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Primary Study on the Identification Method of Rice Shade-Endurance

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Abstract: In order to provide scientific theoretical basis for identifying the rice shade-endurance and develop the rice production of china. The effects of 50% shading in different breeding stage on root system, photosynthetic rate, the leaf area index and yield of rice were studied. Results showed that under shading stress, the growth of root system was inhibited, the photosynthetic rate, number of effective panicles, grains per panicle, filled grain per plant, seed setting rate, 1000 grain weight and grain yield decreased meanwhile, the leaf area index and number of sterile per seed increased. The biggest effect was shading in elongating-heading stage and then were shading in filling stage and tillering stage. Six indexes such as root vigor, root volume, root active absorbing area, photosynthetic rate of leaf, seed setting rate and grain yield, etc., could be taken as identification indexes of rice shade-endurance. By using integrated shade-endurance coefficient as evaluating index and rice shade-endurance could be divided into 3 grades. Among these varieties, the shade-endurance of 5 varieties such as Dyou158 and Dyou527, etc., were stronger, the shade-endurance of Gangyou906 and Yifeng8 were weaker.

Key words: Identification method, rice, root system, shading, indexes, P.R. China

INTRODUCTION

Shading is an adverse circumstance which was encounter by rice during its growth period in most areas of China, restricting to increase yield and quality of rice. The research shows that the effects on growth and yield of rice were different under shading in different periods. In prophase, the main effect is morphological development, like tillering, the leaf area index and accumulation of dry matter and so on in later stage, the main effects are yield and quality (Li *et al*., 1990; Li and Zhang, 1994a, b; Li and Zhang, 1995; Kunzheng and Shiming, 1999).

The shade-endurance of different varieties or the same variety in different breeding stages is different but generally speaking as far as shade-endurance is concerned, keng rice is stronger than hsien rice; late keng rice is stronger than keng rice (Li and Zhang, 1991; Li *et al*., 1994).

So, breeding rice varieties which have stronger shade-endurance is a valid method to improve the yield and quality of rice in shading ecotypes. The root is an important organ of rice to absorb water and nutrient, it also is an important organ to compose amino acid and many kinds of endogenous hormone. The growth of root system is related to illumination closely. The research shows that the distribution of root was effected by illumination and temperature. The root vigor of rice dropped under 70% shading treatment in filling stage (Li and Zhang, 1994b). But because of difficulties of taking samples, imitating and controlling adverse circumstances of shading, at present, only a few researches were selecting and appraising the shade-endurance of rice varieties according to content of chlorophyll, photosynthetic rate, the vigor of PSII (Demao *et al*., 1995; Chen, 1997; Li *et al*., 1999) but they were not all-round and the method was difficult.

MATERIALS AND METHODS

Varieties of hybrid rice in the experiment: Neixiangyou13 (II-32A×Neixianghui1), Gangyou99-14 (Gang46A×Neihui99-14), Dyou158 (D62A×Shuhui158), Jinyou188 (Jin23A×Lehui188), Gangyou188 (Gang46A× Leghui188), IIyou498 (II-32A×Shuhui498), IIyou162 (II-32A×Shuhui162), Chuanxiang9838 (Chuanxiang29A× Fuhui838), Dyou527 (D62A×Shuhui527), Fuyou1 (II-32A×R21), Gangyou881 (Gang46A×Shuhui881), Gangyou363 (Gang46A×Shuhui363), Gangyou906 (Gang46A×Shuhui906), Yifeng8 (K22A×Shuhui527), Gangyou527 (Gang46A×Shuhui527) and Gangyou99-11 (Gang46A×Neihui99-11).

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Design of experiment: The experiment was carried out on the farm of Sichuan Agriculture University from March, 2006 to October, 2007 (data based on the same site but replicate 2 years). A dopting two factors split-plot design, the main factor is shading in breeding stage (A) including 4 levels. A_1: CK (natural daylight); A_2: shading in tillering stage; A_3: shading in elongating-heading stage; A_4: shading in filling stage.

The secondary factor is variety (B) including 16 levels. B_1: Neixiangyou13; B_2: Gangyou99-14; B_3: Dyou158; B_4: Jinyou188; B_5: Gangyou188; B_6: IIyou498; B_7: Iiyou162; B_8: Chuanxiang9838; B_9: Dyou527; B_{10}: Fuyou1; B_{11}: Gangyou881; B_{12}: Gangyou363; B_{13}: Gangyou906; B_{14}: Yifeng8; B_{15}: Gangyou527; B_{16}: Gangyou99-11.

Each treatment planted 4 lines ×17 scoops, the area of areola is 1.07×3 m, row spacing is 26×18 cm. In different breeding stages, using 16 meshes white gauze to shade and then measuring the transmittance everyday by luminometer insuring that actual transmittance is 50%.

Measuring items and methods

Root volume: Absorbing root water by filter paper then using draining method to measure root volume of 3 scoops rice, replicate 3 times.

Root overall absorbing area, active absorbing area and comparing surface: Adopting adsorbing methylenum coagulum to measure 3 scoops rice, replicate 3 times (Xiong, 2003).

Root vigor: Adopting α-naphthylamine method, replicate 3 times (Xiong, 2003).

Photosynthetic rate: Measured by photosyntometer, replicate 3 times.

Leaf area index: Measured by plant canopy instrument (CI-110), replicate 3 times.

Grain yield: Take 30 scoops to measure number of effective panicles, grains per panicle, filled grain per plant, sterile per seed, seed setting rate, 1000 grain weight and grain yield, replicate 3 times.

Analysis data: Using software such as DPS7.55 and Excel 2003. According to Huai-Zhu Chen's Method, calculating shade-endurance index, shade-endurance coefficient and integrated shade-endurance coefficient (Chen *et al*., 2003). The formates are as follows; shade-endurance index = |(data under shading-data under natutural day light)|/data under naturual day light; shade-endurance coefficient = 1 - shade endurance index; integrated shade-endurance coefficient; the upgma average of shade-endurance coefficient which could be used to identify shade-endurance.

RESULTS

Effects of shading on root system, photosynthetic rate, leaf area index and grain yield: Analyzing 16 varieties' root system, photosynthetic rate, leaf area index and grain yield under shading in different stages are in Table 1. The research showed that each character of root system, photosynthetic rate, leaf area index and grain yield put up discrepancies between shading treatment and natural daylight treatment in whole stages. Its fundamental tendency was that the root volume, root overall absorbing area, root active absorbing area, root comparing surface and root vigor were dropped with shading treatment; photosynthetic rate, number of effective panicles, grains per panicle, filled grain per plant, seed setting rate, 1000 grain weight and grain yield decreased while leaf area

Table 1: Average values of the variance of characters between shading and CK and their significant difference test (F)

	Treatments				
	Average values of the variance (Shading)			Significant analysis	
Items	In tillering stage	In elongating-heading stage	In filling stage	Variety	Shading treatment
Root volume	-15.62	-25.37	-35.22	1.78*	7.71**
Root overall absorbing area	-8.32	-15.04	-8.96	1.55	4.71
Root active absorbing area	-1.95	-2.93	-3.49	6.26**	16.02**
Root comparing surface	-0.07	-0.01	-0.17	1.65	2.93
Root vigor	-23.31	-17.14	-8.11	2.55*	11.50**
Photosynthetic rate	-2.32	-12.54	-6.85	3.64*	12.75**
Leaf area index	1.20	2.21	1.44	1.24	3.25
Number of effective panicles	-21.02	-32.58	-27.85	7.55**	4.88
Grain per panicle	-2.75	-5.85	-4.77	7.22**	6.25**
Filled grain per panicle	-3.78	-6.52	-4.44	8.25**	12.27**
Number of sterile per seed	15.24	22.20	17.50	6.66**	14.27**
Seed setting rate	14.25	18.75	16.60	7.52**	13.32**
1000 grain weight	-1.20	-1.82	-1.55	3.35	2.75
Grain yield	-24.50	-31.24	-28.80	8.77**	12.75**

*For 0.05 significant level; **for 0.01 significant level

index and sterile per seed increased. By analysis of variance, the result of significance test showed that the variation of the root volume, root overall absorbing area, active absorbing area comparing surface, root vigor, photosynthetic rate, grains per panicle, filled grain per plant, sterile per seed, seed setting rate and grain yield caused by shading treatment reached to statistical significance at the 0.01 probability level. Variation of different genotypes varieties existed discrepancy, some indexes such as active absorbing area, number of effective panicles, grains per panicle caused by shading treatment reached to statistical significance at the 0.01 probability level. It reflected the shade-endurance of different varieties.

The effects of shading on root, photosynthetic rate, leaf area index and grain yield could be measured by the variation degree of each index under shading that is shade-endurance index. According to the numerical value of each character under shading treatment and natural daylight, researchers can calculate shade-endurance index then adding these shade-resistance indexes under three shading treatments, the sequence is root active absorbing area (3.948)>sterile per seed (3.424)>seed setting rate (3.101)>photosynthetic rate (2.886)>grain yield (2.875)>filled grain per plant (2.530)>root vigor (2.134)>root volume (1.960)>grains per panicle (1.834)>number of effective panicles (0.734)>root overall absorbing area (0.655)>leaf area index (0.522)>root comparing surface (0.467)>1000 grain weight (0.112). It is thus clear that the effects of shading on the anterior 9 indexes are stronger; the effects of shading on latter 5 indexes are weaker.

Methods of evaluating the shade-endurance of rice: May know by the above analysis after shading treatment, all characters of root system, photosynthetic rate, leaf area index and yield component had changed, the effected degree of different characters also existed discrepancies. Researchers thought that these indexes such as root active absorbing area, sterile per seed, seed setting rate, photosynthetic rate, grain yield, filled grain per plant, root vigor, root volume and grains per panicle can be regarded as evaluating indicator of shade-endurance.

However, because seed setting rate is focused on filled grain per plant, sterile per seed and grains per panicle, so there can omit the three indexes and only select seed setting rate. Therefore, we considered that root active absorbing area, seed setting rate, photosynthetic rate, grain yield, root vigor and root volume can be used for calculate integrated shade-endurance coefficient which is used to appraise a variety's shade-endurance. From Table 2, the integrated shade-endurance coefficient under shading treatment in tillering stage was the biggest, next were the filling stage and the elongating-heading stage. So, the ability of resisting shading in tillering stage was strongger, the ability of resisting shading in elongating-heading stage was weaker. By cluster analysis, divide the ability of resisting shading in tillering stage into 3 levels. The 1st level is stronger, the integrated shade-endurance coefficient ≥0.735; the 2nd level is medium, the integrated shade-endurance coefficient is 0.617-0.735; the 3rd level is weaker, the integrated shade-endurance coefficient is ≤0.617. Divide the ability of resisting shading in the elongating-heading stage into 3 levels. The 1st level is stronger, the integrated shade-endurance coefficient ≥0.711; the 2nd level is medium, the integrated shade-endurance coefficient is 0.552-0.711; the 3rd level is weaker, the integrated shade-endurance coefficient ≤0.552. Divide the ability of resisting shading in the filling stage into 3 levels.

Table 2: Shade-endurance coefficient and integrated shade-endurance coefficient of six identification indexes

	Shade-endurance coefficient		
Items	In tillering stage	In longating-eheading stage	In filling stage
Root active absorbing area	0.487^{aA}	0.239^{cC}	0.326^{bB}
Seed setting rate	0.488^{aA}	0.305^{bB}	0.240^{cC}
Photosynthetic rate	0.452^{aA}	0.227^{cC}	0.288^{bB}
Grain yield	0.124^{bB}	0.018^{cC}	0.192^{aA}
Root vigor	0.261^{cC}	0.310^{aA}	0.285^{bB}
Root volume	0.479^{aA}	0.320^{cC}	0.385^{bB}
Integrated shade-endurance coefficient	0.381^{aA}	0.237^{cC}	0.286^{bB}

Small letter for 0.05 significant levels, big letter for 0.01significant levels

The 1st level is stronger, the integrated shade-endurance coefficient ≥0.718; The 2nd level is medium, the integrated shade-endurance coefficient is 0.628-0.718; the 3rd level is weaker, the integrated shade-endurance coefficient ≤0.628.

Appraisal the shade-resistance of these varieties: According to the integrated shade-endurance coefficient, researchers could cluster 16 different genotypes varieties under shading in the 3 stages. When shading in tillering stage, shade-endurance of these varieties are stronger: Dyou158, Jinyou188, Gangyou188, Chuanxiang9838 and Dyou527; Medium including: Nei-xiangyou13, IIyou162, Gangyou527 and Gangyou99-11; weaker including: Gangyou99-14, IIyou498, Fuyou1, Gangyou881, Gangyou363, Gangyou906 and Yifeng8 (Fig. 1). When shading in elongating-heading stage, shade-endurance of these varieties are stronger: Gangyou188, Chuanxiang9838, Dyou527, Gangyou881 and Gangyou363; Medium including: Neixiangyou13,

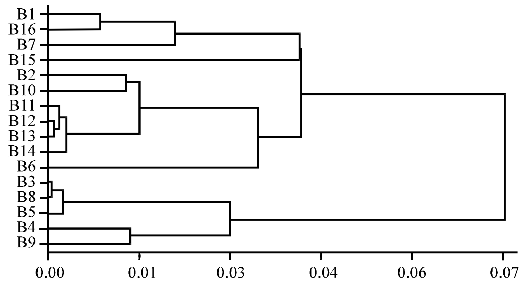

Fig. 1: Cluster analysis dendrogram of variety with Shading in tillering stage (B_1: Neixiangyou13; B_2: Gangyou99-14; B_3: Dyou158; B_4: Jinyou188; B_5: Gangyou188; B_6: IIyou498; B_7: Iiyou162; B_8: Chuanxiang9838; B_9: Dyou527; B_{10}: Fuyou1; B_{11}: Gangyou881; B_{12}: Gangyou363; B_{13}: Gangyou906; B_{14}: Yifeng8; B_{15}: Gangyou527; B_{16}: Gangyou99-11

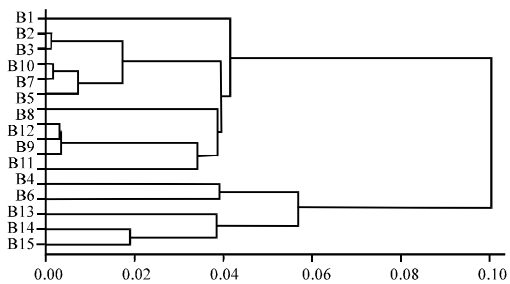

Fig. 2: Cluster analysis dendrogram of variety with shading in elongating-heading stage (B_1: Neixiangyou13; B_2: Gangyou99-14; B_3: Dyou158; B_4: Jinyou188; B_5: Gangyou188; B_6: IIyou498; B_7: IIyou162; B_8: Chuanxiang9838; B_9: Dyou527; B_{10}: Fuyou1; B_{11}: Gangyou881; B_{12}: Gangyou363; B_{13}: Gangyou906; B_{14}: Yifeng8; B_{15}: Gangyou527; B_{16}: Gangyou99-11

Gangyou99-14, Dyou158, IIyou162, Fuyou1 and Gangyou99-11; Weaker including: Jinyou188, Iiyou498, Gangyou906, Yifeng8 and Gangyou527 (Fig. 2). When shading in filling stage, shade-endurance of these varieties are stronger: Gangyou881, Gangyou363 and Gangyou99-11; Medium including: Neixiangyou13, Gangyou99-14, Dyou158, Jinyou188, IIyou498, Chuanxiang9838, Dyou527, Fuyou1 and Gangyou527; Weaker including: Gangyou188, IIyou162, Gangyou906 and Yifeng8 (Fig. 3).

Therefore, among these genotypes varieties, Dyou158, Dyou527, Chuanxiang9838, Neixiangyou13 and Gangyou99-11 could resist shading in the whole stage while Gangyou906 and Yifeng8 have weaker shade-endurance.

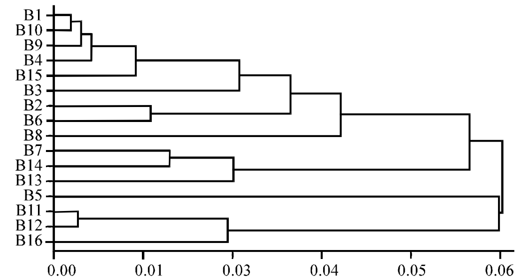

Fig. 3: Cluster analysis dendrogram of variety with Shading in filling stage (B_1: Neixiangyou13; B_2: Gangyou99-14; B_3: Dyou158; B_4: Jinyou188; B_5: Gangyou188; B_6: IIyou498; B_7: IIyou162; B_8: Chuanxiang9838; B_9: Dyou527; B_{10}: Fuyou1; B_{11}: Gangyou881; B_{12}: Gangyou363; B_{13}: Gangyou906; B_{14}: Yifeng8; B_{15}: Gangyou527; B_{16}: Gangyou99-11

DISCUSSION

The relationship between illumination and growth of root system: Illumination is one of the most important environment factors that effect the growth of root system. Shade has an important effect on the synchronous growth of roots and the leaves and the effect on the growth of underground far bigger than overground. The research indicated that after shading, the weight of root drops, the number of new born root reduces, the root density reduces (Mawaki *et al*., 1990a, b; Morita and Yamazaki, 1992). Moreover after shading, root vigor drops (Osaki *et al*., 1995), the total sugar content of root drops (Yamaguchi *et al*., 1995), the breath of root drops (Tatsumi and Kono, 1983; Tsuno and Yamaguchi, 1989), simultaneously after shading, the oxidizing power of root system drops when they were new, increases when they were old (Tatsumi and Kono, 1980).

The research believed that shading seriously hindered the growth of root, promoted the senile of root system such as the dropping of root volume and root vigor, these results are in accordance with Pan *et al*. (1996)'s findings. Among them, the biggest effect was shading in elongating-heading stage then is shading in filling stage and shading in tillering stage.

This may be has close correlation with the growth characteristic of root system. That is the effects of shading on root system were bigger in the root system most exuberant and starting senile. The different variety have the different abilities of resisting shading, displays the scope of the root system character dropping are difference compared with CK. This experiment believed that the shade-resistance of Jin-you188 and II-you498 are stronger, Gang-you881, Gang-you363 is weaker by the growth of root system. By using 1,081 varieties, Yoshida investigated the relationship between plant height, tillering and the root system growth in the greenhouse with the root box, discovered that the deeper the root system distributed, the higher plant height grows and the less tillered. In addition, the research indicated that the root system of big ear variety is wider, the proportion of deep-seated root is bigger; the root system of small ear variety is slender and mostly distributing in the soil surface.

Therefore, may believe like this, the shade-endurance of 5 varieties such as Dyou158, Dyou527, etc., were stronger, the shade-endurance of Gangyou906 and Yifeng8 were weaker.

Application root system character to select shade-resistance rice variety: Selecting indexes which are used for appraisal shade-resistance of rice relates the reliability which evaluates the shade-resistance synthesis. The selection index character not only needs to consider reliability but also must have the feasibility of actual operation in actual field.

In the experiment, taking root vigor, root volume, root active absorbing area, photosynthetic rate, seed setting rate and grain yield as appraising indexes, compared with former researches which based on chlorophyll content, photosynthesis rate, PS II activeness8-10, it is more operational to use the integrate shade-resistance coefficient to valuate the shade-resistance of rice.

Meanwhile, combine photosynthetic rate, leaf area index and grain yield with root system, it not only makes identification more scientific but also lead the research to a new area that is the growth and development of crop root system and promote to establish appraisal system of rice shade-resistance.

CONCLUSION

The experiment studied 16 genotypes rice under shading treatment in different stages by artificial shading. It not only can reveal the effects of low-light for root system in different growth stages but also can offer new method for selecting rice varieties in low-light areas.

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