CHAPTER 5
DISCUSSION

5.1 Rice Consumption and Production in Yunnan

A well-documented finding is that as income increases, significant changes occur in dietary patterns (Bouis, 1990; Marks and Yelley, 1988). Duff (1991) suggested that, as incomes rise, consumer are able to substitute more preferred foods in their diet, and shifts in food demand occur. The implicit assumption is that consumers desire to improve the quality of their diets. The survey information of this study support Duff's assumption, indicating that there is substitution between quantity and quality of rice consumption in Yunnan since late of 1980's. As Cai et al. (1992) concluded that, for its low elasticity, per capita rice consumption for food will tend to reduce along with the improvement in food structure. Similar trends were reported by Huang et al. (1990), showing that over last thirty years, per capital rice consumption has declined in Japan, Taiwan, Singapore, Malaysia, and Thailand.

Over the past fifteen years, modern agro-technology has had a significant impact on increasing rice production in Yunnan. From being one of the largest rice importer, Yunnan almost achieved rice self-sufficiency in 1984 (Li, 1988). Self-sufficiency in rice as well as increase of living standard of Chinese people have made quality of rice becoming increasingly important. Consequently, it also implies that both breeders and producers need to concern more about increasing demand of quality rice in the future's rice production. Improvement in high quality rice production would provide benefits to all sectors of society.

5.2 Economic and Agronomic Considerations for Rice Quality Characteristics and Market Prices

Varietal classification of sixty milled rice samples showed that percent indica rice available in the markets accounted for 36% in 1994, was nearly 8% higher than the percent area of indica-growing of Yunnan. This is mainly due to the unbalance of per unit grain yield between indica rice and japonica rice. In 1990, hybrid rice varieties have covered nearly 80% indica-growing area in Yunnan (Yang, 1992). Hence, high promotion of hybrid indica rice along with double cropping of indica would have made very high quantity of market supply. Aside of import of good quality indica rice from Thailand, the trade of crossing provinces and regions would also result in relative high opportunity for indica rice available in the domestic market in Yunnan.

At present, the diversified milled rice with various prices were available in the domestic market, it is the reflection of advantages of free trade marketing systems. In the past years especially before 1988, Chinese government imposed restriction regulation in grain marketing by contracting or negotiated price system that controlled by government policy. Under this system, farmers were not free to sell their grains directly to consumers at negotiated prices. As a result, most of the farmers did not care about the quality of their produced rice. Despite the tremendous achievement have been obtained in rice production and rapid increment in national economy since 1980's, the planning economic systems which is single price brought about inefficiencies in rice production systems as well as in rice marketing systems (Zhang et al., 1991).

The information based on market survey and samples confirmed that there was a big variation in market prices within one region as well as among the three regions. The possible cause of these price variation involve a number of factors which are mostly determined by socioeconomic and biophysical conditions of region. As summarized by Abansi et al. (1992), the price determinations for rice involved consumers characteristics (i.e. income, location, education, age, occupation), and physicochemical characteristics of rice.

In the consumer's sense, quality characteristics such as aromatic and whiteness are among the most important indicators for "high quality rice. In the study, these two parameters were not analyzed, simply because of the difficulty of pricise measurement. However, degree of chalkiness score in total milled rice provided insight into how consumer considered whiteness.

The laboratory analysis of sixty milled rice samples showed that on an average, grain physicochemical quality characteristics of the majority predominantly grown rice varieties (which cover more than 6,600 ha) belong to the medium grade in terms of quality classification. The similar situation was found in most of the rice-producing provinces in China (Luo et al., 1992). This indicates that there is a significant room for quality improvement, especially in terms of hybrid rice breeding programs.

Recently, food based strategy for improving human health being raised attention of researchers worldwide. As human malnutrition is still prevail widespread in the rice-consuming countries, nutritional quality of rice has attracted the attention of many nutritionists. In this study, upland and glutinous rice showed high nutritional quality in terms of Zn and protein content. Thus, the finding that Zn contents were high in upland and glutinous rice opens up many possibilities in the efforts to improve Zn nutrition for rice. Upland rice may take advantage of their deep root systems to absorb more Zn from soil. Graham et al. (1993) believe that the better approach to solve problem of Zn-deficiency is to breed cereals with root systems which will penetrate subsoil of low phosphorous and micronutrient availability.

The correlation analysis showed the positive association between P and protein. This finding is similar with Zhang' report (1992). However, it was found that there was a negative relationship between protein content and Zn content of grain. This result was contrasted to Zhang' finding (1992). Noticeably, results of this study demonstrate a negative association between protein and degree of chalkiness. This finding could probably support that highly translucent rice was significantly related its higher protein content (Zhang, 1992).

Regional regression equations of this study indicated that consumers' preference for rice varied among three regions, namely Dali, Kunming and Xishuangbanna. This finding agrees with suggestion of Unnevehr et al. (1985). Nevertheless, the results of implicit price estimation in this study suggested that two types of quality improvement in modern rice varieties benefit to consumers and producers in all three regions. First, development of low to mediate amylose rice would have widespread benefits because consumers in all three regions prefer low to mediated grains. Second, improvement of grain length would also benefit to consumers and producers. This is why consumer normally consider slender long-grain as one distinguish indicator for good quality of indica rice, such as Dianrui 408, Dianrui 446, Dianlong 201, Diantun 502, and Thai rice " Khao Dok Mali 105", all of them are well-known by their slim long-grain.

In most cases of regression estimates of implicit price for rice quality characteristics in Yunnan, the percentage of head rice was not found to be significantly associated with rice price. This means that producers in Yunnan used to sell their rice which head rice was not separated from broken rice. There are two major explanations related to issue of head rice percentage. First, Chinese government paid more attention to high yield for rice production due to rapid increasing of population, while milling quality in terms of head rice recovery was given less attention. Second, the producers were not very much interested in the head rice recovery due to the single price of grain marketing systems in the past years.

Meanwhile, head rice percentage showed expected sign (positive) in case of indica rice regression. For this reason, it implies that consumers' preferences for good milling quality (particularly with respect to indica rice) are quite similar among the most of Asian countries (Unnevehr et al., 1985).

The study demonstrated a simple methodology for testing consumer preferences. Laboratory measures of physical and chemical quality characteristics of rice grain can be regressed on rice prices to explain observed difference in market prices. The regression parameter estimates show the implicit value of characteristics to consumers, and the significant of parameter estimates indicates the importance of those characteristics. Such estimates are useful to identify the grain characteristics that plant breeding programs should focus on to improve quality.

Because consumer preferences for other characteristics vary, provincial programs have substantial room to tailor varieties to local preferences. Provincial rice research should provide regional programs with plant materials having diversity of grain characteristics. Regional programs should further study consumer preferences to focus on quality objectives important to most consumers of that region.

In fact, in the consumer's sense, variety was recognized as the most important indicator for rice quality. This means that breeding can offer one of most promising solution in improve rice quality. Quality improvement without the reduction in yield will generally benefit consumers by lowering the cost of better quality rice. Improving grain quality characteristics of genetic sources or varieties could reduce processing costs and directly increase returns to farmers. If higher quality varieties were widely adopted, producers would not receive extra price premium because of satisfaction of consumer's demand as well as market supply, but would benefit in two other ways. First, they would remain better quality rice for their own consumption. Second, they would have a wider domestic market for their rice.

Moreover, the results indicated that environmental conditions and crop management techniques had some effects on rice quality, this impact could further affect on market price of rice. This information should warrant greater attention among breeders, agronomists, as well as producers.

5.3 Effects of P and Zn Application on Rice Grain Quality

Stunted plant growth and delayed flowering and maturity in rice could be resulted from soil Zn deficiency (Xie, 1986; Yang and Huang, 1986; Quijano, 1988) as well as by P deficiency (Shi, 1988). However, such symptoms were not observed in this experiment, presumably because the available Zn and P excess critical value in the natural soil. The critical limited value for Zn and P supplies of soil have been recommended by a number of literature (Xie, 1986; Yoshida and Tanaka, 1969; Lui, personal communication). The soil conditions of experimental field were classified as low Zn and low P but not critical as deficiency. In this experiment, it was evidenced that plant developmental stage in terms of panicle emergency, flowering and final maturity were advanced 2 days with increasing of P or Zn applied. This finding may also suggested that Zn and P play an important role for maintaining the normal plant development. There is general agreement that most distinct zinc deficiency symptoms are stunted growth and little leaf which are related to disturbance in the metabolism of auxins, indoleacetic acid (IAA) in particular (Marschner, 1986). It has been reported that supplementation of Zn to Zn-stressed plants (maize, barley, and oat) roots not only increased growth but also increase levels of gibberellin-like substances (Suge et al., 1986).

The responses of grain yield to Zn and P applications showed differences among three various varieties. However, grain yield of Xunza 29 was the lowest among three varieties, this was because of problem of seeds contamination. In this experiment, it has been confirmed that, grain yield of Xunza 29 was mainly determined by the numbers of contaminated plants (male sterile line) which gave very low grain set (0-30%).

Productivity of Hexi 35 and Yungeng 34, whether measured in terms of total grain yields and the dry matter of biomass (straw) at the period of final harvesting, all indicated clearly advantage of P and Zn application. Moreover, in Hexi 35, the grain yield with combined 5 kg Zn /ha and 150 kg P_2O_5 /ha application reached 11.3 t/ha (see Appendix c-2), which excesses the grain yield in application by 200 kg P_2O_5 /ha. Therefore, in addition to the advantage in relative term, there is also absolute beneficial effect of combined Zn and P application, due to its lower cost of Zn fertilizer, and the farmer can expect a higher economic return from combined Zn and P application. Similar advantages of this combined Zn and P application have been observed in previous study on rice (Yang et al., 1986) and barley (Lian, 1989).

Increase of grain yield was due to an enhancement of panicle weight and thousand grain weight in Hexi 35 and Yungeng 34. Although there was only slightly increase in thousand grain weight, notable effect of added Zn and P for panicle weight of Hexi 35 and Yungeng 34 were clearly observed confirming higher P or Zn requirement for reproductive growth. The prime effect of P and Zn application, which resulted in an increase in vegetative growth in terms of biomass and reproductive growth in terms of numbers of productive tiller, numbers of filled grain, and thousand grain weight, has been observed in rice (Yang et al., 1986; Yoshida, 1975) and in barley (Afudaoning, 1992).

Noticeably, in this experiment, plant height was detected a reduction (about 5.0 cm) as applied Zn regardless application of P and variety. This finding contradicted with the general principles (Marschner, 1986; De Datta et al., 1981). Nevertheless, it was hardly to predict whether the plant height was really reduced with applied because there was limited information about nutritional status of plant and soil throughout the whole period of this experiment. Hence, this finding need to be verified by conducting further research.

The most common interaction in which P salts decrease plant Zn concentrations encountered when the supplies of both P and Zn are marginal or limiting and addition of P promotes growth sufficiently to dilute the concentration of Zn in plant to levels which induce or enhance Zn deficiency (Boawn et at., 1954; Loneragan et al., 1979; Singh et al., 1988). It has been recognized that the incident of Zn deficiency throughout the rice-growing world was due to increased use of P fertilizer resulting in P-induced Zn deficiency (De Datta, 1981). Yang et al. (1986) confirmed that P induced Zn deficiency often occur when grown rice in low Zn or Zn deficiency soils. In this study, results only showed trend of P-induced Zn deficiency in Hexi 35. In contrast, P-induced Zn deficiency was not observed in Xunza 29 and Yungeng 34. This probably due to a number of factors concerned. There are many factors affecting Zn deficiency, i.e. soil available Zn content, soil pH, internal requirement of plants etc. Recent study (Robson, 1993) indicated that there is wide variability in Zn-efficiency among rice genotypes, it may explain the differences of the Zn concentration in Xunza 29 and Yungeng 35. Those finding might also suggest that: it does not necessarily indicate that higher rate of P application will cause Zn deficiency (Afudaoning, 1988).

Yang et al. (1986) cited that plant absorption and translocation of P and Zn were affected by levels of P and Zn application. In this study, both P content of dry weight in stem, leaf and grain and total amount of P uptake were increased by increase of P applied, moreover they were also enhanced by Zn applied. These findings were confident with conclusions of Yang et al. (1986) as shown in Table 2.5 (see Chapter 2). On the other hand, the total amount of Zn uptake showed an enhancement with Zn applied regardless applications of P and genotype. Similar result was also observed in previous works of Yang et al. as given in Table 2.6 (see Chapter 2).

Experimental results indicated that there were similar trends in terms of plant distributions of P and Zn of all three varieties regardless of application of Zn and P. However, the proportion of P and Zn differed among varieties regardless application of Zn and P. Therefore, the results revealed that different varieties have various capability to absorb and translocate P and Zn into grains. This basically suggested that genetic selection could be one efficient way for higher Zn in grain.

The concentration of Zn in edible plant parts can vary widely depending on a number of complex, dynamic and interacting factors including plant genotype, plant part, and plant's environment (including soil-Zn availability) during development (Robson, 1993). In this study, Zn content of grain in Xunza 29 was increased under higher Zn supply. Similar result was only demonstrated in barley by Lian (1986). This finding confirmed that it is an alternative way to improve nutritional quality in terms of Zn content in grain through Zn application. This finding also suggested that Zn fertilizer application may alleviate the problem of Zn deficiency in cereal crops included in rice. However, in case of Xunza 29, increase of Zn content in grain due to applying Zn was only about 2.5 ppm. Therefore, to be economically flexible, the further research is needed before recommendation ready for Zn application in farmer practice.

On the other hand, results of this experiment indicated that although Zn content of grain for Yungeng 34 and Hexi 35 were reduced as Zn applied, the total amount of Zn in grain increased with Zn applied. This result suggested that reduction of Zn content of grain in these two varieties may probably due to remarkable contribution of Zn for yield increment. This might also explain why Xunza 29 only gave relatively lower grain yield but gained higher Zn content of grain with Zn applied.

Zn content of grain is one of the important nutritional quality characteristics in rice. Ross and Welch (1993) listed the medium (16 mg/kgdw) and range (10-22 mg/kgdw) of Zn concentrations in rice (whole kernel). However, it has also been found (Hambidge et al., 1986, Welch and House, 1984; Torre et al., 1991) that crop contain substances which interfere with Zn absorption and utilization (i.e. bioavailibility) to human, example of these substances include phytic acid and certain types of fiber, especially fiber from whole cereal grain (such as cereal brans are associated with reduced Zn bioavailablity).

Hence, results of this experiment, especially with respect to the genotypic differences in response to Zn and P application, provided new insight into impact of genotype and crop management on Zn in grain. That is: first, it is not wise to increase Zn content in grain without a more through understanding of their roles in plant growth and human health. Second, practically, it may be more desirable to increase the Zn concentration in grain through genetic selection, breeding cultivars which should be higher Zn content in grain and/or respond to Zn applying but produce grain yield economically as well.

One of the limitation of this experiment is that Zn content in brans and roots have not been measured. For further research, it is worth to determine the edible Zn in grain of cultivars before and after conducted field experimental treatments. Zn distribution from soil to plant and further to human should become to be an important and interesting topic for future research.

P play important role in protein synthesis, Mosulofu and Fuleit (Afudaoning, 1992) stated that there was a positive correlation existed between P supply and protein content of grain in wheat for example, but it might be a negative influence of P supply on protein synthesis in some other cereal crops. In this experiment, the protein content of grain was found to be increased by P applied regardless applications of Zn and varieties. Meanwhile, the experimental results showed that protein content of rice grain was linearly increased by P. This means that the optimal levels of P that produces the highest protein content will also produce maximum grain yield accordingly. To be economically flexible, hence, breeders should warrant theses attention to be paid to protein content in grain in breeding program. That is, comparing efforts to be paid for genetic selection and crop management, P management may be more efficient practice to improve protein content in grain regarding large scale of rice production.

Theoretically, the adequate Zn supply is considered as an important factor affecting protein synthesis in crops including rice (Robson, 1993; Academy of Agricultural Sciences of China, 1984). However, in this experiment, there was no clear advantage in use of Zn, in terms of protein content and total amount of protein of grain of Hexi 35 and Yungeng 34. In contrast, it was found that protein contents of grain of all three varieties were not significantly affected by Zn applied, but there was a tendency that the protein contents of grain of Hexi 35 and Yungeng 34 declined with Zn applied. This finding was not consistent with previous research, and other evidences remained lacking. With Zn applied, lower Zn content of grain due to higher grain yield in Hexi 35 and Yungeng 34 might probably explain depression of protein content of grain, because the Zn content of rice grain was positively associated with protein content of grain (Zhang, 1993). This means that an increase in grain yield induced a reduction of protein content of grain with Hexi 35 and Yungeng 34. At this point, the results of the study might suggest that there was a trade-off between yield and protein quality which should be considered for Zn application in rice production. Yet the negative correlation between grain yield and protein content of grain has been commonly found in many rice cultivars (Chuangdaolianyi, 1985).

Phytates are presumably involved in the regulation of starch synthesis during grain filling (Michael et al., 1980). However at current study, amylose content of grain was not detected significant in association with P application. This is because grain amylose is directly related to temperature and water supply during the process of grain filling. During period of grain filling, higher temperature and drought were believed to be significant factors which could probably increase amylose content of grain in rice

(Resurreccion et al., 1977; Paul, 1977).

This experimental results revealed that amylose content of grain seems to be increased approximately 1.0 % by Zn applied regardless application of P and genotype. Thus, Zn may play an important role in the metabolism of starch (Marschner, 1986). A reduction of starch formation under Zn deficiency has been confirmed in beans (Jyung et al., 1975) and other cereal crops (Reed, 1940). Juliano (1993) reported that an increase in protein content was essentially at expense of reduction in starch content (Juliano, 1993). Consequently, for Hexi 35 and Yungeng 34, an enhancement of grain amylose content might also relate to reduction of grain protein. If so, interaction between Zn and P should be considered as one limiting factors for gaining rice with lower amylose and higher protein in farmer's practice. Furthermore, it is possibility that interaction between Zn and P will make negative impact on consumers' preference based on information of implicit price estimation.

Results of this study exhibited an increase of head rice recovery as increasing in amount of P applied. In fact, higher head rice recovery was also found to be associated with higher grain protein content. This explained that the increase in head rice recovery in the chalky varieties as a result of P application was due to an increase in the protein content of brown rice and increase in hardness of kernels. Similar relationships were found with nitrogen application (Nangju and De Datta, 1970).

Milling quality, in terms of brown rice yield and milled rice recovery did not show clear response to P, Zn, and varieties. This finding supported to general agreement that yield of brown and milled rice recovery were not distinguished among genotypes which belong to the same sub-species, i.e. japonica or indica rice (Chen and Lui, 1994.

personal communications).

The degree of hardness of grain is believed to be positively associated with head rice recovery (Juliano, 1993). In this study, it was found that the degree of hardness of grain significantly was negatively correlated with Zn applied. This might further explain an reduction of head rice recovery due to applying Zn.

Milling quality especially with respect to head rice recovery, one of important quality characteristics which determine rice price in the market, showed no differences among three varieties in this experiment. Nevertheless, the results also provided information with alternative solution how to solve problem in terms milling quality improvement, i.e. P management might be more desirable. This finding need to further verify and explore to indica rice. Accordingly, P management will create benefit for farmer since percentage of head rice was identified as one of price determinants in indica rice.

The physical quality characteristics in terms of grain length and width, did not respond to P and Zn application for any varieties and this traits remained fairly constant. This is because that grain shape and size was genotypically determined (Juliano et al., 1990). It also suggested that effect of P on grain physical properties was not as profound as that of nitrogen. Previous researches indicated that increment nitrogen fertilizer would increase the physical characteristics of grain which including length, width, and thickness (Attaviriyasuk et al., 1990; Jongkeawattana, 1990; Somchit, 1995, personal communication).

In summary, the field experimental study demonstrated how the grain yield and grain quality advantages were related to their Zn and P nutrition in both soil supply and plant uptake two aspects. From view of consumers' preferences as reflected market prices in rice, Zn and P played significant role for improving economically important quality characteristics, for example, percentage of head rice, nutritional value in terms of protein and Zn content. Consequently, farmers and consumers could obtain some benefits from apply rice variety with fertilizer management in terms of Zn and P application.