Potential for Canola as a Dryland Crop in Northeastern Colorado

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Reduced tillage systems have increased precipitation storage efficiencies and increased the amount of available water for crop production in the central Great Plains (Greb et al. (1970), Smika and Unger (1986), Nielsen and Anderson (1993)). Increased available water affords producers the opportunity to diversify and intensify their production systems from the traditional wheat-fallow system (Halvorson and Reule (1994), Peterson et al. (1994), Halvorson et al. (1994)). Precipitation timing and amounts exhibit wide year-to-year variation, producing variations in timing and severity of water stress. The production potential for any alternative crop grown under dryland agricultural production systems needs to be evaluated with regard to this variable availability of water.

Canola (*Brassica napus* L.) is an oil seed crop that may have potential for the central Great Plains. A market is readily available due to the existence of processing facilities that currently handle sunflower oil production. Producers would be able to use their existing wheat production equipment for tillage, spraying, planting, and harvesting of canola. Sims et al. (1993) reported that canola yields in Montana increased greatly with increased availability of water, but that increased water lowered mean oil content. Canola production in Alberta is reported to be about 900 lb/a for 8 inches of water use, and to increase by 135 lb/a for each additional inch of water used (Anonymous , 1985). Shafii et al. (1992) reported that four winter canola varieties grown in 1988 in Kansas yielded from 1045 to 1384 lb/a with oil contents ranging from 37.7 to 40.0%. They provided no precipitation or water use data. Francois (1994) reported that the oil content of irrigated canola (cv. Westar) grown in Brawley, CA averaged 40% in a 2-year study. He also reported that the long-term average oil content for Westar grown in Canada was 43%. Wright et al. (1988) reported that when evironmental stresses become severe during the rapeseed growing season, causing intense competition for assimilates, pod abortion occurred resulting in seed loss.

Evaluations of the response of crops to varying water availability and water stress can be easily accomplished by calculating the Crop Water Stress Index from crop temperatures obtained with an infrared thermometer (Gardner et al., 1992a, 1992b). This calculation requires knowledge of the relationship between crop temperature, air temperature, and vapor pressure deficit for a non-water-stressed crop (the non-water-stressed baseline). This relationship has not been determined for canola.

The objectives of this study were to determine:

1. a water use/seed yield production function for spring canola,
2. the sensitivity of yield components, oil content, and leaf area development to water deficits at various growth stages,
3. canola rooting depth,
4. canola production potential from the long-term precipitation record at Akron, CO, and
5. a non-water-stressed baseline for future water stress evaluations of canola.

MATERIALS AND METHODS

Two studies were conducted during both the 1993 and 1994 growing seasons at the USDA Central Great Plains Research Station, 4 miles east of Akron, CO (45° 09' N, 103° 09' W, 4540' above m.s.l). The soil type is a Rago silt loam (fine, montmorillonitic, mesic Pachic Argiustoll). The canola variety used in both years was Westar. In both studies evapotranspiration was calculated by the water balance method using measurements of soil water content and assuming runoff and deep percolation were negligible. The measurements of soil water content in the 0-12" layer were made by time-domain reflectometry. Measurements of soil water content at 18, 30, 41, 53, and 65 inches were made with a neutron probe.

Experiment 1

This experiment was used to determine a water use/seed production function for canola. Canola was planted on 3 May 1993 and 22 April 1994 using a grain drill with double disk openers. Seeding rate was approximately 900,000 seeds/a in rows spaced 8" apart. Prior to planting the plot area was fertilized with 62 lb/a N and 30 lb/a P_2O_5 in 1993 and 84 lb/a N and 35 lb/a P_2O_5 in 1994. Treflan (trifluralin) was applied at a rate of 1.5 lb ai/a and disk-incorporated prior to planting.

Irrigations were applied to the plot area with a gradient line-source solid-set irrigation system, with full irrigation next to the irrigation line, and linearly declining water application as distance increased from the line. Four replications of four irrigation levels existed along the line-source system, with a soil water measurement site and irrigation catch gage at each of the 16 locations. Irrigations were applied weekly to replace evapotranspiration losses from the measurment sites closest to the irrigation line. These were considered the fully irrigated, non-water-stressed plots.

Canopy temperatures were measured on six dates from 21 June to 27 July 1993 and five dates from 9 June to 5 July 1994. Measurements were taken every 45 minutes from 1000 to 1700 MDT on the fully irrigated plots from the southeast and southwest corners of the plots following the methods described by Gardner et al. (1992a, 1992b). These data provided a range of temperature and vapor pressure deficit conditions from which to construct the non-water-stressed baseline for canola.

Plots were harvested for seed yield on 6 August 1993, and 18 and 27 July 1994. Two harvest dates were used in 1994 due to differences in development rate associated with the gradient application of water.

Experiment 2

This experiment was used to determine the effect of timing of water stress on canola yield components. Canola was hand-planted in rows 12" apart on 20 April 1993 and 7 April 1994 into 12 small plots (9' by 8.75') which could be covered by an automated rainout shelter during precipitation events. The twelve plots were arranged in a randomized complete block design of three replications of four water treatments (Table 1). All plots received the same amount of water over the growing season, but at different times. The 15-week growing season was divided into a 5-week vegetative period (V), a 5-week reproductive period (R), and a 5-week grain-filling period (GF). Long-term average precipitation during the 15 week growing season is 9.2 inches.

This amount of water was applied in equal weekly amounts as shown in Table 1.

Following emergence, plots were thinned to a stand of about 442,000 plants/a. Leaf area was measured periodically during the growing season with the LAI-2000 Plant Canopy Analyzer (Li-Cor, Inc., Lincoln, NE). Prior to planting the plots were fertilized with 60 lb/a N. Plots were hand-weeded as needed throughout the experiment. Final seed yields were taken on 29 July and 4 August 1993 and 11 July 1994.

Table 1. Irrigation treatments to determine effect of timing of water stress on canola production.

Treatment	Water Withheld During:	Water Applied During:	Number of Irrigations	Weekly Irrigation Amount (in)	Total Water Applied (in)
TRT1	----------	V, R, GF	15	0.62	9.20
TRT2	GF	V, R	10	0.92	9.20
TRT3	R	V, GF	10	0.92	9.20
TRT4	V	R, GF	10	0.92	9.20

V= vegetative stage, R=reproductive stage, GF=grain-filling stage

RESULTS

The results of the gradient irrigation treatments are shown in Figure 1. The linear regression fit to the combined data for the two years indicates that 175.2 lb/a of seed are produced for every inch of water used after the first 6.2 inches of water use. The yields ranged from 480 lb/a with 9.8 inches of water use to 3050 lb/a with 20.5 inches of water use. A similar yield function for winter wheat grown in northeastern Colorado shows a much higher water use efficiency for wheat, with 390.4 lb/a produced for every inch of water use after the first 6.8 inches of water use.

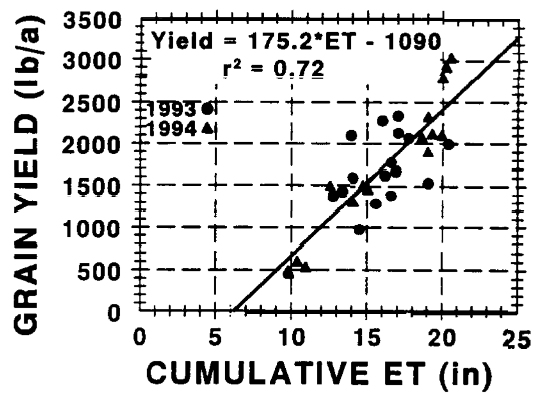


Fig. 1. Water use/seed yield production function for canola grown at Akron, CO, during 1993 and 1994 growing seasons.

The change in soil water content between the beginning and ending soil water readings is shown in Figure 2a (rainout shelter plots, TRT2) and Figure 2b (solid set irrigation plots, low end of the irrigation gradient). The data show that water extraction by canola occurred from depths down to 71", but 92 to 95% of growing season water use comes from growing season precipitation and water extracted from the 0-47" soil layer. Under the extreme water deficit condition of TRT2 in the rainout shelter (no water applied during the last 5 weeks of development), canola was able to extract water out of the soil down to a volumetric water content of 0.08 m^3/m^3.

Water stress during the vegetative growth stage (TRT4) limited early leaf area development, but plants recovered and produced more leaf area as water became available later in the growing season (Figure 3). Water stress during the grain-filling stage (TRT2) resulted in a more rapid loss of leaf area than water stress occurring during other growth stages. Water stress during the reproductive growth stage (TRT3) was the most restrictive to leaf area development, with maximum leaf area development 64 to 68% of that observed when water stress did not occur until the grain-filling period (TRT2) (Figure 4).

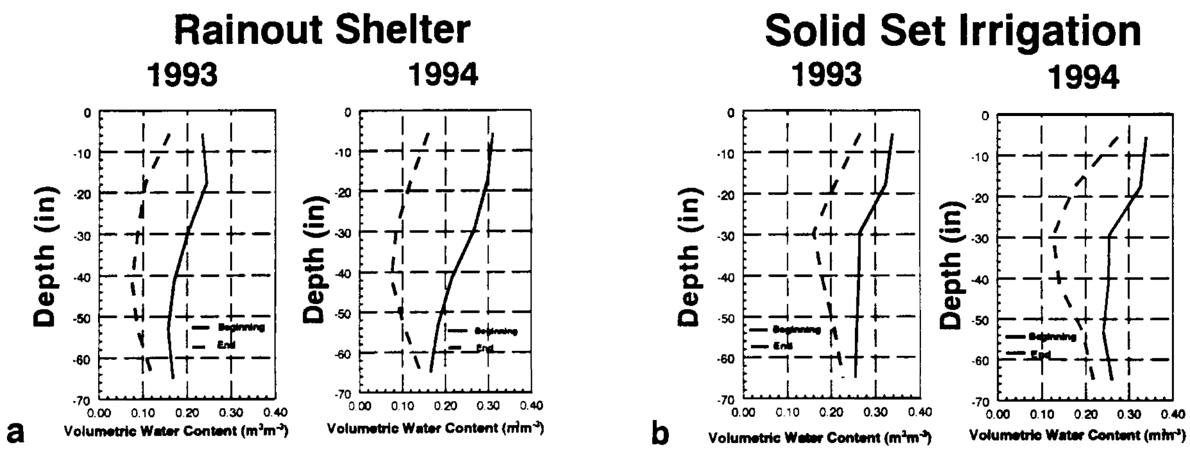
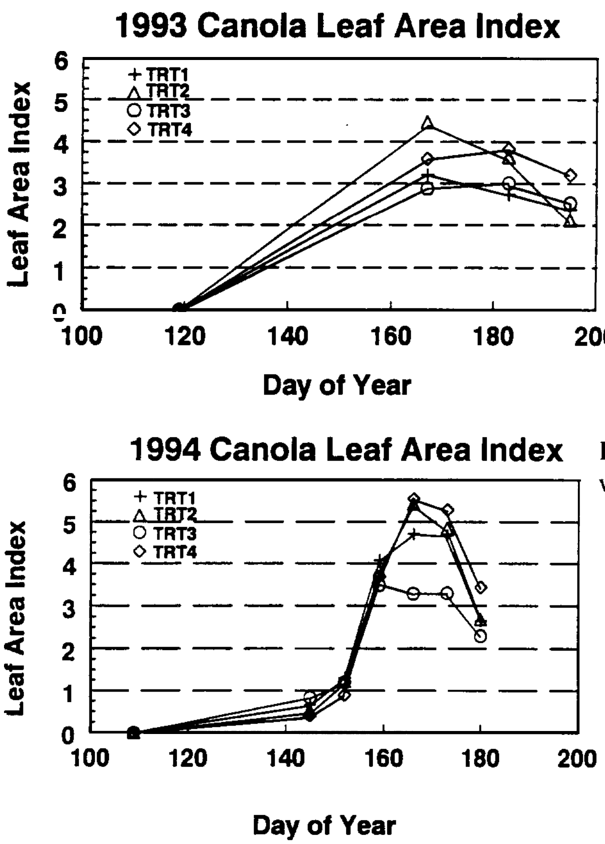


Fig. 2. Soil profile volumetric water content at the beginning and end of the canola growing season in (a) the rainout shelter and (b) the solid set irrigation area.



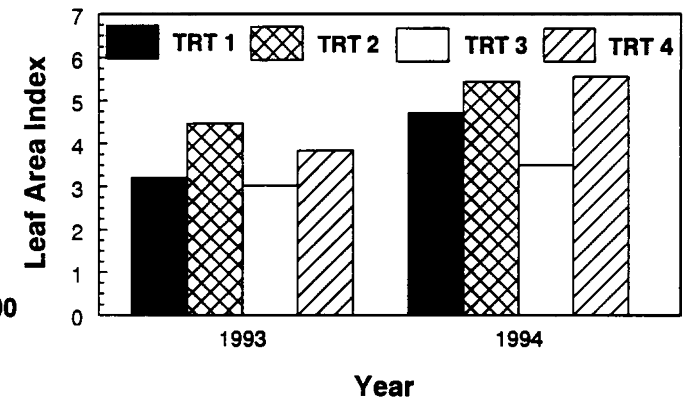


Fig. 4. Maximum leaf area index as affected by timing of water stress.

Fig. 3. Seasonal development of leaf area index.

In neither 1993 nor 1994 was there a statistically significant effect of timing of water stress on seed yield, although the trend in 1993 was for the lowest yield to occur when water stress occurred during the grain-filling period (TRT2) (Table 2). This was a result of fewer branches/plant and pods/branch, and smaller seeds. The seed yields ranged from 562 lb/a when water stress occurred during grain-filling to 909 lb/a when water stress occurred during the vegetative period. Yields were much lower for all four treatments in 1994, for which we have no explanation. Plants showed no visual signs of insect or disease problems. There was no trend for any particular treatment to result in higher or lower yields than the other treatments. Water stress during grain-filling (TRT4) did result in fewer branches/plant than the other treatments, as in 1993.

Table 2. Yield component analysis for water stress timing treatments imposed in Experiment 2 (rainout shelter).

1993 Component	TRT1	TRT2	TRT3	TRT4	p
Branches/plant	4.55	3.51	4.61	4.69	0.058
Pods/branch	6.65	5.61	6.01	8.68	0.009
Seeds/pod	10.0	10.6	8.9	7.7	0.374
1000 seed wt (g)	3.19	2.7	3.44	2.90	0.145
Seed yield (lb/a)	841	562	830	909	0.343
Evapotranspiration (in)	14.1	15.7	11.9	13.1	0.001
Water use efficiency (lb/a/in)	60.6	35.6	70.2	69.7	0.179

1994 Component	TRT1	TRT2	TRT3	TRT4	p
Branches/plant	2.95	2.78	2.20	3.45	0.093
Pods/branch	8.34	8.34	7.44	7.68	0.597
Seeds/pod	3.9	5.1	3.8	4.2	0.391
1000 seed wt (g)	2.93	2.67	3.00	3.22	0.134
Seed yield (lb/a)	368	331	277	350	0.490
Evapotranspiration (in)	15.6	18.1	14.1	16.5	0.010
Water use efficiency (lb/a/in)	23.7	18.3	20.0	26.5	0.400

The highest water use in both years occurred with water stress during grain-filling (TRT2). The larger leaf area that developed early in the growing season and maintained itself during the reproductive stage was the probable cause of this higher water use. This higher water use resulted in a statistically nonsignificant trend for lowest water use efficiency in TRT2. Water use efficiencies from Experiment 1 (line source) ranged from 50 to 100 lb/a/in between the evapotranspiration range of 10 to 15". similar to the values obtained from Experiment 2 (rainout shelter) in 1993 (35.6 to 70.2 lb/a/in). The low yields in Experiment 2 in 1994 resulted in extremely low water use efficiencies (18.3 to 26.6 lb/a/in).

There was a small reduction in oil content with water stress during grain-filling (TRT2) (Figure 5). The oil contents in Experiment 2 in the rainout shelter ranged from 34 to 39%, with higher contents in 1994. Oil contents in Experiment 2 under the solid set gradient irrigation were also higher in 1994 than in 1993. These data showed a strong trend for increasing oil content with increasing level of irrigation. with values ranging from 37% for the low irrigation level in 1993 to 44% for the high irrigation level in 1994.

In order to assess the long-term yield potential for canola in the central Great Plains, I looked at the precipitation record for the 15-week growing season of 2 April to 15 July over the 30-year period of 1965 to 1994 (Figure 6). These data show that 50% of the years have growing

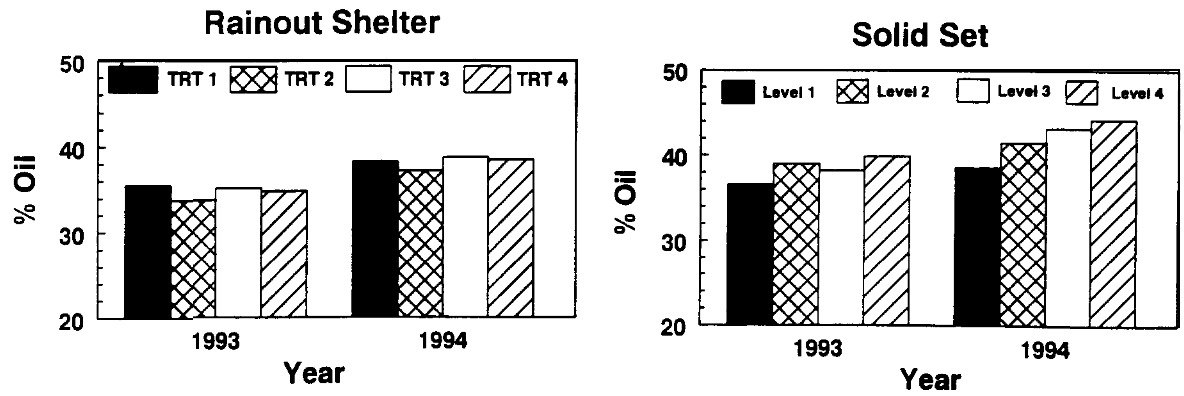


Fig. 5. Percent oil content for canola grown under four water stress timing treatments (rainout shelter) and four irrigation application levels (solid set).

season precipitation of less than 8 inches. Assuming, conservatively, that canola could extract 4 inches of soil water from the profile during the growing season, and applying the water use/seed yield production function given in Figure 1, we see that 50% of the years would have seed production less than 1012 lb/a. The predicted range of seed production over the past 30 years was 280 to 2360 lb/a, averaging 1020 lb/a.

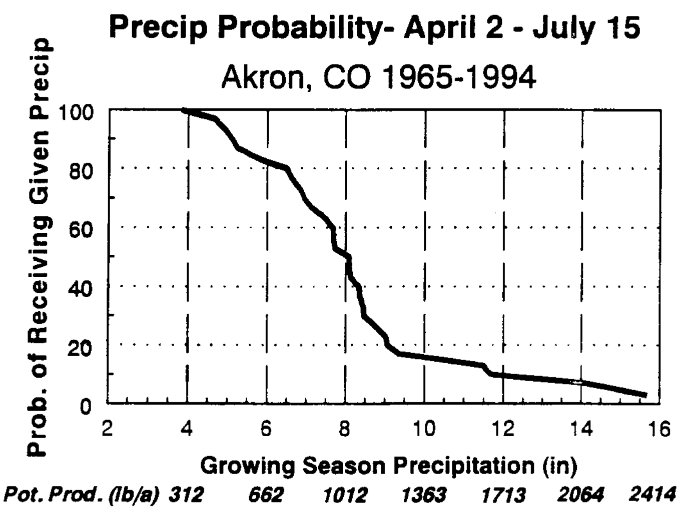


Fig. 6. Probability of receiving at least a given amount of precipitation (x-axis) during the period of April 2 through July 15 at Akron, CO.

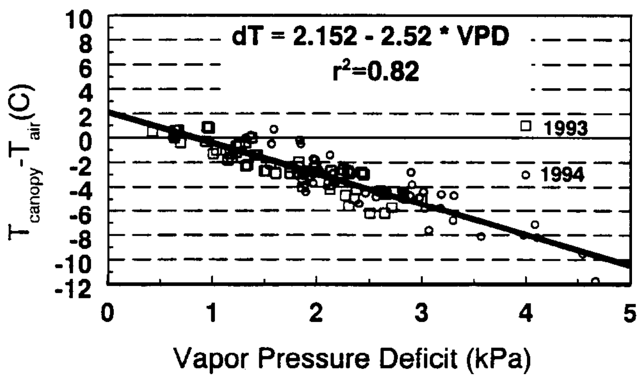


Fig. 7. Non-water-stressed baseline for canola.

Figure 7 shows the relationship between vapor pressure deficit and canopy temperature minus air temperature (the non-water-stressed baseline). The data over the two growing seasons shows a linear response over the vapor pressure deficit range of 0.5 to 4.6 kPa. Infrared thermometry can be used with the non-water-stressed baseline to reliably quantify water stress in canola in future studies of water stress effects on canola production.

SUMMARY

Canola exhibits a linear response of seed yield to water use with approximately 175 lb/a of seed produced for every inch of water used after the first 6 inches of water use. Soil water extraction comes primarily from the top four feet of the soil profile. Canola is most sensitive to water deficits during grain-filling, and least sensitive during vegetative development. Oil contents ranged from 34 to 44% for the various water treatments in the two years of this study. Average canola production under the dryland conditions of the central Great Plains would likely average about 1020 lb/a with a range of 280 to 2360 lb/a. Water stress effects on canola development can be quantified with infrared thermometry measurements of canopy temperature.

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