CHAPTER 5

GENERAL DISCUSSION

5.1 Growth, nutrient uptake and yield of rainfed lowland rice

The amount and timing of rainfall is considered the major constraint to rice growth and productivity followed by low soil fertility. In practice, low soil fertility, particularly availability of N and P is strongly influenced by changing soil-water regime, which alters nutrient forms and their availability in the soil (Bell *et al.,* 2001). Thus, yields of rainfed lowland rice are often low due to rainfall and applied fertilizers. Interaction between soil-water and nutrients can occur even without water stress *per se* (Seng *et al.,* 1999; Seng, 2000). The implication of extremely variable soil-water regimes during the growing season for rice yields and nutrient uptake are particularly important for the application of the present study more widely to rainfed lowland ecosystems.

Growth under rainfed lowland conditions roots of rice have to adapt to varied environments by changing root morphology and/or physiology. In fact, the rice growing regions of rainfed lowland in Southeast Asia are often insufficient water to flood the soil and keep about 15-20 cm of standing water in the field as required for rice growth in about first two months of the growing season. In Northeast Thailand and Cambodia, an early monsoon season from May to June is followed by a short dry period in June-July before the main rainy season (Fukai *et al.,* 1995). In central Vietnam, the summer season from June to August followed by rainy season from late

August to December. Transplanting is often delayed until there is sufficient rainfall at the start of the main rainy season for flooding of the soil to occur.

In Chapter 3, the rice plant was grown under aerobic soil until PI, followed by waterlogged soil to maturity to compare with the rice, which was grown under continuously waterlogged soil. The result of present work shows that grown under aerobic soil, plants depress P uptake and also plant dry weight compared with those of plants in waterlogged soil. Although the availability of P (native soil-P and applied P) to plants in waterlogged soil is not known, Seng *et al.* (2004) suggested that the increase growth and plant P uptake indicated enhanced soil P availability. Aerobic rice in this study, which was determined plant dry weight was lower than waterlogged rice; but the root:shoot ratio of aerobic rice was significantly greater than waterlogged rice at PI. These data agreed with Bell *et al.* (2001), who discussed that plants in aerobic condition usually develop their roots in length in order to facilitate for nutrient capture at deep layers of the soil. Particularly, some plants are able to increase the length and fineness of their roots when subjected to low P supply (Foeshe and Jungk, 1983). This therefore results in increasing root dry weight while shoot dry weight is still depressed.

Surprisingly, the results of this study showed that the growth of aerobic rice after submerged was better than continuously waterlogged rice (Chapter 3). Based on the data of plant dry weight, and also plant nutrient uptake particularly P uptake I had hypothesized that first the flooding of aerobic soil could release more P availability which includes native soil-P and applied P in the soil solution. Thus, plants in this condition increase strongly P uptake compared with plants in waterlogged soil throughout. Phosphorus availabilities in aerobic soil after submergence (W0+) and also in waterlogged soil throughout (W++) were not measured. These would be different to be confirmed by difference in plant P uptake (Experiment 2, Chapter 4). Another hypothesis is that when grown under continuously waterlogged condition rice plants are usually undergone by lack of O_2 supply to the roots. The adaptation of plants to waterlogged condition is formation of aerenchyma in adventitious roots (Drew, 1983; Visser *et al.,* 1996). The aerenchyma provides a low resistance internal pathway for movement of O_2 from the shoots to the roots. The roots of waterlogged rice contain a barrier to radial oxygen loss along their length (Armstrong and Armstrong, 1988). The barrier may be an inhibition of nutrient absorption by anaerobic roots (Colmer and Bloom, 1998). This physiological change of rice roots under waterlogged soil could impair plant nutrient uptake and therefore results in lower plant dry weight and plant nutrient content compared with plant in aerated condition (*supported in* Experiment 1, Chapter 4). The growth and nutrient uptake of rice in aerobic, and also in waterlogged conditions is really understood. However, it is still unclear how response of rice to P levels under changing between aerobic and waterlogged conditions. Thus, the study was conducted to examine about these (Experiment 1, Chapter 4).

The current result shows that at maturity the plant dry weight still increased with increasing N and P application up to N160 and P50. At maturity, W0+ plants had higher plant dry weight than that of W++ plants. Interestingly, the grain yield of W0+ rice in present work was significantly by 24% over that of W++ rice (Table 3.3). This data would result from plant dry weight and nutrient uptake in changing between aerobic and waterlogged rice differ with waterlogged rice throughout. I also found that the increasing added N and P increased grain yields in both W0+ and W++. This suggests that application of N rate up to N160, and also P rate with P50 are still deficient for plant growth which relates to grain yield. These were evidenced by low in plant N concentration as well as plant P concentration that were measured at each of the four growth stages. According to Reuter *et al.* (1997) adequate P concentration ranges in whole shoot of rice at mid-tillering, panicle initiation and flowering are 0.37-0.55, 0.36-0.48 and 0.27, respectively. In this study, the P concentration in whole shoot at mid-tillering, panicle initiation and flowering was highest treatments with 0.27, 0.23 and 0.20, respectively in high P supply. Further research is needed to examine how response of plants with higher levels of N and P application.

5.2 Adaptation of rice to aerated and anaerated conditions

Waterlogged soils are usually characterized by the absence of oxygen (Ponamperuma, 1984). Root growth into waterlogged soils therefore depends upon an internal supply of oxygen, which moves from the shoots through aerenchyma to the root apex (Armstrong, 1979; Drew, 1983; Visser *et al.,* 1996). The previous studies have reported that the roots of many wetland plants including rice contain aerenchyma (Jacson and Drew, 1984; McDonal *et al.,* 2002; Colmer *et al.,* 1998). The present work has been shown that the formation of aerenchyma in adventitious roots of stagnant plants was stronger than that of aerated plants. Aerenchyma formation in adventitious roots associated with root porosity, which was found greater in stagnant than in aerated condition. This result is similar to the findings of Colmer *et al.* (1998); McDonald *et al.* (2002). Moreover, after transfer from aerated to stagnant condition, the root porosity increased while transfer from stagnant to aerated the root porosity decreased. This finding suggests that roots differ in their constitutive porosity when grown in aerobic and waterlogged conditions. The formation of aerenchyma which associated with the formation of barrier to radial oxygen loss as discussed in early chapter really confirmed to hinder nutrient uptake by anaerobic roots. The result of this study clearly showed that plant P uptake of stagnant plants was lower than that of aerated plants. This is similar to the finding in wheat which grown in aerated and stagnant solution (Wriengweera *et al.,* 2004).

Moreover, Fan *et al.* (2003) reported that growth under low P condition roots of plants had more aerenchyma compared with plants growth under high P condition. They also supported that more aerenchyma formation in roots of low P plants reduces the respiratory and P requirements of soil exploration by roots. However, the result in present study has shown applying P the plants formed more aerenchyma than low P condition. Also, root porosity was greater in high P plants than low P plants. I hypothesize that the formation of aerenchyma in adventitious roots responds to P levels may be different among cultivars. Therefore, further research is required to test how aerenchyma formation in roots of other cultivars when grown in different P levels. This study also found that the production of plant dry weight and number of tillers per plant were depressed in stagnant condition compared with aerated condition. These evidences are possible with the data of plant nutrient uptake which shown in Chapter 4. Moreover, the adaptation of plants to aerated or stagnant condition by changing their root length, adventitious root number in this study are similar with findings of many previous studies in rice, tribe Triticeae (Colmer *et al.,* 1998; McDonald *et al.,* 2002). The growth, nutrient uptake of rice really confirmed to be influenced by P levels. The effect of P deficiency to rice plants is more severe in stagnant than aerated condition.

5.3 Soil-phosphorus under changing between aerobic and waterlogged conditions in rainfed lowland rice

The effects of alternate drying and flooding of soils on P transformations, and subsequent effects on crop growth are importance in the rainfed lowland rice. The cause of limiting P supply for rice plants may be low total P content and/or a high P sorption capacity of the soil, which relates to soil-water regime. In rainfed lowland rice soils are commonly acid, the compounds of aluminum-phosphates and iron-phosphates occur frequently in acid soils are stable, particularly in aerobic soils (De Datta *et al.,* 1990; Kirk *et al.,* 1995). Thus, an aerobic or unsaturated soil is usually low P availability in the soil solution. Seng *et al.* (1999) tested the effect of a 3-week period of loss of soil-water saturation on P uptake by rice in a pot experiment with two acid rainfed lowland soils from South-eastern Cambodia. They found that temporary loss of soil-water saturation led to decreased P uptake and shoot dry matter, whether with and without P fertilizer application. The decreases were attributed to the decreased availability of P during the period of loss of soil-water saturation. Subsequent field experiments on the same soil also suggested that the period of loss of soil-water saturation also depressed P uptake by rice (Seng, 2000). The results of present experiment showed plant dry weight and also plant P uptake were lower in aerobic rice than waterlogged rice (Chapter 3). These are consistent with the findings of Seng (2000) above.

On the other hand, flooding has mostly beneficial effects on the availability of nutrients and their uptake by rice (Ponnamperuma, 1972). Flooding, by increasing pH and P availability and decreasing levels of soluble Al, particularly and significantly benefits growth and nutrient uptake of rice growing on acidic, low-fertility, rainfed lowland soils (Ponnamperuma 1972; Willett and Intrawech, 1988). In addition, Dobermann *et al.* (2000) reported that flooding of dry soil causes an increase in the concentration of P in the soil solution because the release of sorbed and co-precipitated P following the reduction of Fe^{3+} compounds. Flooding also enhances diffusion, the main mechanism of P supply to roots. The results of experiment in this thesis showed that after transplanting seven-weeks, the plants grown in waterlogged soil, which was submerged at transplanting (W0+) had more plant dry weight and also P uptake compared with plants grown in waterlogged soil throughout (Chapter 4). These results suggest that plant uptake more P in W0+ than in W++ condition resulting in better growth of plant in W0+ than in W++. However, P availability in aerobic, waterlogged as well as aerobic followed by waterlogged soil in this study was not measured. Further work is needed to determine P availability in soils at each status of soil-water, and how effect of soil chemistry on nutrient availability.