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Early yield responses of three promising chili pepper hybrids to different mulch types

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Abstract

High early yields of chili pepper is very important traits to gain economic return for farmers. Developing superior genotypes and using mulches are among promising methods to have high early yields of chili peppers. This experiment aimed to determine (1) early yields of three promising chili-pepper genotypes, (2) effects of mulch types on early yields of chili peppers and (3) the best combination of mulch type and chili pepper genotype for early yields. An experiment was conducted at Ultisol site and designed in a factorial randomized complete block design with three replicates. The first factor was three promising chili pepper genotypes; H23, H53, and H73. The second factor was the types of mulches; black-silver plastic, rice straw, empty palm-oil fruit bunch and no mulch. Early yields were expressed in terms of fruit number per plant, fruit weight per plant[1] (g) and average fruit weight (g). Results indicated that after five harvests, hybrid of H23 was the best genotypes to produce early yields of chili peppers. Fruit number and fruit weight plant^{-1} of chili pepper grown using both rice straw and empty palm-oil fruit bunch mulches were significantly higher than those of grown using black-silver plastic mulch and control plot. Overall, best average fruit weight early yields of chili peppers was found in hybrid of H23 grown in bare soil.

Keywords: Chili pepper, Promising genotypes, Early yields, Mulch

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Introduction

Chili pepper (*Capsicum annuum* L.) is a very important vegetable for Indonesian people with average consumption of 2.9 kg per capita per year (Farid and Subekti, 2012). Total annual consumption of chili pepper will continue to increase since the population number continues to increase. The significance of chili pepper is not only limited to household level, but also to national level as its extremely high selling price during market scarcity contributes to regional and national inflation. High selling price, but reasonable for consumers, is very important for farmers to ensure their farming sustainability. The price of chili pepper in Indonesian markets is very expensive when the products are less available in the market and drastically decreases during the peak harvesting season. Meanwhile, high early productions of chili pepper is very important to gain profitable economic values which could be attained by developing superior genotypes that have high early yields as well as using mulch to modify growing environments. Nsabiyera et al. (2012) concluded that there were significant differences among genotypes of chili pepper for earliness (days to 50% flowering and fruit maturity). The number of days to 50% flowering ranged from 24 days to 83 days, while days to 50% fruit maturity ranged from 54 days to 119 days, depended on genotypes and environmental conditions.

A study conducted by Bank of Indonesia (2007) revealed that harvest peak of chili pepper takes place at 30th day after first harvest and reaches 1-1.5 tons ha^{-1} for one harvest. Farmers generally harvest their chili pepper as much as 10-20 times with three days of interval, depends on environmental factors. However, after the sixth harvest prices usually go down as producers from the same and other regions flood the markets. Developing early maturing genotypes that have high harvest yields during the first four to five harvests would be very beneficial for the farmers. University of Bengkulu has successfully screened five promising chili-pepper genotypes (H13, H23, H43, H53 and H73) that are potentially grown well in low altitude growing environment (Fahrurrozi and Ganefianti, 2016; Ganefianti et al., 2017). Extending areas for chili-pepper production in lower altitude is expected to compensate the declining arable areas in high-land. In Indonesia, Ultisol is one of the major soil types found in many vegetable production areas of lowland altitude. This type of soil is generally characterized by low pH, high Al^{3+}, poor organic-C and P, as well as low cation exchange capacity (CEC) and base saturation (Santoso, 2006; Wagito et al., 2007) which eventually reduces crop growth and yields. Modifying growing environment is another way to improve early growth and yields of chili-pepper grown in Ultisol environments. Nsabiyera et al. (2012) suggested that effects of environmental differences and cultural practices may have caused genotypes earliness. Modifying growing environment might be beneficial to have superior early yields of chili pepper. Lamont (2005) and Ibarra-Jimenez et al. (2004), resumed that use of plastic mulches has shown earlier (7 to 14 days) and increased yields (two to three times) over bare soil in many vegetable crops.

According to Gimenez et al. (2002) mulching plants with plant residues and synthetic material are well-established techniques for increasing the profitability of many horticultural crops. The use of mulch (either plastic or organic) to modify growing environment has been widely practiced to produce chili peppers (Fahrurrozi et al., 2006; 2009) and bell peppers (Law et al., 2006; Diaz-Perez, 2010) and had been reported to accelerate early growth and early yields of chili peppers (Iqbal et al., 2009). Mulches modify growing environment by preventing nutrient leaching and soil compacting, conserving soil moistures in rhizospheres, suppressing weed growth and pest attacks (Lamont, 2005) and bathing crops with carbon dioxide (CO_2) through planting holes (Soltani et al., 1995), resulted from soil respiration under mulch (Aziz et al., 2001a). The use of plastic mulches also modifies the light spectral balance in the crop canopy (Diaz-Perez, 2010). Such modifications bring about positive effects to chili pepper growth and yields by creating favorable microenvironment through retaining soil moisture, changing root-zone temperatures and altering light quantity and quality reflected to the plants. However, very rare studies have focused on responses of chili pepper genotypes to mulching, especially in the efforts to increase early yields of chili pepper.

This experiment aimed to determine early yields of three promising chili-pepper genotypes, effects of four types of mulch on early yield of chili peppers and the best combination of mulch type and chili pepper genotype for early yields.

Material and Methods

An experiment was conducted from September 2014 to January 2015 at Ultisol site of 28 m above sea level in experimental site of Faculty of Agriculture, University of Bengkulu, Indonesia (3º 45'18" South Latitude, 102º 16'19" East Longitude), designed in a factorial randomized complete block design with three replicates. The first factor was three promising genotypes of chili peppers developed by University Bengkulu; (1) H23, (2) H53 and (3) H73. The second factor was the types of mulches; (1) black-silver plastic mulch, (2) rice straw mulch (3) empty palm-oil fruit bunch mulch, and (4) no mulch.

Experimental site was cleared, ploughed, and harrowed before 36 soil beds of 1 x 6 m were established. Rice-straw mulch and empty palm-oil fruit bunch mulch were chopped into smaller pieces, dried and uniformly applied at the 5-cm thickness to cover the soil beds. Black-silver plastic mulch of 0.03 mm in thickness was stretched over the soil bed, secured into the soil. Plant spacing was double row of 0.5 x 0.5 m to make 24 plants per plot. A week before transplanting, each planting hole was fertilized with 0.35 kg goat manure and 5 g NPK (16:16:16). The seedlings of each genotype (4-week-old, 6-8 true leaves) were transplanted into the planting holes. Every week plants received fungicide application (mancozeb 85%), insecticides profenofos 550 g L^{-1} and imidakloropid 220 g L^{-1} and the application was discontinued at the time of flowering.

Harvesting of chili peppers was started when 50% of fruits in the plots turned reddish, conducted at five days of interval. Early yields, accumulation of first five harvests were expressed in terms of fruit number $plant^{-1}$, fruit weight $plant^{-1}$ (g) and average fruit weight (g). Rainfall data was taken from the closest meteorological station. Morning (06.00 hours) and day-time (14.00 hours) soil temperatures at the depth of 5-8 cm were recorded. Soil nutrient analysis (Al-*exchangeable*, pH (H_2O), organic-C (%), Total-N (%), P_2O_5 (ppm), K (me/100 g^{-1}) was conducted before fertilizing and after harvesting. Data were statistically analyzed by using PROC GLM in Statistical Analysis System version 9.1.3 at $P < 0.05$.

Results and Discussion

Environmental conditions

Monthly rainfalls on September, October, November, December, and January were 66 mm, 230 mm, 542 mm, 185 mm and 406 mm, respectively. Morning and day-time soil temperatures under no mulch treatment were 28.7 and 33.5 °C, respectively, while under black-silver plastic mulch were 28.5 and 31.4 °C. In addition, morning and day-time soil temperatures under rice straw mulch were 27.8 and 30.8 °C and those under empty palm-oil fruit bunch mulch were recorded at 28.1 and 30.5 °C, respectively.

Soil nutrient properties under mulching systems were also measured at before planting and after harvesting (Table 1). Overall, drastically changes in soil nutrient properties were noticed in terms of soil *exchangeable*-Al and P_2O_5. Decreased *exchangeable*-Al and *exchangeable*-P might have related to high content of P_2O_5 in goat manure applied to the soil before planting. Goat manure contained more than 2001 mg kg^{-1} available P (Uwah and Eyo, 2014) and might have accumulated P in the soil-beds, resulted in high concentration of P_2O_5 in the soils. High P in soil-beds might have responsible to decrease Al-*exchangeable*, since this metal might have bonded with P. Soil pH increased after the chili peppers were harvested. Such increased might have related to additional goat manure applied before planting in all experimental plots. Soil C-organic only increased in soil beds applied with rice straw mulch and empty palm-oil fruit bunch mulch. It appeared that these organic mulches supplied additional organic-C to mulched soils. Total-N and K of mulched soils generally increased over the growing season. Increased of N-total and K might have attributed to supply from goat manure (Uwah and Eyo, 2014), the ability of plastic mulch to prevent nutrient loss through percolation (Lamont, 2005), and additional supply from organic mulches (Hill et al., 1982).

Table-1: Soil nutrient properties before planting and after harvesting

Soil properties	Before Planting	After Harvesting*			
		M_0	M_1	M_2	M_3
Al-*exchangeable* (%)	3.03	0.00	1.84	1.82	2.42
pH (H_2O)	4.41	5.29	4.60	4.95	4.85
Organic-C (%)	15.46	13.32	11.73	17.37	16.87
Total-N (%)	0.17	0.24	0.22	0.17	0.27
P_2O_5 (ppm)	6.22	95.96	44.76	29.87	29.56
K (me/100g^{-1})	0.50	0.56	0.65	0.59	0.87

*M_0=no mulch, M_1=black-silver plastic mulch, M_2=rice straw mulch, M_3=empty palm-oil fruit bunch mulch.

Hybrid responses

Hybrids of chili pepper significantly influenced average of fruit weight (P≥F= 0.0097), but not fruit number $plant^{-1}$ (P≥F= 0.8437) and fruit weight $plant^{-1}$ (P≥F= 0.8626). Summary of analysis variance is presented in Appendix 1. The average fruit weight of H23 was the highest compared to those of H53 and H73 (Table 2). With respect to total fruit number and fruit weight $plant^{-1}$, it appeared that H23, H53 and H73 genotypes had similar fruit number and weight. This result implied that superiority of H23 in term of individual fruit weight had nothing to do with total fruit number and fruit weight $plant^{-1}$.

Higher average fruit weight of H23 over other genotypes was previously reported by Ganefianti et al. (2017) where H23 had shorter days to flowering and harvesting compared to H53 and H73 genotypes. These characters of H23 genotype might have induced fruit growth during the early harvesting period, resulting in increase of individual pepper weight. According to Barchenger et al. (2018) individual yield components of chili pepper such as fruit length, width, and weight were influenced more strongly by pepper genotype.

Table-2: Effects of chili pepper hybrids on fruit number plant^{-1}, total fruit weight plant^{-1} and average fruit weight

Hybrids	Total fruit number plant^{-1}	Total fruit weight plant^{-1} (g)	Average fruit weight (g)
H23	43.8 a	237.1 a	5.8 a
H53	45.5 a	220.2 a	5.1 b
H73	47.0 a	228.3 a	5.1 b

Note: Means in the same column followed by the same letter are not significantly different according to Least Significant Difference at 5%

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Effects of mulching

The use of mulches significantly influenced fruit number (P≥F= 0.0020) and fruit weight plant^{-1} (P≥F= 0.0050), but not average fruit weight (P≥F= 0.0888) (Appendix 1). Total fruit number of chili pepper grown using rice straw and empty palm-oil fruit bunch mulches were significantly higher than those of grown using black-silver plastic mulch and bare soil (Table 3). Similar trend was also noticed on total fruit weight plant^{-1}. However, the average fruit weight of chili pepper grown in bare soil was as good as with those of grown in rice-straw and empty-palm oil fruit bunch mulches.

Higher total fruit number of chili pepper grown using both organic mulches compared to those of grown using black-silver plastic mulch and bare soil might be related to lower soil temperatures recorded under these types of mulches. According to Panayotov et al. (2006) *in* Yordanova and Gerasimova (2015), optimum soil temperature for chili pepper rooting ranged from 18-22 °C. Soil temperatures under organic mulches from this experiment were lower than those of under plastic mulch and bare soil, hence increased fruit sets and fruit numbers. Aziz et al. (2001b) and Laulina and Hasan (2018) reported that soil temperatures under plastic mulch were significantly higher than those of under bare soil.

Table-3: Effects of mulching on fruit number plant^{-1}, total fruit weight plant^{-1} and average fruit weight of chili pepper hybrids

Types of mulches	Total fruit number plant^{-1}	Total fruit weight plant^{-1} (g)	Average fruit weight (g)
Bare soil (no mulch)	39.2 b	213.0 bc	5.7 a
Black-silver plastic	32.1 b	151.6 c	5.0 a
Rice straw	56.8 a	288.5 a	5.6 a
Empty palm-oil fruit bunch	53.5 a	261.0 ab	5.2 a

Note: Means in the same column followed by the same letter are not significantly different according to Least Significant Difference at 5%

In addition, increased fruit number might be related to the ability of organic mulch in conserving soil moisture content, lowering soil temperatures, preventing soil compaction (Yordanova and Gerasimova, 2015; Teame et al., 2017). Favorable soil temperatures and sufficient soil moisture in rhizosphere benefit chili pepper fruit sets, since most determinate crops, including chili pepper are very sensitive to water deficit during flowering (Decoteau, 2000). The ability organic mulches to conserve soil moisture, accompanied with lowering soil temperatures, might have improved the fruit sets and eventually increased fruit number. According to Techawongstein et al. (1992) and Christopher et al. (2011) water availability in the rooting zone profoundly influenced chili pepper growth and development, including flowering. In addition, positive response of these two types of organic mulches might be related to the facts that soil organic-C of those under rice straw and empty palm-oil fruit bunch mulches were higher than those of under plastic mulch (Table 1). Berke et al. (2005) stated that chili pepper growth and development require soil pH in the range of 5.5-6.8.

Furthermore, higher fruit number and total fruit weight plant^{-1} of chili pepper grown using both rice straw and empty palm-oil fruit bunch mulches might have attributed to higher organic-C of those under rice straw and empty palm-oil fruit bunch mulches (Table 1). Soil organic-C refers only to C component of organic compounds and about 58% of organic matter mass exists as C (USDA, 2009). Previous research indicated that increased soil organic matter increased fruit number and fruit weight of chili pepper (Khandaker et al., 2017). Research conducted by Mochiah et al. (2012) confirmed that the use of straw mulch induced flowering and fruit number in pepper compared to other organic and plastic mulches. Early flowering of chili pepper grown in rice straw and empty palm-oil fruit bunch mulches concurrently induced the number of fruit sets. Results from this experiment indicated that chili pepper grown using rice straw mulch had the same average fruit weight with those of grown using empty palm-oil fruit bunch mulch and control plots.

Table-4: Interaction effects of hybrids and mulching on fruit number plant^{-1}, total fruit weight plant^{-1} and average fruit weight of chili pepper hybrids

Interactions	Total fruit number plant^{-1}	Total fruit weight plant^{-1} (g)	Average fruit weight (g)
H23 in bare soil	37.17 a	248.83 a	7.10 a
H23 in black-silver plastic	21.87 a	113.90 a	5.11 bc
H23 in rice straw	63.73 a	330.73 a	5.90 b
H23 in empty palm-oil fruit bunch	52.43 a	254.87 a	5.14 bc
H53 in bare soil	38.46 a	180.58 a	4.80 c
H53 in black-silver plastic	35.15 a	165.80 a	4.90 c
H53 in rice straw	51.83 a	255.24 a	5.42 bc
H53 in empty palm-oil fruit bunch	56.66 a	279.24 a	5.34 bc
H73 in bare soil	42.20 a	209.56 a	5.07 bc
H73 in black-silver plastic	39.30 a	175.13 a	5.07 bc
H73 in rice straw	54.97 a	279.60 a	5.32 bc
H73 in empty palm-oil fruit bunch	51.47 a	248.92 a	5.11 bc

Note: Means in the same column followed by the same letter are not significantly different according to Least Significant Difference at 5%

Interaction effects

There was an interaction between hybrids and mulching on the average of fruit weight (P≥ F= 0.0190), but not in fruit number plant^{-1} (P≥ F= 0.6578) and fruit weight plant^{-1} (P≥ F= 0.6914) (Appendix 1). The average fruit weight of H23 grown in bare soil was the highest among the treatments (Table 4), followed by those of H23 grown in rice straw mulch.

Genotype of H23 grown in bare soil had the highest average fruit weight was a surprising result since both organic and synthetic mulches is well documented to increase chili pepper yields. Ganefianti et al. (2017) reported that genotype of H23 have better fruit length, fruit diameter, fruit weight, fruit weight per plant compared to H53 and H73 genotypes and grew well in Ultisol without the presence of mulches.

Conclusion

It was concluded from this study that genotype of H23 was the best chili pepper genotype to produce early yields. Rice straw and empty palm-oil fruit bunch mulches were the most effective mulches to promote early yields of chili peppers. Genotype of H23 grown in bare soil produced the highest average of fruit weight

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Appendix-1: Summary of Analysis of Variance fruit number plant^{-1}, fruit weight plant^{-1}, and average fruit weight

Source of Variations	degree of freedom	Sum of Squares	Mean Square	F Value	Pr > F
Fruit number per plant					
Model	13	7479.8914	575.3763	3.18	0.0082
Error	22	3978.7469	180.8521		
Corrected Total	35	11458.6363			
Hybrids	2	61.9338	30.9669	0.17	0.8437
Mulches	3	3703.6403	1234.5468	6.83	0.0020
Hybrids*Mulches	6	751.8741	125.3123	0.69	0.6578
Block	2	2962.4433	1481.2216	8.19	0.0022
Fruit weight per plant					
Model	13	297155.6274	22858.1252	3.98	0.0022
Error	22	126307.1287	5741.2331		
Corrected Total	35	423462.7560			
Hybrids	2	1708.4287	854.2143	0.15	0.8626
Mulches	3	97306.1441	32435.3814	5.65	0.0050
Hybrids*Mulches	6	22315.6434	3719.2739	0.65	0.6914
Block	2	175825.4112	87912.7056	15.31	<.0001
Average fruit weight					
Model	13	24.7341	1.9026	5.79	0.0002
Error	22	7.2270	0.3285		
Corrected Total	35	31.9611			
Hybrids	2	3.7829	1.8915	5.76	0.0097
Mulches	3	2.4329	0.8110	2.47	0.0888
Hybrids*Mulches	6	6.4290	1.0715	3.26	0.0190
Block	2	12.0893	6.0446	18.40	<.0001

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Contribution of Authors

Fahrurrozi F: Conceived idea, conducted experiments and article write up and final approval
Ganefianti DW: Conducted experiments, helped in write up and data analysis