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Statistical Analysis on Selection of Tolerant Peanut Varieties under Environmental Stress

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Abstract: *The study aimed to find out tolerant peanut varieties under growing environmental stress using depth statistical analysis on functional plant growth analysis, combined analysis of variance, and biplot analysis. Five peanut varieties (Biawak, Hypoma 1, Galur G300-II, Wajik, and Lokal Bima) havd been evaluated based on three replicates of randomized complete block design experiment. Aerobic irrigation growing environments were setted in shade and no shade conditions. In the shade condition, peanut varieties were grown under red rice plants, however, for no shade the peanut were planted as monocrop. Statistical analysis was done on derived variables of growth (AGR_{max}, RGR_{max}, inflextion point of growth, and final growth of plant height and tetra-foliate leaf numbers) and yield peanut components (dry pod and dry seeds). The results show that variety of Galur G300-II and Lokal Bima have performaced tolerant and resistant on environmental stress. It is indicated both varieties have good yield stability.*

Keywords: *biplot analysis, combined ANOVA, functional plant growth analysis, growing environmental stresses, peanut varieties*

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I. Introduction

Peanuts are categorized as high-protein food crops and as a source of vegetable oil, so peanuts are one of the important commodities in Indonesia. Currently peanuts become the second important commodity after soybeans, but production and productivity are still low. This is due to many factors including limited crop area, cultivation technology, and soil water availability. The availability prediction of peanut seeds for the period 2016-2020 tends to continue to decline, with a mean of 2.09% per year (Pusat Data dan Sistem Informasi Pertanian Kementerian Pertanian RI, 2016), this is not balanced with the needs of peanut seeds designated as cultivated seeds, consumed directly, processed to become another foodstuff, such as vegetable oil and so on. Therefore, peanuts in Indonesia, particularly in West Nusa Tenggara Province, are widely cultivated in mixed cropping patterns, which are mixed with rice crops, *palawija* crops, or perennial crops inserts, and so on. Peanut planting conditions for those cropping pattern will cause environmental stress and competition with the main crop to obtain optimization of growth factors. Generally peanut plants grown with a single pattern, because it requires high light intensity for the process of photosynthesis. The availability of water for growing needs is now also a limiting factor, so that in the cultivation of peanuts has also begun to be introduced water-saving technology, among others aerobic irrigated system, namely the effort to make unsaturated soil water conditions so that growing media can be utilized throughout the season. From aspect of cultivation technology, the availability of tolerant peanut varieties and resistant stress must be an important concern for the farmers.

Efforts to obtain tolerant varieties on environmental stresses, currently not widely applied in depth analysis of statistical studies, are still limited only to the use of a analysis of variance (ANOVA) on the agronomic phenotype variables studied and continued with the mean treatment comparisons using posthoc test. The disregard of the use of posthoc test in the multiple treatment structure will lead to a biased conclusion. For the reason, this paper is intended to provide in-depth statistical studies to select peanut varieties that have good tolerant to environmental stress and have high yield stability, including mathematical plant growth analysis (Thornley, 1976, Hunt, 1982, Thornley and Johnson, 1990) for studying derived variables, combined analysis of variance (Gomes and Gomes, 1984), and biplot analysis (Gabriel, 1971) on: (1). performance of growth and yield of several varieties of peanuts grown with red rice plants on environmental stresses, (2). environmental stress index and tolerance index of several peanut varieties studied, (3). getting tolerant peanut varieties, resistant to environmental stress, and having yield stability.

II. Statistical Study

2.1. Data Set

This study used five peanut varieties of experimental data, consisting of three newly-introduced varieties and two local varieties grown in shaded and unshaded (optimal) environments. Peanut varieties studied were Biawak, Hypoma-1, Galur G300-II, Wajik, and Lokal Bima. The growing environments with aerobic irrigation system were setted under red rice plants shading and without shading. Experiment used Randomized Block Design with three replications. Some agronomic variables observed included repeated measurements of 7 days started at age 14 to 91 days after planting on plant height and number of tetra-foliate leaves, dry pods, and dry seeds. Implementation of the experiment are presented at Wangiyana *et al*. (2017).

2.2. Statistical Analysis

Plant growth performance were evaluated from four parameters of Eq. (1), ie, absolute growth rate (AGR), relative growth rate (RGR), time of growth turning point happened, and final plant height or final number of tetra-foliate leaf growth, using functional plant growth analysis. Parameterization of the appropriate peanut plant growth curve model in this experiment tended to follow the logistic curve (Gunartha 1995 and 1997), as follows:

$$\mathbf{Y_i} = \frac{\mathbf{A}}{\mathbf{1 + e^{-c(X_i - m)}}} + \varepsilon_i \tag{1}$$

Furthermore, the growth rate (AGR and RGR) is calculated by finding the first derivative of Eq. (1), as follows:

$$\mathrm{AGR}_i = \frac{dY}{dX} = \frac{cY_i}{A}\left(A - Y_i\right) \tag{2}$$

$$\mathrm{RGR}_i = \frac{1}{Y}\frac{dY}{dX} = c\left(1 - \frac{Y_i}{A}\right) \tag{3}$$

where Y_i is data of plant height or number of tetra-foliate leaves on i^{th} observation day, X_i is time of i^{th} observation day, A is the final plant height (cm) or final number of tetra-foliate leaves at the end of growth, c is growth rate parameter. In the initial phase of peanut growth this c value is equal to the maximum RGR value, m is when the inflection point of growth curve (day after planting) happened, ie when AGR maximum occurs. At the time AGR value is equal to 0.5c and plant height or the number of leaves has reached 0.5A, and ε_i is experimental residual, $\varepsilon_i \approx \mathrm{NID}(0, \sigma^2)$.

Then, to evaluate peanut production and productivity are done based on the weight of dry pods and dry seed weight per plant. The treatment structure in this experiment can be expressed as:

$$Y_{ij(k)} = \mu + \alpha_k + \beta_{j(k)} + \tau_i + (\tau\alpha)_{i(k)} + \varepsilon_{ij(k)} \tag{4}$$

where $Y_{ij(k)}$ = i^{th} observational data, j^{th} replication/block, on k^{th}-growing environment, μ = grand mean, α_k = effect of k^{th}-growing environment. $\beta_{j(k)}$ = the effect of the j^{th} block in the k^{th}-growing environment, τ_i = effect of i^{th}-varieties, $(\tau\alpha)_{ik}$ = interaction between i^{th}-varieties with k^{th}-growing environment; $\varepsilon_{ij(k)}$ = combined experimental error effect, $\varepsilon_{ij(k)} \approx \mathrm{NID}(0, \sigma^2)$

Before analyzing the combined ANOVA, Bartletts' variance homoscedasticity test and Shapiro-Wilks normality test were performed. The environmental stress index is calculated based on stress susceptibility index (SSI) and stress tolerance index (STI) on growth rate parameter, dry pods and dry seeds per plant. The tolerance index of stress is defined by Fernandez (1992) as the identification of high yielding varieties in both the growing environments expressed in Eq. (5), while the susceptibility stress index (SSI) is used to assess the reduction of yields due to environmental stresses compared to optimal conditions, as formulated in Eq. (6a) and Eq. (6b) (Fisher and Maurer, 1978).

$$\mathrm{STI} = \frac{y_{ns} * y_s}{\left(\bar{y}_{v\text{-}ns}\right)^2} \tag{5}$$

$$\mathrm{SSI} = \frac{1 - \dfrac{y_s}{y_{ns}}}{\mathrm{SI}} \tag{6a}$$

$$\mathrm{SI} = 1 - \frac{\bar{y}_{v\text{-}s}}{\bar{y}_{v\text{-}ns}} \tag{6b}$$

where :y_{ns} and y_s are peanut yields each under conditions without stress and stress, SI is the intensity of stress, $\bar{y}_{v\text{-}s}$ is the average of all varieties under stress conditions, and $\bar{y}_{v\text{-}ns}$ is the average of all varieties under conditions without stress.

While the yield stability index (YSI) was calculated based on only the dry pods and dry seeds per plant, as formulated in Eq. (7) (Gavuzzi, *et. al*., 1997):

$$\mathrm{YSI} = \frac{y_s}{y_{ns}} \tag{7}$$

To find out the level of stress, tolerance, and stability of peanut yield were further identified using GGE biplot analysis. The GGE biplot model is based on singular value decomposition (SVD) for the first two principal component analyzes, ie PCA1 and PCA2 (Glasser, 2010), expressed as Eq. (8).

$$Y_{ij} - \mu - \beta_j = \lambda_1 \xi_{j1} \eta_{j1} + \lambda_2 \xi_{j2} \eta_{j2} + \varepsilon_{ij} \tag{8}$$

where Y_{ij}: the average of i^{th}-varieties in the j^{th} growing environment; μ: grand mean, β_j : the average yield of all varieties in the j^{th} growing environment, λ_1 and λ_2: each SVD value for PC1 and PC2, ξ_{j1} and ξ_{j2}: each eigenvector value of the i^{th}-varieties for PC1 and PC2, η_{j1} and η_{j2}: each j^{th}-growth environmental eigenvector value for PC1 and PC2, and ε_{ij}: the error is related to the i^{th} varieties and the j^{th} growing environment.

Furthermore, for biplot visualization, the singular values λ_1 and λ_2 in Eq. (8) are partitioned into the combined eigenvectors of varieties and environmental values, being:

$$v_{il} = \lambda_l^{f_l} \xi_{il} \text{ dan } e_{lj} = \lambda_l^{1-f_l} \eta_{lj} \tag{9}$$

where f_l is partition factor of the principle component analysis, in theoritically it can be worth between 0 and 1, but commonly used is 0.5. So Eq. (8) can be written to:

$$Y_{ij} - \mu - \beta_j = v_{i1} e_{1j} + v_{i2} e_{2j} + \varepsilon_{ij} \tag{10}$$

where $v_{i1}e_{1j}$ and $v_{i2}e_{2j}$ each value PC1 and PC2 for the i^{th} varieties in the j^{th} growing environment. All calculations from Eq. (1) to Eq. (10) are done using GenStat 12 statistical software.

III. Results And Discussion

Performance of growth and yield among varieties varied in the different growing environments studied, it appears that peanut varieties grown in shaded environments both growth rates and the yields components tend to be lower than those in the optimal environment, as shown in Table 1 and Table 2. Although the physical observations/measurements of agronomic variables both plant height and tetra-foliate leaf number tend to be higher in shaded planting, but the growth is more slowly. This is indicated by the AGR and RGR values of shaded peanuts lower than optimal growth condition. AGR is an indicator of production system and RGR as an indicator of plant productivity system. Similarly, in shaded plants tend to slow the turning point of growth from rapid (vegetative) growth to slow growth (generative), indicated by the value of m. The m values range from 27 - 40 days after planting (dap) and 27 - 33 dap respectively for shaded and optimal condition. The delay changes from vegetative phase to generative growth can reduce the yield components (both dry pods and dry seeds) of peanut crops. In Table 2, the shaded plant yields are lower than the crop yields under optimal conditions. Predictably shade causes plants to get stress as a result of competition for crops micro-climate, light intensity, and competition for nutrient acquisition and growing space with the shading plants.

Table 1: Performance of peanut plant growth in shaded and non-shaded environment

Variety	Shading				No Shading			
	AGR_{max}	RGR_{max}	m	A	AGR_{max}	RGR_{max}	M	A
Plant Height[1]								
Biawak	0.7807	0.0689	32.82	45.33	1.0268	0.0847	28.26	48.44
Hypoma 1	0.7597	0.0738	27.69	40.90	0.9603	0.0782	29.64	49.16
Galur G300-II	0.8122	0.0795	29.40	41.65	1.1922	0.0921	27.27	50.89
Wajik	0.7326	0.0659	32.62	44.73	1.2277	0.0935	28.52	52.76
Lokal Bima	0.6802	0.0672	28.34	40.59	1.2960	0.0911	29.32	57.02
Leaf Numbers[2]								
Biawak	4.2672	0.0962	32.94	175.57	3.6523	0.0942	28.52	152.87
Hypoma 1	6.0955	0.1232	30.58	198.10	4.4716	0.0828	29.42	212.63
Galur G300-II	6.9426	0.1222	31.95	225.63	4.3638	0.0983	28.10	172.82
Wajik	3.4802	0.0714	40.48	197.80	2.8340	0.0719	33.34	166.14
Lokal Bima	3.2848	0.0825	31.41	154.15	3.8051	0.1109	26.03	135.63

Note : [1] AGR_{max} (cm/day), RGR_{max} (cm/cm/day), m (days after planting), A (cm)
[2] AGR_{max}(leaf/day), RGR_{max} (leaf/leaf/day), m (days after planting), A (leaf)

Table 2: Peanut yields in shaded and non-shaded environments

Variety	Shading		No Shading	
	Dry Pod (g)	Dry Seed (g)	Dry Pod (g)	Dry Seed (g)
Biawak	33.83	22.67	43.61	31.67
Hypoma 1	30.75	22.00	46.71	25.50
Galur G300-II	27.80	20.50	39.86	25.33
Wajik	40.46	30.67	44.35	33.83
Lokal Bima	35.10	25.67	38.17	26.00

To find out whether the growing environment had a significant effect on peanut plant growth and yield, a combined ANOVA was conducted. However, we previously tested Bartlett's variance homoscedasticity assumption and Shapiro-Wilks normality test. All of the growth derived variables and peanut yield variables in Table 1 and Table 2 qualify for homoscedasticity and norcmality ($p> 0.05$) (see Table 3). Then, the Combined ANOVA result is presented in Table 4.

Table 3: Probability of homogeneity test of variance (homoscedasticity) and normality for all parameters/variables studied

Variables/Parameters	Homogeniety of Variances[1]		Normality[2]
	Prob-Environment	Prob-Variety	Prob.
Plant Height :			
AGR_{max}	0.091	0.484	0.254
RGR_{max}	0.279	0.524	0.829
m	0.891	0.514	0.455
A	0.072	0.531	0.115
Leaf Numbers :			
AGRmax	0.057	0.326	0.054
RGRmax	0.801	0.406	0.623
m	0.096	0.721	0.619
A	0.559	0.365	0.183
Dry Pod	0.669	0.561	0.413
Seed	0.793	0.825	0.563

Note : [1] Bartlett's *test*; [2] Shapiro-Wilks's *test*

Table 4: Results of Combined ANOVA for growth and yield of peanut crops

Source of Variance	df	F Probability									
		Plant Height				Leaf Number				Dry Pod	Dry Seed
		AGR_{max}	RGR_{max}	m	A	AGR_{max}	RGR_{max}	m	A		
Env	1	**0.009**	**0.011**	0.415	**0.031**	0.097	0.358	**0.022**	0.099	**0.020**	**0.053**
Rep/Env	4										
Variety	4	0.530	0.757	0.498	0.571	**0.023**	0.071	**0.013**	**0.039**	0.229	**0.042**
Env*Var	4	0.224	0.622	0.216	0.218	0.396	0.120	0.724	0.555	0.354	0.678
Residual	16										

Table 4 shows that there tends to be a significant effect ($p < 0.05$) of the shaded growing environment with no shading. The values of susceptibility stress index, stress tolerance indecx, and yield stability of peanut on environment stress are presented in Figs. 1 – 4.

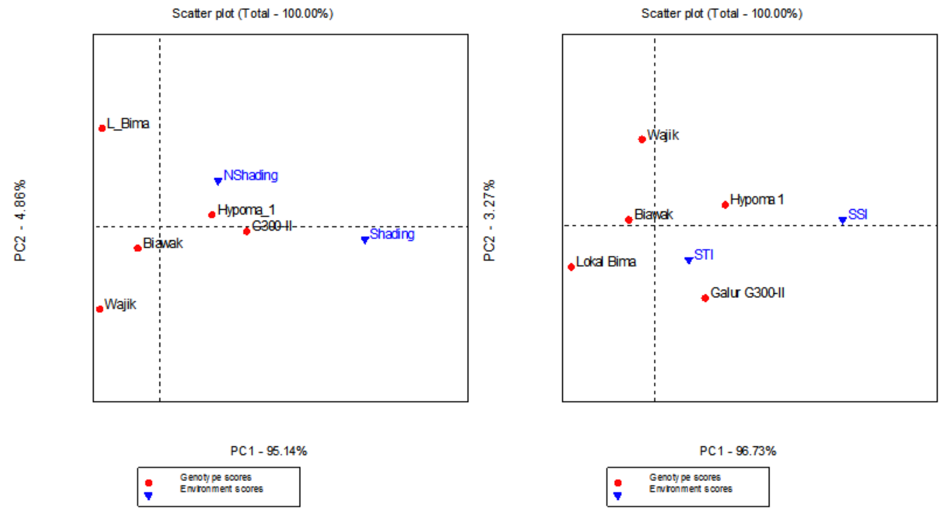

Figure 1. Performance of peanut growth under environmental stress

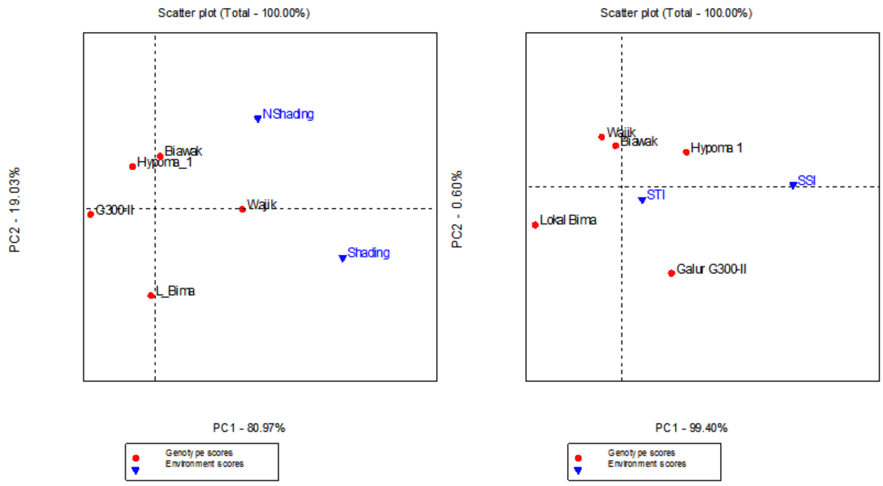

Figure 2. Performance of peanut yields under environmental stress

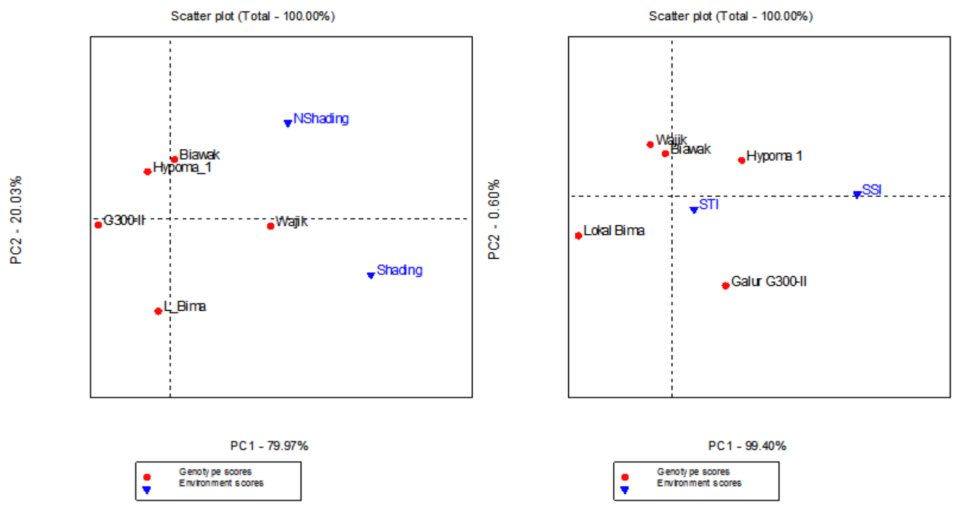

Figure 3. Performance of production and productivity of peanut varieties under environmental stress

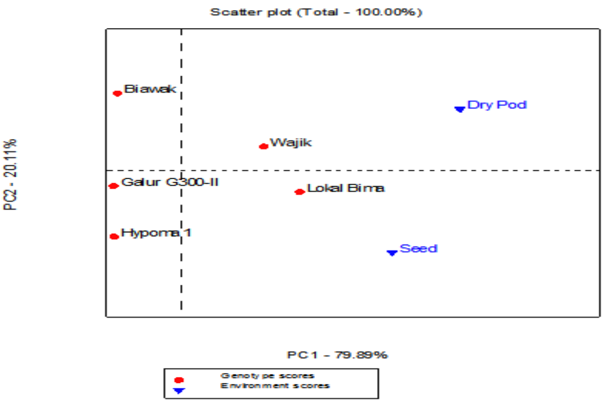

Figure 4: Stability of peanut yields under environmental stress

Figs. 1 - 4 show that the accuracy of the biplot analysis model can explain 100% of the total variability of varieties and environmental interactions described by the first two PC values, ie, PC1 and PC2 values. The value of PC1 is able to explain more than 70% and the PC2 value is more than 20%. In the growth phase of vegetative varieties of Biawak, Galur G300-II, and Wajik tend to be more resistant to shaded conditions compared to other varieties, this is in line with the value of STI and SSI (Table 1, Table, 4, and Fig. 1). In Fig. 1 it is also seen that the STI value of the three varieties is close to each other, and the SSI value is lower than the SSI value of the other two varieties. The lower the SSI value the more tolerant varieties. The varieties of Biawak and Galur G300-II also showed an environment-resistant performance together with Hypoma 1 variety. Specificly, variety of Galur G300-II, both for vegetative growth phase and generative phase, tend to be consistent resistant to environmental stress. The local varieties of Bima although in the vegetative growth phase are less shade tolerant but in the generative phase are classified as low tolerant. Performance of peanut varieties in terms of the overall variables studied, the varieties of Galur G300-II and Lokal Bima tended to resistant and tolerant to environmental stress (Fig. 3). This resistance to environmental stress results in good yield stability, especially dry seeds for both varieties (Fig. 4).

IV. Conclusion

In-depth statistical appraisal applications include functional plant growth analysis, combined analysis of variance, and biplot analysis to explore comprehensive information on the performance of production systems and peanut plant productivity systems that are tolerant to environmental stresses, is promising. The results of this study obtained Galur G300-II and Lokal Bima classified as resistant to environmental stress, although Lokal Bima is considered low tolerant. Therefore, this statistical analysis model can be recommended in the analysis of plant selection that includes the interaction of many varieties/strains of plants and various growing environments.

Acknowledments

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References

[1] Fernandez, G.C.J., 1992. Effective selection criteria for assessing plant stress tolerance. In: Kus EG (ed) Adaptation of Food Crop Temperature and Water Stress. Proceeding of 4th International Symposium, Asian Vegetable and Research and Development Center, Shantana, Taiwan, 257–270.
[2] Fischer, RA, Maurer R., 1978. Drought resistance in spring wheat cultivars. I. Grain yield responses. *Aust J Agric Res* **29**:892–912
[3] Gabriel, K. .R., 1971. The biplot graphic display of matrices with application to principal component analysis. *Biometrika*, **58**: 453–467. DOI: 10.1093/biomet/58.3.453.
[4] Gavuzzi, P., F. Rizza, M. Palumbo, R. G. Campaline, G. L. Ricciardi and B. Borghi, 1997. Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. *Can. J. Plant Sci*., **77**: 523–531.
[5] Glasser, A., 2010. The use of biplots in statistical analysis: with examples in GenStat. European GenStat and ASReml Applied Statistics Conference. 14 July 2010
[6] Gunartha, I.G.E., 1995. Mechanistics Models for Lettuce Growrh. Ph.D Thesis (unpublished). Ttre University of Sydney, Australia 285 p.
[7] Gunartha, I G.E., 1997. Model Dinamik Pertumbuhan Mentimun Jepang : Kajian efek temp.eratur tanah. *Agrivita*, **20(1):** 7-12.
[8] Gomez, K.A. and A. A. Gomez, 1984. *Statistical Procedures for Agricultural Research*. 2nd Ed. John Wiley & Sons. New York.
[9] Hunt, R., 1982. Plant Growth Curves: The Functional Approach to Plant Growth Analysis. Edward Arnold, London,

[10] Pusat Data dan Sistem Informasi Pertanian Kementerian Pertanian RI, 2016. Outlook Kacang Tanah 2016. *Online*: http://epublikasi.setjen.pertanian.go.id/arsip-outlook/81-outlook-tanaman-pangan/430-outlook-kacang-tanah-2016, *Downloaded*: 21 April 2018.

[11] Thornley, J. H. M., 1976. Mathematical Models in Plant Physiology. A Quantitative Approach to Problems in Plant and Crop Physiology. Academic Press, London.

[12] Thornley, J. H. M. And I. R. Johnson, 1990. Plant and Crop Modelling. A Mathematical Approach to Plantand Crop Psysiology. Clarendon Press, Oxford.

[13] Wangiyana, W., I G.P.M. Aryana, I G. E. Gunartha, and N. W. D. Dulur, 2017. Seleksi Berbagai Galur Padi Gogo dan Ampibi Beras Merah untuk Pembentukan Galur Padi Sistem Aerobik dalam Tumpangsari dengan Kacang-kacangan, Pemupukan Organik, dan Hayati dengan Mikoriza pada Bedeng Permanen. Laporan Penelitian Tahun ke-1 dari Rencana 5 Tahun. Universitas Mataram.

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