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Magnitude of heterosis for some quantitative traits in aromatic rice

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Abstract Measurement of heterosis is one among the strategies to achieve the targets in crop improvement, and serves as a guide in making sound decisions in selecting the best hybrids which could be commercially exploited and selected the desirable recombinants in the succeeding generations to develop new lines. The best heterotic effects on maturity was exhibited by CL 1 x P 20, CL 1 x G 12, CL 1 x G 28 and CL 1 X G 10 as shown by their highly significant negative MP heterosis values of -6.2%, -6.85%, -7.41% and -9.01%, respectively and BP heterosis with -8.01%, -7.41%, -10.06% and -9.97%. Heterosis in desirable direction was noted on plant height for Jasmine x P20 over its BP (-8.83%). Heterotic effects on panicle length was highly significantly differed and positively over MP and in maximum on Jasmine x G 28 (76.87%) and heterobeltiosis over the better parent in Kasturi x P 20 (21.13%). The positively significant MP heterosis for spikelet fertility was shown by CL 1 x G 28 (18.77%), Pandan x P 20 (18.39%), CL 1 x G 12 (17.40%), Pandan x G10 (16.76%) and CL 1 x P 20 (6.20%). Most of the crosses had highly significant recorded in positive MP (2.58 to 34.55%) and BP heterosis (6.00 to 30.12%) for 1000 seed weight. CL 1x G 10, CL 2 x G 12 and Pandan x P 20 revealed highly significant and positive MP (138.55%, 88.90% and 81.23%) and BP heterosis (66.00%, 125.36% and 48.60%) for yield. CL 1 x G 10, CL 2 x G 12 and Pandan x P 20 would be forwarded in the next generation for identification and selection of transgressive segregants for yield; CL 1 x P 20, CL 1x G 12, CL 1 x G 20 and CL 1x G 10 for earliness; and Jasmine x P 20 for dwarfness or shortness.

Keywords: Aromatic rice, Heterosis, Recombinants, Yield

Introduction

Rice self sufficiency and sustainability has been shown in the central focus of policy makers, public and private institutions to address the needs of the increasing global population. The area planted for rice was estimated to be 50 million hectares giving an annual production of almost 600,000,000 tons (Khush, 2005). Because of the burgeoning population which will be reached

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8,000,000,000 by 2030, there is a need to increase rice production by 50% (Khush and Brar, 2002).

Aromatic rice belongs to a small group of rices which is a special type of rice due to its exquisite 'pandan or popcorn-like' aroma and excellent eating qualities. This makes it popular and is now gaining wide acceptance both in the domestic and international markets. It is popular in the Philippines, Europe, Middle East, and United States. Most of the aromatic rice varieties introduced in the Philippines are the Basmati types, which originated from India, and Pakistan and Khao Dawk Mali from Thailand. Some were from China Japan and Korea and other parts of the world. Number of aromatic rice varieties in the Philippines were developed by the International Research Institute (IRRI) and Philippine Rice Research Instititute (PhilRice) such as NSIC Rc 220, NSIC Rc 128, NSIC Rc 218, Burdagol, and others. Some are traditional varieties or heirloom but are low yield while other varieties possess undesirable characteristics (very tall and are susceptible to lodging, pests and diseases). The University Research Center of Central Luzon State University (CLSU) has already developed the promising lines of special varieties of rice (CLS- 1, CLS- 2, CLS-3 and CLS-4) and several advanced lines with possible commercialization in the future. Despite all the efforts that have been made, there is a need to continuously develop rice varieties to address the problem on rice self-sufficiency.

In plant breeding activities, especially using the conventional method, selection process which is considered laborious and time consuming is a hit and miss process, which requires skills for visual rigorous selection and judging useful and desirable genotypes in the segregating populations. One of the biometrical tools in plant breeding is the estimation of heterosis. Although, it is quite simple to measure gene effects, this serves as a guide in selecting the best crosses to be exploited commercially or be used in selecting desirable recombinants in the succeeding generations and possibly be released as a new variety when it reaches homozygosity (Kumar *et al*., 2012). Positive and negative heterosis are both depending on the breeding objectives. Positive heterosis is desired when it comes to yield and the yield contributing traits while negative heterosis is desired for earliness and shortness. The knowledge of heterosis or hybrid vigor would help to eliminate poor crosses in the early generation and to search out the best cross combinations that would give useful heterosis. Likewise, this would aid in the characterization of parents for their possible exploitation in the future breeding programs.

The objectives of this study were to estimate the average heterosis (MP) and the bettert parent herosis or heterobeltiosis (BP), to identify the best crosses with the possibility to produce transgressive, and useful segregants for the development of new breeding lines, and to characterize and identify best parents for utilization in future breeding programs.

Materials and methods

This study was conducted at the experimental area of the University Research Center, CLSU, Science City of Muñoz, Nueva Ecija, Philippines. Four selected genotypes of aromatic rice varieties (CL 1, Jasmine, Kasturi and Pandan) were used as lines, and four varieties (G 10, G 12, G 20 and P 20) as testers for the production of crosses.

Variety CL 1, which was derived from Basmati 370 and Kasturi, were originated from India, while Pandan and Jasmine are traditional varieties from the Philippines. Meanwhile, varieties such as G 10, G 12, G 20 and P 20 were originated from China. The crosses were made by following the line x tester mating design (Kempthorne, 1957). The crosses were produced in 2016 and evaluation of these crosses for heterotic effects was carried out in the next planting season.

The F_1 seeds were sown in buckets which were taken cared of inside the glasshouse. In addition, the recommended cultural management practices were employed for normal and healthy seedlings. The experiment was laid out following the randomized complete block design (RCBD) with three replications. Twenty one day-old seedlings of each cross were transplanted in a two-row plot, three meters long, spaced 20 cm between rows and 20 cm between hills, with one seedling per hill under lowland irrigated condition. The crosses were evaluated for heterotic effects in terms of days to maturity, plant height at maturity (cm), number of productive tillers, panicle length (cm), number of filled grains, spikelet fertility (%), 1000 grain weight (g) and grain yield (t $^{ha-1}$). The data were analyzed using SAS statistical software (v.9.1), PROC GLM (SAS) Institute, Cary NC). Mean differences among treatments were compared using Least Significant Difference (LSD) test at 1% (p=0.01) and 5% (p=0.05) probability. The magnitude of heterosis in relation to mid parent (MP) and better parent (BP) were estimated using the procedure suggested by Virmani *et al*. (1997) as follows:

$$\text{Mid parent heterosis (\%)} = \frac{F_1\text{-MP}}{\text{MP}} \times 100$$

Where,

F1 = Mean performance of F_1 hybrids

MP = Mid parent value

$$\frac{F_1\text{-BP}}{} \times 100$$

Better parent heterosis (%) = $\frac{\quad}{BP}$

Where,
BP = Mean performance of better parent

Results

The estimates of MP and BP hetrosis for yield and other traits such as maturity, plant height, number of productive tillers, panicle length, spikelet, fertility, 1000 grain weight and grain yield are presented in Tables 1 and 2.

Maturity

Mid parent heterosis ranged from -9.01% (CL 1 x G 10) to 0.60% (Kasturi x G 20) while BP from .-10.06% (CL 1 x G 12) to 4.63% (Pandan x G 20). Crosses Pandan x G 12, Kasturi x P 20, Jasmine x G 12, CL 1 x P 20, CL 1 x G 12, CL 1 x G 20 and CL 1 x G 10 showed significant negative MP and BP heterosis. Likewise, Pandan x G 12 showed negative and significant MP heterosis (-1.85%). On the other hand, significant negative heterosis was observed in Kasturi x P 20 (-2.08%), Kasturi x G 12, (-2.87%), and Jasmine x P 20 (-0.30%). The rest, Pandan x G 20 (4.63%), Pandan x G 10 (2.42%), Kasturi x G 20 (2.47%), Kasturi x G 10 (0.30%), Jasmine x G 20 (2.16%) and Jasmine x G 10 showed highly significant positive heterosis towards lateness. Most of the crosses showed significant negative heterobeltiosis over the BP which ranged from 0-0.30% to -9.98%.

Plant height

Most of the F_1 crosses showed highly significant positive heterosis over MP which ranged from 4.67% to 15.69%. Similarly, the crosses Kasturi x G 12 Pandan x G 12, Jasmine x G 12, Kasturi x G 10, Jasmine x G 10 and Jasmine x P 20 manifested highly significant positive heterotic effects (4.53-7.99%) over best parents towards tallness. Cross combination Jasmine x P 20 showed highly significant negative values (8.83%) toward shortness for heterobeltiosis. Negative MP heterosis was also estimated on Jasmine x P 20 (-0.89%) and heterobelteosis for cross combinations CL 1 x P 20 (-3.3%) and Pandan x P 20 (-3.30%).

Table 1. Estimates of heterosis (%) over mid parent (MP) and better parent (BP) for days to maturity, plant height, number of productive tillers and panicle length

Cross	Days to maturity		Plant height (cm)		No. of productive tillers		Panicle length (cm)	
	MP	BP	MP	BP	MP	BP	MP	BP
CL 1 x G 10	-9.01**[1/]	-9.98**	3.65	1.24	-12.43**	-13.52*	-3.97	-8.39
CL 1x G 12	-6.85**	-10.06**	5.31**	0.68	18.46**	14.57*	4.92	0.86
CL 1x G 20	-7.41**	-7.41**	3.89	0.35	-6.62**	-3.58	4.85	-11.77*
CL 1 x P 20	-6.20**	-8.01**	4.67*	-3.34	-24.01**	-24.47**	-7.96	11.63*
Jasmine x G 10	-1.48	0.60**	7.47**	4.53*	34.07**	33.20**	28.97**	-14.24*
Jasmine x G 12	-2.45*[2/]	-2.87**	11.97**	6.59**	-13.66**	-16.00**	-12.48*	-5.59*
Jasmine x G 20	-1.05	2.16**	5.56*	1.53	-12.54**	-9.12	76.87**	-17.42**
Jasmine x P 20	-1.47	-0.30**	-0.89	-8.83**	-17.22**	-17.22**	9.44	4.49
Kasturi xG 10	-0.45	0.30**	15.18**	6.22*	-15.88**	-19.18**	28.8**	-0.59
Kasturi x G 12	-0.29	-2.01**	14.70**	7.99*	-5.61**	-11.14	8.58	9.45
Kasturi x G 20	0.61	2.47**	11.95**	4.35	-9.09**	-8.79	5.52	-4.26
Kasturi xP 20	-1.93*	-2.08**	5.52*	2.92	19.38**	15.41	8.53	21.13**
Pandan x G 10	-0.88	2.42**	6.36**	0.92	19.64**	-0.40	31.81**	-15.67**
Pandan x G 12	-1.85*	-1.15	15.69**	7.50**	31.24**	7.43	62.05**	-7.16
Pandan x G 20	0.15	4.63**	8.21**	1.56	8.68**	-6.19	9.75	-18.79**
Pandan x P 20	-1.45	0.89	6.48**	-4.31	14.80**	-3.93	10.62*	2.75

[1/] : Significant at 1%
[2/]: Significant at 5%

Number of productive tillers

Out of the 16 crosses, Jasmine x G 10 exhibited the highest positive value of MP heterosis (34.07%) which was followed by Pandan x G 12 (31.24%). The highest positive heterobeltiosis towards the BP was estimated on CL 1 x G 12 (14.57%). This was followed by Jasmine x G 10 which showed highly significant positive heterobeltiosis of 13.20%. Highly significant positive heterotic values over MP were also observed in crosses Pandan x G 12 (31.24%), Pandan x G 10 (19.64%), Kasturi x P 20 (19.38%), Pandan x P 20 (14.80%) and Pandan x G 20 (8.68%). Nine of the cross combinations showed highly significant negative MP heterosis . Among these crosses, CL 1 x G 10, Jasmine x G 12, Kasturi x G 10, Jasmine x P 20 and CL 1 x P 20 manifested both highly significant negative MP and heterobeltiosis which ranged from -31.24% to -8.68% and -13.52 to 24.47%, respectively. The rest of the lines had low negative heterobeltiosis over their respective best parents which ranged from -0.40 to -11.00%.

Panicle length

Positive MP heterosis ranged from 4.92 to 76.87% while negative MP heterosis from -3.97 to -12.48%. Jasmine x G 20 obtained the highest positive and highly significant MP heterosis (76.87%) followed by Pandan x G 12 (62.05%). Likewise, Pandan x G 10, Jasmine x G 10, Kasturi x G 10 and Pandan x P 20 showed highly significant and positive MP heterosis with 31.81%, 28.97%, 28.80% and 10.62%, respectively. Highly significant and positive heterobeltiosis was registered in CL 1 x P 20 (11.63%) and Kasturi x P 20 (21.13%).

Spikelet fertility

Mid parent heterosis for percent filled grains ranged from -22.60 to 18.77% while BP from 22.30 to 8.46%. Highly significant positive heterosis was observed in CL 1 x G 20 (18.70%), Pandan x P 20 (18.39%), Pandan x G 10 (16.76%) and CL 1 x P 20 (16.20%). Jasmine x G 20 had the highest significant negative MP heterosis (-22.60%) and highly significant negative heterobeltiosis (-21.93%). Likewise, CL 1 x G 10 showed highly significant heterobeltiosis (-22.30%). Most of the crosses had positive MP and BP heterosis.

Table 2. Estimates of heterosis (%) over mid parent (MP) and better parent (BP) for spikelet fertility, 1000 seed weight and grain yield per hectare

Cross	Spikelet fetility (%)		1000 seed weight (g)		Grain yield/ha-1 (t)	
	MP	BP	MP	BP	MP	BP
CL 1 x G 10	-6.54	-22.30**	30.86**	17.83**	138.55**	66.00**
CL 1 x G 12	17.40*[1/]	0.53	26.18**	7.91**	63.98**	26.06**
CL 1x G 20	18.77**[2/]	-1.30	34.55**	24.53**	47.94**	-3.99**
CL 1x P 20	16.20*	-4.70	24.59**	6.00**	39.01**	-9.44**
Jasmine x G 10	-9.46	-8.64	0.19	28.34**	-15.06**	-10.44**
Jasmine x G 12	3.56	8.46	-0.53	18.64**	43.98**	81.50**
Jasmine x G 20	-22.60**	-21.93**	-3.94**	27.75**	8.51*	0.01
Jasmine x P 20	4.70	3.85	-1.53	16.60**	-17.26**	-23.16**
Kasturi x G 10	2.42	5.90	5.14**	10.67**	46.91**	47.66**
Kasturi x G 12	0.69	8.15	0.00	-0.99	88.90**	125.36**
Kasturi x G 20	0.23	3.59	8.17**	17.60**	32.91**	17.52**
Kasturi x P 20	5.34	7.02	11.98**	10.18**	25.77**	12.00**
Pandan x G 10	16.76*	4.81	8.46**	20.38**	59.57**	45.81**
Pandan x G 12	10.58	2.57	2.58*	6.78**	27.01**	35.60**
Pandan x G 20	13.19	1.56	13.34**	30.12**	-6.23**	-23.60**
Pandan x P 20	18.39**	4.68	12.74**	16.60**	81.23**	48.60**

[1/] : Significant at 5%
[2/]: Significant at 1%

Grain yield

Most of the lines exhibited highly significant and positive MP (8.51-138.55%) and BP heterosis (12.00- 125.36%). The highest and highly significant positive MP heterosis was revealed on CL 1 x G 10 followed by Kasturi x G 12 (88.90%) and Pandan x P 20 (81.83%). These crosses also obtained significantly higher and positive heterobeltiosis over their best parents with 66.00%, 125.36% and 48.60%, respectively. These cross combinations also produced higher yield performance over all cross combinations. Highly significant and negative MP heterosis for grain yield was estimated in Pandan x G 20 (-6.23%), Jasmine x G 10 (-15.06%) and Jasmine x P 20 (-17,26%). Similarly, these crosses exhibited highly significant negative BP heterosis with -10.44%, -23.16%, -23.60%, respectively. Highly significant negative BP heterosis was also manifested in CL 1 x G 20 (-3.99%) and CL 1 x P 20 (-9.44%) for grain yield.

Discussion

Heterosis is defined as the deviation either increase or decrease of hybrids over their parents with which the value could either be negative or positive. Bagheri *et al.* (2010) explained that the nature of gene action invoved in the inheritance of characters could be manifested through heterotic effects while the extent of heterosis may differ from cross to cross and from character to character. Both negative and positive heterosis are important depending on the breeding objective. In terms of maturity, negative heterosis is desirable because hybrids or crosses tend achieve early maturity than those with positive heterosis. Hence, negative heterosis is desirable when it comes to breeding of early maturing types. In this study, cross combination involving CL 1 as female parent showed highly significant and negative heterosis of both MP and BP heterosis. The other cross combinations involving either parents differed in the degree of heterosis of both types. The same results were reported by Baghari *et al.* (2010) and Tiwari *et al.* (2011). On the other hand, Xu and Wang (1980) pointed out that days to maturity in hybrids depends on male parent. However, this does not conform with this present study. Likewise, Tiwari *et al.* (2011) pointed out that most hybrids have long growth duration. Similary, negative heterosis is desirable when it comes to breeding dwarfed types and resistance to lodging. On the other hand, positive heterosis towards tallness is considered undesirable because the hybrids to be produced are likely prone to lodge. The high positive and negative values and low negative and positive values both MP and BP heterosis that manifested on the different cross combinations could be due to the varying extent of genetic diversity between parents of different crosses. These results conformed with the findings of Bagheri *et al.* (2010), Kumar *et al*. (2012), Abdel-Moneam *et al.* (2016), and Borah *et al.* (2017). Positive heterotic effects are desirable on yield and the other contributing traits such as number of productive tillers, panicle length, number of filled grains, number of unfilled grains, spikelet fertility, 1000 seed weigh and grain yield per hectare. Virmani *et al.* (1991) reported that increasing the yield of rice based on heterosis can be achieved, which is in accordance with the results of several studies not only in rice but also in other crops.

The highly positive MP and BP heterosis which were observed from the crosses of each character suggested over-dominance of gene action. Yield is the ultimate goal in plant breeding. However, it was suggested to give more importance on the yield contributing traits since there is no separate gene for yield due to the individual contribution of these traits (non-additive gene effects). Positive heterosis for grain yield and the other parameters were documented by several researchers as in the work of Virmani *et al*. (1991), Nuruzzaman *et al*. (2002), Kumar *et al.* (2012), Jarwar *et al*. (2013), Abdel-Moneam *et al*. (2016), and Santos Kumar *et al*. (2017) which pointed out that such depends on the genetic diversity and may be attributed to the specific combining or nicking ability of parents (Kumar *et al.,* 2012). The negative heterosis for maturity and plant height, the positive heterosis for grain yield, and the other component traits are of practical interest in rice breeding program. The high positive and negative values and low negative and positive values both MP and BP heterosis manifested on the different cross combinations could be due to the varying extent of genetic diversity between parents of different crosses. Those that showed significant and positive MP heterosis but had non-significant and positive BP heterosis, manifested partial dominant of gene action (Bagheri *et al.,* 2010). It was also claimed that high heterosis could be due to good combining ability and high nicking ability of parents. These results conformed with the findings of Kumar *et al*. (2012), Veeresha *et al*. (2015), Borah *et al*. (2017), Santos Kumar *et al*. (2017), and Abdel-Moneam *et al*. (2016).

Based on the overall performance, CL 1 x G 10, Kasturi x G 12 and Pandan x P 20 are the most promising crosses. Hence, these crosses can be recommended in the next generation for selection of transgressive seggregants for further selection for the development of new elite lines, which can be exploited in the future breeding program. Likewise, CL 1 x P 20, CL 1 x G 12, CL 1 x G 20 and CL 1 x G 10 may also be evaluated further in the next generations for the development of early maturing types of aromatic rice varieties. On the other hand, Jasmine x P 20 can be utilized in the in the future breeding program for development of dwarf or short plant types.

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