NONPARAMETRIC STABILITY ANALYSIS OF YIELD FOR NINE CHILI PEPPER (Capsicum annuum L.) GENOTYPES IN EIGHT ENVIRONMENTS

Vitria Puspitasari Rahadi[1], Muhamad Syukur[2*], Sriani Sujiprihati[2] and Rahmi Yunianti[2]

[1] Center for Tropical Horticulture Studies Bogor Agricultural University Baranangsiang
Jl. Padjajaran Bogor West java Indonesia
[2] Horticulture and Agronomy Department Faculty of Agriculture Bogor Agricultural University Darmaga
Jl. Meranti Bogor West java Indonesia
[*] Corresponding author Phone: +62-251- 8629348   Email : muhsyukur@ipb.ac.id

ABSTRACT

The objectives of this study were to compare nonparametric stability measures, and to identify promising high yield and stability of chili pepper (Capsicum annuum L.) genotypes in eight environments. In every environment, a Randomized Complete Block Design was used with three replications. The method of Nassar and Huehn, Kang, Fox, and Thennarasu was used to analyze the stability and high yield. Spearman's correlation and Principal Component analysis distinguishes the methods based on two different concepts of stability: the static (biological) and dynamic (agronomic) concepts. The top method was found to be the dynamic stability. Meanwhile, the methods of S_i^1, S_i^2, S_i^3, S_i^6, Npi^1, NPi^2, NPi^3 and NPi^4 were found to be the static stability. Based on the ranking frequency stability of the nonparametric method, the genotypes with the highest frequency of static stability ranking were genotypes IPB002003, IPB002046, IPB009019 and Tit Super, whereas IPB009002 and Tombak were categorized as those of dynamic stability. Genotype IPB120005 and IPB019015 were less adaptable in the multiple environments tested. It shows that the genotypes were specific in certain environments. IPB120005 had high yield and specific location in Boyolali in dry season and IPB019015 genotype was specific in Bogor in wet season.

Keywords: chili pepper, nonparametric stability, high yield, dynamic stablility

INTRODUCTION

Stable yield is very substantial in the formation of high yielding varieties (Aryana, 2009). This needs to be considered systematically and continuously, starting from the establishment of the base population to the testing of candidate varieties. The appearance of plants depends on the genotype, environmental conditions, and interaction between genotype and environment. Plant growth is the function of genotype and environment. Specific plant responses to diverse environments lead to an interaction between genotype and environment (G x E); a great effect of interaction would directly reduce the contribution of genetic components to the final appearance of plants (Anniciarico, 2002). This suggests that the development of plants should be directed to obtain varieties that can adapt to a wide variety of environmental conditions. The testing of yield stability through a series of multi-location testing is an important step before a new variety is released. The result of multi-location testing is expected to obtain genotypes that can adapt well and be stable in certain environments (Sujiprihati et al., 2006).

Yield stability studies based on the interaction of genotype x environment have been widely conducted among others by the Finlay-Wilkinson (1963), Eberhart and Russell (1966), Francis and Kannenberg (1978), and Gauch (2006). Mattjik et al. (2011) reported that the interaction of genotype and environment is complex because of the variations in the environmental components. The interaction of genotype and environment can also hinder the progress of selection, disrupt the selection of exellent varieties in a testing of varieties (Eberhart and Russell 1966), and make it difficult to make appropriate conclusion if a genotype test is performed in a wide range of environments (Nasrullah, 1981).

The testing of yield stability on the genotypes of free pollinated chili pepper in this study used a non parametric method. Huehn in Akcura and Kaya

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(2008) suggests that the nonparametric procedure has several advantages compared to the parametric stability. These benefits are the reduction of bias caused by outliers, no assumptions needed of the observed values, and ease of use in interpreting, adding, or deleting unsuitable genotypes.

The nonparametric method put forwad by Huehn (1990), Nassar and Huehn (1987), Kang (1988), Fox *et al.* (1990), and Thennarasu (1995) was based on the ranking of genotypes in each environment. Genotypes are considered stable if they are in the top rank. Nonparametric methods in the analysis of stability can give the response pattern of a genotype to environmental changes so that it can facilitate the selection of varieties suitable for environment and provide optimal yield. This study was aimed to 1) compare and explore different methods of nonparametric stability analysis, 2) identify genotypes free pollinated chili that has a good stability and high yield potential.

MATERIALS AND METHODS

The testing of yield stability on chili was conducted in four locations (Bogor, Boyolali, Riau and Sumedang) and in two growing seasons (July 2010 - January 2011, February-July 2011). A total of 20 genotypes were used in the experiments, consisting of 15 genotypes of free pollinated chili, namely: IPB120005, IPB110005, IPB001004, IPB002003, IPB002005, IPB002046, IPB015002, IPB002001, IPB009002, IPB009003, IPB009004, IPB009015, IPB 009019, IPB015008, IPB019015 and 5 commercial varieties of free-pollinated chili for comparison, namely Gelora, Tit Super, Tombak, Lembang and Trisula.

The testing in each location used a randomized complete block design with three replications in each experimental site and nested replications within the site. Each location had 60 experiment units, each of which consisted of 20 plants. Chili seeds were planted in trays of sterile seedling media. Transplanting seedlings to the field was done after the age of 7 weeks after sowing. Each replication was divided into 20 beds with the size of 1 x 5 m and the height of beds of 20 cm, and 50 cm spacing between beds. Calcification was then performed with a dose of 1.5 tons/ha and base fertilizer (Urea of 150 kg/ha, SP-18 of 300 kg/ha and KCl of 200 kg/ha, the beds were covered with silver-black plastic mulch and the planting holes were made using *cemplong method* with the distance of 50 cm x 50 cm with the depth of 20 cm. Plant maintenance involved replanting, watering, fertilizing, weeding and *cutting unproductive branches.* Pest and disease control was intensively given as needed. Harvesting was done twice a week after the population produced 75% of ripe fruits.

Data analyses consisted of the analysis of variance followed by nonparametric stability analysis with 10 methods of S_i^1, S_i^2, S_i^3 dan S_i^6 (Nassar and Huehn, 1987), Rank-Sum (Kang 1988), Top (Fox *et al.*, 1990) and NP_i^1, NP_i^2, NP_i^3 and NP_i^4 (Thennarasu, 1995) against the production characteristics of each plant.

RESULTS AND DISCUSSION

The variant analysis of the combined 12 chilli genotypes tested in 8 environments showed that the environment, genotype and the interaction of genotype x environment had significant effect on the production characteristics of each plant (Table 1). This suggests that different environments have different response to the tested genotypes. Mattjik *et al.* (2011) states that the extent of the effect of G x E interaction is highly dependent on the genotype and the complexity of environment influence.

Table 1. Variant analysis of the combined production per plant

Variant Sources	DF	SS	MS	F-calc	CV
Environment (E)	7	14690965.84	2098709.41	166.21**	24.05
Replication/Environment	16	202031.85	12626.99	1.45tn	
Genotipe (G)	11	371276.50	33752.41	3.87**	
G x E	77	2593630.82	33683.52	3.86**	
Errors	176	1534354.19	8717.92		
Total	287	19392259.20			

Remarks: ** highly significant, tn = not significantly different at the level of 0.05 %
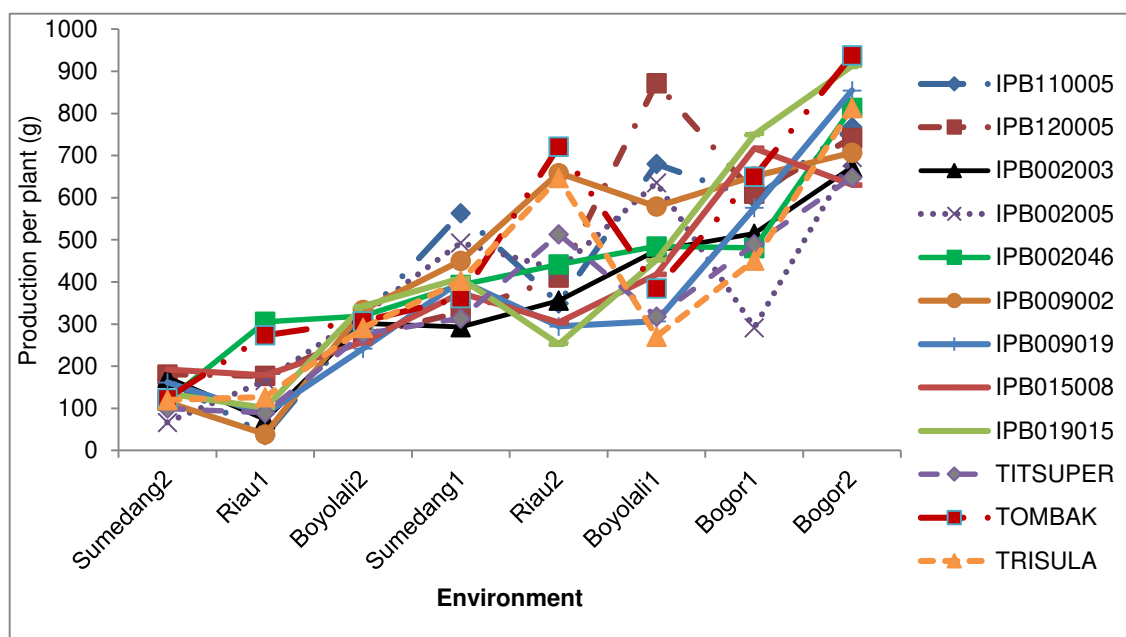
Figure 1. Response of genotipe x environment interaction (GxE)

The interaction response was mainly indicated by the production fluctuations, resulting in an increased productivity that was different in the genotypes in each testing site (Figure 1). A genotypes or even a variant would not always produce the same yield when grown in different environments. This is because of the high variability in the macro geophysical environment that will result in a very large diversity in the growing environment (Satoto *et al.*, 2009).

The genotype of IPB001004 had the highest production per plant compared with other genotypes (Table 2), and also the highest yield per plant in the environment of Boyolali 1 and Sumedang 2. The Genotype of IPB019015 had the highest average of production per plant compared with other genotypes in Bogor. The highest production per plant in Riau 1 and Riau 2 were respectively from IPB019015 and IPB009002 genotypes, whereas in Sumedang 1 it was from IPB110005.

The average yield of Bogor in season 2 is higher than that of Bogor in season 1. This is thought so because high rainfall leads to high frequency of diseases. In contrast, Sumedang and Boyolali in season 1 had higher production per plant than that of season 2. This is due to the high intensity of pest attacks in the dry season. The low production in Riau 1 was caused by the frequent attack of Gemini virus and the delayed wet season. In general, Bogor environment is better than other environments.

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Table 2. Production per plant 15 chili genotypes in 8 environment

Genotype	Bgr 1	Bgr 2	Byl 1	Byl 2	Riau 1	Riau 2	Smd 1	Smd 2	Average of Genotypes
					.g.				
IPB110005	598.2[abc]	767.6[abcd]	680.1[cd]	312.5[a]	36.7[f]	349.5[efg]	563.5[a]	168.2[abcd]	434.6[bcde]
IPB120005	609.4[abc]	742.2[abcd]	872.0[ab]	273.9[a]	177.3[bcd]	410.4[cde]	327.2[bc]	180.4[abc]	449.1[bcd]
IPB001004	610.4[abc]	794.7[abcd]	946.4[a]	285.9[a]	-	-	341.0[abc]	225.7[a]	534.0[a]
IPB002003	514.9[abcd]	672.4[bcd]	474.8[fghi]	301.8[a]	73.9[e]	355.9[efg]	291.0[bc]	173.0[abc]	357. 5[fg]
IPB002005	291.5[d]	695.7[abcd]	635.3[cd]	321.0[a]	165.7[bcd]	429.5[cde]	492.7[ab]	66.6[f]	387.3[cdefg]
IPB002046	480.6[abcd]	813.5[abcd]	484.6[efgh]	319.1[a]	305.5[ab]	441.7[bcd]	392.8[ab]	118.3[cdef]	419.5[bcdef]
IPB015002	440.0[bcd]	580.5[de]	405.5[fghi]	276.2[a]	-	486.9[bc]	286.8[bc]	109.3[cdef]	369.3[efg]
IPB002001	425.3[bcd]	732.4[abcd]	478.2[fghi]	238.9[a]	-	384.4[def]	455.0[ab]	162.0[abcd]	410.9[bcdefg]
IPB009002	651.1[abc]	706.8[abcd]	579.1[cdfe]	333.8[a]	38.5[f]	658.5[a]	450.5[ab]	114.9[cdef]	441.6[bcd]
IPB009003	458.5[abcd]	632.0[cde]	722.5[bc]	349.3[a]	-	304.0[fgh]	418.0[ab]	113. 5[cdef]	428.3[bcdef]
IPB009004	675.0[abc]	629.5[cde]	545.1[edfg]	322.5[a]	-	382.9[def]	500.4[ab]	145.4[bcde]	457.3[bc]
IPB009015	382.5[cd]	739.7[abcd]	505.7[efg]	-	429.5[a]	257.5[h]	440.4[ab]	150.3[bcde]	415.1[bcdef]
IPB009019	576.1[abcd]	854.7[abc]	306.9[i]	241.8[a]	86.4[e]	294.5[gh]	402.7[ab]	161.4[abcd]	365.6[efg]
IPB015008	717.5[ab]	630.5[cde]	418.2[fghi]	257.5[a]	178.6[bc]	303.6[fgh]	374.0[abc]	192.4[ab]	384.1[defg]
IPB019015	750.1[a]	912.2[ab]	452.2[fghi]	342.5[a]	101.0[cde]	252.4[h]	408.5[ab]	135.3[bcdef]	419.3[bcdef]
Gelora	651.9[abc]	634.7[cde]	310.0[hi]	239.6[a]	-	275.9[gh]	477.0[ab]	98.2[def]	383.9[defg]
Lembang	530.5[abcd]	390.0[e]	-	127.3[b]	-	274.5[gh]	154.5[c]	81.8[ef]	259.8[h]
Tit Super	489.5[abcd]	648.0[cd]	317.7[hi]	276.3[a]	89.5[de]	513.3[b]	313.5[bc]	99.5[def]	343.4[g]
Tombak	650.3[abc]	937.7[a]	384.6[ghi]	306.7[a]	273.8[ab]	721.5[a]	362.0[abc]	123.6[bcdef]	470.0[b]
Trisula	451.0[bcd]	813.4[abcd]	270.1[j]	291.0[a]	126.6[cde]	646.6[a]	402.8[ab]	119.9[cdef]	390.2[cdefg]
Environment average	**547.71B**	**716.41A**	**515.22B**	**285.15D**	**160.23E**	**407.55C**	**392.81C**	**136.97F**	**405.16**

Remarks: Bgr1 (Bogor season 1), BGR 2 (Bogor season 2), Byl 1 (Boyolali season 1), Byl 2 (Boyolali season 2), Riau 2 (Riau season 2), Smd 1 (Sumedang season 1), Smd 2 (Sumedang season 2).The numbers followed by the same letter in the same column and a number followed by a capital letter on the line means not significantly different based on Duncan's test at the level of 0.05%.

Nonparametric stability analysis in this study measured the stability of nine chili genotypes based on ranks in 8 environments. Table 3 shows the mean production of 12 genotypes of chili and the resulted calculation of nonparametric stability index. The genotype of Tombak produced the highest yield per plant compared with other genotypes, then followed by the genotypes of IPB120005, IPB009005 and IPB110005.

Nonparametric Stability Index (NSI) based the method of Nassar and Huenh (1987) showed that Tit Super was the most stable genotype. This is because Tit Super has the smallest NSI on S_i^2, S_i^3 dan S_i^6. The next stable genotype is IPB002003, while the genotype IPB019015 is an unstable one.

Kang Method (1988) (RS) is the sum of the rankings in production with the Shukla method. The smallest value from the sum indiactes the genotype is stable. Kang method found the genotype IPB002046 to be the most stable, followed by the genotypes IPB110005 and IPB009002. Kang method also found that the genotype IPB002005 was unstable (Table 4).

Fox *et al*. (1990) divides genotypes into 3 layers: top, mid, and low in each environment. Genotypes in the top 4 ranks from each environment are categorized as stable and adaptive. Top NSI is a value to indicate the number of a genotype on the Top layer from 8 experimental environments. IPB009002 genotype had the highest TOP NSI compared with other genotypes. This indicates that IPB009002 is the most stable genotype. The next stable genotypes were IPB019015 and Tombak; both had the NSI value of 50 (Table 3), but the Tombak genotype is recommended because it has higher average production. Genotypes IPB0090019 and IPB002003 were the most unstable genotypes based on the Top NSI.

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Table 3. Average production and nonparametric stability values of 9 chili genotypes in 8 environments

Genotype	Y	Si^1	Si^2	Si^3	Si^6	Top	RS	NPi^1	NPi^2	NPi^3	NPi^4
IPB110005	435	5.86	12.84	15.98	6.89	37.50	3	2.63	0.48	0.21	0.76
IPB120005	449	5.71	11.36	13.83	8.02	37.50	6	2.63	0.44	0.21	0.73
IPB002003	357	5.43	7.27	6.26	5.85	12.50	4	2.50	0.31	0.14	0.49
IPB002005	387	6.64	16.29	17.54	10.38	37.50	12	3.13	0.57	0.20	0.71
IPB002046	420	5.07	8.55	10.64	4.76	37.50	1	1.88	0.38	0.16	0.57
IPB009002	442	5.79	13.70	17.84	8.52	62.50	3	3.13	0.89	0.23	0.80
IPB009019	366	6.21	10.57	9.25	3.75	12.50	8	3.13	0.39	0.14	0.49
IPB015008	384	7.07	18.41	18.75	8.44	37.50	11	3.38	0.42	0.20	0.72
IPB019015	419	5.79	14.13	20.28	4.67	50.00	8	3.00	0.67	0.26	0.95
Tit Super	343	5.14	5.55	4.26	1.78	12.50	8	2.50	0.26	0.10	0.34
Tombak	470	5.43	11.27	16.18	7.85	50.00	6	4.13	0.83	0.31	1.06
Trisula	390	5.79	9.64	9.31	3.12	12.50	11	2.75	0.39	0.17	0.60

Remarks: Y average production per plant from 9 genotypes in 8 environments, Si^1, Si^2, Si^3 and Si^4 (Nassar and Huenh 1987), *Top* (Fox *et al.*, 1988), RS (Kang, 1990). NPi^1, NPi^2, NPi^3, NPi^4 (Thennarasu, 1995)

Table 4. Spearman correlation of nonparametric stability parameter against the yield of 9 chili genotypes in 8 environments

	Y	Si^1	Si^2	Si^3	Si^6	Top	RS	NPi^1	NPi^2	NPi^3
Si^1	0.12									
Si^2	-0.32	0.74**								
Si^3	-0.48	0.48	0.91**							
Si^6	-0.44	0.35	0.72**	0.64*						
Top	0.79**	-0.03	-0.64*	-0.84**	-0.61*					
RS	0.45	0.62*	0.33	0.14	-0.04	0.29				
NPi^1	-0.23	0.61*	0.61*	0.57	0.43	-0.42	0.41			
NPi^2	-0.73**	0.34	0.75**	0.83**	0.63*	-0.88**	-0.03	0.62*		
NPi^3	-0.83**	0.21	0.66*	0.80**	0.52	-0.89**	-0.13	0.52	0.95**	
NPi^4	-0.81**	0.17	0.64*	0.81**	0.52	-0.89**	-0.17	0.49	0.92**	0.99**

Remarks: * and ** : significant at the levels of 0.05 % and 0.01% Y: average production per plant of 9 genotypes in 8 environments, Si^1, Si^2, Si^3 and Si^4 (Nassar and Huenh, 1987), *Top* (Fox *et al.*, 1988), RS (Kang, 1990). NPi^1, NPi^2, NPi^3, NPi^4 (Thennarasu, 1995)

The stability values were obtained from the Thennarasu method from the corrected ranking. The smallest value indicates that a genotype is more stable compared with other genotypes. Based on the stability index of Thennarasu, Tit super and IPB002003 were the most stable genotypes, while Tombak variety was the most unstable (Table 3).

Each method of nonparametric stability analysis produced a different ranking for each genotype. To demonstrate the relationship of the various methods of stability and production, this study used the Spearman correlation. Table 4 shows that the average production of chili is significantly and positively correlated to the Top method, but negatively correlated to Npi2, Npi3, and NPi4. Table 4 also shows that the method Si2 has highly significant and positive correlation to Si1, Si3 dan Si6. Si6 is positively and very significantly correlated to Si2 and Si3. This is because the calculation of the stability of these three values used a variety of environments. NPi3 is positively and very significantly correlated to NPi4. The correlation values of NPi3 and NPi4 even reached 0.99. This happens because NPi3 method results in almost the same rank as NPi4 method on each genotype. The stability values of NPi3 and NPi4 are obtained from corrected environment diversity.

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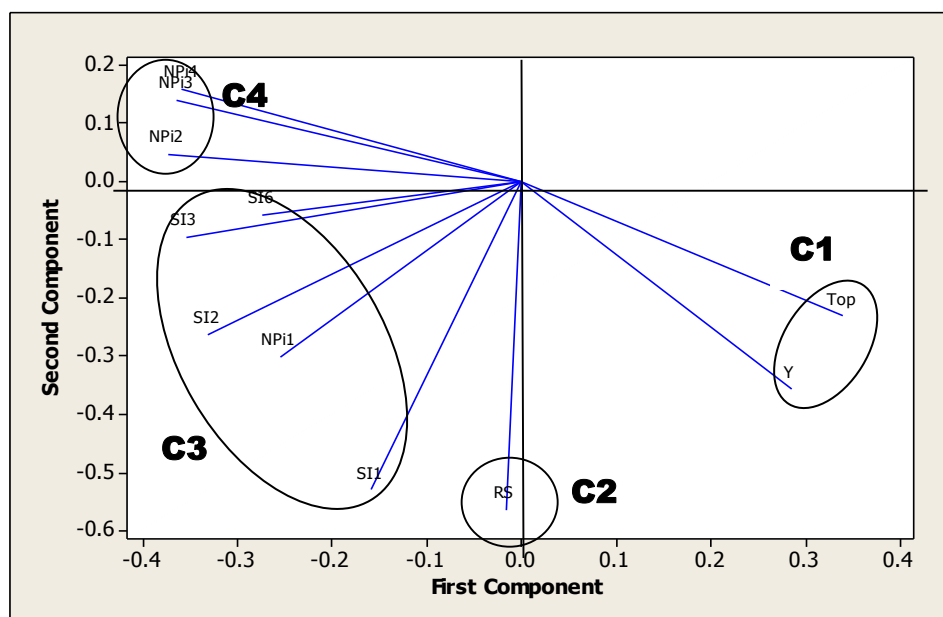
Figure 2. Principal Component Analysis of production ranking and 10 nonparametric stability methods in 9 chili genotypes in 8 environments

The result of Principal Component Analysis (PCA) describes the relationship between the nonparametric stability methods based on the correlation matrix already made (Figure 2). Zulhayana (2010) said that nonparametric stability index of a high and positive correlation with production can identify dynamically stable genotype. PCA divides the nonparametric stability methods into 4 groups. Top parameter and average production (Y) are in the same group (C1). Rank-Sum (RS) is in group C2. Methods Si^1, Si^2, Si^3, Si^6, and Npi^1 are in group C3, whereas NPi^2, NPi^3 and NPi^4 are in group C4.

Principal component analysis separates different methods based on two concepts of stability, namely dynamically stable (agronomic) and statically stable (biological). Group C1 shows the concept of dynamic stability. This is because the Top method has the highest and positive correlation with the average production, 0.79. Sabaghnia *et al.* (2006) and Mut *et al.* (2008) state that Top and RS methods are included in the dynamic stability concept. Mohammadi *et al.* (2007) adds that Top method is related to high production. Based on the results of this study, RS method did not have a correlation with production and top method. This is

because the calculated stability value of RS method was the sum of the production rankings and shukla variants. The effect of high environmental diversity leads to changes in the stability value by RS method.

The stability of groups C2, C3 and C4 shows the concept of static stability. This is because the stability method of the three groups is significantly and negatively correlated to production. Sabaghnia *et al.* (2006), Mohammadi and Amri (2008) report that a significant correlation with the methods Si^1, Si^2, Si^3 and Si^6 was found on legume crops. Nassar and Huehn (1987) suggest that the methods of Si^1 and Si^2 are related to the concept of static stability. Stability methods can be used in selecting the best genotypes of a high production. Mut *et al.* (2009) adds that a stable genotype classification is based on different environmental conditions.

The production component is an important characteristic in stability testing of chili pepper plants. The stability of a genotype is determined based on the number of ranking frequencies obtained from the stability methods. Table 5 shows the ranking frequency for the two stability concepts: dynamic and static.

Table 5. Ranking of production and nonparametric stability of 12 genotypes in 8 environments

Genotype	Dynamic Stability		Freq	Static stability									Freq
	Y	Top		Si^1	Si^2	Si^3	Si^6	RS	NPi^1	NPi^2	NPi^3	NPi^4	
IPB110005	4	8	1	9	8	7	7	3	4	8	9	9	1
IPB120005	2	8	1	5	7	6	9	6	5	7	8	8	0
IPB002003	11	12	0	3	2	2	6	4	3	2	2	3	8
IPB002005	8	8	0	11	11	9	12	12	8	9	7	6	0
IPB002046	5	8	0	1	3	5	5	1	1	3	4	4	7
IPB009002	3	1	2	6	9	10	11	3	9	12	10	10	1
IPB009019	10	12	0	10	5	3	3	8	10	4	3	2	6
IPB015008	9	8	0	12	11	11	10	11	11	6	6	7	0
IPB019015	6	3	1	7	10	12	4	8	7	10	11	11	1
Tit Super	12	12	0	2	1	1	1	8	2	1	1	1	8
Tombak	1	3	2	4	6	8	8	6	12	11	12	12	1
Trisula	7	12	0	8	4	4	2	11	6	5	5	5	3

Remarks: Y= average production per plant of 9 genotypes in 8 environments, Si^1,Si^2,Si^3 and Si^4 (Nassar and Huenh, 1987), *Top* (Fox *et al.* 1988), RS (Kang 1990). NPi^1,NPi^2, NPi^3, NPi^4 (Thennarasu, 1995)

The genotypes with the highest rank of static stability frequencies are IPB002003, IPB002046, IPB009019 and Tit Super. The concept of static stability is highly dependent on the range of region and testing sites. If the range of testing sites is more extensive, resulting in more diverse site conditions, then the concept of stability will change. The genotypes categorized as dynamically stable frequency based on ranking frequency are IPB009002 and Tombak. Both genotypes are sensitive to environmental changes and adapt specifically to optimum environment.

The genotypes of IPB120005 and IPB019015 were less adaptative to some environments tested. It can be seen from the different production per plant in each environment (Table 2). However, in certain environments both genotypes resulted in high production. This shows that the genotypes are specific to certain environments. Based on the potential production, the genotype IPB120005 is suitable to grow in Boyolali in the dry season, while IPB019015 is suitable in the rainy season in Bogor.

The concept of static and dynamic stability can also be based on the comparison of genotypes tested. The static stability of a geno-type compares the yield variability in some environments,while the dynamic stability compares the yield variability of a genotype in some environments and the yield variability of other genotypes in a single set of testing. This indicates that the concept of dynamic stability explains the genotype variability by comparing directly with other genotypes. The concept of dynamic stability is more appropriate as the basis of selecting genotypes at the time of releasing genotype varieties because this stabiltity concept can explain the stability and adaptability of a genotype. However, the production potential of a genotype should still be considered. This is related to the purpose of releasing varieties that still need improvement in production quantity.

CONCLUSION

Based on the testing of nonparametric stability methods, two concepts of stability are obtained, namely dynamic stability (agronomic) and static stability (biological). The Top Method is included in the concept of dynamic stability. The methods of Si^1, Si^2, Si^3, Si^6, Npi^1, NPi^2, NPi^3 and NPi^4 are included in the concept of static stability.

Based on the ranking frequency of nonparametric stability methods, four genotypes are obtained and categorized as genotypes with static stability, namely IPB002003, IPB002046, IPB009019 and Tit Super, while the genotypes categorized as those of dynamic stability are IPB009002 and Tombak.

In terms of potential production, the genotype IPB120005 is suitable for planting in Boyolali in the dry season, while IPB019015 is suitable in the rainy season of Bogor.

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