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Analysis of Combining Ability and Heritability about Nut Quality of Walnut

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Abstract: Total 24 hybrid combinations were formulated by NC II design using hybrids (*J. sigillata* × *J. regia*) Yunxin 7926 (P_{11}), 8064 (P_{12}), 8034 (P_{13}), 7914 (P_{14}) as female parent and 6 superior trees of *J. sigillata* from Sichuan as male parent. The combining ability and heritability of walnut characters were studied, including diameter, weight, thickness and rate of kernel. The result shown that: both additive variation and non-additive variation were significant in these 4 characters, but the additive variation was principle. Different parent had different excellent genes. P_{24}, P_{23}, P_{22} and P_{14} were the best parent to improve walnut diameter and weight, followed by P_{21}, P_{13} and P_{11}. In contrast, P_{25} and P_{26} shown poor effect on diameter and weight. Cross $P_{1}\times P_{23}$, $P_{11}\times P_{24}$ and $P_{12}\times P_{24}$ were good for increasing diameter, while cross $P_{11}\times P_{26}$ was the best in increasing rate of kernel. The broad-sense heritability was ordered from high to low as diameter (0.990)>thickness(0.968)>rate of kernel (0.970)>weight (0.968) and the narrow-sense heritability was ordered as diameter (0.844)>thickness (0.821)>weight (0.735)>rate of kernel (0.693).

Key words: Walnut, nut quality, combining ability, heritability, China

INTRODUCTION

Cross breeding of *Juglans* between interspecies began in the 60s of the 20th century in China. According to incompletely statistics, about 35 hybrid varieties were cultivated up to 2002 (Hua-Bai and Fang, 2004). There were few reports about genetic development of walnut at home and abroad. Only Hansche *et al*. (1972), analyzed heritability of 18 characters of *J. regia* L. by standard deviation method and no any report about combining ability. This study analyzed and estimated the combinding ability and heritability of progenies of 24 hybrid combinations by their 4 main characters can reflect walnut's quality, which provides references for selective mating of hybrid parent, the selection of hybrid progeny and the collocation of clones and families in breeding garden.

MATERIALS AND METHODS

Female parents (P_1) are 7926 (*J. sigillata* × *J. regia*), 8064 (*J. sigillata* × *J. regia*), 8034 (*J. regia* × *J. sigillata*) and 7914 (*J. sigillata* × *J. regia*) cultivated by cross breeding of (*J. sigillata*) and (*J. regia* Dode). P_{11}~P_{14} represent 4 female parents respectively, which were introduced from Yunnan Province in China in 2001 are characterized by early bearing and thin shell. Six male parents (P_2) are *J. sigillata* with characteristics of thin shell and high yields, which were selected from Sichuan province in China represented by P_{21}~P_{26}, respectively. There are 1080 hybrid nuts picked from above 24 hybrid combinations in 2006 in the present study.

Experiment site located in Cheng Du city in Sichuan province of China, where the altitude is 480 m, mean annual temperature is 16.5°C, annual amount of precipitation is 900 mm and annual sunshine hours are 1298.2 h has a subtropical climate, the wet summer, moderate and moist climate and the space of seed tree is 5×5 m.

NCII was used in experiment, data was processed by Excel 2003, genetic parameter was estimated by the method of Zhi-Ren (1986). Combining ability was estimated by fixed model and variance component and the genetic parameters were estimated by random model. The nuts were picked after they are fully matured, then natural withered. Measure their thickness of abdomen, diameter of abdomen, diameter of seam and height by vernier caliper, calculate the average of above 3 values as nut diameter, weigh their weight and kernel weight by electronic balance and calculate the rate of kernel. Each

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combination repeated 3 times, each repetition selected 5 nuts randomly from 3 seed trees. Analyzed their average means, the percentage should be transferred into arcsine by their square root.

RESULTS AND DISCUSSION

Measured characters: In this study, the characters have obvious differentiation between single nuts. Diameter: 29.5-46.1 mm, weight: 9.05-18.91 g, thickness: 0.56-1.06 mm, kernel rate: 50.02-68.33%. But, there is no obvious difference between repetitions in a combination. Four characters of each combination are shown in Table 1.

Four characters of hybrid nuts and parents in original place shown in Table 2.

From Table 2, hybrid nuts showed a significant heterosis on the whole, which is consistent with Zhi-Yuang and Xue-Liang (2002). The values of 4 characters of hybrid nuts are not only higher than their parents average, but also surpass the dominant parent reflecting heterobeltiosis to some extent, which is in line with Yin and Mei-Yong (2005).

From Table 3 and 4 characters have no significant difference between repetitions, but have an extremely significant between combinations, which indicate that the true genetic difference dose existed. Then analyze the General Combining Ability (GCA) and Special Combining Ability (SCA).

Analysis of combining ability

Variance analysis of combining ability: The results of variance analysis of combining ability based on the average values of the repetition in combinations are as follow (Table 4).

It can clearly shown from Table 4 that the characters of nut diameter, weight and thickness are affected by parent's GCA and SCA, while rate kernel is only affected by the male parent's GCA and SCA. Male parent's GCA has an extremely significant difference on 4 characters, while female parent's GCA has difference only on rate kernel. In combinations, all SCA have an extremely significant difference on 4 characters, which indicated that the selection of parents mating is very important to the quality of nuts. From the results, we can show that both GCA and SCA will affect the characters of nut. From the standpoint of quantitative inheritance, the 4 characters are affected by additive effect and non-additive effect at the same time.

Although, thickness is also affected by GCA and SCA of parents, up to 0.01 levels notable difference on statistics, thickness of both parents is thin, so the hybrid nut has thin shell: 0.56-1.06 mm, which is thinner than top-grade (1.1 mm) one and superior tree (1.5 mm) stipulated by national standard (GB 7907-87). It reflects thickness has no large variability from commodity value.

GCA of parents and its expression: Different parents have a low GCA on thickness of hybrid nut, because both parents are characterized by thin shell. While, nut diameter, weight and rate of kernel display a significant difference between different parents. GCA ranges from 3.63-2.29 on nut diameter and P_{24} has the highest GCA, P_{23} takes second place, P_{26} at lowest. For nut weight, GCA ranges -2.12-1.34, P_{24} has the highest GCA, P_{23} takes second place, P_{25} at lowest. For kernel rate, GCA ranges from -2.64-1.59, P_{21} has the highest GCA, P_{26} takes second place, P_{23} at lowest. GCA of the same parent is different even on different characters. For example, P_{23} and P_{24} have superiority on nut weight and diameter, but their GCA is lower on kernel rate. On the contrary, P_{26} and P_{25}, with small diameter and light weight, their kernel rates display a high positive effect, which shows different parents have different excellent genes. The results indicate that not any parent can promote qualities of nut (Table 5).

SCA effect: From Table 6, SCA of different combinations has significant difference on the same character except thickness. Take kernel rate as an example, the variability

Table 1: Characters means of crosses

	Nut diameter (mm)				Nut weight (g)				Thickness (mm)				Rate of kernel (%)			
Variables	P_{11}	P_{12}	P_{13}	P_{14}	P_{11}	P_{12}	P_{13}	P_{14}	P_{11}	P_{12}	P_{13}	P_{14}	P_{11}	P_{12}	P_{13}	P_{14}
P_{21}	37.98	40.36	38.06	40.50	12.72	13.30	12.36	14.43	0.92	0.93	0.91	0.92	60.89	60.77	59.83	60.04
P_{22}	40.17	40.77	39.06	40.76	13.16	13.62	13.10	14.79	0.93	0.94	0.92	0.94	59.14	58.28	60.00	57.09
P_{23}	41.35	40.06	39.92	41.47	14.41	14.45	13.32	14.37	0.95	0.96	0.94	0.96	56.10	55.77	57.64	55.08
P_{24}	41.73	42.02	39.78	41.61	13.98	13.90	13.76	15.31	0.92	0.96	0.93	0.95	58.12	57.96	58.28	55.33
P_{25}	36.53	36.99	36.93	38.40	10.21	10.88	10.72	11.31	0.90	0.90	0.90	0.92	59.86	59.41	59.92	60.43
P_{26}	34.69	34.77	34.93	37.07	12.75	9.95	10.39	12.67	0.88	0.89	0.89	0.91	61.77	59.17	59.86	60.26

Table 2: Means of parents and hybrids character

Hybrids characters	Nut diameter (cm)	Nut weight (g)	Thickness (mm)	Rate of kernel (%)
Female	30.8-36.4	9.19-11.74	0.92-0.95	53.1-55.7
Male	33.4-38.1	9.58-12.37	0.93-0.98	52.2-56.3
Progeny	39.0-00.0	12.91-00.00	0.92-0.00	58.79-0.0

Table 3: Variance analysis

		Nut diameter		Nut weight		Thickness		Rate of kernel	
Source	df	Variance	F	Variance	F	Variance	F	Variance	F
Repetition	2	0.32	2.48	0.162	<1.00	0.003	<1.00	0.087	<1.00
Combination	23	1.03	7.91**	0.823	4.21**	0.014	3.37**	0.451	5.09**
Residual error	46	0.13		0.195		0.004		0.088	

Table 4: Variance analysis of combining ability

		F-value			
Source	df	Nut diameter	Nut weight	Thickness	Rate of kernel
Female GCA	3	6.93**	6.05**	9.16**	2.77
Male GCA	5	39.59**	20.18**	30.52**	17.33**
SCA	15	12.11**	6.46*	5.16**	7.81**

Table 5: Effect size of general combining ability in parents

Variance	P_{11}	P_{12}	P_{13}	P_{14}	P_{21}	P_{22}	P_{23}	P_{24}	P_{25}	P_{26}
Nut diameter	-0.26	0.17	-0.88	0.97	0.23	1.19	1.71	2.29	-1.79	-3.63
Nut weight	-0.04	-0.23	-0.64	0.90	0.29	0.76	1.23	1.33	-2.13	-1.47
Thickness	-0.01	0.01	-0.01	0.01	0.00	0.01	0.03	0.02	-0.02	-0.03
Rate of kernel	0.52	-0.23	0.46	-0.75	1.59	-0.16	-2.64	-1.37	1.11	1.47

Table 6: Effect size of special combining ability in crosses

	Nut diameter				Nut weight				Thickness				Rate of kernel			
Variables	P_{11}	P_{12}	P_{13}	P_{14}	P_{11}	P_{12}	P_{13}	P_{14}	P_{11}	P_{12}	P_{13}	P_{14}	P_{11}	P_{12}	P_{13}	P_{14}
P_{21}	-0.99	0.96	-0.28	0.30	-0.45	0.33	-0.21	0.33	0.01	0.00	0.00	-0.01	-0.01	0.62	-1.01	0.41
P_{22}	0.23	1.37	-0.25	-0.40	-0.47	0.18	0.07	0.22	0.01	0.00	-0.01	0.00	-0.01	-0.11	0.91	-0.78
P_{23}	0.90	-0.81	0.10	-0.20	0.31	0.54	-0.18	-0.67	0.00	0.00	0.00	0.00	-0.56	-0.15	1.03	-0.31
P_{24}	0.69	0.10	-0.63	-0.65	-0.22	-0.10	0.16	0.17	-0.01	0.02	-0.01	0.00	0.17	0.77	0.40	-1.34
P_{25}	-0.43	-0.39	0.60	0.21	-0.53	0.33	0.58	-0.38	0.00	-0.01	0.00	0.00	-0.56	-0.26	-0.45	1.28
P_{26}	-0.42	-0.76	0.44	0.72	1.35	-1.26	-0.41	0.33	-0.01	-0.01	0.01	0.01	0.98	-0.86	-0.87	0.75

Table 7: Heritability and contribution rate of genotype variance of characters

	Genotype variance			Contribution rate (%)				Broad-sense heritability	Narrow-sense heritability
Variance	P_1	P_2	$P_1 \times P_2$	V_g	V_{g1}	V_{g2}	V_s	(h_B^2)	(h_N^2)
Nut diameter	0.519	5.067	0.482	92.06	8.56	83.50	7.94	0.990	0.844
Nut weight	0.222	2.018	0.356	86.30	8.55	77.75	13.70	0.968	0.735
Thickness	0.096	0.519	0.057	91.55	14.24	77.31	8.45	0.973	0.821
Rate of kernel	0.068	0.941	0.201	83.40	5.63	77.77	16.60	0.970	0.693

of SCA between combinations is -1.34~1.28. SCA of $P_{11} \times P_{26}$ is 1.35 on nut weight, while $P_{12} \times P_{26}$ is -1.26. Even the same combination has obviously different SCA on different characters. For example, $P_{11} \times P_{23}$ has a high positive effect on nut diameter, but displays a high negative effect on kernel rate. The variability of SCA on different characters is larger, $P_{11} \times P_{26}$ has the highest value, which is 1.35, $P_{24} \times P_{14}$ has the lowest value, which is -1.34.

GCA and SCA have no relationship by comparing their effect. For example, $P_{11} \times P_{26}$ has a higher SCA on kernel rate, P_{11} and P_{26} have a higher GCA effect, while P_{23} have the lowest GCA effect although, combination $P_{13} \times P_{23}$ has a higher SCA; although, $P_{11} \times P_{26}$ has the highest SCA on nut weight, the two parents have negative GCA values; there are not any combinations with a higher SCA among P_{14}, P_{24} and P_{23}, which have a higher GCA on nut weight and diameter. The result shows that not any GCA effect can totally decide qualities of nut. All the expression of characters is depend on multiple factors and even the low GCA effect parents can form a high SCA effect combination.

Estimation of colony genetic parameters: Estimate the genotype variance of GCA (P_1, P_2) and SCA ($P_{1\times2}$) and analyze their contribution rate (V_g, V_s) in total variance and the GCA contribution rate (V_{g1}, V_{g2}) of two parents, respectively to know about the effect of two parents and their co-effect on nut quality shown in Table 7.

As can be shown in Table 7, 4 characters are affected by GCA and SCA at the same time, but the contribution rate of GCA is over 80%, while contribution rate of SCA is low, which reflects additive effect of gene has a leading role to decide hybrid expression and nut quality is decided by genetic traits of the parents, matching of parents has a lower effect to hybrid. GCA contribution rate of male parent is larger than that of female parent, which indicates that the hereditable character of male parent is larger than that of female one and hereditable character of male parent has a direct effect on nut quality.

CONCLUSION

Effect of combining ability and parent selection: GCA reflects additive effect of parents. If the parents have a higher additive effect, they will combine out an excellent progeny. But, it has a low possibility to possess an ideal GCA effect on several characters at the same time. So, we will select the parents by the main target breeding in cross breeding work. In this study, we can see that P_{24}, P_{23}, P_{22} and P_{14} has a good effect on improving nut diameter and weight, P_{21}, P_{13} and P_{11}take the second place, P_{25} and P_{26} at lowest. For kernel rate, P_{21} is the best, followed by P_{26} and P_{25}, P_{23} and P_{24} are worst. SCA displays non-additive effect. Although, effect value can not decide expression of offspring directly, it has a meaning of guidance to combinations and collocation of pollination trees. We can not select the combinations only with a higher SCA, but to select the higher SCA ones based on parents with higher GCA. So $P_{11}\times P_{23}$, $P_{11}\times P_{24}$ and $P_{12}\times P_{24}$ can improve diameter of nut. Although, $P_{13}\times P_{25}$, $P_{13}\times P_{26}$ and $P_{14}\times P_{26}$ have a high SCA, their parents have a lower GCA, the expression of the offspring is not so good. For nut weight, $P_{11}\times P_{26}$ has the highest SCA, but the GCA of P_{11} and P_{26} are negative, so their hybrid nut has no superiority. Although, SCA on kernel rate of $P_{11}\times P_{26}$ is not the highest, P_{11} and P_{26} have a higher GCA and the SCA is also higher, the kernel rate of its offspring is the highest among all the combinations.

Heritability of hybrid nut: Heritability is the percentage of genetic variance to phenotypic variance, which reflects stability of parent's property and the ability to pass their traits to offspring. Broad sense heritability reflects co-action of additive effect and non-additive effect, while narrow sense heritability is the measure of additive effect. For the 4 characters in this study, broad sense heritability is over 0.95, which is more than the heritability ($\geq$0.8) of thickness, diameter, weight and kernel rate estimated by Hansche *et al*. (1972). It shows that environment has a little effect on characters can guarantee genetic stability by asexual propagation. So, we can conserve and enlarge excellent genotype by grafting on excellent individual tree. Narrow sense heritability is between 0.693~0.844 shows 4 characters have a higher additive effect, so they have a stable heritability in sexual reproduction. It will be better to reselect after the walnut tree flowering and seedling.

Effect of genetic background of parents: Six male parents used in the research are seed trees selected from Sichuan province in China, where is the regional differentiation of two main walnut populations, with complex topography, diverse climates, rich in resources and the male parents have a larger difference of hereditary basis leading the great variability of the hybrid offspring. As can be shown in Table 7, variation of offspring mainly came from male parents. Although, GCA of different female parents is different, the difference is not large. Effect on offspring variation of Female parents is up to an extremely significant difference but much weaker than that of male parents, because of their consistent genetic background. The largest genotype contribution rate of female parents on thickness is only 14.24% shown in Table 7. It also, is the main reason female variability of GCA much smaller than that of male ones.

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