NUTRIENT DEFICIENCY IN INTERMEDIATE WHEATGRASS

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PHOTOGRAPHS COURTESY OF STACY HOLT JR. AND ANGELA BREKALO

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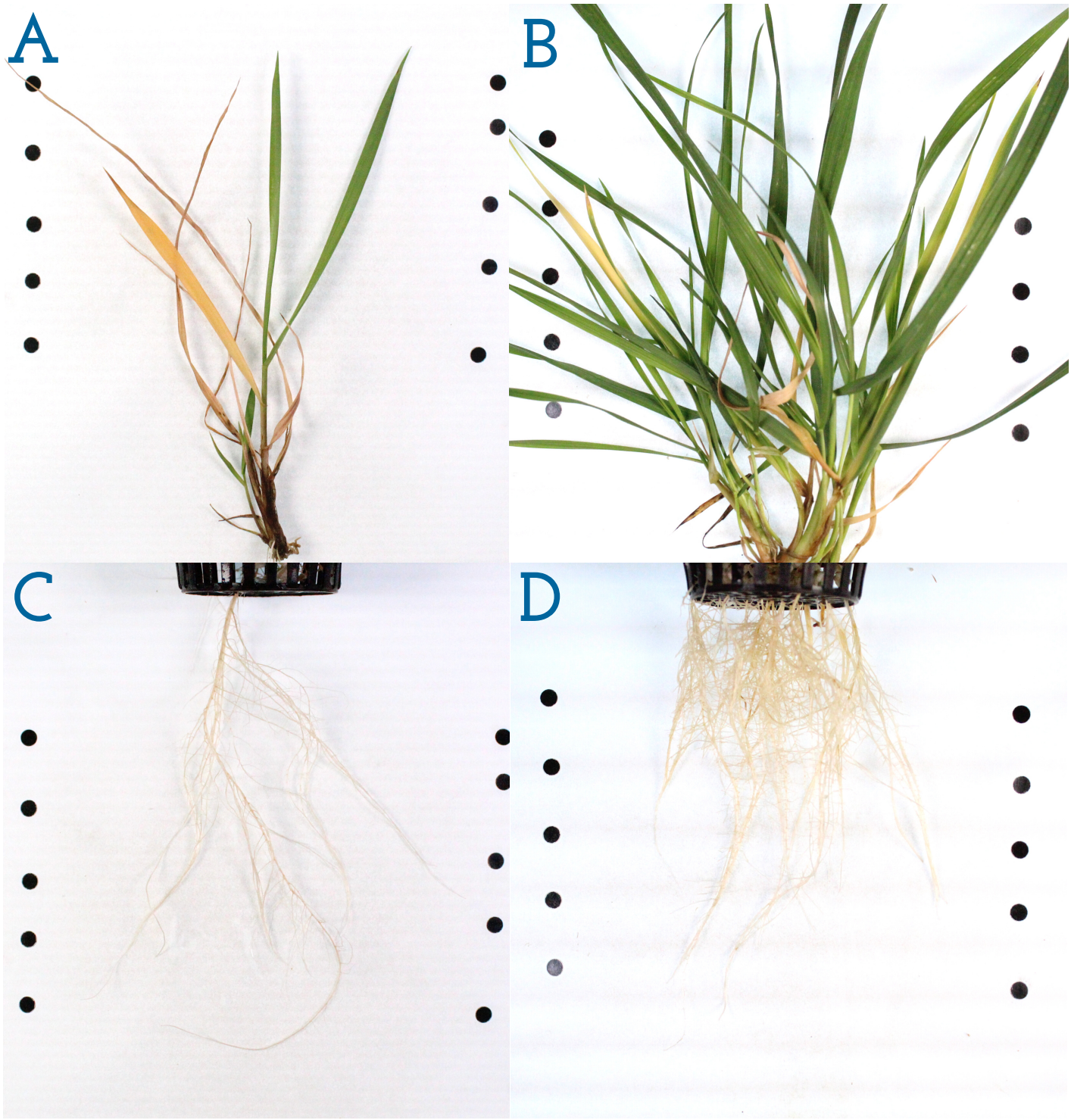
Methods

This project aimed to characterize the symptoms of various nutrient deficiencies in intermediate wheatgrass (the plant that produces Kernza® grain) in order to help growers and researchers identify nutrient deficiencies in their plantings.

To do this, 5-week-old intermediate wheatgrass plants were grown hydroponically in a greenhouse setting in net pots. Plants were fed a fertilizer solution containing either all the necessary nutrients or all the necessary nutrients minus one; these plants missing a specific nutrient (nitrogen, for example) are called deficient in this guide, assuming they need some amount of the nutrient higher than none. After 5.5 weeks in these treatment nutrient solutions, we took pictures of leaves and roots, described visible symptoms of nutrient stress, measured heights of plants from the base of the leaves to the tips, and weighed dried biomass. Leaf biomass is the dried weight of all aboveground plant matter. Root biomass is the dried weight of all roots. All images shown here were taken after 5.5 weeks of treatment unless otherwise noted. The black dots in the photographs are there to help with scale: the length of a row of dots is about 4 inches.

All plants in this study shared a single mother and had various fathers. This genetic similarity made finding common symptoms easier but might have caused us to miss symptoms that may appear differently based on genetics. This study is also limited by not following the plants through a "winter-time" nor through flowering and grain production. The pictures and descriptions here are a starting point and we welcome and encourage feedback about what you're seeing in your plantings!

Nitrogen (N)



A. Nitrogen-deficient plant. Older leaves turn yellow and die off starting at the leaf tip. Yellowing happens across the whole leaf. Leaves are short compared to control plants. Plants show reduced height and reduced leaf biomass. **B. Healthy control plant** with minimal leaf yellowing and die back. **C. Nitrogen-deficient roots.** N-deficient plants seem to have fewer thick roots than **D. Healthy control roots.**

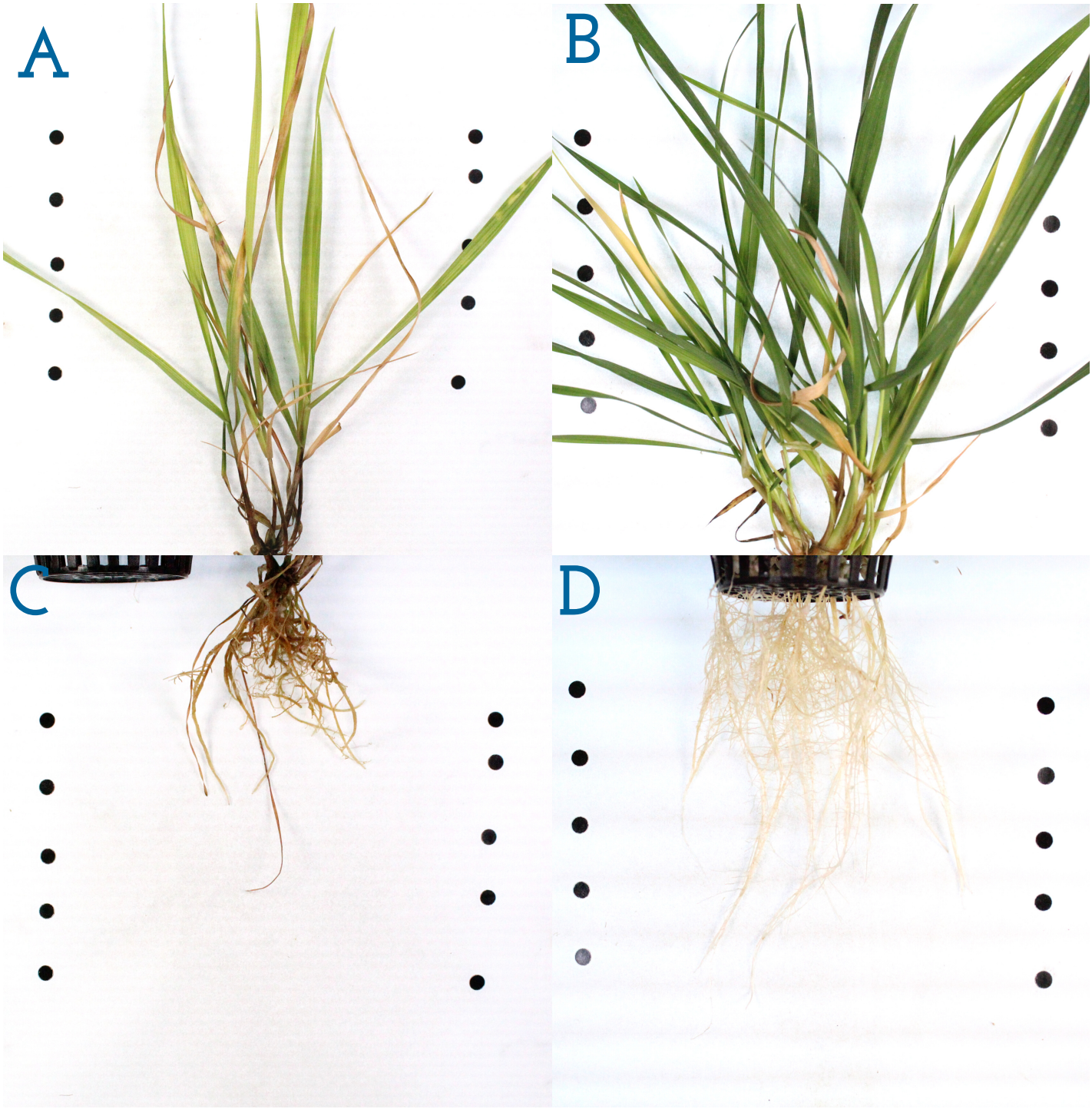
Nitrogen (N)

Intermediate wheatgrass leaves, from left to right: healthy control leaf; young nitrogen-deficient leaf; old nitrogen-deficient leaf. Nitrogen-deficient wheatgrass plants will continue to produce new green leaves, but they are stunted and quickly yellow and die back.

Potassium (K)

Leftmost leaf is a healthy leaf from a control plant. Right three leaves are from potassium-deficient plants. Potassium-deficiency causes new leaves to come in mildly yellowed. Older leaves will yellow at the edges of the leaves with some yellowing between the veins. Leaves may die back from the tips or develop brown dead spots. Potassium-deficient plants have reduced height compared to healthy control plants.

Potassium (K)

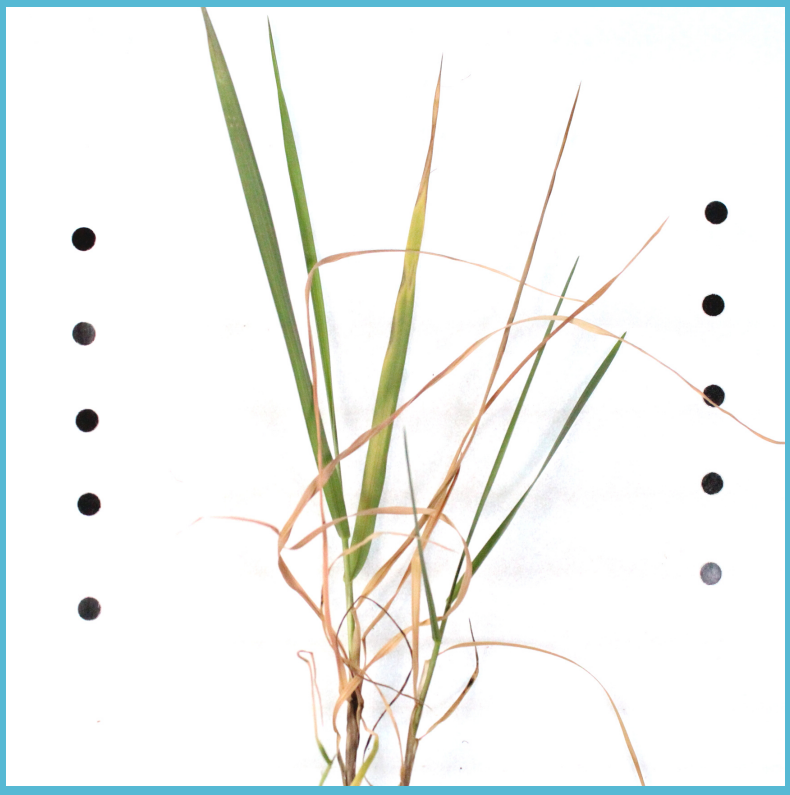


A. Potassium-deficient plant. This plant has a variety of symptoms, including general yellowing, yellow splotches on living leaves, and brown, dying splotches on the oldest leaves. K-deficient plants are shorter than **B. Healthy control plant.** **C. Potassium-deficient roots.** Roots are shorter and darker than **D. Healthy control roots.**

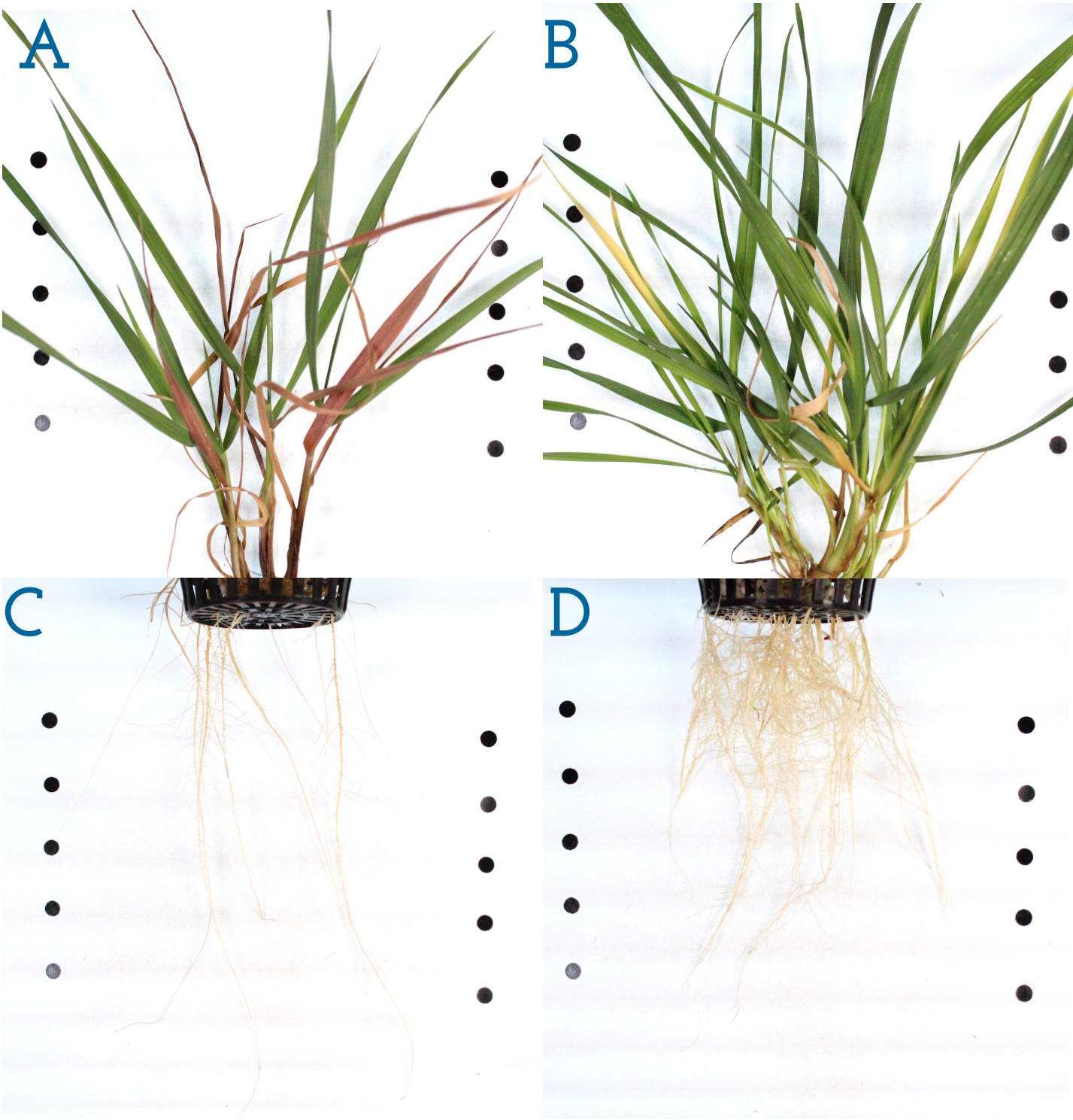
Phosphorous (P)

Intermediate wheatgrass leaves, from left to right: healthy control leaf; green phosphorous-deficient leaf, red-purple phosphorous-deficient leaf. Leaves begin growing green and look similar to healthy leaves. Eventually, older leaves turn red-purple and die off, remaining red-tinted compared to the dead leaves of healthier plants.

Depending on genetics and other factors, symptoms for the same nutrient deficiency may vary. Phosphorous-deficient leaves here did not turn red-purple while living but yellowed in large splotches before dying off. Dead leaves were still slightly red-tinted compared to healthy plants.



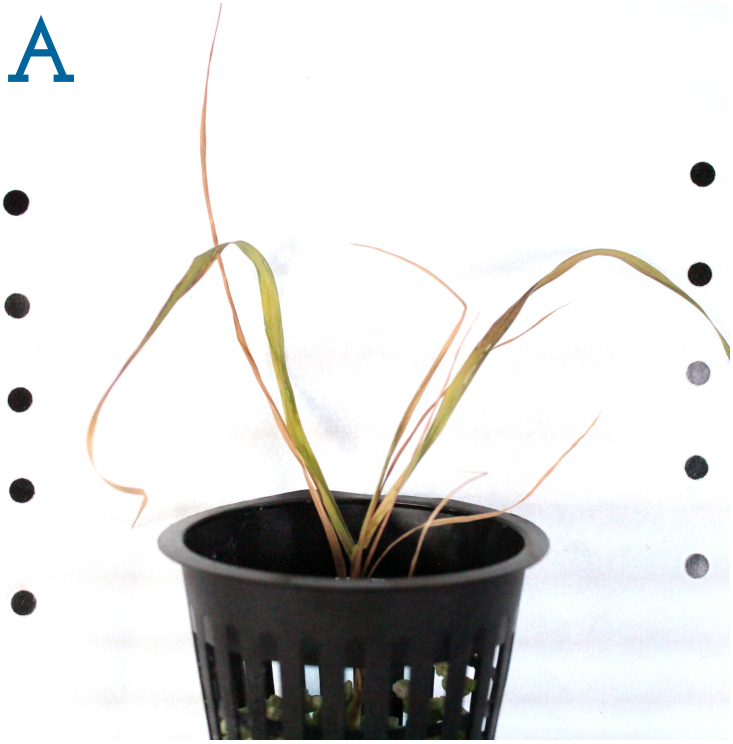
Phosphorous (P)



A. Phosphorous-deficient plant. Older leaves turn red-purple and die off. New leaves grow in green and roughly normal-sized. **B. Healthy control plant.** Healthy plants did not have red-tinting on living leaves, and dead leaves are more tan than on phosphorous-deficient plants. **C. Phosphorous-deficient roots.** Roots are longer and finer with reduced branching compared to **D. Healthy control roots.**

Calcium (Ca)

A



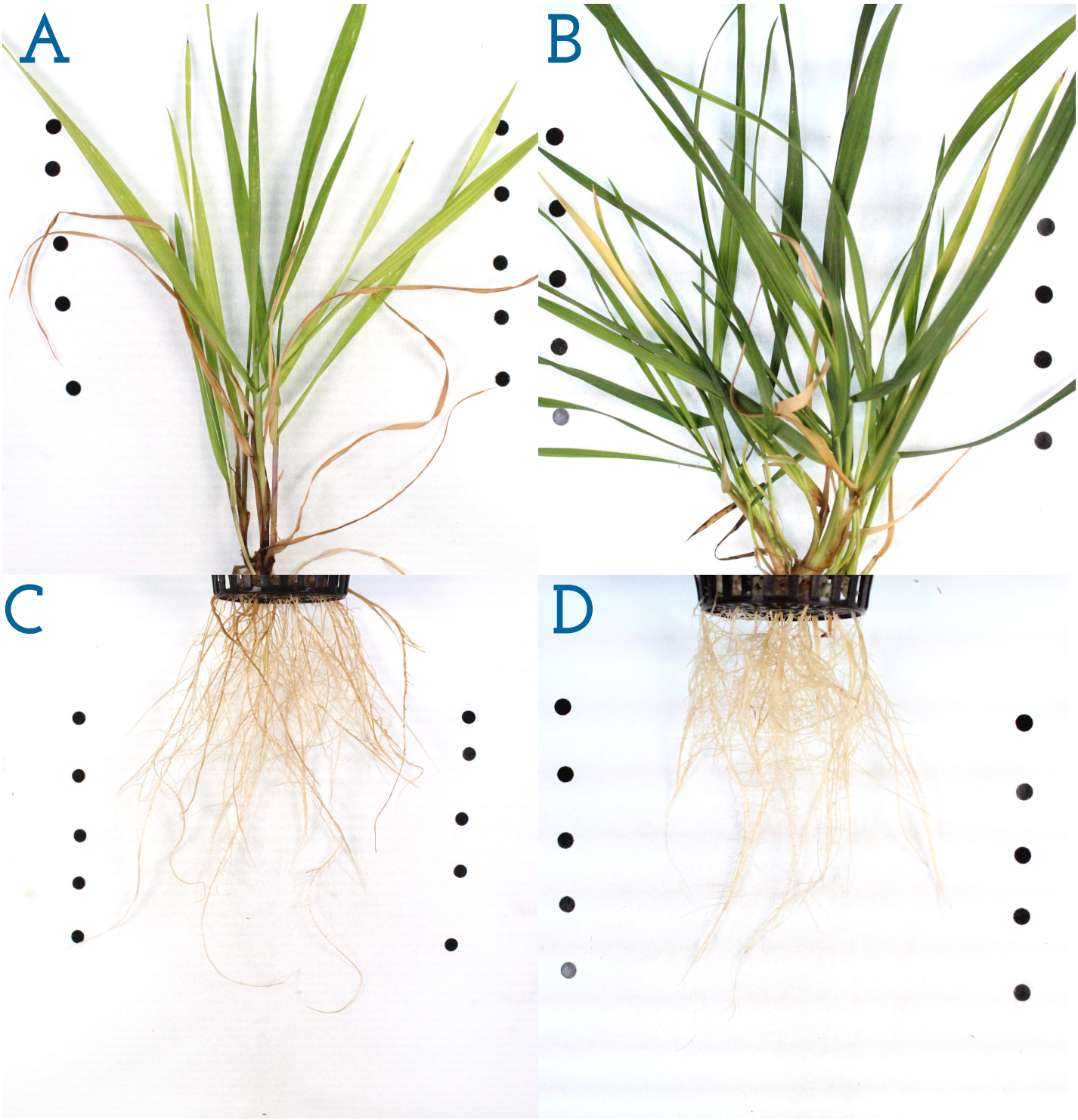
Calcium-deficient plants were not able to grow any new leaves or roots and thus had reduced leaf and root biomass compared to healthy control plants. These photos were taken after 3.5 weeks on calcium-deficient solution. The plants fully died soon after. Less severe calcium-deficiency may produce different or more distinctive symptoms.

A. Calcium-deficient leaves. Leaves yellowed or browned, curled over, and died.

B. Calcium-deficient roots. Existing roots became brown and mushy once they lost access to new calcium.

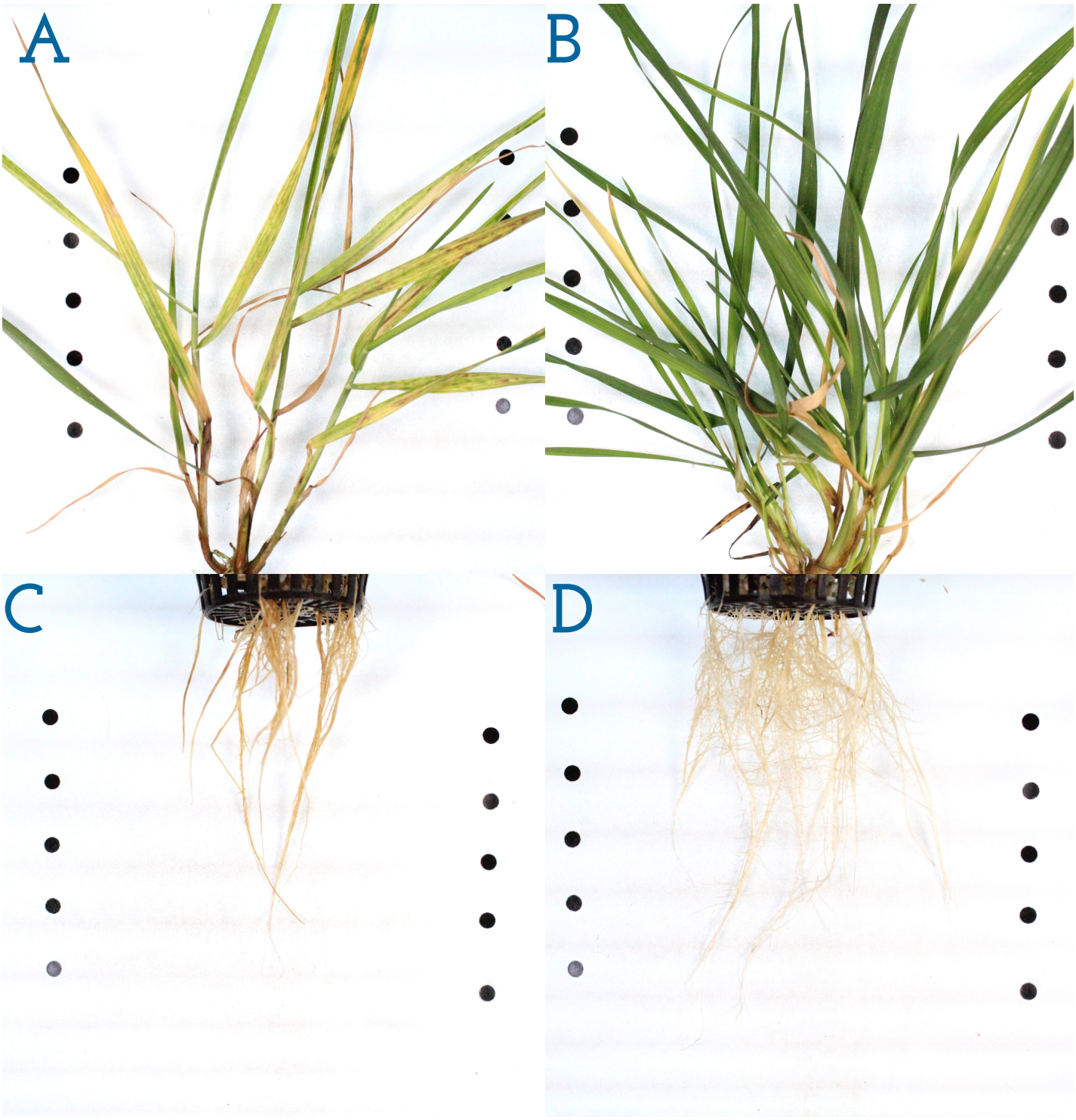
B

Sulfur (S)



A. Sulfur-deficient plant. All leaves are slightly yellowed. Yellowing occurs more evenly across the plant than in nitrogen-deficient plants and more evenly across the leaves than in potassium and iron deficiencies. S-deficient plants also have reduced height compared to healthy control plants. **B. Healthy control plant. C. Sulfur-deficient roots.** Roots are visibly similar to **D. Healthy control roots.**

Magnesium (Mg)



A. Magnesium-deficient plant. Leaves have yellow and reddish-brown splotches all over. New leaves come in light green with some splotches already. Some splotches (as seen on a couple of leaves here) were more tan than yellow. **B. Healthy control plant. C. Magnesium-deficient roots.** Roots appear to have reduced branching compared to **D. Healthy control roots.**

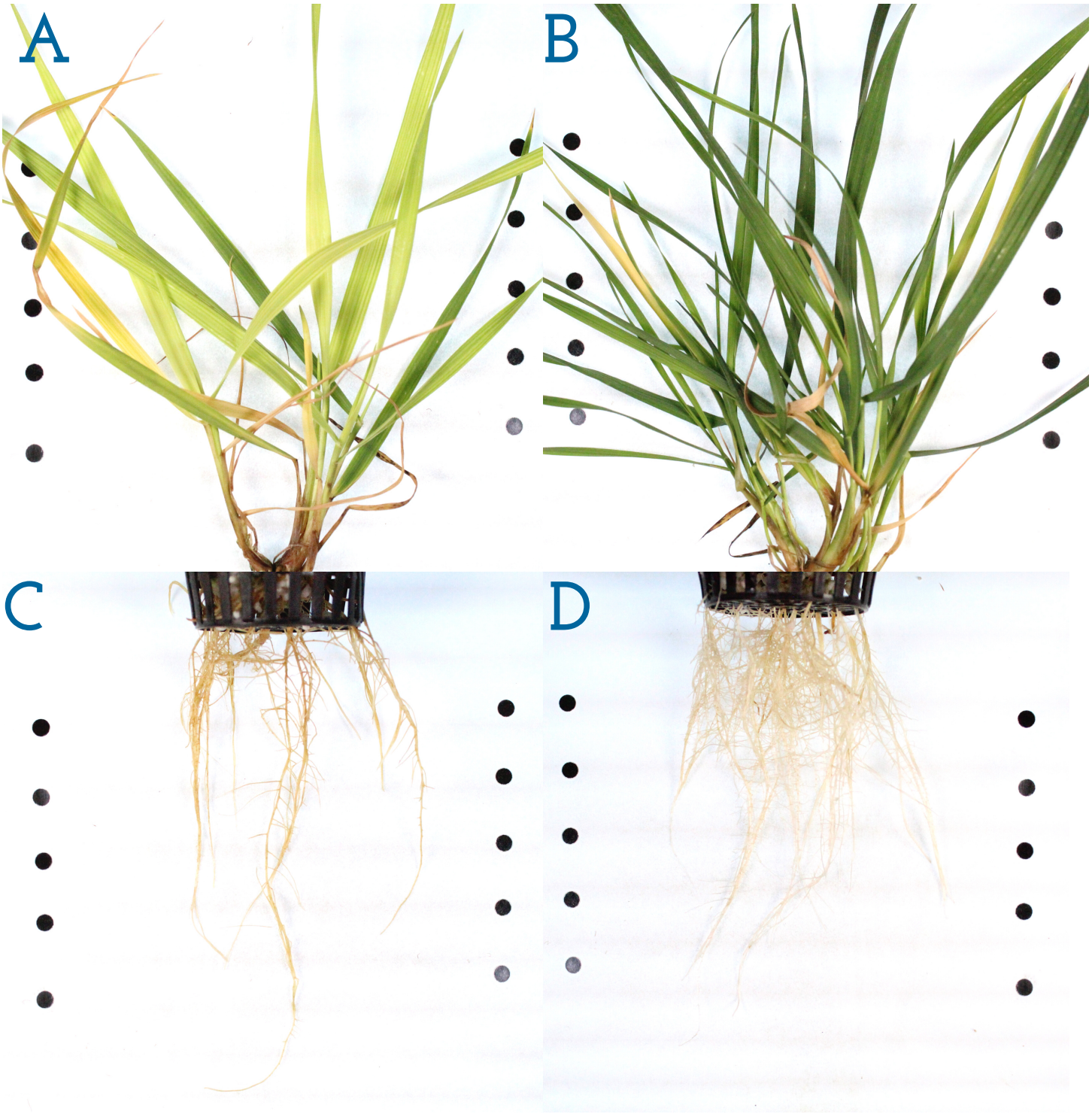
Magnesium (Mg)

Intermediate wheatgrass leaves, from left to right: healthy control leaf; mostly green Mg-deficient leaf with leaf tip die-back; Mg-deficient leaf with yellow streaking; Mg-deficient leaf with red-brown dead splotches and streaks; Mg-deficient leaf with yellow and tan splotches (near the base) and leaf tip die-back. Mg-deficient leaves are roughly the same size as control leaves.

Iron (Fe)

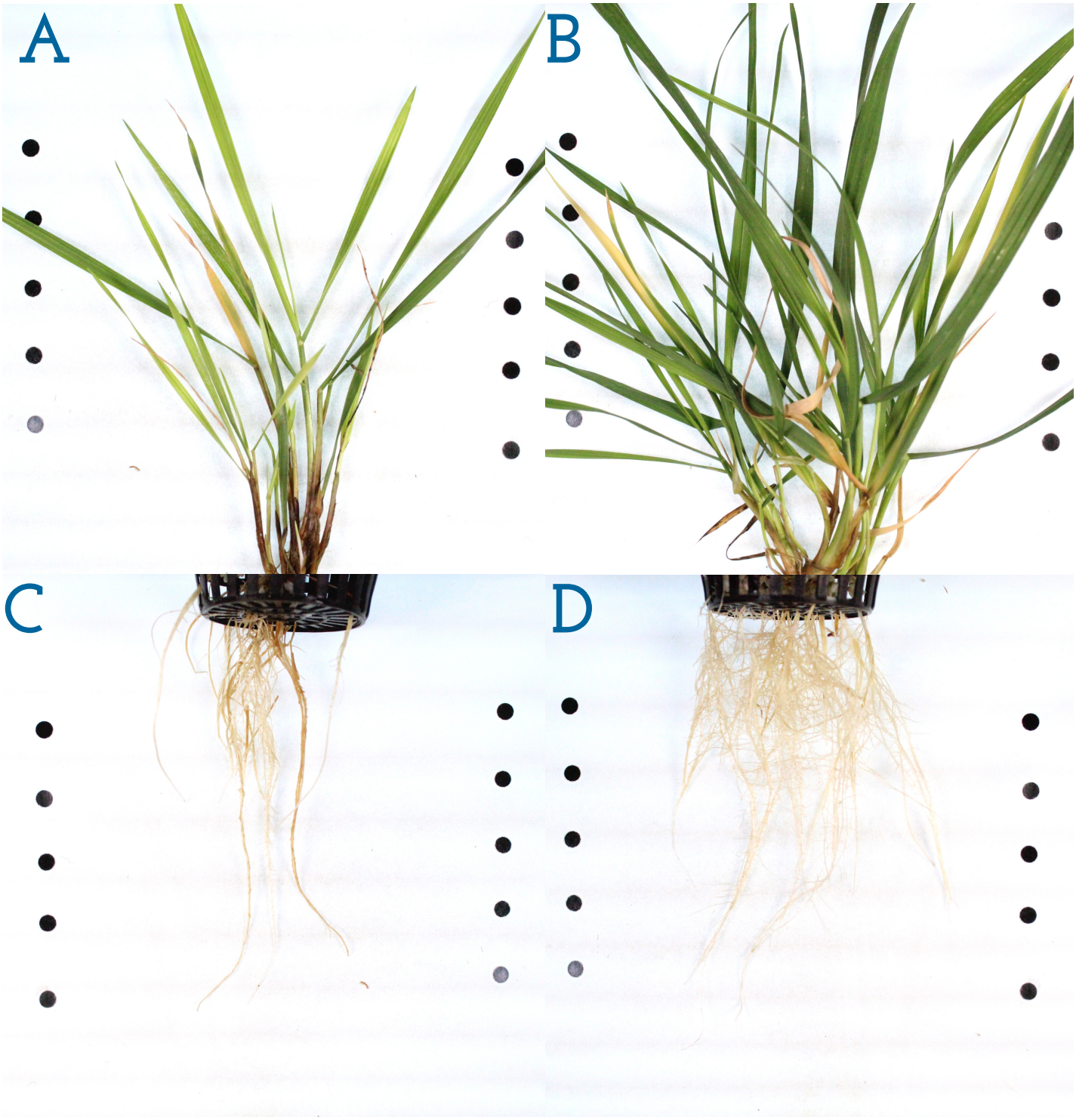
Leftmost leaf is a healthy leaf from a control plant. Right four leaves are from iron-deficient plants; leaves are on a gradient from oldest (leftmost) to youngest (rightmost). Iron deficiency causes leaves to yellow between the veins (yellowing appears streaky). Newer leaves are the most yellow (verging on white with severe deficiency) while older leaves may stay green and appear healthy. Some iron-deficient intermediate wheatgrass plants may slow down putting on new growth.

Iron (Fe)



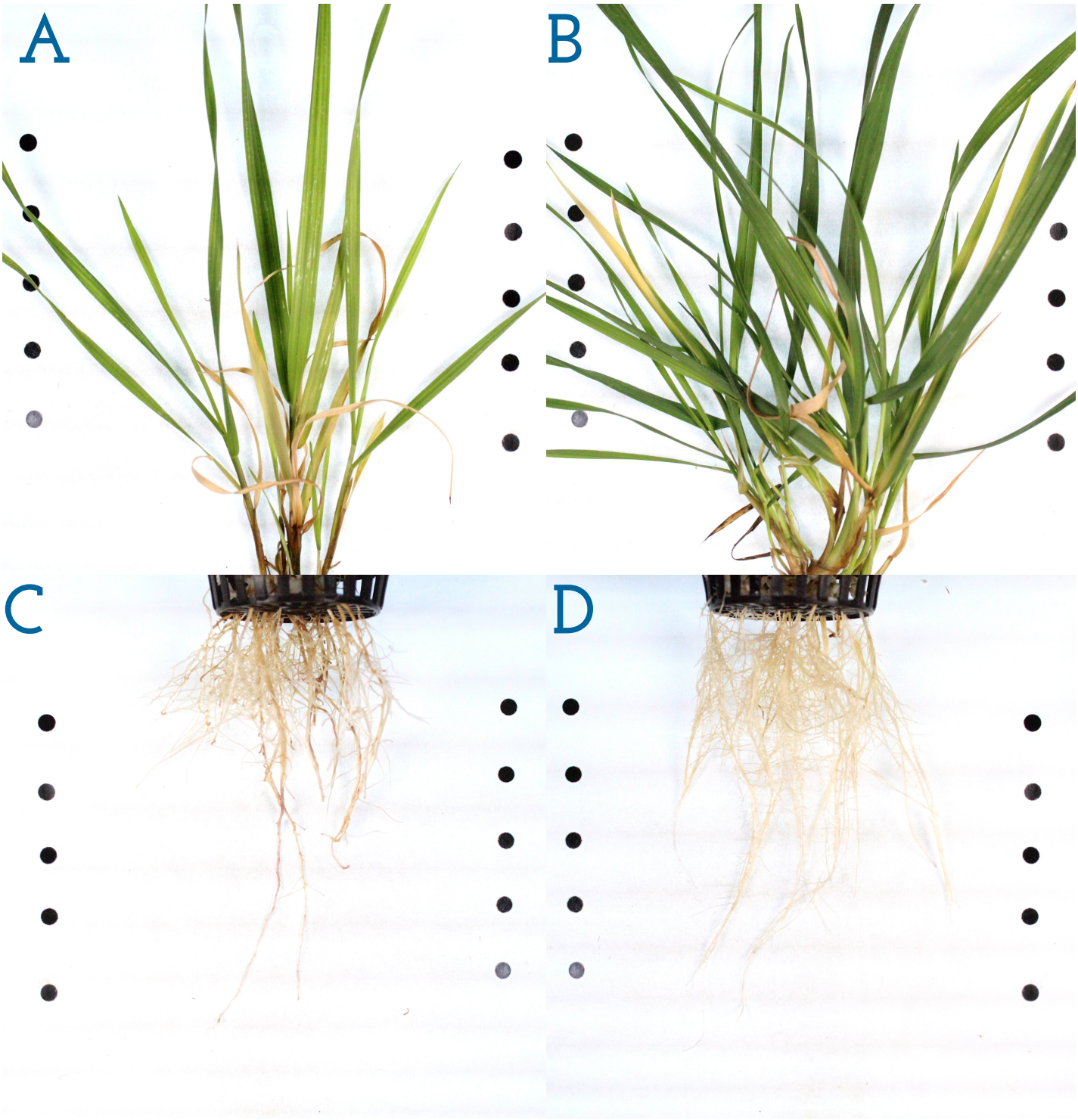
A. Iron-deficient plant. Newer leaves grow in increasingly yellowed between the veins. Older leaves stay green. Leaf size is similar to that of **B. Healthy control plant. C. Iron-deficient roots.** Iron-deficient plants seem to have fewer roots than healthy control plants. **D. Healthy control roots.**

Boron (B)



A. Boron-deficient plant. Some leaves slightly yellowed, primarily between veins. Leaf die-back begins at the base of the leaf. B-deficient plants also have reduced height compared to healthy control plants. **B. Healthy control plant. C. Boron-deficient roots.** Roots have reduced branching and root biomass compared to **D. Healthy control roots.**

Zinc (Zn)



A. Zinc-deficient plant. Leaves have yellow-white streaking between veins and/or small white dead spots. **B. Healthy control plant. C. Zinc-deficient roots.** Zinc-deficient plants have reduced root biomass compared to **D. Healthy control roots.**