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The Path Analysis on Yield Due to the Sunflower's (*Helianthus annuus* L.) Oil Under Drought Stress

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ABSTRACT

The study was conducted under controlled environment in order to path analysis on sunflower. Treatments were a combination of four levels of drought (100, 80, 60, and 40 percent of Field Capacity (FC) laid out in a Block Randomized Design with three replications. The ten treatments as follow: 100% FC both vegetative and generative phase, 80% FC both vegetative and generative phase, 60% FC both vegetative and generative phase, 40% FC both vegetative and generative phase, 100% FC on vegetative and 80% FC on generative phase, 100% FC on vegetative and 60% FC on generative phase, 100% FC on vegetative and 40% on generative phase, 80% FC on vegetative and 100% FC on generative phase, 60% FC on vegetative and 100% FC on generative phase, 40% FC on vegetative and 100% on generative phase. Drought stress was applied from 8 leaves stage up to the end of plant growth periods in vegetative and generative phases. The result indicated that drought stress affected most of the measured parameters, 80% FC treatments have been able to give the same effect as control or untreated (100% FC on the entire growth phase), but above 80% FC treatments will decrease the plant growth and yield of sunflower. This sunflower is not resistant to reduction of soil water until 40% FC, which decrease oil content up to 17%. The highest correlation of yield of sunflower's oil was observed with dry matter weight of seed per plant, followed oil content and head diameter. Maximum direct effect on seed yield was exerted by dried matter weight of seeds per plant. It was concluded that it is critical to manage deleterious effect of drought stress at generative phase. The dried matter weight of seed per plant was important character to improve seed yield under drought stress.

Keywords: drought stress, effect, sunflower, field capacity, path.

INTRODUCTION

Sunflower is one of the most important annual crops grown for edible oil [1], as well as the oils crops and due to its high content of unsaturated fatty acids and a lack of cholesterol, the oil benefits from a desirable quality [2]. Plant responds to variations in water levels in the soil through the morphological, anatomical, physiological, biochemical and molecular adjustments [3][4]. Water deficiency commonly occurs in commercial production of many crops. It can cause substantial negative effects to plant development and reducing the productivity [5]. The level and response of damage depends on genotype, duration and severity of stress and the developmental stage at which the drought occurs [6][7].

Drought limits the agricultural production by preventing the crop plants from expressing their full genetic potential [8]. Drought is a multidimensional stress affecting plants at various levels of their organization ([9][10][11] reported that drought stress on sunflower had a considerable effect also caused a reduction on plant height, dry matter, stem diameter, head size, seed number as well as seed weight per head and 100-seed weight. Razi and Asad [2] found that stress during vegetative phase, flowering or seed filling period causes considerable decrease in yield and oil content of sunflower.

Correlation between yield character and others on sunflower with different treatments can be seen by using path analysis**.** Path analysis is a statistical technique of partioning the correlation coefficients into its direct and indirect effect [12]. Correlation of seed yield of sunflower mainly depends upon the number of filled seed per plant, seed filling percentage and head diameter [13]. Seed yield generally exhibit positive and significant correlation with number of filled seed, head diameter and 1000-seed weight [14][15].

The aim of this study is to evaluate the correlation of particular character with other character of sunflower under drought stress.

MATERIALS AND METHODS

The study was carried out in the glass house of the experimental station of Agriculture Faculty, University of Brawijaya. Drought stress was induced at four levels *i.e.* 100 (control), 80, 60 and 40 precent
of Field Capacity (FC). The seeds of sunflower (HA 45, Indonesian Sweetener and Fibber Crops Research Institute Collection) were planted in 20 kg plastic pots containing soil, sand and organic fertilizer (1:1:1 in volume).

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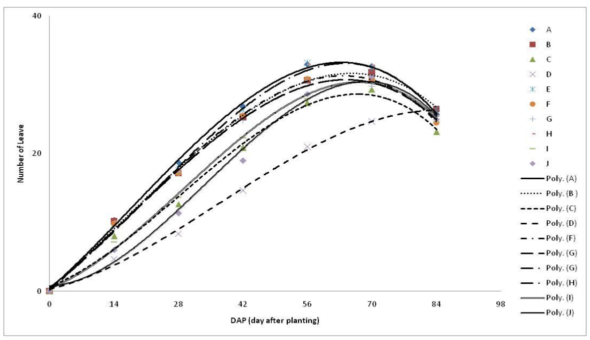
The determination of soil moisture content in FC was done by saturate the media in pots , and kept for 60 hours to let gravimetric water be drained and then the pots were weighed. The difference between pot weight after 60 hours with initial pot weight (before saturation) was considered as soil water content in FC. Drought stress was imposed from 8 leaf stage of seedling to the end of the growth periods. The experiment was arranged in Randomized Complete Design using 10 treatments with 3 replications. The treatments as follows: A. 100 % FC both vegetative and generative phases (no stressed), B. 80 % FC both vegetative and generative phases, C. 60 % FC both vegetative and generative phases, D. 40 % FC both vegetative and generative phases, E. 100 % FC on vegetative and 80 % FC on generative phase, F. 100 % FC on vegetative and 60 % FC on generative phase, G. 100 % FC on vegetative and 40 % FC on generative phase, H. 80 % FC on vegetative and 100 % FC on generative phase, I. 60 % FC on vegetative and 100 % FC on generative phase, J. 40 % FC on vegetative and 100 % FC on generative phase. Plant height, stem diameter, number of leaves, head size flower, stomatal density, dry matter of seed/plant, yield of sunflower's oil, oil contents declined upon drought stress as compared to control (untreated).

The data were recorded for plant height, stem diameter, number of leaves, stomatal density, head size, dried matter of seed/plant, oil content and yield of sunflower's oil. Statistical analysis was carried out through analysis of variant with significance level of 5%. If significant influence occurs during treatment, it will be followed by LSD test. Path coefficients were determined following Singh and Chaudary [12] to study direct and indirect effect of different morphological traits under drought stress.

RESULTS AND DISCUSSION

The effect of drought stress to growth of sunflower

The morphological components were influenced by drought stress treatments (Fig.1a, 1b, 1c). Increasing drought stress resulted the decrease in plant height, number of leaf, stem diameter.



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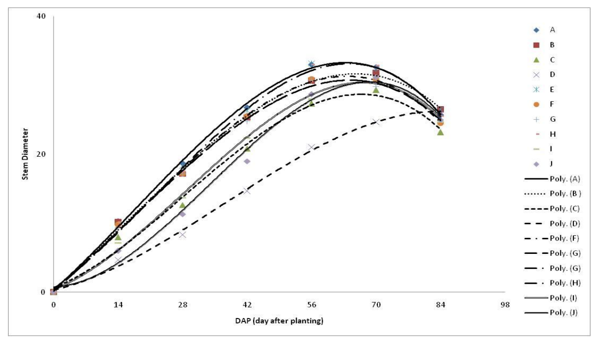

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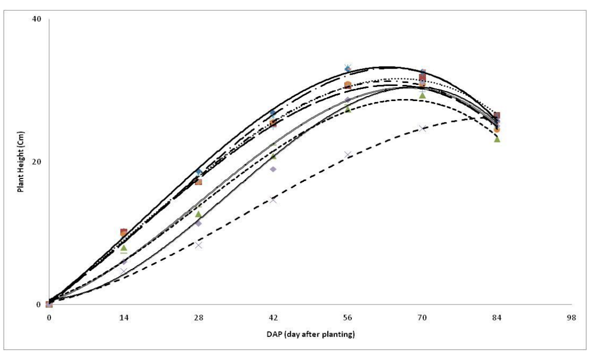

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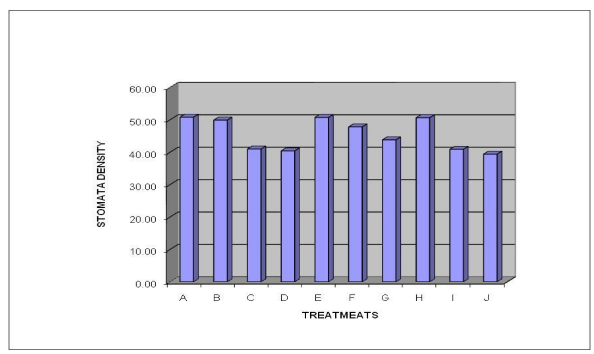

d

Figure 1. Trend of average plant growth of sunflower under drought stress

a. Trend of average number of leaves
b. Trend of average stem diameter
c. Trend of average plant height
d. Trend stomatal density

Note. A. Control(100% FC on Veg and Gen Phase), B. 80% FC on Veg and Gen Phase, C. 60% FC Veg and Gen Phase, D. 40% FC Veg and Gen Phase, E. 100% FC on Veg - 80% FC on Gen Phase, F. 100% FG on Veg - 60% FC on Gen Phase, G. 100% FC on Veg - 40% FC on Gen Phase, H. 80%FC on Veg - 100% FC on Gen Phase, I. 60% FC on Veg - 100% FC on Gen Phase, J. 40% FC on Veg - 100% FC on Gen Phase

In the plant height, 80% FC on vegetative-100% FC on generative phase's treatment and 100% FC on vegetative-80% FC on generative phases treatment had been able to affect the similar result to the treatment of control (100% FC). The 60% FC on vegetative-generative phase and 40% FC on vegetative-generative phase treatments had the highest and lowest value, respectively, so that it reduced plant height up to 22% and 39%. In number of leaves and stem diameter, it indicated that increasing drought stress on generative phase had troubled the growth phase (80% FC, 60% FC and 40% FC on generative phase treatments), but increasing drought stress on vegetative phase will influence growth speed of generative phase growth (80% FC, 60% FC and 40% FC on vegetative phase treatments).

The number of leaves and stem diameter of 80% FC, 60% FC and 40% FC on generative phase treatments produced the same as with control (100% FC treatment). But, reduction of soil water content to 80%, 60% and 40% FC on generative phase caused reduction in the parameters as compared to control. The 80% FC on generative phase treatment showed that it began an obstruction on 70 dap, on the other hand, 60% FC and 40% FC on generative phase treatments begin an obstruction since it was 56 dap. Nezami *et al.* [11] reported that stem diameter was affected by drought stress. Reduction of soil water content to 60 and 30% FC caused a 20 and 46% reduction in this parameter as compared to control. In field condition, Attene and Porru [10] reported that one of the effect of low water availability is the reduction of stem diameter due to lower radius growth of stem.

The 40% FC on vegetatative-100% FC on generative phase treatment prove that plant get shorter the influence of stress condition compared to normal condition. Whigham and Minor [16] found that drought stress on vegetative phase could reduce of leaf, stem diameter and plant height. Islami and Utomo [17] had explained that drought stress reduced generally on all parameters in plant as compared in normal conditions.

Stomata density of sunflower

Stomatal density data is shown in Figure 1d and 2. It shows that the plant decreases its stomatal density and tries to adapt to drought stress conditions. The 100% FC on Vegetative - 80% FC on generative phase treatment and the 80% FC on vegetative - 100% FC on generative phase treatment do not show any difference from control. All of vegetative phase on 80% FC treatments are still same with parameter observation of control and the 100% FC on vegetative phase-60% FC on generative ve phase treatments, however 40% FC Vegetative - Generative and 40% FC Vegetative- 100% FC on Generative phase treatment show a lower stomatal density. This sunflower adapts to drought stress by reducing its stomatal density in 100% FC on Vegetative-40% FC Generative. Rauff [19] reported that drought in plants during the vegetative development the loss of water will affect the main stem height and stem diameter.

One of the earliest responses against drought is stomatal closure that limits CO_2 diffusion toward chloroplast [19]. During drought two main reasons why plants to close their stomatal are hydraulic signals (leaf water potential, cell turgor) and chemical signals (Abscisic acid; ABA) [20].

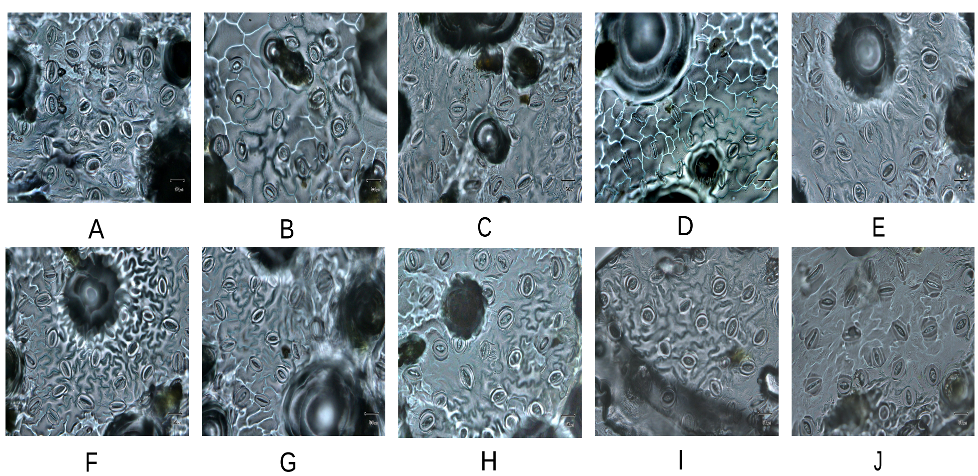

Figure 2 Stomatal Density on Different Treatments

Note. A. Control(100% FC on Veg and Gen Phase), B. 80% FC on Veg and Gen Phase, C. 60% FC Veg and Gen Phase, D. 40% FC Veg and Gen Phase, E. 100% FC on Veg - 80% FC on Gen Phase, F. 100% FG on Veg - 60% FC on Gen Phase, G. 100% FC on Veg - 40% FC on Gen Phase, H. 80%FC on Veg - 100% FC on Gen Phase, I. 60% FC on Veg - 100% FC on Gen Phase, J. 40% FC on Veg - 100% FC on Gen Phase

Uptake and loss water in guard cells changes their turgor and modulates stomatal opening and closing. Because guard cells are located in the leaf epidermis, they can lose turgor as a result of a direct loss of water by evaporation to the atmosphere. Solute loss from guard cells can be triggered by a decrease in the water content of the leaf and abscise acid plays an important role in this process [21]. Chemical signals from the root system may affect the stomatal responses to water stress [22]. Stomatal conductance is often much more closely related to soil water status than to leaf water status, and the only plan part than can be directly affected by soil water status is the root system. In fact, dehydration only part of the root system may cause stomatal closure even if the well-watered portion of the root system still delivers water to the shoots.

Kramer [23] explained that water deficit on plant tissues are caused by much of water loss in transpiration process through stomatal and another cells (cuticula). But, the transpiration process happens through stomatal more 90% in leaf. Stomatal, as a tool plant adaptation, have an important role to drought stress adaptation. The stomatal will be closed to reduce transpiration rate [24]. Reduction of transpiration helps conserve the available water. As a modulate adaptation, this takes place by timely closure of the stomatal. A modified change is seen when leaves growing under conditions of water deficiency develop smaller but more densely distributed stomatal. This modification makes a leaf able to reduce transpiration by a quicker onset densely cutinized epidermal walls and are covered with thicker layers of wax. In this way the boundary layer resistance is increased and the air outside the stomatal become moister. An effective reduction of water losses are transpiring surface [25]. Many plants has adaptation to drought stress with decrease size of stomatal and number of stomatal [26].

The effect of drought stress on yield of sunflower

Yield components were affected by drought stress only in vegetative phase, generative phase or both. The treatment of 80% FC vegetative – 100% FC generative phase had stem diameter a lower than control (100% FC Vegetative-Generative Phase). In Table 1, showed that 100-seed weight was significant with head size and the treatments had significantly different with 100-seed weight. Increasing drought stress produced the decrease in head size, seed number/head, 100-seed weight and seed weight/head**.** These were in agreement with the results of Khan *et al*. [27]. These authors showed that drought stress could decrease the yield components of sunflower (head size and 100-seed weight). Ariffin [7] stated that the change of plant growth environment (water deficit) would initiate stomatal closure in the leaves, under the influence of hormones synthesized in the leaves in a response to drought, changes occur in the allocation of assimilates, the ratio of shoot to root growth is altered, characteristic feature develop and, as a rule, reproductive processes begin prematurely. The treatments of 40% FC can inhibit the time of flowering. Sunflower will slow its growth rate and has a longer time of vegetative phase. The control had a time of flowering of 37 dap, while the 40% FC vegetative-generative phase was 56 dap.

The fresh and dry matter observations of sunflower showed that the drought stress condition can decrease its dry matter. The control treatment had a higher dry matter, 60% FC treatment and 40% FC treatment decreased the plant until 32%. Blum [28] reported that a further increase in water deficit, turgor is lost, stomatal fully close, plant growth ceases and the plant enters the prelethal. During this stage, carbon is lost by respiration, and tissue water status continues to decrease slowly, transpiration and assimilation decreased. Havaux [29] stated that photosynthesis capacity can be marker as plant respond under drought stress. The dry matter is the model of plant photosynthesis capacity. Based on Levit [30], the decrease of plant biomass level is a response model of plant under drought stress.

Oil Content

The oil content resulted that the drought stress condition could decrease oil content 17%. In 100% FC vegetative-80% FC generative phase treatment and 80% FC vegetative-100% FC generative did not significant difference in term of the control treatment oil content. The 80% FC vegetative-generative phase and 60% FC vegetative - 100% FC generative phase treatments still resulted the same oil content observation in the control. The 80% FC, 60% FC and 40% FC treatments decreased oil content in all the growth phases. These were in agreement with the results of Khan *et al* [27]. The decrease of field capacity would decrease oil content of sunflower.

This study, drought stress condition influenced show a seed number/head, but the variance analysis of seed number/head did not significant difference. In Table 1, the 60% FC and 40% FC treatments had the lower seed number/head. In 40% FC treatment showed that the seed number/head decreased up to 57%. Higher decrease in growth and yield were seen at 60% FC treatment and the highest inhibition over the growth and yield component was exhibited at 40% FC on the entire growth phase.

Table 1. The yield component of sunflower under drought stress conditions

FC Treatments	Yield of Sunflower's Oil (g.plant^{-1})	Dried Seed Weight/ Plant (g.plant^{-1})	Oil Content (%)	Seed Number /head	Weight of 100 seeds (g)	Head Diameter of flower (cm)
100% Veg- Gen	16,85 h	35,81 g	46,99 cd	539,5	6,22 d	16,20 de
80% Veg-Gen	13,44 efg	29,61 def	45,38 bcd	460,17	5,98 d	14,20 bc
60% Veg-Gen	8,75 b	20,17 b	43,41 abc	466,5	4,37 b	11,40 a
40% Veg-Gen	5,29 a	13,50 a	39,16 a	413,33	3,23 a	10,40 a
100% Veg - 80% Gen	14,63 fgh	30,29 ef	48,29 d	512,17	5,77 cd	14,90 cd
100% Veg - 60% Gen	11,43 cde	26,15 cde	43,69 abc	528	4,87 bc	13,20 b
100% Veg - 40% Gen	9,95 bc	22,00 bc	45,38 bcd	496,17	4,41 b	11,60 a
80% Veg - 100% Gen	15,47 gh	33,04 fg	46,83 cd	481,33	6,37 d	16,70 e
60% Veg - 100% Gen	12,65 def	27,42 de	46,43 cd	526,17	5,62 cd	13,00 b
40% Veg - 100% Gen	10,34 bcd	24,94 bcd	41,1 ab	506,67	4,32 b	13,10 b
LSD 5%	2,619	4,81	1,086	ns	1,024	1,393
CV (%)	12,849	10,665	6,0197	12,062	11,678	6,033

Note. In a column, means followed by a common letter are not significantly different at 5% level of significance

Veg = Vegetative phase (1-35 DAP), Gen = Generative phase (36- 110 DAP)., ns= non significantly
DAP = day after transplanting

In Table 1, the control and 60% FC on vegetative - 100% FC on generative treatments affected the almost same oil content as control, but the yield of oil content had decreased until 24%. The result indicated that 100-seed number due to all treatments were lower than control. Khan *et al*. [28] and Nezami *et al.* [11] reported that the seed number per head significantly decreased with increased drought stress in field capacity. It seems that most reduction in seed number per head due to stress, is related to reduction of head size. Rauf and Sadaqat [31] reported that the lower assimilation of photosynthesis during the reproductive phase will reduce head diameter. Reduction in head diameter further decreases the number of rows per head and number of achenes per head and resulted in correlation of yield components to severity of drought.

The Main Character on Yield of The Sunflower's Oil under Drought Stress

Path analysis on the six morphological characteristics and HA45 results, promotes causal relation among those six characters in time of giving different water in both vegetative and generative phases in its growth. Path coefficient (Table 2) revealed that dried seed weight per plant had maximum direct effect on yield of oil content. The indirect effect of all other traits under discussion was negative and positive through dry seed weight per plant. Oil content and head diameter were the second and third highest direct effects on yield of sunflower's oil. This emphasizes that the selection based on dry seed weight per plant and head diameter will be more effective in improving seed yield under drought stress. High direct effect of head diameter on seed yield was also reported by Vanozzi *et al*. [32].

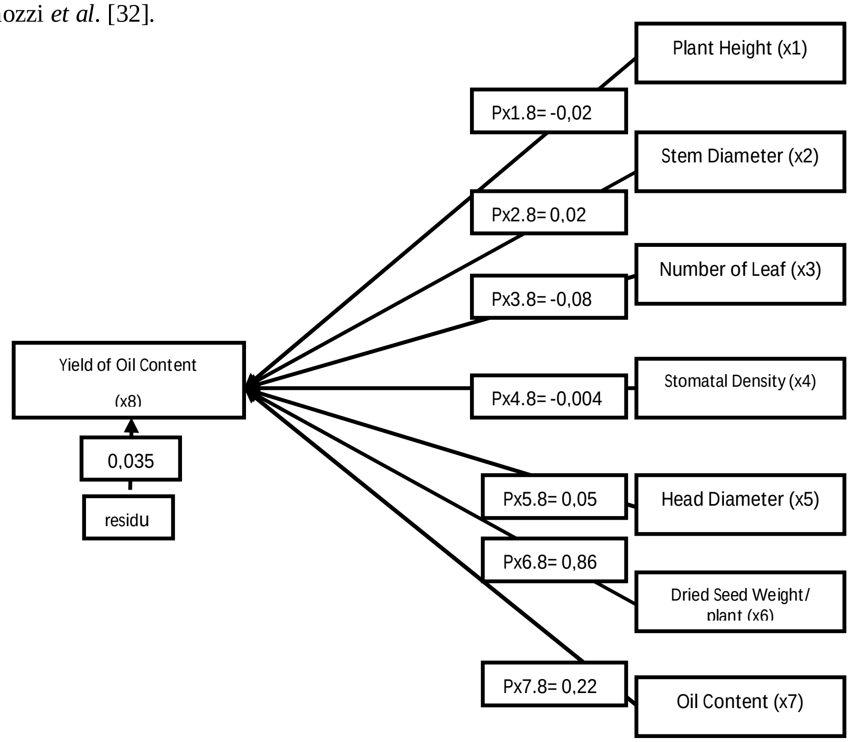

Figure 3 Path Diagram of direct and indirect effect of yield components on yield of sunflower's oil

Table 2. Direct (in bold) and indirect effects of yield components on yield of sunflower's oil

Character	**Direct Effect**	**Plant Height**	**Stem Diameter**	**Number of Leaf**	**Stomatal Density**	**Head Diameter**	**Dried Seed Weight/ plant**	**Oil Content**	Correlation with Yield (XY)
Plant Height	-0.02		0.01	-0.06	-0.001	0.04	0.66	0.08	0.72
Stem Diameter	0.02	-0.02		-0.07	-0.002	0.04	0.70	0.13	0.81
Number of Leaf	-0.08	-0.02	0.02		-0.002	0.04	0.70	0.12	0.79
Stomatal Density	-0.004	-0.008	0.010	-0.041		0.037	0.569	0.093	0.66
Head Diameter	0.05	-0.01	0.01	-0.06	-0.003		0.74	0.14	0.87
Dried Seed Weight/Plant	0.86	-0.02	0.01	-0.06	-0.003	0.04		0.14	0.98
Oil Content	0.22	-0.01	0.01	-0.04	-0.002	0.03	0.54		0.75

Based on path analysis, it shows that all characters observed indicate that there are both direct and indirect influences on oil product of each plant. Those six observed characters do not always give neither direct nor indirect significant effect to the characters of oil product of each plant. The analysis result show the direct positive effect on the character of dried seed weight per plant (0.86), oil content (0.22), head flower diameter (0.05) and stem diameter (0.02). The direct effect characters are number of leaf (-0.08) and plant height (-0.02). The total seed weight, the more oil content is found. It is caused by sunflower oil actually comes from the extract of sunflower seed. The influencing factor to oil product of each plant is the character of dried seed weight per plant and its oil content.

Both direct and indirect is relations the dried seed weight per plant. This dried seed weight per plant character is expected to be able to function as a basic guidance in selecting the sunflower oil product in drought.

CONCLUSION

The sunflower is not resistance to reduction of soil water until 40% FC, which decreased plant growth, yield and oil content up to 17%.

Yield of sunflower's oil mainly depends upon the dried matter weight seed per plant. This emphasizes that selection based on these characters will be more effective in selection on yield of sunflower's oil under drought stress.

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