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Research Article

Evaluation of qualitative and quantitative traits of ten lowland chili genotypes

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ABSTRACT

One of the important stages in chili breeding is the multi-location test. The lowlands became one agroecology in the chili multi-location test because most farmers, especially in Sumatra, plant chilies on the lowlands after the rice planting season. The purpose of this study was to understand the qualitative and quantitative characteristics of chili genotypes in a lowland area. The experiment was arranged in a single-factor randomized complete block design (RCBD) with three replications. The chili genotypes evaluated were four test lines and six check varieties. The quantitative data were statistically analyzed using analysis of variance (ANOVA) followed by evaluation of genotype means using the least significant difference (LSD) tests by SPSS Statistics software. The results showed that the check variety having the lowest productivity was CH3 (1.19 tons ha^{-1}) and the highest was Elegant (4.55 tons ha^{-1}). The productivity of four genotypes from IPB were significantly different from the CH3 and Imperial 10 varieties, but not significantly different from Baja (2.96 tons ha^{-1}), Balebat (3.87 tons ha^{-1}), Elegant (4.55 tons ha^{-1}) and Gada (3.04 tons ha^{-1}) varieties. This research shows that the four genotypes from IPB have the potential to become new superior varieties.

Keywords: *Lampung; multi-location; plant breeding; varieties*

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INTRODUCTION

Chili plants (*Capsicum spp*.) are widely cultivated and consumed throughout the world, mainly because of their delicious taste, abundant nutrients (Kim et al., 2019), and several health benefits such as antioxidant (Giuffrida et al., 2017), anti-inflammatory and antidiabetic effects (Kim et al., 2019; Njume et al., 2019). Curly chili is the main characteristic of curly fruit shape (Herison et al., 2018). Currently, the constraints on curly chili cultivation in Indonesia are related to seed quality, cultivation techniques, pest and disease attacks, and the use of low-yielding chili varieties. Another issue that also impacts productivity is climate change and unpredictable weather in recent years. Efforts to improve chili quality and yield must be carried out through a breeding process to maintain chili productivity. So far, a large number of chili varieties have been discovered and developed around the world (Tripodi et al., 2019).

Yield is a quantitative character that is controlled by many genes, so efforts to improve yields take several generations. Genetic improvement of agronomic traits can be done through breeding, and genetic diversity can be studied based on morphological and agronomic traits (Pereira et al., 2005; Stoilova, 2007). The yield evaluation is one of a series of plant breeding activities that aims to evaluate the yield potential of selected lines from previous selections. The evaluation phase carried out on the lines before being registered as new varieties, consisted of preliminary yield trials, advanced yield trials, and multi-location trials. All testing activities were carried out to analyze the adaptation and stability of candidate varieties (Syukur et al., 2012). Yield evaluations need to be carried out under various environmental conditions. The ability of the nature of a plant is influenced by the number of genes and environmental factors. Yield is influenced by genotype, location, season (year), and the interaction between genotype and these environmental factors (Syukur et al., 2010).

The genotype-by-environment interaction effect in plants may reduce the genetic contribution to the final appearance of the plant (Furbank et al., 2015). According to (Govindaraj et al., 2015). Morphological characters in plants can be either qualitative or quantitative. Qualitative characters are manifestations of sharply different phenotypes from one another which can be categorized qualitatively to form groups, and controlled by a single or small number of genes. Meanwhile, quantitative characters are controlled by many genes and are usually influenced by the environment. Information on the inheritance pattern of each character is important in determining plant breeding strategies (Syukur et al., 2012). Characterization is very important to characterize genetic resources, especially morphological and agronomic (Singh, 2001) and biochemical and molecular properties (Beebe et al., 2000). According to Muniarti et al. (2013), the component of chili production is strongly influenced by the growth component, this is because the two components are interconnected, if the growth component has a small value, then the yield component may also have a small value as well.

One of the characteristics of lowland soil is that it has a varied texture. This is because the land is located close to sea level. Apart from that, generally, the texture of lowland soil tends to be looser, making it suitable for planting various types of plants such as chili plants (Syafruddin et al., 2020). This study aimed to understand the qualitative and quantitative characteristics of chili genotypes in the lowland Lampung at an altitude of 100-200 meters above sea level.

MATERIALS AND METHODS

The research was conducted on the Seed Teaching Farm (STEFA), Politeknik Negeri Lampung at an altitude of 120 m above sea level. The minimum and maximum temperatures were 23 and 37°C, relative humidity was 60-85%, and annual rainfall was 1857-2454 mm/year. The material used in this research includes genetic material as well as tools and materials used to support the implementation of the research. This research was conducted from April to September 2022. The experiment was arranged in a single-factor randomized complete block design (RCBD) with three replications. The chili genotypes evaluated were four test lines and six check varieties (Table 1). The quantitative data were statistically analyzed using analysis of variance (ANOVA). If the genotype effect is significant ($p<0.05$), then the significance between genotype means was evaluated by the least significant difference (LSD) test at 0.05 level using the SPSS Statistics software.

Measurements were performed on 10 sample plants selected randomly in each experimental unit. The observed characters consisted of qualitative characters, including leaf shape, fruit color, leaf base shape, leaf edge wave, fruit shape, fruit tip shape, fruit cross-section, fruit curly curve, fruit color, intermediate fruit color, old fruit color, fruit base, seed shape, and seed color. The RHS color chart is used to measure color characters. The observed quantitative characters consist of yield components and outcome characters. Yield characters included plant height, dichotomous height, stem diameter, crown width, leaf length, leaf width, flowering age, harvest age, fruit length, fruit diameter, flesh thickness, number of fruits, and weight of 1000 seeds. Yield components included weight per fruit, the weight of fruit planted, the weight of fruit per bed, and productivity. The selection of characters observed was based on the Decree of the Minister of Agriculture of the Republic of Indonesia Number 12/Kpts/SR.130/D/8/2019 concerning

Technical Compilation of Descriptions and Validity Testing of Horticultural Plant Varieties (Ministry of Agriculture 2019), while the method of observation was based on descriptors for capsicum (IPGRI 1995) and calibration book (Naktuinbouw, 2010). Observation of color on qualitative characters using RHS color chart.

Table 1. Information about the genotype of curly red chili.

Genotype	Source	Information
F1074005	IPB University	Test lines
F1074003	IPB University	Test lines
F1374005	IPB University	Test lines
F1374003	IPB University	Test lines
CH3	IPB University	Commercial variety
Baja	PT. Ewindo	Commercial variety
Balebat	PT. BCA	Commercial variety
Imperial 10	PT. BISI International, Tbk	Commercial variety
Gada	PT. Ewindo	Commercial variety
Elegant	PT. Ewindo	Commercial variety

The quantitative data were analyzed using the analysis of variance (ANOVA) at the 5% level. If the genotype effect was significant, then the least significant difference (LSD) test at the 5% level was performed. Correlation analysis was performed to determine the relationship between quantitative characters (Gomez and Gomez, 2010).

RESULTS AND DISCUSSION

Qualitative characters of the curly chili genotypes

Qualitative characters are controlled by simple genes and are very little influenced by environmental factors. Qualitative characters are used as markers of plant varieties (Hasan et al., 2020). Qualitative characters in plants are controlled by a particular gene (Carrizo et al., 2016). Qualitative characters will not be changed by environmental influences (Hafsah et al., 2021).

For qualitative characters, all chili genotypes (Table 2) have the same leaf shape, namely Lanceolate. The Balebat and Imperial 10 genotypes had a Moderate Olive Green/137 B color while the other genotypes had a Greyish Olive Green/NN137 A leaf color. The chili plant genotype F1074003 has a blunt leaf base that is different from other genotypes which have a rounded, tapered, and pointed leaf base. Based on the leaf margin waves in chili plants with genotypes F1074005, F1374003, Baja, Elegant, and Gada have none or very weak criteria, while the genotypes F10740003, F13740005, CH3, Balebat, and Imperial 10 have very weak leaf margins. The results are obtained in Table 3. It can be explained that all types of genotypes used have the same fruit shape, fruit tip shape, and fruit cross-section. The results of the qualitative character showed that the shape of the fruit was narrowly triangular, the shape of the tip of the fruit was pointed and the cross-section of the fruit was not choppy. The genotypes F1074003 and Balebat had medium fruit curls, while the other genotypes had little fruit curls.

The identification results on several genotypes (Table 4) were as follows. F1074003 has the same young fruit color as the Balebat, Elegant, and Gada genotypes, namely Greyish Olive Green/NN137A and F1074005 genotype has Greyish Olive Green/NN137 B fruit color, while the F1374003 genotype has the same fruit color as CH3 and Baja, namely Moderate Olive Green/137A and F1374005 genotype has Moderate Olive Green/ 137C fruit color. Imperial 10 genotype has a young fruit color Strong Yellow Green/144B. In the intermediate fruit color variable, genotype F1374005 has an intermediate fruit color, namely Moderate Olive Brown / N199A which is the same as F1374003, while Imperial 10 has a color namely Dark Greyish Yellow/N 199 D, in genotypes F1074005, F1074003, CH3, Baja, Balebat, Elegant, and Gada has the same intermediate fruit color, namely Strong Yellowish Brown/200 A. In the old fruit color variable, there are color similarities between the genotypes F1074005, F1074003 F1374005, Baja, Balebat, Elegant, and Gada namely

Moderate Red/N45 A. Meanwhile, the genotypes F1374003, CH3, and Imperial 10 have the same old fruit color, namely Vivid Red/45 A. In all genotypes, the base of the fruit showed a blunt shape, the shape of the seeds looked the same between Baja and Balebat, namely thick, while the other genotypes had flat seed shape. The color of the seeds was dark yellow in all genotypes.

Table 2. Qualitative data observation of leaf.

Genotype	Leaf shape	Leaf color	Leaf base shape	Leaf edge wave
F1074005	Lanceolate	Greyish Olive Green NN137A	Round	None or very weak
F1074003	Lanceolate	Greyish Olive Green NN137A	Blunt	Weak
F1374005	Lanceolate	Greyish Olive Green NN137A	Tapered	Weak
F1374003	Lanceolate	Greyish Olive Green NN137A	Tapered	None or very weak
CH3	Lanceolate	Greyish Olive Green NN137A	Tapered	Weak
Baja	Lanceolate	Greyish Olive Green NN137A	Pointed	None or very weak
Balebat	Lanceolate	Moderate Olive Green 137B	Tapered	Weak
Elegant	Lanceolate	Greyish Olive Green NN137A	Tapered	None or very weak
Imperial 10	Lanceolate	Moderate Olive Green 137B	Tapered	Weak
Gada	Lanceolate	Greyish Olive Green NN137A	Pointed	None or very weak

Table 3. Qualitative data observation of fruits.

Genotype	Fruit shape	Fruit tip shape	Fruit cross-section	Fruit curliness
F1074005	*Narrowly triangular*	Pointed	Not choppy	A little
F1074003	*Narrowly triangular*	Pointed	Not choppy	Medium
F1374005	*Narrowly triangular*	Pointed	Not choppy	A little
F1374003	*Narrowly triangular*	Pointed	Not choppy	A little
CH3	*Narrowly triangular*	Pointed	Not choppy	A little
Baja	*Narrowly triangular*	Pointed	Not choppy	A little
Balebat	*Narrowly triangular*	Pointed	Not choppy	Medium
Elegant	*Narrowly triangular*	Pointed	Not choppy	A little
Imperial 10	*Narrowly triangular*	Pointed	Not choppy	A little
Gada	*Narrowly triangular*	Pointed	Not choppy	A little

Table 4. Qualitative data observation of fruit color and seeds.

Genotype	Young fruit color	Intermediate fruit color	Old fruit color	Fruit base	Seed shape	Seed color
F1074005	Greyish Olive Green NN137 B	Strong Yellowish Brown 200 A	Moderate Red N45 A	Blunt	Flat	Dark yellow
F1074003	Greyish Olive Green NN137 A	Strong Yellowish Brown 200 A	Moderate Red N45 A	Blunt	Flat	Dark yellow
F1374005	Moderate Olive Green 137 C	Moderate Olive Brown N199 A	Moderate Red N45 A	Blunt	Flat	Dark yellow
F1374003	Moderate Olive Green 137 A	Moderate Olive Brown N199 A	Vivid Red 45 A	Blunt	Flat	Dark yellow
CH3	Moderate Olive Green 137 A	Strong Yellowish Brown 200 A	Vivid Red 45 A	Blunt	Flat	Dark yellow
Baja	Moderate Olive Green 137 A	Strong Yellowish Brown 200A	Moderate Red N45 A	Blunt	Thick	Dark yellow
Balebat	Greyish Olive Green NN137 A	Strong Yellowish Brown 200A	Moderate Red N45 A	Blunt	Thick	Dark yellow
Elegant	Greyish Olive Green NN137A	Strong Yellowish Brown 200A	Moderate Red N45 A	Blunt	Flat	Dark yellow
Imperial 10	Strong Yellow Green 144 B	Dark Greyish Yellow N 199D	Vivid Red 45 A	Blunt	Flat	Dark yellow
Gada	Greyish Olive Green NN137 A	Strong Yellowish Brown 200A	Moderate Red N45 A	Blunt	Flat	Dark yellow

Quantitative characters of the curly red chili genotypes

The observed quantitative characters consist of yield components and yield characteristics. According to Zuhry et al. (2012), Dalimunthe et al. (2016) and Fitria et al. (2021), plant growth and production components are quantitative traits as the expression of genetic and environmental factors. The production ability is determined by growth during the vegetative phase before entering the generative phase.

The results of the qualitative character research are presented in Table 5. The genotype planted had a significant effect on plant height, dichotomous height, and stem diameter. The test genotype F1074003 had the highest plant height significantly different from other genotypes, but not significantly different from the comparison genotype Balebat. The dichotomous height and stem diameter were highest in the comparison genotype Balebat, followed by the test genotype F1074003 which was significantly different from the other genotypes. This shows that each genotype has advantages and diversity based on the traits carried. In addition, plant parts have a function and purpose to assist in the growth process. Plant height, dichotomous height, and stem diameter indicate good vegetative conditions because the taller and larger the plant, the plant can utilize sunlight better so that the resulting photosynthate results will be better and beneficial for plant growth. Plant growth is caused by the activity of xylem formation, phloem, and cell enlargement, these activities push the cambium out to form new cells so that the plant grows taller (Setiawan et al., 2019; Rahayu & Sri, 2018). Plants with high plant height are expected to produce high productivity (Syukur et al., 2022b). The diameter of the stem determines the strength to support the plant crown. The larger the diameter of the plant stem, the stronger the ability of a plant to be able to support plant branches and fruit (Jones, 2013; Silva et al., 2016; Ahmadi & Souri, 2020). In addition, plants with higher dichotomous will be more resistant to fruit diseases such as anthracnose (Kusmanto et al., 2015).

The results of leaf observations include canopy width, leaf length, and leaf width, which are the main organs that play a role in the process of plant photosynthesis and the formation of productive branches (Muniarti et al., 2013; Desita et al., 2015; Kusmana et al., 2017). Genotype F1074003 (70.33 cm) showed a higher crown width and was significantly different from other genotypes. While leaf length and leaf width showed significantly different results, where the comparison genotype Balebat (13.76 cm) showed the highest leaf length followed by the Gada, F1374003, F 1074005, and F1074003 genotype, leaf width of the comparison genotype Balebat (5.27 cm) had the highest leaf width compared to other genotypes and followed by genotypes F1074003, F1374003, Gada. The width of the canopy is an important character of the photosynthesis rate, which indirectly affects plant production (Pedo et al., 2013).

Table 5. Quantitative data observation of plant size, leaf size, and age of flowering and harvesting.

Genotype	Plant height (cm)	Dichotomous Height (cm)	Stem diameter (cm)	Canopy width (cm)	Leaf length (cm)	Leaf width (cm)	Flowering age (DAT)	Harvest age (DAT)
F1074005	60.47bcd	19.63abc	10.38bc	58.37bc	9.82bc	3.61abc	30.33bc	78.00bc
F1074003	76.03e	24.42e	11.29c	70.33c	9.43abc	3.98c	32.00cd	72.67a
F1374005	51.23a	19.92abcd	9.52b	48.33ab	8.93abc	3.63abc	33.33d	73.67ab
F1374003	62.13d	22.12d	9.57b	55.40b	9.53abc	3.85bc	32.67cd	73.00a
CH3	45.76a	16.20a	7.79a	37.30a	7.31a	3.08ab	31.67cd	71.00a
Baja	49.40a	21.83cd	9.25ab	56.47b	9.12abc	2.89a	36.33e	78.33c
Balebat	75.27e	31.48f	11.40c	55.43b	13.76d	5.27d	41.00f	87.00d
Elegant	53.67abc	17.32ab	9.79bc	59.23bc	8.75abc	3.21abc	27.67ab	70.00a
Imperial 10	61.07cd	21.42bcd	9.94bc	51.47b	7.52ab	3.41abc	32.01cd	74.00abc
Gada	52.83ab	17.12a	10.66bc	57.76bc	9.95c	3.82bc	27.00a	71.33a
LSD 5%	8.11	2.30	9.80	13.55	2.42	0.90	2.99	4.45
CV (%)	8.04	6.15	1.67	14.35	15.01	14.27	5.38	3.46

Note: DAT: days after transplanting

Flowering age and harvest age between genotypes were significantly different, flowering age ranged from 27.00-41.00 DAT while harvesting age ranged from 70.00-87.00 DAT (Table 6). The fastest flowering age was dominated by the comparison genotype, namely Elegant, Balebat (27.00 DAT), while the shortest flowering age was the test genotype F1074005 (30.33 DAT) F1074003 (32.00 DAT), and F1374003 (32.67 DAT). Harvest period showed the same thing, where the comparison genotypes dominated the fastest harvesting ages, namely Elegant (70.00 DAT), CH3, Gada (71.00 DAT) followed by the test genotypes, namely F1074003 (72.00 DAT), F1374005, F1374003 (73.00 DAT). However, a faster flowering period does not guarantee a faster harvest time, whereas the test genotypes F1374003, F1374005, and F1074003 only require 40 days after planting from flowering to being ready to harvest. The Gada genotype has a flowering age and a faster harvest age takes 44 days to be ready to be harvested. In line with (Arumingtyas et al., 2022), fast flowering time does not guarantee an early harvest time. One of the targets for breeding chili plants is to produce chili varieties that are early in age (Syukur et al. 2014; Wahidatun et al., 2018). The early flowering age character is one of the superior characteristics of a plant. The harvest age character is one of the characteristics used to measure the superiority of a variety (Sari et al., 2014). Harvest age is influenced by genetics and the environment, where genetic background greatly affects the length of crop harvest. In addition, the harvest age is also related to the flowering age in plants (Mejaya et al., 2010; Hilmayanti et al., 2015; Surmaini et al., 2018). In line with Padilha et al. (2016) stated that harvest age is an important aspect in the development of new varieties with shorter or longer life cycles so that farmers have many options for planting on land.

Fruit length, fruit diameter, and flesh thickness were different between curly chili genotypes. The test genotype F1374005 had the longest average fruit length, while the Balebat as a check produced the shortest fruit length. The largest fruit diameter was found in the tested genotype F1374005, which was not significantly different from F1074005, CH3, Balebat, and the smallest fruit diameter was found in the Imperial 10 comparison genotype, which was significantly different from other genotypes. Meanwhile, the thickness of the flesh showed that the genotype Balebat had the thickest flesh, significantly different from other genotypes except for CH3 and Elegant (Table 6). The length, diameter, and thickness of the fruit flesh are the variables that determine the quality of chili that is of interest to consumers. In addition, fruit quality is influenced by the ability of plants to produce fruit in each genotype and depends on the assimilation produced in the growth process during the vegetative phase. The length and diameter of the fruit shown in each plant can be caused by the structure of the genes that compose it, it is thought that there are three to ten pairs of genes with heritability values of around 40-50% in chili (Zhigila et al., 2014). According to Syukur and Rosidah (2014), the long character of chilies is strongly influenced by genetic factors.

Each genotype produced a significantly different number of fruits. The genotype Elegant had the highest average number of fruits (803.33 fruit), followed by the test genotype F1074003 (692.33 fruit). In contrast, the smallest number of fruits was produced by CH3 (249.67 fruit). The number of fruits is one of the yield components that greatly determines the production of chili, the higher the number of fruits per plant, the higher the total weight of fruit per plant. The number of fruits influences weight per fruit. This caused assimilation shared equally on organ *sink* (fruit) which formed so that the length and diameter of the fruit are reduced drastically when compared to plants that have many fruits (Do Rêgo et al., 2011; Wahidatun et al., 2018). The number of fruits planted affects the weight of the fruit produced (Sahid et al., 2022). Chili productivity is influenced by fruit weight and the number of fruits per plant (Yang et al., 2018). Supported (Syukur et al., 2022a) The higher the number of fruits per plant, the higher the productivity, and can be shown in chili plants that have high plant height.

The weight of 1,000 seeds is an illustration of the seeds themselves where the heavier the weight of the seeds produced, the better the quality of the seeds. The results of the weight of 1,000 seeds showed that the Balebat genotype (6.40 g) had the highest weight, followed by the test genotype F1074003 (6.26 g) which was not significantly different but significantly different from the other genotypes. Seeds are a place for food reserves that will have a direct impact on seed viability, seed storability, germination, and the ability to grow stronger seeds so it will affect the quality of seeds when they are replanted. This is in line with the statement (Nkansah et al., 2011; Fitriani et al., 2013) that the higher the number of seeds and the higher the weight of the beans, the higher the level of spiciness and the higher food reserves.

Fruit weight, fruit weight per plant, and fruit weight per bed showed varying results between the test and comparison genotypes (Table 6). The heaviest fruit weight produced by the comparison genotype Balebat (11.50 g), followed by the test genotypes F1374005 (11.10 g) and F1074005 (10.76 g), were not significantly different. The smallest fruit weight was produced by the comparison genotype Imperial 10 (5.17 g) and followed by the test genotype F1074003 (6.51 g). The results of the variable fruit weight of cropping showed that the comparison genotype Elegant had the heaviest weight (80.07 g) and followed by the test genotype F1374003 (77.20 g), the smallest fruit weight yielded the comparison genotype CH3, Baja, and followed by the test genotype F1374005. The results of the observation of the weight of the seedbeds of the comparison genotype Elegant showed the heaviest weight of 369.88 g, the weight of the smallest seedbed CH3 (110.79 g). The number of fruit, fruit weight, fruit weight per plant, and fruit weight per bed are yield characters that influence each other on fruit weight. In line with the statement (Wahidatun et al., 2018) that, the more number of fruits produced, the smaller the size of the fruit. Although the weight per fruit is low, the accumulation of a large number of fruits can increase the weight of the fruit per plant and affect the yield. In line with the statement (Sahid et al., 2020). Chili fruit weight is strongly influenced by fruit length and fruit diameter. Differences in fruit weight per plant and weight per fruit can be caused by strains and according to their genes (Inardo et al., 2014).

Table 6. Quantitative data observation of fruit and productivity.

Genotype	Fruit length (cm)	Fruit diameter (cm)	Thickness of flesh (mm)	Number of fruits (fruit)	Weight 1,000 seeds (g)	Weight per fruit (g)	Fruit weight per plant (g)	Fruit weight per bed (g)	Productivity (tons ha^{-1})
F1074005	12.54cd	12.64cd	1.11bcd	536.00bcd	5.54de	10.76d	51.87ab	262.70cd	3.23cd
F1074003	11.54abc	11.13b	0.92ab	692.33cd	6.26f	6.51ab	55.87b	296.64de	3.59d
F1374005	13.56d	13.46d	1.06bcd	400.33ab	5.48cde	11.10d	62.83bc	296.59de	3.54d
F1374003	12.76cd	11.10b	1.03abcd	481.33abc	5.73e	7.64bc	77.20c	204.83bc	2.52bc
CH3	10.86ab	12.53cd	1.23de	249.67a	4.85ab	7.70bc	36.03a	110.79a	1.19a
Baja	12.13bcd	11.68bc	1.20cd	536.33bcd	4.64a	8.65c	53.57ab	238.73bcd	2.96cd
Balebat	10.27a	12.47cd	1.44e	358.33ab	6.40f	11.50d	65.20bc	307.55de	3.87de
Elegant	13.45d	11.30b	1.21de	803.33d	5.28bcd	8.67c	80.07c	369.88e	4.55e
Imperial 10	12.67cd	8.90a	0.85a	446.00abc	5.17abc	5.85a	62.73bc	154.00ab	1.64ab
Gada	13.44d	11.34b	0.06abc	675.33cd	5.34bcd	8.57c	55.83b	252.93cd	3.05cd
LSD 5%	1.55	1.09	0.21	267.45	0.44	1.50	18.43	88.22	3.41
CV (%)	7.32	5.43	11.19	30.10	4.74	10.06	17.87	20.61	17.81

Results of the productivity analysis (Table 6) show that the comparison genotype has the highest productivity, namely Elegant (4.55 tons ha^{-1}), Balebat (3.87 tons ha^{-1}) and followed by the tested genotype, namely F1074003 (3.59 tons ha^{-1}), F1374005 (3.54 tons ha^{-1}). However, when compared between the tested genotype and the comparison, the productivity of the tested genotype has an average of 3.22 tons ha^{-1}, which is higher than the comparison genotype 2.87 tons ha^{-1}. Characters such as fruit diameter, flesh thickness, plant height, and the number of fruit per plant are the most influential factors on crop yields (Cankaya et al., 2010). In addition, the high productivity of chili is influenced by several factors, namely genetic factors (Zboralski & Martin, 2020) and environmental (Yang et al. 2018b). Genetic factors play a more important role between these two factors because the environment can be controlled using adaptive genetics (Majid et al., 2017).

Environmental factors are known to influence the expression of quantitative traits greatly. However, in some cases, environmental factors affect the qualitative character and harvest age (Pimenta et al., 2016; Kandel et al., 2017). All quantitative traits were found to differ significantly between genotypes and also between environments. Variations in growth and yield components have been reported in many studies (Sharma et al., 2010; Thul et al., 2009). Plant breeding activities are expected to be able to produce superior genetic material (Syukur et al., 2022b). The genetic material used and the environment where chili is grown are the main factors that influence chili productivity (Jeeatid et al., 2018; Kim et al., 2019).

Yield components become direct reference data for chili plant yields, while yield characteristics become indirect reference data for chili plant yields (Syukur et al., 2022). The relationship between yield component factors and yield characters is presented in (Table 7), the results of the correlation analysis elucidated that the characters that had a positive and significant correlation with the yield component (productivity) were the canopy width, number of fruit, and fruit weight per bed characters. Several research results showed that the number of fruits had a positive and significant correlation with yield components (Ozukum et al., 2019; Negi & Sharma, 2019; Usman et al., 2017; Lavinia et al., 2013).

Table 7. Correlation coefficients among traits.

	DH	SD	CW	LL	LW	FA	HA	FL	FD	TF	W/F	W 1,000S	NF	FW/P	FW/B	PH
PH	0.80*	0.81**	0.63*	0.62	0.78**	-0.02	0.49	-0.43	-0.20	0.13	-0.02	0.71	0.12	0.29	0.33	0.32
DH	1	0.52	0.66	0.23	0.40	0.48	0.26	-0.22	-0.42	0.06	-0.49	0.07	0.26	0.24	0.13	0.12
SD		1	0.80**	0.71*	0.73*	-0.33	0.44	-0.06	-0.14	-0.25	0.20	0.52	0.45	0.33	0.61	0.60
CW			1	0.36	0.28	-0.17	0.09	0.14	-0.26	-0.23	-0.10	0.33	0.79**	0.39	0.64*	0.64*
LL				1	0.89**	-0.21	0.79**	-0.39	0.33	0.14	0.63	0.47	-0.01	0.26	0.52	0.51
LW					1	-0.29	0.67*	-0.44	0.17	0.07	0.42	0.88**	-0.16	0.25	0.34	0.33
FA						1	0.61	-0.39	0.11	0.53	-0.04	-0.38	-0.52	-0.19	-0.31	-0.32
HA							1	-0.58	0.27	0.46	0.59	-0.17	-0.37	-0.01	0.19	0.17
FL								1	-0.18	-0.50	-0.04	0.59	0.53	0.46	0.26	0.27
FD									1	0.33	0.81**	0.04	-0.31	-0.28	0.28	0.27
TF										1	0.29	-0.20	-0.41	0.07	0.08	0.09
W/F											1	0.27	-0.20	0.06	0.50	0.49
W1000S												1	0.19	0.57	0.32	0.31
NF													1	0.44	0.64*	0.65*
FP/P														1	0.56	0.57
FW/B															1	1.00**

Note: PH = plant height; DH = dichotomous height; SD = stem diameter; CW = canopy width; LL= leaf length; LW = leaf width; FA = flowering age; HA = harvest age; FD= fruit length; FD= fruit diameter; TF = thickness of flesh; W/F = weight per fruit; W1000S = weight 1000 seeds; NF = number of fruits; FW/P = fruit weight per plant; FW/B = fruit weight per bed; P = productivity. **significant at 0.01 level, *significant at 0.05 level, ns not significant.

CONCLUSIONS

The results showed that the productivity of CH3 (4.43 tons ha^{-1}) and Imperial 10 (6.20 tons ha^{-1}) had the lowest productivity levels. Statistical analysis data showed that the two varieties were not significantly different. The Elegant variety (15.13 tons ha^{-1}) had the highest productivity and was significantly different from other genotypes in this study. The genotype of IPB, namely F1374005 (11.86 tons ha^{-1}) was not significantly different when compared with F1074003 (11.87 tons ha^{-1}) and F1074005 (10.51 tons ha^{-1}) but significantly different with F1374003 (8.19 tons ha^{-1}). The four genotypes from IPB were significantly different from the control varieties, namely CH3 and Imperial-10, but not significantly different from other control varieties, such as Baja (9.55 ton ha^{-1}), Balebat (12.30 tons ha^{-1}), Elegant (15.13 tons ha^{-1}) and Gada (10.12 tons ha^{-1}). The results of the correlation analysis show that the characters that had a positive and significant correlation with the yield component (productivity) were the canopy width, number of fruit, and fruit weight per bed characters. All types of genotypes used have the same fruit shape, fruit tip shape, and fruit cross-section. The results of the qualitative character showed that the shape of the fruit was narrowly triangular, the shape of the tip of the fruit was pointed and the cross-section of the fruit was not choppy. The genotypes F1074003 and BALEBAT had medium fruit curls, while the other genotypes had little fruit curls. The research data indicated that the four genotypes from IPB had the opportunity to register and release new superior varieties of chili plants in Indonesia.

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