Research Article

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Correlation and Path Coefficient Analysis of Yield and Component Traits of KAFACI doubled haploid Rice (*Oryza sativa* L) Genotypes in Malawi

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ABSTRACT

The present study exhibits a yield and yield component traits correlations and path coefficient analysis in some KAFACI doubled haploid and other rice {Oryza sativa L} genotypes. The experiment was laid out in a Randomized Complete Block Design {RCBD} with 3 replications at Lifuwu Agricultural Research Station trial fields during the 2018/2019 and 2019/2020 rainy seasons. Eight selected traits namely number of productive tillers per hill, spikelets per panicle, panicle length, days to 50% flowering, days to maturity, 1000 grain weight, and grain yield were considered in this study. ANOVA table illustrated significant differences (p<0.001) for all studied traits and this means that the germplasms comprised a pool of genotypes with huge variations. The new promising lines, which exceed the yield, record of 7000kg/ha of paddy rice for Malawi varieties were identified in the present evaluation of KAFACI lines. Generally, genotypic correlations were higher than phenotypic correlations though in some instances were similar implying that much expression of the lines were influenced by genetic factors. Grain yield showed positive significant correlation with number of productive tillers per hill and only positive in panicle length and spikelets per panicle. This means selection for these traits can improve grain yield. Path Coefficient showed that characters like days to reach maturity, panicle length and spikelets per panicle were directly influencing grain yield thus are important contributors in coming up with selection criteria for the set objectives in a rice breeding program.

Keywords

Correlations, Path coefficient, Rice breeding, Grain yield, Anther-culture, Yield components.

Introduction

Rice {*Oryza sativa*} is an important cereal crop worldwide with increased consumption mainly due to population growth, urbanization and economic growth [1]. The global rice productivity is rising at a rate of 1% per year instead of the needed 2.4% per year in order to double production by 2050. It is the second most widely consumed food grain after wheat [2] and provides 20% caloric intake worldwide [3]. It is the second most important cereal crop in Malawi, after maize. The use of unimproved varieties among other reasons, had led to declined rice productivity for Malawi in particular and Africa as a whole. Presently, the national average rice productivity in Malawi is <2000 kg/ha. However, rice-breeding efforts carried out over the years had offered Malawian farmers some improved varieties such as Kayanjamalo, Katete, Mpheta, Nanzolo, Mpatsa, Wachangu and Makafaci among others.

Interventions to evaluate, select and disseminate improved high-yielding rice varieties, combined with widespread adoption, would lead to increased productivity above the current national average of <2000 kg/ha to, at least, 3000 kg/ha, standing for a 50% rise. Korea Africa Food and Agriculture Cooperation Initiative (KAFACI) through the Rural Development Administration (RDA) is further supporting rice-breeding activities so that more improved high yielding and quality rice varieties are released and made available to farmers. The KAFACI Rice project in Malawi can contribute towards attainment of rice self-sufficiency through release of improved high yielding and preferred grain traits varieties developed by anther – culture.

Photo 1: Tongil - type KAFACI germplasm well adapted in Malawi.

The aim of this project was to evaluate, release and disseminate high-yielding, drought tolerant and aromatic rice varieties possessing preferred grain quality traits for both rain fed and irrigated lowland ecologies of Malawi. So far, 10 high yielding KAFACI doubled haploid germplasms had been identified and advanced into the National Performance Trial with the expectation that they would be nominated for release after further testing. Generally, traits of interest to breeders such as grain yield are complex in nature thus controlled by the contribution of other traits [3,4]. It is therefore vital to understand the interrelationship of rice yield with some yield attributing traits in order to distinguish genotypic correlations into their direct and indirect effects. Correlation analysis studies the joint variation of two or more variables for determining the amount of association between those variables Kothari and Garg [5]. Trait correlation stipulated by correlation coefficient is a vital criterion for selecting superior genotypes for advancement through consideration of attributing traits on yield. Path coefficient is the standardized partial regression coefficient, which measures direct influence of one variable upon another, as such are categorized into causal and effect groups [6,7]. It partitions the components of correlation coefficient into direct and indirect effect and visualize the relationship in a more meaningful manner [8,9]. Path coefficient analyses are fundamental in identifying traits that are helpful as selection criteria in order to advance superior crops in a breeding programme. This paper therefore presents a yield and yield component traits correlations and path coefficient study conducted on 10 KAFACI doubled haploid germplasms mainly for the objective of breeding for high yield.

Materials and Methods

Plant

A total of 172 high yielding KAFACI rice genotypes were introduced in Malawi during 2018/2019 wet season and used in this study. The most superior germplasms were selected and advanced into NPT after passing through Observation Yield Trial, Preliminary Yield Trial and Advanced Yield Trial experimental stages. This work comprises combined results obtained during the two wet seasons of 2018/2019 and 2019/2020 for the most superior selected germplasms. So far, the 10 lines were designated as KF18002, KF18007, KF18010, KF18055, KF18068, KF18019, KF190223 KF18135, KF18156, and KF18171 along with the two checks; Nanzolo and Mtupatupa.

The lines were tested under the KAFACI funded project "Development of high yield and grain quality rice variety". The background of these plant materials was a series of tremendous breeding work conducted at Africa Rice under the bigger project "Enhancement of high-yielding rice germplasms and breeding capacity of rice producing countries in Africa – the Africa Rice Development Partnership". In this partnership, 18 KAFACI member countries including Malawi are involved and Korea is the lead player. Thousands of doubled haploid rice germplasms were therefore developed through anther culture in a Tissue culture laboratory available at Africa Rice, Saint Louis (Senegal). Since crop breeding is more dependent on variation, different traits combinations were considered during hybridization for the development of the filial generations. These traits included but not limited to high yielding potential, medium – long grain, low –medium amylose content, earliness to maturity, high biomass, disease resistance, semi- dwarfism and drought tolerance. Lines possessing one or more plantlets were regenerated from separated calli of the F2 – F3 generations obtained from interspecific crosses among Korean Tongil - type, Japonica with African cultivars and wild species. The lines were grown at Sahel Station in OYT for further fixation and selection. In advanced generation, potential lines with the desired traits were selected by breeders of member countries during the workshop organized at the end of every year and shared accordingly.

Experimental site

The KAFACI doubled haploid germplasms were screened at Lifuwu Agricultural Research Station trial fields during both rain fed and irrigated seasons. However, this study presents work done in two rainy seasons. The site lies at an altitude of 500 meters above sea level (masl), forming part of the great expansive seasonally flooded Katete dambo. It lies at a latitude and longitudinal coordinates of 13.40" S and 34.35" E, respectively. The site receives a unimodal type of rainfall which falls between December and June and the average amount is 1230 mm annually. Supplementary water for irrigation was pumped from Lake Malawi using electric energy through pipes which are directly connected into the experimental fields. Mean annual temperatures range between a minimum of 19 degrees Celsius to a maximum of 29 Degrees Celsius. The soils for the sites could be described as vertisol, 45% clay, comprising low nitrogen and phosphorus content, with pH range of between 7 to 8.

Experimental design

The screening of KAFACI Doubled Haploid rice germplasms along with their checks was conducted in a Randomized Complete Block Design (RCBD) with three replications. Plant to plant and row to row spaces were maintained at 20 cm and one seedling was transplanted per plant hill. The plot size was therefore distinguished into 5 m long x 0.4 m wide thus three rows with 25 hills per row. A space of 0.5 m was maintained between plots and 1m between replications. The NPK6S1Zn fertilizer was applied at the rate of 68+12+6+7.5+2.5S kg per hectare, in relation to the old recommended times and doses [10] of the NPK phased-out basal dressing fertilizer in Malawi. Urea fertilizer was applied as a top dresser at the rate of 120 kg per hectare. Other recommended cultural practices such as weeding, scuffling, rouging and supplementary application of water were done at respective crop stages and conditions.

Photo 2: KAFACI lines in PYT at Lifuwu Agricultural Research Station, 2019/2020.

Data collection and analysis

Data collection was done for yield and yield components such as heading date, panicle length, number of productive tillers/hill, plant height, number of spikelets /panicle, 1000 - grain weight, and grain yield on five randomly selected plants for each entry per replication. Days to 50% flowering was recorded basing on the entire plot and days to maturity was captured when 85% of the spikelets per panicle had matured. The agronomic traits were measured at relevant crop stages. The Standard Evaluation System for Rice (2013 edition) reference booklet was used for all trait measurements except where stated otherwise. Analysis of variance for traits of the studied genotypes was achieved using Genstat 18th Edition. Observations were recorded and the data was subjected to statistical analysis following [11] for correlation coefficient and path analysis study. Microsoft office Excel was used where data was standardized before a regression analysis was carried out for a partial regression coefficient. This was achieved by containing one dependent variable Y (8) and 7 independent variables (P1…. P7); using the equation: X = (x – m)/Sd to the raw data for standardization Kang (2015).

Where: X = value for each trait of {Y (8), P1. …...P7};

m = mean

Sd = Standard deviation

After standardization the direct and indirect effects calculations were done.

Alternatively, the path coefficient values for the traits could be obtained through simultaneous equations as pioneered by Dewey and Lu [12]. The simultaneous equations (n-1 for n traits) for solving effect of each of seven traits (1 to 7) on trait number 8 (Figure 1) were indicated by double and single arrows. The double arrowed lines illustrate mutual association as captured from the correlation coefficient rij while the single arrowed lines depict direct effect as it related to the path coefficients; Pij. Where rijs is the correlation coefficient between ith and jth traits (i = 1 to 7, and j = 2 to 8), also Pi8s stands for direct effect of ith trait on grain yield (trait 8). R =1 - $\{PRS\}^2$; where R is residual effect. The simultaneous equations were formulated in the present study as follows;

r12 = P18 + P18 + r12P28 + r13P38 + r14P48 + r15P58 + r16P68 + r17P78 (i)
r23 = P28+r12P18+P28+r23P38 +r24P48+r25P58+r26P68+r27P78 (ii)
r34 = P38+ r13P18 +r23P28 +P38 +r34P48+r35P58+r36P68+r37P78 (iii)
r45 = P48 +r14P18 +r24P28+r34P38+P48+r45P58+r46P68+r47P78 (iv)
r56 = P58+r15P18 +r25P28+r35P38+38+r45P48+P58+r56P68+r57P78 (v)
r67 = P68+r16P18 +r26P28+r36P38+r46P48+r56P58+P68+r67P78 (vi)
r78 = P78+r17P18+r27P28+r37P38+r47P48+r57P58+r67P68+P78 (vii)
R = 1– $(PRS)^2$ (viii)

Photo 3: The KAFACI genotypes at maturity stage during 2019/2020 season.

Results and Discussions

Analysis of Variance

The analyzed yield data revealed that the 10 lines were superior and five of them, namely; KF18007, KF18002, KF18068, KF18171 and KF190223 were significantly higher than the two check varieties used. These 10 KAFACI lines have been advanced into NPT with mean yield range of 6794 to 9628 kg/ha. Regarding specific traits, there was significant differences in terms of grain yield ($P<0.001$) and other traits among the studied lines. This also means that the germplasms comprised a pool of large genetic variations. Significant differences were also observed for 1000-grain weight, days to reach maturity, plant height, number of tillers per plant and panicle length. The mean highest yielding line was K18007 with average yield of 9628kg per hectare and it matured at 114days (Table 1). The significant differences observed among the lines imply that there is diversity within these lines and that is vital in crop breeding, as superior ones are there to be advanced and/or be used as parents during hybridization.

Correlation Co-efficient

Correlation illustrates only the relationship between two traits while path coefficient analysis permits separation of the direct and indirect effects via other attributes by partitioning the associations. The phenotypic and genotypic correlation coefficients tabulated for eight traits under study are presented in Table 2. The genotypic correlations were higher than phenotypic ones for some traits except in other instances where they were similar. This illustrates that much expression of the lines was influenced greatly by genetic composition.

Tillers per hill

Grain yield per hectare depicted positive and significant correlation with number of tillers per hill (0.454*). This implies that rice genotypes that produce high number of productive tillers per hill have a greater yield advantage, thus this trait can form one of the bases for selection of rice genotypes. This result agrees with Nandan et al. [13], Rathod et al. [2] and Padmaja et al. [14]. Furthermore, there was positive significant correlation for this trait with panicle length. Positive non – significant correlation was also observed for this trait with spikelets per panicle, days to 50% flowering and days to maturity. However, non-significant negative correlation was observed for this trait with plant height and 1000-grain weight. The correlation result for tillers per hill on 1000-grain weight is in great agreement with findings by Kumar et al. [15].

Spikelets per panicle

Positive non-significant correlation was obtained for spikelet's per panicle with grain yield. This means genotypes that are able to

Table 1: Analysis of variance (ANOVA) for the eight traits in 10 KAFACI and other rice genotypes.

Sr. No	PEDIGREE	Tillers/hill	PH	Yield (Kgs /ha)	1000gwt (g)	PL (cm)	Spik/pan	DTM	DTF50 %
1	KF18002	16	103	9393	29	28	167	115	86
2	KF18007	19	101	9628	28	28	161	110	84
3	KF18010	14	95	7908	28	24	147	112	83
4	Nanzolo	10	103	7286	25	25	152	115	87
5	KF18055	11	122	6794	30	26	141	113	85
6	KF18068	9	100	8449	32	25	162	112	82
7	KF18019	15	99	7907	30	27	163	120	94
8	KF190223	18	105	8134	27	29	155	112	88
9	KF18135	15	101	7145	30	26	157	114	88
10	KF18156	11	107	7848	33	28	163	113	89
11	KF18171	14	117	8263	31	28	154	111	85
12	Mtupatupa	17	104	7152	26	27	176	121	91
	MEAN SED	1.9	3.2	686	1.8	0.9	10.8	0.464	1.8
	MEAN LSD	4.0	6.6	1424	3.6	2.0	29	0.962	3.7
	P-Value	<.001	<.001	<0.001	0.001	<.001	<0.001	<0.001	<.001
	CV (%)	14.2	1.3	4.7	3.9	1.6	9.5	0.5	0.8

Table 2: Genotypic and phenotypic correlations for some traits of the studied rice genotypes.

Traits		Grain yield (Y/8)	Tillers per hill (P1)	Spikelets per panicle (P2)	Panicle length (P3)	Plant height (P4)	DTF 50% (P5)	Days To Maturity (P6)	1000 grain weight (P7)
Y(8)		1							
P1	G P	0.454756* 0.452801*	1						
P2	G P	0.345339 0.344020	0.359339 0.359242	1					
P3	G P	0.361743 0.361432	0.587183* 0.587098*	0.395433 0.395372	1				
P4	G P	-0.32752 -0.32537	-0.22432 -0.22432	-0.38301 -0.38301	0.295509 0.295509	1			
P5	G P	-0.32023 -0.32011	0.263512 0.263512	0.459269* 0.459269*	0.351378 0.351378	-0.08864 -0.08864	1		
P6	G P	-0.33582 -0.31573	0.108036 0.108036	0.551576* 0.551576*	-0.03478 -0.03478	-0.19747 -0.19747	0.80582** 0.80582**	1	
P7	G P	-0.10171 -0.10171	-0.40084 -0.40084	-0.02111 -0.02111	0.104578 0.104578	0.245769 0.245769	-0.13101 -0.13101	-0.29202 -0.29202	1

In the correlations table; G = Genotypic, P = Phenotypic, P1= Tillers/hill, P2 = Spikelets per panicle, P3 = Panicle length, P4 = Plant height, P5 = Days to 50% flowering, P6 = Days to maturity, P7 = 1000 grain weight and Y (8) = Grain yield.

*, ** = Significant at 0.05 and 0.01 alpha levels respectively. The correlation coefficient must exceed the two-tailed critical values of 0.451 and 0.708 to be significant at 0.05 and 0.01, respectively.

produce more spikelets per panicle are likely to give high yield when other factors are kept constant. Selection of rice genotypes basing on this trait would form one of the best criteria. This result is in agreement with the findings by Kumar et al. [15] and Reddy et al. [16]. Furthermore, spikelets per panicle had positive significant correlation with days to 50% flowering and days to maturity. This is attributed by the fact that grain filling and ripening are, besides other factors, dependent on the duration the crop stays in the field to complete its growth cycle. Harvesting the crop before maturity means that only few grains might have ripened and counted as spikelets. On the other hand, spikelets per panicle had negative non-significant correlation with 1000-grain weight. This implies that as more grains are produced per panicle, the average seed size declines because of competition among grains for assimilates thus contributing a smaller weight per given number of grains.

Panicle length

There was positive non-significant correlation for panicle length with grain yield. This implies that a longer panicle has the ability to hold more grains compared to a very short panicle. Besides other traits, breeders should therefore consider panicle length as a selection criterion if the purpose is to work on yield. This result is in agreement with other workers such as Rathod et al. [2], Akinwale et al. [17] and Bekele et al. [18]. Positive non-significant correlation was also achieved for this trait with spikelets per panicle, days to 50% flowering and 1000-grain weight. However, negative non-significant correlation was noticed for this trait with days to maturity. This means that panicle length is not necessarily dependent on the duration the crop reaches maturity.

Plant height

There was negative correlation for plant height with grain yield indicating that increased plant height does not necessarily mean an increase in rice yield. This trait had also negative correlation with number of tillers per hill, spikelets per panicle, and days to flowering at 50% and days to maturity. Zahid et al. [9] while studying Basmati Rice also found that grain yield is negatively correlated with plant height. On the other hand, positive correlation was achieved for plant height with panicle length and 1000-grain weight. The positive correlation for this trait with 1000-grain weight was because increased plant height permitted fewer spikelets per panicle (corr. -0.38301) which had little competition for nutrients thus growing heavier. Rathod et al. [2] and Babu et al. [19] found similar results on 1000-grain weight and agreed with Sarker et al. [20] on panicle length.

Days to 50% flowering

Negative non-significant correlation was observed for days to 50% flowering with grain yield. Negative non-significant correlation was also achieved for this trait with plant height and 1000-grain weight. There was positive significant correlation for days to 50% flowering with spikelets per panicle and days to maturity; the latter is in great agreement with a report by Kumar et al. [15] and the former agrees with Babar et al. [21].

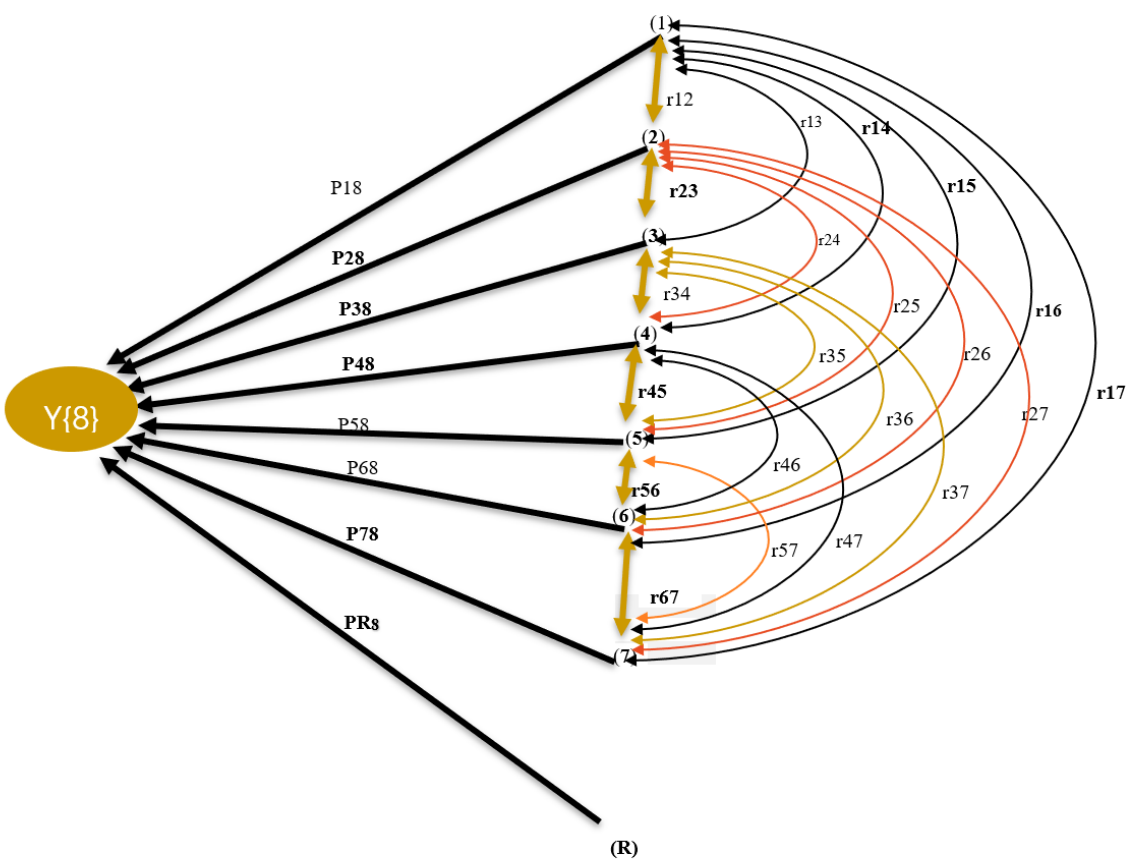

Figure 1: Path Coefficient.

Table 3: SD, Mean, minimum and maximum values for the eight traits of the studied genotypes.

Sr. No	Trait/variable	No of observations	Std Dev	Minimum	Maximum	Mean
1	Tillers per hill	12	3.09	9	19	14
2	Spikelets per panicle	12	8.91	141	176	27
3	Panicle length (cm)	12	1.48	24	29	27
4	Plant height (cm)	12	7.29	95	122	105
5	Days To 50% Flowering	12	3.29	82	94	87
6	Days To Maturity	12	3.24	110	136	114
7	1000 grain weight (g)	12	2.29	25	33	29
8	Grain yield (kg/ha)	12	962.31	6,794	10,628	8,176

Days to maturity

Negative non-significant correlation was noticed for days to maturity with grain yield. This means grain yield is not largely dependent on growth duration as there is a genetic possibility for an early maturing genotype to give higher yield than a late maturing crop and vice versa. Thus, selection of genotypes for advancement cannot dwell on days to maturity alone as a direct trait for selection, but other attributes, Li et al. [22]. There was positive significant correlation for this trait with spikelets per panicle and days to 50% flowering and non-significant with tiller number per hill. This means that the time the crop reaches maturity is dependent on the days that crop flowered; thus, an early flowering genotype will reach maturity earlier than the late flowering genotype and vice versa.

1000-grain weight

The correlation between 1000-grain weight and grain yield was negative and non-significant. This means 1000 grain weight, which is largely influenced by genetic factors does not define grain yield as such cannot be used as a direct selection criterion for rice crop advancement in Japonica –type. These results are in agreement with Li et al. [22], who reported that 1000-grain weight did not influence yield in Japonica ecotypes but largely in Indica - type. Negative non-significant correlation was obtained in the present study for this trait with number of tillers per hill, spikelets per panicle, days to 50% flowering and days to maturity and positive non-significant correlation with panicle length and plant height.

Path Coefficient

The path coefficient diagram (Figure 1) depicting interrelationships among eight traits. Pi8s (single-head arrows) stand for direct effects, while rijs (double-head arrows) stand for correlation coefficients. R stands for all unexplained traits that had not formed part of the analysis. PR8 represents residual effect of all characters represented by R.

In the path diagram, eight variables were included for coefficient analysis namely: (1) productive tillers/hill; (2) Spikelets per panicle; (3) Panicle length; (4) Plant height (5) Days to 50% flowering; (6) Days to maturity; (7) 1000 grain weight; (8) Grain yield; (R) Residual factor. The Standard Deviation, mean, maximum and minimum values for the eight traits are illustrated in Table 3.

Table 4: Direct and indirect Path Coefficients of selected seven traits of rice on grain yield.

Path Coefficient
Path ways of trait association
1. Tillers per hill vs grain yield …………………………….............. r = **0.4550**
Direct effect (Path Coefficient) of P1 on Y (8), P18…………….………….-0.0261
Indirect effect of P1 via P1 on Y (8), P18 …………………………........-0.0261
Indirect effect of P1 via P2 on Y (8), P28 x r12…………………………… 0.0436
Indirect effect of P1 via P3 on Y (8), P38 x r13…………………………… 0.4766
Indirect effect of P1 via P4 on Y (8), P48 x r14………………………….... 0.1204
Indirect effect of P1 via P5 on Y (8), P58 x r15………………………….. -0.2286
Indirect effect of P1 via P6 on Y (8), P68 x r16…………………………… 0.0201
Indirect effect of P1 via P7 on Y (8), P78 x r17…………………………… 0.0489
Total indirect effect……………………………………………………… 0.4550
2. Spikelets per panicle vs grain yield ………………………………… r = **0.3453**
Direct effect (Path Coefficient) of P2 on Y (8), P28 ……………………… 0.1214
Indirect effect of P2 via P1 on Y (8), P18 x r12 ………………………...-0.0094
Indirect effect of P2 via P2 on Y (8), P28 ………….…………………... 0.1214
Indirect effect of P2 via P3 on Y (8), P38 x r23 …………..……………...0.3210
Indirect effect of P2 via P4 on Y (8), P48 x r24 …………..……………...0.2057
Indirect effect of P2 via P5 on Y (8), P58 x r25 …………..……………. -0.3985
Indirect effect of P2 via P6 on Y (8), P68 x r26 …………..……………. 0.1025
Indirect effect of P2 via P7 on Y (8), P78 x r27 …………..……………..0.0026
Total indirect effect………………………………………………......... 0.3453
3. Panicle length vs grain yield ……………………………………...r = 0.3617
Direct effect (Path Coefficient) of P3 on Y (8), P38 ……………………... 0.8117
Indirect effect of P3 via P1 on Y (8), P18 x r13 ………..…………...…. -0.0153
Indirect effect of P3 via P2 on Y (8), P28 x r23 …………..……………. 0.0480
Indirect effect of P3 via P3 on Y (8), P38 ………………….................... 0.8117
Indirect effect of P3 via P4 on Y (8), P48 x r34 ……….……......……. -0.1587
Indirect effect of P3 via P5 on Y (8), P58 x r35 .....……………………. -0.3049
Indirect effect of P3 via P6 on Y (8), P68 x r36 ………………………. -0.0065
Indirect effect of P3 via P7 on Y (8), P78 x r37 .....……………………. -0.0128
Total indirect effect……………………………….....……………… 0.3617
4. Plant height vs grain yield ……………………………………… r = -0.3275
Direct effect (Path Coefficient) of P4 on Y (8), P48 ………………...…. -0.5369
Indirect effect of P4 via P1 on Y (8), P18 x r14 …………………...…... 0.0058
Indirect effect of P4 via P2 on Y (8), P28 x r24 ………..…………...……. -0.0465
Indirect effect of P4 via P3 on Y (8), P38 x r34 .....……………………… 0.2399
Indirect effect of P4 via P4 on Y (8), P48 ……………………….......... -0.5369
Indirect effect of P4 via P5 on Y (8), P58 x r45 ....…………………... 0.0769
Indirect effect of P4 via P6 on Y (8), P68 x r46 ………………………. -0.0367
Indirect effect of P4 via P7 on Y (8), P78 x r47 ...……………………. -0.0300
Total indirect effect ………………………………………...……… -0.3275
5. Days To 50% Flowering vs grain yield …………………………… r = -0.3202
Direct effect (Path Coefficient) of P5 on Y (8), P58 ……………….…...... -0.8676
Indirect effect of P5 via P1 on Y (8), P18 x r15 ……………………….. -0.0069
Indirect effect of P5 via P2 on Y (8), P28 x r25 .....……………………… 0.0558

Indirect effect of P5 via P3 on Y (8), P38 x r35	0.2852
Indirect effect of P5 via P4 on Y (8), P48 x r45	0.0476
Indirect effect of P5 via P5 on Y (8), P58	-0.8676
Indirect effect of P5 via P6 on Y (8), P68 x r56	0.1497
Indirect effect of P5 via P7 on Y (8), P78 x r57	0.0160
Total indirect effect	**-0.3202**
6. Days to Maturity vs grain yield	r = -0.3358
Direct effect (Path Coefficient) of P6 on Y (8), P68	0.1858
Indirect effect of P6 via P1 on Y (8), P18 x r16	-0.0028
Indirect effect of P6 via P2 on Y (8), P28 x r26	0.0670
Indirect effect of P6 via P3 on Y (8), P38 x r36	-0.0282
Indirect effect of P6 via P4 on Y (8), P48 x r46	0.1060
Indirect effect of P6 via P5 on Y (8), P58 x r56	-0.6991
Indirect effect of P6 via P6 on Y (8), P68	0.1858
Indirect effect of P6 via P7 on Y (8), P78 x r67	0.0356
Total indirect effect	**-0.3358**
7. 1000 grain weight vs grain yield	r = -0.1017
Direct effect (Path Coefficient) of P7 on Y (8), P78	-0.1219
Indirect effect of P7 via P1 on Y (8), P18 x r17	0.0104
Indirect effect of P7 via P2 on Y (8), P28 x r27	0.0849
Indirect effect of P7 via P3 on Y (8), P38 x r37	-0.1320
Indirect effect of P7 via P4 on Y (8), P48 x r47	-0.0026
Indirect effect of P7 via P5 on Y (8), P58 x r57	0.1137
Indirect effect of P7 via P6 on Y (8), P68 x r67	-0.0542
Indirect effect of P7 via P7 on Y (8), P78	-0.1219
Total indirect effect	**-0.1017**

Path Coefficient

Grain yield was regarded as a resultant "dependent" variable and plant height, number of productive tillers per hill, panicle length, number of spikelets per panicle, 1000-grain weight, days to 50% flowering and days to maturity as independent or causal variables in this study. The cause and effect relationship between grain yield and yield component traits have been illustrated in Figure 2 in form of a diagram and explained in Table 4. The path coefficient results and discussions have been presented as follows:

Tillers per hill versus grain yield

The direct effect of tillers per hill was negative (-0.0261) and insignificant. The indirect effect of tillers per hill on grain yield through spikelets per panicle (0.0436), panicle length (0.4766), plant height (0.1203), days to maturity (0.0201) and 1000-grain weight (0.0489) was positive and only significant for panicle length. Therefore, it is suggested that indirect selection using these traits in order to isolate genetically superior lines for high yield among rice germplasms should be considered. These results are in great agreement with Mohanty et al. [23], Rathod et al. [2] and Basavaraja et al. [24]. Total correlation was positive and significant despite the indirect negative effect of tillers per hill on grain yield through days to 50% flowering (-0.2286). This is mainly due to the huge positive indirect effect of panicle length (0.4766) through number of tillers per hill.

Spikelets per panicle versus grain yield

The direct effect of spikelets per panicle on grain yield was positive (0.1214) and insignificant. This result strongly agrees with findings by Karim et al. [25]. Negative indirect effect of spikelets per panicle on grain yield was noticed via tillers per hill (-0.0094) and days to 50% flowering (-0.3985). However, the total correlation of spikelets per panicle on grain yield was positive and insignificant. This was due to the positive indirect effects of panicle length (0.321), plant height (0.2057), and days to maturity (0.1026) and slightly by 1000-grain weight (0.0026).

Panicle length versus grain yield

The direct effect of panicle length on grain yield was positive and significant (0.8117). The total correlation (0.3617) was positive and insignificant mainly due to the indirect negative effects of panicle length on grain yield via plant height (-0.1587), days to 50% flowering, days to maturity (-0.0065) and 1000 grain weight (-0.0128. This implies that the indirect association of panicle length via these traits does not influence yield.

Plant height versus grain yield

The direct effect of plant height on grain yield was significant and negative (-0.5369). Furthermore, total correlation was insignificant and negative (-0.3275). The negative correlation of plant height with grain yield was largely due to the negative and significant indirect effect of the same trait with a magnitude of -0.5369, spikelets per panicle (-0.0455), days to maturity (-0.0367) and 1000 grain weight (-0.0300). Other workers Rauf et al. [26] reported similar findings on plant height, Wright [27].

Days to 50% flowering versus grain yield

There was a significant and negative (-0.8676) direct effect for days to 50% flowering on grain yield. The total correlation was insignificant and negative (-0.3202) mainly due to the indirect negative effects of days to 50% flowering on grain yield via tillers per hill (-0.0069) and the same trait with the value of -0.8676.

Days to Maturity versus grain yield

The direct effect of days to maturity versus grain yield was positive and insignificant (0.1858). However, there was insignificant and negative (-0.3358) total correlation for this trait with grain yield. This is due to the significant indirect effect of days to 50% flowering (-0.6991*) via this trait.

1000 grain weight versus grain yield

There was insignificant and negative (-0.1219) direct effect of 1000 grain weight on grain yield. Total correlation was negative (-0.1017) and insignificant. The negative and non-significant indirect effect of 1000 grain weight on grain yield was due to panicle length (-0.1320), plant height (-0.0026) and days to maturity (-0.0542). These results agree with earlier studies by Li et al. [22] on Japonica - type in which the 1000-grain weight could not account for a yield advantage. The negative direct effect of 1000-grain weight on yield was also in agreement with earlier reports by Kohnaki et al. [28]. On the other hand, these findings are in conflict with those reported by other workers, Karim et al. [25] and Iftekharuddaula et al. [29]. It is further argued in the present study therefore that the negative insignificant effect implies that 1000-grain weight does not have any direct effect on grain yield for the Japonica. This is true because experience has shown that genotypes with reduced weight per 1000 grains can still give higher yield than those with increased weight per 1000 grains. There is generally trade – off between 1000-grain weight and number of filled grains "spikelets" per panicle. In this instance, all factors constant, a genotype may produce as fewer grains per panicle as possible. These grains can be large and heavier due to reduced competition for assimilates among them; however, the total weight per panicle can be lower due to few grains; leading to low yield. On the other hand, a genotype, which produces many grains with reasonable weight, can accumulate as many 1000-grain weights possible. This is because there would be as accumulatively many 1000-grain weights as possible, which eventually contributed to total higher weight than a small number of 1000 of grain weights, thus higher yield. Yang and Zhang [30] and Li et al. [22] attested to the same fact. Furthermore, the rest of the traits showed positive negligibly insignificant indirect effects on grain yield via this trait.

Conclusion and Recommendation

The germplasms in this study noticed through ANOVA results, comprise a pool of lines that are largely variable which is good for rice breeding. The traits association results depicted that there was positive correlation for number of tillers per plant, number of spikelets per panicle and panicle length on grain yield but was only significant for the first trait. Positive direct effect on grain yield was expressed by number of spikelets per panicle, panicle length and days to maturity. Therefore, great consideration should be provided to these characters in developing some selection criteria for better yield and high grain quality in rice breeding programs. Through the KAFACI project, many promising high yielding lines such as KF18002, KF18007, KF18010, KF18019, KF18055 and KF190223 with yield ranging between 6000kg/ha to 9500kg/ha, for both rain fed and irrigated conditions, have been identified and complete nomination awaits further advancement stages.

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