GENETIC CONTROL OF GRAIN LENGTH AND SHAPE IN BASMATI LINES OF RICE (*ORYZA SATIVA* L.)

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ABSTRACT

Understanding the genetics of grain length and grain shape is the prerequisite for developing premium quality Basmati varieties/lines. Two short grain with bold *Japonica* shape, one long grain slender Basmati shape and two extra long grain slender Basmati shape parental lines were used in the study. All the parents, F_1's and F_2 generations were raised during kharif 2008 at Rice Research Institute, Kala Shah Kaku, Pakistan. Grain length and shape was measured with a micrometer and were categorized following the Standard Evaluation System for Rice (IRRI, 1996). Chi square was used to compute the number of genes controlling the rice grain length and shape. All F_1's of crosses involving extra long grain Basmati parents resulted in long grain and Basmati shape. No segregation for grain length and shape was observed in F_2 of crosses involving extra long grain and long grain Basmati and non Basmati parents. F_1 of long grain Basmati line 00521 showed short and bold shaped *Japonica* grains. The F_2's of 99417 / TN1 segregated into 63:1 for grain length, indicating 3 dominant genes responsible for extra long grain length in 99417. However, Pusa Basmati / TN1 segregated for grain length as 1023:1 indicating thereby 5 dominant genes for extra long grain length in Pusa Basmati. F_2 generation of both the extra-long grain parents i.e., Pusa Basmati and 99417, showed no genetic segregation revealing that the genes responsible for grain length may be same in Pusa Basmati and 99417. The F_2 of 00521 x King Dang Potang segregated into 1:67 for grain length indicating three recessive genes for Basmati grain length in 00521. A single dominant gene for Basmati grain shape in Pusa Basmati / TN1 and three recessive genes for Basmati shape in 00521 x King Dang Potang were observed.

KEYWORDS: ***Oryza sativa; japonica; indica;*** **grain length, grain shape, Basmati rice, segregating generations; Pakistan.**

INTRODUCTION

Rice is the second staple food of Pakistan after wheat. Rice input-output relationship is a source of increasing returns to the farmers (5). Early maturing lines having high activities of peroxidase enzymes alongwith the

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phenomenon of non-premature senescence can be developed through better pedigree selections (4). Grain size may be indicated by weight and volume. Grain weight may correlate with the components of grain volume, i.e., length, breadth and thickness but weight and length are commonly used indicators. Takeda (12) showed that the grain length is the strongest determinant of grain size. Environmental variation in grain length is generally smaller than that in grain weight, thus results in higher value of heritability of grain length. Variations in kernel breadth and thickness are much smaller than that in kernel length. Therefore grain length may be the best character for analysing the inheritance of grain size. Generally, grain size in commercial varieties with normal grain size is controlled by polygene. In hybrids between varieties with similar grain size, transgressive segregation for grain size may occur due to accumulation of plus or minor factors.

In crosses between varieties with very large or small grains, grain size is controlled by major gene(s) in some cases, but many cases involve multifactorial segregations. Morinaga *et al* (8) analysed the inheritance of long-kernel variety Ko-to (9.3mm) using several crosses with varieties having normal kernel length (around 5mm). Observing the segregating populations they concluded that long kernel of Ko-to was controlled by five cumulative genes. Takita (17) examined several F_2 populations of crosses between varieties with large and normal kernel size, and found that two to five cumulative genes were responsible for inheritance of kernel length. Takeda and Saito (16) analysed the inheritance of kernel length using F_2 population and backcross F_1 plants from a cross between Oochikara (7.0mm) and Taichung 65 (5.0mm). In backcrossed F_1 as well as in F_2, kernel length varied continuously, suggesting it was controlled by polygene. Diallel analyses revealed that the grain size is controlled by quantitative genes that adapt to the additive dominance model (7, 11, 18).

High frequency of progenies with maximum grain weight was observed in crosses involving bold and slender shaped parents (19). Chandraratna and Sakai (2) found matroclinous inheritance for grain weight in *indica* varieties (2). The difference between reciprocal crosses was 4.5 mg in F_1 and 0.9 mg in F_2. The analysed components of variance to estimate the heritability values were 0.77 (broad sense) and 0.40 (narrow sense).

Syakudo (11) and Ikeda (6) found in cultivar Tairyu-to incomplete dominant major gene pleiotropically controlling kernel length and plant height. Takeda and Saito (15) also detected in local variety Fusayoshi an incompletely dominant major gene, judging from their gene action, these three genes could be the same.

Generally, grain size correlates negatively with number of grains per plant, and seed weight correlates closely with seedling vigour (12). Therefore grain size may affect the fitness of genotype via seedling vigour and number of seeds. Small grain plants bear more seeds than large grain plants and small grain genotype and large grain genotype may equilibrate in the natural population.

The larger the grain, the higher is the frequency of grains with white belly or white core. Takeda and Saito (15) analysed the relationship between kernel weight and frequency of kernels with white belly using four F_2 populations with a large variation in kernel weight. The genetic imbalance between kernel length and hull length is more serious in small grain plants than in normal ones (14).

The mean weight of grains on primary rachis branches was 10 percent higher than that on secondary rachis branches. On the other hand, CV of weight of grains developing on secondary rachis branches was 30 percent larger than on primary rachis branches. This suggests that grain filling on secondary rachis branches is inferior to that on primary ones. Yield is a product of number and weight of kernels, large kernels do not necessarily cause high yield because of general negative association between kernel number and weight. For increasing yield potential, the source of photosynthate as well as the sink capacity (size x number of grains) must be improved (12). The present study was conducted to understand the genetics of grain length and grain shape for developing the best quality Basmati varieties.

MATERIALS AND METHODS

The study was conducted at Rice Research Institute, Kala Shah Kaku, Pakistan during 2008-10. Two short grain and bold shaped *Japonica* parents, two long grain slender Basmati shaped, one long grain slender non Basmati and two extra long grain slender Basmati shaped parents were crossed in 2006 (Table 1, Fig. 1).

Table 1. List of parents used in the study.

Genetic source	Length (mm)	Shape
TN_1	4.86	Short and bold (Japonica)
King Dang Potang	5.02	Short and bold (Japonica)
00521	7.15	Long slender (Basmati)
Basmati 385	7.17	Long slender (Basmati)
KS 282	7.15	Long slender (non Basmati)
99417	8.30	Extra long slender (Basmati)
Pusa Basmati	8.20	Extra long slender (Basmati)

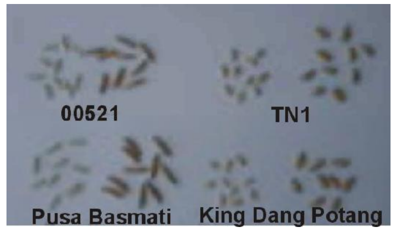

Fig.1. Parents used in the study for grain length and shape of rice.

F_1 was raised in kharif 2007. Fresh crosses among these parents were attempted to produce F_0 seed for the next year. All parents, F_1's and F_2 generations were raised and transplanted during kharif 2008. Fifty plants per parent, F_1's and almost 200 plants for F_2 generation per cross were used in the study. 20x20cm plant to plant and row to row distance was maintained from all sides. Recommended agronomic and plant protection measures were adopted. NPK was applied @ 100-85-62 kg per hectare. At maturity, main panicles were collected from parents and all generations. Micrometer was used to measure the grain length and width. Grain length and grain shape were measured according to Standard Evaluation System for Rice (1) which are given in Table 2.

Table 2. Specifications of brown rice length and shape according to Standard Evaluation System for Rice (IRRI, 1996).

Length		
Scale	Length (mm)	Category
1	> 7.5	Extra long grain
3	> 6.61-7.5	Long grain
5	> 5.51 – 6.6	Medium grain
7	< 5.5	Short grain
Shape		
Scale	Shape	Ratio
1	Slender	Over 3.0
5	Medium	2.1-3.0
9	Bold	Less than 2.0

For computing the number of genes responsible for grain length and grain shape Chi square method was used (3).

RESULTS AND DISCUSSION

Inheritance pattern of extra long grain parents Pusa Basmati, 99417 with short grain *Japonica* parent TN_1 is given in Table 3(a). It is evident that all the F_1's from Pusa Basmati x TN_1 and 99417 x TN_1 resulted in extra long grains (Fig. 2 & 3).

Fig. 2. F_1 of Pusa Basmati x TN_1

Fig. 3. F_1 of 99417 x TN_1

F_2 of 99417 x TN_1 segregated into 67:1, meaning thereby 3 dominant genes are important for extra long grain in 99417 (Fig. 4). However, F_2 of Pusa Basmati x TN_1 segregated into 656:1 showing 5 dominant genes for extra long grain in Pusa Basmati (Fig. 4).

Fig. 4.F_2 of Pusa Basmati x TN_1

Fig. 5. F_2 of 99417 x TN_1

Inheritance of long grain parent 00521 with short grain *Japonica* parent King Dang Potang is presented in Table 3(b). Short grain plants were observed in F_1 indicating recessive behaviour of grain length in 00521 (Fig. 6). F_2 from 00521 x King Dang Potang segregated into 1:67 which denotes the presence of 3 recessive genes for long grains in 00521 (Fig. 7). These results are in line with the findings of earlier researchers (7, 9, 12, 17, 18).

Fig. 6. F_1 of 00521 x King Dang Potang

Fig.7. F_2 of 00521 x King Dang Potang

The genetic segregation for grain length using both extra long grain parents i.e., Pusa Basmati and 99417 is presented in Table 3(c). F_1 of Pusa Basmati x 99417 showed extra long grain plants while F_2 of this cross did not show any genetic segregation for grain length (Fig. 8). These results indicate that the genes responsible for grain length may be same in both the parents i.e., Pusa Basmati and 99417.

Fig. 8. F_1 of 99417 x Pusa Basmati

It is clearly evident from Table 3(d) and Table 3(e) that using extra long grain and long grain parents (99417, Basmati 385 and KS 282) only long grain plants were observed in F_1's and F_2's and no short grain plant was observed in both crosses (Fig. 9 & 10).

Fig. 9. F_2 of 99417 x Basmati 385

Fig. 10. F_2 of 99417 x KS 282

Table 3. Segregation trials for grain length at RRI, Kala Shah Kaku during 2008.

a) Segregation in extra-long grain parents, Pusa Basmati, 99417 and short grain parent TN_1							
Parent/combination	Number of plants	Number of long grain plants	Number of short grain plants	Actual ratio (Sl.:Sh)	Expected ratio (Sl.:Sh)	X^2	P value
Pusa Basmati (P_1)	50	50	0	1:0	1:0		
99417 (P_2)	50	50	0	1:0	1:0		
TN1 (P_3)	50	0	50	0:1	0:1		
Pusa Basmati / TN1 (F_1)	50	50	0	1:0	1:0		
99417 / TN1 (F_1)	50	50	0	1:0	1:0		
Pusa Basmati / TN1 (F_2)	1970	1967	3	656:1	1023:1	8.1334	<0.005
99417 / TN1 (F_2)	204	201	3	67:1	63:1	0.2431	0.75-0.5
b) Segregation in long grain parent, 00521 and short grain parent King Dang Potang							
Parent/combination	Number of plants	Number of long grain plants	Number of short grain plants	Actual ratio (L.:Sh)	Expected ratio (L.:Sh)	X^2	P value
00521 (P_1)	50	50	0	1:0	1:0		
King Dang Potang (P_2)	50	0	50	0:1	0:1		
00521 / King Dang Potang (F_1)	50	0	50	0:1	0:1		
00521 / King Dang Potang (F_2)	204	3	201	1:67	1:63	0.6030	0.50-0.25
c) Segregation in extra-long grain parents, Pusa Basmati and 99417							
Parent/combination	Number of plants	Number of long grain plants	Number of short grain plants	Actual Ratio (L:Sh)	Expected ratio (L:Sh)	X^2	P value
Pusa Basmati (P_1)	50	50	0	1:0	1:0		
99417 (P_2)	50	50	0	1:0	1:0		
Pusa Basmati / 99417 (F_1)	50	50	0	1:0	1:0		
Pusa Basmati / 99417 (F_2)	200	200	0	No genetic segregation -			
d) Segregation in extra-long grain parent 99417 and long grain Parent KS 282							
Parent/combination	Number of plants	Number of long grain plants	Number of short grain plants	Actual ratio (L. :Sh)	Expected ratio (L. :Sh)	X^2	P value
99417 (P_1)	50	50	0	1:0	1:0		
KS 282 (P_2)	50	50	0	1:0	1:0		
99417 / KS 282 (F_1)	50	50	0	1:0	1:0		
99417 / KS 282 (F_2)	200	200	0	No genetic segregation			
e) Segregation in extra-long grain parent 99417 and long grain Basmati 385							
Parent/combination	Number of plants	Number of long grain plants	Number of short grain plants	Actual ratio (L. :Sh)	Expected ratio (L. :Sh)	X^2	P value
99417 (P_1)	50	50	0	1:0	1:0		
BAS. 385 (P_2)	50	50	0	1:0	1:0		
99417 / Bas. 385 (F_1)	50	50	0	1:0	1:0		
99417 / Bas. 385 (F_2)	204	204	0	No genetic segregation			

L. Long grain; Sh. Short grain; Sl. Slender

Basmati grain shape is the most important trait that a breeder conceives before starting breeding for the development of Basmati varieties. Table 4(a) indicates the pattern of genetic behaviour for grain shape. Basmati slender grain shape was observed in F_1 of Pusa Basmati x TN_1, indicating dominant nature of Basmati slender grain shape in Pusa Basmati (Fig. 2). F_2 of Pusa Basmati x TN_1 segregated into 2.79:1 that confirms the monogenic inheritance of Basmati slender grain shape (Fig. 4).

Table 4. Segregation trials for grain shape at RRI, Kala Shah Kaku during 2008.

a) Segregation in extra-long grain Pusa Basmati and TN_1							
Parent/combination	Number of plants	Plants bearing slender Basmati shaped grain	Plants bearing bold Japonica shaped grain	Actual ratio (Sl. :B)	Expected ratio (Sl. :B)	X^2	P value
Pusa Basmati (P_1)	50	50	0	1:0	1:0		
TN_1 (P_2)	50	0	50	0:1	0:1		
Pusa Basmati / TN_1 (F_1)	50	50	0	1:0	1:0		
Pusa Basmati / TN_1 (F_2)	197	145	52	2.79:1	3:1	0.0150	> 0.90
b) Segregation in long grain 00521 and bold grain King Dang Potang							
Parent/combination	Number of plants	Plants bearing slender Basmati shaped grain	Plants bearing bold Japonica shaped grain	Actual ratio (Sl. :B)	Expected ratio (Sl. :B)	X^2	P value
00521 (P_1)	50	50	0	1:0	1:0		
King Dang Potang (P_2)	50	0	50	0:1	0:1		
00521 / King Dang Potang (F_1)	50	0	50	0:1	0:1		
00521 / King Dang Potang (F_2)	204	3	201	1:67	1:63	19.134	<0.005
c) Segregation in extra-long grain parent 99417 and long grain parent KS 282 at RRI							
Parent/combination	Number of plants	Plants bearing slender Basmati shaped grain	Plants bearing bold Japonica shaped grain	Actual Ratio (Sl. :B)	Expected Ratio (Sl. :B)	X^2	P value
99417 (P_1)	50	50	0	1:0	1:0		
KS 282 (P_2)	50	50*	0	1:0	1:0		
99417 / KS 282 (F_1)	50	50*	0	1:0	1:0		
99417 / KS 282 (F_2)	200	200*	0	No genetic segregation			
d) Segregation in extra-long grain parents 99417 and long grain Basmati 385							
Parent/combination	Number of plants	Plants bearing slender Basmati shaped grain	Plants bearing bold Japonica shaped grain	Actual ratio (Sl. :B)	Expected ratio (Sl. :B)	X^2	P value
99417 (P_1)	50	50	0	1:0	1:0		
BAS. 385 (P_2)	50	50	0	1:0	1:0		
99417 / Bas. 385 (F_1)	50	50	0	1:0	1:0		
99417 / Bas. 385 (F_2)	207	207	0	No genetic segregation			

Sl. Slender; B. Bold; *Slender grain but non Basmati shape.

The inheritance pattern for grain shape using Basmati slender shape parent 00521 and bold *Japonica* shaped parent King Dang Potang is presented in Table 4(b). Bold *Japonica* shape was observed in F_1 of 00521 x King Dang Potang, indicating recessive behaviour of Basmati slender grain shape in 00521 (Fig. 6). F_2 of 00521 x King Dang Potang segregated into 1:67, meaning thereby 3 recessive genes are controlling Basmati slender shape in 00521 (Fig. 7). Slender but non Basmati grain shape was observed in F_1 and F_2 of 99417x KS 282, whereas, 99417 and Basmati 385 showed slender Basmati shape in F_1 and F_2. No plant bearing bold *Japonica* shaped grain was observed in both combinations and both generations (Table 4(c) & (d), Fig. 9 & 10). These findings are in line with the findings of Vivekanadan & Giridharan (19) and Takeda (12).

CONCLUSION

It is concluded that the choice of parents plays a vital role to get desirable recombinants for grain length and Basmati shape. All F_2 population of 99417 and KS 282 resulted in long slender grains but no Basmati grain shape was recorded in the population studied indicating the need for increase in population size in F_2 in this particular cross to get desirable slender Basmati shaped grain. Hence, breeders can plan to raise the population size of the material to be tested.

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