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Effects of Water Deficit at Tasseling on Photosynthesis, Development, and Yield of Corn

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ABSTRACT

This study was conducted to determine the effects of water deficits on net assimilation rates and development which were causes of grain yield reduction in maize. Two maize inbreds, Ki3 (purported drought sensitive) and Ki11 (purported drought tolerance), were pot-grown in greenhouse. Plants were exposed to water deficit by withholding water until wilting occurred at tassel initiation and at anthesis. Water deficit at both stages reduced net assimilation rates (NAR) and relative growth rates (RGR) significantly in both maize inbreds. The reduction was more evident in Ki3 than that in Ki11. Water deficit at tassel initiation increased anthesis-to-silking interval (ASI) for 3 and 2 days in Ki3 and Ki11, respectively, while water deficit at anthesis increased ASI for only 1.25 and 0.75 days in Ki3 and Ki11, respectively. Considering yield and yield components, it was found that water deficits reduced ear girth, seed weight, grain yield, and harvest index in both inbreds. Water deficit at tassel initiation showed greater effects on those components than did the one at anthesis.

Key words: water deficit, photosynthesis, development, yield, corn

INTRODUCTION

Water deficit is an important environmental factor limiting growth and yield of plants. The effect is through increasing leaf abscisic acid (ABA) (Aspinall, 1980; Udomprasert *et al.*, 1999), inducing stomatal closure (Heitholt *et al.*, 1991) and thus reducing photosynthetic rates (Ludwig and Matthews, 1993). Rewatering increases the rates to the same levels as those of the non-stressed plants.

The effect of water deficit on photosynthesis has consequent influence on plant growth and yield (Westgate and Boyer, 1985; Schussler and Westgate, 1991). Water deficit at seedling stage of maize caused wilting, stunting, delayed rate of leaf emergence, reduced leaf area, causing the decrease in dry matter accumulation of above ground portion of plants (Abrecht and Carberry, 1993).

Responses of maize to water deficit differed among varieties, levels of water deficit, and growth stages. It was usually found that tasseling is the most drought-sensitive stage (Udomprasert and Thiraporn, 1994; Westgate and Grant, 1989). Water deficit prior to tasseling to kernel set caused the delay in tasseling and silking more than 2 weeks and more than 90% decrease in yield (NeSmith and Ritchie, 1992).

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The objective of this study is to determine the effect of water deficit on photosynthesis and development which consequently effect yield of maize. The experiment was carried out using drought-sensitive and drought-tolerant varieties. The result from this study will be used as primary information for crop improvement toward drought tolerance.

MATERIALS AND METHODS

Plant Materials

The purported drought-sensitive inbred, Ki3 and the purported drought-tolerant inbred, Ki11 were planted one in each 30-cm-diameter pot. The soil mixture used composed of soil : manure : rice husk charcoal in the ratio of 1 : 1 : 1. Plants were grown under greenhouse conditions at Central Laboratory and Greenhouse Complex, Kasetsart University Research and Development Institute, Kasetsart University, Kamphaeng Saen campus. The 15-15-15 fertilizer was applied at the rate of 1.5 g/pot every two weeks. Corn hybrids and treatments were organized in split plot arrangement in a completely randomized design with inbred as a main plot and treatment as a subplot.

Water Treatments

Plants were watered twice a day and soil moisture was maintained at field capacity level throughout the growing season, except during periods of water-supply restriction. At tassel initiation (about 45 days after emergence) and at anthesis (about 55 days after emergence), the water was withheld until plants wilted which lasted for 3 days and they were rewatered to the original level.

Measurements

The following growth and development parameters were collected: 1) number of leaves; 2) leaf area, by measuring width and length of leaves and leaf area calculated from the equation : Leaf area = width × length × 0.75 ; 3) anthesis-to-silking interval (ASI), which is the interval between the day of 50% tasseling and the day of 50% silk emergence.

Five plant samples from each treatment were collected every 2 weeks for relative growth rate (RGR) and net assimilation rate (NAR) analyses using the following equations:

$$RGR = 1/W * dW/dt$$

$$NAR = 1/L_A * dW/dt$$

where W = dry weight, t = time, and L_A = leaf area.

When plants reached physiological maturity (about 120 days after planting), plants were harvested for yield components which are number of ear/plant, number of row/ear, number of seed/row, ear length, ear girth, 1000-seed weight, and grain yield. Dry matter of the whole plant was also determined and harvest index (HI) calculated from the following equation:

$$HI = \frac{\text{grain yield}}{\text{Total dry matter}} \times 100\%$$

Statistical analysis was carried out using Analysis of Variance and means were compared using $LSD_{(0.05)}$.

RESULTS AND DISCUSSION

Water deficit at tassel initiation (45 days after emergence) and at anthesis (55 days after emergence) reduced photosynthetic rates (Fig.1), consequently reduced growth in both corn varieties (Fig. 2). The reduction in photosynthetic rates and growth in Ki3, the purported drought sensitive variety, was greater than those of Ki11, the purported drought tolerant variety.

Water deficit at tassel initiation and at anthesis increased the anthesis-to-silking interval (ASI) (Table 1). The increase was 3 days in Ki3 and 2 days in Ki11 when water deficit was imposed at tassel initiation, whereas the increase was 1.25 days in Ki3 and 0.75 day in Ki11 when water

deficit was imposed at anthesis. This indicated that ASI was affected more in Ki3 than in Ki11 and that the effect of water deficit was greater at tassel initiation than that at anthesis.

Water deficit had no effect on number of ear/plant, number of row/ear, number of seed/row, and ear length but reduced ear girth, seed weight, grain yield, and harvest index (Table 2). The reduction caused by water deficit was greater at tassel initiation than that at anthesis. This contradicted with photosynthetic rate (Figure 1) and growth rate (Figure 2), but corresponds with ASI (Table 1). The results suggested that silk growth decreased when plants were subjected to water deficit at tassel initiation which may be due to less assimilate transported to silk during water

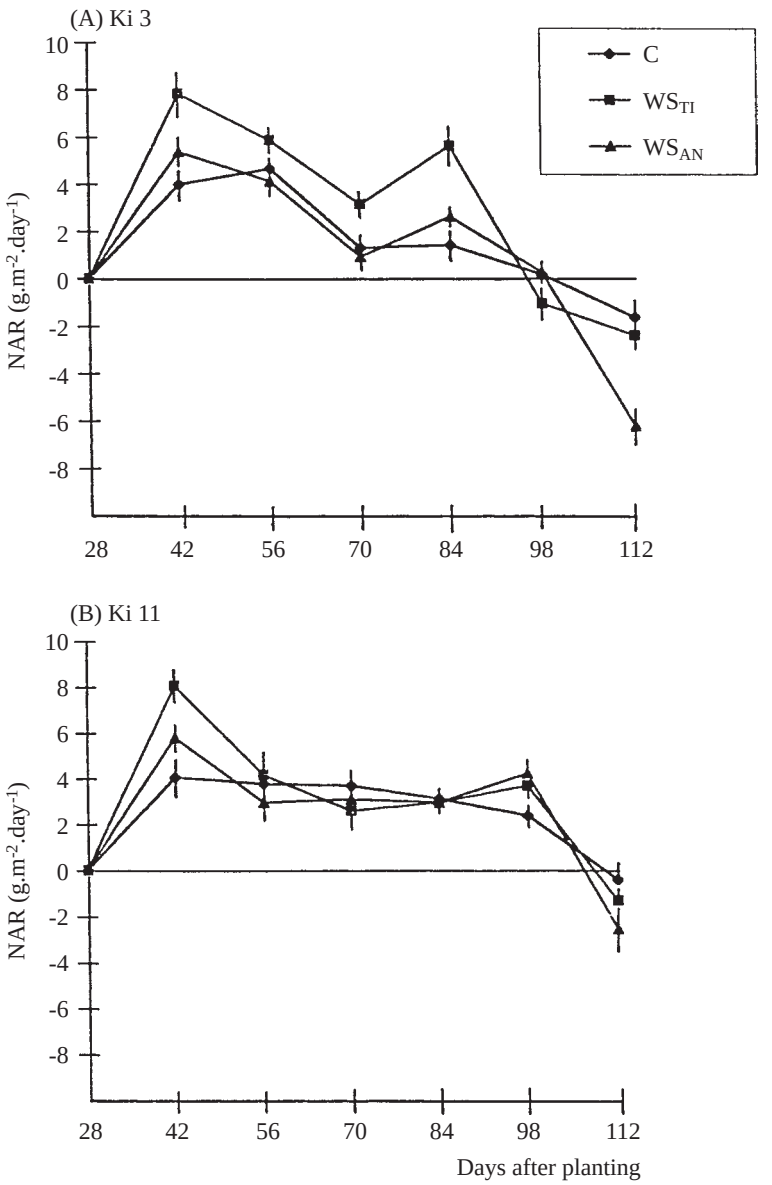

Figure 1 Net assimilation rates (NAR) of two corn inbreds Ki3 (A) and Kill (B), as affected by water stress at tassel initiation and at anthesis. Data are the mean ±SE of five plants.

deficit. Bolanos and Esmeades (1993) reported that ASI contributed up to 76% in determining variation of grain yield. Some studies found that water deficit during tasseling reduced grain yield regardless of the occurrence of pollination (Schussler and Westgate, 1991; Westgate and Boyer, 1986). Water deficit reduced silk and ovary water potential (ψ_W) but fertilization still took place until silk ψ_W was as low as –1.0 MPa (Westgate and Boyer, 1986; Bassetti and Westgate, 1993). Therefore, seed loss in fertilized plants may be due to the abortion of zygote right after fertilization (Westgate and Boyer, 1986).

While there were convincing evidences that water deficit delays silk emergence which reduces silk growth directly, there were reports suggesting that reduced photosynthesis due to water deficit had greater effect on seed set

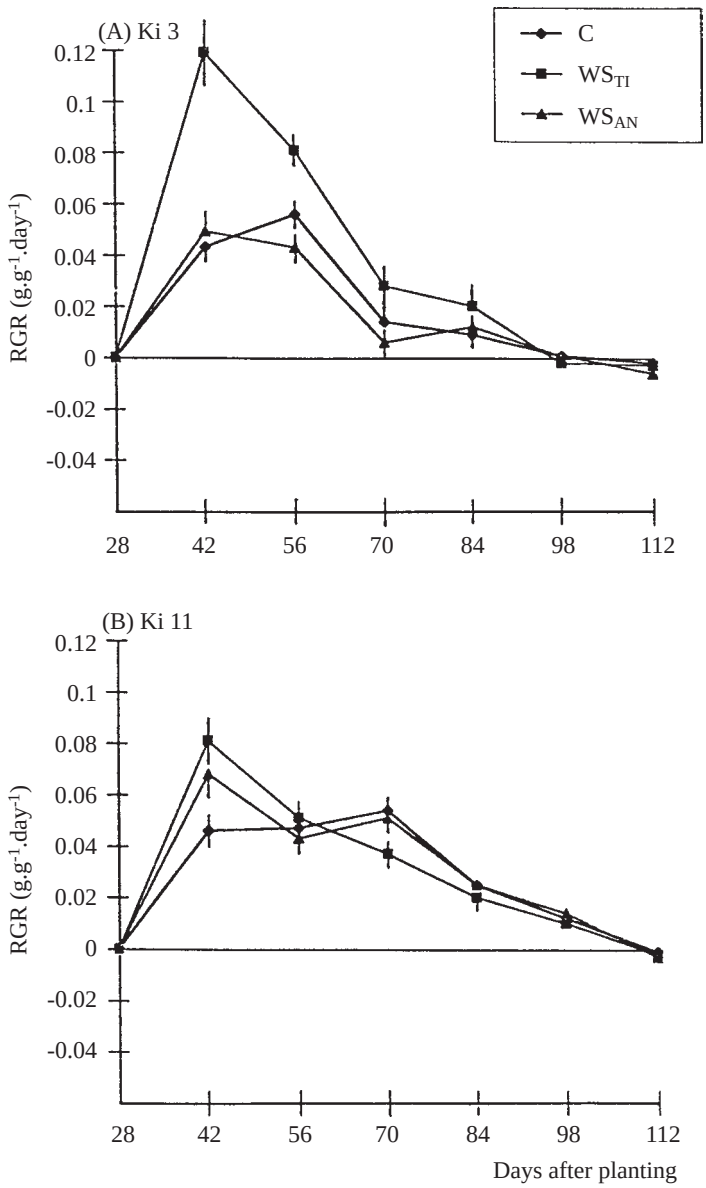

Figure 2 Relative growth rates (RGR) of two corn inbreds Ki3 (A) and Kill (B), as affected by water stress at tassel initiation and at anthesis. Data are the mean ±SE of five plants.

(Westgate and Boyer, 1986; Schussler and Westgate, 1991). A number of studies indicated that reduction of assimilates during water deficit was the major factor decreasing plant yield (Westgate and Boyer, 1985; Schussler and Westgate, 1991). Water deficit which inhibited photosynthesis for 6 days during pollination completely inhibited seed set in corn (Schussler and Westgate, 1991). It was found in the same study that inhibition of photosynthesis in well-watered corn plants during the same period caused about 70% reduction in seed set. In the subsequent study, it was found that photosynthesis prior to and during water deficit had greater effect on seed set than did the previously accumulated assimilates and that selection for greater assimilates during pollination did not help increasing seed set under water stress conditions in corn (Schussler and Westgate, 1994).

CONCLUSION

1. Water deficit during tasseling reduced photosynthesis and growth in corn.

2. Water deficit reduced assimilates which promotes silk growth and increased anthesis-to-silking interval, thus reduced corn kernel set.

Table 1 Anthesis-to-Silking Interval (ASI) of two corn inbraeds in response to different water stress treatments.

Inbred	Treatment	ASI (days)
Ki3	Control	2.75
	WS_{TI}	5.75
	WS_{AN}	4.00
Ki11	Control	4.00
	WS_{TI}	6.00
	WS_{AN}	4.75
F test	(inbred)	*
	(treatment)	*

* = significant at 5% level

WS_{TI} = water stress at tassel initiation;

WS_{AN} = water stress at anthesis

Table 2 Yield and yield components of two corn inbreds in response to different water stress treatments.

Variety	Treatment	No. of ear /plant	No. of row /ear	No. of seed /row	Ear length (cm)	Ear girth (cm)	Seed weight (g/1000 seeds)	Grain yield (g/plant)	HI (%)
Ki3	Control	1.75	12.00	2.60	9.48	6.06	156.13	3.23	4.23
	WS_{TI}	1.25	10.00	1.77	7.25	4.65	98.00	1.73	3.13
	WS_{AN}	1.50	10.50	2.44	8.05	4.90	118.25	2.61	5.63
Ki11	Control	1.75	11.75	3.71	9.25	6.00	250.75	10.17	9.53
	WS_{TI}	1.50	10.75	1.67	8.51	5.56	156.00	3.80	4.30
	WS_{AN}	1.50	12.25	2.58	8.77	5.90	176.25	5.62	6.10
F test	(variety)	**	ns	ns	ns	*	**	**	*
	(treatment)	ns	ns	ns	ns	*	*	*	*

** = significant at 1% level; * = significant at 5% level

WS_{TI} = water stress at tassel initiation; WS_{AN} = water stress at anthesis

3. Reduced photosynthesis due to water deficit also impaired seed development after fertilization which consequently reduced kernel size.

4. Water deficit had greater effect on Ki3 (a purported drought sensitive inbred) than Ki11 (a purported drought tolerant inbred).

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