Review Article

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

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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.

Keywords:
Altitude, Rice, Yield, Quality
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 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 °C and the japonica rice is above 10 °C (Zhang, 1983). Therefore, the temperature suitable for the seed of rice stabilizes higher than 12 °C while, during the rearing period, the average daily temperature of the japonica types is more than 20 °C, and the indica types requires above 22 °C. If the average daily temperature is less than 22 °C 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 °C will be postponed from 3 to 5 days correspondently and the final day in autumn which stably passes 22 °C 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 °C, and about 150 days above 15 °C, 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 tilling will be postponed with a low rate of tillation. 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/hm² (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/hm²(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 ‘Il Youming 86’ in Taoyuan county which is the famous region of rice ultra high production making the rice yield records of 17782.5 kg/hm² and 17947.5 kg/hm² 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


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