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Superiority test of mixed-cropping models for chili pepper hybrid varieties through participatory plant breeding

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Abstract Mixed cropping system is reported to increase chili pepper productivity by suppressing insect and pathogen developments. Participatory plant breeding might produce desired variety and combination of hybrid varieties. The superior model for mixed cropping for chili pepper variety, insect and disease resistances is designed as preferred by consumers. Results showed that the best mixed cropping for chili pepper hybrids was UNIB CH13 and Dwiguna UNIB. This combination produced total fruit weight of 300.12 g per-plant, longest fruit length of 13.66 cm, fruit stalk of 5.43 cm, canopy area of 3172.53 cm^2, biggest stem diameter of 11.79 mm and highest fruit weight of 5117.22 g per-plot. Mixed cropping of UNIB CH13 and Dwiguna UNIB had the lowest disease incidence caused by *Cercospora* sp. Infested by *Colletotrichum*, *Fusarium* and *Begomovirus* on chili peppers plants were not significantly different. Although growers prefered to select monocropping of UNIB CH13 and Dwiguna UNIB, but growers chose the combination of UNIB CH13 and Dwiguna UNIB for fruit shape and homogeneity.

Keywords: mixed cropping, chili pepper hybrid, participatory plant breeding

Introduction

Chili pepper is the most important vegetable for many Indonesians average per capita consumption of 1.08 kg $year^{-1}$ (Badan Pusat Statistik, 2019). In 2018, total area production of chili pepper was accounted for 136.857 ha with the productivity of 8.82 ton ha^{-1} (Ministry of Agriculture, 2019). Another source of chili peppers for consumer demands is the production of Thai pepper or bird's eye chili pepper which in 2018 was produced in 171.690 ha of lands with the productivity of 7.78 ton ha^{-1}. Although total yearly Indonesian chili pepper production is able to feed consumer demands, fluctuation of chili pepper production across the year resulted in product scarcity in particular months which later increased the selling prices and hence eventually contributed to regional and national inflation. Such fluctuations in productions and prices lead serious attention

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from many parties, including farmers, government, and researchers to develop relevant production technologies. Price fluctuation of chili pepper was, for example, determined by seasonal conditions in the production areas. Boga (2014) reported that price fluctuation was positively correlated with rain fall. High intensity of rain fall increased the incidence pest attacks to the crop and eventually reduced chili pepper production. Reduction of chili pepper production brought about significant increase in chilli pepper price as much as four times of normal prices. Many other environmental factors might be also responsible to reduction of chili pepper production. Under such conditions, government offer an import policy to meet consumer demands and reduce market selling price. During the period of 2010 to 2013, for example, rate of growth chili pepper imports reached the highest level in history, *i.e.*, 166.27% (Anonymous, 2014).

Plant breeding program is one of the best ways to achieve national chili pepper self-sufficiency, including establishment new high yielding chili pepper hybrids which are preferred by wide range of customers. Since 2007, Chili Pepper Research Group in University of Bengkulu, in collaboration with researchers from Bogor Agricultural University has conducted series of experiments to establish high yielding chili pepper cultivars (Ganefianti *et al.*, 2008). Those experiments have successfully produced high yielding hybrids (more than 10 ton ha^{-1}) and resistant to yellow leaf curl *Begomovirus* (Ganefianti *et al.*, 2017) and had been officially registered to Ministry of Agriculture, Republic Indonesia as UNIB CH13, UNIB CH23, UNIB CH43, Dwiguna UNIB, and UNIB CH73. Those promising hybrids are urgently introduced to the farmers and participatory plant breeding is one the best way to benefit farmers.

At the farm levels, chili pepper productions are generally cultivated using a single variety cropping system. Although this technique is able to increase crop productivity and reduce crop production costs, a single variety cropping system is very risky from the pathogen attacks' point of view. Popularizing mixed-variety cropping systems might benefit farmers, since this technique is able to suppress pathogen attacks to chilli pepper. Research conducted by Tutupary *et al*. (2004) concluded that each crop variety has different resistance to pathogen attacks. The effectiveness of mixed variety cropping system had been reported to suppress *Fusarium* attacks on tomato (Adriani *et al.*, 2012) and chilli pepper (Wandani *et al.*, 2015), *Begomovirus* on chili pepper (Ganefianti *et al.*, 2008) and brown planthopper (*Nilaparvata lugens*) on rice (Dianawati dan Sujitno, 2015). This concept will be adopted in this experiment by combining selected promising hybrids in mixed cropping systems that are able to increase crop productivity and comply with consumer's standards.

Study on application of mixed-variety cropping systems in chili pepper production in the farm levels in Indonesia is less reported. This cropping system is expected to allow farmers to grow more than two chilli

cultivars in a piece of land and hence will increase crop genetic diversity, reduce pest and pathogen attacks, and increase genetic adaptability to environmental changes. A Participatory Plant Breeding program must be established by involving local farmers in order to select leading chilli pepper cultivar that has high yielding traits and meet the consumer's preferences. A Participatory Plant Breeding (PPB) program was defined as plant breeding program in which users of breeding programs are actively involved, including farmers, traders, and food processing industries (Sperling *et al*., 2001). According to Weltzien and Christinck (2009), global PPB programs significantly increased adoption of new crop variety to the society since this approach was able to provide local based superiority of particular crop that have an ability to grow in less favour environmental condition and unique agronomical performances. In addition, PPB programs are able to accelerate innovation dissemination from university to the community. Introduction a new leading chili pepper variety to the farmers by using PPB approach is expected to easily be adopted by the farmers and consumers. Although PPB program has been well practiced in many international agriculture research agencies, the use of PPB program in Indonesia, especially in chili pepper breeding program, has not been widely practised.

This experiment aimed to determine the superior model for mixed cropping for chili pepper variety in Bengkulu through a participatory plant breeding program. This experiment is further expected to establish a model for chili pepper production in mixed-variety cropping system.

Materials and Methods

An experiment was conducted from March to July 2019, located in experimental site of Faculty of Agriculture, University of Bengkulu, Kota Bengkulu, Indonesia at 10 m above sea level. Experiment was located in area of chili pepper was generally cultivated and involved farmers/consumers in the process of hybrid selection. Selected hybrids were four promising chili pepper hybrids that resistant to Begomovirus, (1) UNIB CH13, (2) Dwiguna UNIB, (3) UNIB CH63, and (4) UNIB CH65. Hybrid seeds were prepared by crossing selected parental seeds and then were used as plant materials in this experiment.

Experiment was arranged in randomized completely block design with four replicates. Treatments consisted ten combinations of four selected chili pepper hybrids, planted in mono cropping or mixed copping amongst the selected hybrids, *i.e.* (1) K01=mono cropping of UNIB CH13, (2) K02=mono cropping of Dwiguna UNIB, (3) K03= mono cropping of UNIB CH63, (4) K04=mono cropping of UNIB CH65, (5) K05=mixed cropping of UNIB CH13 and Dwiguna UNIB, (6) K6=mixed cropping of UNIB CH13 and UNIB CH63, (7) K07=mixed cropping of UNIB CH13 and

UNIB CH65, (8) K08= mixed cropping of Dwiguna UNIB and UNIB CH63, (9) K09=mixed cropping of Dwiguna UNIB and UNIB CH65, (10) K10=mixed cropping of UNIB CH63 and UNIB CH65. Each hybrid combination was planted as many as 24 plants in each replication as suggested by Guidelines for Establishing Description of Horticultural Variety issued in 2011 by Directorate of Horticultural Seeds, Directorate General of Horticultural, Ministry of Agriculture, Republic of Indonesia.

Experimental sites were ploughed and harrowed manually and 30 soil beds for experimental plots were established. The size of experimental plot was 1 x 5m, separated with 0.5 m distance within the block and 1 m away between the blocks. Each plot was uniformly fertilized with 250 kg ha^{-1} Urea, 500 kg ha^{-1} TSP, kg ha^{-1} KCl. In addition, the soil beds were amended with 20 ton ha^{-1}cattle-based compost and covered with rice straw mulch.

Thirty days old seedlings were transplanted into the soil beds into a plant spacing of 0.5 x 0.5m. Each planting hole was planted with one chili pepper seedling accordingly and applied with five to ten pieces of Carbofuran-based insecticide at immediately after transplanting. Plant maintenances included watering, retransplanting, staking, weeding and pest controls were conducted accordingly during the course of growing season.

Plant samples, 20 % of plant population in each plot, were randomly determined. Observation variables were conducted as suggested by Directorate of Horticultural Seeds, Directorate General of Horticultural, Ministry of Agriculture, Republic of Indonesia, *i.e.,* plant height, stem diameter, number of branches, days to flowering, days to harvesting, canopy width, fruit length, length of fruit stalk, fruit diameter, thickness of fruit skin, weight of per fruit, total number of fruit per plant, fruit weight per plant and fruit weight per plot. Pathogen attacks were determined in term of damage intensity, expressed in percentage of attacked plant, P=$\frac{n}{N} \times 100\%$, where n=number attacked plants, and N=number of planted plants in each plot. Consumers/farmers were invited to participate in consumer preference surveys.

Quantitative data were subjected to analysis of variances, using SAS V9.1. Means of treatments were compared by using Duncan's Multiple Mange Test at 5% level of confidence.

Results

Chili pepper performances

Results indicated that treatments (cropping systems) significantly affected stem diameter, number of branches, fruit length, length of fruit stalk, fruit diameter, thickness of fruit skin, canopy width, fruit weight per plant and (Table 1). However, treatments did not significantly influence

plant height, days to flowering, days to harvesting, and total number of fruit per plant.

Table 1. Analysis variances summary of cropping systems on all observed variables

No	Observed Variables	Mean Square	F values
1.	Fruit length	19.58	22.82*
2.	Length of fruit stalk	1.19	8.29*
3.	Fruit diameter	2.19	9.84*
4.	Thickness of fruit skin	0.01	4.99*
5.	Canopy width	933714.4	3.75*
6.	Total number of fruit per plant	1511.83	1.19ns
7.	Fruit weight per plant	17777.76	3.39*
8.	Fruit weight per plot	6440388.2	2.52*
9.	Number of branches	1.46	3.15*
10.	Stem diameter	8.82	2.86*
11.	Plant height	109.39	1.52ns
12.	Days to flowering	0.33	0.83ns
13.	Days to harvesting	0.31	1.47ns
14.	Percentage of fusarium attacks	5,92	0,81ns
15	Percentage of leaf spot attacks	34,16	5,35*
16	Percentage of antraknosa attacks	13,42	0,87ns
17	Percentage of virus attacks	18,61	0,85ns

Notes: * = significant, ns = non-significant at 95 % level of confidence

Stem diameter of chili peppers in all treatments ranged from 8.55 to 14.73 mm. Chili pepper grown in mixed-variety cropping of UNIB CH13 and UNIB CH65 had the highest stem diameter, although it was not significantly different with those grown in mono cropping of Dwiguna UNIB (Table 2). The number of branches for chili pepper hybrids ranged from 3.25 to 5.6 branches. In addition, chili pepper hybrids grown in mixed cropping of UNIB CH13 and UNIB CH65 had the highest number of branches, although it was not significantly different with those grown in mono cropping of Dwiguna UNIB.

Results also indicated that chili peppers grown in mixed cropping of UNIB CH13 and Dwiguna UNIB had the longest fruit and fruit stalk, although it was significantly different with those grown in mono cropping of Dwiguna UNIB (Table 3). In term of fruit diameter, chili peppers grown in mixed cropping of UNIB CH13 and UNIB CH65, Dwiguna UNIB and UNIB CH63, Dwiguna UNIB and UNIB CH65, UNIB CH63 and UNIB CH65 and UNIB CH13 and Dwiguna UNIB had similar fruit diameter. However, fruit diameters of those mixed cropping were smaller than those grown in mono cropping of UNIB CH63. In addition, thickness of fruit skin of those grown in mono cropping of UNIB CH63 had the thickest fruit skin. However, all chili peppers grown in mixed cropping systems were not significantly different and lower that those grown in mono cropping of UNIB CH13 (Table 3).

Table 2. Effects of cropping systems on stem diameter and number of branches of chili pepper

Cropping systems	Stem diameter (mm)	Number of branches
Mono cropping of UNIB CH13	13.18^{ab}	4.58^{ab}
Mono cropping of Dwiguna UNIB	14.73a	5.67^{a}
Mono cropping of UNIB CH63	11.06^{bc}	3.67^{bc}
Mono cropping of UNIB CH65	11.94^{abc}	4.00^{bc}
Mixed cropping of UNIB CH13 and Dwiguna UNIB	10.92^{bc}	3.75^{bc}
Mixed cropping of UNIB CH13 and UNIB CH63	10.48^{bc}	3.83^{bc}
Mixed cropping of UNIB CH13 and UNIB CH65	12.06^{ab}	4.25^{bc}
Mixed cropping of Dwiguna UNIB and UNIB CH63	11.30^{bc}	3.25^{c}
Mixed cropping of Dwiguna UNIB and UNIB CH65	8.55^{c}	3.33^{bc}
Mixed cropping of UNIB CH63 and UNIB CH65	9.93^{bc}	4.17^{bc}

Note: Means in the same column followed by the same letter are not significantly different according to Duncan's Multiple Mange Test at 5%

Tabel 3. Effects of cropping systems on fruit length (FL), fruit stalk length (FSL), fruit diameter (FD) and thickness of fruit skin (TFS) of chili peppers

Cropping systems	FL (cm)	FSL (mm)	FD (mm)	TFS (mm)
Mono cropping of UNIB CH13	10.92^{bc}	3.99^{bc}	5.64^{c}	0.76^{bc}
Mono cropping of Dwiguna UNIB	13.24^{a}	4.29^{b}	6.66^{b}	0.79^{b}
Mono cropping of UNIB CH63	11.81^{ab}	4.25^{b}	8.11^{a}	0.92^{a}
Mono cropping of UNIB CH65	5.22^{f}	2.87^{d}	6.39^{bc}	0.70^{c}
Mixed cropping of UNIB CH13 and Dwiguna UNIB	13.25^{a}	5.01^{a}	5.73^{c}	0.77^{bc}
Mixed cropping of UNIB CH13 and UNIB CH63	10.54^{bc}	3.99^{bc}	4.79^{d}	0.72^{bc}
Mixed cropping of UNIB CH13 and UNIB CH65	8.23^{de}	3.29^{cd}	5.83^{bc}	0.78^{bc}
Mixed cropping of Dwiguna UNIB and UNIB CH63	10.53^{bc}	3.96^{bc}	6.27^{bc}	0.74^{bc}
Mixed cropping of Dwiguna UNIB and UNIB CH65	9.78^{cd}	4.46^{ab}	6.23^{bc}	0.76^{bc}
Mixed cropping of UNIB CH63 and UNIB CH65	7.35^{e}	3.33^{e}	6.31^{bc}	0.73^{bc}

Note: Means in the same column followed by the same letter are not significantly different according to Duncan's Multiple Mange Test at 5%

Chili peppers grown in mono cropping of UNIB Dwiguna had the widest canopy (2920.78 cm^2), although it was not significantly different with those grown in mixed cropping of UNIB CH13 and Dwiguna UNIB (2580.59 cm^2) (Table 4). Mono cropping of Dwiguna UNIB also had the highest fruit weight per plant (305 g) and fruit weight per plot (7920.59 g). However, the mixed cropping of Dwiguna UNIB had the highest canopy width, fruit weight per plant and fruit weight per plot (2580.59 cm^2, 274.32 g, and 5210.55 g, respectively) than those grown under other mixed cropping systems.

Table 4. Effects of cropping systems on canopy width, fruit weight per plant, fruit weight per plot of chili peppers

Cropping systems	Canopy width (cm)	Fruit weight per plant (g)	Fruit weight per plot (g)
Mono cropping of UNIB CH13	2487.45^{ab}	315.23^{abc}	6304.62^{ab}
Mono cropping of Dwiguna UNIB	2920.78^{a}	385.05^{a}	7920.59^{a}
Mono cropping of UNIB CH63	1919.08^{bcd}	344.07^{ab}	5051.75^{abc}
Mono cropping of UNIB CH65	1629.64^{b}	186.99^{cd}	3739.8b^{c}
Mixed cropping of UNIB CH13 and Dwiguna UNIB	2580.59^{ab}	274.32^{abcd}	5210.55^{abc}
Mixed cropping of UNIB CH13 and UNIB CH63	2102.87^{ab}	226.31^{bcd}	4526.05^{bc}
Mixed cropping of UNIB CH13 and UNIB CH65	1902.78^{bcd}	234.15^{bcd}	3968.95^{bc}
Mixed cropping of Dwiguna UNIB and UNIB CH63	2101.74^{abc}	209.08^{bcd}	4181.68^{bc}
Mixed cropping of Dwiguna UNIB and UNIB CH65	1134.10^{d}	134.72^{d}	2694.48^{c}
Mixed cropping of UNIB CH63 and UNIB CH65	1324.85^{cd}	208.89^{bcd}	4177.87^{bc}

Note: Means in the same column followed by the same letter are not significantly different according to Duncan's Multiple Mange Test at 5%

Major pathogen attacks

There were four major pathogens encountered to chili pepper cropping systems during this experiment, i.e., attacks of *Cercospora* sp., *Colletotrichum*, *Fusarium*, and *Begomovirus* (Table 5 and Figure 1). Results indicated that cropping systems had significant disease afftected by *Cercospora* sp, but not significantly affected by *Colletotrichum*, *Fusarium* and *Begomovirus* Table 5). Percentage disease incidence of *Cercospora* sp in all cropping systems ranged from 5.00 % to 16.67 %. Chili peppers grown in mixed cropping of UNIB CH13 and Dwiguna UNIB had the lowest infestation of *Cercospora* sp. (6.67%), although it was not significantly different with those of grown in monocropping of UNIB CH53. Meanwhile, chili pepper grown in a mono cropping of UNIB CH65 had the highest infestation of *Cercospora* sp. Symptom visualization of all pathogens infestations are presented in Figure 1.

Figure 1. Pathogen attack symptoms on chili pepper crops, [a] *Cercospora* sp, [b] *Fusarium*,[c] *Colletotrichum* and [d] *Begomovirus*

Table 5. Effect of cropping systems of chili pepper on percentage pathogen infestations

Cropping systems	Pathogen infestation (%)			
	Cerco-spora	Fusarium	Colleto-trichum	Begomo-virus
Mono cropping of UNIB CH13	13.33^{ab}	5.00^{a}	8.33^{a}	15.00^{a}
Mono cropping of Dwiguna UNIB	6.67^{d}	5.00a	10.00^{a}	13.33^{a}
Mono cropping of UNIB CH63	11.67^{bc}	6.67^{a}	6.67^{a}	10.00^{a}
Mono cropping of UNIB CH65	16.67^{a}	5.00^{a}	6.67^{a}	15.00^{a}
Mixed cropping of UNIB CH13 and Dwiguna UNIB	6.67^{d}	8.33^{a}	8.33^{a}	16.67^{a}
Mixed cropping of UNIB CH13 and UNIB CH63	13.33^{ab}	6.67^{a}	8.33^{a}	10.00^{a}
Mixed cropping of UNIB CH13 and UNIB CH65	8.33^{cd}	8.33^{a}	11.67^{a}	15.00^{a}
Mixed cropping of Dwiguna UNIB and UNIB CH63	11.67^{bc}	5.00^{a}	8.33^{a}	11.67^{a}
Mixed cropping of Dwiguna UNIB and UNIB CH65	11.67^{bc}	5.00^{a}	13.33^{a}	11.67^{a}
Mixed cropping of UNIB CH63 and UNIB CH65	15.00^{ab}	5.00^{a}	10.00^{a}	10.00^{a}

Note: Means in the same column followed by the same letter are not significantly different according to Duncan's Multiple Mange Test at 5%

Grower preference analysis

Results indicated that chili peppers grown in monoculture had more uniform in shape than those of grown in mixed cropping systems (Figure 2). From the growers point of view, hybrids of chili peppers from monoculture of UNIB CH13 was the most needed by growers, followed by those of from monoculture of UNIB CH53, and the third most wanted hybrids was chili peppers grown in mixed cropping of UNIB CH13 and Dwiguna UNIB. The basis of grower decision was both size and shape of chili peppers.

1 2 3

Figure 2. Performances of chili pepper fruits as affected by cropping systems; 1=mono cropping of UNIB CH13, 2=mono cropping of Dwiguna UNIB,3=mixed cropping of UNIB CH13 and Dwiguna UNIB

Discussion

It was revealed that chili peppers grown in mixed cropping of UNIB CH13 and UNIB CH65 and those grown in mono cropping of Dwiguna UNIB had the highest stem diameter. Such characteristics resulted in strong and robust plants, not easily uprooted and able to hold many fruits. According to Murniati *et al.* (2013), chili peppers with high stem diameter allow plants to have well-developed xylem and phloem which later increased water and nutrient absorption by leaves through xylem. Haice *et al.* (2013) concluded that stem diameter in chili peppers was genetically controlled.

Chili peppers grown in monocropping of both Dwiguna UNIB and UNIB CH13 had the highest number of productive branches. The number of productive branches reflected the number of fruit set in chili peppers since fruit organs served as the highest sinks received assimilates from photosynthetic organs. Research conducted by Setiawan *et al.* (2012) concluded that chili peppers with high number of branches were able to produce more fruits. Some researchers also reported that fruit weight of chili peppers in each plant was positively correlated with fruit number and fruit (Ganefianti *et al*., 2006; Sharma *et al.,* 2013). According to Sobir (1994), increased number of chilli pepper branches resulted in increased stem nodes and eventually increased the number of flowers and fruits. High number of branches is usually followed by wider crop canopy.

In relation to chili pepper yields, mixed cropping systems of UNIB CH13 and Dwiguna UNIB had the longest fruit (13.25 cm) compared to other cropping systems. This character is very important since the length of fruits determined the fruit quality and complied with consumer (Kirana *et al.,* 2014). Chili pepper crops with longer fruit produced heavier fruit weight (Ganefianti *et al.,* 2006). Research conducted by Ganefianti *et al.* (2017) found that fruit length of UNIB CH13 was 12.7 cm and UNIB CH53 was 13 cm. Previously, Febriansyah (2013) concluded that both UNIB CH13 and UNIB CH53 had fruit length of 14.68 cm and 16.06 cm, respectively. According to Badan Standardisasi Nasional (1998), a national board for product standardization, chili pepper will be classified into grade I if the fruit length ranged from 12 to 14 cm, 9 to 11 cm (grade II), less than 9 cm (grade III). It is therefore, fruits of those grown in mono cropping of UNIB CH53 and from mixed cropping of UNIB CH13 and Dwiguna UNIB are classified as grade I. Meanwhile, chilli pepper fruits from those grown in mono cropping of UNIB CH13 and from mixed cropping of Dwiguna UNIB and UNIB CH65 are classified as grade II. Finally, chilli pepper fruits from those grown in mono cropping of UNIB CH65 and from mixed cropping of UNIB CH13 and UNIB CH65 are classified as grade III.

Chili pepper fruits from those grown in mixed cropping of UNIB CH13 and Dwiguna UNIB was not only had the longest fruit length, but

also had the longest fruit stalks. These two characters are positively correlated, the longer fruit stalks, longer fruit length would be (Desita *et al*., 2015). Fruits from those grown in mixed cropping of UNIB CH13 and Dwiguna UNIB that had small in diameter and thin in fruit skin are preferable by consumers. From mixed cropping systems, growers preferred fruits grown in mixed cropping of these two hybrids compared to fruits from other cropping systems since those fruits had similar size and shape. With respect to fruits grown in mono cropping, growers preferred fruits from those grown in mono cropping of UNIB CH13 and followed by those grown in mono cropping of Dwiguna UNIB.

Results also suggested that chili peppers that had wide canopy also had high fruit weight per plant and fruit weight per plot. Such phenomenon was clearly shown in chili peppers that grown in mixed cropping system of UNIB CH13 and Dwiguna UNIB. Crops with wide canopy had high internodes and from each node produced a fruit. According to Kusmanto *et al.* (2014), chili peppers that had more branches and more internodes will produce more fruits since each node will produce a flower that eventually becomes a fruit.

With respect to pathogen attacks, chili pepper that grown in mixed cropping system of UNIB CH13 and Dwiguna UNIB had the lowest *Cercospora* sp attacks (6.67%) compared to other cropping systems. Garrett and Mundt (1999) reported that planting plant genotypes in mixed cropping were able to decrease the incidence of pathogen attacks. In addition, mixed cultivar cropping systems of wheat significantly reduced *Cercospora* sp attacks in three out of four year experiments (Cox *et al*., 2004).

Overall, the performances of chili pepper fruits grown in mixed cropping systems of UNIB CH13 and Dwiguna UNIB comply with first grade standard, thin fruit skin, medium in fruit diameter, widest canopy, highest fruit per plant and fruit per plot, less incidence of pathogen attacks led the growers prefer these fruits than those from other cropping systems. Another reason is a relatively no differences in fruits sizes and shapes of chili hybrids grown under this cropping systems. According to Rofidah *et al.* (2018), fruit size and fruit quality are among the major basis of consumer preferences to chili pepper fruits. Adiyoga (2012) also previously reported that consumer preferred medium fruit size to big or small chili pepper fruits. Since research conducted by Pramanta *et al.* (2017) concluded that selling price of many fruits increased by using fruit grading, fruit size of chili peppers must be taken into account in chili pepper agribusiness.

In conclusion, mixed cropping of UNIB CH13 and Dwiguna UNIB is the best hybrid combination compared to other hybrid combinations. Chili pepper fruits grown in this mixed cropping combination produced the best fruit length, widest canopy, highest fruit per plant and fruit per plot, fruits

complied with highest grade standard and had fewer incidences of pathogen attacks.

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