CRITICAL WATER CONTENT AND WATER STRESS COEFFICIENT OF SOYBEAN (<u>Glycine</u> <u>max</u> [L.] Merr.) UNDER DEFICIT IRRIGATION

R.A. Bustomi Rosadi[*], Afandi[*], Masateru Senge[**], Kengo Ito[**], and John T. Adomako[**]

Introduction

Soybean is a very important commodity in Indonesia. About 1.3 million tons of soybeans is imported to meet 45 of its national consumption (Siswono, 2004). Water stress is a major constraint to increasing soybean yields in the tropical regions such as Indonesia. Soybean is normally planted at the end of the rainy season, therefore, water availability becomes a limiting factor to plant growth. Due to inadequate water resources the implementation of deficit irrigation seems beneficial. The objective of this research was to investigate the critical water content (θ_c) and water stress coefficient (K_s) of soybean plant in the frame of optimum water management. The critical water content (θ_c) mentioned above can be estimated by the following equation.

$\theta_c = \theta_{FC} - p(\theta_{FC} - \theta_{PWP})$ ----- (1), and

K_s from $ET_{c\ adj} = K_s\ ET$ ------- (2)

Where θ_{FC} is moisture at field capacity and θ_{PWP} is moisture at permanent wilting point; ET is the crop evapotranspiration under standard condition.

Materials and Method

This research was done in a plastic house of the Faculty of Agriculture in University of Lampung from June to September 2000. Soybean cultivar *Willis* was used. Soil type was *Ultisol.* This research was conducted using a randomised complete block design with four replications. The treatments were 5 levels of water deficit (WD): WD1 (0-20)%, WD2 (20-40)%, WD3 (40-60)%, WD4 (60-80) % and WD5 (80-100)% of total available water (TAW). Daily monitoring of soil water was done by gravimetric method. Variables evaluated in this research were plant height, leaf number, flower and pod number, dry weight of top and root biomass, yield, evapotranspiration rate, crop water requirement (CWR), water use efficiency (WUE), and yield efficiency (YE). Statistical analysis was done by the F-test at 5 and 1 % significant levels, followed by LSD (Least Significant Different) test at the same level. The soil texture was clay. Soil water content at field capacity was 39.3 % and wilting point was 21.6 %. Total available water (TAW) was 17.7 % by volume. This amount was considered as 100 % of total available water. Soybean seeds together with fertilizer were planted in black plastic containers (10 liters volume), which were filled of 7 kg air-dry soil. Evapotranspiration (ET) was calculated by gravimetric method. 2 seeds were planted on each container. The soybean plants were sprayed with insecticide to protect them from insect. The growth period of soybean plant was 85 days, and two weeks before harvesting, the irrigation was stopped.

Results and Discussion

The effects of water deficit on plant growth indicators are shown in tables 1 and 2, It can be observed from the tables that, water deficits WD1 and WD2 had no significant difference with regard to plant growth indicators throughout the growth period. On the other hand, significant differences in growth indicators were observed for water deficits WD3, WD4, and WD5 treatments from week IV.

From table 1, with the exception of WD3, which experienced stress at week VII, WD4 and WD5 showed stress from week V as far as the plant heights are concerned. However, in table 2, the plant leaves experienced stress from week IV for WD3, WD4, and WD5 treatments. It is clear that the growth performance indicators did not show water stress phenomenon at the same growth stage.

The yield of soybean plants were significantly affected under WD4 and WD5 treatments as shown in table 3. Further more, it can be seen that, the total biomass was also significant under WD3, WD4, and WD5 treatments.

Based on the explanation above, the fraction of the total available water, (p) at the point where the plants started experiencing stress could be taken as the average of WD3 (40-60%), p =50% or 0.5 .From equation 1 above, the critical water content can be computed as (θ_c) = [39.3 % - 0.5 (39.3 % - 21.6 %)] = 30.5 %.

Assuming that the evapotranspiration at WD1 (0-20 %) occurred under favorablel condition for plant growth, in which soil water content is near the field capacity, and there is no limitation for plant to meet the maximum evapotranspiration (ET_m), the evapotranspiration (ET_a) at WD1 is crop evapotranspiration (ET_c), which means the evapotranspiration of plant under standard condition (Allen et. al., 1998). If evapotranspiration ($ET_{c\ adj}$) of plant is measured under water stress, the K_s value can be calculated by using equation 2.

From table 4, it can be seen that the K_s values of soybean plant varied depending on the growth stage and the AW deficit level. The K_s values are the same as the values of ET_a/ET_m when the plants were in stress condition (*). Table 4 shows that the K_s values tended to decrease week by week if there

*)Faculty of Agriculture University of Lampung **) Faculty of Agriculture,Gifu University, Japan

keyword soybean. critical water content. deficit irrigation

is no change of AW deficit level at WD4 and WD5. But, the K_s value at WD3 (p=0.5) varied from week IV to week VII with an average of 0.78.

Table 3 showed that the WD3 treatment was the most efficient in yield efficiency (0.021 g/mm).

Based on the equation as mentioned before, the average K_y values is 0.85 (Table 5). Doorenboss and Kassam (1979), also found K_y of soybean to be 0.85. It means that this experiment was good enough for calculating the θ_c and K_s.

Table 5 showed that the K_y value of WD3 treatment was 0.61, or $K_y < 1$. It meant that WD3 treatment was in the deficit irrigation, and based on the crop water requirement and yield of soybean plant as mentioned previously, it can be concluded that the optimum yield of soybean plant with the highest of yield efficiency (0.021) was reached by deficit irrigation maintaining the soil water condition at the level 40-60 % of AW deficit (WD3), with p = 0.5, θ_c = 30.5 %, K_s = 0.78, and can conserved 10.1 % of water compared to the WD1. The optimum soybean yield was 7.88 g/pot and crop water requirement was 372 mm.

Conclusion

The soybean plant started to experience stressed from week IV with (p) = 0.50, and θ_c = 30.5 %. The yield response factor of soybean (K_y) was 0.85. The optimum yield of soybean plant was reached by deficit irrigation at the level of 40-60 % of AW deficit, which conserved 10.1 % of water, and the value of K_s was 0.78. The optimum yield of soybean plant was 7.88 g/pot and crop water requirement was 372 mm.

References

Allen, R.G., LS. Pereira, d. Raes, and M. Smith.1998. Crop Evapotranspiration. Irrigation and Drainage Paper no.56, FAO, Rome, Italy.301.

Doorenbos, J. and A.H. Kassam. 1979. Yield Response to Water. FAO, Roma: 1-57.

Siswono. Y. 2004. Development in Agriculture continuous to retret. Kompas. January 8, 2004: 1.

Table 1. The effect of WD to the plant height (cm), flower and pod number

WD deficit level (%)	Plant height			Flower	Pod
	Week V	Week VI	Week VII	Week VI	Week VII
WD1 (0-20)	67 a a	96 a a	97 a a	25 a a	23 a a
WD2 (20-40)	58 a a	87 a a	97 a a	23 a a	15 a a
WD3 (40- 60)	56 aab	81 a a	85 b b	23 a ab	15 ab ab
WD4 (60-80)	38 b b	52 b b	58 c b	9 b b	6 bc b
WD5 (80-100)	37 b b	48 b b	51 c b	9 b b	5 c b
BNT (%)	5 1	5 1	5 1	5 1	5 1

Remarks: numbers followed by the same letters vertically were not significant different

Table 2. The effect of WD to the leaf number

WD deficit level (%)	Week IV	Week V	Week VI	Week VII
WD1 (0-20)	15 a a	32 a a	57 a a	78 a a
WD2 (20-40)	14 a a	30 ab a	50 ab a	71 a a
WD3 (40-60)	11 b b	25 b ab	46 b a	64 a a
WD4 (60-80)	11 b b	18 c bc	26 c b	29 b b
WD5 (80-100)	10 b b	16 c c	20 c b	26 b b
LSD (%)	5 1	5 1	5 1	5 1

Remarks: The same as table 1.

Table 3. The effect of WD to total biomass , yield, CWR, WUE, and YE.

WD level (%)	Total Biomas (g)	Yield (g)	CWR (mm)	WUE (g/mm)	YE (g/mm)
WD1	46 a a	9.13 a a	479 a a	0.096	0.019
WD2	45 a a	9.08 a a	456 a a	0.098	0.020
WD3	35 b b	7.88 a b	372 b b	0.095	0.021
WD4	15 c c	3.13 b b	246 c c	0.059	0.013
WD5	11 c c	2.68 b b	223 c c	0.051	0.012
LSD(%)	5 1	5 1	5 1		

Remarks: The same as table 1.

Table 4. The Ratio ET_a/ ET_m, and K_s.

WD level	Week						
	I	II	III	IV	V	VI	VII
WD1	1	1	1	1	1	1	1
WD2	0.94	0.95	0.97	0.90	0.98	0.87	0.93
WD3	0.92	0.87	0.95	**0.78**	**0.86**	**0.78**	**0.71**
WD4	0.89	0.87	0.80	**0.67**	**0.67**	**0.43**	**0.39**
WD5	0.81	0.85	0.79	**0.62**	**0.67**	**0.41**	**0.34**
ET_m (mm)	2.6	1.41	1.88	3.9	4.6	9.6	13.2

Assume: The bold number is in stress condition. K_s is ET_a/ ET_m value in stress condition or $ET_{c\ adj}$ / ET_c.

Table5.The yield, ET, $1-Y_a/Y_m$, $1-ET_a/ET_m$, and Ky

WD deficit level (%)	Yield (g)	ET (mm)	$1-Y_a/Y_m$	$1-ET_a/ET_m$	Ky
WD1 (0-20)	9.13	479	-	-	-
WD2 (20-40)	9.08	458	0.055	0.045	0.12
WD3 (40-60)	7.88	372	0.132	0.224	0.61
WD4 (60-80)	3.13	246	0.659	0.486	1.35
WD5 (80-100)	2.68	223	0.703	0.535	1.32
				Average	0.85

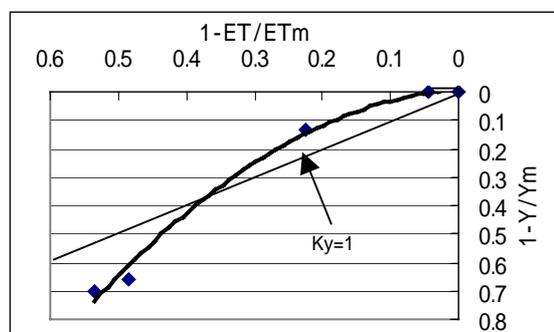Remarks: It is assumed that ET and yield at WD1 is the max. ET (ET_m) and max. yield (Y_m)

Figure 1. The relation between relative decreased (1-Ya/Ym) and relative ET (1-ETa/ETm)