Lower moisture limit for three crop species grown on a medium textured soil in southwestern Saskatchewan

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Introduction

For many years soil scientists have attempted to develop laboratory procedures to correlate the wilting point of plants with the soil water potential. Approximately 75 years ago, Briggs and Shantz (1912) found that the lower limit of water availability for above ground plant growth was reached at a soil water potential of approximately -1.5 MPa. Since that time many researchers have found that the lower limit is not constant but depends upon environmental, plant and soil factors (Hillel 1980), and upon the definition of wilting (Cassel and Nielsen 1986). Kramer and Spomer (1990) found root growth for corn seedlings ceased at root tissue water potentials of -10 MPa and lower. Nevertheless, many researchers continue to estimate and report laboratory-determined lower limit water contents using -1.5 MPa potentials. Ratliff et al. (1983) compared field-measured lower limits (defined as the soil water content at which plants were practically dead or dormant as a result of the soil water deficit) with laboratory determined soil water contents at -1.5 MPa for various soils throughout the United States. They found that field-measured lower limits of available water were dependent upon soil texture, and appeared to be crop-dependent. Therefore, they concluded that if absolute accuracy is necessary, laboratory-estimated lower limits should be used with caution and that field-measured lower limits, if available, would be preferable.

Objective

Our objective was to determine the pressure potential that best relates to the lower limit of cereals and forage crops, for our soil type, determined under field conditions. A second objective was to determine whether the lower limit varied markedly between annual and perennial crops. The lower limit was assumed to be the lowest soil water content in the soil profile under the respective crop during the period studied. For each crop this moisture level occurred in 1986, a year when excellent growing conditions during May and June produced maximum vegettive growth and moisture use, followed by a very dry July and August when the plants were severely stressed. As defined, the lower limit of available water represents the limit for transpiration, which is lower than the limit for growth.

Materials and Methods

Soil water measurements from several field studies on a Swinton silt loam soil, an Orthic Brown Chernozem (Ayres et al. 1985), were used to determine lower limits for Neepawa spring wheat (*Triticum aestivum* L.), for Swift Russian wildrye (RWR) (*Psathyrostachys juncea*

[Fisch.] Nevski), and for alfalfa (*Medicago sativa* L.). Soil samples, for depths 0-15 cm, 15-30 cm, and at 30 cm intervals thereafter, were taken from an ongoing long-term crop rotation study initiated in 1967 (Campbell et al. 1984) and from a 3-yr wheat growth analysis study (Cutforth et al. 1988). For RWR, soil water measurements were taken from an irrigated-seed yield study (1982 to 1986 - Y. Jame, unpublished data). In this study soil water at 20 cm increments from 0 to 120 cm depth was measured with a neutron moisture meter every two weeks from early spring to late fall each year. Soil samples from breeding evaluation test plots (with individual plants spaced on a 0.9 m grid) were used to determine the effect of stand age on water use pattern, and to approximate the lower limit for alfalfa. The 1, 5 and 10 year-old stands were pure alfalfa, whereas the 17 year-old stand had been overseeded with crested wheatgrass *(Agropyron desertorum* (Fischer ex. Link) Schultes) to the point where the alfalfa was weak and sparse. Soil water to 300 cm was measured gravimetrically directly below 4 plants/stand, taken at random on May 28 and 29, 1988. Conditions had been very dry from early fall, 1987, and the soil samples were collected while the soil profile was still dry. The following day, the five adjacent alfalfa plants at each site were sampled for midday leaf water potential using a pressure chamber apparatus. An adjacent irrigated plot, cv Rambler, was also sampled for midday leaf water potential. At the time of sampling, the alfalfa was in the late-bud stage and, although under apparent stress (as evidenced by folded leaflets at midday), appeared to be actively growing. As noted by Ratliff et al. (1983), lower limits occurred in years and under irrigated conditions where plants had reached maximum vegetative growth before undergoing severe water stress.

Bulk densities (BD) were determined from core samples taken with a Giddings soil-coring truck from each alfalfa stand and from the wheat growth analysis site. Standard pressure membrane procedure was used to determine soil water contents at -1.5 MPa (Cassel and Nielsen 1986) on soil of <2 mm diameter; similar procedures were used to determine soil water contents at -4 and -10 MPa. Bulk densities and the percentage water retained by soil subjected to -1.5, -4 and -10 MPa potentials had previously been determined for the crop rotation site (Campbell et al. 1984).

Results and Discussion

Under both spring wheat and RWR, soil water in the top 120 cm of soil was extracted to water potentials lower than -4 MPa as measured by the pressure plate procedure (Figs. 1 and 2). The lower limit of available water under field grown spring wheat and RWR was best approximated in the laboratory by the -10 MPa water potential. Further, under RWR,water was extracted from the surface 50 cm of the soil profile to well below the -10 MPa water potential. However, evaporative losses from this layer may be very large making it difficult to determine lower limits with confidence (Ritchie 1981). As the soil profile dries, evaporative losses from greater depths become minimal with the majority of water being removed by transpiration (Hillel 1980). Also plotted in Figure 2 is the late May 1988 soil water content under the 17 year-old alfalfa plot in which crested wheatgrass had become the dominant species. Here too, the lower limit was best approximated in the laboratory by the -10 MPa water potential. These results agreed well with previous research in Saskatchewan where Yang and de Jong (1968) reported that, for spring wheat, temporary wilting occurred at soil water potentials of -3.5 to -4 MPa. At Swift Current, Lehane and Staple (1960) related the soil water content corresponding to the permanent wilting percentage (PWP) for dwarf sunflowers to the soil water content at -1.5 MPa (FAP, the 15-atm percentage) for a number of soils of varying texture. The regression obtained was PWP = 0.35 + 0.833 FAP (r=0.995). Values calculated for the volumetric permanent wilting moisture content, VPM = PWP (BD/100), were equivalent to those we obtained at -4 MPa with the pressure membrane apparatus (Fig. 1a). When Lehane and Staple compared lower limits measured in the field at harvest with calculated PWP, they found that wheat could use soil water at potentials below PWP (i.e., wheat used water held at potentials < -4 MPa as measured with the pressure membrane apparatus) at some soil depths.

The soil water content to 300 cm under alfalfa decreased as the age of the stand increased to 10 years (Fig. 3). Although the lower limit for water use under alfalfa cannot be determined from our data (the alfalfa was not dormant but still actively growing), the soil water content to 200 cm under the 10 year-old stand approached that measured in the laboratory at a potential of -10 MPa. Thus, as with spring wheat and RWR, alfalfa can withdraw soil water to well below the laboratory-measured -1.5 MPa water content. Therefore, it would appear that the lower limit of available water under alfalfa may also be best approximated in the laboratory with the -10 MPa potential.

Summary

It has been stated that for most soils, changes in soil water content with change in potential below -0.8 to -1.0 MPa is negligable (Cassel and Nielsen 1986). However, this study showed that within the rooting depth the amount of available water between -1.5 and -10 MPa was substantial (i.e., 4.4 and 11 cm available water to soil depths of 120 and 240 cm, respectively). Even if this water is not readily available to the crop, we agree with Lehane and Staple (1960) that, at least for wheat, this water may be important to the yield and quality of grain. For example, in the 3-yr wheat growth analysis study, approximately 15% of the total water used from seeding to harvest (287 mm) by dryland wheat in 1986 was held at potentials <-1.5 MPa. However, much of this water was used after anthesis and comprised approximately 45% of the total water used during grain filling (91 mm).

We agree with Ratliff et al. (1983) that field-measured lower limits are preferable to laboratory-measured lower limits. However, if laboratory-measured lower limits are all that is available then, for loam soils, they should be determined at water potentials of at least -4 MPa, and possibly -10 MPa, when using pressure membrane procedures. Under the conditions of our study, these limits did not vary markedly with species. This is not to imply that soil water potentials for field-measured lower limits are lower than -4 MPa, but that to approximate lower limits in the laboratory requires water potentials of at least -4 MPa using pressure membrane procedures. However, the lower limit for root growth may indeed be at soil water potentials of -4 MPa or less. As stated earlier, Kramer and Spomer (1990) found that, depending upon previous stress history, root growth for corn seedlings ceased at root tissue water potentials of -10 MPa or less.

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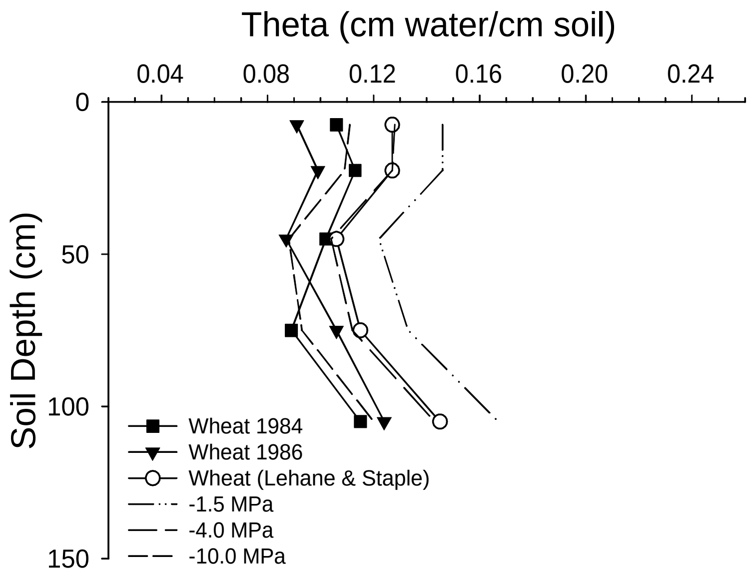

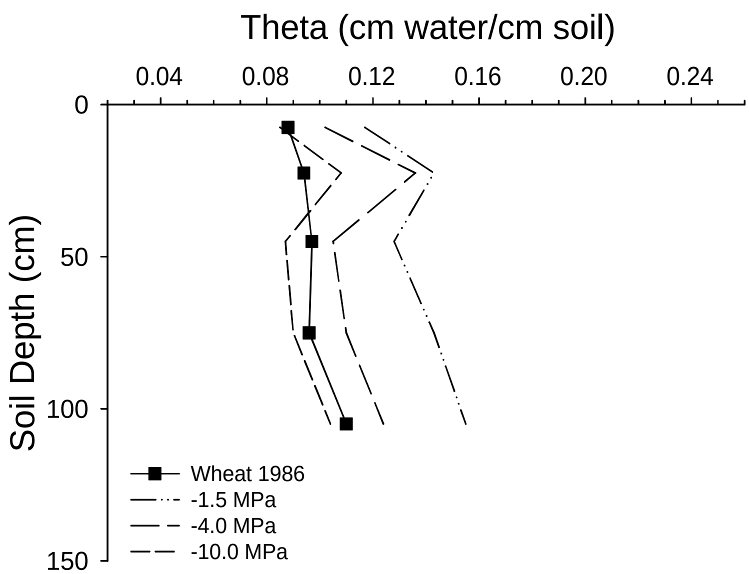

Fig. 1. Volumetric soil water contents at harvest for Neepawa spring wheat grown on the wheat growth analysis site (top) and on the old rotation site (bottom). Also plotted in the top graph is the volumetric permanent wilting moisture content VPM = (0.35 + 0.833 FAP) BD/100 (adapted from Lehane and Staple 1960) (open symbols). In this and subsequent figures, laboratory-determined volumetric soil water contents at potentials -1.5, -4 and -10 MPa are also plotted.

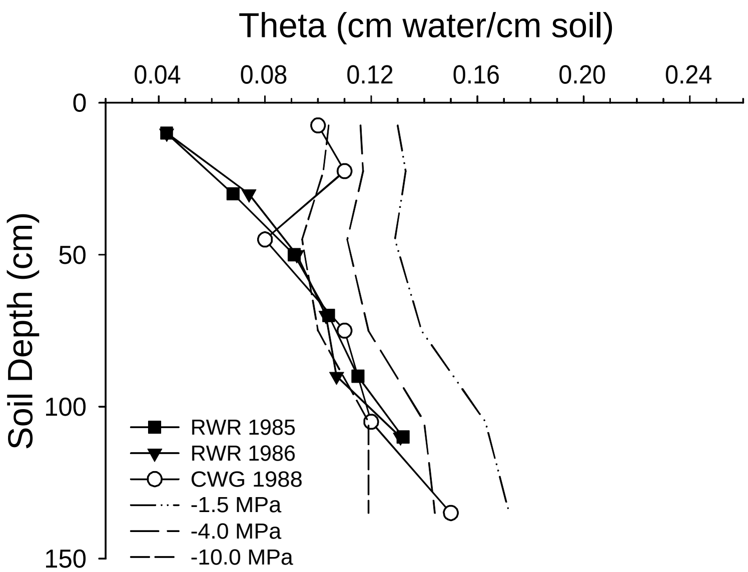

Fig. 2. Volumetric soil water contents in mid to late summer under Russian wildrye. Also shown are the volumetric soil water contents for the 17-year-old alfalfa-grass (mainly crested wheat grass) stand (open symbols) sampled in late May 1988.

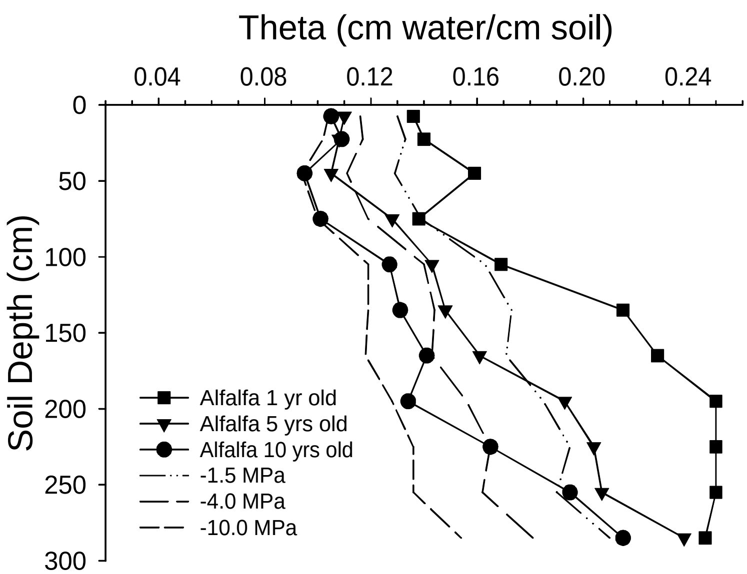

Fig. 3. Volumetric soil water contents under 1-, 5- and 10-year-old alfalfa stands sampled in late May 1988.