Available online freely at www.isisn.org

Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2019 16(2): 1492-1499. **OPEN ACCESS**

Correlations and path analysis to determine the selection characters for developing new-type of upland rice

Reny Herawati*, Masdar, and Alnopri

Department of Agroecotechnology, Faculty of Agriculture, University of Bengkulu, Bengkulu, **Indonesia**. 38371.

***Correspondence:** reny.herawati@unib.ac.id **Accepted: 13** Dec. 2018 **Published online:** 20 May. 2019

Correlation between growth characters and yields substantially efforted to determine the right character selection. Another method called path analysis could be used to identify essential traits, either directly or indirectly, to the crop yield. This research aimed to determine the selection criterion in agronomic characters of several genotypes in new-type upland rice. The experiment was laid out in a Randomized Block Design with three replications. The rice seed used was 50 rice genotypes derived from the recurrent selection. Growth character observed were plant height, total tillers number, number of productive tillers, panicle length, number of fill grain, number of empty grain, flowering age, harvest age, the 1000 grains weight, and grain weight per hill. The results showed that the characters of the total number of tillers, productive tillers number, and fill grains number had a positive correlation and very significant on grain weight per hill were 0.58, 0.64, 0.53 respectively and significant positive correlation with time flowering and 1000-grains weight were 0.23 and 0.29 respectively. Other characters such as plant height (0.06), total number of tillers (0.16), productive tillers number (0.59), panicle length (0.01), fill grains number (0.42), and 1000 grains weight (0.26) all directly and positively influenced the grain weight per hill, which character closely related to the yields. Plant characters such as plant height, productive tiller numbers, panicle length, filled grain number, and filled grain weight per hill was applied as selection criteria for developing of new-type of upland rice.

Keywords: correlation, path analysis, characters, new-type, upland rice

INTRODUCTION

Upland rice is a prospective crop as a supporting plant of national production, which has been dominated by lowland rice. In other words, up land rice cultivation is an effort to increase domestic rice production, due to many difficulties in lowland rice extensification. The development of upland rice cultivation has done through suboptimal land utilization, where more than 11 million hectares could develop as upland rice fields in Indonesia. The national productivity of upland rice has been only 3.2 tons/ha, which has been lower than the productivity of lowland rice of 5.3 tons/ha (Statistics Indonesia, 2017). Lower productivity of upland rice being caused by varying climatic and soil conditions, applying more inferior cultivation technology in varieties, fertilization and blast disease control. Applying high adapted varieties has been one of the efforts for the national production .

Plant breeding in the effort of upland rice varietyy assembling, in this case, using the elder plant pool of wild rice relatives, which have tolerant genetic diversities to both abiotic and biotic stress. Sources of importantly plant breeding, selection, and evaluation techniques yield new, improved varieties (Hairmansis et al., 2016). There have been several genetic

resources to improve upland rice. Importantly, tolerance to both abiotic and biotic stresses, most of the agronomic quality of rice obtained from the gene pool of local varieties.

A superior variety of rice types ideally expected to increase the upland rice yield. New-type of upland rice has been assembled through anther culture technique (Herawati et al., 2010), but the criteria for determining the desired character limited due to limited of the selected another. Modified agro-morphological characters in upland rice have been developed through conventional breeding of recurrent selection (Herawati et al., 2017). Nnecessary to modify the characteristics in order to assemble the new-type of upland rice, such as the panicle density above 150 filled grain per panicle, productive tiller numbers above 6, grain filling above 70 percent, plant hight below 150 cm, maturity age below 130 days, 10^0-15^0 flag leaf angle, the second and third leaves slightly drooped for more extensive canopy, stem diameter above 0.7 cm (Herawati et al., 2010). Iimproved varieties of upland rice in dispensed these characteristics to increase plant yields and upland rice area.

The diversity of plant morphological characters has been crucial in determining the best method to improve the yield. These morphological characters are significantly important in relations to the yield potential that being used as an indirect selection criterion or a to enhance/magnify the variety in the new population. The genetic diversity plays an essential aspect in which breeders always work (Gowane et al., 2013; Herawati et al., 2019; Osundare et al., 2017; Pachauri et al., 2017).

The yield potential character means the complex trait that strongly influenced by both growth and yield component (Zhou et al., 2018; Ikeda et al., 2013). Both yield potential and yield component controlled by many genes, which are strongly affected by environmental factors. Sravan et al. (2012) revealed that the system of breeding programs involved genetic diversity, and selected genotypes to develop prospective breeding lines. Plant breeders who assemble high yield plants rarely interested in just one character. So, learning about the relationship between yield and many other characters have been necessary (Agyei et al., 2012).

Several types of researches to examine relationships between characters by correlation illustrate the closeness of two traits (Aryana et al., 2011; Gupta et al., 2015; Osundare et al., 2017). The simple correlations coefficient is used to evaluate the relationship between each character. The correlation coefficient value ranged between -1 and 1 (Krualee et al., 2013). The positive correlation value between each character means the character increases yield with the rise of other character value. In contrast, a negative correlation value means the increased character value decreases other traits. Hussein and Hugo (2011), stated that path analysis helps to measure the indirect effect of one variable on other variables, through the separated correlation coefficient of both, directly and indirectly, influential variables. According to Zare et al. (2012), the yield potential means complex character derived from several components in both positive and negative influences on the trait. Accordingly, significant contributions of each element significantly contributeded to the yield potential. This research aims to determine the selected agronomic characteristic criteria for developing of new-types of upland rice genotypes through both correlation and path analysis.

MATERIALS AND METHODS

This research had been conducted from July to October 2017 in Rawa Makmur, Bengkulu, as well as in Crop Production Laboratory, Faculty of Agriculture, University of Bengkulu, Indonesia. The experiments arranged in a Randomized Block Design (RBD) with three replications. The experiments used 50 rice genotypes derived from the recurrent selection in the F3 generation, and early-stage screened to tolerate drought stress (Herawati et al., 2017b). Rice grain from 50 lines sown in plastic containers. After 21 days, the seedlings transplanted in the rice fields. Each genotype number planted in two rows, 20 seedlings in each row. Plants fertilized with 200 kg ha^{-1} Urea, 100 kg ha^{-1} SP36, and 100 kg ha^{-1} KCl. The observation of agronomic characters are plant height (cm), total tiller numbers, productive tiller number per hill (stem), flowering age (day after planting), maturity age (day after planting), grain numbers per panicle (grain), filled grain numbers per panicle (grain), 1.000 grain weight (g), and weight of filled grain per hill (g). The effects of agronomic character on grain weight per hill analyzed by both correlation and path analysis. Genotypic correlations calculated by the formula as:

$$r_{g(xixj)} = \frac{cov.g(xixj)}{\sqrt{\sigma^2_{g(xi)} \cdot \sigma^2_{g(xj)}}}$$

cov.g(xixj) = genotypic covariance between i and j,

$\sigma^2_{g(xi)}$ = genotypic variance of character i,
$\sigma^2_{g(xj)}$ = genotypic variance of character j.

The significance of the correlation value between each character used t-test according to Singh and Chaudhary (2010), as follows:
$t = r [(n-2): (1-r^2)]^{1/2}$ where, t = obtained value compared with t student, df=degree of freedom (n-2), r = replication, n = observed population. Path coefficient analysis to determine the direct and indirect effects of agronomic characters, based on the following equation (Singh and Chaudary 2010):

$$\begin{bmatrix} r_{11}\ r_{12}....r_{1p} \\ r_{21}\ r_{22}...r_{2p} \\ .... \\ r_{p1}\ r_{p2}....r_{pp} \end{bmatrix} \begin{bmatrix} c_1 \\ c_2 \\ ... \\ c_p \end{bmatrix} = \begin{bmatrix} r_{1y} \\ r_{2y} \\ .... \\ r_{py} \end{bmatrix}$$

Rx Ci Ry

Based on the above equation, the C_i value (directed influence) calculated by the formula:
$C_i = R_x\text{-}1.R_y$, where;
R_x = correlation matrix between independent variables,
R_{x-1} = inverse matrix Rx
C_i = cross coefficient vector which shows the direct influence of any free variable that standard to the non-free variable
R_y = vector coefficient of correlation between free variables X_i = (i = 1,2, ... p)

RESULTS AND DISCUSSION

Correlation Between Yield and Yield Components

The association between plant characters chose the rightly selected trait. The pattern of relationships between the yield characters and yields known from the value of the correlation. The correlation between each character presented in Table 1. The plant height positively correlated to the filled grain (0.32) and positively correlated to the empty grain number (0.43), but inversely proportional to both productive tiller number (-0.24) and maturity age (-0.23). The data shows that the increased plant height will increase the fill grain number, but the higher the plant height higher the empty grains. Limited photosynthate for grain filling due to most of the photosynthates partitioned for the vegetative plant. Although the higher the plant height positively correlated with filled grains per panicle, the selection based on the plant high character needs to consider due to the plant height related to the plant lodges which limited the yield. Peng et al. (2008) reported that plant height and leaf width are the characters associated with lodge resistance, nutrient content and, the efficiency of photosynthetic.

Total tiller number positively correlates to the productive tiller numbers (0.95) indicates the observed whole productive tillers, according to the desired criteria of new types of upland rice which tiller numbers are all productive (Khush, 2013). The productive tiller numbers positively correlated to panicle length (0.29), flowering age (0.35), maturity age (0.31), and significantly affected the grain weight per hill (0.64). The panicle length positively correlated to both the empty grain numbers and the flowering age. However, the panicle length negatively related to the 1000 grain weights. Increasing the number of filled grains per panicle will significantly increase grain yield per hill. The results of this study are also shown in the study of Yang et al. (2007) and Herawati et al. (2019) on a new type of upland rice.

On the contrary, increased un-fill grains per panicle can decrease grain yield per hill which indicated the negative correlation value (-0.08). A large number of grains per panicle followed by filling grain at a long panicle will increase grain yield. Panda et al. (2015) have reported that the sucrose synthase (SUS3) enzyme actively involved in the seed filling period, increased spikelets density of panicle affected SUS3 expressions in the basal spikelets.

The characters such total tiller numbers, productive tiller numbers, and filled grain numbers positively correlated to the grain weight per hill, and the panicle length, flowering age and 1000 grain weight. Thus, all five characters could be used as selected criteria to increase grain yield. According to Gomez and Gomez (2002) and Matchik and Sumertajaya (2002), the correlation value between the two characters approached -1 or +1, closer relationship between two characters. The more positively correlation coefficient indicated that, the higher the value of the variable the more significant the yield. In contrast, the smaller the value, the lower the yield in drought stress conditions. The negative correlation coefficient value showed the higher the value, the lower the yield of grains obtained.

The increased 1,000-grain weights followed by the increased yield per hill shows by the value of the positive correlation. The 1,000-grain weight relates to the grain both size and level of un-filled

such the more extensive the filled grain would, the higher the 1000 grain weight. Overall, increased yield per hill obtained by increased total tiller number, productive tiller numbers, panicle length, filled grain number per panicle, and 1000 grain weight, but inversely related to both plant height and empty grain number (Table 1).

The higher the flowering age, the longer the maturity age, indicating the value of the positive correlation (0.58). The plant characteristics determine the flowering age due to plant growth determines the vegetative phase. Rreproductive phase of rice in the tropics 65 days consisted of a 35-day generative period and a 30-day maturation phase (IRRI, 2008).

Path Analysis to Determine the Effect of Characters on Yields

Characters correlated to the yields (Table 1) used as a selected character for new-types of upland rice. Path analysis determines growth characters, either directly or indirectly, influenced the yield (Singh and Chaudhary, 2010). So, the path analysis aims to find out the correlation coefficients of either direct or indirect effects. Based on the path analysis (Table 2), plant height, the total number of tillers, productive tiller numbers, panicle length, filled grain weight per panicle, and the 1000 grains weight directly and positively affected the grain weight per hill. Productive tiller numbers, fill grain number per hill, and the 1000 grain weight profoundly and positively influences the grain weight per panicle respectively 0.59, 0.42, and 0.26. This result shows that the three variables contribute significantly to the yield.

The path analysis creates a path diagram with the one-way causal model. Based on the path analysis results in Table 2, the path diagram of characters influences the yields. If the character that has a direct influence coefficient is low on yield, it is essential to attend to the value of the character's influence on the yield indirectly through other characters (Singh and Chaudhary, 2010). Characters that do not affect yields through other traits chosen which have an indirect effect coefficient above 0.09.

The plant height character indirectly and negatively affected the productive tiller numbers with the coefficient value of -0.14. This data has shown that the higher the plant height variable will reduce the formation of productive tillers. However, precisely the plant height increases the filled grain number per panicle by 0.14 (Figure 1).

The total number of tillers affected the productive tiller numbers with a coefficient of 0.56. The coefficient value indicated that almost all of the planted tillers in the genotypes produced panicles. The character of new-type rice clearly with the tiller number more than 12, which were all productive (Herawati et al., 2010; Khush, 2013). The prolific tiller numbers per hill have become a character that used as a selected criterion to improve the yield of new-type rice. Reference Peng et al. (2008) at least 330 productive tillers per m^2 (10-14 crops per hill) to increase 10% yield potential in wetland rice.

The high productive tiller number affected by the flowering age and indirectly by maturity age respectively of 0.21 and 0.18. The figure shows that the higher the plant maturity age led to the more prolonged the vegetative period and the chance to form more tillers. However, the tiller numbers depended on the plant ability to produce photosynthate. Khush (2013) revealed that increasing the yield potential; the rice increased the biomass production with the harvest index that responsive to nitrogen fertilization, resistant to lodge, and photosynthate partition.

The panicle length showed a negative coefficient value to the 1000 grain weights. The data shows that the more extended the panicle led to the smaller the grain and the lower the grain yield per hill. This data indicates that the longer panicle led to smaller the grain size which causes a decrease in grain yield per hill. Das et al. (2018) revealed that poorly grain filling subjected to the expression of the recessive allele for high ethylene production, but the allele being amenable for suppression to the dominant allele in genetic breeding. Based on the path analysis, the residual of 0.47 indicated that other effect on the grain yield could not be explained through this research. Further, researches required to describe the relationship between grain yield and morpho-physiological properties such as leaf angle, and selections to drought and resistance to blast disease.

Determination of Selection Characters of Rice Genotype for Developing of New Type of Upland Rice

Correlation between any characters was used as an indirect selection for the main characters so that some information obtained from this research determines the selection character for new-type of upland rice (Table 3).

Table 1. The Coefficient Correlations of Agronomical Characters of Upland Rice Lines

Characters	PH	TNT	PTN	PL	FG	UFG	TF	TH	1000W	GWH
PH	1	-0.25*	-0.24*	0.14	0.32*	0.43**	0.04	-0.23*	-0.03	-0.06
TNT		1	0.95**	0.28*	0.03	0.15	0.34*	0.35*	-0.25*	0.58**
PTN			1	0.29*	0.09	0.19	0.35*	0.31*	-0.2*	0.64**
PL				1	-0.00	0.37*	0.27*	0.12	-0.43**	0.03*
FG					1	0.09	0.21*	0.07	0.24*	0.53**
UFG						1	0.04	0.05	-0.31*	-0.08
TF							1	0.58**	-0.1	0.23*
TH								1	-0.48**	0.01
1000W									1	0.29*
GWH										1

PH = Plant Height; TNT=Total Number of Tillers; PTN = Productive Tiller Number; PL = Panicle Length; FG = Filled Grain per Panicle; UFG = Unfilled Grains per Panicle; TF=Time of Flowering; TH = Time of Harvest; 1000W = 1,000 Grain Weight; GWH= Grain Weight per Hill, * and ** = significantly different at P < 0.05 and P < 0.01

Table 2. The Direct and Indirect Effect of Some Agronomic Characters on the Yield

Characters	Direct effects	Indirect effects								
		PH	TNT	PTN	PL	FG	UFG	TF	TH	1000W
PH	0.06	-	-0.02	-0.01	0.01	0.02	0.03	0.00	-0.01	-0.002
TNT	0.16	-0.04	-	0.15	0.05	0.00	0.02	0.05	0.06	-0.04
PTN	0.59	-0.14	0.56	-	0.17	0.06	0.11	0.21	0.18	-0.12
PL	0.01	0.001	0.003	0.003	-	-0.00	0.004	0.003	0.001	-0.004
FG	0.42	0.14	0.01	0.04	-0.001	-	0.04	0.08	0.03	0.09
UFG	-019	-0.09	-0.03	-0.04	-0.07	-0.02	-	-0.007	-0.01	0.06
TF	-0.05	-0.002	-0.017	-0.02	-0.01	-0.01	-0.002	-	-0.03	0.005
TH	-0.08	0.02	-0.03	-0.02	-0.01	-0.01	-0.004	-0.04	-	0.04
1000W	0.26	-0.01	-0.07	-0.05	-0.11	0.06	-0.08	-0.03	-0.13	-

PH = Plant Height; TNT=Total Number of Tillers; PTN = Productive Tiller Number; PL = Panicle Length; FG = Filled Grain per Panicle; UFG = Un-filled Grains per Panicle; TF=Time of Flowering; TH = Time of Harvesting; 1000W = 1,000 Grain Weight

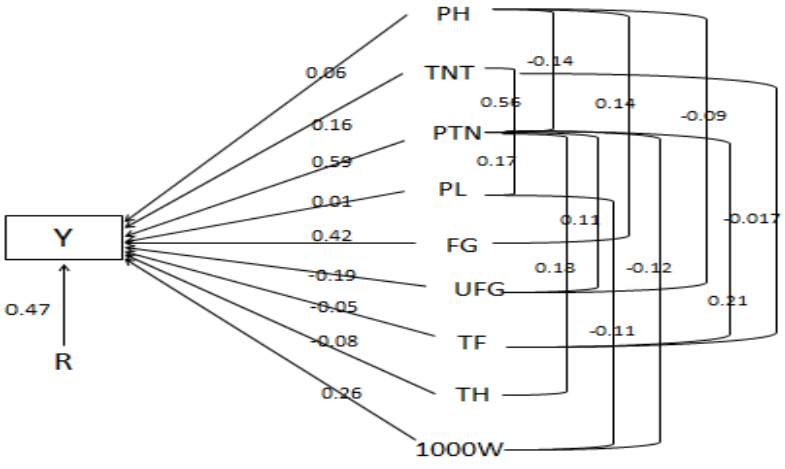

Figure 1. Path Analysis of Some Characters which Directly and Indirectly Affected the Yields

Table 3. Determination of Selection Characters of Rice Genotype for New Type of Upland Rice

Characters	Genotype	Range	Mean
Plant Height (cm)	G29, G50, G49, G38, G46, G25, G44, G45	110-125	120.2
Productive tillers number	G23, G24, G22, G40, G14, G28, G48, G25, G44, G17, G33, G9, G28, G45, G21, G36, G7	12-18	13.9
Panicle length (cm)	G25. G21, G42, G17, G14, G3, G28, G22, G1, G44, G23, G35, G50, G36, G12, G31, G18, G13, G46, G9, G19, G39, G47, G41, G16, G2, G4, G7, G6, G11, G24	30-36	30.87
Number of fill grains	G5, G11, G3, G10, G14, G15, G20, G36, G4, G19, G24, G13, G40	160-200	171.2
Grains Weight per tiller (g)	G14, G24, G40, G10, G44, G23, G29, G28, G45, G25, G33	25-38	29.5

This research found that the yield of new-type of upland rice predicted several characters effect on plant yield such plant height, productive tiller numbers, panicle length, grain number per panicle, and grain weight per hill. Herawati et al. (2010) developed some criteria for new-type of upland rice by modified the characters of new-type rice, big panicle (> 150 grain per panicle), productive tillers (> 6), filled grain > 70%, plant height below 150 cm, short maturity age (less than 130 days), 10^0-15^0 flag leaf angle, the second and third leaves slightly drooped to allow the plant canopy broader, stem diameter > 0.7 cm. The characteristics of new-type upland rice presented in the selected genotype as Table 3.

Plant height and productive tillers have been an agronomic character as a specific identity of a genotype. The standard of plant height, which IRRI specified in the new-type rice has been at least 100 cm (Peng et al., 2008). While the characteristics of the ideal plant according to Ma et al. (2006) was a plant height of 115-120 cm. These criteria prepared eight selected genotypes with plant height close to ideal for new-type rice (110-125 cm). Productive tiller numbers, which > 12 filled grain clearly with opportunity for higher yields, this could be seen from the direct effect of the number of fertile tillers of 0.59 on the grain weight per hill (Table 2). According to Peng et al. (2008) the number of productive tillers at least 330 tillers per m^2 (10-14 tillers per hill) to increase 10% of yield potential in lowland rice.

The panicle length ranges between 30-36 cm presented 31 selected genotypes (Table 3). Although the panicle length effects with a value of 0.01, however, it is necessary to consider indirect effects through productive tillers of 0.17 (Figure 1). Long panicles allow the formation of many panicles, but insufficient supply of photosynthates from leaves increases the empty grains. Kobata and Iida (2004) showed that lower filled grains in new-type rice attributed to lower efficiency of the assimilate partition from the plant leaf to the grains. Virk et al. (2004) developed a new-type rice strategy on panicle length for 150 grains per panicle. Furtherly, Peng et al. (2008) confirmed that the number of panicles per m^2, the percentage of grain filling, total biomass and harvest index required for new-type rice. Moreover, Khush (2013) reported that poor grain filling of new plant type line attributed to lack of apical dominance within a panicle, compact arrangement of spikelets and a limited number of large vascular bundles for assimilating transport to grains. Increased grain fillings after the grain disposal prepared with high photosynthetic rates, increased biomass production, aging of leaf and root (Wei et al., 2016).

Based on the information from path analysis, the fill grain number per panicle highly direct the effect on grain yield as 0.42 (Figure 1). The fill grain number per panicle became one of the significant characters to be used as a selected criterion concerning higher grain yield. Selected genotypes filled grain numbers per panicle of 160-200 and grain weight of 25-38 gram per hill (Table 3). Zhengjin et al. (2005) developed the ideal rice, which criteria of the grain numbers per panicle higher than 160 grains, while Virk et al. (2004) developed new-types rice, which character of the filled grain of 150 grains per panicle. The selected genotypes in this F4 generation expected to produce new-superior genotypes on the next generation.

CONCLUSION

The characters of the total number of tillers, productive tillers number, and fill grains number had a positive correlation and very significant on grain weight per hill were 0.58, 0.64, 0.53 respectively and significant positive correlation with time flowering and 1000 grains weight were 0.23 and 0.29 respectively. Other characters such as plant height (0.06), total number of tillers (0.16), productive tillers number (0.59), panicle length (0.01), fill grains number (0.42), and 1000 grains weight (0.26) all directly and positively influenced the grain weight per hill, which character closely related to the yields. Plant ccharacters such as plant height, productive tiller numbers, panicle length, filled grain number, and filled grain weight per hill was applied as selection criteria for developing of new-type of upland rice.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

ACKNOWLEGEMENT

Acknowledgments and appreciations to the Ministry of Research, Technology and Higher Education of Republic of Indonesia, through Directorate for Research and Community Service which funded through Applied Research in the 2019 budget year (Contract number 165/SP2H /LT/DRPM/ 2019).

AUTHOR CONTRIBUTIONS

All authors contributed equally in all parts of this research.

REFERENCES

Agyei DD, Ofori K, and Kaledzi PD. 2012. Variation and correlation analysis of growth parameters in D X P oil palm (*Elaeis guineensis* J.) seedlings. Elixir Agriculture. 47: 8946- 8949

Aryana, IGPM., Nur B, dan Kuswanto. 2011. Sidik lintas padi beras merah pada tiga lingkungan tumbuh berbeda. Agroteksos 21(1):1-10.

Das K, Panda BB, Shaw1 BP, Das SR, Dash SK, Kariali E, and Mohapatra PK. 2018. Grain density and its impact on grain filling characteristic of rice: mechanistic testing of the concept in genetically related cultivars. Scientific REPOrts. 8:4149). doi: [10.1038/s41598-018-22256-2]

Gomez, K.A. dan A.A. Gomez. 2002. Statistical Procedures for Agricultural Research. Jakarta: UI Press.

Gowane GR., Prakash V, Chopra A, and Prince LLL. 2013. Population structure and effect of inbreeding on lamb growth in Bharat Merino sheep. Small ruminant Research 114:72-79. Journal homepage: www.elsevier. com/ locate./ smallrumres.

Gupta N, Bhardwaj ML, Singh SP, And Sood S. 2015. Correlation and path analysis of yield and yield components in some genetic stocks of bitter gourd (*Momordica charantia* L.). SABRAO Journal of Breeding and Genetics 47(4):475-481

Hairmansis A, Yullianida, Supartopo, dan Suwarno. 2016. Rice Improvement for Upland Areas. Iptek Tanaman Pangan. 11(2):95-106

Herawati R, Purwoko BS, and Dewi IS. 2010. Characterization of doubled haploid derived from anther culture for new type upland rice. J. Agron. Indonesia. 38(3):170-176.

Herawati, R, Masdar, Ganefianti DW, Hermawan B, and Alnopri. 2017. Screening and identification of upland rice lines derived recurrent selection for drought tolerance. IJASEIT. 7(6):2322-2327.

Herawati, R, Masdar, and Alnopri. 2019. Genetic analysis of grain yield of F_4 populations for developing new type of upland rice. SABRAO Journal of Breeding and Genetics. 51(1):68-79.

Hussein S and Hugo A. 2011. Determination of selection criteria for seed yield and seed oil content in Vernonia (*Vernonia galamensis* variety ethiopica). Industrial Crops and Products 33 (2011) 436-439. Journal hom-page: www. Elsevier.com/locate/indcrop.

Ikeda M, Miura K, Aya K, Kitano H, Matsuoka M (2013). Genes offering the potential for designing yield-related traits in rice. Curr. Opinion Plant Biol. 16:213-220.

International Rice Research Institute (IRRI). 2008. Growth dan Morphology. (http://www. knowledgebank.irri.org/regionalsites/indonesi /default.htm, accessed May 4, 2018).

Khush. 2013. Strategies for increasing the yield potential of cereals: case of rice as an example. Plant Breeding. 132:433–436.

Kobata T and Iida K. 2004. Low grain ripening in the New Plant Type rice due to shortage of assimilate supply. New directions for a diverse planet: Proceedings of the 4th International Crop Science Congress Brisbane, Australia, 26 Sep – 1 Oct 2004.

Krualee S, Sayan SS, Theera E, and Vinich S. 2013. Correlation and path analysis of palm oil yield components in oil palm (*Elaeis gueneensis* Jacq.). Kasetsart J. (Nat. Sci.) 47:528–533.

Ma J, Ma W, Ming D, Yang S, and Zhu Q. 2006. Characteristics of rice plant with heavy panicle. Agricultural Sciences in China 5(12):101-105.

Matchik, A. and Sumertajaya IM. 2002. Designing Experiments with SAS and Minitab Applications Volume 1. Bogor: Department of Statistics FMIPA, Bogor Agricultural University.

Muhammad, A.N. 2010. Analysis of correlation and cross-print between morphological characters and fruit components of pineapple plants (Ananas comosus L. Merr). Crop Agro. 3 (1): 1- 9.

Osundare OT, Akinyele BO, Fayeun LS, and Osekita OS. 2017. Evaluation of qualitative and quantitative traits and correlation coefficient analysis of six upland rice varieties. Journal of Biotechnology and Bioengineering. 1(1):17-27

Pachauri AK, Sarawgi AK, Bhandarkar S, and Ojha GC. 2017. Agro-morphological characterization and morphological based genetic diversity analysis of Rice (*Oryza sativa* L.) germplasm. Journal of Pharmacognosy and Phytochemistry 6(6): 75-80

Panda BB, AK. Badoghar A, K. Das A, R. Panigrahi B , E. Kariali B , SR. Das C , SK. Dash D , BP. Shaw A and Mohapatra PK. 2015. Compact panicle architecture is detrimental for growth as well as sucrose synthase activity of developing rice kernels. Functional Plant Biology 42(9):875-887

Peng S, Khush GS, Virk P, Tang Q, and Zou Y. 2008. Progress in ideotype breeding to increase rice yield potential. Field Crops Res. 108(1):32–38

Singh RK and Chaudhary BD. 2010. Biometrical Methods in Quantitative Genetic Analysis. Kalayani, Ludhiana. page 275-280.

Sravan T, Rangare NR, Suresh BG, and Ramesh KS. 2012. Genetic variability and character accosiation in rainfed upland rice (*Oryza sativa* L.). Journal of Rice Research 5(1&2):24-28.Statistics Indonesia. 2017. https://www.bps.go.id/publication.html.

Virk PS, Khush GS, and Peng S. 2004. Breeding to enhance yield potential of rice at IRRI: the ideotype approach. (Mini Review). International Rice Research Notes. 29(1):5-9.

Wei H, Zhang H, Blumwald E, Li H, Cheng J, Dai Q, Huo Z, Xu K, and Guo B. 2016. Different characteristics of high yield formation between inbred japonica super rice and inter-sub-specific hybrid super rice. Field Crops Res. 198, 179–187.

Yang W, Peng S, Laza RC, Visperas RM, and Sese MLD. 2007. Grain Yield and Yield Attributes of New Plant Type and Hybrid Rice. Crop Sci. 47:1393-1400.

Zare M, and Sharafzadeh S. 2012. Genetic variability of some rapeseed (Brassica napus L.) cultivars in Southern Iran. Africal Journal of Agriculture Research. 7(2) : 224-229. January 2012.

Zhengjin XU, Wenfu C, Longbu Z, and Shouren Y. 2005. Design principles and parameters of rice ideal panicle type. Chinese Science Bulletin. 50(19):2253-2256.

Zhou Y, Tao Y, Yuan Y, Zhang Y, Miao J, Zhang R,Yi C, Gong Z, Yang Z, Liang G. 2018. Characterization of a novel quantitative trait locus, GN4‑1, for grain number and yield in rice (O. sativa L.). Theor. Appl. Genet. 131(3):637-648.