Abstract. Understanding plant–water relations and predicting plant water stress are essential for improving irrigation efficiency and maximizing crop yields (10, 11). Plants are seldom completely free from some period of water stress during their life cycles. However, controversy exists as to when the onset of water stress occurs and how reliably it can be detected in the field (3). Many different criteria have been used for scheduling irrigation, most involving measurements or estimates of the soil water status with tensiometers, gypsum blocks, and neutron probes. However, the most reliable indicators of crop water stress are those that involve direct measurements on the plant (9–11). Insufficient information exists on suitable plant indicators of water stress for irrigation scheduling in peas. One possible indicator that is recognized by farmers is the appearance of a color change from green in a well-watered crop to a bluish green cast, which is a plant adaptation to drought (6, 15), and a change in leaf coloration. Visual indicators have the advantage of simplicity and the lack of need for any instrumentation.

Although soil water status is assessed in commercial fields with tensiometers (16), it would be desirable to augment these measurements and refine them with some easy and reliable plant measurements. Leaf water potential measurements make it possible to follow plant water status closely as soil water declines and water stress develops (1, 4). We have observed the appearance of a blue color in water-stressed pea treatments but not in well-watered controls. However, the change in leaf color in peas has not been documented nor used to indicate water stress. The objective of this preliminary study was to determine the relationship between pea leaf $\Psi$, as measured with a pressure chamber, and a change in leaf coloration.

Glaucousness, the bluish-green cast that imparts the bluish-green cast, has been cited as a plant adaptation to drought (6, 15), and wax amounts have been shown to increase under drought conditions (8). It has been suggested that the blue in water-stressed plants may be associated with an increase in the diketone component of the surface wax, which apparently appears as spicules extruding from the surface wax of the cuticle and with ultraviolet light absorption gives rise to the distinct blue coloration (M. Parker, personal communication). However, the relationship between the color change and the associated decreases in leaf $\Psi$ has not been established.

Leaf Water Potential and Crop Color Change in Water-stressed Peas

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Understanding plant–water relations and predicting plant water stress are essential for improving irrigation efficiency and maximizing crop yields (10, 11). Plants are seldom completely free from some period of water stress during their life cycles. However, controversy exists as to when the onset of water stress occurs and how reliably it can be detected in the field (3). Many different criteria have been used for scheduling irrigation, most involving measurements or estimates of the soil water status with tensiometers, gypsum blocks, and neutron probes. However, the most reliable indicators of crop water stress are those that involve direct measurements on the plant (9–11). Insufficient information exists on suitable plant indicators of water stress for irrigation scheduling in peas. One possible indicator that is recognized by farmers is the appearance of a color change from green in a well-watered crop to a bluish coloration (M. Parker, personal communication). However, the relationship between the color change and the associated decreases in leaf $\Psi$ has not been established.

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Fig. 1. Measurement of pea leaflet water potential with a pressure chamber. (a) Pea leaf showing excised leaflet used. (b) Position of pea leaflet and petiolule in the rubber gasket of the pressure chamber.

Fig. 2. Pea leaflet water potential for the well-watered and water-stressed treatment with time in days after the last irrigation of the water-stressed plants. The appearance of the blue color in the stressed treatment has been indicated. Vertical bars represent ± se.

Crop color and leaf water potential. When irrigation was withheld from the pea crop, the appearance of the plants changed from a green color in well-watered plants to a distinct blue color. Measurements of leaflet $\Psi$ made during the season on well-watered control plants that exhibited a green crop color and on plants from the water-stressed treatment after irrigation had been withheld from that treatment indicated that the blue coloration of the crop was associated with a decrease in leaf $\Psi$ (Fig. 2). The color change in the stressed treatment occurred 6 days after irrigation had been withheld. The appearance of the blue color coincided with the onset of water stress, as indicated by a significant decrease in leaf $\Psi$ of the water-stressed treatment compared to the well-watered control (Fig. 2). The color change was found to occur with a decrease in $\Psi$ of $<300$ kPa of the water-stressed treatment compared to the well-watered control. Change in pea leaf color has the advantage of providing an easily identifiable visual symptom of water stress. Visual estimation of plant water status also has been used in cereals (7).

The first appearance of the color change is important, as any delay in applying irrigation after the onset of water stress possibly could result in reduced yields. Visual symptoms such as leaf movements or wilting may not always be very useful indicators of plant water deficits in all crops, as they could occur after some photosynthetic activity has been lost (2), and more quantitative methods of measuring plant water status may be preferred (10). However, the appearance of the blue color in peas with a decrease in $\Psi$ may constitute a useful parameter to monitor the onset of water stress, particularly when the tensiometer is "off-scale" ($>80$ kPa), possibly could provide a refinement of tensiometer criteria, permitting more accurate timing of irrigation water.

The pressure chamber gave accurate and reliable measurements of pea leaflet $\Psi$ provided that certain precautions were exercised during the placement of the leaflet in the rubber gasket of the pressure chamber. The preliminary studies showed that the change in crop color was associated with a decrease in leaflet $\Psi$ during the onset of water stress. Changes in crop coloration are an easily identifiable indicator of the onset of water stress, which, with further testing, could possibly be used in irrigation scheduling.

Literature Cited

Acceleration of Sweet Corn Germination at Low Temperatures with Terra-Sorb or Water Presoaks

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Abstract. Early season sweet corn has a potentially greater market value than peak-season sweet corn. However, most sweet corn cultivars, especially the “super sweets”, do not germinate well at temperatures below 10°C. To determine if pregermination treatments could be an effective means to accelerate corn germination in cool soils, seeds were treated and then incubated at 4.4°, 7.2°, and 10.0°C. Treatments included seed presoaked in an aqueous preparation of Terra-Sorb GB (TS) or water for 24, 48, 72, and 96 hr before incubation. The cooler the incubator temperature, the greater the differences among water, TS, and control treatments. Pretreatments with TS over 48 hr are not practical if seeds are to be planted with a mechanical planter because the radicles are elongated to the point of potential damage. A 24-hr TS presoak offers the potential for early germination without prior radicle emergence, which would allow the seed to be mechanically sown.

Several preplanting seed treatments have been developed to improve germination and seed emergence at low temperatures, including osmocotilizing (4, 7), wetting and then drying (1, 5), and fluid drilling (3). Fluid drilling of pregerminated seeds suspended in a protective gel reduces adverse environmental effects and it can be used as a carrier for nutrients, plant growth regulators, or pesticides (2). Although seeds of 20 crops have been pregerminated and fluid-drilled, large-seeded crops such as sweet corn have been studied less (3). Generally, sweet corn has few germination problems, but the newer “super sweets” or “shrunken-seed” sweet corn cultivars are less vigorous than the standard cultivars. Rapid seed emergence also reduces attack by pathogens and avoids environmental stresses, including hindrance caused by soil crusting after a rainfall. To meet the demands of early markets, the supersweet corn cultivars are often planted in many areas in soils cooler than 10°C.

Fluid drilling usually involves seed incubation in aerated water until radicle emergence and then suspension in a gel (3). Terra-Sorb GB (TS), a synthetic potassium-based acrylic polymer, is a superabsorbant gel capable of absorbing 500 times its weight in water (2). It has been used as a gel carrier for pregerminated seeds (2). In this study, we evaluated its use as a medium for pregermination, whether or not the seed is subsequently fluid-drilled or planted with a traditional dry seeder.

In this study, we examined the rate and extent of germination of corn at three temperatures (4.4°, 7.2°, and 10.0°C) using either water or TS presoak treatments for various lengths of time to assess the potential of this technique for early season sowing of pregerminated corn seed under field conditions. Temperature effect could not be evaluated simultaneously due to a limited number of incubators; therefore, each temperature experiment was conducted separately but in a similar manner. This precludes statistical comparison for the same treatments among temperatures. ‘Florida Staysweet’, a shrunken-seed, supersweet cultivar, was pregerminated at 22° for 0 (control), 24, 48, 72, or 96 hr in either water or 26.7 g liter−1 TS and then incubated at 4.4° up to 15 days, at 7.2° for 16 days, or at 10.0° for 13 days. ‘Silver Queen’, a standard sweet corn, was also incubated in the 10.0° treatment at the same time as ‘Florida Staysweet’ using the same experimental regime, allowing comparison. All pregermination treatments were administered to 10 seeds/30 ml plastic beaker in 25 ml of water or TS. After pregermination and prior to incubation, seeds were rehydrated in the pregermination medium and the percentage of those seeds whose radicle and/or coleoptile were visible and had broken the seedcoat were determined. Unrinsed TS- and water-treated seeds were placed on Whatman #3 filter paper in 9-cm plastic petri dishes moistened with 10 ml deionized water, and were remoistened as needed. Treatments, replicated four times, were completely randomized within the incubator. All controls were untreated seeds placed in covered petri dishes. They were watered and placed in the incubator at the same time as the other treatments. Radicle and coleoptile emergence were recorded at regular intervals, subjected to analysis of variance and