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Short Communication: Morpho-agronomic performances of bird pepper (*Capsicum annuum*) lines under varying agro-ecological locations in Indonesia

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Abstract. *Syukur M, Sahid ZD, Sobir, Maharijaya A, Ritonga AW, Sulassih, Istiqlal MRA, Hakim A, Pangestu AY, Undang, Yudilastari T, Arandito DS, Ashar S, Hasanah A, Agustina K, Purwanto RJ, Karyani, Mustafa M, Syahri YF, Ramlasari C. 2022. Short Communication: Morpho-agronomic performances of bird pepper (*Capsicum annuum*) lines under varying agro-ecological locations in Indonesia. Biodiversitas 23: 4838-4843.* Bird pepper price fluctuations are caused by an imbalance between production and market demand. One effective way to overcome this is to increase the productivity of bird pepper. Genetics and the growing environment of bird pepper greatly affect the productivity produced. Therefore, this study aimed to determine the character of yield and yield components of four genotypes of bird pepper at three lowland locations. Planting was carried out at three locations representing Indonesia's bird pepper growing environment. The planting procedure in all sites was carried out according to the same guidelines. A randomized complete block design (RCBD) was used with three replications. Twenty (20) plants per genotype were planted in each replicate, with 10 plants taken as samples. Shiara IPB had the highest productivity in all environments compared to the other line. The main characteristics that distinguish this variety had a purplish color on the fruit petals when young, and the fruit color was greenish-yellow. Hierarchical cluster analysis results showed that Shiara IPB in almost all observation variables based on legend color was superior. The highest productivity was found in Palembang, followed by Bogor and Kolaka.

Keywords: Bird pepper, HCA, multi-location, yield component

INTRODUCTION

Bird pepper is a famous type of chili because it has a tiny fruit size and high spiciness. Sahid et al. (2020) proved that bird pepper has a spiciness measurement that exceeds curly and large pepper. Based on species, bird pepper that is commonly consumed by the public are *Capsicum annuum* L. and *Capsicum frutescens* L. species. The spiciness of bird pepper is also often used by the pharmaceutical industry in making chili patches (Baenas et al. 2019) and can also be an alternative to bio-stain in a microscope (Camara 2020). In addition, bird pepper can potentially prevent blood clot formation in hypertensive patients (Singh et al. 2022).

Indonesia, well known as the center of biodiversity, has more than 75 varieties of bird pepper (Directorate General of Horticulture Indonesia 2022). This variety consists of the results of plant breeding programs and various local varieties that previous researchers have explored. This will lead to a significant increase in production in 2020 by 9.76% (BPS 2021). Production increasing induced by the increase in yield productivity. However, the increased productivity is still below the potential results that can be obtained. The potential yield value that can be obtained is 20 tons.ha^{-1} (Sahid et al. 2021).

The breeding program can increase the productivity of bird pepper. There are two main factors in increasing the productivity of bird pepper, namely: the environment (Olubanjo and Alade 2018) and the genetic material used (Hafsah et al. 2020). Bird pepper has high productivity potential because this type of chili has a high fruit number that can be produced in one plant (Mantja et al. 2020). Land management also plays a role in the productivity of the resulting bird pepper (Taher et al. 2022). Plant breeding programs have been developed by hybridization, selection, and evaluation. This process has taken 8-10 generations (4-

5 years) because it requires accurate validation before commercialization. Testing varieties yielded evaluation at various locations (Ansa and Woke 2018).

IPB chili plant breeder team has been carrying out a hybridization process for bird pepper since 2015. The selection was carried out for each generation starting from the second to the seventh generation. This selection activity resulted in several pure lines that have the potential distributed to become new high-yielding varieties for farmers. Thus, this study aims to obtain information on the performance of bird pepper compared to commercial varieties. The information can be used in chili breeding programs.

MATERIALS AND METHODS

Study area and genetic material

This research was conducted to examine the performance of four genotypes of bird pepper at 3 locations. The first location was in the experimental field of Tajur, Center for Tropical Horticulture Studies (PKHT), Institut Pertanian Bogor, Bogor, West Java, Indonesia. The second and third locations were in the experimental fields of the Universitas Sembilan Belas November (Kolaka, Southeast Sulawesi, Indonesia) and the experimental field of Universitas IBA (Palembang, South Sumatra, Indonesia), respectively. The information on bird pepper genotype is shown in Table 1. Meanwhile, the information regarding locations can be seen in Table 2.

Each planting site followed a completely randomized block design (RCBD) with three replications. A total of 20 plants were planted in beds and 10 were observed as sample plants. Bird pepper planting was carried out simultaneously using the same planting guide in three locations. Formed planting beds and sowed chili seeds on the nursery tray were done simultaneously. Treatment in the nursery phase was carried out for five weeks. Intensive fertilization was carried out using ABMix for chili fertilizer every week. The fertilizer dose used in this research was 1000 ppm. In addition, insecticide spraying with the active ingredient Abamectin (in a concentration of 2 mL L^{-1}) is routinely carried out every two weeks. Observation variables made refer to the Descriptor for Capsicum International. Plant Genetic Resources Institute.

Observation variables were separated into two, namely: growth character and productivity character. Growth character was measured before the plant entered the generative phase (when a flower candidate appeared). Observational variables of the measured growth characters included: plant height (cm), leaf length (cm), leaf width (cm), and stem diameter (mm). Meanwhile, the measurement of yield component starts after flowering time, which includes: flowering time (the day after sowing), harvest time (the day after sowing), fruit length (cm), fruit weight (g), fruit diameter (mm), total fruit per plant, fruit weight per plant (g), and productivity (ton.ha^{-1}). Harvesting activities were carried out for 2 months. After that, every week, two harvests were carried out. Productivity (ton.ha^{-1}) was calculated by multiplying the fruit weight per bed with the correction factor.

Data analysis

The application of PKBT Stat and R 4.0.5 helped in the analysis carried out in this study. The analyses carried out include: The 5% HSD test and Heatmap performed when the results were significantly different on ANOVA. The heatmap analysis refers to Li et al. (2022) using the R 4.0.5 program with the heatmap package.

Table 1. Information on bird pepper genotypes

Number	Genotypes	Owner agency	Status
1	Shiara IPB	PKHT, IPB University	New varieties
2	Bara	East West Seed Indonesia	Comparative varieties (872/Kpts/Tp.240/7/1999)
3	Genie	Tunas Agro Persada Indonesia	Comparative varieties (048/Kpts/Sr.120/D.2.7/5/2017)
4	F7160291-3-12-5-51-1-1-2	PKHT, IPB University	Comparative varieties

Table 2. Information about locations

Locations	Altitude (m asl)	Rainfall (mm $month^{-1}$)	Humidity (%)
Bogor	250	52.80-679.60	76.25-86.50
Kolaka	38	45.00-263.90	74.23-83.45
Palembang	8	96.00-507.20	86.00-91.59

Note: Humidity and Rainfall data from BMKG Indonesia (http://dataonline.bmkg.go.id) in January-July 2020

RESULTS AND DISCUSSION

Tables 3 and 4 show the growth characteristics of bird pepper genotypes. Bogor was the best location for the average plant height (Table 3) of bird pepper (66.91 cm). It was caused by Bogor having a reasonably high altitude for chili growth (> 200 m asl). Following research, Preethy et al. (2018) found that chili plants grown at an altitude (> 200 m asl) showed a better plant height compared to other heights. This is also because chili plants require an environment with a temperature of 24°C-27°C, which can be found at an altitude above 200 meters above sea level (Mailena et al. 2021). Shiara IPB genotypes at Bogor (80.03 cm) and Kolaka (42.61 cm) showed significantly higher plant height than the other three. Meanwhile, at Palembang, Shiara IPB showed the second-highest plant height after Bara, although it was not significantly different. The mean per genotype from the three locations showed that Shiara IPB had the highest plant height (55.87 cm). This result differed statistically significantly from the commercial varieties (Bara and Genie). Plants with high plant height were expected to produce high productivity (Syukur et al. 2022).

The observations of stem diameter at the Bogor did not show a significant difference between the genotypes used. In contrast to the Kolaka, Shiara IPB showed the thickest stem diameter and was significantly different from all genotypes. However, in Palembang, the stem diameter of the Shiara IPB genotype was not thick (second lowest). Mean stem diameter per genotype of commercial varieties (Bara and Genie) was not significantly different from Shiara IPB. This shows that the stem diameter of Shiara IPB competed with commercial varieties that farmers have used. Palembang was the best location to produce the thickest stem diameter and was significantly different from Bogor and Kolaka. The thick stem diameter indicates that the transport of nutrients from the roots to the leaves was greater (Ahmadi and Souri 2020).

Leaf observations consisting of leaf length and width (Table 4) at the Kolaka showed results that were not significantly different. Leaf length and width of Shiara IPB at the Bogor show the same results with stem diameter characters. Its showed Shiara IPB became a superior variety in terms of growth characters when planted in the Bogor. The mean leaf length per genotype was not significantly different. The order of leaf length from the highest was Genie, Shiara IPB, Bara, and F7160291-3-12-5-51-1-1-2. Meanwhile, leaf width was significantly different from the sequence per genotype, which was the same as leaf length. Based on the mean per location, each location had a different response regarding the superiority of growth characteristics. Bogor was the best location for the character of plant height. Kolaka was the best location for leaf-width characters. Meanwhile, Palembang was the best location for stem diameter and leaf length characters.

Information on flowering time and harvesting time was useful for predicting the productivity of bird pepper (Jang et al. 2020). The faster the results were obtained, the faster the plant variety produces so that it can reduce the time of one generation of planting (Kpinkoun et al. 2019). Generally, the time required in one generation of planting from the beginning to the last harvest is 6 months. If plants flower and harvest faster, it can reduce planting time and can save expenses (Balakrishnan et al. 2022). The results showed that Bara became a superior variety in all locations during the flowering time (Table 5). But uniquely, Shiara IPB is a variety quickly harvested at the Kolaka planting site. In line with Arumingtyas et al. (2022), a fast-flowering time does not guarantee a fast harvest time. Kolaka was also the best place that produced the fastest flowering and harvest times. The mean flowering time in Kolaka was not significantly different from Palembang. Meanwhile, the average harvest time in Kolaka was significantly different from Palembang but not different from Bogor.

Table 3. Plant height and stem diameter on bird pepper

Genotypes	Plant height (cm)			Mean per	Stem diameter (mm)			Mean per
	Bogor	Kolaka	Palembang	genotypes	Bogor	Kolaka	Palembang	genotypes
Shiara IPB	80.03^{a}	42.61^{a}	44.97^{a}	55.87^{a}	1.03^{a}	0.95^{a}	1.10^{c}	1.03^{a}
F7160291-3-12-5-51-1-1-2	52.17^{c}	29.29^{b}	38.60^{a}	40.02^{c}	1.02^{a}	0.60^{b}	1.01^{c}	0.87^{b}
Bara	63.47^{b}	34.03^{ab}	46.93^{a}	48.14^{b}	0.86^{a}	0.66^{b}	1.96^{a}	1.16^{a}
Genie	71.97^{ab}	34.44^{ab}	41.77^{a}	49.39^{b}	0.90^{a}	0.66^{b}	1.53^{b}	1.03^{a}
Mean per location	66.91^{A}	35.09^{C}	43.07^{B}		0.95^{B}	0.71^{C}	1.40^{A}	

Note: Numbers followed by the same capital letter in the same row and the same non-capital letter in the same column were not significantly different based on HSD 5% test

Table 4. Leaf observations on bird pepper

Genotypes	Leaf length (cm)			Mean per	Leaf width (cm)			Mean per
	Bogor	Kolaka	Palembang	genotypes	Bogor	Kolaka	Palembang	genotypes
Shiara IPB	8.86^{a}	8.76^{a}	10.47^{ab}	9.36	3.48^{a}	3.81^{a}	2.56^{b}	3.29^{ab}
F7160291-3-12-5-51-1-1-2	5.91^{b}	10.61^{a}	9.17^{b}	8.56	2.05^{b}	4.61^{a}	2.62^{b}	3.09^{b}
Bara	6.29^{b}	9.63^{a}	10.51^{ab}	8.81	2.90^{ab}	4.19^{a}	2.27^{b}	3.12^{b}
Genie	7.57^{ab}	8.55^{a}	12.78^{a}	9.63	3.42^{a}	3.72^{a}	4.08^{a}	3.74^{a}
Mean per location	7.16^{C}	9.39^{B}	10.73^{A}		2.96^{B}	4.08^{A}	2.88^{B}	

Note: Numbers followed by the same capital letter in the same row and the same non-capital letter in the same column were not significantly different based on HSD 5% test

Statistically, Bogor's fruit diameter and length (Table 6) in Palembang showed no significant difference between genotypes. Shiara IPB's fruit length in Bogor and Palembang consistently showed the highest (5.17cm and 4.25 cm). The highest average fruit length was shown by Shiara IPB, significantly different from the commercial variety Genie. The same commercial varieties (Bara and Genie) showed a fruit length that was not significantly different. The highest fruit length based on mean per location was shown in Bogor and was not significantly different from Kolaka. The highest mean per location fruit diameter was obtained from Palembang. Each of the three locations differed significantly. The lowest average fruit diameter was found in Bogor, with a range of 0.67 mm (Shiara IPB) and -0.76 mm (Bara). If based on the average of three locations, Shiara IPB has the thickest fruit diameter (0.89 mm).

Shiara IPB has fruit weights ranging from 1.75-1.94 g. The mean fruit weight of Shiara IPB for the three locations was 1.88 g. It significantly differed from the commercial varieties Bara (2.30 g) and Genie (1.55 g). The lowest mean was indicated by F7160291-3-12-5-51-1-1-2 (1.28 g). The highest fruit weight (Table 7) was obtained from the Kolaka and was significantly different from Palembang and Bogor. Bogor produced the most total fruit per plant. Following the characteristics of bird pepper, Shiara IPB has high productivity potential supported by high total fruit per plant and fruit weight per plant as well. It was directly proportional to the results of the study by Sahid et al. (2022), which shows that the high total fruit per plant and fruit weight per plant will also result in high productivity. This indicates that each location has specific characteristics that affect the observed value of bird pepper fruit. The environment in which it grows greatly affects the yield of plant fruit (Yang et al. 2018).

The fruit weight per plant range of Shiara IPB, Bara, Genie, and F7160291-3-12-5-51-1-1-2 was shown in Table 8. The commercial variety's fruit weight per plant was lower than Shiara IPB but higher than F7160291-3-12-5-51-1-1-2. Palembang (275.14 g) showed the highest mean fruit weight per plant compared to Bogor (255.40 g) and Kolaka (217.97 g). The highest mean fruit weight per plant was shown by Shiara IPB, which was not significantly different from the commercial variety Bara. F7160291-3-12-5-51-1-1-2 was the genotype with the lowest fruit weight (219.29 g).

Table 5. Lowering time and harvesting time of bird pepper

Genotypes	Flowering time (day after planting)			Mean per genotypes	Harvesting time (day after planting)			Mean per genotypes
	Bogor	Kolaka	Palembang		Bogor	Kolaka	Palembang	
Shiara IPB	44.33^{a}	28.27^{a}	32.00^{a}	34.87^{a}	88.00^{a}	69.93^{b}	87.00^{ab}	81.64
F7160291-3-12-5-51-1-1-2	41.33^{a}	29.40^{a}	34.00^{a}	34.91^{a}	74.33^{b}	73.70^{b}	96.33^{a}	81.46
Bara	40.67^{a}	28.23^{a}	26.33^{b}	31.74^{b}	81.00^{ab}	76.46^{b}	90.67^{ab}	82.71
Genie	43.00^{a}	29.97^{a}	30.00^{ab}	34.32^{ab}	88.00^{a}	91.49^{a}	83.00^{b}	87.50
Mean per location	42.33^{A}	28.97^{B}	30.58^{B}		82.83^{AB}	77.90^{B}	89.25^{A}	

Note: Numbers followed by the same capital letter in the same row and the same non-capital letter in the same column were not significantly different based on HSD 5% test

Table 6. Fruit length and diameter on bird pepper

Genotypes	Fruit length (cm)			Mean per genotypes	Fruit diameter (mm)			Mean per genotypes
	Bogor	Kolaka	Palembang		Bogor	Kolaka	Palembang	
Shiara IPB	5.17^{a}	4.60^{ab}	4.25^{a}	4.67^{a}	0.67^{a}	0.89^{a}	1.11^{ab}	0.89^{a}
F7160291-3-12-5-51-1-1-2	4.90^{a}	4.14^{b}	3.79^{a}	4.27^{ab}	0.69^{a}	0.70^{b}	1.01^{b}	0.80^{b}
Bara	4.08^{b}	5.07^{a}	3.69^{a}	4.28^{ab}	0.76^{a}	0.80^{ab}	1.09^{ab}	0.88^{a}
Genie	4.09^{b}	3.89^{b}	4.04^{a}	4.01^{b}	0.68^{a}	0.74^{b}	1.17^{a}	0.86^{ab}
Mean per location	4.56^{A}	4.43^{A}	3.94^{B}		0.70^{C}	0.78^{B}	1.09^{A}	

Note: Numbers followed by the same capital letter in the same row and the same non-capital letter in the same column were not significantly different based on HSD 5% test

Table 7. Fruit weight and total fruit per plant of bird pepper

Genotypes	Fruit weight (g)			Mean per genotypes	Total fruit per plant			Mean per genotypes
	Bogor	Kolaka	Palembang		Bogor	Kolaka	Palembang	
Shiara IPB	1.75^{a}	1.94^{b}	1.94^{b}	1.88^{b}	319.97^{a}	115.91^{bc}	158.12^{a}	198.00^{a}
F7160291-3-12-5-51-1-1-2	1.28^{b}	1.29^{c}	1.29^{c}	1.28^{d}	294.67^{a}	76.90^{c}	90.56^{b}	154.04^{b}
Bara	1.13^{b}	2.91^{a}	2.86^{a}	2.30^{a}	199.23^{b}	174.07^{a}	134.31^{ab}	169.20^{b}
Genie	1.09^{b}	2.11^{b}	1.47^{c}	1.55^{c}	221.97^{b}	125.87^{b}	155.75^{a}	167.86^{b}
Mean per location	1.31^{C}	2.06^{A}	1.89^{B}		258.96^{A}	123.19^{B}	134.69^{B}	

Note: Numbers followed by the same capital letter in the same row and the same non-capital letter in the same column were not significantly different based on HSD 5% test

Table 8. Yield components on bird pepper

Genotypes	Fruit weight per plant (g)			Mean per genotypes	Productivity (ton.ha^{-1})			Mean per genotypes
	Bogor	Kolaka	Palembang		Bogor	Kolaka	Palembang	
Shiara IPB	342.08^{a}	225.97^{a}	281.88^{b}	283.31^{a}	8.94^{a}	6.05^{a}	7.56^{b}	7.52^{a}
F7160291-3-12-5-51-1-1-2	314.76^{a}	219.33^{a}	123.77^{c}	219.29^{c}	8.43^{a}	5.88^{a}	3.32^{c}	5.88^{c}
Bara	172.40^{b}	227.83^{a}	391.12^{a}	263.78^{ab}	4.62^{b}	6.11^{a}	10.48^{a}	7.07^{ab}
Genie	192.37^{b}	198.73^{a}	303.80^{b}	231.63^{bc}	5.15^{b}	5.33^{a}	8.14^{b}	6.21^{bc}
Mean per location	255.40	217.97	275.14		6.79	5.84	7.37	

Notes: Numbers followed by the same capital letter in the same row and the same non-capital letter in the same column were not significantly different based on HSD 5% test

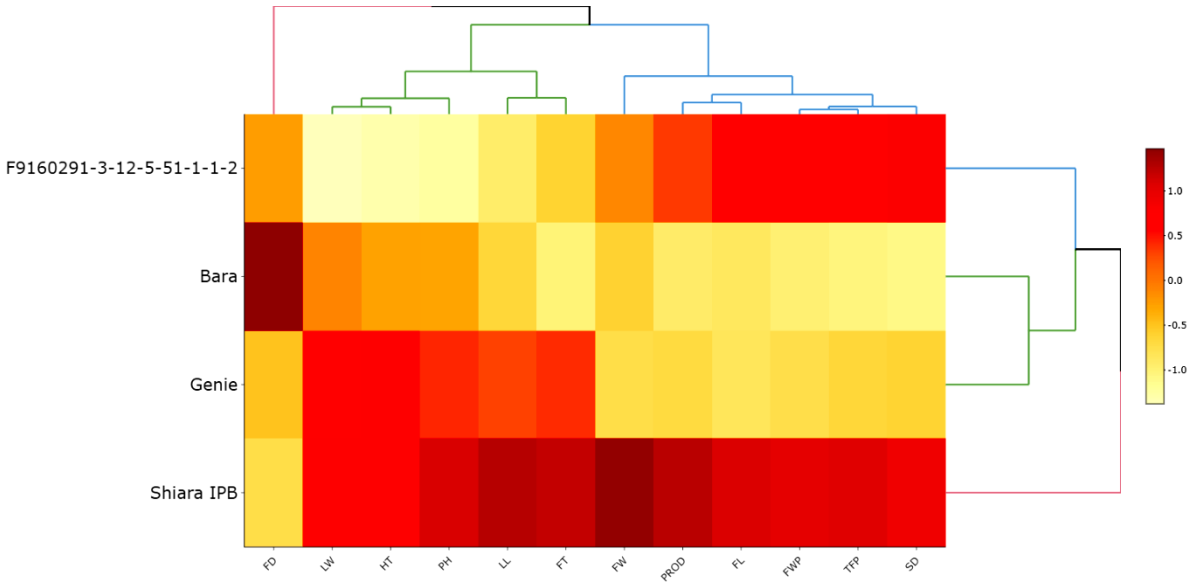

Figure 1. Hierarchical cluster analysis on bird pepper genotypes

Yield components in Table 8 showed that Shiara IPB consistently occupies the highest position in two locations (Bogor and Kolaka). Mean per location shows no significant difference in yield components of bird pepper. Shiara IPB produced productivity of 6.05-8.94 ton.ha^{-1} at three locations. The average productivity of Shiara IPB reached 7.52 ton.ha^{-1} and showed the highest value. It was significantly different from the commercial varieties Genie (6.21 ton.ha^{-1}) and F7160291-3-12-5-51-1-1-2 (5.88 ton.ha^{-1}).

The relationship between the genotype and all observed variables is presented in Figure 1. It can be seen that the commercial varieties Bara and Genie were one group. Meanwhile, Shiara IPB and F9160291-3-12-5-51-1-1-2 separated each into different groups. It can also be seen based on color legend Shiara IPB had a dominant red color in all observed characters except for fruit diameter, which was dominated by the Bara variety. This supports the performance resulting in Table 6 that Bara as a whole has the largest fruit diameter. Meanwhile, Shiara IPB was a variety that had advantages in almost all observed variables. The relationship between observed variables can also be explained in Figure 1. Broadly speaking, the observed variables were separated into 3 large groups where the diameter of the fruit separates itself into one group. At the same time, the others were evenly separated into two large groups.

In conclusion, it can be obtained in this study were the Shiara IPB, a new variety, had superiority in almost all observation variables based on heatmap analysis. The productivity produced by this genotype was highest at the Bogor and Kolaka, so it had great potential to be distributed to farmers on a large scale. The planting environment had advantages in each observation variable. The highest productivity was found in Palembang, although the results showed no significant difference.

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