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Original Article

Correlation and path analysis studies of upland rice (*Oryza sativa* L.) collected from Pala-U village, Prachuap Khiri Khan, Thailand

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Abstract

The decline in rice production experienced by ethnic minority (Pa-gha-ker-yor) farmers at Pala-U village, Prachuap Khiri Khan Province, Thailand, has multiple causes. The effect, however, is threatening the sustainability and well-being of the local populations. The objective of this study is to determine the relative yield and yield components of upland rice varieties collected from these farmers, both inside and outside of forested areas. Such information is then used to help determine the most promising breed varieties for future cultivation. Correlation and path coefficient analysis were conducted for yield, yield components, and related characteristics in seven genotypes of upland rice. The research was conducted during planting seasons in 2015 and 2016 in Prachuap Khiri Khan and Phetchaburi provinces, Thailand, respectively. Results show a significant positive correlation between *grain yield hill*$^{-1}$ and *seed number panicle*$^{-1}$. Though non-significant, positive correlations were found between grain yield and four other criteria: *panicle length*, *tiller number hill*$^{-1}$, *plant height*, and *seed weight panicle*$^{-1}$. In 2015 and 2016, as for path analysis, *grain yield hill*$^{-1}$ was directly influenced by factors either showed high positive effect such as: *seed number panicle*$^{-1}$, *panicle length*, *plant height* and *percent of grain filling*, or high negative effect as *100 seed weight*. *Seed number panicle*$^{-1}$, *percent of grain filling*, *seed weight panicle*$^{-1}$, and *plant height* were shown to have an indirect effect on *grain yield hill*$^{-1}$. However, *grain yield hill*$^{-1}$ was negative indirectly influenced through other characteristics by *percent of grain filling*. As such, *seed number panicle*$^{-1}$, *panicle length*, and *plant height* demonstrated the greatest influence on yield may be considered as primary criteria, with *percent of grain filling* and *seed weight panicle*$^{-1}$ qualifying as secondary criteria for high yield selection

Keywords: Upland rice, Indigenous varieties, Yield components, Correlation coefficient, Path analysis

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Introduction

Rice is a major source of human nutrition, accounting for up to 43 percent of required caloric intake (Tejaswini et al., 2016). As such, lowland rice is considered an important crop in terms of production and demand, worldwide (Khush and Brar, 2002; Salim et al., 2003). Upland rice (*Oryza sativa* L.) is also as important crop, and has been cultivated in a number of countries, especially in Asia (IRRI, 1975; Gupta and O'Toole, 1986; Coutois, 1988). Upland rice is a critical food source for many ethnic minority farmers worldwide, including those in Thailand, where is has been cultivated continuously for generations (Van Keer et al., 2000; Pintasen et al., 2007). Thus, for long time cultivation of these genotypes, they are well adapted to those environments more than to explain about high productivity (Joshi et al., 2001). However, the most important characteristic of both lowland and upland rice is yield. Yield-a quantitative measure-is highly influenced by several environmental factors (Jennings et al., 1979). Even so, selection of rice genotypes based solely on yield performance may produce suboptimal outcomes. Instead, focus should be on the contributing factors to yield in several environments, as such data will provide greater accuracy in determining the adaptability and sustainability of each genotype (Simmonds, 1991; Bose et al., 2014).

Certain other traits, such as *days to maturity*, *number of tillers per plant*, and *plant height* are also critical in selecting high-yield rice genotypes (Atlin, 2003). The casual impact of these traits may be determined using correlation and path analysis (Samonte et al., 1998; Surek and Beser, 2003; Hairmansis et al., 2010). Identification of those characteristics having a high correlation to yield can help plant breeders select criteria characteristics for selection in a breeding program for higher rice yields (Chandra et al., 2009; Nagaraju et al., 2013). Secondary characteristics, i.e., those showing a significant indirect effect on yield, should also be carefully considered (Hairmansis et al., 2010). These secondary factors, however, should be considered only in conjunction with the primary factors.

Farmer's field of ethnic minority (Pa-gha-ker-yor) people at Pala-U, Prachuap Khiri Khan Province, Thailand [Latitude 12°30.642'N: Longitude 099°29.839'E: about 300 m above sea level] is spread throughout Pala-U area. Pala-U forest is located on the border between Thailand and Myanmar. While there are many genotypes of upland rice, only a few varieties are cultivated in this area. This is because only a few varieties have characteristics-such as high yield, stem not lodging-which make them suitable for planting in this area. Unfortunately, because the same varieties of rice have been planted year after year, diseases and insects infestation have become increasingly common, and rice yields have diminished in recent years, thus imperiling indigenous communities.

The objective of this study is to determine the yield and yield components of upland rice varieties collected from Pala-U village, Hau Sat Yai, Hua-Hin district, Prachuap Khiri Khan Province, Thailand. The relationships among grain yield, yield components, and other characteristics are assessed using Pearson correlation coefficients. Both direct and indirect effects of these characteristics on grain yield of major upland rice varieties in the area are investigated. The study was conducted both inside and outside the forested areas in the Pala-U vicinity in order to determine those genotypes best suited to each of these sub-areas.

Material and Methods

Plant material, site experiment, and planting method

The study encompassed seven indigenous upland rice varieties collected from four planting areas and then divided into three groups;

1) Group 1: Nah San, Beu Ge, Khao Niaw Pala-U, Beu Gaw Bi, Beu Soo Ser Lah; Pala-U village, Prachuap Khiri Khan province, Thailand.
2) Group 2: Rao-Su-Ya; the Royal Project Foundation, Chiang Mai province, Thailand.
3) Group 3: Aung Jern Yai; Phetchaburi province, Thailand.

For upland rice varieties in Group 1 and 3, although those are grown in different provinces, but locates in the same region (South East Coast, when divided by meteorology) of Thailand. An above sea level elevation of these planting areas (about 300 meters above sea level) are similar. For Rao-Su-Ya in Group 2, this variety is grown in northern Thailand at more than 500 meters above sea level. Upland rice was collected in the Pala-U forest, Prachuap Khiri Khan Province in 2015, and in Phetchaburi Province (12° 59´N and 99° 42´E) in 2016. In each case, collections were made during the rainy season (July to November). In both cases, five upland rice seeds were sowed (per hill) into the ground at depths between 2-3 cm. The spacing between row and hill of upland rice in both places was 50 cm x 30 cm. Both fields were irrigated by rainfall. Weeding was controlled manually once per month, after seedlings had sprouted from the soil.

Yield, yield components, and some characteristics

Data for the following the following eight criteria were collected from the inner row of each plot on 20 hills: *grain yield hill^{-1} (GYH), panicle length (PL), tiller number hill^{-1} (TNH), plant height (PH), seed weight panicle^{-1} (SWP), 100 seed weight (100-SW), seed number panicle^{-1} (SNP),* and *percent of grain filling (PGF)*. *PH* was measured from the soil base to the tip of highest leaf on a particular hill. Going forward, for the brevity of exposition, the above criteria abbreviations will be used. Basis for determining the primary and secondary criteria for yield selection is to consider the correlation coefficient and path analysis. The result of the consideration of path analysis will make understanding the correlation coefficient value (or total effect in path analysis) presented. Thus, correlation coefficient value, degree and direction of directed effect; influenced by each factor (agronomy or yield component characteristics) to grain yield, and indirect effect in positive values through other characteristics are important point to determine the primary and secondary criteria for yield selection.

Statistical analysis

Experimentation was randomized complete block design (RCBD) with four replications. The factor including seven upland rice varieties was studied both in 2015 and 2016. The correlation coefficient between all pairs of variables (traits) was computed. Path analysis was analyzed among these traits using the statistical software: R program, version 3.4.1 (R Core Team, 2017).

Results

Correlation coefficient

Testing was conducted in Palau-U and Phetchaburi Province in 2015 and 2016, respectively [Table 1].

Table 1 shows results from the correlation coefficients of eight varieties that grow in rainy season of 2015. Per the Table, the following five variables demonstrated positive, but not statistically significant correlations with GYH: PL (r = 0.0505), TNH (r = 0.0323), PH (r = 0.2158), SWP (r = 0.2411), SNP (r = 0.1364). Negative with no significant correlation was found between GYH and two variables: 100-SW (r = -0.2173) and PGF (r = -0.1296).

In 2015, two variables: SWP (r = 0.5746) and PGF (r = -0.5930), showed positive significant correlation and negative with highly significant correlation with PH, respectively [Table 1]. In 2016, correlation coefficients between all of seven traits were found to be positive with GYH. Only SNP, however, had the significant correlation with GYH (0.5673).

Table 1. Correlation coefficients between grain yield [grain yield hill^{-1} (GYH)] and yield-related traits [panicle length (PL), tiller number hill^{-1} (TNH), plant height (PH), seed weight panicle^{-1} (SWP), 100 seed weight (100-SW), seed number panicle^{-1} (SNP) and percent of grain filling (PGF)] of upland rice grown in rainy season 2015 and 2016.

In rainy season, 2015.

Traits	TNH (X_2)	PH (X_3)	SWP (X_4)	100-SW (X_5)	SNP (X_6)	PGF (X_7)	GYH (X_8)
PL (X_1)	0.1126 ns	-0.2032 ns	0.0420 ns	0.1200 ns	-0.0044 ns	-0.2665 ns	0.0505 ns
TNH (X_2)		0.1150 ns	0.1130 ns	0.1461 ns	0.0970 ns	0.0710 ns	0.0323 ns
PH (X_3)			0.5746*	-0.3015 ns	-0.0240 ns	-0.5930**	0.2158 ns
SWP (X_4)				-0.3358 ns	0.1704 ns	-0.4316 ns	0.2411 ns
100-SW (X_5)					0.0200 ns	0.4093 ns	-0.2173 ns
SNP (X_6)						0.2719 ns	0.1364 ns
PGF (X_7)							-0.1296 ns
GYH (X_8)							

In rainy season, 2016.

Traits	TNH (X_2)	PH (X_3)	SWP (X_4)	100-SW (X_5)	SNP (X_6)	PGF (X_7)	GYH (X_8)
PL (X_1)	0.2690 ns	-1.392×10^{-5} ns	-0.0256 ns	0.3860 ns	0.2459 ns	0.3271 ns	0.2590 ns
TNH (X_2)		0.5514*	0.1271 ns	0.1100 ns	0.3562 ns	0.1667 ns	0.4080 ns
PH (X_3)			0.0830 ns	0.0610 ns	0.2162 ns	0.0720 ns	0.2514 ns
SWP (X_4)				-0.6024**	0.5456*	-0.1393 ns	0.1567 ns
100-SW (X_5)					-0.0230 ns	0.4076 ns	0.0150 ns
SNP (X_6)						0.3269 ns	0.5673*
PGF (X_7)							0.3646 ns
GYH (X_8)							

Note: ns, not significant difference at the 0.05 level of probability
*, significant difference at the 0.05 level of probability
**, significant difference at the 0.01 level of probability

Correlation coefficient values among seven yield-related traits in 2016 showed significant correlation on a non-similar direction of values. SWP had a negative, highly significant correlation with 100-SW (r = -0.6024), and a positive, significant correlation with SNP (r = 0.5456). A positive, significant correlation was also found between TNH and PH (r = 0.5514). PGF showed positive values with 100-SW (r = 0.4093, r = 0.4076) and with SNP (r = 0.2719, r = 0.3269) in 2015 and 2016, respecitively, although there were not significant correlations.

Path analysis

Path analysis was analyzed after the study of the correlation coefficient. Results are presented in Table 2. In 2015 and 2016, the direct effect of PL on GYH was found to be positive, with total effect results of 0.1529 at 59.9% and 1.274 at 49.2%, respectively [Table 2]. The total indirect effect on GYH by other traits was found to be -0.1025 at 40.1% in 2015, and 0.1316 at 50.81% in 2016. The indirect effect through SWP was only trait that showed positive values in both years. The residual effect was insignificant in both years.

TNH traits on GYH were -0.0102 in 2015 and 0.1836 in 2016 [Table 2]. Total effect percentages for 2015 and 2016 were 19.4% and 45.0%, respectively. The indirect effect had high positive value in both years: 0.0425 at 80.6% in 2015 and 0.2243 at 55.0% in 2016. Indirect effect traits that showed positive in both years were: PL, PH, SNP and PGF. The residual values between 2015 and 2016 were even lower than direct and indirect effects (about 0.0% in total effect).

Values on the direct effects of PH on GYH in 2015 and 2016 were 0.2228 at 65.5% and 0.0606 at 24.1%, respectively [Table 2]. Values on the indirect effect of PH on GYH in 2015 and 2016 were 0.0551 and 0.1206 respectively. Total effect percentages of indirect effect between 2015 and 2016 were 16.2% and 48.0%, respectively. The indirect effect of two related traits, PL and SWP, showed positive values in both years. The residual values in total effect were 18.3% and 27.9% in 2015 and 2016, respectively.

Direct effect values of SWP on GYH registered both positive and negative values: 0.0833 at 31.7% in 2015, and -0.3756 at 41.4% in 2016. The corresponding indirect effect values were 0.1686 (2015) and 0.1966 (2016). The total effect percentage values were 64.2% (2015) and 21.7% (2016). The indirect effect of the three related traits (PL, PH, and SNP) showed positive values in both years. Residual effect results were -0.0108 at 4.11% and 0.3358 at 37% for 2015 and 2016, respectively.

100-SW was the only trait included in the study that registered a negative direct effect on GYH in both years: -0.1957 at 90.1% (2015) and -0.3450 at 49.0% (2016)) [Table 2]. Indirect effects were measured at -0.0216 at 9.9% (2015) and 0.35059 at 43.4% (2016). The indirect effect of three related traits (PL, SNP and PGF) showed positive values in both years. Residual effects were zero percent (2015) and 7.6% (2016).

SNP showed a high, positive direct effect on GYH (0.0967 and 0.5952) with high percentages (70.9% and 88.1%) in total effect for 2015 and 2016, respectively [Table 2]. Indirect effects in 2015 and 2016 showed positive values as 0.0397 at 29.1% and 0.0264 at 3.9%, respectively. Two traits, SWP and PGF, had positive

values of effect from SNP to GYH in both years. The residual effect of SNP on GYH showed lower values in both years at 0.0% (2015) and 8.0% (2016).
Positive values of PGF on GYH were found on the direct effect (0.1338 at 33.7% in 2015 and 0.1817 at 49.8% in 2016) [Table 2]. Indirect effects in 2015 and 2016 showed negative and positive values: -0.2633 at 66.3% and 0.0117 at 3.2%, respectively. Indirect effects through SWP and SNP were the only two traits registering positive values in both years. The percentages in total effect on residual effect were 0.0% and 47% in 2015 and 2016, respectively.

Table 2. Path analysis showing direct and direct effects of seven traits [panicle length (PL), tiller number hill^{-1} (TNH), plant height (PH), seed weight panicle^{-1} (SWP), 100 seed weight (100-SW), seed number panicle^{-1} (SNP) and percent of grain filling (PGF)] on upland grain yield hill^{-1} (GYH) for two years (2015-2016).

Rainy season, 2015		**Rainy season, 2016**	
Traits	**Effect values (% in total effect)**	**Traits**	**Effect values (% in total effect)**
Panicle length (PL)		*Panicle length (PL)*	
Direct effect on GYH	0.1529 (59.9)	Direct effect	0.1274 (49.2)
Indirect effect	-0.1025 (40.1)	Indirect effect	0.1316 (50.8)
TNH	-0.0011	TNH	0.0494
PH	-0.0452	PH	-8.44×10^{-7}
SWP	0.0035	SWP	0.0096
100-SW	-0.0234	100-SW	-0.1332
SNP	-0.0004	SNP	0.1463
PGF	-0.0356	PGF	0.0594
Residual	-1.01×10^{-8} (0.0)	Residual	1.03×10^{-8} (0.0)
Total effect	0.0504	Total effect	0.2589
Tiller number hill^{-1} (TNH)		*Tiller number hill^{-1} (TNH)*	
Direct effect	-0.0102 (19.4)	Direct effect	0.1836 (45.0)
Indirect effect	0.0425 (80.6)	Indirect effect	0.2243 (55.0)
PL	0.0172	PL	0.0343
PH	0.0256	PH	0.0334
SWP	0.0094	SWP	-0.0478
100-SW	-0.0285	100-SW	-0.0379
SNP	0.0094	SNP	0.2121
PGF	0.0095	PGF	0.0302
Residual	-9.11×10^{-9} (0.0)	Residual	5.38×10^{-9} (0.0)
Total effect	0.0323	Total effect	0.4079
Plant height (PH)		*Plant height (PH)*	
Direct effect	0.2228 (65.5)	Direct effect	0.0606 (24.1)
Indirect effect	0.0551 (16.2)	Indirect effect	0.1206 (48.0)
PL	0.0311	PL	0.0412
TNH	-0.0012	TNH	-0.0027
SWP	0.0478	SWP	0.0096
100-SW	0.0589	100-SW	-0.1332
SNP	-0.0023	SNP	0.1463
PGF	-0.0793	PGF	0.0594
Residual Total effect	-0.0622 (18.3) 0.2157	Residual Total effect	0.0702 (27.9) 0.2514

Continued

Rainy season, 2015		**Rainy season, 2016**	
Traits	**Effect values (% in total effect)/1**	**Traits**	**Effect values (% in total effect)**
Seed weight panicle^{-1} (SWP)		*Seed weight panilcle^{-1} (SWP)*	
Direct effect	0.0833 (31.7)	Direct effect	-0.3756 (41.4)
Indirect effect	0.1686 (64.2)	Indirect effect	0.1966 (21.7)
PL	0.0172	PL	0.0412
TNH	-0.0011	TNH	0.0494
PH	0.1280	PH	0.0334
100-SW	0.0657	100-SW	-0.1332
SNP	0.0164	SNP	0.1463
PGF	-0.0578	PGF	0.0594
Residual	-0.0108 (4.11)	Residual	0.3358 (37.0)
Total effect	0.2411	Total effect	0.1567
100 seed weight (100-SW)		*100 seed weight (100-SW)*	
Direct effect	-0.1957 (90.1)	Direct effect	-0.3450 (49.0)
Indirect effect	-0.0216 (9.9)	Indirect effect	0.3059 (43.4)
PL	0.0183	PL	0.0412
TNH	-0.0014	TNH	0.0494
PH	-0.0672	PH	-8.43×10^{-7}
SWP	-0.0279	SWP	0.0096
SNP	0.0019	SNP	0.1463
PGF	0.0547	PGF	0.0594
Residual	-2.30×10^{-9} (0.0)	Residual	0.0538 (7.6)
Total effect	-0.2172	Total effect	0.0148
Seed number panicle^{-1} (SNP)		*Seed number panicle^{-1} (SNP)*	
Direct effect	0.0967 (70.9)	Direct effect	0.5952 (88.1)
Indirect effect	0.0397 (29.1)	Indirect effect	0.0264 (3.9)
PL	-0.0007	PL	0.0412
TNH	-0.0010	TNH	0.0494
PH	-0.0052	PH	-8.44×10^{-7}
SWP	0.0142	SWP	0.0096
100-SW	-0.0039	100-SW	-0.1332
PGF	0.0363	PGF	0.0594
Residual	-1.31×10^{-9} (0.0)	Residual	-0.0543 (8.0)
Total effect	0.1365	Total effect	0.5674
Percent of grain filling (PGF)		*Percent of grain filling (PGF)*	
Direct effect	0.1338 (33.7)	Direct effect	0.1817 (49.8)
Indirect effect	-0.2633 (66.3)	Indirect effect	0.0117 (3.2)
PL	-0.0007	PL	0.0411
TNH	-0.0010	TNH	0.0494
PH	-0.0052	PH	-8.43×10^{-7}
SWP	0.0142	SWP	0.0096
100-SW	-0.0039	100-SW	-0.1332
SNP	0.0364	SNP	0.0447
Residual	-4.31×10^{-9}(0.0)	Residual	0.1712 (47.0)
Total effect	-0.1296	Total effect	0.3646

1/ Percents in total effect calculated by determining the ratio of each effect (direct, indirect and residual effects) on total effect which ignored the direction of value in each effect (Dumlupinar et al., 2012).

Discussion

The best approach to determine direct and indirect effect of traits on yield is to interpret the correlation coefficient and path analysis results in combination. Identification of the selection criteria for high-yield provides an important means to achieve plant improvements (Milligan et al., 1990; Dumlupinar et al., 2012).

Based on results from 2015, the correlation coefficient value of PL on GYH was found to be lower than that in other traits with GYH, except TNH. On the other hand, a moderate positive value was found among traits in the 2016 study [Table 1]. Although relatively high correlation coefficients were observable between PL and both TNH and 100-SW (in 2015), as well as with TNH, 100-SW, SNP and PGF (in 2016), the path analysis showed an indirect effect through TNH and 100-SW that were either unstable or negative direction [Table 2]. Interestingly, the direct effect of PL on GYH showed high rates in both years. Similarity, Soni et al. (2013) and Ogunbayo et al. (2014) also reported a significant positive correlation of PL with grain yield in rice. It is also reported that PL has high genetic control, as evidenced by high heritability in rice improvement study (Ullah et al., 2011).

A number of tillers were reported as important yield components and used as criteria for genotype selection for high-yielding performance. Many studies found significant positive correlation between the of number of tiller with grain yield in rice (Ibrahim et al., 1990; Efisue et al., 2014). Results of the present study, however, showed that TNH had lower and higher positive values on correlation coefficient with GYH in 2015 and 2016, respectively [Table 1]. This may be because this study was conducted with seven genotypes of upland rice, using of various genetics may affect the relationship measured by the correlation coefficient between TNH an GYH (IRRI, 1984; Gupta and Toole, 1986). On the other hand, TNH was found significantly correlated with PH in 2016. The indirect effect of TNH though PH was positive with higher values in both years (2015 and 2016) when compared with other traits. This suggests that, if using these genotypes in breeding program, TNH should not be used as the main criteria for selection on high yield. PH should be considered instead of TNH because of its higher positive values than other traits on the indirect effect to grain yield in both years.

PH showed moderate values on correlation coefficient with GYH in both years [Table 1]. PH also demonstrated a significant correlation with SWP and PGF in opposite direction values in 2015 [Table 1]. Moreover, PH also showed positive correlation with GYH in both years. The percentage in total effect, however, was lower than that of SWP in 2016. Thus, when using these varieties as plant material in yield improvement program, PH is recommended as a secondary criterion for selection of high yield.

Plant height showed a significant negative correlation with grain yield in oat and rice. This may be attributable to the increased lodging problem in plant, which ultimately affected grain yield (Buerstmayr et al., 2007; Ratna et al., 2015). Beside plant height, other factors that should be considered include: the degree of plant height, lodging index, breaking strength, and characteristics related with culm both on morphological and anatomical characteristics (Rocquigny et al., 2004; Zhang et al., 2016).

Panicle weight was reported as selected character for high grain yield, seed weight, and number of productive panicles in cereal such as pearl millet (Haryanto et al., 1998). Akinwale et al. (2011) reported that some inbred genotypes displayed moderate to high heritability on panicle weight, and showed more advancing on genetic improvement in rice by used this trait as criteria for selection. In this study, moderate positive values were found on the correlation coefficient between SWP and GYH in rice growing in both year. A significant correlation was also observed between SWP and both 100-SW and SNP in negative and positive values in 2016 [Table 1]. In addition, path coefficient of SWP on GYH showed direct effects of SWP in different directions in these two years of study. For 100-SW and SNP, which significantly correlated with SWP as shown in Table 1, a similar direction on indirect effects of SWP was found only through SNP in both years [Table 2]. Based on these results, SNP, rather than SWP, could be criteria for selection on high yield instead of SWP. Such decision, however, will depend on the size of the direct effect of SNP on GYP.

100-SW showed a lower correlation coefficient with GYH in both years; however, there is high correlation coefficient between 100-SW and PGF in positive values. High percentage ratios in total effect determined from the direct effect of 100-SW on GYH were observed in negative direction values [Table 2]. Although seed weight exhibited high heritability in the inbred genotype of rice, it showed low genetic advance (Ali et al., 2002; Seesang et al., 2013). From results of these studies, the ability of genetic controlling may not guarantee the successful on genetic advance by using this character as criteria for selection. The high negative direct effect from 100-SW on GYH suggested that small seed varieties displayed high yield among these seven genotypes. Lower values on indirect effect on 100-SW through other traits were found; however, among traits that had an indirect effect through from 100-SW, PGF was positive both years. Correlation and path analysis showed similar results. This was due to: a) the high positive correlation coefficient between 100-SW and PGF in both years [Table 1], and b) path analysis of 100-SW on GYH, which showed a higher indirect effect through PGF in both years [Table 2]. As such, PGF could be used as criteria for high yield improvement program.

In 2016, only SNP showed significant correlation with GYH [Table 1]. SNP also showed a significant correlation with SWP followed by TNH and PGF, respectively. For path analysis, the direct effect of SNP on GYH showed high values and a high percentage ratio in total effect in both years [Table 2]. Although the indirect effect was less value of SNP on GYP, the positive indirect effects on SNP through PGF and SWP was found in 2015 and 2016, respectively. Sumanth et al. (2017) reported that heritability estimated from variance component in rice, spikelets per panicle of rice were found high value (98.39%). In addition, this trait was also found categorized in high genetic advance for selection (Anjaneyulu et al., 2010). These indicate that SNP may be controlled by additive gene action. Therefore, this trait could be used for improving the population through many selection methods (Sumanth et al., 2017). Consider together with result in this study, SNP is recommended to use as the primary selection criterial for high yield.

PGF had a greater indirect effect on GYH than did the other traits including 100-SW and SNP, and its path analysis impact had only a moderate positive direct effect on GYH [Table 2]. Moreover, the correlation between PGF and GYH showed cross-directional coefficients between in 2015 and 2016 [Table 1]. While positive correlation and positive direct effect of PGF on grain yield in rice was found (Agbo and Obi, 2005; Ranawake and Amarasinghe, 2014), its effect was reported to vary by genotype (Agbo and Obi, 2005; Shahruddin et al., 2014). Thus, PGF may be recommended as secondary criteria for effecting high-yield genotypes.

Conclusion

According to Pearson's correlation analysis, *grain yield hill*$^{-1}$ has a significant positive correlation with *seed number panicle*$^{-1}$ and, to a lesser extent, with *panicle length, tiller number hill*$^{-1}$*, plant height,* and *seed weight panicle*$^{-1}$. For path analysis, direct effect on *grain yield hill*$^{-1}$ had higher effect in traits such as *seed number panicle*$^{-1}$*, 100 seed weight, panicle length, plant height,* and *percent of grain filling*. The higher indirect effect to *grain yield hill*$^{-1}$ from the traits was found through related traits such as *seed number panicle*$^{-1}$*, percent of grain filling, seed weight panicle*$^{-1}$*,* and *plant height.* As such, the research shows that *seed number panicle*$^{-1}$*, panicle length,* and *plant height* may be considered as primary criteria for selection of upland rice genotypes. *Percent of grain filling* and *seed weight panicle*$^{-1}$ constitute secondary criteria.

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Contribution of Authors

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