## SUMMARY

Each of the three years included in this study exhibited distinctly different weather conditions. The fall of 1994 was very warm and late resulting in excessive growth and significant winter injury particularly with the early planting dates. The late Sept. or Oct. planting dates in 1990 and 1992 resulted in significant death loss and no or greatly reduced yields. From this study, it can be concluded that winter canola can be successfully grown in northern Indiana if planted between mid Aug. 25 and Sept. 20. Plantings which are made after Sept. 20 will result in significant yield reductions or total loss of the crop. Data from southern Indiana indicate that plantings made during the month of Sept. are most likely to be successful with both Aug. and Oct. plantings resulting in death loss or yield reductions.

Cultivar performance varied by site indicating that some cultivars may be more tolerant to adverse weather than others. 'Touchdown' appears to be the best performer under adverse conditions while 'Liborius' was the poorest performer.

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# Potential of Canola as a Dryland Crop in Northeastern Colorado

David C. Nielsen

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 water availability.

Canola (*Brassica napus* L.) is an oil seed crop that may have production potential in the central Great Plains. A market is readily available due to the existence of processing facilities that currently handle sunflower oil production and consumer demand for low saturated fat oil. 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 1008 kg/ha for 203 mm of water use, and to increase by 59.5 kg/ha for each additional 10 mm of water used (Anonymous

1985). Shafii et al. (1992) reported that four winter canola cultivars grown in 1988 in Kansas yielded from 1170 to 1550 kg/ha 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, California 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 severe evironmental stresses during the rapeseed growing season caused intense competition for assimilates, pod abortion, and seed loss.

Evaluations of the response of crops to varying water availability and water stress can easily be accomplished by calculating the Crop Water Stress Index from crop temperatures obtained with an infrared thermometer (Gardner et al. 1992a, b). 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, Colorado; and (5) a non-water-stressed baseline for future water stress evaluations of canola.

## METHODOLOGY

Two studies using 'Westar' canola were conducted during both the 1993 and 1994 growing seasons at the USDA Central Great Plains Research Station, 4 miles east of Akron, Colorado (45° 09' N, 103° 09' W, 1384 m). The soil type is a Rago silt loam (fine, montmorillonitic, mesic Pachic Argiustoll). 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 0–30 cm layer were made by time-domain reflectometry. Measurements of soil water content at 45, 75, 105, 135, and 165 cm 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 May 3, 1993 and Apr. 22, 1994 using a grain drill with double disk openers. Seeding rate was approximately 2,223,900 seeds/ha in rows spaced 20 cm apart. Prior to planting, the plot area was fertilized with 69 kg/ha N and 14 kg/ha P in 1993 and 94 kg/ha N and 17 kg/ha P in 1994. Treflan (trifluralin) was applied at a rate of 1.7 kg ai/ha 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 June 21 to July 27, 1993 and five dates from June 9 to July 5, 1994. Measurements were taken every 45 min 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, b). 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 Aug. 6, 1993, and July 18 and 27, 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 water stress timing on canola yield components. Canola was hand-planted in rows 30 cm apart on Apr. 20, 1993 and Apr. 7, 1994 into 12 small plots (2.74 m by 2.67 m) 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 234 mm. 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 1,092,000 plants/ha. Leaf area was measured periodically during the growing season with the LAI-2000 Plant Canopy Analyzer (Li-Cor, Inc., Lincoln, Nebraska). Prior to planting, plots were fertilized with 67 kg/ha N. Plots were hand-weeded as needed throughout the experiment. Final seed yields were taken on July 29 and Aug. 4, 1993 and July 11, 1994.

## RESULTS

The results of the gradient irrigation treatments are shown in Fig. 1. The linear regression fit to the combined data for the two years indicates that 7.73 kg/ha of seed are produced for every mm of water used after the first 158 mm of water use. The yields ranged from 538 kg/ha with 249 mm of water use to 3416 kg/ha with 521 mm of water use. A similar yield function for winter wheat grown in northeastern Colorado shows a much higher water use efficiency for wheat, with 17.21 kg/ha produced for every mm of water use after the first 172 mm of water use (Nielsen 1995).

The change in soil water content between the beginning and ending soil water readings is shown in Fig. 2a (rainout shelter plots, trt. 2) and Fig. 2b (solid set irrigation plots, low end of the irrigation gradient). The data show that water extraction by canola occurred from depths down to 180 cm, but 92% to 95% of growing season water use comes from growing season precipitation and water extracted from the 0–120 cm soil layer. Under the extreme water deficit condition of trt. 2 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 (trt. 4) limited early leaf area development, but plants recovered and produced more leaf area as water became available later in the growing season (Fig. 3). Water

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

| Treatment | Water withheld[z] | Water applied[z] | No. irrigations | Weekly irrigation amount (mm) | Total water applied (mm) |
|---|---|---|---|---|---|
| 1 | -- | V, R, GF | 15 | 15.7 | 234 |
| 2 | GF | V, R | 10 | 23.4 | 234 |
| 3 | R | V, GF | 10 | 23.4 | 234 |
| 4 | V | R, GF | 10 | 23.4 | 234 |

[z]V = vegetative stage, R = reproductive stage, GF = grain-filling stage

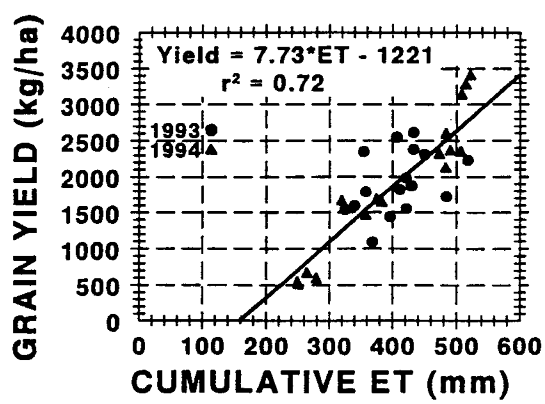



**Fig. 1.** Water use/seed yield production function for canola grown at Akron, Colorado, during 1993 and 1994 growing seasons.

stress during the grain-filling stage (trt. 2) resulted in a more rapid loss of leaf area than water stress occurring during other growth stages. Water stress during the reproductive growth stage (trt. 3) 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 (trt. 2) (Fig. 4).

In neither 1993 nor 1994 was there a statistically significant effect of water stress timing on seed yield, although the trend in 1993 was for the lowest yield to occur when water stress occurred during the grain-filling period (trt. 2) (Table 2). This was a result of fewer branches/plant and pods/branch, and smaller seeds. The seed yields ranged from 629 kg/ha when water stress occurred during grain-filling to 1018 kg/ha 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 (trt. 4) did result in fewer branches/plant than the other treatments, as in 1993.

The highest water use in both years occurred with water stress during grain-filling (trt. 2). 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 trt. 2. Water use efficiencies from Experiment 1 (line source) ranged from 2.20 to 4.41 kg/ha/mm between the evapotranspiration range of 254 to 381 mm, similar to the values obtained from Experiment 2 (rainout shelter) in 1993 (1.58 to 3.08 kg/ha/mm). The low yields in Experiment 2 in 1994 resulted in extremely low water use efficiencies (0.81 to 1.04 kg/ha/mm).

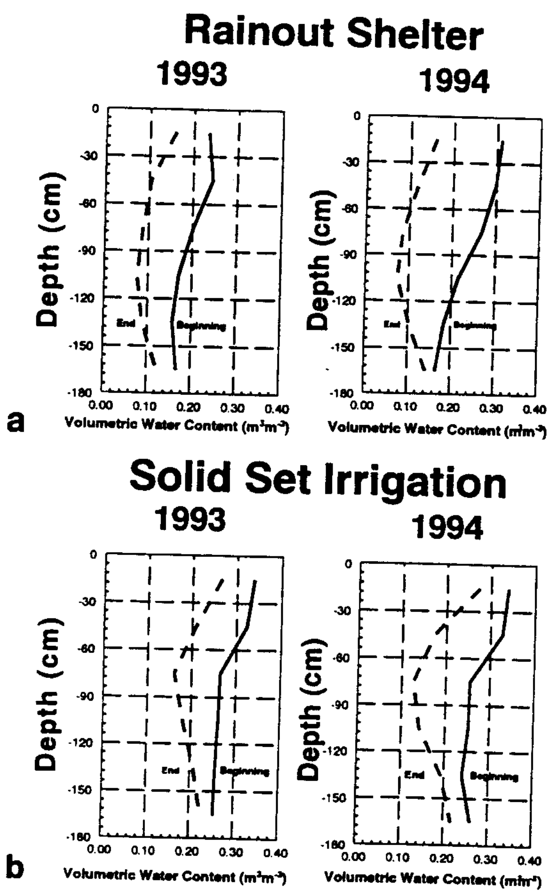



Fig. 2. Soil profile volumetric water content at the beginning and end of the canola growing season in (a) the rainout shelter and (b) the solid set irrigation area.

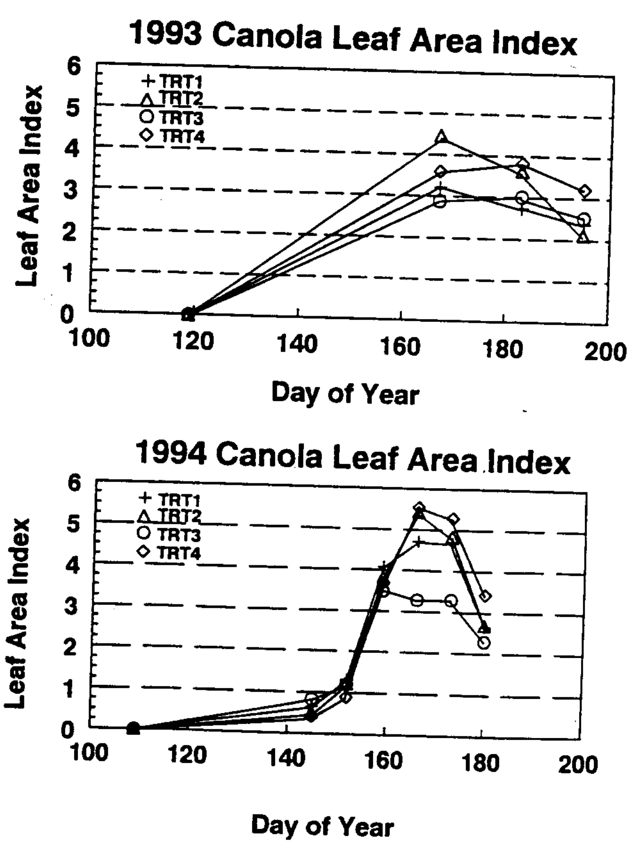



Fig. 3. Seasonal development of leaf area index.

There was a small reduction in oil content with water stress during grain-filling (trt. 2) (Fig. 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.

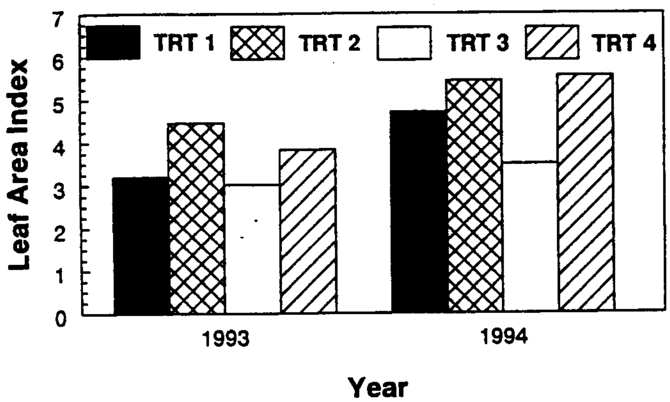
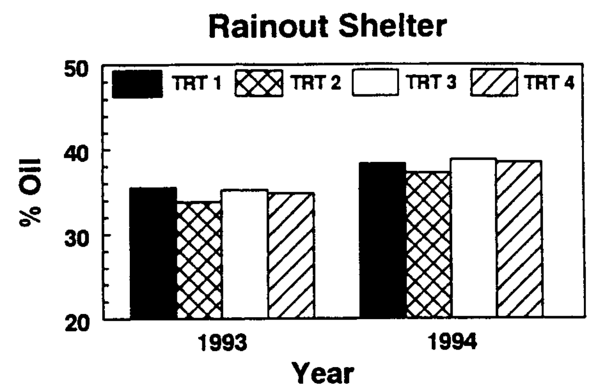



**Fig. 4.** Maximum leaf area index as affected by timing of water stress.



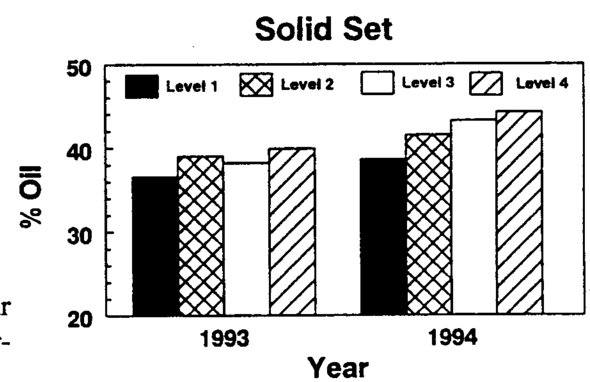




**Fig. 5.** Percent oil content for canola grown under four water stress timing treatments (rainout shelter) and four irrigation application levels (solid set).

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

| Irrig. trt. | No. branches/ plant | No. pods/ branch | No. seeds/ pod | 1000 seed wt (g) | Seed yield (kg/ha) | Evapotrans-piration (mm) | Water use efficiency (kg/ha/mm) |
|---|---|---|---|---|---|---|---|
| | | | | *1993* | | | |
| 1 | 4.55 | 6.65 | 10.0 | 3.19 | 942 | 358 | 2.63 |
| 2 | 3.51 | 5.61 | 10.6 | 2.70 | 629 | 399 | 1.58 |
| 3 | 4.61 | 6.01 | 8.9 | 3.44 | 930 | 302 | 3.08 |
| 4 | 4.69 | 8.68 | 7.7 | 2.90 | 1018 | 333 | 3.06 |
| p | 0.058 | 0.009 | 0.374 | 0.145 | 0.343 | 0.001 | 0.179 |
| | | | | *1994* | | | |
| 1 | 2.95 | 8.34 | 3.9 | 2.93 | 412 | 396 | 1.04 |
| 2 | 2.78 | 8.34 | 5.1 | 2.67 | 371 | 460 | 0.81 |
| 3 | 2.20 | 7.44 | 3.8 | 3.00 | 310 | 358 | 0.87 |
| 4 | 3.45 | 7.68 | 4.2 | 3.22 | 392 | 419 | 0.94 |
| p | 0.093 | 0.597 | 0.391 | 0.134 | 0.490 | 0.010 | 0.400 |

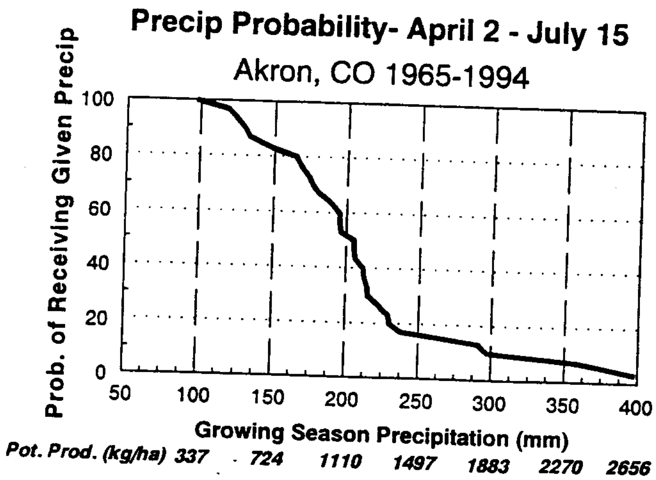



**Fig. 6.** Probability of receiving at least a given amount of precipitation during the period of Apr. 2 through July 15 at Akron, Colorado.

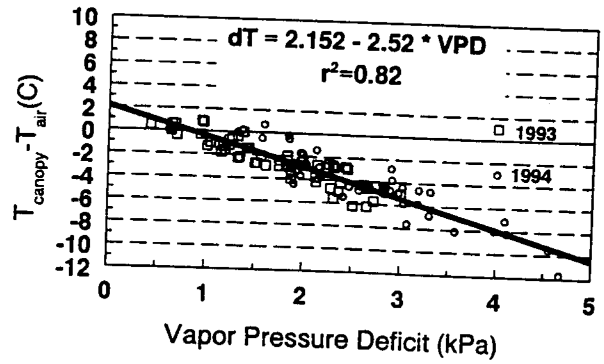



**Fig. 7.** Non-water-stressed baseline for canola.

In order to assess the long-term yield potential for canola in the central Great Plains, the precipitation records were examined for the 15-week growing season of Apr. 2 to July 15 over the 30-year period of 1965 to 1994 (Fig. 6). These data show that 50% of the years have growing season precipitation of less than 203 mm. Assuming, conservatively, that canola could extract 102 mm of soil water from the profile during the growing season, and applying the water use/seed yield production function given in Fig.1, 50% of the years would have seed production less than 1133 kg/ha. The predicted range of seed production over the past 30 years was 314 to 2643 kg/ha, averaging 1142 kg/ha.

Fig. 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 7.73 kg/ha of seed produced for every mm of water used after the first 158 mm of water use. Soil water extraction comes primarily from the top 120 cm 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 1142 kg/ha with a range of 314 to 2643 kg/ha. This average level of seed production would not make canola a profitable dryland crop at current market prices (about $0.22/kg). Water stress effects on canola development can be quantified with infrared thermometry measurements of canopy temperature.

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# Canola Production in Virginia*

David E. Starner, Harbans L. Bhardwaj, Anwar A. Hamama, and Muddappa Rangappa

Use of canola (*Brassica* spp.) oil is increasing steadily among health-conscious consumers due to its lowest content of saturated fatty acids (5% to 8%) among edible oils (Downey 1990; Sovero 1993). The United States is dependent upon imported canola oil to meet the consumer demands. During 1993–94 and 1994–95, approximately 409,508 and 425,852 t, respectively, of canola oil were imported. The imports of canola oil during 1995–96 are expected to be approximately 500,000 t (Foreign Agricultural Service, 1995). Domestic production of canola would offset costly imports, enhance the productivity of American farms, and diversify agriculture.

Evaluation of rapeseed as a new crop has been continuing since 1982 at the Northern Piedmont Agricultural Research and Extension Center in Orange, Virginia. Spring and winter types were evaluated for their yielding potential by planting during both fall and spring seasons from 1983 to 1986 at Orange, Virginia. The spring types planted during fall did not survive due to lack of winter-hardiness whereas the yield of spring-types planted in the spring was very low as compared to winter types.

Commercial canola production in Virginia has been declining since 1990–91 when canola was planted on about 600 ha. During 1991–92 and 1992–93, approximately 300 and 200 ha were planted with canola. Pro-

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