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Growth responses of tobacco to flooding

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Abstract. The effects of flooding injury to tobacco plants were quantitatively investigated. Total, root, and leaf dry weights, leaf area, relative growth rate, and net assimilation rate were significantly lower in tobacco plants flooded for 4 days than in the corresponding controls. However, stem dry weight was not affected by flooding. None of the growth parameters, except stem dry weight, were restored during the recovery period. Flooding treatment resulted in an increase in stem dry weight ratio, and a decrease in root dry weight ratio. However, leaf dry weight ratio was not changed by flooding. These results indicate that flooding causes an accumulation of assimilates in the stem.

Key words: Dry matter accumulation; Flooding; Growth analysis; *Nicotiana tabacum*.

Introduction

Soil water stress is a major ecological factor in the growth and productivity of crop plants. For most crop plants that are not adapted to wetland conditions, soil flooding reduces shoot and root growth, dry matter accumulation, and crop yield (Bourget *et al.*, 1966; Cameron, 1973; Harkett and Burton, 1975; Musgrave and Vanhoy, 1989; Trought and Drew, 1980; Watson *et al.*, 1976; Williamson and Kriz, 1970). Root metabolism of most crop plants responds to soil flooding more rapidly than shoot assimilation and metabolism (Arm-

injury in mung bean plants in considerable detail, using the technique of growth analysis. In the study presented here, we investigate the effects of flooding on the growth of tobacco plants.

Materials and Methods

Seedlings of *Nicotiana tabacum* cv. Speight G-70 were selected 30 days after sowing the seeds in plastic trays and grown in a greenhouse thereafter, each in a small plastic pot (25 cm^2) bag. After 30 days, the seedlings were again selected for uniformity and transplanted to pots (5 dm^2) containing a sandy loam. Each pot then divided into leaves, stems and roots. Leaf area was determined by a leaf-area meter (AAC-400, Hayashi Denkoh, Japan). Prior to weighing, the plant tissues were oven-dried in paper bags for 2 days at 65°C with forced convection. Net assimilation rate (NAR), leaf specific weight (LSW), relative growth rate (RGR), leaf area durtion (LAD) and dry matter accumulation ($\triangle W$) were calculated according to Patterson (1982). Given that $\triangle T$ = length of harvest interval, W_1 and W_2 = total dry weight at the beginning and end of the interval, and A_1 and A_2 = total leaf area at the beginning and end of the interval, then $\triangle W = W_2 - W_1$, $NAR = (W_2-W_1)/\triangle T \times (\ln A_2 - \ln A_1)/(A_2-A_1)$, $RGR = (\ln W_2 - \ln W_1)/\triangle T$, and $LAD = (A_2-A_1)/(\ln A_2 - \ln A_1) \times \triangle T$. Given that W, L, R, and S = dry weights of total plant, leaves, roots, and stems, respectively, and A = leaf area, then leaf dry weight ratio = $L/W \times 100$, stem dry weight ratio = $S/W \times 100$, root dry weight ratio = $R/W \times 100$, and specific leaf weight = L/A.

Results and Discussion

Total dry weight of flooded tobacco plants was lower than that of the control plants during the flooding period and recovery period (Fig. 1). This was also reflected in the measurement of RGR (Table 1).

For a given interval, $\triangle W$ is approximately equivalent to the product of the rates of net photosynthesis per unit area (NAR) and amounts of leaf area duration (LAD). Table 1 shows the effects of flooding on $\triangle W$, LAD and NAR of tobacco plants during the flooding and recovery periods. It is clear that the decrease in dry matter accumulation of tobacco plants during the flooding period can be attributed to the reduction in NAR, and the decrese during the recovery period is due to the reduction in both NAR and LAD. Musgrave and Vanhoy (1989) reported that the NAR of mung bean plants increased during the flooding period.

Root, leaf and stem tissues responded to flooding differently (Fig. 1). Root and leaf dry weights of the plants whose roots were flooded for 4 days were lower than those of the controls during the flooding and recovery periods, whereas stem dry weight was not sig-

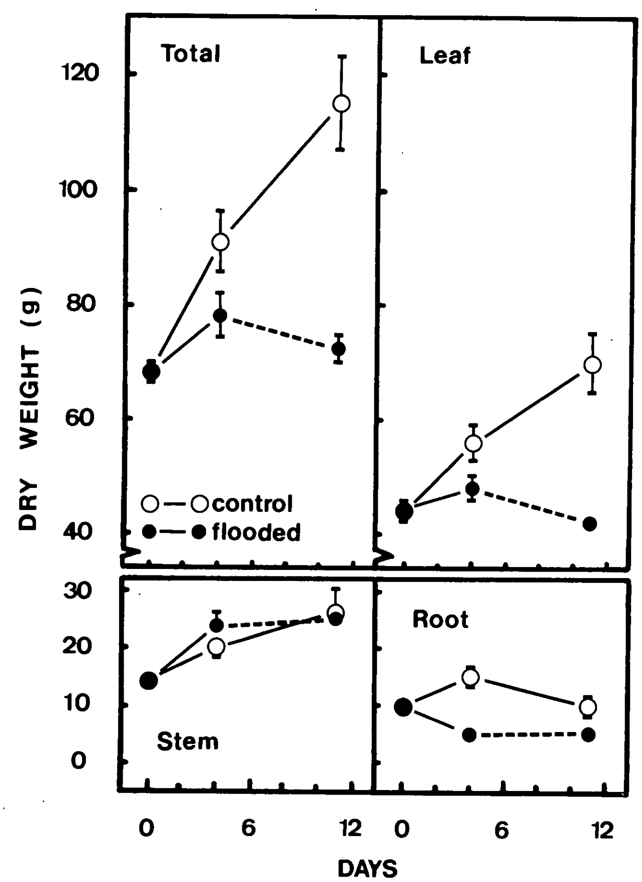

Fig. 1. Changes in total, leaf, stem, and root dry weights in tobacco plants during flooding and recovery (broken lines) compared with unstressed controls. Bars indicate standard errors.

Table 1. *Effects of flooding on relative growth rate (RGR), dry matter accumulation ($\triangle W$), leaf area duration (LAD), and net assimilation rate (NAR) of tobacco plants during flooding and recovery. Means ± SE are shown*

	Flooding Period		Recovery Period	
	Control	Flooding	Control	Flooding
RGR, g $g^{-1}day^{-1}$	0.073±0.012	0.031±0.007	0.048±0.010	0.006±0.003
$\triangle W$, g	22.9±4.8	8.8±3.8	47.6±8.5	4.7±1.4
LAD, dm^2 days	327.6±10.3	306.2±11.4	970.3±25.3	732.5±23.0
NAR, g dm^{-2} day^{-1}	0.070±0.006	0.029±0.007	0.043±0.007	0.006±0.002

nificantly affected by flooding. The effects of flooding on root dry weight ratio, stem dry weight ratio, and leaf dry weight ratio are presented in Fig. 2. Flooding resulted in an increase in stem dry weight ratio and a decrease in root dry weight ratio. However, leaf dry weight ratio was not significantly affected by flooding.

The effects of flooding on leaf area and SLW of tobacco plants are shown in Fig. 3. Similar to other growth parameters measured, leaf area was reduced by the 4-day-flooding treatment. By the end of the recovery period, the leaf area of flooded plants was greatly reduced. The great reduction of leaf area in the flooded plants was possibly due to flooding-inhibited leaf growth and flooding-promoted leaf abscission. Fig. 3 [illegible]

Musgrave and Vanhoy (1989) also demonstrated that large increase in SLW in mung bean occurred during the flooding period. However, our results with tobacco did not confirm their findings. Neither leaf dry weight nor SLW of tobacco plants was increased by flooding. Furthermore, the leaf dry weight ratio of flooded tobacco leaves was similar to that of untreated control leaves during the flooding and recovery periods. The increase in leaf dry weight in the leaves of flooded plants as compared with untreated controls found by Trought and Drew (1980) and Musgrave and Vanhoy (1989) was attributed to the reduction of translocation of assimilates out of the leaves. Wample and Davis (1983) reported that chloroplasts in the leaves of sun- [illegible] showed that starch did not accumulate in the leaves of flooded tobacco plants (Hurng and Kao, 1993). It seems that no reduction of the translocation of assimilates out of the leaves of tobacco plants occurred during flooding and recovery.

Of particular interest of the present investigation is the finding that flooding causes an increase in stem dry weight ratio, a decrease in root dry weight ratio, and no change in leaf dry weight ratio. These results suggests that flooding causes an accumulation of assimilates in the stem. Our results are inconsistent with those of other investigators (Musgrave and Vanhoy 1989; Trought and Drew 1980), who reported that flooding caused an accumulation of assimilates in the leaves.

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淹水對菸草生長之影響

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本研究主要是探討淹水對菸草生長之影響。菸草經 4 天之淹水處理，植株之總乾重、根乾重、葉乾重、相對生長速率、淨同化速率與葉面積明顯的降低，經過七天的恢復期，亦無法恢復。然而，莖乾重在淹水期與恢復期均不受淹水處理的影響。淹水處理導致莖乾重比值增加，根乾重比值降低，但不影響葉乾重比值。顯示淹水處理使得同化物質無法由莖運移到根，而在莖累積。