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Selection for Reproductive Stage Drought Avoidance in Rice, Using Infrared Thermometry

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ABSTRACT

Water deficits cause major yield reductions on the world's rainfed riceland. The most severe water deficits occur during the reproductive phase. Differences in canopy temperature among crop cultivars are known to be related to drought avoidance characters. In developing a practical field screening system for reproductive phase drought resistance in rice (*Oryza sativa* L.), we assessed the canopy temperature response of a range of germplasm, and related the results to other plant characters related to drought resistance. Field experiments were conducted on a silty clay loam Typic Hapludoll at the International Rice Research Institute. Planting of the test cultivars was staggered, to synchronize flowering during the water-deficit period. Canopy temperature measurements were made on 12 dates in Trial 1 and 8 dates in Trial 2. Mean canopy temperatures (T_c) increased from 28 to 37°C during the stress period. Grain yield ($r^2 = -0.63$) and spikelet fertility ($r^2 = 0.51$**) were related to midday T_c on the day of flowering. Highly significant differences were observed in canopy temperature among entries, with low coefficients of variation (2.0–2.7%). Entries with a history of outstanding vegetative stage drought screening scores consistently remained coolest under stress. Visual drought tolerance scores ($r = 0.72$**) and leaf rolling scores ($r = 0.68$**) were correlated with mean canopy temperatures under moderate water stress, but not under severe stress ($r = 0.31$NS; $r = 0.21$NS). Infrared thermometry was judged well-suited to monitor the progression of crop water stress development, and to aid in classifying cultivars for relative drought avoidance. However, caution is necessary to assure proper application of the technique and in data interpretation.**

WATER DEFICIT STRESS is the most serious factor limiting production on the world's rainfed riceland. Studies of research priorities for rice genetic improvement implicate drought stress as a dominant research target (Hargrove, 1978; Mackill, 1986; Widawsky and O'Toole, 1990). The sensitivity of rice is greatest during the reproductive phase (O'Toole, 1982). Improved screening methods for detecting resistance at this phase would be valuable in a rainfed rice breeding program. To date, visual scoring methods have proven most suitable (De Datta et al., 1988). Most other methods are not sufficiently convenient or are insufficiently related to yield.

Water deficit stress causes partial stomatal closure in a crop canopy, reducing transpiration and allowing sunlit leaves to become warmer (Jackson et al., 1981). The apparent ease and rapidity of canopy temperature measurements with a handheld infrared thermometer have elicited interest in the technique as a means of screening germplasm of various crop species for drought resistance in a number of crops, including wheat (*Triticum aestivum* L.) (Blum et al., 1982), pearl millet [*Pennisetum glaucum* (L.) R. Br.] (Singh and Kanemasu, 1983), maize (*Zea mays* L.) (Kirkham et al., 1984; Mtui et al., 1981), sorghum [*Sorghum bicolor* (L.) Moench] and millet (Chaudhuri et al., 1986), and cotton (*Gossypium hirsutum* L.) (Hatfield et al., 1987). Fischer et al. (1989) used canopy temperature to augment various indices based on maize leaf and stem extension, anthesis to silking interval, and foliar senescence. They found that canopy temperature prior to flowering was correlated ($r = -0.73$**) with yield in severe water stress treatments.

Blum (1988) reviewed the use of canopy temperature as a screening tool. He claimed that it can be a useful technique when used in tandem with other practical measures, if adequate care is taken in the measurements. Canopy temperature can be measured rapidly, and because it is remotely sensed it is both nondestructive and nondisruptive; it does not require sampling of tissue or repeated traffic within plots). Only visual scoring for symptoms such as leaf tip drying and degree of leaf rolling are more rapid. Because T_c is theoretically related to crop water use, it has additional interpretive value related to canopy evapotranspiration (Idso et al., 1981; Jackson et al., 1981). These crop water stress index techniques require measurement of ancillary micrometeorological variables. Chaudhuri et al. (1986) gave one possible method to use the relationships between T_c and micrometeorological variables to screen germplasm for drought resistance.

The objectives of this study were to (i) assess canopy temperature response to water deficit stress in a range of rice germplasm, (ii) relate the results to other drought resistance characters, and (iii) determine the utility of infrared thermometry in the selection of drought-resistant rice cultivars at the flowering stage. The work was conducted in association with studies on the development of a practical field screening system for reproductive phase drought resistance (Garrity and O'Toole, 1994).

MATERIALS AND METHODS

The research was conducted at the upland experimental farm of the International Rice Research Institute (IRRI), Los Baños, Laguna, Philippines, at 121°15′ E, 14°10′ N. The experiments were conducted during the dry season on a silty clay loam (Typic Hapludoll) with pH 5.9 and a bulk density of 1.23 ± 0.02 Mg m^{-3} in the upper 0.15-m soil layer and 1.00 ± 0.02 Mg m^{-3} in the lower layers. The water table during the dry season was >2 m below the soil surface.

The planting dates for the test cultivars in Trial 1 (1981) were set at intervals, to synchronize the flowering dates of all entries as close as possible to the target flowering date of 14 April. The latest-maturing entries were assigned to the earliest planting date and the earliest-maturing entries were planted latest. The check cultivars were seeded on all planting dates. Entries were selected to provide a considerable range of known variation in drought resistance.

Trial 1 employed a line-source sprinkler system (Hanks et al., 1976; Puckridge and O'Toole, 1981). Uniform irrigation was applied twice weekly until late panicle development at rates calculated to replace 100% of USDA Class A pan evaporation (as recorded at the IRRI upland farm agrometeorological station located 300 m from the field site). During the flowering period

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Abbreviations: CWSI, crop water stress index; E_{pan}, Class A pan evaporation; ET_a, evapotranspiration; ET_p, potential evapotranspiration; T_c, canopy temperature; T_a, air temperature. **, Significant at the 0.01 probability level; NS, not significant at the 0.05 probability level.