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Genetic effects on grain characteristics of *indica* black rice and their uses on indirect selections for some mineral element contents in grains

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Abstract

Complete diallel crosses with *Oryza sativa* L., six varieties of black rice and one variety of aromatic white rice were conducted to study the seed, maternal and cytoplasmic genetic effects on grain characteristics such as 100-grain weight, length, width and shape and their genetic correlations with Fe, Zn, Mn and P mineral contents in kernels by using the genetic model on quantitative traits of seed in parents and their F_1s and F_2s. The seed genetic effects were found more important than the maternal genetic effects for grain characteristics, and seed additive effects constituted a major part of their genetic effects. The heritabilities of seed effects were high for 100-grain weight, width and shape and moderate for grain length. Single seed selection based on the 100-grain weight, width and shape was advocated in early generations, whereas single plant and seed selection based on grain length were advocated in late generations. Significant genetic correlations including seed additive, dominance, cytoplasmic, maternal additive and dominance between 100-grain weight, length, width and shape and Fe, Zn, Mn and P mineral contents were observed. Indirect selection of grain characteristics may be one of the breeding methods to select for higher contents of Fe, Zn, Mn and P in black pericarp *indica* rice.

Introduction

As people's living standard rises and their food structure changes, research and development of special food resources such as black rice, corn, wheat, black soybean and sesame attracts more attention nowadays than ever before (Zhang et al. 1998; Zhang 2000). The well-known traditional non-staple foods particularly the black foods are favored by people in China for a long time and considered as delicacy of China. The new kinds, especially those made from raw black rice materials are constantly produced and fascinate people (Wang and Wang 1998). These market developments, however, more and more rely on the genetic improvement of black rice especially its grain characteristics and nutrient quality traits such as the contents of mineral elements, Fe, Zn, Mn and P. These minerals are known to play an important role in our body, for instances, Fe is an important component of hemoglobin and myoglobin; Zn stimulates the activities of many enzymes in the human body and is closely related to children intelligence development and adult reproductive functions; Mn is the active radical and cofactor of many enzymes in the human body and P is closely related to the development of bones and brains. The crop breeders in general are now paying more attention to the improvement of rice minerals such as Fe, Zn, Mn and P, particularly in China (Qiu et al. 1993;

Liu et al. 1995; Zhang et al. 1996; Zhang 2000). The black pericarp rice is rich in Fe, Zn, Mn and P and has a high variability in their contents ranging from 15.41 to 162.37 mg/kg for Fe, 23.92 to 145.78 mg/kg for Zn, 18.33 to 161.92 mg/kg for Mn and 2.89 to 492 mg/g for P have been reported in different varieties and areas with different soil types (Qiu et al. 1993; Liu et al. 1995; Zhang et al. 2000).

The data from *indica* white rice showed that grain characteristics were either controlled by one to two major genes plus few minor genes (Mckenzie and Rutger 1983; Qi and Li 1983; Guo 1985), or purely quantitative minor genes that could be described by additive-dominance models (Guo and Xie 1982; Yi and Cheng 1991; Mo 1993; Shi and Zhu 1993). Zhang et al. (1996, 2000, 2001) had also showed that seed, cytoplasmic and maternal genetic effects could affect quality traits of *indica* black rice. But, no work has been done on the partitioning of these genetic effects on different grain characteristics of *indica* black rice. Similarly, no results have been reported on the genetic correlations, particularly seed additive or dominant correlations, cytoplasmic correlations and maternal additive or dominance correlations between grain characteristics and mineral element contents.

In this study, complete diallel crosses with six varieties of *indica* black rice and one variety of *indica* aromatic white rice were conducted to analyze the seed, cytoplasmic and maternal genetic effects on 100-grain weight, length, width and shape (length/width) and their genetic correlations with Fe, Zn, Mn and P mineral contents in kernels by using the genetic model on quantitative traits of seed of parents and their F_1s and F_2s (Zhu 1992; Zhu and Weir 1994a, b). The objectives of this study are to evaluate the different genetic effects, and to estimate genetic components of variance, covariance and heritability for grain characteristics and also to analyze their genetic correlations with some mineral element contents in kernels. These results mainly aim at the uses on breeding of black rice, while also at the breeding of non-black rice using genetic resources of black rice.

Materials and methods

The plant materials used in this study were six black pericarp varieties viz. Hung Hsien Ju (P_1), Heinuo83 (P_2), Zhidao5 (P_3), Xizhenheimi (P_4), Pangniraj (P_5) and Dhan Baggi 441 (P_6) and one aromatic white pericarp variety viz. Della (P_7) of *indica* sub-species of rice. The mating design used in this experiment was a complete diallel crosses with seven parents including reciprocal crosses. Main panicles of 10 plants of each parent were selected to cross with main panicles of the other six parents planted in the same plot, and the seeds of F_1 and reciprocal F_1 were obtained at maturity in 1991. The seeds of parents, F_1 and reciprocal F_1 were sown in yellow–brown earth in May 1992 at Huazhong Agricultural University. The basic agrochemical characteristics of the soil were: pH (water/soil = 1/1) 6.64, organic mater 15.5 g/kg, alkaline hydrolysis nitrogen 80.5 mg/kg, Olsen-phosphate 8.11 mg/kg, exchangeable potassium 120.6 mg/kg. The single plants of 30-days-old seedlings were transplanted with three replications at spacing of 20×20 cm^2. The soil was fertilized as per the general management during the whole growing season. The seeds of 7 parents, 21 F_2s from F_1 plants and 21 reciprocal F_2s from reciprocal F_1 plants were collected from the middle part of each plot at maturity, and seeds from the same plot were mixed. During the same growing season in 1992, 7 parents were again planted with three replications, and main panicles of 10 plants of each parent were selected to make fresh crosses with main panicles of other six parents planted in the same plot, and the fresh seeds of F_1 and reciprocal F_1 were again obtained.

The contents of mineral elements, Fe, Zn, Mn and P and other grain characteristics including 100-grain weight, length, width and shape of brown rice grain were determined. The materials were sampled with the brown rice mixture in each plot of parent, F_1 and F_2, which the contents of Fe, Zn and Mn were measured by Atomic Absorption Spectrophotometer (Z-5000 AA Spectrophotometer, Hitachi, Japan) using atomic absorption method (Huang 1995), and P was measured by UV-Spectrophotometer (UV-2501PC UV-VIS Spectrophotometer, Shimadzu, Japan) using Vitriot-Mo colorimetric analysis method (Huang 1995).

The genetic main effects for the four mineral element contents were analyzed using the genetic models for quantitative traits of seeds in cereal crops (Zhu 1992; Zhu and Weir 1994b). According to this model, the phenotypic variance

Table 1. Means of the grain quality characteristics of seven parents (1992).

	W (g)	L (mm)	W (mm)	GS	Fe (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	P (g/kg)	AC (g/100g)	ASV-GT (Score)
Hung Hsien Ju (P_1)	1.91	6.04	2.43	2.49	42.04	57.53	50.29	3.73	26.80	2.44
Heinuo83 (P_2)	1.84	6.08	2.36	2.58	35.21	88.85	56.25	4.06	1.02	6.12
Zhidao5 (P_3)	1.86	6.37	2.24	2.84	45.44	61.54	49.67	3.97	0.95	6.56
Xizhenheimi (P_4)	2.25	6.25	2.80	2.23	51.24	52.97	43.02	4.09	0.93	6.90
Pangniraj (P_5)	2.05	6.55	2.37	2.76	44.21	56.49	53.04	3.28	30.13	2.91
Dhan Baggi 441 (P_6)	1.74	5.60	2.39	2.34	44.66	80.90	42.27	3.77	29.75	4.72
Della (P_7)	1.45	7.14	2.16	3.31	50.36	62.19	64.61	3.73	18.79	4.24

W = 100-grain weight, L = length, W = width, GS = grain shape, AC = amylose content, ASV-GT = gelatinization temperature represented by alkali spreading value, the same as below.

(V_P) or covariance (C_P) can be partitioned inter-several components. Partitioning for the phenotypic variance is done as given below:

$$\begin{aligned} V_P &= V_G + V_C + V_{Gm} + 2C_{G\cdot Gm} + V_e \\ &= (V_A + V_D) + V_C + (V_{Am} + V_{Dm}) \\ &\quad + 2(C_{A\cdot Am} + C_{D\cdot Dm}) + V_e \end{aligned}$$

where V_G = seed genetic variance, V_C = cytoplasm variance, V_{Gm} = maternal genetic variance, $C_{G\cdot Gm}$ = covariance between seed and maternal genetic effects, V_A = seed additive variance, V_D = seed dominance variance, V_{Am} = maternal additive variance, V_{Dm} = maternal dominance variance, $C_{A\cdot Am}$ = covariance between seed and maternal additive effects, $C_{D\cdot Dm}$ = covariance between seed and maternal dominance effects, and V_e = residual variance.

Estimates of variances and covariances were further used for calculating seed heritability in the broad sense $h_o^2 = (V_A + V_D + C_{A\cdot Am} + C_{D\cdot Dm})/V_P$, maternal heritability in the broad sense $H_m^2 = (V_{Am} + V_{Dm} + C_{A\cdot Am} + C_{D\cdot Dm})/V_P$ and seed heritability in the narrow sense $h_o^2 = (V_A + C_{A\cdot Am})/V_P$; maternal heritability in the narrow sense $h_m^2 = (V_{Am} + C_{A\cdot Am})/V_P$, and cytoplasmic heritability $h_c^2 = V_C/V_P$.

Seed additive $(r_A = C_A/\sqrt{V_{A(x)}V_{A(y)}})$, seed dominance $(r_D = C_D/\sqrt{V_{D(x)}V_{D(y)}})$, cytoplasmic $(r_C = C_C/\sqrt{V_{C(x)}V_{C(y)}})$, maternal additive $(r_{Am} = C_{Am}/\sqrt{V_{Am(x)}V_{Am(y)}})$, maternal dominance $(r_{Dm} = C_{Dm}/\sqrt{V_{Dm(x)}V_{Dm(y)}})$ and residual correlation $(r_e = C_e/\sqrt{V_{e(x)}V_{e(y)}})$ between the four mineral element contents and the grain characteristics of 100-grain weight, length, width and shape were also estimated.

MINQUE(1/0) method (Zhu 1992; Zhu and Weir 1994a, b) was used to estimate genetic variances, covariances, heritabilities, correlation coefficients and predicted genetic effects. The Jackknife method (Miller 1974) was applied by sampling generation means of entries for estimating the standard errors of estimated components, and *t*-test was used to test significance of differences. All data were analyzed with the software of C programs developed by Zhu at Zhejiang University (Zhu 1997).

Results

Phenotypic means of the generations for the grain characteristics

Substantial differences of means in the grain characteristics, mineral Fe, Zn, Mn and P contents and cooking quality traits of amylose content and gelatinization temperature represented by alkali spreading value existed among some of the seven parents (Table 1). This showed that the selected materials had enough variations for genetics studies. Large variation for 100-grain weight, length, width and shape of seven parents and their F_1s and F_2s was found (Table 2). The coefficients of variation (CVs) of parents for 100-grain weight, length, width and grain were13.32%, 7.60%, 8.49% and 13.66%, respectively. The variation of the grain

Table 2. Ranges, means and CVs of the grain characteristics of F_1, F_2 seeds (1992).

	W (g)	L (mm)	W (mm)	GS
Parental mean	1.87 ± 0.25	6.29 ± 0.48	2.39 ± 0.20	2.65 ± 0.36
Parental CV(%)	13.32	7.60	8.49	13.66
F_1 range	1.42–2.20	5.56–7.11	2.20–2.76	2.21–3.22
F_1 mean	1.86 ± 0.24	6.27 ± 0.43	2.35 ± 0.19	2.67 ± 0.36
F_1 CV(%)	12.76	6.78	8.12	13.33
F_2 range	1.44–2.17	5.52–7.16	2.10–2.89	2.28–3.37
F_2 mean	1.86 ± 0.30	6.29 ± 0.64	2.39 ± 0.27	2.63 ± 0.44
F_2 CV(%)	16.33	10.23	11.34	16.67

characteristics of F_1s and F_2s was also large. In F_1s, the values ranged from 1.41 to 2.20 g for 100-grain weight, 5.56 to 7.11 mm for grain length, 2.20 to 2.76 mm for grain width and 2.21 to 3.22 for grain shape, and in F_2s, the values ranged from 1.44 to 2.17 g for 100-grain weight, 5.52 to 7.16 mm for length, 2.10 to 2.89 mm for width and 2.28 to 3.37 mm for shape. The grain characteristics of F_1s showed tendency toward their female parents, while those of F_2s toward to their mid-parents.

Estimation of components for genetic main variance and covariance of the grain characteristics

Highly significant ($P < 0.01$) seed additive and dominance, maternal dominance and cytoplasmic variances for 100-grain weight, length, width and shape and highly significant ($P < 0.01$) maternal additive variances for 100-grain weight and length were detected (Table 3). The grain characteristics were controlled by seed, maternal genetic effects as well as by cytoplasmic effects. The seed additive variances accounted for 82.41%, 70.49%, 81.17% and 86.21% of the total genetic variance ($V_A + V_D + V_C + V_{Am} + V_{Dm}$) for grain weight, length, width and shape, and maternal additive and dominance variances accounted for 8.64% for grain weight, and maternal additive variance accounted for 13.95% of the total genetic variance for length. These results indicated that the grain characteristics were controlled by seed, maternal genetic effects as well as by cytoplasmic effects. The seed genetic effects were found more important than the maternal genetic effects for grain characteristics, and seed additive effects constituted a major part of their genetic effects. Significant additive covariance and dominance covariance were detected for grain length and shape in this experiment. These suggested that the relationships between seed and maternal genetic effects might be important for grain length and shape. Cytoplasmic variances, however, accounted for only 2–3% of the total genetic variances for the grain characteristics (Table 3). This showed that the genetic effect of cytoplasmic effects has less influence on grain characteristics. The large values of the estimated residual variances indicated that the grain characteristics were not only affected by genetic effects, but also significantly affected by environment effect.

Table 3. Estimations of genetic variance and covariance components of the grain characteristics for *indica* black rice.

Parameter	W($\times 10^{-3}$)	L($\times 10^{-3}$)	W ($\times 10^{-3}$)	GS ($\times 10^{-3}$)
V_A	34.80^{**}	79.91^{**}	34.41^{**}	89.91^{**}
V_D	0.77^{**}	2.65^{**}	0.94^{**}	1.52^{**}
V_C	1.23^{**}	3.25^{**}	1.25^{**}	2.38^{**}
V_{Am}	2.73^{**}	15.81^{**}	0.00	0.00
V_{Dm}	0.92^{**}	5.59^{**}	1.82^{**}	3.12^{**}
$C_{A\cdot Am}$	1.66	23.40^{*}	0.00	0.00
$C_{D\cdot Dm}$	0.09	0.68	0.43	0.98^{+}
V_e	1.78^{**}	6.16^{**}	3.97^{**}	7.36^{**}

$^{+,}$ * and ** were significant at 10%, 5% and 1% level, respectively. Degree of freedom = 90; V_A = seed additive variance; V_D = seed dominance variance; V_C = cytoplasm variance; V_{Am} = maternal additive variance; V_{Dm} = maternal dominance variance; $C_{A\cdot Am}$ = seed and maternal additive covariance; $C_{D\cdot Dm}$ = seed and maternal dominance covariance; V_e = residual variance.

Estimation of components for heritabilities of the grain characteristics

Since there were seed, cytoplasmic and maternal genetic effects, the total narrow-sense heritability

Table 4. Heritabilities of the grain characteristics for *indica* black rice.

Parameter	W	L	W	GS
h_o^2	0.780^{**}	0.515^{**}	0.796^{**}	0.846^{**}
h_o^2	0.798^{**}	0.651^{**}	0.828^{**}	0.870^{**}
h_c^2	0.027^{+}	0.021^{**}	0.029^{**}	0.022^{**}
h_m^2	0.082^{*}	0.130^{**}	0.000	0.000
h_m^2	0.096^{+}	0.247^{**}	0.052^{**}	0.039^{**}

$^{+}$, * and ** were significant at 10%, 5% and 1% level, respectively. Degree of freedom = 90; h_o^2 = seed heritability in the narrow sense, ${h_o}^2$ = seed heritability in the broad sense, h_c^2 = cytoplasmic heritability, h_m^2 = maternal heritability in the narrow sense, h_m^2 = maternal heritability in the broad sense.

was also further partitioned into seed (h_o^2), cytoplasmic (h_c^2) and maternal (h_m^2) heritabilities for the grain characteristics. The h_o^2 s of 100-grain weight, length, width and shape at $P < 0.01$; the h_C^2s of grain weight, length, width and shape at both $P < 0.10$ and $P < 0.01$; and h_m^2s of 100-grain weight and length at both $P < 0.05$ and $P < 0.01$ were found significant (Table 4). The narrow-sense heritabilities of seed genetic effects were high for 100-grain weight, width and shape (78.0%, 79.6% and 84.6%, respectively), while that of seed effect was moderate for length (51.5%).

Estimation of genetic correlations between the grain characteristics and four mineral element contents

Correlation components of total genetic correlation include seed additive (r_A), dominance (r_D), cytoplasmic (r_C), maternal additive (r_{Am}) and dominance (r_{Dm}). Estimates of genetic correlation components and residual correlation (r_e) between grain characteristics and four mineral element contents were summarized in Table 5.

Significantly ($P < 0.05$ and $P < 0.01$) negative r_As between 100-grain weight and Zn, Mn and P contents, width and Mn content, and length and Zn and P contents while significantly ($P < 0.01$) positive r_As between grain length and Fe and Mn contents were detected. Significantly ($P < 0.01$) positive r_{Am} between 100-grain weight and P content was also detected. These results indicated that the improvement of Fe, Zn, Mn and P contents could be accomplished by making selection through grain characteristics in the black rice hybrid progeny. The selection of narrow and small grain tends to increase Zn, Mn and P contents; long grain tends to increase Fe and Mn contents, short grain tends to raise Zn and P contents and selection of single plant with high grain weight tends to increase P content.

Significantly ($P < 0.05$ or $P < 0.01$) positive r_Cs between 100-grain weight and Fe content; width and Fe, Zn and Mn contents; length and Mn and P contents, shape and P content was observed. Significantly ($P < 0.05$ or $P < 0.01$) negative r_Cs between 100-grain weight and Mn and P contents; length and Zn content; shape and Fe, Zn and Mn contents was also detected. This indicated that cytoplasm correlations, which could be effectively applied in black rice breeding for nutrient quality, controlled relationships between grain characteristics and the four mineral element contents. Significant ($P < 0.05$ or $P < 0.01$ or $P < 0.10$) r_Ds and r_{Dm}s between 100-grain weight, length, width and grain shape and Fe, Zn, Mn and P contents suggested that the indirect selection of grain characteristics could also influence the mineral element contents of black rice hybrid progenies.

Discussion

Since seeds are the progenies of maternal plant and the nutrient materials of rice also come from the maternal, many quality traits were affected by genetic effects of the seed, maternal plant and its cytoplasm (Mo 1993; Shi and Zhu 1993, 1998; Shi et al. 1996, 1999a, b; Zhang and Peng 1995; Zhang et al. 2001). Various workers have suggested many genetic models to estimate genetic effects but the model used in the present study has advantage over others (Zhu and Weir 1994a, b). This model needs only the means of three generations of parents, F_1s and F_2s with two or three replications in a set of diallel crosses without measuring a single seed or plant. The models and statistical methods proposed by Bogyo et al. (1988) and Mo (1995, 1998) could be used for analyzing the additive and dominance effects of seed endosperm genes but biased estimation would be obtained when analyzing the endosperm quantitative traits controlled by seed, cytoplasmic and maternal effects. Pooni et al. (1992) proposed a model which can analyze the seed effects and maternal/cytoplasm effects of

Table 5. Genetic correlation coefficients between grain characteristics and the four mineral element contents of *indica* black rice.

	Parameter	Fe	Zn	Mn	P
W	r_A	0.011	-0.333^{**}	-0.503^{**}	-0.111^{*}
	r_D	-0.198^{**}	-0.333^{**}	-0.078^{+}	0.079^{*}
	r_C	0.543^{**}	0.001	-0.104^{*}	-0.176^{**}
	r_{Am}	0.000	−0.015	−0.072	0.233^{**}
	r_{Dm}	0.294^{**}	0.160^{**}	-0.148^{**}	-0.414^{**}
	r_e	-0.162^{*}	0.135^{*}	−0.020	0.201^{**}
L	r_A	0.314^{**}	-0.495^{**}	0.646^{**}	-0.141^{**}
	r_D	-0.622^{**}	0.073^{*}	0.078^{*}	0.036
	r_C	-0.100^{+}	-0.261^{**}	0.106^{*}	0.292^{**}
	r_{Am}	0.000	−0.024	0.001	−0.004
	r_{Dm}	-0.095^{+}	−0.036	-0.118^{*}	−0.065
	r_e	0.041	0.024	-0.160^{*}	−0.100
W	r_A	0.006	−0.051	-0.582^{**}	−0.027
	r_D	-0.091^{*}	-0.290^{**}	-0.753^{**}	−0.023
	r_C	0.282^{**}	0.208	0.240^{**}	−0.034
	r_{Am}	0.000	0.000	0.000	0.000
	r_{Dm}	0.238^{**}	−0.070	0.090^{*}	0.093^{*}
	r_e	-0.179^{*}	0.034	0.014	−0.067
GS	r_A	0.150^{**}	-0.178^{**}	0.685^{**}	−0.020
	r_D	-0.238^{**}	0.311^{**}	0.632^{**}	-0.065^{*}
	r_C	-0.331^{**}	-0.318^{**}	-0.128^{**}	0.144^{**}
	r_{Am}	0.000	0.000	0.000	0.000
	r_{Dm}	-0.292^{**}	0.036	-0.173^{**}	-0.115^{*}
	r_e	0.160^{*}	−0.013	−0.087	0.009

$^{+}$, * and ** are significant at the levels of 0.10, 0.05 and 0.01, respectively. Degree of freedom = 90; r_A = seed additive correlation; r_D = seed dominance correlation; r_C = cytoplasm correlation; r_{Am} = maternal additive correlation; r_{Dm} = maternal dominance correlation; r_e = residual correlation.

endosperm traits, but this model cannot differentiate the maternal and cytoplasm effects. However, the genetic model proposed by Foolad and Jones (1992) can estimate seed, cytoplasmic and maternal effects for quantitative traits of endosperm, it is very difficult to use this model as it requires the measurement of single seed and 17 generations.

It is important to develop suitable and effective breeding selection scheme reliable information on the relative role of various genetic effects obtained by estimating genetic components of variance and heritability. When a quality character is controlled by maternal additive and cytoplasmic effect, or its maternal and cytoplasmic heritability are relatively high, the separation of the character in the hybrid progeny will not be very significant. Therefore, response to selection can be achieved through selection based on the general performance of the quality character in maternal plants. For those quality characters whose seed additive effect or their seed heritability is high, mainly single grain selection should be used because the characteristics of seeds in the hybrid plants will separate significantly. The present study also showed that the grain characteristics were controlled by seed, maternal genetic effects and cytoplasmic effects. The seed genetic effects were more important than the maternal genetic effects on grain weight, width and shape and seed additive effects constituted a major part of their genetic effects, whereas seed, maternal additive and dominant effects formed the main part in the inheritance of grain length. The heritabilities of seed effects of the grain characteristics were all highly significant. Therefore, more attention should be paid to the single plant selection and/or single grain selection of hybrid progenies.

In addition to the genotype, the environmental influence on the contents of the elements in black pericarp rice was also high as revealed by the high environmental variances in the present study. The influence of genotype and environment interaction on the contents of the mineral elements have also been studied by Zhang et al. (1996) in his multi-locations trials over the years. In this study, the seeds for the three generations of parents, F_1 and F_2 were obtained in the same season of the same year (1992). The F_1 seeds were obtained by making fresh crosses in the same season of 1992 to reduce environmental factors.

The high or low contents of mineral elements in grain largely determine the nutrient value of rice. Because the heritabilities of Fe, Zn, Mn and P contents in black rice grain are not high (Zhang et al. 2000), these traits cannot be easily measured, so it is easier to indirectly select using highly correlated traits. The high genetic correlations between grain characteristics and some mineral element contents can be used to conduct indirect selection of a grain characteristic for another mineral element content in a breeding program. Because additive effect is effective for selection, and cytoplasmic maternal plants can transfer effect. It is also particularly important when it is difficult to achieve desired result by directly selecting genetically complex nutrient quality characters. In such cases, to realize the breeding purpose by indirectly selecting grain characteristics with high additive and cytoplasmic correlation. If the correlation between the two characters is mainly due to maternal additive effects, selection for quality characters can be made on the basis of general performance of grain characteristics of maternal plants, whereas if the correlation between the two characters is due to seed additive effects, response to selection can only be achieved through single grain selection due to genotype separation of seeds. Furthermore, dominance correlation is produced by the interaction among dominance effects of genes, which control related characters and is more evident in F_1 generation can be used in heterosis. However, the dominance correlation will gradually disappear with the increase of homogenization of genes and will affect indirect selection results in early generations. So, for those characters whose correlations are mainly due to dominance, selection should be delayed to later generations. Significant ($P < 0.05$) or highly significant ($P < 0.01$) positive or negative seed additive correlations and maternal additive correlations existed between grain characteristics such as 100-grain weight, length, width, shape of black pericarp rice and contents of Fe Zn, Mn and P. It is known that indirect selection based on correlation coefficient(r) is relevant only when the r is higher and significantly different from zero. However, in this case, the r was rather small but highly significant ($P < 0.05$ or $P < 0.01$), which indicated existence of their correlation. So in the whole, it is concluded that single grain selection of narrow grains tends to increase the contents of Zn, Mn and P; single grain selection of long grains tends to increase the contents of Fe and Mn; single grain selection of short grains tends to increase contents of Zn and P; while selection of single plants with bigger grain weight tends to increase the content of P. The result can be used to guide the indirect selection for nutrient quality of black *indica* rice.

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