FLOODING-INDUCED SOIL AND PLANT ETHYLENE ACCUMULATION AND WATER STATUS RESPONSE OF FIELD-GROWN TOBACCO*

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KEY WORDS
C_{2}H_{4} Eh Ethylene Flooding \(O_{2}\) Redox potential Sandy soil

SUMMARY

Ethylene (C_{2}H_{4}) accumulation in flooded soil was related to oxygen (\(O_{2}\)), redox potential (Eh), and flooding rate. The water status response of tobacco (\textit{Nicotiana, tabacum} L.) to these conditions was evaluated from stem diameter, relative water content, leaf water potential, and C_{2}H_{4} content of leaf tissue. Treatments were: flooded with either 0, 5, or 15 cm of water per day for 6 days. By the third day, \(O_{2}\) in the soil decreased to less than 9\% in treatments flooded with 5 or 15 cm of water. When \(O_{2}\) in the soil air was less than 9\% and redox potential (Eh) was less than +150 mv, most of the soil air samples contained some C_{2}H_{4} and 16\%, contained more than 6 ppm. Very little C_{2}H_{4} was present in soil air when \(O_{2}\) exceeded 9\%. Tobacco leaf C_{2}H_{4} peaked 3 days after flooding and then declined to the preflooding level a day later, one day ahead of the rapid increase in soil C_{2}H_{4}. Wilting developed progressively beginning with the rise of C_{2}H_{4} in the soil; leaf water potential, stem diameter, and relative leaf water content all were decreased. Soil- and plant-produced C_{2}H_{4} are suggested as factors in reducing root permeability and increasing resistance to water uptake by tobacco.

INTRODUCTION

In the Southeastern Coastal Plains of the United States, crops are exposed to both excessive soil water and drought due to a combination of erratic rainfall and low water retention of the predominant soil types. Physical properties of soils from this region have been described by Campbell, Reicosky, and Doty. In a study on a Varina loamy sand, Campbell and Phene found that matric potentials of less than −85 mb were associated with low \(O_{2}\) concentration in soil-air and reduction of millet (\textit{Pennisetum glaucum} (L.) R. Br.) yield. Tobacco (\textit{Nicotiana tabacum} L.), a crop more sensitive to low \(O_{2}\) and high soil water than millet, is economically important in this physiographic region. Wilting has been shown to take place in the presence of optimal soil water when oxygen...
has been excluded, or under flooding per se. Campbell\(^5\) reported that flue-cured tobacco yields were reduced 40\% when tobacco was flooded for longer than 48 hours. Kramer and Jackson\(^26\) reported that reduced soil O\(_2\) levels and reduced permeability of root systems under flooding could not totally explain the injury of tobacco in flooded soils, and suggested the involvement of microorganisms in the damage. Other scientists have more recently suggested nutritional involvement\(^12,15,37\). They have shown sufficiently rapid nutritional concentration changes to account for some physiological responses. They indicated partial relief of stress symptoms with nitrate addition under partially flooded conditions. However, under totally flooded conditions nitrate addition to the soil did not prevent flooding damage.

Ethylene, a plant hormone, has been found in numerous soils around the world\(^10,35,36\). Ethylene production in Norfolk loamy sand was cited as the possible cause of damage to potato plants and tubers\(^6\). Laboratory studies showed C\(_2\)H\(_4\) accumulations were associated with low O\(_2\) and high soil water content in Norfolk loamy sand\(^16\). Soil C\(_2\)H\(_4\) has also been reported to be translocated through the roots to the shoots of tomato plants and to cause epinastic growth when the soil concentration of C\(_2\)H\(_4\) was greater than 2 ppm\(^17\). Their results suggest that flooding damage to sensitive plants can be caused by soil-produced C\(_2\)H\(_4\). However, tomato plants can also produce C\(_2\)H\(_4\) in shoots in response to stress, specifically when roots are exposed to low O\(_2\) concentrations\(^19\). Bradford and Dilley\(^2\) have substantiated that C\(_2\)H\(_4\) is produced by tomato plants under flooded conditions and that this C\(_2\)H\(_4\) caused epinastic growth. They also showed that silver nitrate, a C\(_2\)H\(_4\) inhibitor, blocks the epinastic effect. These results suggest that both plant-produced and soil-produced C\(_2\)H\(_4\) may be related to the devastating flooding damage to tobacco.

We conducted a field study to more clearly define in situ (1) the extent of C\(_2\)H\(_4\) production in relation to soil oxygen, redox potential (Eh), and flooding and (2) to evaluate leaf water potential, stem diameter and leaf relative water content of tobacco in relation to C\(_2\)H\(_4\) and O\(_2\) concentrations produced in time by flooding of soil.

**MATERIALS AND METHODS**

The field experiment consisted of two blocks that contained: nonflooded (F\(_0\)), intermittently flooded (F\(_1\)), and continuously flooded (F\(_2\)) treatments. During a 6-day flooding period, 5 cm of water was applied to F\(_1\) each day at 0800. For the F\(_2\) treatment, approximately 15 cm of water was applied each day to keep the surface continuously flooded. Each block contained four replicates each of F\(_1\) and F\(_2\), but only one F\(_0\) treatment (extra F\(_1\) and F\(_2\) replicates resulted from pooling nonsignificant organic matter and nitrate treatments).