academicJournals

Vol. 8(7), pp. 109-116, July 2016
DOI: 10.5897/JPBCS2016.0579
Article Number: EA3454D59371
ISSN 2006-9758

http://www.academicjournals.org/JPBCS

Journal of Plant Breeding and Crop Science

Full Length Research Paper

Correlation and path co-efficient analysis for grain quality traits in F_1 generation of rice *(Oryza sativa* L.)

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Received 29 March 2016; Accepted 22 June, 2016

A study on correlation and path co-efficient analysis was conducted on eleven F_1 generation derived from crosses between aromatic and non-aromatic parental landraces genotypes. The results showed that high standard deviation was observed on head rice recovery (16.12) followed by gel consistence (13.81) and milling recovery (10.74). The results also showed that correlation between brown rice length and paddy grain width (r= 0.692); paddy grain length and brown grain length (r = 0.558); head rice recovery and milling recovery (r = 0.511) and brown rice shape and grain rice length (r = 0.404) were positive highly significant, while correlation between brown rice shape and brown rice length were negative (r = -0.497). These highly correlated characters could be used for indirect selection and improvement of grain rice quality. The path co-efficient analyses revealed a low direct and positive effect for paddy grain length on brown grain length (0.009). The direct effect of brown rice width (2.774) and brown grain shape (2.481) on brown grain length was high and positive showing that these characters have a direct effect and influence on brown grain length thus indicating their importance in grain rice quality improvement.

Key words: Rice, correlation, path co-efficient analysis, F_1 generation, quality, aroma.

INTRODUCTION

Rice *(O. sativa* L*)* is one of the most important cereal crops for human consumption. It feeds billions of people around the world, and more especially in less developed countries in Asia, Latin America and Africa. Rice is one of most important crop in Mozambique, being the fourth most consumed crop in the country after cassava, maize and wheat (Ministry of Agriculture, 2013). It is the second most consumed crop in Malawi after maize (Magreta et al., 2013). According to Abade *e*t al. (2016), Kilombero, Faya, and Nunkile are the most aromatic landraces that are produced and have high marketability value in Malawi. However the low yield, and longer maturity time contribute to less production. Mozambique has a great diversity of local genotypes of rice, mostly concentrated in the provinces of Zambézia, Sofala and Nampula. However, there is a lack of information on grain quality characteristics for the rice germplasm in the country and most of them are non-aromatic (Ministry of Agriculture, 2013).

Rice landraces are the groups of lineages that originated and evolved in the field over millennia through selective breeding by generations of farmers, who chose

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random mutants and gene combinations in domesticated rice, for better yield, grain size and other agronomic or cultural values (Ray et al., 2013). According to this author, those landraces, carry appreciable genetic information on their genome that can be exploited for developing new varieties with desirable characteristics for grain quality. Selection of promising genotypes, in a breeding program, is based on various criteria, most importantly final crop yield and its quality (Kiani and Nematzadeh, 2012).

The persistence of rice farms growing local landraces with low yield over the improved high yielding varieties has been attributed to their adaptability to environmental conditions, resistance to pests and diseases, grain quality, test, aroma and also marketability, which are not present in many cases in the improved varieties (Dey, 2009). This phenomena presents a special challenge for plant breeders in such a way that they have to take in consideration all of those aspect in order to develop a variety that fulfills the needs of the farmers as well as the consumers. Grain quality in rice, is defined in two different criteria: the millers' basis of quality is dependent upon total recovery and the proportion of head and broken rice on milling; While the consumers base their concept of quality on the grain appearance, size and shape of the grain, the behavior upon cooking, the taste, tenderness, flavor of cooked rice and today the nutritional value (Khush and Cruz, 2000).

Grain quality is an important character to study not only because of its contribution to yield, but also because of its influence in rice marketing and trade (Prem et al., 2010). Grain weight and grain shape (length, width, length/width ratio) are positively correlated characters (Anandakumar et al., 2015). Studies on grain quality characters have shown different results concerning its genetic control. Nevertheless it's possible to study rice grain quality in first generation of crosses as were proposed by Yan and De-lin (2004).

Most of the high-quality preferred varieties in major rice growing countries are aromatic (Khush and Cruz, 2000). Thus, introgression of this character into varieties with aroma absent is a quit difficult because of that genetics of the aroma characteristic is somewhat complex has been associated with the presence of 2-acetyl-1-pyrroline (Bradbury et al., 2005). Although many other compounds are also found in the headspace of fragrant rice varieties possibly due to secondary effects related to the genetic background of the rice variety, 2-acetyl-1-pyrroline is widely known to be the main cause of the distinctive basmati and jasmine fragrance (Khush and Cruz 2000). The desirability of fragrance has resulted in strong human preference and selection for this trait. Non- fragrant rice varieties contain very low levels of 2-acetyl-1- pyrroline, while the levels in fragrant genotypes are much (Khush and Cruz, 2000; Jewel et al., 2011).

The data obtained from correlation coefficient can be augmented by path analysis. Path coefficient analysis splits the genotypic correlation coefficient into the measure of direct and indirect effects (Train *et al.,* 1999). In rice, those analyses can be performed in order to assess the inheritance of earlier generation of crosses with their parents. Because there was no report about breeding program involving these parental genotypes in Mozambique and Malawi, and the preferences of aromatic rice is high than the non-aromatic, there was a need to produce crosses and evaluate then in order to generate enough information for their use in the next breeding program for quality improvement, that is why the main objective of this study was to determine the correlation and path co-efficient analysis for grain quality character improvement on first generation of rice *(Oryza sativa* L) derived from aromatic and non-aromatic landraces genotypes from Mozambique and Malawi under irrigation.

MATERIALS AND METHODS

Three non- aromatic parental landraces genotypes brought from Mozambique namely (Marista Djissa, Chibiça, and three aromatic genotypes (Faya, Kilombero and Nunkile) from Malawi were planted and crossed with each other under field and greenhouse conditions to produce sufficient F_1 generation seeds for the trial during December, 2014 to May, 2015. The field crossing blocks were established in Lifuwo Rice Research Station and the greenhouse crossing blocks were established at Bunda College Campus (Lilongwe). Eleven (11) crosses involving aromatic versus non-aromatic landraces genotypes, namely Nunkile x Chibiça, Chibiça x Nunkile, Nunkile x Marista, Kilombero x Djissa, Nunkile x Djissa, Kilombero x Chibiça, Kilombero x Marista, Djissa x Nunkile, Faya x Marista, Djissa x Kilombero, and Chibiça x Kilombero which were selected for the field trial.

Field trial site description

The trial was conducted at Lifuwu Rice Research Station in Salima-Malawi; is situated at the foot of the Lifuwu hill and is part of the expansive and seasonally flooded Katete dambo. The station is located at an altitude of 513 meters above sea level (masl) with coordinates sited on Latitude 13°40' South and Longitude 34°35' East. Paddy fields are predominantly clay soils types characterized by low Nitrogen and Phosphorus content, with pH 7 to 8 and annual average rainfall of 1,200 mm. Mean minimum and maximum temperatures are 19°C and 29°C, respectively. Between May and August, absolute air temperatures may drop to as low as 16°C, and because of that the growth rate of dry season irrigated rice is slowed and also, prolongs the growth duration of rice varieties by 10 to 30 days depending on variety and other weather parameters.

Experimental design, field layout and crop management

In the winter season, on 24th June, 2015, the eleven (11) F_1 generation and their six (6) parent were sowed on the petri-dishes after surface-sterilization as recommended by Coffman and Herrera (1980). Soon after germination and before the roots entangled, the seedlings were transferred to the pots while the parents were directly planted in the pots as nursery. Thirty five (35) days old plants were transplanted in the field trials in a completely randomized block design with 3 replicates under irrigation.

Table 1. Descriptive statistics for grain quality in 11 F_1 rice generation.

Characters	Range	Mean	Std. deviation	Coefficient of variation (%)
GrL	2.80	9.52	0.65	6.84
Grw	1.40	3.09	0.23	7.49
BrL	2.90	6.45	0.68	10.50
BRw	1.70	2.67	0.36	13.54
BrS	1.80	2.44	0.41	16.90
MR	51.00	62.66	10.74	17.13
HRR	75.90	71.18	16.12	22.65
GTr	6.00	4.22	2.50	59.31
Ass	3.00	2.25	1.00	44.43
GCs	62.00	145.67	13.81	9.48

Grw: Paddy grain width (mm); BRw: Brown rice width; BrS: brown rice shape; GrL: paddy grain length; HRR: Head rice recovery; MR: milling recovery; GTr: Gelatinization temperature; Ass: Aroma sense and BrL: Brown grain length, GCs: gel consistence.

Single plant per hill were transplanted in 3 rows with 5 plants per row in total and only the middle plants were considered for that collection as described by Kiani and Nematzadeh (2012). The first line was planted with the female parent genotypes; the second line was planted with the F_1 derived from the cross between the two parents and the last line was planted with the male parent spaced by 25 cm x 25 cm (Shanthala et al., 2005). The plot size was 0.94 m^2 with a total of eleven (11) plots per replication. The block size was 10.34 m^2 and a total trial area of 31.02 m^2. NPK (12-24-12) compound fertilizer was applied at a rate of 100 Kg/ha at transplanting time and 60 Kg of Urea 46% as topdressing at 45 days after sowing and at 60 days after sowing respectively. The harvesting time varied from middle October to middle November of 2015 and the laboratory analyses were conducted three months later (February, 2016).

Data collection on paddy grain length GrL (mm), paddy grain width Grw (mm), brown rice length BrL (mm), brown rice width BRw (mm), brown rice shape BrS (mm), percentage of milling recovery (MR), percentage of head rice recovery (HRR), gelatinization temperature/alkali spread GTr (mm) and aroma sense (Ass) were recorded according to Yan and De-lin (2004).

Samples were dried for 4 h under the sun and stored for the sometime at room temperature, rough rice was processed to brown rice and milled rice using a conventional rice miller machine. Paddy grain length and grain width, brown rice length, brown rice width, brown rice shape, of head rice was measured using caliper with the precision of 0.02 mm as described by Khush and Cruz (2000).

For each trait of every F_1 generation, 10 grains were measured in three replicates. Percentage of milling recovery (MR) and percentage of head rice recovery (HRR) were accessed following the procedure developed by International Rice Research Institute (IRRI) and used by Khush and Cruz (2000). Gelatinization temperature (alkali spread value, ASV) were measured and graded while gel consistency was measured and classified according to the method as used by Rafii et al. (2014). The Amylose content was determined according to Hu et al. (2010).

For the aroma sense assessment, 40 milled grains for each sample were soak with 10 ml 1.7% KOH solution in a glass Petri-dishes for 1 h. The samples were scored on a scale of 1 to 4 where 1,2,3 and 4 corresponding to absence of aroma, slight aroma, moderate aroma and strong aroma as recommended by IRRI (2007). The test for aroma was assessed by a rating panel of eight people selected and trained for their ability to differentiate between the smelling of the genotypes with aroma and the ones with do not have aroma by smelling and chewing the grains, this methodology was used by Khush and Cruz (2000). Statistical package for social sciences (SPSS) 20th edition was used for statistical analyses at 95% of the probability.

Data analysis

Correlation coefficients were calculated for all the characters and the path coefficient analysis splits the genotypic correlation coefficient into direct and indirect effect according to Bhati et al. (2015). The path coefficient analysis was estimated by the formula below used by (Yakubu, 2010).

$P_{YXi} = b_i(S_{xi}/S_y)$; Where: $P_{y.xi}$ = path coefficient from Xi to Y (i= Grw, BR, BrS, GrL, HRR, GTr, Ass); b_i = regression coefficient; S_{xi}= standard deviation of Xi; S_y= standard deviation of Y.

RESULTS AND DISCUSSION

It's important to have high genetic variability in crops for particular traits in order to achieve successful plant breeding programs (Kiani and Nematzadeh, 2012). Estimates for range, mean, standard deviation and coefficient of variation (CV) for selected F_1 generation evaluated are shown in Table 1. The maximum standard deviation was observed on head rice recovery (16.12) followed by gel consistence (13.81) and milling recovery (10.74). Among the grain quality traits, gelatinization temperature measured as alkali dispersion, aroma sense, head rice recovery, milling recovery and brown rice shape with the CVs of 59.31, 44.43, 22.65, 17.13 and 16.90 percent had more phenotypic variation, respectively.

The paddy grain rice length (6.84%), paddy grain width (7.49%), gel consistence (9.48), paddy grain length (10.50%) and brown rice width (13.54%) had less variation. Plant breeder uses selection for improving of traits of interest of crop by management of available genetic variability and landraces are known to have larger range of variability (Shanthala et al., 2005; Kiani and

Table 2. Correlation coefficients recorded among various rice grain quality traits.

Variable	Grw	BRw	BrS	GrL	HRR	MR	GTr	Ass	BrL
Grw	1.000	-	-	-	-	-	-	-	-
BRw	0.692**	1.000	-	-	-	-	-	-	-
BrS	-0.497**	-0.787**	1.000	-	-	-	-	-	-
GrL	-0.100	-0.080	0.404**	1.000	-	-	-	-	-
HRR	0.040	0.122	-0.080	0.000	1.000	-	-	-	-
MR	0.046	0.238	-0.104	-0.065	0.511**	1.000	-	-	-
GTr	-0.205	-0.068	0.116	0.225	0.212	0.109	1.000	-	-
Ass	-0.278*	-0.171	0.094	0.087	-0.052	0.004	0.157	1.000	-
BrL	0.036	0.116	0.476**	0.558**	-0.009	0.095	0.241	0.001	1

**Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed). Grw: Paddy grain width; BRw: Brown rice width; BrS: brown rice shape; GrL: paddy grain length; HRR: Head rice recovery; MR: milling recovery; GTr: Gelatinization temperature; Ass: Aroma sense and BrL: Brown grain length.

Nematzadeh 2012). This study reveals the possibility of effective selection for improvement of rice grain quality in subsequent segregating populations for these landraces genotypes.

Correlation and path coefficient analysis for grain quality and aroma

The analyses of correlation for grain quality including aroma sense (Table 2), showed strong and highly significant positive correlation between brown rice width and paddy grain width (r = 0.692**). There was a highly significant and negative, but strong correlation between brown rice shape and paddy rice width (r= -0.497**) while for aroma sense the correlation was statistically significant and negative, although weak (r= -0.278*). The strong and positive correlation observed between brown rice width and paddy grain width reveals that an increase on the grain width leads to 69.2% increase on paddy grain width and vice-versa. The negative relationship between brown rice shape and paddy grain width means that an increase of rice shape leads to a decrease of 49.7% in grain width and vice-versa. The results elsewhere shows that an increase in 27.8% of width of the brown rice can decrease the aroma scent by 27.8% (Anandakumar et al., 2015).

The brown rice length was statistically high and negatively but strong correlated with brown rice shape (-0.787**). There was no correlation between brown rice length and brown rice width, paddy grain length, head rice recovery, milling recovery, gelatinization temperature and aroma sense. There was a statistically highly significant positive correlation between the brown rice length and brown rice shape (0.476**). A positive correlation between these two character were also reported by Golam et al. (2014). The paddy grain length was strongly and positively correlated with brown rice length (r = 0.558**). There was no significant correlation between paddy grains lengths and 8 other character evaluated in this study. Brown rice shape statistical highly significant correlated positively with paddy grain length (r = 0.404**). There were no correlations between the brown rice shape and head rice recovery, milling rice recovery, gelatinization temperature and aroma sense.

Head rice recovery was highly and positively correlated with milling rice recovery (r = 0.511**), and there were no relationship between head rice recovery and other characters evaluated. The aroma sense correlated negatively with grain width (r = - 0.278*). Jewel et al. (2011) reported that aroma had significant and positive relationship with paddy grain length-width ratio; significant and negative association with grain width, significant and negative association with gelatinization temperature, and no significant association with grain length.

Regression and path co-efficient analysis

The regression anova (Table 3) showed a highly statistically significant regression model (p=0.000). The brown rice length was considered as resultant variable (dependent) while paddy grain width, brown rice width, brown rice shape, paddy grain length, head rice recovery, milling recovery, gelatinization temperature and aroma sense were considered as casual (independent) variables and the model mean square was equal to 2. 619. The model summary provide the values of R = 0.956; coefficient of multiple determination (R^2 = 0.915) and the standard error of the estimate was 0.215.

The high R^2 obtained on the regression model indicates that it explains all the variability of the response variable are around the mean. In other ways the variation on the characters was more likely due to genetic makeup rather than environmental influences.

The regression analysis was used to determine the direct effect of the characters that contribute to brown grain length. The B values presented in Table 4, are the

Table 3. Analysis of variance for the regression model.

Sources of variance	df	Sum squares	Mean square	F	Sig.
Regression	8	20.950	2.619	56.202	0.000[b]
Residual	42	1.957	0.047	-	-
Total	50	22.907	-	-	-

adependent variable: BrL: brown grain length.

Table 4. Regression co-efficient (B), standard error and P values for the brown rice length (BrL).

Variable	B	Std. Error	Sig.
(Constant)	-5.091	0.762	0.000
Grw	-0.563	0.197	0.007
BRw	2.774	0.198	0.000
BrS	2.481	0.152	0.000
GrL	0.009	0.060	0.885
HRR	-0.002	0.002	0.413
MR	-0.005	0.004	0.144
GTr	0.037	0.013	0.007
Ass	0.023	0.032	0.478

Grw: Paddy grain width; BRw: Brown rice width; BrS: brown rice shape; GrL: paddy grain length; HRR: Head rice recovery; MR: milling recovery; GTr: Gelatinization temperature; Ass: Aroma sense and BrL: Brown grain length.

Table 5. Direct (diagonal bolded) and indirect effect of studied grain quality traits on brown grain length in eleven F_{1s} and their six parents**.**

Variable	Grw	BRw	BrS	GrL	HRR	MR	GTr	Ass	R
Grw	**-0.563**	0.443	-0.227	0.000	-0.288	-0.061	-0.089	-0.001	0.036
BRw	-0.390	**2.774**	1.121	0.001	1.417	0.302	0.436	0.668	0.116
BrS	0.280	-2.183	**2.481**	0.001	1.268	0.270	0.390	0.235	0.476
GrL	0.056	-0.223	-0.199	**0.009**	0.004	0.001	0.001	0.000	0.558
HRR	-0.023	0.337	-0.258	0.000	**-0.002**	0.000	0.000	-0.001	-0.009
MR	-0.026	0.661	-0.258	-0.001	-0.001	**-0.005**	-0.001	-0.003	0.095
GTr	0.115	-0.188	0.287	0.002	0.000	-0.001	**0.037**	0.003	0.241
Ass	0.157	-0.474	0.233	0.001	0.000	0.000	0.006	**0.023**	0.001

Grw: Paddy grain width; BRw: Brown rice width; BrS: brown rice shape; GrL: paddy grain length; HRR: Head rice recovery; MR: milling recovery; GTr: Gelatinization temperature; Ass: Aroma sense and BrL: Brown grain length; The bold values represent the direct effect for the brown grain length.

regression co-efficient that indicate the direct effect character on the path co-efficient analysis. The results on path co-efficient analysis showed direct and indirect effect on brown grain length for 8 grain quality characters (Table 5). The results are as followed:

Paddy grain length (GrL)

There was a positive direct effect of paddy grain length on brown grain length, although very low (0.009). The indirect effect of paddy grain length was detected for paddy grain width (0.056), head rice recovery (0.004), milling recovery (0.001), and gelatinization temperature (0.001). There was no indirect effect of aroma sense (0.000) for GrL. The negative indirect effect for the GrL was reflected by brown rice width (-0.223) and brown rice shape (-0.199).

This results shows that selecting for paddy grain length could use indirect characters such as paddy grain width, head recovery, milling recovery and gelatinization temperature. The path analysis shows that aroma sense character does not have any influence on paddy grain length. Brown rice width and brown rice shape have a negative indirect influence of selection for improvement of paddy grain length. The results were not in agreement with those of (Anandakumar *et al*. 2015) and Nandan and Singh, (2010), who found high positive direct effect on the paddy grain length.

Paddy grain width

There was a negative direct effect of paddy grain width (-0.563). The indirect effect was high and positive only for brown rice width (0.443) and no indirect effect were found for paddy grain length. The indirect and negative effect was observed on the brown rice shape, head rice recovery, milling rice recovery, gelatinization temperature and aroma sense (Table 5). These results suggest that brown grain length could be utilized for indirect selection and improvement. This results was similar to those of (Nandan and Singh, 2010), but contradicted with findings by Sedeghi, (2011) who found a positive direct effect of paddy grain width on paddy grain length.

Brown rice width

The direct effect of brown rice width on brown rice length was very high and positive (2.774), and the indirect effect was negative for paddy grain width (-0.390). There was high indirect effect of brown rice width thru head rice recovery (1.417), milling rice recovery (0.302), and gelatinization temperature (0.436) and aroma sense (0.668). The paddy grain length indirect effect was positive but negligible (0.001). These results suggest that direct selection for brown rice length could be made by directly selecting for brown rice width and also indirectly through brown rice shape, head rice recovery, milling recovery, gelatinization temperature and aroma sense. Kumar et al. (2016) reported high positive direct effect for brown rice width and other grain quality character studied and concluded that this is one of the most important contributing character toward brown rice length.

Brown rice shape

There was a high and direct positive effect of grain rice shape (2.481) on brown rice length. The indirect effect was high but negative for brown rice width, (-2.183) only. The indirect effect was high and positive for paddy rice width (0.280), head rice recovery (1.268), milling recovery (0.270), gelatinization temperature (0.390) and aroma sense (0.235), however low for paddy grain length (0.001). These results suggest that selection in earlier breeding material through the brown rice shape can have positive improvement on brown rice length directly. The same could be indirectly done through paddy grain width, paddy grain length, head rice recovery, milling rice recovery, gelatinization temperature, and also aroma sense. The results are in agreement with findings by Kumar et al., (2016).

Head rice recovery

The direct effect of head rice recovery on brown rice length was lower and negative (-0.002). The indirect effect was high and positive for brown rice width (0.337). There was no indirect effect for paddy grain length (0.000), milling recovery (0.000) and gelatinization temperature (0.000). The indirect effect was high and negative for brown rice shape (-0.258) and negative and low for paddy rice width (-0.023) and aroma sense (-0.001). These results show that selection of brown grain length through head rice recovery is not possible because the direct effect and indirect effect are negative and largely insignificant. Results do not agree with those of Kumar et al. (2016) but are supported by findings from Vanisree et al. (2013).

Milling rice recovery

The direct effect of milling rice recovery was negative and negligible (-0.005). The indirect effect was high and positive for brown rice width (0.661) and negative for brown rice shape (-0.258). Other characters had negative and very low indirect effect. These results show that selection of brown rice length trough milling recovery has no direct effect but indirectly could be done through brown rice width. The same could be achieved through selection of brown rice shape. Vanisree *et al*. (2013) evaluated for brown rice length and Brown rice width and the results were high and positive for direct effect.

Gelatinization temperature

There was a low and positive direct effect on gelatinization temperature (0.037) on brown rice length. The indirect effect was high and positive for brown rice shape (0.287) and paddy rice width (0.115). A lower positive indirect effect was recorded for brown rice length via paddy grain length (0.002) and aroma sense (0.003). Head rice recovery showed no effect (0.000). The high indirect and negative effect was recorded only for brown rice width (-0.188). Verma et al. (2014) reported differences on the grain quality characters for the study done to evaluate aromatic short grain rice cultivars and elite lines for yield and quality character.

Aroma sense

The direct effect of aroma sense over brown rice length was positive (0.023) although lower and insignificant. The high indirect effect was observed on the paddy grain width (0.157) and brown rice shape (0.233). There was a high and negative effect of brown rice width (-0.474) for brown rice length selection. Verma et al. (2014) found similar results in evaluating grain quality character on aromatic short grain rice cultivars.

Conclusions

Estimates for range, mean, standard deviation and coefficient of variation (CV) for selected F_1 generation evaluated were good enough, revealing the possibility of effective selection for improvement of rice grain quality in subsequent segregating populations. The correlation and path-coefficient analysis for grain quality and aroma show that improvement of these two important rice quality characters could be done through selection starting from earlier generations.

There was a strong and positive correlation between brown rice width and paddy grain width; brown rice shape and paddy grain length; paddy grain length and brown grain length; brown rice shape and brown grain length; and also head rice recovery and milling recovery concluding that there is a cause and effect on those characters. There was a negative and strong correlation between brown rice shape and brown rice width; brown rice width and brown rice shape and also aroma sense and paddy grain width. These results show that the variation recorded on the characters under evaluation was due to genetic makeup of the genotypes used for crossing program rather than the environmental effect.

This conclusion is also supported by the highly statistically significant result obtained on the regression model. The path co-efficient analyses revealed a low direct positive effect for paddy grain length through brown grain length. The direct effect of brown rice width, brown grain shape through brown grain length was high and positive. Selecting for paddy grain length could be done using indirect characters such as paddy grain width, head recovery, milling recovery and gelatinization temperature. Aroma sense character does not have any influence on paddy grain length. Brown rice width and brown rice shape have a negative indirect influence of selection for improvement of paddy grain length showing that these characters have a direct effect and influence on brown grain length indicating their importance in grain rice quality improvement.

Conflict of interests

The authors have not declared any conflict of interests.

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