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RESPONSE OF RED CHILLI VARIETIES UNDER DROUGHT STRESS

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ABSTRACT
Red chilli (*Capsicum annuum* L.) is the vegetable commodity that is widely cultivated in Indonesia. Growth and yields of the plants may be hampered by drought stress. The research to evaluate the effect of drought stress to agronomical and physiological characteristics of red chilli was done from October 2015 to April 2016 in a screen house of the Horticulture Seed Centre, Jambi Province, Indonesia. The Split Plot Design was used in this research with drought stress as main plot (100%, 75%, 50% of field capacity, FC) and chilli varieties as sub plot (Lado, Kastilo, BCA, Tanamo, Laris, Romario, Ferosa, Azimuth). The maximum decrease of growth and yield was recorded under the high level of water stress (50% FC) compared to optimum water supply (100% FC). The tolerance chilli varieties will increase the proline content and maintain the total sugar and chlorophyll content. Tanamo, Lado, Kastilo and BCA are varieties that can survive under drought stress and still provide the higher yield.

KEY WORDS
Agronomy, physiology, drought, red chilli, Capsicum annuum.

Red chilli (*Capsicum annuum* L.) is one of the commodities of vegetables that have an important meaning because it has economic value and high nutrient content in Indonesia. In Indonesia, red chilli production in 2015 is 1.045.182 ton, and its productivity is 8.65 ton per hectare (Ministry of Agriculture, 2016). Global warming and climate change that is occurring today cause the limited water availability for crops, this is an obstacle in efforts to increase production and productivity of red chilli (Budiastuti, 2010).

The inadequacy of availability of water will cause drought stress to plants. Drought stress is one of the factors that can impede seriously cultivated area production and it is also considered as a severe threat for sustainable crop production in conditions of climate change (Anjuum *et al*., 2011; Hammad and Ali, 2014).

The plant will respond to the drought by changing its morphological and physiological characteristics. The growth of plant shoot, crop growth rate, number and leaf area, plant fresh and dry weight are decreased caused by drought (Abdalla, 2014). The increasing of proline concentration to the plants is a mutation of plant physiological characteristics that experiences drought stress (Djazuli, 2010).

The intensity of drought, the length of drought, species and the genotype of plants are the factors can be affected yields losses from drought (Demirevska *et al*., 2009). Decreasing water availability to 40% filed capacity for three months reducing fresh weight and dry weight of purwoceng (*Pimpinella* pruatjan Molk.).

The improvement of plant characteristics related to adaptation to the environment experiencing water stress or use of crop varieties that are tolerant to drought stress is an effort that can be done to reduce losses from drought (Abdul Malik, 2012; Sumartini, *et al*., 2013).

The assessment of the character changes in agronomy and physiology in the various varieties of red chilli in different levels of drought stress needs to be done to get red chilli varieties that are tolerance to drought stress. This research was aimed to evaluate the agronomical and physiological changes that occur on different varieties of red chilli in different levels of drought stress.

MATERIALS AND METHODS OF RESEARCH

The research was conducted in a screen house of the Horticulture Seed Center, Sungai Tiga, Jambi ($101^\circ10'$- $104^\circ55'$BT – $0^\circ45'$ - $2^\circ45'$LS) Indonesia, started from October 2015 until April 2016, using a Split Plot design in three replications. The main plot were three drought stress level (based on soil water content /field capacity, FC), i.e. 100% FC; 75% FC and 50% FC. The determination of soil water content was calculated gravimetrically. The sub plot was red chilli varieties, i.e. Lado, Kastilo, BCA, Tanamo, Laris, Romario, Ferosa, and Azimuth. Selection of varieties based on popular varieties.

Drought stress is given from planting to harvest (0 Week After Planting / WAP to 15 WAP). Determination of soil water content using the gravimetric method with a formula:

$$Ka_1 = 100\% \, (Bt - BtKON)/BtKON$$

The weight of soil + water in each treatment is as follows:

$$100\%\ FC = (Ka_2 \times BtKON) + BtKON$$
$$75\%\ FC = Bt + [(75\% \times Ka_2) - Ka_1] \times BtKON$$
$$50\ \%\ FC = Bt + [(50\% \times Ka_2) - Ka_1] \times BtKON$$

Ka_1 is the first soil water content; Ka_2 is water content at field capacity (100% FC); Bt is soil weight/pot at the first soil water content and BtKON is soil dry weight.

The red chilli seeds were sown in seedling media and after the seedlings were 10 days old, they were transferred to the nursery until the age of 3 weeks, and then they were planted in 25 x 40 cm of 10 kg soil of polybag. Media for the seedbed nursery and cultivation used was a mixture of soil, sand, and compost (2:1:1). The plants were nourished by a standard method of red chilli care in a polybag.

The observation was done at the age of 4 and 8 weeks after planting (WAP) toward plant agronomy, i.e. a number of branches, shoot dry weight, root dry weight, fruit number, and fruit weight. Proline content, total sugar, and leaf chlorophyll at 8 WAP were physiology parameter observed. The method of Bates *et al.* (1973) was used to measure of proline content of fresh leaves. Total sugars were measured according to Irigoyen *et al.* (1992), and total chlorophyll was determined by immersion methods (Hall and Rao, 1987).

The data was analyzed using analysis of variance (ANOVA). Least Significant Different Test was used to see the difference of drought stress level, its varieties, and interaction, and the simple correlation of Pearson was also used to see the relationship between two pairs of parameters. Stress Susceptibility Index (SSI) is calculated using equation according to Fisher and Maurer (1978):

$$SSI = (1 - (Ys/Yp)) / (1 - (\hat{Y}s / \hat{Y}p));$$

Ys and Yp = observation value for one variety of drought stress and optimal conditions;
$\hat{Y}s$ and $\hat{Y}p$ = observation value for all varieties of drought stress and optimal conditions.

RESULTS AND DISCUSSION

Effect of drought stress on plant agronomy. The result showed that the drought stress has not significantly different on parameters at 4 WAP but has significant different on branch number, shoot dry weight, fruit number, and fruit weight, except on root dry weight at 8 WAP. Drought stress at 75% FC decreased branch number of red chilli 26.37% (75% FC), and 58.93% (50% FC) compared to 100% FC. The highest decrease of branch number at 75 % FC is Kastilo and the lowest is Ferosa, while BCA is the highest decrease and Ferosa is the lowest at 50% FC (Table 1).

Table 1 – Reduction of branch number and shoot dry weight of red chilli varieties at drought stress levels

Level of drought	Reduction (%)								Average of reduction (%)
	Lado	Kastilo	BCA	Tanamo	Laris	Romario	Ferosa	Azimuth	
				….branch number…					
75% FC	31.53	42.41	28.90	21.72	34.52	30.72	6.20	14.95	28.37
50% FC	54.19	52.53	69.94	54.04	65.99	62.09	51.94	60.75	58.93
				…shoot dry weight…					
75% FC	25.96	26.16	32.04	29.60	20.75	11.42	10.32	26.48	22.84
50% FC	31.49	45.85	56.37	44.89	40.64	53.63	31.47	39.13	42.94

The decline in the number of branches large enough from BCA at 50% FC in line with the number of branches produced (17.33). Ferosa produces branch number is 20.67 (Fig. 1).

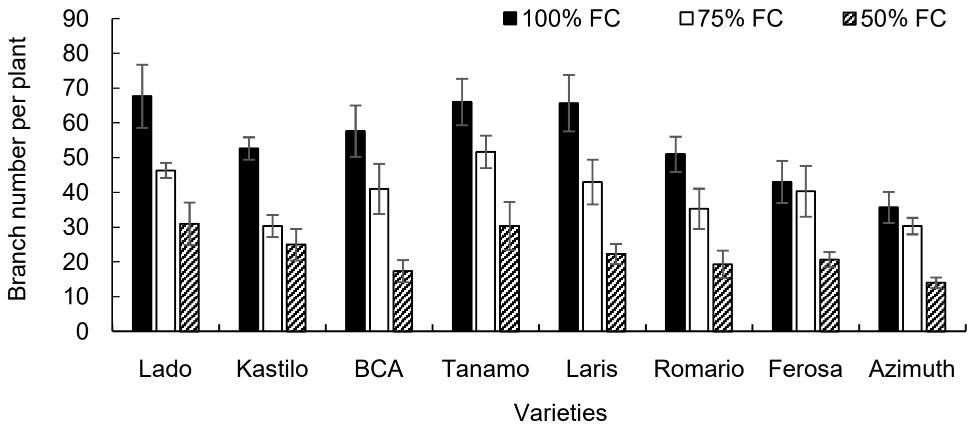

Figure 1 – Branch number of red chilli varieties at drought stress levels at 8 WAP. Error bars indicated standard error (n = 3)

Increase drought stress lowered shoot dry weight at 75% FC (22.84%) and 42.94% (50% FC). The biggest decrease of shoot dry weight of 50% FC is BCA and smallest is Ferosa (Table 1). Dry weight decreased of Kastilo at 75% FC and 50% FC is smaller than BCA. Tanamo gave a relatively similar response to Kastilo.

The dry weight of red chilli varieties at various levels of drought stress can be seen in Figure 2. The varieties of Kastilo and Tanamo have higher shoot dry weight (8.50 and 8.80) than BCA (7.62) at 50% FC.

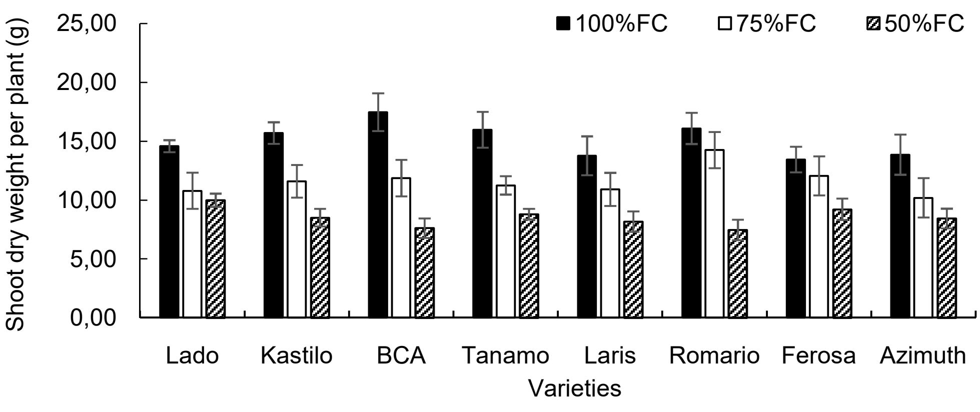

Figure 2 – Shoot dry weight of red chilli varieties at drought stress levels at 8 WAP. Error bars indicated standard error (n = 3)

Reduced of water supply to plants or the transpiration rate increase caused drought stress (Anjuum *et al.*, 2011). The plants will respond the shortage of water by lowering water content, decreasing the potential of water, leaf and cell turgor, closing the stomata, reducing the expansion and cell growth (Jaleel *et al.*, 2002), that caused lowering growth and dry matter accumulation (Delfine *et al.*, 2002). The result showed that drought stress condition will reduce the number of branches, followed by decreasing the shoot dry weight. The lowering of shoot dry weight was positively correlated with the number of branches of red chilli with r = 0.829 (p<0.01) (Table 3).

Root dry weight was not significantly affected by drought stress and varieties. Drought stress decreased root dry weight at 0.0005% (75% FC) and 0.0018% (50% FC) (data not shown). The root length of peanuts did not effect by drought stress. The red chili tends to maintain the volume and root length at a certain depth to withstand drought stress (Riduan *et al.,* 2005).

Drought stress decreased the number of fruit at 75% FC (7.71%) and 29.50% (50% FC). The decline in the fruit number of Kastilo, BCA, and Tanamo was smaller than the others varieties (Table 2).

Table 2 – Reduction of fruit number and fruit weight of red chilli varieties at drought stress levels

Level of drought	Reduction (%)							
	Lado	Kastilo	BCA	Tanamo	Laris	Romario	Ferosa	Azimuth
….fruit number……								
75% FC	5.00	4.95	-1.25	5.08	4.55	20.55	3.08	19.75
50% FC	37.50	16.83	18.75	19.49	31.82	36.99	27.69	46.91
…..fruit weight ………								
75% FC	-2.23	6.52	-2.63	5.66	6.12	24.22	10.48	18.32
50% FC	32.98	19.97	18.50	20.69	33.03	39.09	43.75	45.99

The decrease in the number of fruits in the varieties of Kastilo, BCA and Tanamo produced more fruits than other varieties (Figure 3). The correlation analysis showed that the decrease in the number of fruit was more affected by the decrease in the number of branches compared with the decrease of shoot dry weight (r = 0.642, r = 0.429, p <0.01) (Table 3).

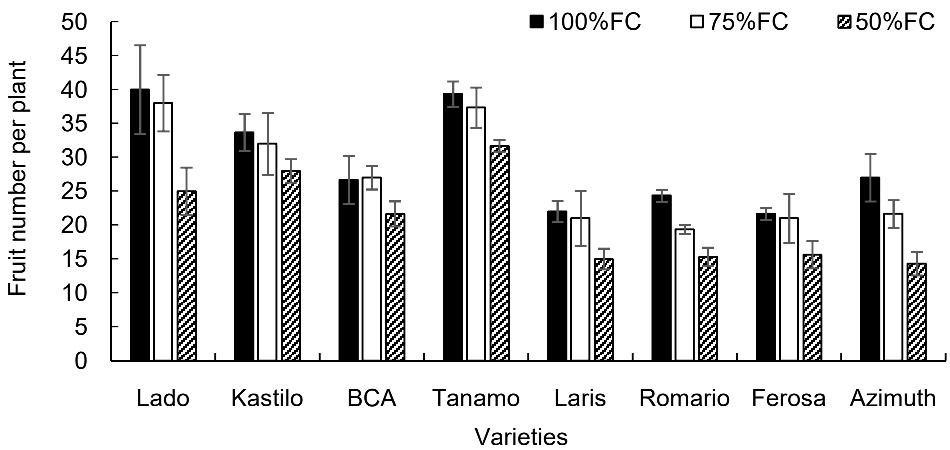

Figure 3 – Fruit number of red chilli varieties at drought stress levels.
Error bars indicated standard error (n = 3)

The branches number of red chilli greatly affects the number of flower buds produced because the flower buds on red chilli will appear on each branch (Poulos, 1994). Drought stress on some cultivars of sweet red chilli affects the number of flower buds, the percentage of flowers fall, the percentage of fruit set and fruit production (Abdulmalik *et al.,* 2012). A decrease in the amount of tested fruit on the varieties of red chilli may also cause by the lowering of flower buds and increased flower fall percentage due to drought stress. The amount of fruit per plant on cultivar chilli "*low and medium pungent*" in drought stress is significantly lower than without drought stress (Phimcan *et al*., 2012).

The fruit weight of red chilli was decreased by drought stress at 8.31% (75% FC) and 31.75% (50% FC) (Table 2). The decline of fruit number caused by the decrease of fruit number because of drought. Fruit weight is closely related to the number of branches and the number of fruits with r respectively is 0.554 and 0.988, but it was not significantly correlated to shoot dry weight (r = 0.348) (Table 3).

Table 3 – The correlation coefficient between growth parameters at 8 WAP and yield at various of drought stress

Parameters	Branch number	Shoot dry weight	Root dry weight	Fruit number	Fruit weight
Branch number	-	0.829**	0.430*	0.642**	0.554**
Shoot dry weight		-	0.683**	0.429*	0.307tn
Root dry weight			-	0.195tn	0.094tn
Fruit number				-	0.988**

Fruit number of red chilli varieties can be seen in Figure 4. Tanamo, Kastilo, and BCA have more fruit weight than the other varieties at 50% FC, except Lado.

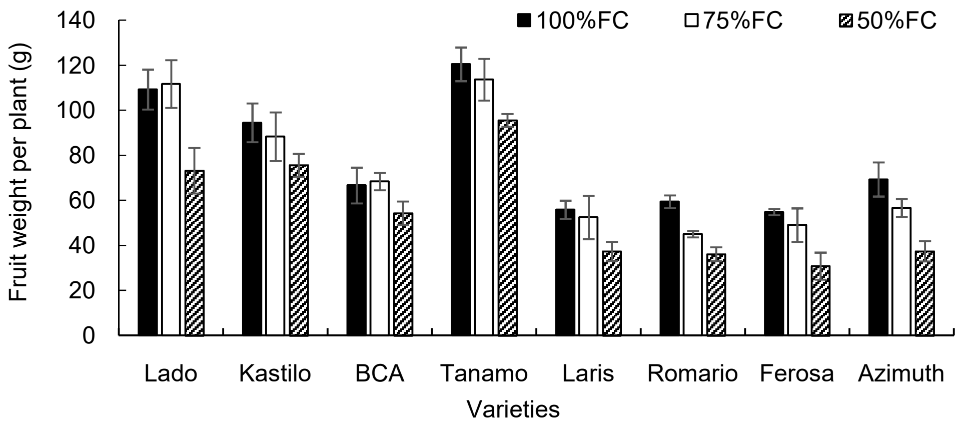

Figure 4 – Fruit weight of red chilli varieties at drought stress levels.
Error bars indicated standard error (n = 3)

The growth parameter that has a closer correlation to the number and weight of the fruit than other parameters is a number of branch. The decrease of branch number in drought stress 50% FC is greater than 75% FC. Because of that, the number of branches at 50% FC can be used to filter the tolerance of red chilli to drought.

The plant susceptibility index to drought stress (SSI) calculated based on the number of branches, the number of fruits and the fruit weight at 50% drought of KL can be seen in Table 4.

Table 4 – SSI of eight red chilli varieties at 50% FC based on branch number at 8 WAP and plant yield

Parameter	SSI							
	Lado	Kastilo	BCA	Tanamo	Laris	Romario	Ferosa	Azimuth
Branch number	0.92 (T)	0.89 (T)	1.18 (P)	0.92 (T)	1.12 (P)	1.05 (P)	0.88 (T)	1.03 (P)
Fruit number	1.29 (P)	0.58 (T)	0.65 (T)	0.67 (T)	1.10 (P)	1.28 (P)	0.96 (T)	1.62 (P)
Fruit weight	1.11 (P)	0.67 (T)	0.62 (T)	0.70 (T)	1.11 (P)	1.32 (P)	1.48 (P)	1.55 (P)

The letters in parentheses indicate tolerance grouping into tolerant (T) if SSI <1.0 and sensitive (P) if SSI ≥ 1.0

Based on SSI in Table 4, BCA, Kastilo, Tanamo and Ferosa are drought tolerant varieties, while Lado, Laris, Romario and Azimuth are sensitive. The drought tolerant varieties have fruit weight greater than the sensitive with smaller yield decreases except for Ferosa (Figure 4 and Table 2).

Effects of drought stress on plant physiology. The results showed that drought stress generally increases the levels of proline content at 4.79% (75% FC) and 62.28% (50% FC) (data not shown). Proline accumulation in plants is important in the effort to plant tolerance to osmotic stress (Shao, *et al.,* 2005). Proline helps the plant reduce oxidative damage, and this is an important strategy for plants to withstand drought stress (Vendruscolo *et al.,* 2007; Chegah, *et al.,* 2013). Drought stress in various rice varieties increases the proline content (Maisura *et al.* 2014).

The proline content of BCA, Kastilo, Tanamo, and Ferosa increased with increasing drought (Table 5). The proline content of drought tolerant varieties is relatively higher compared to the sensitive varieties.

Table 5 – The content of proline, total sugar and red chilli chlorophyll at drought stress levels at 8 WAP

Level of drought	Varieties							
	Lado	Kastilo	BCA	Tanamo	Laris	Romario	Ferosa	Azimuth
				….prolin (mM/g)……				
100% FC	0.26	0.20	0.19	0.25	0.20	0.15	0.13	0.29
75% FC	0.11	0.24	0.32	0.27	0.16	0.16	0.36	0.13
50% FC	0.10	0.36	0.36	0.27	0.21	0.12	1.08	0.21
				….total sugar (mg/g)…				
100% FC	42.17	45.47	41.79	50.00	32.92	35.28	36.04	46.51
75% FC	27.14	27.27	21.69	33.77	49.16	25.65	39.87	37.6
50% FC	11.36	20.91	20.82	23.55	18.36	20.45	38.27	28.91
				...total chlorophyll (cm^2/ml)…				
100% FC	56.04	49.46	56.04	56.09	45.38	58.41	65.61	41.90
75% FC	43.86	46.65	54.62	52.19	64.04	59.02	51.10	53.73
50% FC	44.93	46.55	53.29	53.35	62.15	44.28	56.67	60.83

Drought stress treatments lower total sugar content of almost all varieties of red chilli except Ferosa that has relatively constant (Table 5). Alfalfa total sugar content increase in mild drought, but with increasing drought stress, the total sugar content decreased compared with the plant under optimal conditions (Irigoyen *et al*., 1992). The decrease of total sugar content of Kastilo was higher compared with Tanamo (52.90%) and BCA (50.18%) at 50% FC (data not shown). Liu *et al*. (2011) found that intensive and prolonged drought would inhibit the accumulation of total sugar in two species of shrubs and four tree species.

Chlorophyll content of red chili varieties decreased with increasing drought. The decrease in chlorophyll content of drought tolerance red chilli varieties smaller than other varieties (Table 5). The sensitive varieties to drought stress have inability to chlorophyll synthesis (Sikuku *et al.* (2010).

The mechanism of red chilli tolerance to drought stress seems to be done by increasing the proline and maintaining its total sugar and chlorophyll content.

CONCLUSION

Sufficient water supply is fundamental to obtain optimal growth and yield of chilli. The decrease in the plant yield to drought stress was due to the reduced number of branches, shoot dry weight and number of fruits. Drought stress at 75% FC can already lower the agronomical and physiological characteristics of red chilli. Mechanism tolerance of red chilli to drought is done by increasing the proline content and maintaining its total sugar and chlorophyll content. Chilli varieties that able to withstand under drought stress and still provide higher yield was Tanamo, followed by Kastilo, Lado, and BCA.

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