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CORRELATION COEFFICIENT AND PATH ANALYSIS FOR SEED WEIGHT SELECTION OF EX-SITU NUTMEG (*MYRISTICA FRAGRANS* HOUTT.) COLLECTION

Purwiyanti Susi*

Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University & Indonesian Spice and Medicinal Crops Research Institute, Indonesian Agricultural Agency for Research and Development (IAARD), Indonesia

Sudarsono, ORCID: 0000-0003-4688-5628

Wahyu E.K. Yudiwanti, ORCID: 0000-0003-1966-5064

Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University, Indonesia

Rostiana Oti

Indonesian Spice and Medicinal Crops Research Institute, Indonesian Agricultural Agency for Research and Development (IAARD), Bogor, West Java, Indonesia
ORCID: 0000-0002-8083-3963

*E-mail: s.purwiyanti.81@gmail.com

ORCID: 0000-0003-0542-5916

ABSTRACT

Nutmeg (*Myristica fragrans* Houtt.) is a perennial crop that yielded fruits about 5-7 years after planting. Determining the yield before the production phase required a considerable amount of time and was costly. The implementation of selection methods to observe characters that correlated to yields can shorten the selection period. Correlation and path analysis are methods used to select important characters that could be applied as marker-assisted selection based on morphological characters. Therefore, this research aims to observe the character as a selection criterion for seed weight in ex-situ nutmeg collections. The research was conducted at the ex-situ nutmeg collection garden at Cicurug Experimental Station, Sukabumi, West Java. The samples used were 104 females and 43 bisexual trees. The morphological characters observed were habitus, mature leaves, blooming flowers, ripe fruits, mace, and seeds. The relationship between characters was tested using Pearson correlation and continued with path analysis using the MINITAB 17 software. The results showed that the value of the correlation coefficient between fruits, seeds, and mace with the weight of the seeds was classified from strong to very strong and can be used for seed weight prediction. The selection of seed weight using the characters of fruit weight, fruit length, fruit diameter, mace weight, and seed length must be done simultaneously. While the selection with seed diameter character can be done independently.

KEY WORDS

Direct effect, fruit weight, indirect effect, reproductive, yield, vegetative.

Nutmeg is a perennial plant. The main products of nutmeg are fruits which consist of flesh, mace, and seeds. Nutmeg is harvested at about 5-7 years after planting. To find out the fruit yield potential takes a long time and a high cost. The yield is influenced by many characters. The implementation of selection methods to observe characters that correlated to yields can shorten the selection period. Correlation and path analysis is a method that can be applied to select morphological characters and yield components that affect the yield. In cocoa plant height, a number of secondary branches, and diameter, primary branch diameter can be used as selection criteria for assessing the yield (Wardiana and Pranowo 2020).

Correlation coefficients help determine which characters are important or not in the selection program. If a character and the response character are correlated, the improvement of characters which difficult to observe can be made by selecting other easily

observed characters (Bakhtiar et al. 2010). Relationships among characters can be expressed by simple correlations. However, the simple correlation leads to misinformation due to the multicollinearity effect between characters. Moreover, the correlation coefficient cannot differentiate the direct and indirect effects of the characters. The weakness of correlation analysis can be solved by using path-analysis (Singh and Chaudary 1979).

Path analysis is a linear regression that shows the relationship effect of direct and indirect, through other characters (Singh and Chaudhary 1979). Path analysis provides information on the relationship between characters and explains the causal relationship between characters through separate paths constructed in a cross diagram. The use of correlation and path analysis in studying the relationship between quantitative characters is a guideline for a more efficient selection program (Wirnas et al. 2006). The use of correlation and path analysis to study the relationship between characters to yield and develop selection criteria has been carried out on various *Cicer arietinum* (Ali et al. 2009), *Tamarindus indica* (Okello et al. 2018), *Theobroma cacao* (dos Santos et al. (2018), *Moringa oleifera* (Karunakar et al. 2018), *Macadamia integrifolia* L. (Usha et al. 2018), *Ricinus communis* (Rofiq et al. (2019)), *Cocos nucifera* ((Miftahorachman and Sulistyowati (2015); Mawardi et al. (2017)), *Areca catechu* (Miftahorachman et al. 2019), and cotton (Rehman et al. 2020).

The high economic value of nutmeg is the high quality of seeds. The quality of nutmeg seeds includes the size, weight, and content of essential oils and myristicins. Several studies aimed at finding selection criteria for seed weight have been carried out. Vikram (2016) research showed that fruit weight was significantly positively correlated with fruit flesh, fruit volume, and thickness of pericarp. Further (Vikram, Miniraj, and Mathew 2018) evaluated 25 morphological characters of the nutmeg population in Kerala, India, by using path analysis to assess the yield potential of the fruits. However, their result has not specifically shown the important characters affected to the seed weight and the population used for analysis limited to the same ecotype. In the meantime, the expression of characters and their relationship is influenced by genetic and environmental factors. Usha *et al.* (2018) stated that environmental differences cause variability between different characters. Therefore correlation and path-analysis are needed to assess ex-situ nutmeg collection, which is derived from different ecotypes. This study aimed to observe the characters as selection criteria for the seed weight of ex-situ nutmeg collections.

MATERIALS AND METHODS OF RESEARCH

The plant material used are nutmeg ex-situ collection at Cicurug Experimental Station, Sukabumi, West Java, of Indonesian Spices and Medicinal Crops Research Institute (ISMCR). The samples used were 104 females and 43 bisexual nutmeg accessions, aged approximately 25 years. The characters observed were plant height, canopy width, stem circumference, branch internodes length, branch diameter, leaf length, leaf width, leaf thickness, leaf petiole length, corolla length, pedicels length, corolla diameter, pedicels diameter, fruit weight, fruit length, fruit diameter, fruit flesh thickness, mace weight, seed weight, seed length, seed diameter and fruit production per plant per year. The morphological characters were observed according to the Tropical Fruit Descriptors (IPGRI, 1980; Marzuki, 2007; Soeroso 2012). The number of samples observed for mature leaves, flowers, and ripe fruit, were 10 pieces for each tree. However, observation on habitus such as plant height, canopy width, and stem circumference were done only on a single tree its self. The data were analyzed by using Pearson correlation at 5% level. Correlation coefficient resulted from the data analysis were then classified according to Sarwono (2006). The significant value ($p > 0.05$) for seed weight were then evaluated by using path analysis. The correlation and path analysis were tested using the MINITAB 17 software.

RESULTS AND DISCUSSION

The correlation values ranged from 0.007 to 0.888 (Table 1), which implies a very weak to very strong correlation (Sarwono 2006). Gomez and Gomez (1984) stated the correlation

value between two characters, close to -1 or +1, which indicates a closer relationship. The significant positive correlation between characters shown between leaf length and width (0.495), corolla length with fruit production per plant per year (0.475), fruit weight with fruit length (0.664), fruit diameter (0.888), fruit flesh thickness (0.523) and seed weight (0.531); fruit diameter with a fruit flesh thickness (0.653); fruit length with seed length (0.534); mace weight with seed weight (0.527); seed weight with seed length (0.588) and seed diameter (0.863); seed length with seed diameter (0.637). This research showed similar results with the research carried out by Vikram (2016), which showed that fruit weight was significantly positively correlated with fruit breadth, fruit volume, and thickness of pericarp. Positive correlation tends to increase or decrease in the same direction at the same time. In contrast, the significant negative correlation is indicated by the relationship between stem circumference with canopy width (-0.637) and corolla length with corolla diameter (-0.475).

Plant breeders widely use correlation analysis to conduct an indirect selection of main characters. In nutmeg, the weight of the seeds is one of the main characteristics that is used as a measure of quality. Therefore, it is very necessary to predict seed weight through other highly correlated and easily observable characters. The information on the correlation value in the ex-situ population can be used as a reference in the nutmeg selection program. The results of the correlation analysis on seed weight showed that six characters were significantly correlated, which are fruit weight (0.531), fruit length (0.402), fruit diameter (0.446), mace weight (0.527), seed length (0.714), and seed diameter (0.891). The value of the correlation coefficient between fruits, seeds, and mace with the weight of the seeds was classified from strong to very strong. Therefore, these characters can be used on seed weight prediction. The results of this research are similar to Anita-sari and Wahyu (2013), namely that the fruit weight and dry weight of cacao beans have a high and significant correlation.

Table 1 – Correlation matrix among morphological characters of ex-situ nutmeg collection

	PH	CW	SC	BL	BD	LL	LW	LT	PTL	CL	PDL	CD	PDD	FWEI	FL	FD	FFT	MWEI	SWEI	SL	SD
CW	-0.106																				
SC	0.067	-0.637																			
BL	-0.096	0.046	0.021																		
BD	-0.084	0.092	0.092	0.267																	
LL	-0.019	-0.045	0.201	0.183	0.078																
LW	-0.071	0.066	0.058	0.279	0.234	0.495															
LT	0.007	-0.055	-0.089	0.068	0.008	-0.088	0.212														
PTL	-0.124	0.106	-0.054	0.169	0.055	0.055	0.160	0.147													
CL	-0.024	-0.083	0.164	0.029	0.009	-0.033	0.026	0.050	-0.107												
PDL	0.046	-0.012	0.027	-0.111	0.009	0.124	0.064	-0.072	0.014	-0.003											
CD	-0.027	0.053	-0.117	0.092	0.063	0.036	0.107	0.024	0.126	-0.475	0.208										
PDD	-0.163	0.085	-0.090	0.034	0.070	-0.108	0.056	0.040	0.110	-0.120	0.106	0.062									
FWEI	-0.124	-0.068	-0.055	0.174	0.089	0.083	0.226	0.025	0.168	0.008	0.147	0.065	0.097								
FL	-0.175	0.041	-0.109	0.029	0.051	0.091	0.195	0.006	0.242	0.090	0.087	-0.069	0.010	0.664							
FD	-0.089	-0.076	-0.016	0.117	0.064	-0.029	0.212	-0.007	0.119	0.003	0.129	0.095	0.153	0.888	0.527						
FFT	-0.055	-0.048	-0.039	0.079	0.082	-0.012	0.110	-0.021	0.072	-0.045	0.095	0.104	0.131	0.523	0.343	0.653					
MWEI	-0.035	0.008	-0.033	0.054	-0.164	0.051	0.021	-0.041	0.153	-0.005	0.016	-0.006	-0.084	0.430	0.265	0.359	-0.112				
SWEI	-0.104	-0.158	0.102	0.058	-0.045	0.038	0.145	-0.056	0.096	-0.029	0.076	-0.005	0.060	0.531	0.402	0.466	0.527	0.332	0.714		
SL	-0.209	-0.181	0.092	0.066	-0.070	0.065	0.193	-0.020	0.138	0.007	0.010	-0.036	0.086	0.485	0.534	0.389	0.108	0.495	0.891	0.637	
SD	-0.106	-0.156	0.102	-0.016	-0.100	0.019	0.125	-0.124	0.039	-0.089	0.083	0.073	0.022	0.493	0.271	0.475	-0.056	0.495	0.891	0.637	0.049
PROD	-0.053	-0.121	0.172	0.210	0.086	0.088	0.112	-0.009	0.062	0.475	0.162	-0.234	0.201	0.158	0.188	0.080	-0.071	0.150	0.138	0.110	

Note: Bold numbers show significant correlation at $\alpha = 0.05$; bold and underline number show significant correlation at $\alpha = 0.01$; PH=plant height; CW=canopy width; SC=stem circumference; BL=branch internodus length; BD=branch diameter; LL=leaf length; LW=leaf width; LT=leaf thickness; PTL=leaf petiole length; CL=corolla length; PDL=pedicellulslenght; CD=corolla diameter; PDD=pedicellus diameter; FWEI=fruit weight; FL=fruit length; FD=fruit diameter; FFT=fruit flesh thickness; MWEI=mace weight; SWEI=seed weight; SL=seed length; SD=seed diameter; PROD=fruit production per plant per year.

Table 2 – Direct and indirect effect of the morphological character on the seed weight of ex-situ nutmeg collection

Characters	Direct effect	Indirect effect						Total effect
		FWEI	FL	FD	MWEI	SL	SD	
FWEI	0.065		0.055	-0.069	0.040	0.090	0.350	0.531
FL	0.083	0.043		-0.041	0.025	0.099	0.192	0.402
FD	-0.078	0.058	0.044		0.033	0.072	0.337	0.466
MWEI	0.093	0.028	0.022	-0.028		0.062	0.351	0.527
SL	0.186	0.032	0.045	-0.030	0.031		0.452	0.714
SD	0.709	0.032	0.023	-0.037	0.046	0.118		0.891

Note :FWEI=fruit weight; FL=fruit lenght; FD=fruit diameter; SL=seed length; SD=seed diameter.

The information provides from path analysis concerning the direct and indirect effect of character observed as in table 2. The fruit weight strongly correlates with seed weight (0.531), but the direct effect (0.065) is low. There was also a strong correlation with fruit length, mace weight, and seed length, but this had a weak direct effect (0.083, 0.093, 0.186).

Fruit diameter is positively correlated with seed weight but has a negative value on the direct effect (-0.078). It's due to the low direct influence of fruit weight, fruit length, fruit diameter, mace weight, and seed length. Therefore the seed weight selection must include all characters simultaneously. If the correlation between X and Y was positive, but the direct effect was negative or negligible, then the indirect effect might be due to the correlation itself (Singh and Chaudary 1979).

The highest correlation showed the relationship between seed diameter and weight (0.891). The value of the direct influence of the seed diameter on the seed weight is high (0.709) and is almost close to the correlation value. Therefore the seed weight estimation can be used as a marker-assisted selection without other characters. Singh and Chaudary (1979) stated that if the correlation coefficient between the independent and non-independent variables remains positive and almost the same as the direct effect value, the correlation requires the correct relationship and the selection using characters effectively.

In this research, path analysis results showed that the selection of seed weight using the characters of fruit weight, fruit length, fruit diameter, mace weight, and seed length must be done simultaneously. While the selection with seed diameter character can be done independently.

In path analysis, there is a value that has not been calculated as a part of direct and indirect effect assessment (unidentified characters), it's called the residual value. The residual value calculated was 15.5%. This means that the observed characters, 84.5%, sufficiently represent the determination of direct and indirect effects among characters.

CONCLUSION

The value of the correlation coefficient between fruits, seeds, and mace with the weight of the seeds was classified from strong to very strong and can be used for seed weight prediction. The selection of seed weight using the characters of fruit weight, fruit length, fruit diameter, mace weight, and seed length must be done simultaneously. While the selection with seed diameter character can be done independently.

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