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SELECTION CRITERIAS DEVELOPMENT FOR CHILI PEPPER UNDER DIFFERENT FIELD WATER CAPACITY AT VEGETATIVE STAGE

ROSMAINA[1,4*]; SOBIR[2]; PARJANTO[1,3]; AHMAD YUNUS[1,3]

[1] *Sebelas Maret University, Department of Agriculture Science, Graduated School, Surakarta, 57126, Indonesia*
[2] *Bogor Agriculture University, Faculty of Agriculture, Departement of Agronomy and Horticulture, Bogor 16680, West Java, Indonesia*
[3] *Sebelas Maret University, Faculty of Agriculture, Department of Agrotechnology, Surakarta, 57126, Indonesia*
[4] *State Islamic University of Sultan Syarif Kasim Riau (UIN SUSKA Riau), Faculty of Agriculture and Animal Sciences, Department of Agrotechnology, Panam Campus-Pekanbaru 28293, Riau, Indonesia*

Abstracts

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Low of water availability is a major limits the growth and production of horticulture crops including chili pepper (*Capsicum annuum* L.). The study was aimed to determine the water deficit critical level that resulted 50% decreasing of the yield, and to determine the selection criteria of chili pepper under water deficit in the vegetative phase, as well. The research arranged under completely randomized design of two factorials, which first factor was four levels regarding to water field capacity of 100%, 75%, 50% and 25%, while second factor was five genotypes of chili pepper. The result of this study revealed that water deficit at the vegetative stage was affected to growth and production of chili pepper that indicated by severe decreasing of the yield (71%), number of fruit per plant (69.25%) and fruit set (68.89%). Regression analysis based on yield, number of fruit per plant and fruit set showed that average water deficit critical level of 50% decreasing of the yield was 52.39% of field water capacity. Correlation analysis revealed that different characters that associated with the yield under different field water capacity level. Path coefficient analysis revealed that character of number of flowers abortion (3.05), flowers set (0.06), fruit weight (0.29) and number of fruit (1.23) have direct effect with fruit weight per plant in 100% of field water capacity, character of number of fruit per plant (0.68), fruit weight (1.43), percentage of flower abortion (0.36), and root length (0.21) have direct effect with fruit weight per plant in 50% of water field capacity viz., whereas in 25% of field water capacity, only character of number of fruit (0.78) has direct effect with fruit weight per plant. High of water deficit tend to decrease the number of character correlated and direct effect with yield.

Key words: Capsicum annuum L.; water deficit critical level; correlation and path analysis
Abbreviations: FWC: field water capacity, CL_{50}: critical level of field water capacity that decrease 50% of yield

Introduction

Climate change due to rising concentration of greenhouses gases in atmosphere has impact to increasing the temperature, changing in precipitation pattern and water scarcity in the earth. This phenomenon indeed caused severe production failure of agricultural crop, such as Chili Pepper (*Capsicum annuum* L.) since water deficit (drought) is the main limiting factors for plant growth and productivity. Physiologically, water deficit decreased metabolism activities, disturbed growth and development of plant cells, decreased photosynthesis, transpiration, stomatal conductivity, nutrients translo-

**Corresponding author*: rosmaina@uin-suska.ac.id

cation and assimilate activities in plant (Hamad et al., 2004; Gomes-Laranjo et al., 2006; Ou and Zou, 2012; Sam-Amoah et al., 2013; Panella et al., 2014) and ultimately leading to a massive loss in crop yield and quality. However, the stress response depends upon the intensity, rate and duration of exposure, stage of crop growth and plant genotype (Hamad et al., 2004; Kalefetoglu and Ekmekci, 2005; Kusvuran, 2012; Ou and Zou, 2012).

The research on impact of water deficit on plant growth and development of chili pepper has reported by many researchers from different country, but it was still limited in Indonesia. Indonesia consistently experiences dry climate condition and drought, especially during the warm phase of El-Nino with significant consequently for horticulture crop output. Chili pepper is one of the most sensitive horticulture crops to drought stress (Gonzalez-Dugo et al., 2007). It that grows under water deficit will tend to reduce drastically in yield. Loss of yield is the main concern of the farmer and plant breeder. To avoid excessive loss of actual yield crop, critical level of field water capacity that decreases 50% of yield (CL_{50}) must be determined. CL_{50} value is the safe of level at which plant produce half of the yield. Identification of the critical water deficit based on accurate basis to the crop is the key to keep the productivity of plant. The critical level of water field capacity that decreases 50% of yield will be used as an indicator of selection in breeding program. While using higher concentration of water deficit will inhibit plant growth and decrease extremely yield. In contrast, using a relatively low concentration of water deficit will result in plant similar to control so that we difficult to identification whether plant tolerant or not tolerant to drought.

The main objective of the chili pepper breeding programs are to increase of yield potential, stability and adaptation, improve tolerance to abiotic stresses such as drought and resistance to pests and diseases. Therefore, the development of chili pepper tolerant to drought stress is required. Additionally, the use of chili pepper resistant to drought in the tropical region will decrease the costs of both maintenance and watering, and it increases the plant's survival successes (Hakan and Mehmet, 2015). For efficiency and successful breeding of chili pepper to drought through conventional approach, there is need to identify selection criteria that can identify high yielding genotypes under water deficit. Selection is the major technique used in a breeding program that is mainly based on phenotypic characters (Allard, 1961 and Poelhman & Sleper, 1995). To effective and efficient of selection, breeders are still looking for traits that are suitable for screening chili pepper germplasm under drought conditions.

Response to selection depends on many factors such as the interrelationship of the characters. Knowledge of inter-character associated is very important in plant breeding for direct selection for the character that is not easily measured. Correlation studies provide information on the nature and magnitude of various relationships among characters. It measures the mutual relationship between two characters but not permit to depict the cause and effect relationship of trait contributing directly or indirectly toward the yield (Hasanuzzaman and Golam, 2011). However, under the complex situation, correlations alone become insufficient to explain relationships among characters and thus path analysis of yield components with yield is important. Path analysis is a tool that is available to breeder for better understanding the causes involved in the associations between traits and to partition the existing correlation into direct and indirect effects of yield factors (Lorencetti et al., 2006). The advantage of path analysis is that it permits the partitioning of the correlation coefficient into direct and indirect effect of yield factors (Dewey and Lu, 1959). The total correlations between predictor variables and response variable are partitioned into direct and indirect effects by path analysis. Path coefficient analysis has been used by plant breeder to assist in identifying traits that are useful as selection criteria in a number of crops to improve crop yield under drought condition, such as in chili (Hasanuzzaman and Qolam, 2011; Vikram et al., 2014; Rodriguez et al., 2008), Oat (*Avena sativa*) (Dumlupinar et al., 2012), Okra (*Abelmoschus esculentus* L, Moench) (Akinyele and Osekita, 2006), rice (Ahmadikhah and Marufinia, 2016). The objectives of this research were: i) to know the CL_{50} value, and ii) to determine the selection character for screening of chili pepper genotype in water deficit conditions for supporting the breeding strategies to improve chili pepper yield in a drought stress.

Materials and Methods

This research was conducted in greenhouse, Laboratory of Genetic and Breeding, Faculty of Agricultural and Animal Science, State Islamic University of Sultan Syarif Kasim Riau from March to August 2015. The temperature and daily relative humidity during research were recorded in the morning between 07:00–08:00 hours (with an average ±28.5°C and ± 78.7%, respectively), in the middle of day between 12:00-13:00 hours (with an average ± 32–36°C and ± 61.2%, respectively) and in afternoon between 16:00-17:00 hours (with an average ± 31,8°C and ± 63%, respectively). Experiment was laid out following completely randomized design in two factorial arrangement, the first factor was five chili pepper genotypes of collection of Genetic and Breeding laboratory, Faculty of Agriculture and Animal Science UIN Suska Riau e.g, UIN-K35, UIN-K36, UIN-K37, UIN-K38, and UIN-K39, and second factor was field water capacity that consisted of four levels viz. 100%, 75%, 50% and 25% so that is obtained 20 of treatment combinations. Each treatment was replicated four times.

The seed of each genotype of chili pepper is sown in a small polybag, when they aged four weeks; seedlings were transplanted into big polybag containing the mixture medium of soil and compost with ratio 3:1, respectively. Water deficit was applied at one-week ages after transplanted. During the experiment, plants are not given the fertilizing to avoid others effect. The parameter observed was plant height, dichotomous height, stem diameter, leaf length, petiole length, leaf width, days to flowering, days to harvest, total of flowers abortion, percentage of flowers abortion, total of fruit set, percentage of fruit set, number of fruit per plant, fruit weight per fruit, fruit weight per plant, fruit length, fruit diameter, number of seed per fruit, wet weight of canopy, dry weight of canopy, wet weight of root, dry weight of root, and root length.

Data analysis

Data were subjected to analysis of variance (ANOVA) with field water deficit, genotypes and their interaction as treatment. When the F-test was significant, differences between means were evaluated with Duncan Multiple Range Test (P = 5%). Correlations and path analysis were carried out as Al-Jibouri et al. (1958) and Dewey and Lu (1959), respectively. The all calculations were performed using SAS software (2010).

Results and Discussions

Analysis of variance (ANOVA) showed that interaction between genotype and field water capacity was only significantly different in in the leaf length and leaf width, while the other characters are influenced by a single factor (genotype or field water capacity). The average values of all characters in each genotype and each level of field water capacity are displayed in Table 1. In general, each genotype showed the variation in the growth and yield responses; UIN-K35 genotype has the highest value in the parameter of plant height, dichotomous height, and the number of seeds per fruit. UIN-K36 displayed the highest value in the parameter of stem diameter, leaf width, percentage of flowers abortion, and root length. The highest value of the petiole length, days to harvest, the percentage of fruit set, fruit weight, fruit weight per plant, fruit length, and fruit diameter characters were observed in UIN-K37 genotype. The highest values of the leaf length, and fresh weight of root were observed in UIN-K38, while the UIN-K39 showed the highest value in the parameter of total of flowers abortion, total of fruit set, number of fruit, wet weight of the canopy and root dry weight (Table 1).

The days to flowering, days to harvest, fruit weight, fruit length, and fruit diameter characters were only affected by the genotype (Table 1). The similar result was reported by Kisman (2005) that the days to flowering in soybean was influenced by genotypes tested and it was not affected by the water stress treatments. However, the different genotypes were significantly affected as indicated by higher percentage of flowers abortion and higher percentage of fruit set. Out of the five genotypes tested, the genotype of UIN-K37 had the lower percentage of flowers abortion and higher percentage of fruit set, 84.02% and 15.98% respectively (Table 1) and it was significantly different with other genotypes. Based on the yield, UIN-K37 genotype also showed the highest value compared to other genotypes.

Water stress has impact on the growth and development of plants. Water deficit has significant effect to some characters like plant height, dichotomous height, stem diameter, length of petiole, leaf width, percentage of flowers abortion, percentage of fruit set, number of fruit per plant, weight fruit per plant, total of flowers abortion, total of flower set, wet weight of canopy, and dry weight of canopy. The decline in growth occurred significantly in 50% of field water capacity, while in 75% of field capacity decreased was not significant different with control plant, it indicated that at this stage plant growth was still normally. The similar result was also reported by Swasono (2012) in *Allium cepa*; Supriyanto (2013) in rice and Prihastanti (2010) in cocoa plant. Prihastanti (2010) stated that decreasing in plant height occurred in 50% to 25% of field capacity, and plants can still grow normally at 75% of field capacity.

The character of plant height, stem diameter, dichotomous height declined with increased in water deficit, viz -11.37%, -16.78%, and -5.58%, respectively. This result similar with reported by R'Him and Radhouane (2015). The authors stated that decreasing of plant height in the *Capsicum annuum* was about 13–15% but it was not significant different with control plants. The reduction in plant height with increase in water deficit in chili pepper agrees with results of Siddique et al. (2000) in wheat. Growth involves both cell growth and development, which a process consisting of cell division, cell enlargement and differentiation and these processes are very sensitive to water deficit because of their dependence upon turgor (Jones and Lazenhy, 1988). The inhibitor of cell expansion is usually followed by closely by a reduction in cell wall synthesis (Salisbury and Ross, 1992). This may have affected plant height of chili pepper.

Table 1

Means comparisons of different traits as influenced by genotype and field water capacity and changes percentage of each parameter from 100% to 25% of field water capacity

Traits	Genotypes					Level of Field Water Capacity				% decrease or increase
	UIN-K35	UIN-K36	UIN-K37	UIN-K38	UIN-K39	100%	75%	50%	25%	100 to 25
PH (cm)	94.09^{a1}	91.91^{a}	80.00^{b}	89.72^{a}	93.25^{a}	94.13^{a}	91.53^{ab}	90.10^{b}	83.43^{c}	-11.37
DH (cm)	56.47^{a}	47.03^{c}	42.94^{d}	54.72^{ab}	53.22^{b}	52.30^{a}	51.15^{ab}	50.68^{ab}	49.38^{b}	-5.58
ST (mm)	6.58^{c}	7.44$_{a}$	6.86$_{bc}$	6.92$_{bc}$	7.14$_{ab}$	7.57^{a}	7.35^{a}	6.72$_{b}$	6.30$_{c}$	-16.78
LL	9.69^{b}	9.90$_{b}$	9.86$_{b}$	10.49$_{a}$	10.03^{b}	10.50$_{a}$	9.85$_{b}$	9.70$_{b}$	9.83$_{b}$	-6.38
PL (cm)	3.29^{c}	3.51^{b}	3.98^{a}	3.10^{c}	3.16^{c}	3.40^{ab}	3.43a	3.18^{b}	3.31^{ab}	-2.65
LW (cm)	3.24^{ab}	3.34^{a}	3.10^{b}	3.18^{b}	3.10^{b}	3.24^{a}	3.25^{a}	3.08^{b}	3.17^{ab}	-2.16
DTF (day)	21.75^{a}	18.88^{bc}	17.94^{c}	21.06^{a}	19.69^{b}	19.35	19.60	20.50	20.00	3.36
DTH	55.25^{b}	64.37^{ba}	78.12^{a}	72.37^{ab}	71.75^{ab}	75.90	66.30	65.70	65.60	-13.57
TFA	32.00^{b}	40.50^{b}	31.47^{b}	39.44^{b}	70.52^{a}	51.95^{a}	47.83^{a}	39.50^{ab}	31.65^{b}	-39.08
TFS	3.00^{a}	3.50^{a}	7.63^{a}	4.63^{a}	7.87^{a}	9.00^{a}	6.00^{ab}	3.40^{b}	2.80^{b}	-68.89
FA (%)	91.34^{ab}	93.95^{a}	84.02^{c}	89.27^{b}	92.49^{ab}	89.16^{bc}	86.85^{c}	91.60^{ab}	93.24^{a}	4.58
FS (%)	8.66^{cb}	6.02^{c}	15.98^{a}	10.72^{b}	7.51^{cb}	10.89^{a}	13.14^{a}	8.40^{b}	6.75^{b}	-38.02
NFP	3.00	3.50	7.63	4.63	7.88	9.10^{a}	6.00^{ab}	3.40^{b}	2.80^{b}	-69.23
WFPF (g)	1.63^{b}	1.83^{b}	3.69^{a}	2.00^{b}	2.08^{b}	2.33	2.16	2.22	2.28	-2.15
FL (cm)	11.41^{b}	10.61^{b}	15.02^{a}	10.27^{b}	10.40^{b}	11.25	11.23	14.62	12.27	9.07
FD (mm)	6.30^{b}	6.28^{b}	6.95^{a}	5.70^{c}	6.64^{ab}	6.12	6.50	6.93	6.60	7.84
NSPF	35.13	33.97	28.85	28.73	33.97	33.62	32.35	30.68	30.01	-10.74
WFPP (g)	7.00^{b}	6.88^{b}	24.34^{a}	9.41^{b}	16.18^{ab}	20.94^{a}	14.65^{ab}	9.46^{b}	6.00$_{b}$	-71.35
WWC (g)	110.74^{bc}	141.85^{a}	97.03^{c}	100.27^{bc}	124.58^{ab}	134.40^{a}	121.52^{ab}	110.36^{bc}	93.30^{c}	-30.58
DWC (g)	22.37^{b}	28.51^{a}	20.14^{b}	20.66^{b}	28.89^{a}	29.71^{a}	25.25^{b}	22.45^{bc}	19.05^{c}	-35.88
WWR (g)	4.22$_{c}$	6.40$_{a}$	5.80$_{ab}$	4.88^{bc}	5.49^{abc}	5.98	5.18	5.58	4.69	-21.57
DWR (g)	1.76	1.89	1.89	1.83	1.94	1.95	1.88	1.86	1.75	-10.26
RL (cm)	30.7	32.28	32.82	31.4	32.12	33.02	29.84	32.08	32.52	-1.51

Notes: PH (plant height); DH (dichotomous height); SD (Stem diameter); LL (leaf length); PL (petiole length); LW (leaf width); DTF (days to flowering); DH (days to harvesting); FA (flowers Abortion); FS (fruit set); NFP (number of fruit per plant); FWPF (fruit weight per fruit); FL (fruit length); DF (fruit diameter); NSPF (number of seed per fruit); WFPP (weight fruit per plant); WWC (wet weight of canopy); DWC (dry weight of canopy); WWR (wet weight of root); DWR (dry weight of root); RL (root length).[1] means followed by same letters within a row are not different at $P < 0.05$

Enhancement of water deficit level caused the high percentage of flowers abortion and low percentage of fruit set. The highest percentage of flowers abortion was observed at 25% of field water capacity (93.24%) and is followed by 50% of field water capacity (91.60%) and 75% of field water capacity (86.85%) as shown in Table 1. The high percentage of flowers abortion is caused declining of pollen viability percentage (data not shown) so that the process of pollination did not occurred and caused the flowers abortion. Dağdelen et al. (2004) reported that the period of flowering and reproductive phases were the most sensitive phases on the water needs in pepper. Furthermore, Falcetti et al. (1995) stated that the lack of water during flowering stage could cause abortion of flowers due to decreasing the viability of pollen, pistil damage and decrease the amount of fruit.

Drought stress also decreased the biomass plant, like fresh weight of canopy, dry weight of canopy, fresh and dry weight of root (Table 1).The higher water stress resulted low of fresh of canopy. Reducing of fresh weight and dry weight of canopy at 25% of field capacity were reached 34.62% and 37.3%, respectively, while fresh weight and dry weight of canopy at 50% of field capacity were reduced about 26.45% and 31.10%, respectively (Table 1). Dry weight of canopy decreased with increase water deficit. The reduction in dry weight of canopy could be associated with reducued rate of leaf production, hence low number of leaves production in leaf growth may also have been contributed by lower rates of cell division and cell extension in the leave. Reduction in leaf growth lead to less photosynthesis hence retarded overall plant growth as the resources required for growth process become limited in supply (Salisbury and Ross, 1992).

The highest percentage of fruit set was found in 75% of field water capacity (13,14%) and the lowest percentage of fruit set was observed in the 25% of field capacity (6.75%) (Table 1). The results of this study showed that drought stress caused the decreasing number of flower set and number of fruit set. Some studies also explained that drought stress directly affected on photosynthesis, plant growth rate, lower division and cell elongation, cell number, cell size, affects the activities of the enzyme, imbalancing the turgor pressure of cells, lower transpiration and distribution of photosynthates (Farooq et al., 2012, 2009; Prasad et al., 2008; Chaves and Oliveira, 2004) that implied to lower the number of fruit set and increasing the percentage of flowers abortion (Showemimo and Olarewaju, 2007). Dağdelen et al. (2004) and Gençoğlan et al. (2006) also reported that drought stress during flowering decreased the amount of flowers set about 28–32% and inhibited the formation of fruit.

Some reports also mentioned that the stresses occurring between the period of flowering and fruit development decreased in total production, fruit weight, fruit number and fruit length (Jaimez et al., 2000; Dağdelen et al., 2004; Gençoğlan et al., 2006; Sam-Amoah et al., 2013), whereas stress continued over time will reduce the fruit weight (Della Costa and Gianquinto, 2002; Sezen et al., 2006). Drought stress led to a decline in production of chili pepper in this study, it can be viewed from the number of fruit per plant and fruit weight that decreased significantly (Table 1). The average of fruit number per plant at 100% of field water capacity was 9.10 of fruit per plant, while the mean of the number of fruit in 75% of field capacity was 6.00 fruits per plant or decreased about 34.10%. At 50% of field capacity, plants only produced an average of 3.40 fruits per plant or a decrease of 62.6% and it continued to decline up to 69.2% (2.80 fruits per plant) at 25% of field water capacity.

The decline in the number of fruits per plant will reduce the weight fruit, which of the highest of decreasing the fruit weight of fruit per plant was 71.35% at 25% of field capacity. From this data were seen that the smaller the amount of water available to the plants resulted in the decreased production sharply, which of availability of water in 25% of field capacity has lower fruit weight per plant and this exhibited that water was the main factor limiting the chili pepper production. Owusu-Sekyere et al. (2010) reported that shortage of 20% water than normal condition at chili pepper affect the growth and development of plants, fruit formation and production. The declines in the number of fruit per plant due to water stress are also reported in some crops like wheat, sweet corn and sweet bell pepper (Ashraf et al., 2015; R'Him and Radhouane, 2015; Aladenola and Madramootoo, 2014; Oktem, 2008; Sezen et al., 2008; Dorji et al., 2005). These authors suggested that high water availability would produce the higher of number of fruit, and vice versa. The using of water at 85% of field capacity has decreased yields of 28.29%, but the use of water at 70% of field capacity reduced the production of 40% (Dağdelen et al., 2004). Aladonelo and Madramootoo (2014) reported that the highest number of fruit of chili pepper found in 120% of field water capacity, while its at 100% of field water capacity have decreased about 23% compared to 120% of field water capacity. Nevertheless, stress tolerance varied greatly between genotypes within a species (Corte's et al., 2012; Gholami et al., 2012; Siddiqui et al., 2015; Yang et al., 2015).

We calculated the decreasing of mean each character to observe the impact of water deficit on chili pepper, as shown in Table 1. The percentage changing of each parameter was varied greatly, the higher decreasing was observed in parameter of fruit weight per plant (-71.35%) followed by the parameter of number of fruits (-69.23%), total of fruit set (-68.89%), dry weight of canopy (-35.88%) and fresh weight of canopy (-30.58%). To estimate the critical level of field water capacity that caused the production decrease of 50% was selected of those characters having percentage decrease of more than 50%, and we decided three characters viz. character of fruit weight per plant, number of fruit and total of fruit set to be calculated by regression analysis. Based on regression analysis in Table 2 is obtained that critical points for fruit weight per plant, number of fruits per plant and total of fruit set characters were 51.03%, 53.49%, and 52.92% of field water capacity, respectively, with mean critical level of field water capacity was 52.39%. This average value reflected that chili production would decline 50% of yield at 52.39% of field water capacity, and than it can be used for screening drought tolerant of chili genotypes.

Determination of traits for the chili pepper selection under water deficit

The plant yield is the result of the interaction of some characters that are interconnected. Correlation between characters showed the relationship between two characters and that was very important to determine the decision of the selection criteria for crop improvement. In this study, a correlation analysis among characters has done at three levels of field water capacity, viz 100% (control), 50% (medium stress) and 25% (extreme stress). In 100% of field water capacity, there were six characters that significantly correlated to yield. The character of number of flowers abortion, total flower set, percentage of fruit set, fruit weight and number of seed per fruit were significantly and positively correlated with yield. Some studies have been reported that fruit weight, fruit number per plant and percentage of fruit set has a positive correlation to yield (Vijaya et al., 2014; Hasanuzzaman and Qolam, 2011; Sarkar et al., 2009; Sharma et al., 2010; Misrha et al., 1998; Sreelathakumary and Rajmony, 2002; Smith and Basavaraja, 2005). Percentage of flowers abortion character was significantly and negatively

In 50% of field water capacity, seven characters were significantly correlated to yield e.g. the percentage of flowers abortion, root length, percentage of fruit set, fruit weight, fruit length, number of seeds per fruit, and fresh weight of canopy. Percentage of flowers abortion, fresh weight of the canopy and root length had a significantly and negatively correlation with yield, meanwhile the percentage of fruit set, fruit weight, fruit length and number of seed per fruits characters have a positive and significant correlation to yield. Root length was significant and negative correlated to yield (-0.70) but it was significantly and positively correlated to the fresh weight of the canopy (0.98). This indicated that addition of root length will increase the fresh weight of the canopy (biomass), but it will reduce the yield. The results of this study explained that changing of root length do not correlate to the production, but it was only correlated an increasing the plant biomass so that root length can be used as a selection parameter on the ability of plants to survive in drought condition. Some of reports said that the root length could be used as one of the selection criteria for the identification of drought resistant in plants (Uppuluri and Krishna, 2015; Kashiwagi et al., 2005).

In extreme stress conditions (25% of field water capacity), percentage of fruit set and number of seed per fruit characters have a positive and significant correlation to yield, while fresh weight of canopy and percentage of flowers abortion have significantly and negatively correlated to yield (Table 2). The result of correlation is of great value in the determination of the most effective procedures for selection of superior genotypes. When there is positive association of major yield characters, component breeding would be very effective but when these characters are negatively associated, it would be difficult to exercise simultaneous selection for them in developing a variety (Akinyele and Osekita, 2006).

There was changed the character that affected on yield under normal and drought stress conditions. In normal condition, the number of flowers abortion, total of flowers set, percentage of pollen viability characters were significantly correlated to yield, but all of these characters were not significantly correlated with yield under stress condition, this indicated that these characters are very vulnerable to the water deficit. A similar result was also reported by Eid (2009) in wheat, which is occurred the changing character that correlated at normal and drought stress environment. The character of fresh weight of canopy, root length and fruit length were not significantly correlated to yield at normal condition, but these characters were correlated significantly to yield on medium stress (50% of water field capacity) (Table 3). This changing was the possibility of adaptation response of plants to fight the stress that occurred.

Out of the many characters are observed, only four characters are significantly and consistently correlated to yield under normal condition (100% of field water capacity) and under drought stress (50% of field water capacity), viz the character of percentage of flowers abortion, the percentage of fruits set, fruit weight and number of fruit. It suggested that these characters could be used as criteria for the selection of high yielding crops under normal and drought stress conditions. Ashraf et al. (2015) stated that the characters that positive correlated with yield in normal and drought stress conditions can be selected as the selection criteria for improving the plant productivity in drought stress.

Correlation between the characters is a complex interaction mechanism. To separate the characters that influence directly and indirectly on yield was determined by path analysis. The results of path analysis in 100%, 50% and 25% of water field capacity are shown in Table 4, 5 and 6, respectively. In 100% of field water capacity displayed that number of flowers abortion had highest direct effect and positive value (2.51), followed by the number of fruit (1.04), fruit weight (0.29) and percentage of fruit set (0.10). These characters had also positive and significant correlation with fruit weight per plant. This indicates that the correlation is a true relationship and direct selection will be effective through this character because an increase in one of these characters is directly contributing to increasing the yield. Direct effect and negative were obtained in the character of the total of flowers set (-2.83) and the percentage of flowers abortion (-0.10). While the percentage of flower abortion has a di-

Table 2
Critical level values of field water capacity at three characters selected

Character	Linear equation	X value at Y = 50%	R^2
Fruit weight per plant	Y= 96.73X – 99.26	50.92	0.9841
Number of fruit per plant	Y= 95.71X – 101.05	53.34	0.9324
Total Fruit Set	Y = 95.422X – 100.50	52.92	0.9327
Average		52.39	

Table 3
Coefficient correlation values among characters in 100%, 50% and 25% of field water capacity on fruit weight per plant

	NFA	FD	TFS	%FA	WWC	**RL**	**%FS**	**FW**	**FL**	**NF**	**FWP**
TFA[1]	1	0.49	0.99**	-0.41	0.49	0.55	0.41	0.19	-0.10	0.90**	0.75*
TFA[2]	1	0.24	0.98**	0.30	0.15	0.08	-0.30	-0.35	-0.29	0.09	-0.15
TFA[3]	1	0.32	0.99**	-0.24	0.49	0.20	0.24	-0.15	-0.29	0.59	0.52
FD[1]		1	0.49	-0.23	0.64*	0.49	0.23	-0.11	-0.12	0.44	0.35
FD[2]		1	0.24	0.12	0.14	0.18	-0.12	0.06	0.40	0.04	-0.04
FD[3]		1	0.28	0.31	0.64*	0.45	-0.31	-0.53	-0.63*	-0.01	-0.30
TFS[1]			1	-0.48	0.48	0.50	0.48	0.24	-0.08	0.93**	0.79*
TFS[2]			1	0.14	0.03	-0.03	-0.14	-0.19	-0.18	0.27	0.03
TFS[3]			1	-0.37	0.41	0.14	0.37	-0.10	-0.26	0.69	0.61
%FA[1]				1	0.12	0.28	-0.99**	-0.75*	-0.28	-0.74*	-0.87**
%FA[2]				1	0.73	0.70	-0.99**	-0.94**	-0.74*	-0.85**	-0.92**
%FA[3]				1	0.44	0.42	-1.00	-0.41	-0.23	-0.91**	-0.76**
WWC[1]					1	0.65*	-0.12	-0.27	-0.44	0.37	0.21
WWC[2]					1	0.98	-0.73*	-0.74*	-0.67*	-0.63	-0.74*
WWC[3]					1	0.79**	-0.44	-0.58	-0.50	-0.18	-0.14
RL[1]						1	-0.28	-0.35	-0.45	0.24	0.05
RL[2]						1	-0.70	-0.72*	-0.65*	-0.57	-0.70*
RL[3]						1	-0.42	-0.72*	-0.62	-0.24	-0.15
%FS[1]							1	0.75*	0.28	0.74*	0.87**
%FS[2]							1	0.94**	0.74*	0.85**	0.93**
%FS[3]							1	0.41	0.23	0.91**	0.76*
FW[1]								1	0.30	0.46	0.71*
FW[2]								1	0.90**	0.75*	0.89**
FW[3]								1	0.90**	0.24	0.48
FL[1]									1	-0.01	0.20
FL[2]									1	0.56	0.71*
FL[3]									1	0.00	0.30
NF[1]										1	0.94**
NF[2]										1	0.94**
NF[3]										1	0.83**
FWP[1]											1
FWP[2]											1
FWP[3]											1

Notes: [1]=100% of field water capacity, [2]=50 of field water capacity, [3]=25% of field water capacity, TFA = Total of flowers abortion, FD = fruit diameter, TFS = total of flowers set, %FA = Percentage of flowers abortion, WWC = wet weight of canopy, RL = root length, %FS = percentage of fruit set, FW = fruit weight, FL=fruit length, NF = number of fruit, FWP = fruit weight per plant

rect negative effect and a significant coefficient correlation is negative, which means the greater the percentage of flower abortion can decline of yield. In drought stress (50% of field water capacity), character of fruit weight have direct effect (1.43), followed by the number of fruits (0.68), the percentage of flowers abortion (0.36) and root length (0.21) while the length of the fruit, fresh weight of canopy and percentage of fruit set had -0.53, -0.33, -0.36 of direct negative effect, respectively. In extreme water stress (25% field capacity), the number of fruit (0.77) and the percentage of fruit set (0.03) have a positive direct effect while the percentage of flowers abortion has a negative direct effect.

At drought stress 50% of field water capacity, there are only two characters that have a direct positive effect and a significant positive coefficient correlation like fruit weight and the number of fruit. Percentage flower abortion, root length and fresh weight of the canopy have a positive direct effect but had a negative coefficient correlation, it indicates that the water stress (50% of field water capacity) caused longer roots and the greater fresh weight of canopy that could be

Table 4
Direct (bold) and indirect effect of different characters on fruit weight per plant in 100% of field water capacity

Characters	NFA	TFS	%FA	%FS	FW	NF	Coefficient correlation with yield
NFA	**2.51**	2.50	-1.03	1.03	0.47	2.26	0.75*
TFS	-2.83	**-2.83**	1.35	-1.35	-0.68	-2.64	0.79*
%FA	0.04	0.05	**-0.10**	0.10	0.07	0.07	-0.87**
%FS	0.06	0.07	-0.10	**0.10**	0.07	0.07	0.87**
FW	0.94	0.97	-0.22	0.22	**0.29**	0.13	0.71*
NF	-2.83	0.05	-0.77	0.77	0.48	**1.04**	0.94**

Notes: NFA (number of flowers abortion); TFS (Total of flower set), %FS (percent of flowers abortion), %FS (fruit set), FW (fruit weight), NF (number of fruit)
Residual effect = 0.0825; *P < 0.05; **P < 0.01, respectively

Table 5
Direct (bold) and indirect effect of different characters on fruit weight per plant in 50% of water capacity

Characters	%FA	WWC	RL	%FS	FW	FL	NF	Coefficient correlations with yield
%FA	**0.36**	0.26	0.25	-0.36	-0.34	-0.27	-0.31	-0.92**
WWC	-0.25	**-0.34**	-0.34	0.25	0.25	0.23	0.22	-0.74*
RL	0.15	0.21	**0.21**	-0.15	-0.15	-0.14	-0.12	-0.70*
%FS	0.36	0.26	0.25	**-0.36**	-0.34	-0.27	-0.31	0.93**
FW	-1.35	-1.05	-1.03	1.35	**1.43**	1.29	1.07	0.89**
FL	0.39	0.35	0.34	-0.39	-0.48	**-0.53**	-0.30	0.71*
NF	-0.58	-0.43	-0.39	0.58	0.51	0.39	**0.68**	0.94**

Notes: %FA (percentage of flowers abortion), WWC (wet weight of canopy), RL (root length), %FS (percentage of fruit set), FW (fruit weight), FL (fruit length), NF (number of fruit),
Residual effect = 0.1344; *P < 0.05; **P < 0.01, respectively

Table 6
Direct (bold) and indirect effect of different characters on fruit weight per plant in 25% of water capacity

Characters	%FA	%FS	NF	Coefficient correlations with yield
%FA	**-0.03**	-0.99	0.03	-0.76**
%FS	-0.03	**0.03**	0.03	-0.74*
NF	-0.71	0.91	**0.78**	0.83**
Residual effect*	0.56			

Notes: %FA (percentage of flowers abortion), %FS (percentage of fruit set), NF (number of fruit),
Residual effect = 0.56; *P < 0.05; **P < 0.01, respectively

decrease number of fruit and yield because photosynthates is used for vegetative growth and not to production. In the extreme water stress (25% of water field capacity), character was not affected directly to yield because the growth of the plant in the extreme conditions of water stress has been hampered.

Characters that have positive direct effect and positive coefficient correlation can be selected as the criteria for selection while the other character although influenced positively can be ignored so that character of the number of fruit and fruit weight under normal conditions (100% of field water capacity) and drought stress can be used as selection criteria for high productivity of chili pepper in drought stress. Many researchers also found that number of fruit and fruit weight as selection criteria to increase pepper production based on path analysis (Rohini and Lakshamanan, 2015; Vijaya et al, 2014; Sharma et al., 2010; Sakkar et al., 2009; Vani et al., 2007; Ukkund et al., 2007; Sreelathkumary and Rajamony, 2002).

The residual value of path analysis in the three levels field water capacity (100%, 50% and 25%) was 0.1077, 0.1344 and 0.5590, respectively. The residual 0.1077 indicates that characters are included in path analysis explained 89.23% of the total variation in yield which showed that there may be some more components that are contributing to ward yield. This residual value means that the model at 100% and 50% of field water capacity were excellent and the characters that directly and indirectly effect can explains about 89.23% and 86.56% of yield, the remaining 10.77% and 13.44% can not be explained by the model. On the other hand, in the 25% of water field capacity can be only explained by 55.90% whereas 44.10% was explained by other factors out the model. The residual values of path analysis were higher than the value of a residual value in chili plants that is reported by Rohini and Lakshamanan, (2015) (r = 0094,) and Vikram et al. (2014) (r = 0.0062).

Conclusions

Critical level level that decreases 50% of yield of chili production was 52.39% of field water capacity.

Traits for selection of chili in 100% of field water capacity were number of flowers set, fruit weight and number of fruit, in 50% of field water capacity was number of fruit and fruit weight, whereas at 25% of field water capacity were only number of fruit.

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