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Research paper

Genetic variability, heritability and path analyses of yield and yield related traits of newly developed rice (*Oryza sativa* L.) genotypes in lowland ecology in Ghana

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The experiment was conducted with the objective of estimating the genetic variability and the path coefficient analysis for yield and yield related traits of 45 newly released rice genotypes at the research field of Council for Scientific and Industrial Research – Crops Research Institute in Sokwai, Kumasi. The Genotypic Coefficient of Variation (GCV) were lower than the Phenotypic Coefficient of Variation (PCV) for all the traits indicates the influence of environment on the traits. The GCV and PCV value ranged from 0.95% to 12.93% and 2.95% to 78.50%, respectively. Panicle length recorded moderate heritability together with moderate genetic advance which suggests that they can be improved through direct selection due to predominant additive variation and indicating that a moderate level of genetic variability is present in these characters. Positive and direct effect was exhibited by the plant height, tiller number per plant, plot weight before winnowing on the grain yield as important traits to be considered during selection and improvement programmes.

Key words: genetic variability, heritability, rice, new lines, path analysis

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the important staple cereal food crops that has been used in feeding more than half of the world population (Babu et al., 2012) and its production is mainly done under wet areas (Manonmani and Khan, 2003). It is known to be a source of income and employment opportunities for rice farmers in Ghana. The crop plays a major role in the livelihood of humans (FAOSTATS, 2012). According to the Ministry of Food and Agriculture (2009), subsequent to maize, rice is considered to be the second most important grain food staple in Ghana. In 2019, there was an increase of 900,000 tonnes of paddy (over 30 percent above average). The increase in the production resulted from the implementation of the key Government rearing for food and jobs programme aiming to achieve self-sufficiency in food production (FAO, 2020). Due to population growth, changes in consumer habitat and urbanization, the demand and consumption of rice keep increasing making it an important crop for food security (Seck et al., 2013). However, lower yield of rice during production can be attributed to the use of unimproved cultivars with poor yielding potentials (Osman et al., 2012), agroclimatic conditions and inadequate high yielding varieties (Manonmani and Khan, 2003). Therefore, in the selection of parents with broader variability for different traits, it is important to consider the genetic divergence among the genotypes (Nayak et al., 2004). Also, for yield improvement there is the need for plant breeders to consider the quantity of genetic variability in the germplasm (Idahosa et al., 2010). Traits with high heritability could be identified through evaluation and characterization of germplasm which will enhance a successful breeding programme (Yang et al., 2007). Path coefficient analysis is a tool which allows the partitioning of the correlation coefficient into its components, where one of the component measures the direct effect of a predictor variable upon its response variable; the other component being the indirect effect of a predictor variable on the response variable through other predictor variables (Dewey and Lu, 1959; Ahmadizadeh et al., 2011). Path coefficient analysis has been used extensively in agriculture by plant breeders to identify traits that are of importance during selection criteria to improve upon the yield of crops (Milligan et al., 1990). In view of that, the study seeks to estimate the genetic variability and path coefficient analysis of the yield traits of the rice lines in a lowland ecology in Ghana.

MATERIALS AND METHODS

Study area and planting materials: The study was carried out at Crops Research Institute of CSIR, Ghana, research site at Sokwai in the Atwima Nwabiagya Municipal during the rainy season of 2020. Sokwai lies approximately on latitude 6º 75'N and between longitude 1º 45' and 2º 00' West. It covers an estimated area of 294.84 sq. km. Sokwai is located within the wet semi-equatorial zone marked by double maximum rainfall, ranging between 170cm and 185cm per annum. The experiment comprised of Forty-five (45) Africa Rice lines, including ARICA 2 (West Africa regional check), CRI-Jasmine 85 and Agra Rice as national and local checks, respectively were used for the study. The layout of the experiment was done using a 2×4 m^2 plot which was arranged in a square block with a distance of 1 meter between blocks in an alpha-lattice design with three replications. During the experiment all the recommended agronomic practices were followed.

Data collection: The descriptor developed by International Rice Research Institute (2013) was used for data collection. Data was collected on the Plant Height, Culm Length, Panicle Length, lodging incidence, Tiller No/Plant, Panicle Number, Plot Weight before Winnowing, Moisture Content, Plot Weight After Winnowing, Total Weight of 5 Hills, Days to Maturity, Days to 50% Flowering.

Statistical analysis: Analysis of variance (ANOVA) was used to test the statistical significance between treatments. All statistical tests were performed using the Statistical Tool for Agricultural Research (STAR) Version 2.0.1 (STAR, 2014). The procedure suggested by Allard (1961) was used to calculate the phenotypic, genotypic and environmental variance with the respective mean squares. The estimation of the phenotypic and the genotypic coefficient of variation were computed using the formula proposed by Johnson *et al.* (1955). The Broad-sense heritability was estimated according to the procedure suggested by (Uguru, 2005; Acquaah, 2009). Path coefficient analysis was carried out following the method suggested by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Estimation of Variability

The phenotypic variance and the genotypic variance values with less than 10% were categorized as low, 10 - 20% as moderate, greater than 20% as high (Sivasubramanian and Menon 1973). The phenotypic variance was greater than the genotypic variance in all the agronomic traits studied indicating that the environment had an important role in the expression of these agronomic traits. The low variation between PCV and GCV estimates may facilitate selection. The GCV value ranged from 0.95% in moisture content to 12.93% in plot weight before winnowing while the PCV value ranged from 2.95% in days to maturity and 78.50% in the plant height. Plot weight after winnowing and plot weight before winnowing recorded moderate PCV and GCV. Low PCV and GCV values was recorded for plant height, culm length, moisture content, days to maturity and days to 50% flowering. Similar findings were reported by Padmaja et al. (2008), Shrivastava et al. (2014), Kumar et al. (2015) and Gour et al. (2017).

According to Bello et al. (2012) heritability estimates are useful for breeding quantitative traits because they provide information on the degree to which a particular trait can be inherited by subsequent generations. Heritability values are categorized as low, moderate and high (Robinson et al., 1949). 0-30% - Low, 30-60% - Moderate and > 60% - High. The broad sense heritability of the traits ranged from 2.26% for moisture content to 90.20% for days to 50% flowering. Also, moderate heritability was recorded for tiller number per plant, panicle number, plot weight before winnowing and plot weight after winnowing (30 – 60%). Further, high heritability (>60%) was observed in days to maturity, plant height and the culm length and days to 50% flowering. Low heritability values (0-30%) was recorded for total weight of 5 hills, panicle length and moisture content. The estimated genetic advance expressed in percentage of mean (GAM) with values less than 10% is low, 10 – 20% is moderate and more than 20% is high (Johnson *et al.,* 1955). GAM was very high in plot weight after winnowing and plot weight before winnowing (>20%). Panicle number, culm number and plant height recorded moderate (10 – 20%) GAM. However, low (<10%) GAM was observed in days to 50% flowering, days to maturity, total weight of 5 hills, moisture content, tiller no/plant and the panicle length. The combination of heritability estimates and genetic advance would be useful in predicting genotypes than the use of heritability alone (Johnson *et al.,* 1955). Also Panse (1957) reported that the traits that have high heritability and high genetic advance are controlled by addictive genes and therefore will benefit from selection. High heritability coupled with low genetic advance is as a result of the non-addictive gene effects. The present study observed a high heritability and low genetic advance for the days to 50% flowering, days to maturity, plant height and the culm length. Moderate heritability coupled with moderate genetic advance was recorded in panicle number, which suggests that the addictive gene effect in controlling the expression of the traits and therefore direct selection can be used to improve the traits. Similar findings were reported by Sidhya *et al.* (2014) in the traits studied in tomatoes. However, low heritability with low genetic advance of the mean was recorded for panicle length, moisture content and total weight of 5 hills. This implies that there is the presence of non-addictive genes and selection of these traits would be ineffective for improvement purposes.

Path Coefficient Analysis

The path correlation coefficient analysis is separated into direct and indirect effects of the different characters (Table 2). Plant height was found to have the highest and positive effect on grain yield (0.5927) followed by tiller number per plant (0.3589), plot weight before winnowing (0.2898) and the lodging incidence (0.0435). The highest and positive direct effect of plant height on gran yield was also reported by Kiani and Nematzadeh (2012). The finding indicates that for an increase in the grain yield, the plant height has a positive and direct effect. The direct and positive effect of some characters indicates that the selection of these traits is directly helpful for the improvement of the trait of interest (Kampe *et al.,* 2018). Panicle number (-0.6529) exhibited high and negative direct effect on grain yield followed by culm length (-0.5943), panicle length (-0.2076), days to flowering (-0.1544). The negative direct effect indicates that the direct selection through these traits would not prove to be useful for the improvement of yield of rice.

Table 1. Estimates of genetic parameters for the agronomic traits

Traits	Mean	GV	PV	EV	GCV (%)	PCV (%)	H^2 (%)	GA (%)	GAM
PH	141.40	104.78	133.48	28.70	7.24	8.17	78.50	18.68	13.21
CL	114.60	99.32	127.67	28.35	8.70	9.86	77.79	18.11	15.80
PL	26.80	2.55	10.64	8.09	5.95	12.17	23.94	1.61	6.00
TNP	11.00	0.53	1.65	1.12	6.60	11.67	31.99	0.85	7.69
PN	10.40	0.74	1.61	0.87	8.28	12.20	46.01	1.20	11.56
PWBW	3.37	0.19	0.32	0.13	12.93	16.78	59.44	0.69	20.54
MC	16.25	0.02	1.05	1.03	0.95	6.30	2.26	0.05	0.29
PWAW	2.94	0.17	0.30	0.13	13.90	18.64	55.64	0.63	21.36
TWH	165.40	208.33	741.33	533.00	8.73	16.46	28.10	15.76	9.53
DM	131.52	11.25	15.00	3.75	2.55	2.95	74.98	5.98	4.55
DF50	92.90	14.08	15.62	1.53	4.04	4.25	90.20	7.34	7.90

Where PH – Plant Height, CL =Culm Length, PL - Panicle Length, TNP =Tiller No/Plant, PN =Panicle Number, PWBW =Plot Weight Before Winnowing, MC =Moisture Content, PWAW =Plot Weight After Winnowing, TWH =Total Weight of 5 Hills, DM =Days to Maturity, DF50 =Days to 50% Flowering, PCV: Phenotypic coefficient of variation, GCV: genotypic coefficient of variation, H^2: broad sense heritability, GA: genetic advance, GAM: genetic advance as percent of mean.

Table 2. Direct (Diagonal) and indirect effect path coefficients for different characters

	PH	CL	PL	TNP	PN	PWBW	MC	PWAW	TWH	LI	DM	DF
PH	**0.5927**	-0.5706	-0.0457	-0.0431	0.1110	0.0087	0.0015	0.0022	-0.0488	0.0157	-0.0046	0.0510
CL	0.5690	**-0.5943**	0.0145	-0.0431	0.1110	0.0203	0.0074	0.0006	-0.0540	0.0148	-0.0018	0.0556
PL	0.1304	0.0416	**-0.2076**	0.0000	0.0131	-0.0464	-0.0192	0.0056	0.0154	0.0044	-0.0103	-0.0170
TNP	-0.0711	0.0713	0.0000	**0.3589**	-0.6137	-0.0666	0.0222	-0.0039	-0.0411	-0.0048	-0.0004	0.0093
PN	-0.1008	0.1010	0.0042	0.3374	**-0.6529**	-0.0522	0.0251	-0.0056	-0.0488	-0.0026	-0.0018	-0.0031
PWBW	0.0178	-0.0416	0.0332	-0.0825	0.1175	**0.2898**	-0.0177	-0.0234	-0.0231	-0.0035	0.0021	-0.0185
MC	-0.0059	0.0297	-0.0270	-0.0538	0.1110	0.0348	**-0.1478**	0.0011	-0.0103	-0.0087	0.0053	0.0216
PWAW	-0.0237	0.0059	0.0208	0.0251	-0.0653	0.1217	0.0030	**-0.0557**	0.0565	-0.0035	-0.0011	0.0062
TWH	0.1126	-0.1248	0.0125	0.0574	-0.1240	0.0261	-0.0059	0.0122	**-0.2570**	0.0048	0.0000	0.0062
LI	0.2134	-0.2021	-0.0208	-0.0395	0.0392	-0.0232	0.0296	0.0045	-0.0283	**0.0435**	-0.0018	0.0154
DM	0.0771	-0.0297	-0.0602	0.0036	-0.0326	-0.0174	0.0222	-0.0017	0.0000	0.0022	**-0.0354**	-0.0880
DF	-0.1956	0.2140	-0.0228	-0.0215	-0.0131	0.0348	0.0207	0.0022	0.0103	-0.0044	-0.0202	**-0.1544**

Residual Effect = 0.6832 Diagonal values (bold) indicates direct effects. *Where* PH – Plant Height, CL =Culm Length, PL - Panicle Length, TNP =Tiller No/Plant, PN =Panicle Number, PWBW =Plot Weight Before Winnowing, MC =Moisture Content, PWAW =Plot Weight After Winnowing, TWH =Total Weight of 5 Hills, LI = Lodging Incidence, DM =Days to Maturity, DF50 =Days to 50% Flowering

Culm length exhibited the highest positive indirect effect (2.5690) followed by lodging incidence (0.2134) on grain yield via plant height. The highest negative indirect effect was observed in tiller number per plant (-0.6137) via the panicle number. The plant height (-0.5706) recorded high negative indirect effect through the culm length. On the contrary, Abebe et al. (2019) reported similar results for plant height. Thus, indirect selection based on these traits should be considered simultaneously as indirect selection criteria for yield improvement. The residual effect (0.6832) showed that the traits which are included in the path coefficient analysis explained 31.68% of the total variation on yield that was contributed by the traits studied. The residual effect of 68.32% indicates that there are some traits that have not been included in the study which could help in contributing to the yield of the different lines of rice.

CONCLUSION

The estimates of the PCV were higher than that of the GCV for all the traits studied. The heritability was high for plant height, culm length, days to maturity and days to 50% flowering. Also, path coefficient analysis revealed that the plant height, tiller number per plant, plot weight before winnowing and the lodging incidence had a positive and direct effect on the grain yield. The selections of traits with such traits are of crucial benefit in future breeding programs for crop improvement purposes.

AUTHOR CONTRIBUTIONS

S.E.B. carried out the experiment. R.R.A. wrote the manuscript with support from E.F.D. A.S.B. S.E.B. and A. D. O. E.F.D supervised the project. All authors read and approved the final manuscript.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

ETHICS APPROVAL

Not applicable.

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