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Yield evaluation of curly chili lines in three lowland locations

MUHAMAD SYUKUR[1,2,♥], ZULFIKAR DAMARALAM SAHID[1,♥♥], SOBIR[1,2], AWANG MAHARIJAYA[1,2], ARYA WIDURA RITONGA[1,2], YUNANDRA[3], SULASSIH[4], MUHAMMAD RIDHA ALFARABI ISTIQLAL[5], ABDUL HAKIM[6], YUDIWANTI WAHYU[1], TOBIAS MONIZ VICENTE[7], MUKHLISIN[1], KARLIN AGUSTINA[8], YURSIDA[8], KUNCI MUSLIMIN[8], SITI HAFSAH[9], NURA[9], ANDRY SETYAWAN[9]

[1]Department of Agronomy and Horticulture, Faculty of Agriculture, Institut Pertanian Bogor. Jl. Meranti, IPB Dramaga Campus, Bogor 16680, Indonesia. Tel./fax.: +62- 251-8622642, ♥email: muhsyukur@apps.ipb.ac.id; ♥♥email: zulfikardds@gmail.com
[2]Center for Tropical Horticulture Studies, Institut Pertanian Bogor. Jl. Raya Pajajaran, Kampus IPB Baranangsiang, Bogor 16144, West Java, Indonesia
[3]Faculty of Agriculture, Universitas Riau. Jl. H.R. Soebrantas Km. 12,5 Simpang Baru, Pekanbaru 28292, Riau, Indonesia
[4]Vocational School, Institut Pertanian Bogor. Jl. Kumbang No.14, Babakan, Bogor 16128, West Java, Indonesia
[5]Department of Agrotechnology, Faculty of Agriculture, Universitas Gunadarma. Jl. Margonda Raya 100, Depok 16424, West Java, Indonesia
[6]Department of Agrotechnology, Faculty of Agriculture, Universitas Siliwangi. Jl. Siliwangi No. 24, Kahuripan, Tasikmalaya 46115, West Java, Indonesia
[7]Ministry of Agriculture, and Fisheries of Timor Leste. 9 Comoro Rd., Dili, East Timor
[8]Faculty of Agriculture, Universitas IBA. Jl. Mayor Ruslan, 9 Ilir, Palembang 30164, South Sumatra, Indonesia
[9]Faculty of Agriculture, Universitas Syiah Kuala. Jl. Tgk. Hasan Krueng Kalee No. 3, Kopelma Darussalam, Banda Aceh 23111, Aceh, Indonesia

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Abstract. *Syukur M, Sahid ZD, Sobir, Maharijaya A, Ritonga AW, Yunandra, Sulassih, Istiqlal MRA, Hakim A, Wahyu Y, Vicente TM, Mukhlisin, Agustina K, Yursida, Muslimin K, Hafsah S, Nura, Setyawan A. 2022. Yield evaluation of curly chili lines in three lowland locations. Biodiversitas 23: 3219-3223.* Yield evaluation of curly chili lines in three lowland locations. Increased consumption of spicy food is the latest trend in the 21st century. Curly chili as a type of chili that has a spiciness that is acceptable to the community is needed to meet consumer needs. This study aims to identify the growth, fruit, and yield components of several genotypes of curly chili. The study was conducted in multi-location at four planting sites. Each location used a randomized complete block design (RCBD) with three replications. Each replication used ten sample plants. Neno IPB as a chili variety produced by breeding has a faster flowering and harvesting time than all other genotypes. In addition, the productivity of Neno IPB was high and consistent in all cultivation locations. The results of the pheatmap analysis show that Neno IPB was one group with commercial varieties (Laris and Kastilo F1). A significant positive correlation based on Pearson's analysis was shown in the combination of flowering time-harvesting time, fruit length-fruit weight, and fruit weight per plant-total fruit per plant-productivity. However, flowering time-harvesting time-fruit weight per plant showed a significant negative correlation.

Keywords: Curly chili, multi-location, Pearson correlation, Pheatmap analysis, yield components

INTRODUCTION

Consumption of chili as spicy food has increased. This is due to the increasing public interest in eating chilies, especially during the current pandemic era. In 2020, it was reported that 60.25% of chili consumption in Indonesia came from household fresh consumption (BPS 2021). Chili can be divided into three types, namely large chili, cayenne pepper, and curly chili. Curly chili is a type of chili that belongs to the large chili group with the main characteristic of curly fruit shape (Herison et al. 2018). In this study, we focused on curly chilies because curly chilies are most often used as household products. Consumption of spicy food produced by chili plants is believed to be able to help improve human health, especially in the era of the coronavirus disease outbreak that is sweeping the world. Zhou et al. (2019) reported that consumption of spicy food can increase human brain activity. The spiciness in chilies is caused by the main biochemical content called capsaicin (Lu et al. 2020). In addition to containing capsaicin, Sahid et al. (2021) reported that chili has antioxidant compounds and α-glucosidase inhibitors that are useful for helping to overcome diabetes mellitus. The amount of market demand for chili must be balanced with the productivity of the chili plants produced. Indonesia as a tropical country has a geographical advantage in the development of chili cultivation.

High chili productivity is influenced by many interrelated factors. The main factors that greatly affect chili productivity are the genetic material used (Kim et al. 2019) and the environment in which chili is grown (Jeeatid et al. 2018). Superior genetic material is obtained through plant breeding activities (Syukur et al. 2022). Plant breeding activities can be done conventionally (artificial hybridization) or modern (molecular breeding). At the conventional level, plant breeders take advantage of the heterotic effect to combine the two superior traits of the two different genotypes (Sran and Jindal 2022). The process of breeding program until the release of varieties is carried out through several stages of testing. One of the most important tests is the multi-location test (Barchenger et al. 2020) which is useful for knowing the performance of the variety at various types of locations.

One of the benefits of multi-location test for chili plants is to ensure superior productivity of plant varieties before being distributed to farmers. Therefore, in this study used three locations that have different environmental characteristics

that can represent the low land environments that exist in Indonesia. The information in this study can be scientifically justified that the chili varieties to be released have scientifically tested results.

Plant Breeding Laboratory, Department of Agronomy and Horticulture, IPB University through Mh. Syukur's plant breeder team has been carrying out the breeding program of curly chili varieties since 2016. Genotype of curly chili has been produced which has the potential to be cultivated by farmers on a large scale. This study aims to identify the yield components and productivity in the genotype of curly chili as a result of plant breeding. The results of this study can provide scientific information about the performance information of curly chili plants that have been successfully produced. This information can also be used by other plant breeders in curly chili breeding program in the future

MATERIALS AND METHODS

Study area and genetic material

This research was conducted at four locations using five genotypes of curly chili. The four locations included the experimental field of Tajur PKHT LPPM IPB University Bogor, experimental field of Leuwikopo Agronomy Department IPB University Bogor, experimental field of IBA University Palembang, and experimental field of Syiah Kuala University Aceh, Indonesia. The genetic materials used in this study were shown in Table 1.

Simultaneous planting of chili in four locations with the same planting method. Planting begins with sowing seeds in the plastic tray as many as 2 seeds per hole. Watering during seeding was carried out intensively once a day every morning for 28 days. The seedlings were transplanted after four weeks. Treatment after transplanting included fertilization and pest and disease prevention. ABMix fertilizer specifically for chili is provided at intervals twice a week at a concentration of 2 mL L^{-1}. Prevention of pest and disease were carried out routinely for two weeks using an insecticide with the active ingredient Abamectin with a concentration of 2 mL L^{-1}.

Variable observations were made referring to chili descriptors (IPGRI 1995). Observation variables included growth character, yield components and productivity. Growth characteristics included: dichotomous height (cm), plant height (cm), and stem diameter (mm). Fruit length (cm), fruit weight (g), and fruit diameter (mm), flowering time (day), harvesting time (day), total fruit per plant, and fruit weight per plant (g) were observed as yield components.

Data analysis

This study used a randomized complete block design (RCBD) with three replications at each location. In each replication, 10 chili plants were used as samples. Data were analyzed using SAS 9.0 and R 4.0.5 applications. The 5% HSD test, Pheatmap Analysis, and Pearson Correlation were performed if the ANOVA showed significant differences in the observed characters. Correlation test using R 4.0.5 with package Pheatmap library (Mangiola and Papenfuss 2020).

RESULTS AND DISCUSSION

The research results were distinguished based on the observed characteristics, which can be seen in Table 2-5. The stem and fruit diameter were not significant based on the 5% HSD test. Gou et al. (2020) stated that the diameter of the stem and fruit of chili was generally not influenced by the environment. Kastilo F1 showed the most minor stem diameter at the Aceh planting site. Meanwhile, Neno IPB at the Aceh planting location showed the second-highest stem diameter (7.14 mm) after F8120005-141-16-35-7-1 (7.90 mm). The planting location that delivers the highest stem diameter was Palembang. Laris (13.13 mm) and F8120005-141-16-35-7-1 (13.83 mm) were the two genotypes that had the highest stem diameter.

The highest average plant height was indicated by the locations of Tajur (85.63 cm) and Leuwikopo (83.63 cm). Both of these locations have a characteristic altitude above 200 meters above sea level (masl). In line with research Mailena et al. (2021) that the height of chili plants was higher when planted in the middle plains of more than 200 masl. Neno IPB showed the second-highest consistent plant height in three locations (Tajur, Leuwikopo, and Palembang). Meanwhile, in the Aceh, the plant height of Neno IPB was in the middle of all the observed genotypes. The dichotomous height measured in this study was in the range of 15.00-34.57 cm in all planting locations. Tajur was a location that has chili plants with high dichotomous height. While the location of Palembang was the opposite.

Observations of the flowering time and harvesting time of curly chili were shown in Table 3. The planting locations of Tajur, Leuwikopo, and Palembang showed that the flowering and harvesting times were not significantly different in all the observed genotypes. In contrast to the planting location in Aceh, which showed a significant difference in the 5% HSD test. Consistently, the Neno IPB genotype showed a faster harvest and flowering time than all the observed genotypes. This was an advantage because chili plants flower and harvest faster, so they will meet market demand for chili faster. Flowering time was positively correlated with harvesting time, which means that the sooner the plant blooms, the faster the plant will be harvested (Yassi et al. 2020).

Yield components which include fruit length, fruit weight, and fruit diameter were shown in Table 4. Like plant height, the character of Neno IPB fruit length was in the second-highest consistent position at three locations (Tajur, Leuwikopo, and Palembang), but became the longest (10.92 cm) at the Aceh planting site. This high fruit length also affects the high fruit weight in the Neno IPB genotype. The diameter of the fruit showed no significant difference, but the average data showed that the Laris and Kastilo F1 genotypes showed a thicker diameter than the other genotypes. Chili fruit weight was strongly influenced by fruit length and fruit diameter (Sahid et al. 2020).

The yield components observed in this study consisted of the number of planted fruits, the weight of the fruit planted, and the productivity in Ton Ha^{-1} can be seen in Table 5. The number of fruits planted has an effect on the weight of the resulting crops (Sahid et al. 2022). The

number of fruits planted by Neno IPB at the four planting locations was high after Laris at the Tajur planting location. The fruit weights produced at this location also showed the same trend, which was the second-highest after the Laris genotype. In addition, the fruit weight of Neno IPB was the highest compared to all other genotypes in the Aceh and Leuwikopo locations. This is also indicated by productivity observations. The Neno IPB had the highest productivity at Aceh (4.08 Ton Ha^{-1}) and Leuwikopo (11.42 Ton Ha^{-1}). Chili productivity was influenced by fruit weight and fruit number per plant (Yang et al. 2018).

Pheatmap analysis between genotypes and observed variables (Figure 1) was made to determine the groupings that occurred in this study. The genotypes were separated into two major groups where Neno IPB, Laris, and Kastilo F1 were the same group. While the other two genotypes became one group which showed that they came from the same cross (120 x 005). A close kinship relationship occurs when it comes from the same cross combination (Hafsah et al. 2021). Uniquely, the observed variables are divided based on the observed characters. The first group consisted of growth characters (PH, DH, FT, and HT). The second group was dominated by fruit characters (FD, FL, and FW). Meanwhile, in the yield component group, the diameter of the stems became one group.

Table 1. Curly chili genotypes used in this research

Genotype	Owner agency	Status
Neno IPB	PKHT, IPB University	New Variety
Laris	East West Seed Indonesia	Commercial Variety (Check Variety) (872/Kpts/TP.240/7/1999)
Kastilo F1	East West Seed Indonesia	Commercial Variety (Check Variety) (3264/Kpts/SR.120/10/2010)
F8120005-141-16-35-1-4	PKHT, IPB University	Line
F8120005-141-16-35-7-1	PKHT, IPB University	Line

Table 2. Growth characters of curly chili

Genotypes	Tajur			Leuwikopo			Palembang			Aceh		
	DH	PH	SD	DH	PH	SD	DH	PH	SD	DH	PH	SD
Neno IPB	27.27^{b}	82.30^{b}	12.70	18.30^{bc}	72.07^{b}	11.63	15.00^{a}	69.00^{a}	11.73	16.87^{b}	36.27^{b}	7.14
Laris	26.03^{b}	81.20^{b}	13.21	16.57^{c}	70.00^{b}	12.20	18.33^{a}	60.33^{a}	13.13	16.13^{b}	35.89^{b}	6.46
Kastilo F1	27.37^{b}	74.00^{b}	10.29	18.07^{c}	75.83^{b}	10.29	19.67^{a}	64.33^{a}	9.33	18.90^{b}	33.67^{b}	5.35
F8120005-141-16-35-1-4	28.88^{ab}	82.90^{b}	10.90	25.20^{a}	92.97^{a}	12.35	20.67^{a}	64.33^{a}	10.47	19.67^{ab}	37.78^{b}	7.08
F8120005-141-16-35-7-1	34.57^{a}	107.73^{a}	12.94	24.93^{ab}	107.27^{a}	12.79	15.67^{a}	73.67^{a}	13.83	26.27^{a}	55.60^{a}	7.90

Note: DH: Dichotomus Height; PH: Plant Height; SD: Stem Diameter. Numbers followed by the same letter in the same column are not significantly different based on HSD test 5%

Table 3. Flowering time and harvesting time of curly chili

Genotypes	Tajur		Leuwikopo		Palembang		Aceh	
	FT	HT	FT	HT	FT	HT	FT	HT
Neno IPB	25.00^{a}	81.00^{a}	35.67^{a}	87.87^{a}	30.67^{a}	67.00^{a}	16.00^{d}	73.67^{d}
Laris	26.00^{a}	81.33^{a}	37.00^{a}	90.23^{a}	27.67^{a}	67.00^{a}	22.00^{cd}	82.00^{c}
Kastilo F1	25.67^{a}	81.33^{a}	35.00^{a}	89.07^{a}	29.33^{a}	67.67^{a}	34.00^{a}	94.00^{a}
F8120005-141-16-35-1-4	29.00^{a}	85.67^{a}	41.67^{a}	92.83^{a}	32.33^{a}	66.67^{a}	30.33^{ab}	90.33^{ab}
F8120005-141-16-35-7-1	28.67^{a}	81.67^{a}	38.00^{a}	89.50^{a}	29.33^{a}	68.00^{a}	26.67^{bc}	86.67^{bc}

Notes: FT: Flowering time, HT: harvesting time of curly chili. Numbers followed by the same letter in the same column are not significantly different based on HSD test 5%

Table 4. Yield components of curly chili

Genotypes	Tajur			Leuwikopo			Palembang			Aceh		
	FL	FW	FD	FL	FW	FD	FL	FW	FD	FL	FW	FD
Neno IPB	17.42^{ab}	7.54^{a}	8.62	16.86^{ab}	6.69^{a}	8.76	16.47^{a}	3.39^{a}	7.97	10.92^{a}	2.68^{ab}	6.48
Laris	15.92^{bc}	7.14^{a}	9.13	15.60^{bc}	6.75^{a}	9.58	16.37^{a}	3.11^{a}	8.77	10.45^{a}	3.13^{a}	7.21
Kastilo F1	18.24^{a}	8.48^{a}	9.50	17.98^{a}	7.13^{a}	9.45	15.53^{a}	3.28^{a}	9.97	10.53^{a}	2.30^{ab}	7.48
F8120005-141-16-35-1-4	13.50^{d}	4.05^{b}	7.12	14.48^{cd}	4.74^{b}	8.23	15.23^{a}	3.11^{a}	8.87	7.97^{b}	1.65^{b}	6.35
F8120005-141-16-35-7-1	13.87^{cd}	4.95^{b}	8.06	13.14^{d}	4.87^{b}	9.08	16.73^{a}	3.39^{a}	9.03	10.46^{a}	3.14^{a}	7.87

Notes: FL: Fruit Length; FW: Fruit Weight; FD: Fruit Diameter. Numbers followed by the same letter in the same column are not significantly different based on HSD test 5%

The Pearson correlation (Figure 2) in this study strengthens the previous discussion. It was shown that the flowering and harvesting times showed a significant positive correlation, which means that these two variables were mutually supportive. In addition, a significant positive correlation was also shown by the variables of fruit length and fruit weight, as well as three productivity variables (FWP, TFP, and PROD). However, it was shown that the character of flowering time and harvesting time showed a significant negative correlation with FWP, which means that fast flowering and harvesting plants had no effect on plant fruit weight.

In addition to harvest time and flowering time, dichotomus height (DH) was significantly positively correlated with plant height (PH). This can be interpreted that in this study the higher the chili plant measured had an effect on the height of the dichotomous seen. Gupta et al. (2022) stated that the character of plant height can also be used to predict chili productivity. In this study, a positive correlation was also shown between plant height and the total fruit per plant. The higher total fruit per plant, the higher the productivity and can be shown in chili plants that have high plant height. Chili plants produced fruit on each growing dichotomus (Stan et al. 2021).

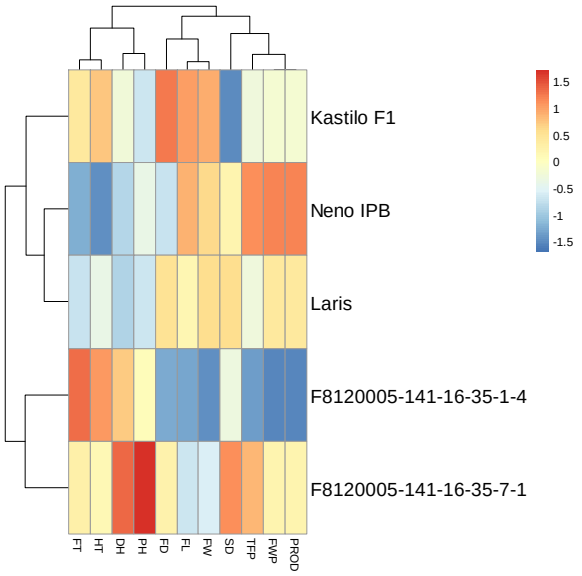

Figure 1. Pheatmap analysis on curly chili genotypes

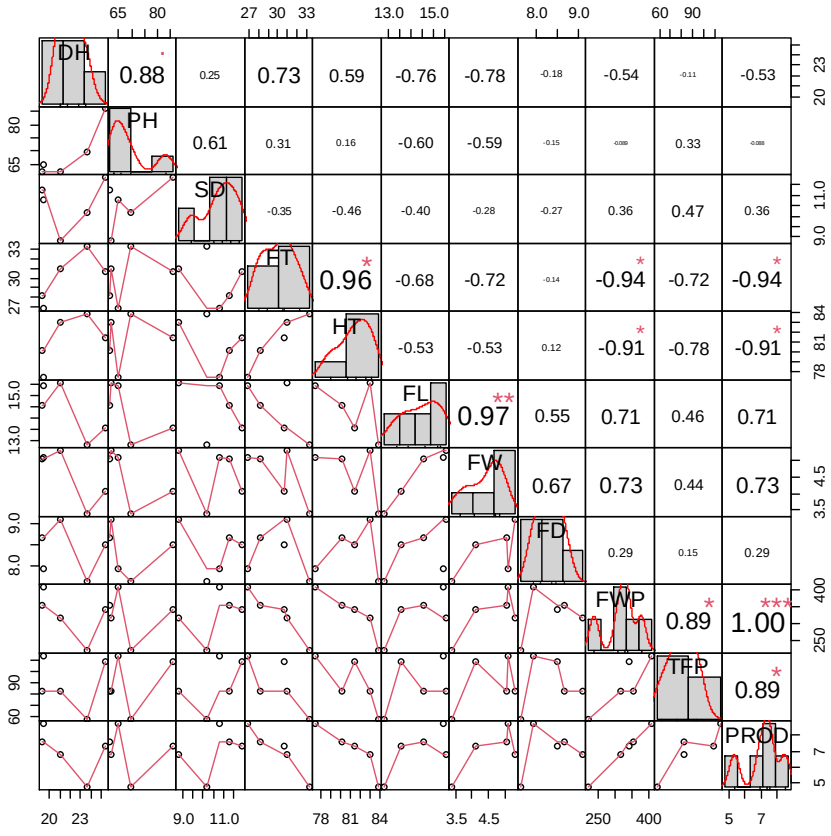

Figure 2. Pearson correlation on curly chili genotypes

Table 5. Yield components of curly chili

Genotypes	Tajur			Leuwikopo			Palembang			Aceh		
	FWP	TFP	PROD	FWP	TFP	PROD	FWP	TFP	PRD	FWP	TFP	PROD
Neno IPB	619.49^{ab}	149.47^{a}	13.22^{ab}	535.21^{a}	123.10^{a}	11.42^{a}	290.00^{a}	19.33^{a}	6.19^{a}	191.44^{a}	163.67^{a}	4.08^{a}
Laris	630.92^{a}	155.73^{a}	13.46^{a}	464.35^{a}	102.40^{a}	9.91^{a}	196.67^{a}	13.67^{a}	4.20^{a}	128.94^{a}	57.00^{bc}	2.75^{a}
Kastilo F1	393.46^{b}	78.60^{ab}	8.39^{b}	506.82^{a}	108.17^{a}	10.81^{a}	236.67^{a}	15.00^{a}	5.05^{a}	131.85^{a}	125.33^{ab}	2.81^{a}
F8120005-141-16-35-1-4	151.96^{c}	67.80^{b}	3.24^{c}	370.29^{a}	116.57^{a}	7.90^{a}	323.33^{a}	22.33^{a}	6.90^{a}	43.23^{a}	23.67^{c}	0.92^{a}
F8120005-141-16-35-7-1	418.99^{ab}	143.67^{ab}	8.94^{ab}	425.70^{a}	128.70^{a}	9.08^{a}	423.33^{a}	28.33^{a}	9.03^{a}	103.65^{a}	130.33^{ab}	2.21^{a}

Notes: FWP: Fruit Weight Plant^{-1}; TFP: Total Fruit Plant^{-1}; PROD: Productivity in Ton Ha^{-1}. Numbers followed by the same letter in the same column are not significantly different based on HSD test 5%

In conclusion, it can be concluded in this study that the Neno IPB genotype as a new variety has the advantages of fast flowering and harvesting time. In addition, the productivity of this genotype is also relatively high so it can be recommended for use by farmers on a large scale in lowland environments. The results of clustering based on pheatmap analysis also showed that Neno IPB was grouped together with Laris and Kastilo F1 which were varieties that have been circulated by farmers. Observational variables in this study are also grouped based on the observed characters.

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