Greener Journal of Agricultural Sciences
ISSN: 2276-7770; ICV: 6.15
Vol. 2(7), pp. 340-344, November, 2012

http://gjournals.org/GJAS

Review Article

Research Progress in Effects of Different Altitude on Rice Yield and Quality in China

Jing Li [1,2] and *Yuan Jichao[1]

[1]College of Agronomy, Sichuan Agricultural University, Wenjiang Sichuan 611130, China.
[2]Academy of Agricultural Sciences, Xichang College, Xichang Sichuan 615013, China.

ARTICLE INFO

Article No.: *110112203*
DOI: *10.15580/GJAS.2012.7.110112203*

Submitted: *01/11/2012*
Accepted: *15/11/2012*
Published: *30/11/2012*

***Corresponding Author**
Yuan Jichao
E-mail: *lijingnmk@163.com*

Keywords:
Altitude, Rice, Yield, Quality

ABSTRACT

This paper reviewed some recent research progress in effects of different altitude on rice yield and quality in China. The results showed that with the increase of altitude, accumulated temperature required for the growth of rice decreased, the whole growth period of rice extended, the tillering stage postponed and the seed-setting rate reduced. Also, yield, effective panicles and grains per spike decreased after increasing with increasing altitude. In terms of quality of rice, altitude had greater effects on the milled rice rate and chalkiness. The milled rice rate had significant increase and chalky grain rate had a clear downward trend with the increase of altitude. There was large difference in the studies between altitude and cooking and eating qualities of rice, which needed to be further studied in the future.

Introduction

Rice (Oryza sativa L.) is one of the most important crops in the world and is the foremost staple food in Asia, providing 35-60% of the dietary calories consumed by nearly three billion people (Liu et al., 2010; Yang and Zhang, 2010; Zheng et al., 2004). Developing countries account for 95% of the total production, with China and India alone responsible for nearly half of the world output. It has been reported that the altitude of planting fields is a very important environmental factor affecting rice yield and quality (Katsura et al., 2008; Khush and Peng, 1996). With the increase of altitude, air density decreases, air temperature decreases gradually, solar radiation intensity increases, and ultraviolet rays' intensity becomes strong. In addition, precipitation and precipitation days are affected, consequently affecting the rice growth, and eventually affecting the yield and quality. Ding et al (Ding, 1964) pointed out that the ecotypes of rice varieties in China were affected by environmental factors, among which the altitude was an important one. Zhang et al.(Zhang, 1983) studied the planting cap and the temperature conditions of rice varieties of different climatic ecotypes of China. Afterwards, many Chinese researchers in different regions launched numerous researches about the effects of altitude on the rice yield and quality. Otherwise, because of different research methods were applied at different areas, the conclusions obtained were also different. On the basis of reference both home and abroad, the author summarized the effects of altitude on the rice growth, yield, components and quality of different breeds of rice, so as to provide new ideas and reference for the study of rice cultivation mode.

The effects of altitude on the growth of rice

Rice, a kind of short day thermophilic crops, requires certain temperature conditions at different stages of growth and reproduction. The indica rice requires that the average daily temperature at the seeding stage should maintain above 12 ℃ and the japonica rice is above 10 ℃ (Zhang, 1983). Therefore, the temperature suitable for the seed of rice stabilizes higher than 12 ℃ while, during the rearing period, the average daily temperature of the japonica types is more than 20 ℃, and the indica types requires above 22 ℃. If the average daily temperature is less than 22 ℃ for more than 3 consecutive days, it tends to cause the phenomenon of Cryogenic false (Yuan et al., 2008). The higher the altitude , the more the first day in spring which stably passes 12 ℃ will be postponed for 3 to 5 days correspondently and the final day in autumn which stably passes 22 ℃ will be advanced in 3 to 5 days. Additionally, the days for safe growth of rice will be reduced by 7 to 9 days. The accumulated temperature of the growth of rice will decrease along with the increase of the altitude, high-altitude areas with a higher rate of reduction. In the areas which have an altitude of more than 900 meters, there are no more than 120 days with an average temperature above 20 ℃, and about 150 days above 15 ℃, while the safe days for the rice growth is 130 (Yan et al., 2007). Thus, with the increase of the altitude and the decrease of the average daily temperature, the whole growth period will be prolonged and the tillering will be postponed with a low rate of tilleration. Effects of altitude on different types of rice influenced by the altitude is that the japonica rice is higher affected than the mixed japonica rice, which is higher affected than the indica rice (Gu, 1997).

Illumination is the most significant ecological factor which influences the photosynthesis. With the increase of the altitude, the radiation of the sun strengthens and photosynthesis of rice will also be greatly affected. There are studies indicating that the light saturation point and the light compensation point of the rice planted in the high-altitude areas are higher than those of the rice planted in the low-altitude areas (Li and Lin, 1986; Wang and Liu, 1992); both of the compensation point of carbon dioxide and the light aspiration rate decrease as the altitude increases, the rice in the high-altitude areas has a lower efficiency of photosynthesis, while the rice in the low-altitude areas has a higher efficiency of photosynthesis, which reveals that the efficiency of photosynthesis tends to reduce with the increase of altitude (Li and Lin, 1986). In addition, the altitude will affect the morphology of the rice plants. Wang et al. (1984) reported that the height of rice plants will shorten with the increase of the altitude; the leaves of the main stalk tend to be short and slim; the major part of the glume shell has villi, with long and short awns. Since the temperature reduces as the altitude increases, fertile pollen rate reduces, which further influences the seed-setting rate of the rice.

The effects of altitude on the productivity and components of rice

It has been recognized that the maximum altitude in China for rice planting is 2710 meters (Li et al., 2004; Zhang et al., 2004). Different climatic ecotypes of rice has different requirement of temperature condition. Furthermore, geological environment and the vertical decline rate of temperature vary from region to region. Therefore, rice has different maximum altitude in different regions. Planting rice in the mountain region with a large altitude difference, the rice still can get a high productivity within the safe stage if illumination, temperature and water are guaranteed, for example, the average productivity of 'Shanyou 63' in Hainan province is merely 7 t/hm^2 (Huang, 1991). However, if it is transplanted to Taoyuan county (with an altitude of 1107 meters) in Yunnan province, the productivity can reach to more than 15 t/hm^2(CongDang et al., 2006). In addition, as early as in the 1990s, a few fields whose productivity are more than 1000 kilograms appeared in Taoyuan county (with an altitude of 1107 meters) and Binchuan county (with an altitude of 1438 meters) in Yunnan province. In 2001, the researchers of Fujian Academy of Agricultural Sciences (Fuzhou, China) used the 'Teyou 175' and 'II Youming 86' in Taoyuan county which is the famous region of rice ultra high production making the rice yield records of 17782.5 kg/hm^2 and 17947.5 kg/hm^2 respectively (Xie et al., 2003).

If the altitudes are different, the average daily temperature of the whole growth period will be various, which will further influence the days of the whole growth period and the seed- setting rate of rice. Research has indicated that the seed setting rate decreases with the increase of altitude (Wu and Tang, 1988; Yuan et al., 2005a). The reason is that the lower temperature restrains the transportation and content from the assimilate to grain which cannot be fully made used of (Li and Lin, 1987; Li and Lin, 1990). As to the influence of the altitude on the grain number and the effective panicles, an experiment in Mianyang, Sichuan province whose altitude ranges from 400 meters to 1400 meters has showed that the productivity, with the increase of altitude, yield, the effective panicles and number of grains first increased and then decreased (Luo et al., 1999).

(Yang et al., 1998) reported that the number of grains of the same variety in Yunnan Taoyuan cultivated in Fujian Longhai, cultivated more than 50% to 60% , and obtained a higher yield. (Yuan et al., 2000) further showed that the effective panicles is the main reason of High yield about ' 'Shanyou 63'of Taoyuan county in Yunnan province, whose quantity is 59.9% higher than the average. (Yang et al., 2004) compared Taoyuan county (with an altitude of 1107 meters) and Binchuan county (with an altitude of 1438 meters) in Yunnan province and hangzhou high-yielding rice field yield differences , the results showed that compared with Hangzhou, Yunnan rice planting area increased blossom quantity mainly through the enhancement of the effective panicles and grain number. Another study by Yuan et al., (2005b) reported that the effective panicles of Xichang (with an altitude of 1580 meters) in Sichuan province is much more than basin rice planting area. These results show that the effective panicles is the basis of high-yielding rice in the high altitude area (Taoyuan county and Binchuan county in Yunnan province, in Xichang, Sichuan province, etc), and there are some relations between rice yield and its components and altitude of cultivated fields.

Effects of Altitude on the Rice Quality

It will have great effects on the rice quality due to the different altitude. (Xiang and Tang, 1991) used grey relational analysis method to analyze the changing trends of the rice quality at the different height of altitude. The results showed that within the experiment scope of 500 meters to 1000 meters, the altitude will affect the rice quality. Degree of influence and the trends of rice quality which caused by the altitude will depend on the varieties (combination). A better quality of rice will have the higher degree of the development of rice quality. At the higher planting altitude, the rice quality will reach its optimum.

Generally speaking, the rice quality will be measured by the following four aspects: milling quality (processing quality), appearance quality, cooking and eating quality and nutritional quality. The four aspects will be affected by the altitude. In terms of milling quality, brown rice rate and the milled rice rate will be less affected by the altitude (Huang et al., 2005). Otherwise, the head milled rice rate will have greater affection with the increase of altitude (Liu et al., 1986; Su et al., 2008),the head milled rice rate will increase significantly. In terms of the appearance quality, the altitudes will have fewer effects on the grain shape. Otherwise, it will have greater effects on the chalkiness chalkiness. With the increase of altitude, the trend of chalkiness grain rate will decrease obviously (Fan et al., 1989; Huang et al., 2004). In terms of nutritional quality, (Liu et al., 1986) found that the protein content of indica and japonica will increase accompanied with the increase of altitude. Moreover, (Zhou et al., 1997) reported that the protein content will increase accompanied with the increase of altitude within 800m, but it will appear as the decreasing trend if it exceeds 800 meters.

With regard to the effects of altitude on cooking and eating, (Zhu et al., 2010) found that with the increase of altitude, the change of high strength of cold tolerance varieties will be relatively stable. But the quality of cooking and eating coupled with weak resistance to cold varieties will appear as the bad trend obviously. The rice RVA spectrum characteristics of the high strength of cold tolerance varieties will have fewer effects by the change of altitude related to the weak resistance to cold varieties. According to the increase of planting altitude, the setback of weak resistance to cold varieties will increase obviously. Otherwise, the peak viscosity and breakdown will decrease obviously. But to the peak viscosity and breakdown of high strength will appear the trend of being down then up, while for alkali spreading value will appear the trend of being up then down. (Liu et al., 1986) found that the altitude of altitude will affect the gap of the cooking and eating between indica and japonica significantly. With the increase of altitude, gelatinization temperature, amylose content and gel consistency of the indica will decrease and become soft. Otherwise, the japonica will appear three indicators corresponding rise, increase and no effects with the increase of altitude. (Huang et al., 2004) reported that, the hybrid rice 'Liangyou 363' alkali spreading value and amylose content increases as the altitude increases. However, (Su et al., 2008) reported that the altitude has a weaker effect on the amylose content. It is mainly caused by the differences from the varieties, the altitude gradient will have a greater effect on gel consistency, and it will appear the trend of decreasing corresponding with the increase of altitude. The differences among the results of these surveys may be related to the adopted varieties, the test locations terrain, the cultivation and the management measures. So, the effects on the quality of cooking and eating caused by the altitude are still pending further study.

Conclusions

The production of rice, genetic diversity, germplasm resources distribution have been severely affected by ecological environment, mainly temperature, the difference of altitude mainly results in the change of environmental temperature. Three-dimensional climate caused by intervallic altitude forms a unique three-dimensional cultivation pattern of rice. This three-dimensional cultivation pattern is especially typical in Yunnan province. As effective accumulated temperature of rice growth in high-altitude areas is significantly lower than that in the low altitude areas, and with the delay of sowing time, only early rearing flowering period can ensure the normal seedling emergence, rearing and fructification.Therefore, when planting rice in high altitude areas, the rice varieties with a short growing period and strong frost resistance should be chosen, at the same time, measures to increase effective accumulated temperature should be taken to ensure the normal growth process . As for the effects of altitude on the rice yield and quality, so far a lot of research work has been done and some progress has been made. However, the existing research mainly focused on description of qualitative relationship between the height, yield and quality, and the corresponding mechanism has not been researched deeply enough which needed to be further studied in the future to prove the physiological ecological law of rice yield and quality formation in high altitude area and enrich the three-dimensional cultivation theory of rice, so as to better promote the production of rice in high-altitude areas.

References

CongDang, Y., DeFeng, Z., JiFeng, Y., YuPing, Z., XianQing, L., PingRong, Y. and Neng, Z., (2006). The absorption, distribution and utility of nitrogen in plant of high-yielding rice. Southwest China Journal of Agricultural Sciences 19: 400-403.

Ding, J., (1964). Ecological types of Chinese rice varieties and its relationship with the development of production. Scientia Agricultura Sinica 2: 893-899.

Fan, Y., Zhou, M. and Tang, Q., (1989). The relationship of rice endosperm cell structure and grain quality.Effect of different ecological conditions on the rice endosperm starch cells. Crop Research 3: 19-23.

Gu, M., (1997). The impact of altitude on the growth and development of rice. Tillage and Cultivation 5: 61-63.

Huang, K., (1991). Reproductive characteristics and supporting technology of Shanyou 63 as early rice in Hainan. Hybrid Rice 11:11-13.

Huang, W., Zhao, Z., M., Y., Yuan, X., S., L., Lu, Z. and Ran, Y., (2005). Studies on the variation of rice quality characters. Southwest China Journal of Agricultural Sciences 28:871-873.

Huang, Z., Zhou, W., Wang, J., Xiang, G., Gan, Y., Yang, Z., Chen, F. and Luo, D., (2004). Effect of different ecological conditions on the quality of hybrid rice Liangyou 363. China Rice 4:26-27.

Katsura, K., Maeda, S., Lubis, I., Horie, T., Cao, W. and Shiraiwa, T., (2008). The high yield of irrigated rice in Yunnan, China:'A cross-location analysis'. Field crops research 107:1-11.

Khush, G.. and Peng, S., (1996) Breaking the yield frontier of rice. Increasing yield potential in wheat: Breaking the barriers 6:36-51.

Li, C. and Lin, D., (1986). Comparisons of photosynthetic characteristics of the leaf blade of rice grown at the different altitude localities. Acta Botanica Yunnanica 8:459-466.

Li, C. and Lin, D., (1987). Dry-matter production and partitioning in the aerial part of rice grown at different altitude localities. Acta Botanica Yunnanica. 9:89-95.

Li, C. and Lin, D., (1990). Final partitioning of the 14Cfed before and after heading of paddy rice grown at different altitude localities. Acta Botanica Yunnanica 12:191-196.

Li, J., Liu, C., Yuan, J., LI, X., Ding, Z. and Yao, F., (2004). Primary Study on the Variation and Influenced Factorsof Rice Chalkiness in Panxi Region. Journal of Sichuan Agricultural University 22:26-29.

Liu, J., Wang, Q. and Huang, X., (1986). Study on Effect of altitude conditions on the quality of rice. Yunnan Agricultural Science and Technology 5:27-30.

Liu, M., Liang, Z., Yang, F., Ma, H., Huang, L. and Wang, M., (2010). Impacts of sand amendment on rice (Oryza sativa L.) growth and yield in saline-sodic soils of North-East China. J. Food Agric. Environ 8:412-418.

Luo, X., Zeng, M., Zou, Q. and Liang, Z., (1999). Study on the changes in ecological environment and hybrid rice development at different altitudes in Sichuan. Chinese Journal of Applied And Environmental Biology 12:142-146.

Su, Z., Liao, X., Zhao, G., Shi, R., Jiang, C., Zou, Q. and Dai, L., (2008). Analysis of grain qualities in Japonica rice (Oryza sativa L.) under different altitudes in highland region. Ecology and Environment 17:1157-1162.

Wang, S. and Liu, Z., (1992). Some photosynthetic characteristics and respiration of rice varieties from different altitudes. Journal of Mountain Agriculture and Biology 11:1-5.

Wang, T., Li, J. and Yu, X., (1984). Regional effects of altitude ceiling areas' ecological environment in region of northwest Yunnan on rice growth and yield structure. Tillage and Cultivation 4:22-27.

Wu, D. and Tang, H., (1988) The impact of stages sowing on hybrid one night at different altitudes. Jiangxi Agricultural Science & Technology 9:3-4.

Xiang, Y. and Tang, Q., (1991). Effects of Altitude on Rice Grain Quality by Grey Relational Grade Analysis. Chinese Journal of Rice Science 5:94-96.

Xie, H., Wang, W., Yang, H., Yang, G.. and LI, Y., (2003). The characteristics of super high-yielding hybrid rice. Fujian Journal of Agricultural Sciences 18:201-204.

Yan, M., Huang, W., Lu, Z., Lei, S. and Ran, Y., (2007). The effects of ttemperature on the rice production in high altitude areas and countermeasures. Hunan Agricultural Sciences 2:86-87.

Yang, C., Zhu, D., Zhou, Y., Zhou, N., Yuan, P., (2004). Analysis on rice yield and its components under different environments. Southwest China Journal of Agricultural Sciences S1:35-39.

Yang, H., Li, Y. and Yang, R., (1998). Comparison of super high-yielding rice traits in Yunnan high-yielding rice in Longhai. Fujian science and technology of rice and wheat 2:46-37.

Yang, J. and Zhang, J., (2010). Crop management techniques to enhance harvest index in rice. Journal of experimental botany 61:3177-3189.

Yuan, J., Ding, Z., Cai, G., Yang, S., Zhu, Q. and Yang, J., (2005a). The Factors Influencing RVA Profile of Rice Starch and Their Changes with Altitudes in Panxi Region Acta Agronomica Sinica 31:1611-1619.

Yuan, J., Liu, C., Cai, G., Zhu, Q. and Yang, J., (2005b). Study on variation and its characteristics of yield components of high-quality rice in Panxi region. Southwest China Journal of Agricultural Sciences 18:144-148.

Yuan, J., Yang, S., Wang, M., Wu, Y., Zhu, Q. and Yang, J., (2008). Changes in Growth Duration of Rice with Altitude and Its Temperature Accumulation Effect in Panxi Region, China. Acta Agronomica Sinica 34:247.

Yuan, P., Sun, C., Yang, C., Zhou, N., Ying, J., He, Q. and Wang, X., (2000). Analysis on Grain Yield and Yield Components of the 15 t/hm ~2 Highyielding In dica Rice (Oryza sativa L.) in Yunnan. Acta Agronomica Sinica 26:756-762.

Zhang, Y., (1983). The upper planted limit and their temperature conditions of different climatic and ecological rice varieties in China. Resources Science 5:65-72.

Zhang, Z., Tan, X., Peng, G., He, L. and Tian, W., (2004). Effect of different altitude on the fertile pollen rate of rice. Crops 4:15-16.

Zheng, X., Kang, W., Wang, S. and Wu, J., (2004). Analysis on Climatic Adaptability of Upland Rice Planting in Guizhou [J]. Guizhou Agricultural Sciences 4:13.

Zhou, G., Xu, M., Tan, Z. and Li, X., (1997). Effects of ecological factors of protein and amino acids of rice. Acta Ecologiga Sinica 17:537-542.

Zhu, Z., Kim, K., Yuan, P., Zhao, G., Su, Z., Shi, R., Zou, Q., Yang, S. and Dai, L., (2010). RVA Profile Properties for Cold Tolerant and Sensitive Cultivars of Japonica Rice at Different Altitudes in Highland Region. Chinese Journal of Rice Science 24:151-156.

Cite this Article: Li Jing and Yuan Jichao (2012). Research Progress in Effects of Different Altitude on Rice Yield and Quality in China**.** Greener Journal of Agricultural Sciences, 2(7): 340-344, http://doi.org/10.15580/GJAS.2012.7.110112203**.**