nutrient status on root growth rate is a critical factor with a strong feed-back on nutrition, growth and allocation and the uptake mechanism is interpreted as a protection next to too high uptake rates and internal concentrations at high external concentration (Agren, 1988). Rice plants are susceptible to absorb more iron than most other plant species. Furthermore, the ferrous ion is quite rich in paddy soils. Because the reduced iron is easily absorbed, iron oxide (Fe^{3+}) uptake mechanisms are most likely less important in flooded environments (Mengel, 1972). After absorption in the root cortex, the reduced iron (Fe^{2+}) can make the xylem after its symplastic passage through the Casparian band. The greater portion, however, of the absorbed ferrous ions can reach the xylem directly through an apoplast. This route has been verified, mostly for sodium (Yeo *et al.*, 1987; Tsuchiya *et al.*, 1995). In addition to its adverse effect on root growth, Fe toxicity may also interfere with the function of the root in nutrient uptake (Sahrawat, 2000).

5.2. Screening Fe toxicity tolerance in different rice varieties

In this study, I found that the Lao rice varieties to be moderately tolerant o very tolerant to Fe toxicity. Sahrawat et al (1996) reported a wide range of tolerance to Fe toxicity among rice cultivars. Measured as growth in Fe150 relative to Fe20, Lao rice varieties that were in the same range as tolerance to Fe toxicity as IRRI (IR70617-B4-B-19-2-3-1-1, Fe toxicity tolerant check from International Rice Research Institude) were TDK6 and TDK10; TDK5 and TDK11, along with a Thai variety RD10, were even more tolerant than IRRI. There is a possibility that Lao rice varieties are tolerant to Fe toxicity because they have been selected on a site with Fe toxicity problem at the RCCRC. However, TDK1 and TDK7, also selected at the RCCRC, turned out to be sensitive to Fe toxicity. Similarly, a local variety MNG was also found to be sensitive to Fe toxicity. Clearly, not all of the Lao rice varieties selected at RCCRC can be expected to tolerant to Fe toxicity. Screening for tolerance to the Fe toxicity should be useful for new rice varieties before they are released into farmers' fields on soils prone to Fe toxicity. Genetic differences in adaptation to and tolerance for iron toxic soil conditions have indeed been exploited for developing rice cultivars with tolerance for iron toxicity (Gunawardena et al 1982, DeDatta et al 1994).

The previous study in experiment 2 suggested that the screening for Fe toxicity tolerance rice varieties in nutrient solution was effectively measured by RDW, RPH, LBI, RLN, RRL and RTN at Fe 150 ppm relative to Fe 20 ppm. The results suggested that low Fe level at Fe 20 ppm was beneficial responded on all of growth indicators which supported by previous study (Panomwan Boonchuay, unpublished data). On the other hand, relative value between at Fe 150 ppm to Fe 20 ppm was showed that RRL and RPH strongly correlated to RDW. Correlation coefficient was the highest between RPH and RRL (Table2). It mean RPH and RRL should be a good growth indicator to evaluate effect of Fe toxicity to rice growth because it strong correlate with biomass production (RDW) and it a lot easier to measure than measuring dry weight directly. It is, however, necessary to verify the tolerance to Fe in solution culture in the field.

5.3. Growth and yield of rice varieties with different sensitivity to Fe toxicity in the field with Fe toxicity problem in Vientiane, Laos.

In this study, Three Lao modern rice varieties (TDK5, TDK7 and TDK10) were used in this experiment. The results in nutrient solution (experiment 2) reported a sensitive rice variety was TDK7, moderately tolerant rice varieties was TDK10 and tolerant to Fe toxicity was TDK5 Sahrawat et al (1996) reported the cultivars have differed in tolerance of iron toxicity. When all of these rice varieties were planted at Fe toxic field in Laos, the results showed that TDK5 was the highest gain yield (272.35 g/m^2) and was significant different ($P < 0.05$) with TDK10 (254 g/m^2) and TDK7 (249 g/m^2) respectively. It means that TDK5 was a Fe toxicity tolerance rice variety in culture solution and toxic field condition. Audebert, 2002 said that the Fe toxicity tolerant rice variety may be preventing the entry of ferrous iron at the roots and may be distributing the iron among its own parts differently, or else is expressing some tolerance mechanism at the tissue level.

This experiment used Zn to solve Fe toxicity in the field. The application of Zn is an effective way of reducing iron toxicity (Olaleye and Ogunkunle 2008; Sahrawat et al. 1996; Sahrawat, 2004; Yamauchi, 1989, Yoshida, 1981; Ramirez et al, 2002). Montas Ramirez et al., 2002 reported if Zn deficiency in rice is often linked to Fe toxicity problem in rice cultivation. If dissolved ferrous iron is high in the root zone, iron plaques form at the root-soil interface and acts as an efficient adsorbent for zinc making it unavailable for the rice plant (Sajwan & Lindsay, 1986). The plaques might protect the plant from toxic levels of elements such as Cu and Ni but also reduce the uptake of nutrients such as Zn. (Greipsson and Crowder, 1991). On the other hand, in a study made by Zhang et al. (1998) it has been shown that in iron deficient rice plants an iron plaque can increase the zinc uptake. Zn content in the root is necessary to identify mechanism of Zn uptake and efficiency (Loneragan et al, 1987; Graham & Rangel, 1993; Marchner, 1998). However, at the root surface of most aquatic plants and rice, Zn is found precipitated with Fe oxyhydroxides or iron plaque (Bacha & Hossner, 1977; Ottow et al, 1989). Iron plaque could control Zn availability by either immobilizing Zn and decreasing its uptake, or enhancing Zn uptake through solubilizing Zn in the plaque via Fe oxidation and rhizosphere acidification (Bowen, 1986; Kirk & Bajita, 1995; Cambell & St Cyr, 1996). As a result, Zn application was an alternative that was used to solve Fe toxicity in rice field in Laos.

5.4. Conclusion

The rice varieties from Laos were found to be in 3 groups of tolerance to Fe toxicity. Those sensitive to Fe toxicity were TDK1, TDK7 and MNG. Those moderately tolerant were TDK6, IRRI and TDK10. Tolerant to Fe toxicity were TDK5 and TDK11, and also a Thai variety, RD10. When grown in the field with soil prone to Fe toxicity, TDK7 and TDK10 showed much higher degree of leaf bronzing than the Fe toxicity tolerant TDK5. Foliar application of Zn significantly lessened the leaf bronzing in TDK7. Finally, the growth of each rice varieties also responds to Zn application. Foliar spraying 0.5% $ZnSO_4.7H_2O$ did not effect to rice growth, but dipping roots seedling in 1% solution of $ZnSO_4.7H_2O$ (10 g L^{-1}) can increase the rice growth and yield of rice varieties that were planted at Fe toxic soil.