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Original Article

Path analysis for yield and its components in F_1 upland rice hybrids and their parental lines

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Abstract

Grain yield is a complicated character which depends on many contributing traits. Little information is available related to the association of yield and its contributing traits in the comparison between F_1 upland rice hybrids and their parental lines. Therefore, the study aimed to determine the associations among grain yield and its components as well as their direct and indirect effects on grain yield of F_1 upland rice hybrids and their parental lines using path analysis. Evaluation of the analysis results revealed that the traits in F_1 hybrids, i.e., grain weight per panicle (highest significant positive association and direct effect), panicle length, spikelet fertility, and flag leaf length (highly positive indirect effects on grain yield via grain weight per panicle), while the number of filled grains per panicle and flag leaf length in parental lines were the most influential traits because they had a positive association and highly positive direct effects on grain yield of upland rice. Thus the selection of these characters should improve the yield of upland rice varieties.

Keywords: upland rice, F_1 hybrid, parental line, path analysis, grain yield

1. Introduction

Rice (*Oryza sativa* L.) occupies the main place among food crops cultivated worldwide. The cultivation of upland (dryland) rice tends to increase due to the shrinking of the potential wetland. However, the average yield of upland rice remains stagnant at around 1 ton per ha. It can be tackled by developing an upland rice hybrid which has a greater potential to increase yield in the upland or dryland area because of its superior performance, especially in yield (large and dense panicles, heavy grains) and due to the robust growth and root system, high tiller capability, and wide adaptation in various types of topography and soil. It is related to the ecosystem since the target environment for F_1 upland rice hybrids cultivation is intertropical dryland areas which are extremely diverse with rainfall as the water source, and weeds are the detrimental constraint to upland rice production.

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Grain yield is a complicated quantitative trait influenced by numerous contributing characters either directly or indirectly associated. Therefore, comprehension of the relationships among these characters is critical for identifying and selecting which characters occur synchronously and affect the associated traits in a desirable direction and contribute highly to grain yield. Correlation analysis can be used to determine the level of association between grain yield and its attributing traits in the favorable direction and furthermore the output of correlation coefficient analysis can be enhanced by considering the direct and indirect effects by path coefficient analysis (Dabholkar, 1992).

Various studies that used the correlation and path analysis have already been conducted to assess the interrelationship among yield and its components in several crops, such as on sesame (Muhamman, Mohammed, Lado, & Belel, 2010), soybean (Sarutayophat, 2012), hybrid rice (Babu, Shreya, Dangi, Usharani, & Shankar, 2012), oil palm (Krualee, Sdoodee, Eksomtramage, & Sereeprasert, 2013), basmati rice (Ratna, Begum, Husna, Dey, & Hossain, 2015), tomato (Meena & Bahadur, 2015), and chickpea (Tadesse *et al*., 2016). However, no studies have compared the trait association between F_1 hybrids and their parental lines in upland rice. Breeders need to determine this in each specific case (F_1 hybrids and their parents) because a hybrid as the first filial generation has vigorous and accurate interactions of heterotic effects (Virmani, Aquino, & Khush, 1982). This will be different with their parental lines which are the inbred varieties that have no heterosis effect. Keeping in view the above framework, the present investigation was carried out to observe and compare the trait association between F_1 hybrids and their parental lines in upland rice using path analysis. In addition, the best traits were selected for yield improvement and to establish selection criteria for the next breeding program on developing high yielding upland rice varieties.

2. Materials and Methods

2.1 Experimental material and design

Twenty-eight F_1 upland rice hybrids were obtained from a half diallel mating design of eight selected local upland rice cultivars in Thailand: Hawm Satun; Dawk Pa-yawm; Dawk Kham; Nual Hawm; Dawk Kha; Hawm Mali Doi; Khun Nan; and Goo Meuang Luang. Most of these parental lines were collected from the southern region of Thailand, except Khom Mali Doi and Khun Nan that came from the northern region of Thailand. Dawk Kham and Dawk Kha are red rice, and the others are white rice. Descriptions of the eight selected parental lines and their outstanding traits are presented in Table 1.

The experiment was conducted in the experimental field of Faculty of Natural Resources, Prince of Songkla University, Hat Yai, Thailand. It is located at latitude 7°00'31"N, longitude 100°29'46"E, and altitude 32 m above sea level. Soil pH was neutral at 7.05. The experiment was conducted during the rainy season from July to November 2016 to avoid the effects of photoperiod sensitivity. The average monthly rainfall, temperature, and humidity were about 130 mm, 24 °C, and 86%, respectively (Meteorological Songkhla Station, 2016). The hybridization generations (F_1) and their parents were grown in a randomized complete block design with two replications. Each entry was grown in a double-row plot of 4×1 m^2 and maintained at a row-to-row spacing of 30 cm and a plant-to-plant spacing of 25 cm.

Weeds were controlled by hand-weeding, especially before applying fertilizer. Fertilizers were applied following the recommended rates. NPK (15-15-15) was applied at 20 g per plant before planting and urea (46-0-0) was applied at 10 g per plant into three splits at 4 and 8 weeks after planting, and at the panicle initiation stage. The plants were treated for insect control (20 mL per 1 L cypermethrin 10% w/v EC and 50 mL per 1 L benfuracarb 20% w/v EC).

Table 1. Description of eight selected parental lines and their outstanding traits.

Selected lines	Source	PH	DM	1000-GW	GYP
Hawm Satun	Farmer, Satun Province, Thailand	107.08	152.85	19.11	24.17
Dawk Pa-yawm	Rice Research Center, Phatthalung Province, Thailand	104.13	141.15	24.22	30.44
Dawk Kham	Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Chumphon Campus, Chumphon Province, Thailand	108.44	149.25	25.62	28.51
Nual Hawm	Farmer, Songkhla Province, Thailand	109.63	134.80	24.53	25.52
Dawk Kha	Rice Research Center, Krabi Province, Thailand	102.28	140.10	25.12	29.90
Hawm Mali Doi	Farmer, Chiang Mai Province, Thailand	98.77	110.15	30.58	26.24
Khun Nan	Farmer, Nan Province, Thailand	145.40	116.10	32.81	30.28
Goo Meuang Luang	Rice Research Center, Phatthalung Province, Thailand	145.53	142.05	33.72	28.97

PH = Plant height (cm), DM = Days to maturity (days), 1000-GW = 1000 grain weight (g), GYP = Grain yield per plant (g).

2.2 Data collection and analysis

Ten plants were selected randomly from each plot per replication for observations and data were recorded on 12 quantitative traits: plant height (cm), flag leaf length (cm), number of tillers per plant, number of panicles per plant, days to flowering, days to maturity, panicle length (cm), number of filled grains per panicle, spikelet fertility (%), grain weight per panicle (g), 1000 grain weight (g), and grain yield per plant (g). The acquired data were analyzed based on analysis of variance (ANOVA) to test the genotypic differences and then analyzed for correlation coefficients based on Pearson's correlation coefficients (Dowdy, Weardon, & Chilko, 2003). Path coefficient analysis was used to determine the direct and indirect effects of the independent variables (grain yield components) on the dependent variable (grain yield) using the correlation coefficients, according to the method suggested by Dewey and Lu (1959) and also quoted by Dabholkar (1992) using the equation $r_{ij} = P_{ij} + \Sigma r_{ik}p_{kj}$, where r_{ij} = mutual relationship between the independent variable (i) and dependent variable (j) as measured by the correlation coefficients, P_{ij} = components of direct effects of the independent variable (i) on the dependent variable (j) as measured by the path coefficients, and $\Sigma r_{ik}p_{kj}$ = summation of components of indirect effects of a given independent variable (i) on a given dependent variable (j) via all other independent variables (k).

3. Results and Discussion

3.1 Genotypic differences

The results of ANOVA revealed highly significant differences among genotypes in all studied traits, both in the F_1 hybrids and parental lines, except for the flag leaf length of F_1 hybrids which was significant at 5% level probability (Table 2). The genotypic differences among F_1 hybrids in all studied traits were established. These indicated they were eligible for further analysis because different hybrids showed different characters. Parental line performances were significantly different at 1% level of probability in all studied traits which indicated that each of parental lines had different characters and they were suitable for plant genetic and hybrid studies. The coefficient of variation was less than 20% for each trait which ranged from 1.64% on days to maturity to 16.35% on the number of tillers per plant. This indicated that the data were accurate although this study was done in one location and in one season. There are many genotypes (8 parental lines 28 F_1 hybrids) which would be very difficult to do in many locations and seasons.

3.2 Trait association in F_1 hybrids

3.2.1 Correlation

Grain yield of F_1 upland rice hybrids revealed significant positive correlations with flag leaf length (0.59^{**}), num-ber of tillers (0.55^{**}), number of panicles (0.47^{*}), panicle length (0.53^{**}), number of filled grains per panicle (0.53^{**}), spikelet fertility (0.64^{**}), grain weight per panicle (0.85^{**}), and 1000 grain weight (0.58^{**}) (Table 3). This conformed to the findings of Hasan, Kulsum, Akter, Masuduzzaman, and Ramesha (2011) who declared that the number of tillers, panicle length, spikelet fertility, and 1000 grain weight showed significant correlations in a positive direction with grain yield of hybrid rice, likewise the research results of Babu *et al.* (2012) noted a significant positive association between the number of tillers and grain yield of some popular hybrids rice in India. The traits listed above showed a significant positive relationship in single plant yield and appeared to be the main yield components which might be useful to improve the grain yield of the upland rice hybrid.

However, plant height and days to maturity showed non-significant negative correlations with grain yield, but a significant negative correlation occurred between days to flowering (-0.38^{*}) and grain yield of F_1 hybrids. Ratna *et al*. (2015) also reported conformable results that a negative correlation happened on plant height with grain yield of basmati rice, and by Hasan *et al*. (2011) who revealed the negative associations of days occurred to flowering and days to maturity with grain yield in hybrid rice. Thus, the results indicated that one of the desirable traits in the upland rice breeding program was early maturing varieties which could produce higher grain yields.

3.2.2 Path analysis

Generally, the valid contribution of traits towards the grain yield is not represented by a simple correlation. Hence, the path coefficient analysis was required by dividing the correlation coefficients into direct and indirect effects. An identical concept also mentioned by Wright (1921) wherein the path analysis enables separating the correlations through different features to reveal direct effects and indirect effects for a preferable interpretation of the interrelationships among yield components.

Table 2. The significance of ANOVA results in all of the studied traits of F_1 upland rice hybrids and their parental lines.

Source	PH	FL	NT	NP	DF	DM	PL	NFG	SF	GWP	1000-GW	GYP
F_1 hybrids	**	*	**	**	**	**	**	**	**	**	**	**
Parental lines	**	**	**	**	**	**	**	**	**	**	**	**
CV (%)	6.22	8.66	16.35	15.92	2.72	1.64	3.67	11.36	5.88	6.44	4.78	5.25

* & ** indicate significance at 5% and 1% levels of probability, respectively.
PH = Plant height, FL = Flag leaf length, NT = Number of tillers per plant, NP = Number of panicles per plant, DF = Days to flowering, DM = Days to maturity, PL = Panicle length, NFG = Number of filled grains per panicle, SF = Spikelet fertility, GWP = Grain weight per panicle, 1000-GW = 1000 grain weight, GYP = Grain yield per plant. CV = Coefficient of variation.

Table 3. Correlation coefficients in all studied traits of F_1 upland rice hybrids.

Traits	FL	NT	NP	DF	DM	PL	NFG	SF	GWP	1000-GW	GYP
PH	0.46*	0.10	–0.06	0.39*	0.39*	–0.13	–0.45*	–0.57**	–0.22	0.003	–0.25
FL		0.71**	0.44*	–0.22	–0.21	0.39*	0.05	0.09	0.55**	0.60**	**0.59****
NT			0.77**	–0.37	–0.37	0.36	0.02	0.35	0.51**	0.62**	**0.55****
NP				–0.19	–0.17	0.30	0.20	0.44*	0.44*	0.52**	**0.47***
DF					0.97**	–0.69**	–0.11	–0.31	–0.64**	–0.65**	**–0.38***
DM						–0.61**	–0.11	–0.29	–0.57**	–0.62**	–0.34
PL							0.28	0.29	0.89**	0.63**	**0.53****
NFG								0.77**	0.46*	0.05	**0.53****
SF									0.53**	0.33	**0.64****
GWP										0.70**	**0.85****
1000-GW											**0.58****

* & ** indicate significance at 5% and 1% levels of probability, respectively. **Bold type face** indicates significant correlation coefficients on grain yield.
PH = Plant height, FL = Flag leaf length, NT = Number of tillers per plant, NP = Number of panicles per plant, DF = Days to flowering, DM = Days to maturity, PL = Panicle length, NFG = Number of filled grains per panicle, SF = Spikelet fertility, GWP = Grain weight per panicle, 1000-GW = 1000 grain weight, GYP = Grain yield per plant.

The direct and indirect effects of each component on the grain yield of F_1 upland rice hybrids were discovered using path coefficient analysis (Table 4). The results revealed that grain weight per panicle showed the highest positive direct effect (1.93) on grain yield of F_1 hybrids. Consequently, some important traits had high indirect effects on grain yield via the grain weight per panicle, i.e., panicle length (1.72), 1000 grain weight (1.36), flag leaf length (1.07), spikelet fertility (1.03), number of tillers (0.99), number of filled grains (0.88), and the number of panicles (0.85). On the other hand, it was desirable to have a negative direction in the traits of days to flowering and days to maturity to obtain early maturing hybrid varieties. The results demonstrated that the days to maturity expressed a negative direct effect to grain yield (–0.02), while the days to flowering and days to maturity (–1.24 and –1.10, respectively) had negative indirect effects to grain yield through grain weight per panicle.

The path analysis design of F_1 hybrids was slightly different with the path analysis of the parents, because the path analysis was performed two times. The path analysis of F_1 hybrids revealed that the grain weight per panicle had the highest positive direct effect on grain yield of F_1 hybrids which was in agreement with an earlier report by Bhadru, Reddy, and Ramesha (2011).

The results indicated that lots of filled grain on a long panicle was a highly reliable component of grain yield, and hybrid plants which had a wide flag leaf area could be considered as an encouraging hybrid for a high yield because the flag leaf is directly related with the photo-physiological process as the main photosynthetic organ for rice grain filling (Rao, 1991). This finding is in accordance with Hasan *et al.* (2011) and Hasan, Kulsum, Hoque, Miah, and Azam (2010) for spikelet fertility and flag leaf length, and Babu *et al.* (2012) for panicle length. These characters might be the choice criteria on circumstantial selection for improving the grain yield of upland rice hybrid. The residual effect in the path analysis of F_1 hybrids was 0.0756 which indicated that 7.56% of grain yield of F_1 hybrids might be attributed to other reasons.

Table 4. Path coefficients showing direct and indirect effects of the studied traits on grain yield of F_1 upland rice hybrids.

Traits	PH	FL	NT	NP	DF	DM	PL	NFG	SF	GWP	1000-GW	GYP-C
PH	**0.02**	–0.04	0.01	0.00	0.04	–0.01	0.15	–0.01	0.02	–0.43	0.00	–0.25
FL	0.01	**–0.08**	0.06	–0.02	–0.02	0.00	–0.44	0.00	0.00	*1.07*	0.01	**0.59****
NT	0.00	–0.06	**0.08**	–0.04	–0.04	0.01	–0.40	0.00	–0.01	*0.99*	0.01	**0.55****
NP	0.00	–0.04	0.06	**–0.05**	–0.02	0.00	–0.34	0.00	–0.02	*0.85*	0.01	**0.47***
DF	0.01	0.02	–0.03	0.01	**0.11**	–0.02	0.77	0.00	0.01	*–1.24*	–0.01	**–0.38***
DM	0.01	0.02	–0.03	0.01	0.10	**–0.02**	0.68	0.00	0.01	*–1.10*	–0.01	–0.34
PL	0.00	–0.03	0.03	–0.02	–0.07	0.01	**–1.12**	0.01	–0.01	*1.72*	0.01	**0.53****
NFG	–0.01	0.00	0.00	–0.01	–0.01	0.00	–0.31	**0.02**	–0.03	*0.88*	0.00	**0.53****
SF	–0.01	–0.01	0.03	–0.02	–0.03	0.01	–0.33	0.01	**–0.03**	*1.03*	0.01	**0.64****
GWP	0.00	–0.04	0.04	–0.02	–0.07	0.01	–1.00	0.01	–0.02	**1.93**	0.01	**0.85****
1000-GW	0.00	–0.05	0.05	–0.03	–0.07	0.01	–0.71	0.00	–0.01	*1.36*	**0.02**	**0.58****

* & ** indicate significance at 5% and 1% levels of probability, respectively.
GYP-C = Correlation coefficients to grain yield per plant. **Bold** in vertical direction indicates significant correlation coefficients, **Bold** in diagonal direction indicates the direct effects, **Bold** indicates highest direct effect in desirable direction. PH = Plant height, FL = Flag leaf length, NT = Number of tillers per plant, NP = Number of panicles per plant, DF = Days to flowering, DM = Days to maturity, PL = Panicle length, NFG = Number of filled grains per panicle, SF = Spikelet fertility, GWP = Grain weight per panicle, 1000-GW = 1000 grain weight. Residual effect = 0.0756.

3.3 Trait association in parental lines

3.3.1 Correlation

Pearson's analysis was used to estimate the correlation coefficients among the investigated traits of the parental lines. The results showed that the grain yield exhibited significant positive correlations with flag leaf length (0.71*), panicle length (0.72*), and grain weight per panicle (0.91**) (Table 5). The results suggested that these traits were related to grain yield in the positive direction and worthy for further analysis, i.e., path analysis to determine the direct and indirect effects of these traits on grain yield of Thai local upland rice cultivars. Ekka, Sarawgi, and Kanwar (2011) also reported similar results of a positive association of flag leaf length and panicle length with grain yield of traditional rice accessions in India. An understanding of the interrelationships among the yield components is necessary when selection should be performed on several traits at a time according to their potency and direction of selection for the simultaneous improvement of these traits (Gopikannan & Ganesh, 2013). Although the final objective is on a single trait (grain yield), it is still important to identify other beneficial yield attributes and prevent unfavorable associated impacts to other traits. For example, in this study plant height showed a significant positive correlation with flag leaf length (0.80*) while flag leaf length and panicle length showed significant positive correlations with grain weight per panicle (0.76* & 0.94**, respectively), and days to flowering showed highly significant positive correlations with days to maturity (0.99**). These characters might be related to other traits and affect grain yield, but to find out more a path analysis was done to recognize the direct and indirect effects of those traits on grain yield of upland rice.

3.3.2 Path analysis

The direct and indirect effects of the studied traits on grain yield of parental lines which is indicated by path coefficients are presented in Table 6. Out of all characters, the number of filled grains per panicle exhibited a positive maximum direct effect (1.55) to grain yield followed by flag leaf length (1.06) with significant positive associations, the number of panicles (0.80), 1000 grain weight (0.70), and grain weight per panicle (0.55). These findings were also corroborated by Ekka *et al*. (2011), Hasan *et al*. (2010), and Hasan *et al*. (2011) who found similar results for those traits in rice cultivars. On the other hand, the highest negative direct effect to grain yield was recorded on days to flowering (–1.33). This result was confirmed by a previous report by Sarker, Hassan, Islam, Rashid, and Seraj (2014) who observed a negative direct effect of days to flowering on grain yield of rice. In addition, the negative direct effect was also observed on spikelet fertility (–1.11) which indicated that some other characters had positive indirect effects on grain yield through spikelet fertility, i.e. grain weight per panicle (0.34), number of filled grains (0.32), and 1000 grain weight (0.27). Likewise, the number of tillers showed a negative direct effect on grain yield (–0.21) which indicated that some characters, i.e. number of panicles (0.56), flag leaf length (0.49), and grain weight per panicle (0.23), had positive moderate indirect effects on grain yield via the number of tillers. The residual effect was 0.0888. It was very low, which indicated that almost all variability of grain yield of upland rice parental lines was described by 11 yield elements involved in the present study.

As a result of the present study, the two characters that were selected which had great potential to improve the grain yield of upland rice parental lines were the number of filled grains per panicle because it had the highest positive direct effect on grain yield and flag leaf length because it had a highly positive direct effect along with significant positive correlation on grain yield. This was in accordance with the previous report by Seesang, Sripicchitt, Somchit, and Sreewongchai (2013) that those characters had positive direct effects on grain yield of some inbred rice genotypes in Thailand. Chuchert, Nualsri, Junsawang, and Soonsuwon (2018) also reported that flag leaf length had the highest significant positive correlation and the number of filled grains per panicle had the highest direct effect on grain yield of indigenous upland rice in Thailand.

It was supposed that the flag leaf is the principal organ for photosynthesis which plays an important role in grain filling; therefore, it can increase the grain yield of rice. This was in agreement with an earlier report by Rao (1992) who stated that flag leaf area is one of the key factors that could be selected to increase rice grain yield at around 41–43%. Al-Tahir (2014) also reported the existence of a

Table 5. Correlation coefficients in all studied traits of upland rice parental lines.

Traits	FL	NT	NP	DF	DM	PL	NFG	SF	GWP	1000-GW	GYP
PH	**0.80***	0.22	–0.31	–0.20	–0.16	0.54	–0.21	–0.12	0.52	0.70	0.37
FL		0.46	0.03	–0.13	–0.06	0.68	–0.32	0.07	**0.76***	0.70	**0.71***
NT			0.70	–0.04	–0.02	0.30	–0.25	0.15	0.43	0.21	0.50
NP				0.22	0.23	–0.14	–0.19	0.17	–0.02	–0.14	0.15
DF					**0.99****	–0.16	0.62	–0.31	–0.18	–0.69	–0.17
DM						–0.10	0.61	–0.27	–0.12	–0.64	–0.11
PL							0.09	0.61	**0.94****	0.65	**0.72***
NFG								0.20	0.09	–0.56	0.07
SF									0.61	0.38	0.54
GWP										0.61	**0.91****
1000-GW											0.47

* & ** indicate signigicance at 5% and 1% levels of probability, respectively. **Bold type face** indicates significant correlation coefficients. PH = Plant height, FL = Flag leaf length, NT = Number of tillers per plant, NP = Number of panicles per plant, DF= Days to flowering, DM = Days to maturity, PL = Panicle length, NFG = Number of filled grains per panicle, SF = Spikelet fertility, GWP = Grain weight per panicle, 1000-GW = 1000 grain weight, GYP = Grain yield per plant.

Table 6. Path coefficients showing direct and indirect effects of the studied traits on grain yield of upland rice parental lines.

Traits	PH	FL	NT	NP	DF	DM	PL	NFG	SF	GWP	1000-GW	GYP-C
PH	–**1.07**	0.85	–0.05	–0.25	0.27	–0.03	0.07	–0.33	0.13	0.29	0.49	0.37
FL	–0.86	***1.06***	–0.10	0.03	0.17	–0.01	0.09	–0.50	–0.07	0.42	0.49	**0.71***
NT	–0.24	*0.49*	–**0.21**	*0.56*	0.05	0.00	0.04	–0.39	–0.17	*0.23*	0.15	0.50
NP	0.34	0.04	–0.15	***0.80***	–0.30	0.04	–0.02	–0.30	–0.19	–0.01	–0.10	0.15
DF	0.22	–0.13	0.01	0.18	–**1.33**	0.19	–0.02	0.97	0.34	–0.10	–0.48	–0.17
DM	0.17	–0.06	0.00	0.18	–1.33	**0.19**	–0.01	0.95	0.30	–0.07	–0.45	–0.11
PL	–0.58	*0.73*	–0.06	–0.11	0.21	–0.02	**0.13**	0.14	–0.68	*0.52*	*0.45*	**0.72***
NFG	0.23	–0.34	0.05	–0.15	–0.83	0.12	0.01	**1.55**	–0.23	0.05	–0.39	0.07
SF	0.13	0.07	–0.03	0.14	0.41	–0.05	0.08	*0.32*	–**1.11**	*0.34*	*0.27*	0.54
GWP	–0.56	0.81	–0.09	–0.02	0.24	–0.02	0.12	0.14	–0.68	***0.55***	0.43	**0.91****
1000-GW	–0.75	0.74	–0.04	–0.11	0.92	–0.12	0.08	–0.87	–0.42	0.34	***0.70***	0.47

* & ** indicate signigicance at 5% and 1% levels of probability, respectively.
GYP-C = Correlation coefficients to grain yield per plant. **Bold** in vertical direction indicates significant correlation coefficients, **Bold** in diagonal direction indicates the direct effects, ***Bold*** & **Bold** indicates highly and highest direct effect in desirable direction, respectively. PH = Plant height, FL = Flag leaf length, NT = Number of tillers per plant, NP = Number of panicles per plant, DF = Days to flowering, DM = Days to maturity, PL = Panicle length, NFG = Number of filled grains per panicle, SF = Spikelet fertility, GWP = Grain weight per panicle, 1000-GW = 1000 grain weight. Residual effect = 0.0888.

significant positive association between flag leaf area and grain yield of rice plants. Thus, selection of those characters could be considered in the development and release of superior conventional varieties or utilized as upgrade parents for evaluation and further hybridization in upland rice hybrid programs.

4. Conclusions

The trait association on the F_1 upland rice hybrids was slightly different compared with trait association in the parental lines. In F_1 upland rice hybrids, selection of grain weight per panicle had the highest significant positive association and direct effect. Also, the characters that include the panicle length, spikelet fertility, and flag leaf length exhibited highly positive indirect effects on grain yield via grain weight per panicle which might be useful to improve the grain yield. In addition, performing recombination breeding or single hybrid plant selection to develop high yielding upland rice hybrid varieties could be considered. Meanwhile, the number of filled grains per panicle and the flag leaf length were chosen as reliable criteria for improving the grain yield of upland rice parental lines. These characters also contribute in the selection process for development of superior pure line varieties and for evaluating the performance of parental lines to obtain improved parents for further hybridization programs.

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References

Al-Tahir, F. M. M. (2014). Flag leaf characteristics and relationship with grain yield and grain protein percentage for three cereals. *Journal of Medicinal Plants Studies*, *2*(5), 1-7.

Babu, V. R., Shreya, K., Dangi, K. S., Usharani, G., & Shankar, A. S. (2012). Correlation and path analysis studies in popular rice hybrids of India. *International Journal of Scientific and Research Publications*, *2* (3), 1-5.

Bhadru, D., Reddy, D. L., & Ramesha, M. S. (2011). Correlation and path coefficient analysis of yield and yield contributing traits in rice hybrids and their parental lines. *Electronic Journal of Plant Breeding*, *2*(1), 112-116. Retrieved from http://ejplantbreeding.com/index.php?journal=EJPB&page=index

Chuchert, S., Nualsri, C., Junsawang, N., & Soonsuwon, W. (2018). Genetic diversity, genetic variability, and path analysis for yield and its components in indigenous upland rice (*Oryza sativa* L. var. glutinosa). *Songklanakarin Journal of Science and Technology*, *40*(3), 609-616.

Dabholkar, A. R. (1992). *Elements of biometrical genetics*. New Delhi, India: Concept Publishing.

Dewey, D. R., & Lu, K. H. (1959). A correlation and path coefficient analysis of components of crescent Wheat grass seed production. *Agronomy Journal*, *51*, 515-518. doi:10.2134/agronj1959.00021962005100090002x

Dowdy, S., Weardon, S., & Chilko, D. (2003). *Statistics for Research*. New Jersey, NJ: John Wiley and Sons.

Ekka, R. E., Sarawgi, A. K., & Kanwar, R. R. (2011). Correlation and path analysis in traditional rice accessions of chhattisgarh. *Journal of Rice Research*, *4*(1-2), 11-18.

Gopikannan, M., & Ganesh, S. K. (2013). Inter-relationship and path analysis in rice (*Oryza sativa* L.) under

sodicity. *Indian Journal of Science and Technology*, *6*(9), 5223-5227.

Hasan, M. J., Kulsum, M. U., Akter, A., Masuduzzaman, A. S. M., & Ramesha, M. S. (2011). Genetic variability and character association for agronomic traits in hybrid rice (*Oryza Sativa* L.). *Bangladesh Journal of Plant Breeding and Genetics*, *24*(1), 45-51.

Hasan, M. J., Kulsum, M. U., Hoque, N., Miah, M. A., & Azam, F. A. M. S. (2010). Genetic variability, correlation and path coefficient analysis in some restorer lines of hybrid rice (*Oryza sativa* L.). *Journal of Eco-friendly Agriculture*, *3*(5), 222-226.

Krualee, S., Sdoodee, S., Eksomtramage, T., & Sereeprasert, V. (2013). Correlation and path analysis of palm oil yield components in oil palm (*Elaeis guineensis* Jacq.). *Kasetsart Journal* (*Natural Science*), *47*, 528 -533.

Meena, O. P., & Bahadur, V. (2015). Genetic associations analysis for fruit yield and its contributing traits of indeterminate tomato (*Solanum lycopersicum* L.) germplasm under open field condition. *Journal of Agricultural Science*, *7*(3), 148-163. doi:10.5539/jas .v7n3p148

Meteorological Songkhla Station. (2016). *Meteorological month 2016 Songkhla*. Thai Meteorological Department, Ministry of Digital Economy and Society, Bangkok, Thailand

Muhamman, M. A., Mohammed, S. G., Lado, A., & Belel, M. D. (2010). Interrelationship and path coefficient analysis of some growth and yield characterestics in Sesame (*Sesamum Indicum* L.). *Journal of Agricultural Science*, *2*(4), 100-105.

Rao, S. P. (1991). Influence of source and sink on the production of high density grain and yield in rice. *Indian Journal of Plant Physiology*, *34*(4), 339-348.

Rao, S. P. (1992). Flag leaf: a selection criterion for exploiting potential yields in rice. *Indian Journal of Plant Physiology*, *35*(3), 265-268.

Ratna, M., Begum, S., Husna, A., Dey, S. R., & Hossain, M. S. (2015). Correlation and path coefficients analyses in basmati rice. *Bangladesh Journal of Plant Breeding and Genetics*, *40*(1), 153-161.

Sarker, M. M., Hassan, L., Islam, M. M., Rashid, M. M., & Seraj, S. (2014). Correlation and path coefficient analysis of some exotic early maturing rice (*Oryza sativa* L.) lines. *Journal of Bioscience and Agriculture Research*, *1*, 1-7.

Sarutayophat, T. (2012). Correlation and path coefficient analysis for yield and its components in vegetable soybean. *Songklanakarin Journal of Science and Technology*, *34*(3), 273-277.

Seesang J., Sripicchitt, P., Somchit, P., & Sreewongchai, T. (2013). Genotypic correlation and path coefficient for some agronomic traits of hybrid and inbred rice (*Oryza sativa* L.) cultivars. *Asian Journal of Crop Science*, *5*(3), 319-324. doi:10.3923/ajcs.2013.319. 324

Tadesse, M., Fikre, A., Eshete, M., Girma, N., Korbu, L., Mohamed, R., . . . Ojiewo, C. O. (2016). Correlation and path coefficient analysis for various quantitative traits in Desi Chickpea genotypes under rainfed conditions in Ethiopia. *Journal of Agricultural Science*, *8*(12), 112-118. doi:10.5539/jas.v8n12p112

Virmani, S. S., Aquino, R. C., & Khush, G. S. (1982). Heterosis breeding in rice (*Oryza sativa* L.). *Theoretical and Applied Genetics*, *63*, 373-380. doi:10.1007/ BF00303911

Wright, S. (1921). Correlation and causation. *Journal of Agricultural Research*, *20*(7), 557-585.