Research on the Effect of Planting Density on Rice Yield and Quality

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Abstract Planting density is of great significance in adjusting the population structure of rice, increasing yield and reducing the cost. And suitable planting density can not only bring the yield potential of rice population into full play, obtain the maximum grain yield per unit area, but save labor, protect the environment and improve rice quality. This article summarizes the impact of planting density on rice growth, yield, the components as well as qualities at an attempt to provide theoretical guidance for high yield and quality cultivation of rice.

Key words Planting density, Rice, Yield, Quality

Planting density can exert significant regulation effect on the growth and population structure of rice and adjusting basic seedlings per hill, hills per unit area or row and plant spacing can change the planting density[1]. Low seeding density cultivation can exert the individual advantage of rice and is beneficial to its tillering and growth, while less productive ears can affect the population structure as well as yield[2-4]. However, high seeding density cultivation increases the ears per unit area, but intensifies the contradiction among individuals, which results in the structural instability of ears, such as supernumerary spikes, size degradation and low yield[5,6]. Therefore, only rational close planting can make full use of land capacity and guarantee the maximum development of yield components like spike numbers, sizes and weights. And rice can utilize light energy efficiently, which can improve the rice output.

1 Impact of planting density on rice growth

Under the condition of fixed basic seedlings per hill, the larger planting density, the higher starting point of basic seedlings per unit area and the less soil nutrition per hill, which will surely affect rice growth. Yang Shimin[7] studied and discovered that the increase of planting density makes rice stem longer and thinner, decreases the contents of starch, fibrin and lignin as well as worsens the grain plumpness. With the increase of planting density, tillering and spike number per hill decreases regularly while total tillering and spike number per unit area increases[8]. However, sparse planting can promote individual tillering and obviously increase tiller - earing rate as well as numbers of productive ears per[9-12]. Moreover, planting density also influences the duration of each growth period of rice. The decrease of planting density prolongs spike differentiation[13] postpones flowering time[14] and prolongs the whole growth period[11, 15-16]. With the decrease of planting density, blade numbers of per plant, blade length and leaf drooping angle increase accordingly[17,18]. Differently, accumulation of dry matters during the early growth period declines with the decrease of planting density [19] while increases obviously during the late development period[20].

2 Impact of planting density on yield and yield components

Planting density can exert great impact on the reasonable group structure and is closely linked with yield. As to impact of planting density on yield, researches show that different types of rice have their own suitable planting density range. For example, the suitable planting density of Wandao 153 and YangLiangyou 6 is 22.5×10^4 hill/hm^2[21,22] while that of E - Jingnuo 437 is 37.51×10^4 hill/hm^2. And rice yield will decrease whether planting density is over or under the most suitable range[23, 24-27].

Currently, there are quite a number of research achievements about the impact of planting density on yield components. Zhen Kewu[28] discovered that seed setting rate and thousand-grain weight of Liangyoupeijiu experienced slight changes with different planting density (22.5×10^4, 27.0×10^4, 31.5×10^4 hill/hm^2) while the spike number per unit area and grain number per spike changed obviously. Spike number and grain number per spike complemented each other excellently within the planting density between 22.5×10^4 and 31.5×10^4 hill/hm^2. Gao Yang[29] discovered in the research that different planting density (14.29×10^4, 16.67×10^4, 20×10^4 hill/hm^2, 25×10^4 hill/hm^2, 33.3×10^4 hill/hm^2) exerted relatively larger impact on spike number per hill, grain number per spike and seed setting rate of super rice Songjing No.9 while less impact on thousand-grain weight. Spike number per hill decreased steadily with the increase of planting density while grain number per spike, seed setting rate and thousand-grain weight all represented a tendency of increasing before

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decreasing. Impact of planting density on yield components of Songjing No. 6 from big to small in proper order was hill number per square meter, spike number per hill, seed setting rate, grain number per spike and thousand-grain weight. Spike number and seed setting rate declined with the increase of planting density while grain number per spike and thousand-grain weight represented a trend of increasing before decreasing. Research on relationship between planting density and yield traits of Zhongyou 281 conducted by Sheng Xi[25] suggested that planting density showed obvious positive correlation with number of population productive ears while obvious negative correlation with productive ear number per hill, total grain number per spike, real grain number per spike, spike length, seed setting rate and thousand-grain weight. Liang Yinming[30] discovered that under the system of rice intensification, four different planting densities (15.3, 13.2, 11.1 and 6.9 cluster/m^2) obviously affected the productive ears, real grain number per spike and yield of Xieyou 9 308. Seed setting rate and thousand-grain weight decreased with the increase of planting density. The larger planting density, the less productive ears and the larger spike type High planting density decreased number of productive ears but enlarged spike type and increased real grain number per spike as well as the yield. Yield components have contradiction, interaction and coordination with one another. The inconsistency of the above conclusion may be caused by different experiment cultivars and the design scope of planting density.

3 Impact of planting density on rice quality

Rice quality can be measured generally from four aspects, namely milling quality (processing quality), appearance quality, cooking and eating quality as well as nutrition quality. Wu Chunzan[31] studied and believed that impact of planting density on quality was mainly reflected on chalky rice rate, chalkiness degree, amylose content, head rice rate and protein content. Within the experiment scope from 7.5 to 250.5 thousand cluster/hm^2, planting density represented remarkable negative linear correlation with chalky rice rate, chalkiness degree and amylose content, showed inverted quadratic curve relation with head rice rate while represented nearly positive linear correlation with protein content. Wang Chengyuan[24] studied and suggested that impact of planting density on quality was mainly reflected on chalky rice rate, protein content and amylose content. When planting density was lower than 12.5 hill/m^2 or higher than 25.0 hill/m^2, protein content, amylose content and green rice rate were relatively high while chalky rice rate and chalkiness degree increased, hence a decline in rice cooking and eating quality. Generally speaking, nutrition quality, appearance quality as well as cooking and eating quality can be improved under suitable planting density with low chalky rice rate, high protein content and low amylose content. Yang Guocai[32] discovered through researches that planting density exerted small impact on brown rice percentage, head rice rate and amylose content of early hybrid rice W - Liang - You 3 418 while relatively large impact on whole head rice rate, chalky rice rate, chalkiness degree and gel consistency. Whole head rice rate and gel consistency increased while chalkiness degree and chalky rice rate declined with the increase of planting density. Ye Quanbao[33] studied and displayed that planting density exerted greatest impact on setback of japonica hybrid rice Changyou No. 1 and conventional japonica rice Wuyunjing No. 7, followed closely by disintegration, peak viscosity and hot paste viscosity, and relatively less impact on cold paste viscosity, recovery value and peak viscosity time, while the least impact on initial gelatinization temperature. With the increase of planting density, peak viscosity and disintegration of both cultivars represented the tendency of increasing before decreasing while setback showed a completely opposite trend. And other features experienced no obvious variations. Wang Guijiang[34] discovered that under the condition of low nitrogen fertilizer, planting density within the experiment scope represented obvious negative correlation with crude protein content of rice in cold area while remarkable positive correlation with amylose content. Overall, different types of rice have their most suitable planting density to be fine varieties. Over low or over high planting density is not beneficial to the improvement of the comprehensive qualities of rice. Over high planting density may decrease the nutritive area of rice plant, nitrogen absorbed from the soil as well as protein content of rice[35]. Meanwhile, ventilation and penetrating light will be decreased and "green rice" amount may be increased, which worsens the processing quality and appearance quality of rice.

4 Conclusion

Planting density is of great significance in adjusting rice population structure, improving yield and decreasing the cost. Suitable planting density can not only coordinate the relationship between rice individual and population, bring the yield potential of rice population into full play, obtain the maximum grain yield per unit area, but also save labor, protect the environment and improve rice quality. Domestic scholars have already conducted great researches on the impact of planting density on rice yield and quality. However, most researches only focus on one or two cultivars and the research density scopes are different, therefore there are remarkable difference in the research results. In future research, various factors like variety characteristics of rice, seedling quality, fertilizer application and field management should be taken into consideration. The establishment of suitable planting density should based on the consideration of labor-saving, high yield and high efficiency. Hill amount per unit area and basic seedlings should be decreased in order to save labor and tillering advantages of rice should also be used in order to optimize population structure. Light energy should be used to the maximum through adjusting row spacing at an attempt to accumulate the most dry matters and achieve high yield.

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