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Research Paper

Biometrical Study In Assessing Growth And Yield Performances Of Green Bean Varieties Cultivated Under Shaded Environment

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ABSTRACT : *The aim of this study is to assess growth and yield performances of green bean varieties cultivated under shaded environments using in-depth biometrical analysis on functional plant growth analysis, combined analysis of variance, and biplot analysis. An experimental data of five green bean varieties, ie. No. 129, Merak, Vima 3, Vima 1, and Kenari, has been studied. The experiment was layed out in randomized complete block design, with three replicates. Aerobic watering system was setted in shade and no shade environments. For shade condition, the green bean varieties were planted with red rice plants, whereas for no shade, the green beans were grown as single plant. The biometrical assessment step begins with selection of appropriate growth models to explain the behavior of green bean plant growth, then from the selected model used to estimate the growth derived variables (*AGR_m*,* RGR_m*, inflection point of growth, and final growth of plant height and leaf numbers). All of these growth derived variables and yield variables (dry biomass weight, dry seed weight per plant, and 50-dried seed weight) were analyzed using combined-ANOVA-, and visualized using biplot analysis. The results showed that the varieties of Kenari and Vima 1 belong to varieties that have a low level of susceptibility to environmental stress or can be regarded as a tolerant varieties. This is supported by the yield stability of the two varieties better than the variety of No. 129, Merak, and Vima 3.*

KEYWORDS*: biometrical study, biplot analysis, combined ANOVA, functional growth analysis, shade environments*

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I. INTRODUCTION

Nutritional content of green beans as a source of carbohydrates, vegetable protein, vitamins, fiber, and amino acids cause green beans to be one of the food ingredients consumed by many Indonesian people other than rice. The last five years (2013 - 2017) data shows that national production and productivity of green bean plants tends to increase, but the increase has not been able to meet the needs of the people. Indonesia still imports green beans up to 20,000 tons per year [1]. Efforts to intensify the cultivation of green beans continue to be done, in addition to single planting (monocrop) is also widely done with mixed crops (either with rice crops or with other food crops such as *palawija*) or many also inserted on the cultivation of perennials. Efforts to increase the production and productivity of green beans are still constrained by the limited availability of agricultural land as many agricultural lands now have shifted to non-agricultural functions, limited cultivation techniques, and limited availability of irrigation water due to the often uncertain climatic conditions of late. Mixed cropping is one of the alternatives to maximize the use of input resources of cultivation, such as land use, utilization of available ground water, and so on. The constraints of irrigation water limitations are currently being solved by introducing aerobic irrigation system, which is to condition the soil unsaturated water, on the cultivation of green bean plants. Therefore, rice crops mixed with green bean plants should also have aerobic cultivation system, including red rice belonging to the type of upland rice (*gogo*). Although mixed crops on one hand are beneficial, on the other hand, it can result in environmental stresses to the growth and yield performances of plants, such as shade stress, competition to gain growing space, catching light intensity, nutrient uptake and groundwater, etc. Therefore, the implications of mixed cropping, the availability of green bean varieties that are tolerant to the environmental stress conditions is needed.

Evaluation of plant growth and yield performances, including green beans, agroecotechnology researchers still tended to use conventional statistical analysis, ie. analysis of variance and when H_0 was rejected followed by posthoc test. The use of such statistical analysis often creates a bias when the treatment structure involves multiple factors. The application of in-depth statistical analysis can elaborate a comprehensive understanding, has been used well in the selection of peanut varieties that are tolerant to environmental stresses, by combining plant growth functional analysis to assess plant growth performance, combined analysis of variance to determine the effect of growing environment, variety, and interaction, and the use of biplot analysis to select crop varieties that are tolerant to environmental stress [2]. In the evaluation study the growth and yield of green bean plants will also use the same methodology with [2], but the difference is that in this study growth data is evaluated in advance based on the most suitable growth curve model, using logistic model and Gompetz.

II. MATERIALS AND METHODS

1.1 Experimental Data

The study used five experimental varieties of green beans (No 129, Merak, Vima 3, Vima 1 and Kenari) grown in two growing environments, planted with red rice (shaded) and planted singly without shade. The cultivation of the plant is carried out in an aerobic watering system. The experiment was layed out using Randomized Complete Block Design, with three replications. Experimental procedures are presented in the research report of PTUPT-DGHE RI [3]. The observed growth variables were plant height and number of green bean leaf, measured from 7 days after planting (dap) and respectively aged 14, 21, 28, 35, 42, 49, 56, 63, and 70 dap. While the measured yield variables include weight of dry biomass, weight of 50-dry seeds, and dry seed weight per plant, as measured at harvest.

2,2 Biometrical Analysis

Initial analysis of experimental data was to select the growth curve model that best suited the growth of green bean plants. The growth of green bean plants was evaluated based on four parameters of growth model, namely maximum absolute growth rate (AGR_m). maximum relative growth rate (RGR_m), time when changes from vegetative growth to generative (growth turning point) happened, and plant height and number of leaves at the end of growth, as expressed in Eq. (3) and Eq. (4). Assuming full growth (until harvest), green bean growth tends to follow the sigmoid curve model, ie. logistics or Gompertz. Therefore the initial stage of the analysis of this data is to choose a matching green bean growth model by looking at the percentage of the variances that can be explained (R^2) by the logistic model or Gompertz. Furthermore, the model chosen is the model has a high fit value (goodness of fit). The green bean plants are planted directly from the seeds, so the parameterization of logistic and Gompertz models can be expressed as Eq. (1) and Eq. (2) [4].

$$\text{Logistic: } Y_i = \frac{A}{1+e^{-c(X_i - m)}} + \varepsilon_i \quad (1)$$

$$\text{Gompertz: } Y_i = Ae^{-e^{-c(X_i - m)}} + \varepsilon_i \quad (2)$$

where $\mathbf{Y_i}$ = data of the plant height or the number of leaves on i^{th} day of observation, $\mathbf{X_i}$ = time of i^{th} day observation. **A** = height of plant (cm) or number of leaves at the end of growth, **c** = growth rate parameter, **m** = time of inflection curves growth (days after planting), that is, the time when absolute growth rate is maximum, and $\boldsymbol{\varepsilon_i}$ = observation error, $\varepsilon_i \approx NID(0, \sigma^2)$.

The growth rate (AGR and RGR) is calculated by finding the first derivative Eq. (1) for logistic and Eq. (2) to Gompertz.

$$\text{Logistic: } AGR_i = \frac{dY}{dX} = \frac{cY_i}{A}(A - Y_i)$$
$$RGR_i = \frac{1}{Y}\frac{dY}{dX} = c\left(1 - \frac{Y_i}{A}\right) \quad (3)$$

$$\text{Gompertz: } AGR_i = \frac{dY}{dX} = cY_i(\log_e(A) - \log_e(Y_i))$$
$$RGR_i = \frac{1}{Y}\frac{dY}{dX} = c(\log_e(A) - \log_e(Y_i)) \quad (4)$$

For the logistic model, the RGR decreases from the maximum of approximately **c** value (occurring at the beginning of growth) to 0.5c at X = m, ie the point of curve turns, when the plant height or the number of green bean leaves has reached 0.5A, and then becomes zero when growth has reached the final. The symmetric curve is about **m**, in the sense that the curve approaches the asymptote Y = A at the same rate where it moves away from the asymptote Y = 0. While in the Gompertz model, the RGR decreases from a much larger value of $\mathbf{c\, e^{cm}}$ (occurs when X = 0), to be exactly the same as **c** when X = m (when the curve turning point occurs) and the height of the plant or the number of leaves has reached about 1/3 (or more precisely = $\mathbf{e^{-1}}$ of the height or number of leaves at the end of growth), and then zero (when at the end of growth). The curve is not symmetric about m.

The four derived variables of the growth and yield variables (dry biomass weight, weight of 50 dry seeds, and dry seed weight per plant), then are analyzed using the combined analysis of variance to determine the effect of the growth environment, green bean varieties, and their interactions. However, before doing combined ANOVA, the assumptions of variance homogenity using Bartlett's test and normality of Shapiro-Wilks test were performed. So the linear effect model on the experimental data can be written as Eq. (5).

$$Y_{ij(k)} - \mu - \beta_{j(k)} = \alpha_k + \tau_i + (\tau\alpha)_{i(k)} + \varepsilon_{ij(k)} \quad (5)$$

where $Y_{ij(k)}$ = i^{th} observational data, j^{th} replication/block, on intergowing environment of k, μ = grand mean, α_k = growing effect of k, $\beta_{j(k)}$ = effect of the j^{th} block on the k-growing environment, τ_i = the effect of the i^{th} varieties, $(\tau\alpha)_{ik}$ = interaction between the i^{th}-varieties with the k^{th}-growing growth effect, and $\varepsilon_{ij(k)}$ = experimental error effect, ε_{ijk} »NID (0, σ^2)/

The evaluation of the environmental stress, tolerance, and yield stability rates was calculated based on the stress susceptibility index (SSI) defined by [5], stress tolerant index (STI) by [6] and yield stability index (YSI) by [7]. The visualizations are presented with biplot analysis, whose calculations based on singular value decomposition (SVD) in the first two principle component analysis values, PC1 and PC2, are expressed in Eq. (6).

$$Y_{ij} = \mu + \beta_j + \sum_{k=1}^{2} \lambda_k \xi_{ik} \eta_{jk} + \varepsilon_{ij} \quad (6)$$

where Y_{ij} = mean of the i^{th} varieties in the j^{th} growing environment, μ = the general mean, β_j = the yield mean for all varieties in the j^{th} growing environment, λ_k = the SVD value for PCA, ξ_{ik} = the eigenvector values of i^{th} varieties for each k, η_{jk} = the j^{th} grown environmental eigenvector value for each k, and ε_{ij} = experimental error with respect to the i^{th} varieties and j^{th} growth environment.

Subsequently the value of λ_k is partitioned into the eigenvector value of combination of varieties and growing environments, as written in Eq. (7).

$$v_{ik} = \lambda_k^{f_k} \xi_{ik} \text{ dan } e_{jk} = \lambda_k^{1-f_k} \eta_{jk} \quad (7)$$

where f_k is the partition factor of principle component analysis, in theory it can be worth between 0 and 1, but commonly used is 0.5. Eq. (6) can be written into:

$$Y_{ij} = \mu - \beta_j + \sum_{k=1}^{2} v_{ik} e_{jk} + \varepsilon_{ij} \quad (8)$$

where $v_{i1}e_{j1}$ and $v_{i2}e_{j2}$ each value PC1 and PC2 for the i^{th} varieties in the j^{th} growing environment. All calculations from Eq. (1) to Eq. (8) were analyzed using Genstat ver.12.

III. RESULTS AND DISCUSSION

The results show that logistic and Gompertz models tend to explain well the growth of green bean plants, each of which has goodness of fit for the model ranging between 84 - 98% and 82 - 98% (Table 1). That means, the logistics model can explain the variances of green bean plant growth ranges 84 - 98% and 82 - 98% for the Gompertz model. Because the logistic model matches slightly better than the Gompertz model, the logistic model was used to parameterize the growth of green bean plants. Green bean plants shaded by red rice plants tend to have lower growth productivity compared to single planted green beans (without shade). This result is in line with the results of the study of [2] on peanut plants grown in environmental stress. The production system and productivity system of green bean plants are shown in Table 2, the shade tends to be lower performances than that of non shaded green beans.

Table 1. Percentage of variance accounted by logistic and Gompertz model on green bean growth

Varieties	Shading				No Shading			
	Logictic		Gompertz		Logistic		Gompertz	
	Prob.	R^2(%)	Prob.	R^2(%)	Prob.	R^2(%)	Prob.	R^2(%)
Plant Height								
No. 129	< 0.001	**91.6**	< 0.001	90.5	< 0.001	**97.8**	< 0.001	97.2
Merak	< 0.001	**92.4**	< 0.001	90.3	< 0.001	**96.1**	< 0.001	94.4
Vima3	< 0.001	**95.5**	< 0.001	95.3	< 0.001	**96.5**	< 0.001	96.1
Vima1	< 0.001	**92.9**	< 0.001	92.3	< 0.001	**96.0**	< 0.001	95.5
Kenari	< 0.001	**90.9**	< 0.001	90.3	< 0.001	**97.3**	< 0.001	97.8
Leaf Numbers								
No. 129	< 0.001	**84.9**	< 0.001	83.0	< 0.001	**84.3**	< 0.001	82.5
Merak	< 0.001	**90.6**	< 0.001	88.7	< 0.001	**87.3**	< 0.001	84.8
Vima3	< 0.001	**84.1**	< 0.001	81.5	< 0.001	**88.1**	< 0.001	86.1
Vima1	< 0.001	**96.9**	< 0.001	95.9	< 0.001	**84.2**	< 0.001	83.1
Kenari	< 0.001	**85.4**	< 0.001	84.4	< 0.001	**84.6**	< 0.001	83.7

Note : R^2 means the percentage of variance accounted

Table 2. Performances of green bean growth in shaded and non-shaded environment

Varieties	Shading				No Shading			
	AGR_m.	RGR_m	m.	A	AGR_m.	RGR_m	m.	A
Plant Height[1)]								
No. 129	1.429	0.118	22.23	47.70	2.013	0.117	25.40	68.18
Merak	0.715	0.114	25.13	25.13	1.802	0.118	27.16	60.84
Vima3	1.260	0.115	21.32	43.82	1.728	0.111	23.42	62.54
Vima1	1.008	0.122	20.79	33.24	1.078	0.104	22.25	40.40
Kenari	0.974	0.099	21.80	39.20	1.727	0.113	26.65	61.39
Leaf Numbers[2)]								
No. 129	0.468	0.118	21.03	16.11	0.807	0.198	20.56	16.72
Merak	0.662	0.144	22.81	18.55	0.659	0.138	22.20	19.05
Vima3	0.584	0.140	23.04	16.31	0.736	0.172	20.45	17.14
Vima1	0.530	0.106	26.82	19.31	0.422	0.129	19.11	13.92
Kenari	0.547	0.123	22.53	18.11	0.606	0.137	24.09	17.68

Note : [1)] AGR_m (cm/day), RGR_m (cm/cm/day), m (days after planting), A (cm)
[2)] AGR_m (leaf/day), RGR_m (leaf/leaf/day), m (days after planting), A (leaf)

In the shaded environment, green bean plants tend to occur more quickly the growth inflextion point (**m**) from the vegetative phase to the generative phase, which is about 22 days after planting, while planted without shade **m** occurs about 23 days after planting. Similarly, the production of shaded green bean plants (dry biomass weight, dry seed weight, and weight of 50-dry seeds) tended to be lower than that of non-shaded plants (Table 3)

Table 3, Green beans yiels in shaded and non-shaded environment

Varieties	Shading			No Shading		
	DBW (g)	DSW (g)	50-SW (g)	DB (g)	DSW (g)	50-SW (g)
No. 129	4.39	9.79	2.79	10.66	11.78	3.16
Merak	4.84	9.13	2.55	7.82	9.17	2.54
Vima3	9.83	10.09	2.70	12.66	11.66	2.60
Vima1	5.50	9.32	2.63	6.24	6.50	2.49
Kenari	6.79	8.33	3.07	12.18	7.04	3.22

Note : DBW = Dry biomass weight, DSW = Dry seed weight, 50-SW = Weight of 50-seeeds

In order to determine the effect of the growing environment on the four growth derived variables (**AGR_m**, **RGR_m**, **m**, and **A**) and yield variables (dry biomass weight, dry seed weight, and weight of 50 dry seeds), the combined ANOVA was performed. But before doing ANOVA, all variables were tested the assumptions of variance homogenity and of normality, as shown by Table 4. All probabilities of Bartlett Test results for homogeneity of variances and Shapiro-Wilks test for normality show greater than 5% significsnt level ($p > 0.05$), then H_0 is accepted, ie all variables satisfy the assumptions of variance homogenity and normality. The combined ANOVA results are presented in Table 5 and Table 6.

Table 4. Probability of homogenity of variance and normality for all parameters/variables studied

Parameters/Variables	Homogenity of Variances[1)]		Normality[2)]
	Prob. Environment	Prob. Variety	Prob.
a. Plant Height			
AGR_m	0.295	0.582	0.478
RGR_m	0.421	0.719	0.411
m	0.260	0.364	0.953
A	0.374	0.552	0.152
b. Leaf Numbers			
AGR_m	0.988	0.433	0.198
RGR_m	0.280	0.153	0.563
m	0.529	0.188	0.792
A	0.524	0.334	0.200
c. Yields			
Dry Biomass Weight	0.955	0.518	0.057
Dry Seeds Weight	0.062	0.593	0.915
Weight of 50 seeds	0.163	0.818	0.888

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

Table 5 shows that there is a significant effect between the growing environment shaded by the growing environment without shade ($p < 0.05$). Similarly, plant height is strongly influenced by shade, green bean plants tend to show etiolation growth symptoms. This indicates that in mixed planting need to choose green bean varieties that have low levels of stress susceptibility or in other words high tolerant green bean varieties to environmental stress.

Table 5. Results of Combined ANOVA for growth parameters of green beans

Source of Variance	df	F Probability							
		Plant Heigth				Leaf Numbers			
		AGR$_m$	RGR$_m$	M	A	AGR$_m$	RGR$_m$	m	A
Env	1	**0.031**	**0.013**	**0.002**	**0.003**	**0.043**	**0.029**	**0.061**	**0.057**
Rep/Env	4								
Variety	4	**0.003**	0.686	0.186	**<0.001**	0.309	0.384	0.676	0.473
Env*Var	4	**0.034**	0.414	0.906	**0.015**	0.241	0.456	0.178	0.245
Residual	16								

Table 6. Results of Combined ANOVA for yield variables of green beans

Source of Variance	df	F Probability		
		Dry Biomass Weight	Dry Seed Weight	Weight of 50-seeds
Env	1	**0.048**	**0.026**	**0.046**
Rep/Env	4			
Variety	4	0.102	**0.002**	**0.004**
Env*Var	4	0.697	**0.051**	0.474
Residual	16			

Biplot analysis results to evaluate the degree of stress susceptibility, the degree of stress tolerance, and the stability of the yields are presented in Figs. 1 - 4. Model goodness of fit almost 100% can be explained by PC1 and PC2. PC1 can explain data variances ranging from 95 to 99%, and about 1 - 5% described by PC2.

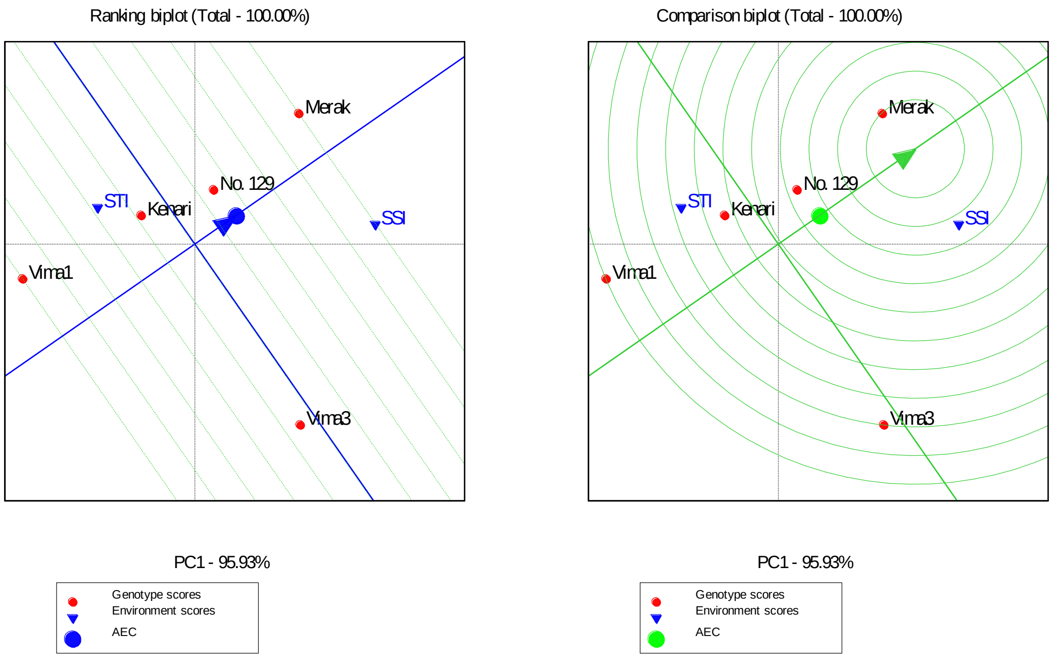

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Figure 1. Growth performances of green beans under environmental stress

Kenari, Vima 1, and Vima 3 varieties are classified as tolerant to environmental stress, although the tolerance level of Vima 3 is lower than that of Kenari and Vima 1. While varieties No. 129, and Merak belong to varieties that have high levels of stress susceptibility. Judging from the ideal stress level based on the angle formed by the varieties on AEC (average environment coordinate), the varieties of Kenari and Vima 1 are varieties whose growth is representative.

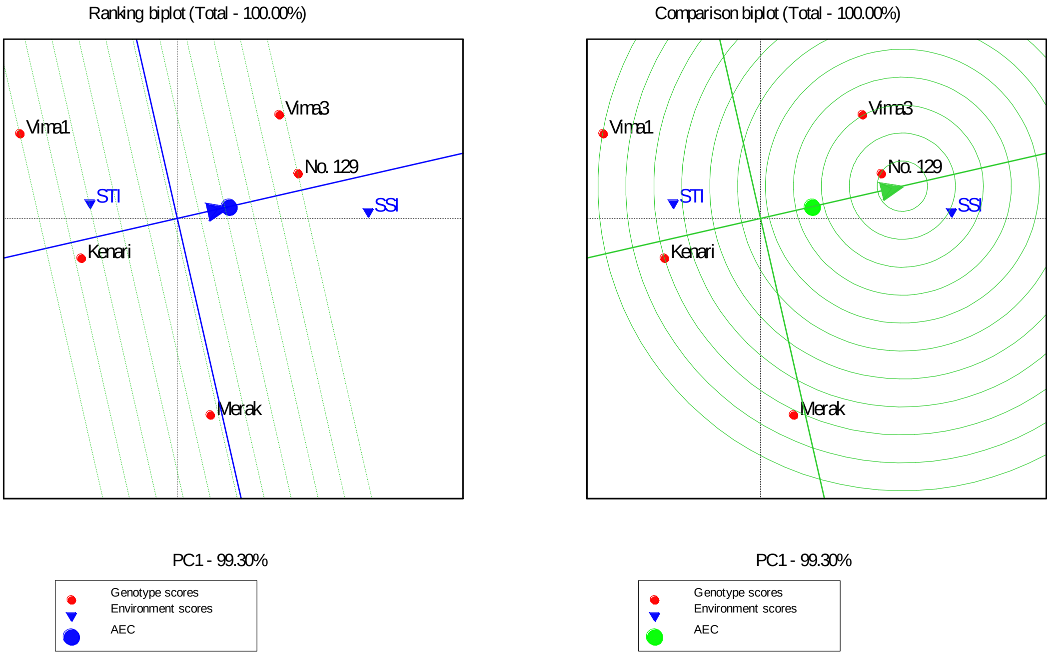

Figure 2. Yield performances of green beans under experimental stress

Performance of green bean yield components as shown by Fig, 2, obtained a linear result with the performance of green bean plant growth, ie. Kenari and Vima 1 varieties classified as having a tolerant level of representative to ideal stress environment.

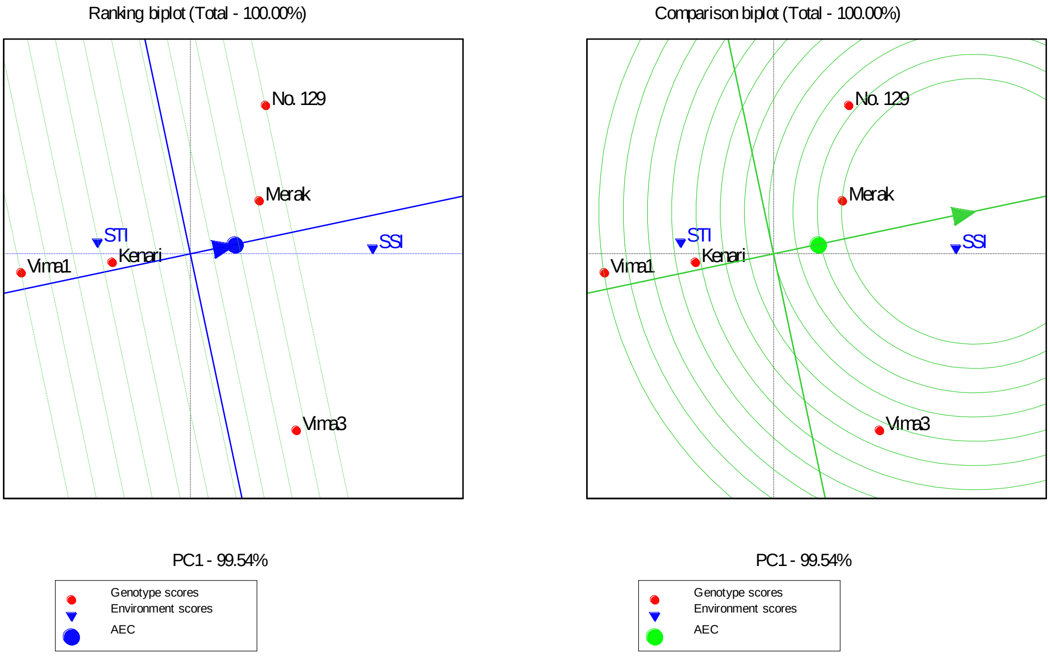

Figure 3. Production and productivity performances of green beans under environmental stress

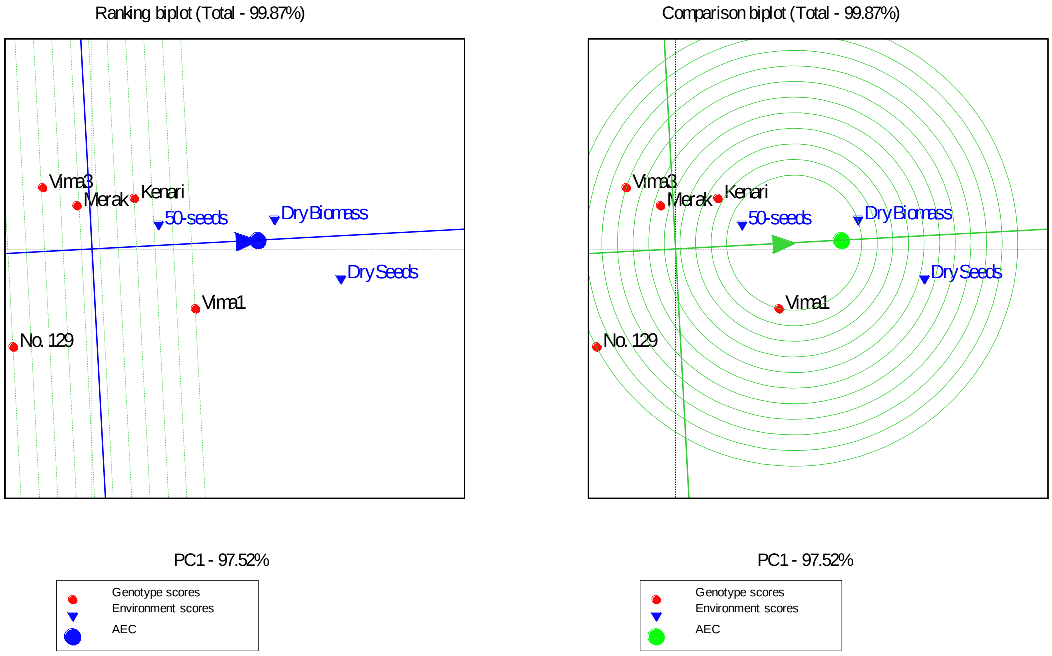

Figure 4, Stability of green beans yield components under environmental stress

In total performances of green bean plants in environmental stress is presented in Fig.3. Varieties of Kenari and Vima 1 tend to have consistency of performance both in production system and in productivity system. This is supported also by the results of the yield component stability analysis (Fig.4), both varieties tend to show good performances for dry biomass weight, dry seed weight, and weight of 50-dry seeds

IV. CONCLUSION

Based upon the in-depth biometrical analysis, it was found that environmental stress had significant effect on growth performance and green bean plant yield. This influence is evident in the growth of plant height, green bean plants have etiolation symptoms due to shade by red rice plants. It can be concluded that the varieties of Kenari and Vima 1 tend to have low levels of susceptibility or have a high tolerance to environmental stress. Similarly both varieties have better yield stability compared to varieties No.129, Merak, and Vima 3. Limited to experimental data used, for next study, it is suggested to use dry biomass to calculate total performances of system production and system productivity of plants. So, it needs repeated measures for dry biomass from early growth until harvest.

REFERENCES

[1]. Badan Pusat Statistik, *Produksi kacang hijau menurut provinsi 2013 – 2017* (Jakarta, BPS,. 2017)

[2]. I G.E. Gunartha, Statistical analysis on selection of tolerant peanut varieties under environmental stress, *IOSR Journal of Mathematics, 14(3).* 2018. 16-22.

[3]. W. Wangiyana, I G.P.M. Aryana, I G. E. Gunartha, and N. W. D. Dulur, *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* (Mataram, Universitas Mataram, 2017)

[4]. I.G.E. Gunartha,. *Mechanistics Models for Lettuce Growrh. Ph.D Thesis (unpublished).* (Australia, Ttre University of Sydney, 1995)

[5]. G.C.J . Fernandez, 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, 1992: 257–270

[6]. RA. Fischer, and R. Maurer, Drought resistance in spring wheat cultivars. I. Grain yield responses. *Aust J Agric Res* 29**,** 1978: 892–912

[7]. P. Gavuzzi, , 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, 1997: 523–531.

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