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YIELDS AND ET OF DEFICIT TO FULLY IRRIGATED CANOLA AND CAMELINA

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BACKGROUND

In the past few years, many areas of Nebraska faced reduced irrigation amounts due to drought, low reservoir supplies or ground water allocations. The production of biofuel crops will compete for acres and irrigation water if there is an economic incentive to increase production. Nebraska is a large producer of ethanol from corn with 35% of the crop being used for biofuel in the state. This does not include the 26% of the crop that is exported and from which ethanol is also produced (http://www.nebraskacorn.org/main-navigation/corn-production-uses/use-stats/). The western portion of the Central Great Plains is defined as the northern High Plains region and has lower rainfall, sandier soils and higher elevation than the eastern portion. Biofuel crops that use less water and are adapted to the northern High Plains include canola, brown mustard, camelina, safflower, and sunflower. Oil-seed crops represent a good alternative for areas with limited water (Pavlista *et al*., 2011a). Due to their higher oil content, canola and camelina can produce over 110 gallons of oil per acre versus soybean that can produce 60 gal/ac (CAST, 2008). There is some information on water use for canola (Nielsen,1997), but the yield potential for canola and camelina under a range of soil, climatic and irrigation management regimes and the associated water use was needed. Spring planting of brown mustard, canola and camelina is viable in western NE (Pavlista*, et al*., 2011b). Growth curves for these crops in this region are currently being developed.

Deficit irrigation applies less water than is required to meet full ET. The goal is to manage irrigation timing such that the resulting water stress has less of a negative impact on grain yield. Previous NE research on limited irrigation (Garrity et al., 1982; Hergert et al, 1993; Klocke, et al., 1989; Maurer et al., 1979; Schneekloth et al., 1991) has looked at a range of crops but not canola and camelina.

Currently, a program for managing limited irrigation water (***Water Optimizer***), enables producers to evaluate what crops to grow, how many acres to irrigate and how much water to apply during a given year, field by field. However, this program did not include potential biofuel crops and deficit irrigation. Over a four-year period (2007-2010), University of Nebraska researchers, with funding from the USDA Risk Management Agency, conducted research to develop additional capabilities in ***Water Optimizer*** to expand its application to other crops and geographic areas. The focus of this report is to present results related to irrigation and water use production functions that will provide additional management tools for predicting spring- planted camelina and canola yields under limited and full irrigation for western NE.

METHODS AND MATERIALS

Camelina (cv. Cheyenne) and Canola (cv. Hyola 357 RR) were planted under linear irrigation systems at the Panhandle Research and Extension Center, Scottsbluff, NE (SB) and the High Plains Ag Lab, Sidney, NE (HP). Canola was planted under a center pivot irrigation system on the Dan Laursen Farm, near Alliance, NE (AL). Camelina and canola were planted at rates of 3 and 5 pounds per acre (pure live seed), respectively. Soils were: Scottsbluff (Tripp very fine sandy loam, pH 8.1, 1.2% OM, root zone water holding capacity (5 ft) ~ 6 to 7 in); Alliance (Creighton fine sandy loam, pH 7.3, 1.8% OM, root zone water holding capacity (5 ft) ~ 5 to 6 in); and Sidney (Keith silt loam, pH 6.8, 2.4% OM, root zone water holding capacity (6 ft) ~ 9 to 11 in.).

Management and cultural practices for experimental plots were adapted from limited tillage/limited irrigation cropping systems and/or relevant research findings, including planting requirements, fertilization recommendations, herbicide/insecticide applications, and harvesting. Roundup®-ready canola was used. Plots were routinely scouted during the summer for insect problems. Helix seed treatment was required for canola to protect against flea beetle but no other insects were a problem. Because of the crop rotation there were no major insect problems in the other crops. During the wetter years of 2009 and 2010, there was a downy mildew problem on both canola and camelina that was treated with fungicide.

Cumulative irrigation treatments had targeted amounts of 0, 4, 8 and 12 inches of water; however, if insufficient soil moisture or soil crusting was present, all treatments received light irrigations (0.25 inches) to enhance and ensure uniform seed germination and plant emergence. Treatments were replicated three times in a randomized complete block design and applied to subplots within main plots of each crop. Irrigation was based on estimated crop use and/or critical growth stages.

Rain gauges were placed within plot areas to accurately record irrigation and rainfall amounts. Soil water content from 0-6 inches was determined gravimetrically, while water contents at soil depths of 1, 2, 3, 4 and 5 feet were determined from neutron probe measurements.

Cumulative water use (evapotranspiration) was calculated from the water balance equation. These calculations assume negligible rainfall and irrigation loss by deep percolation and runoff. However, observed runoff losses, resulting from significant/intense rainfall events, were estimated from differences in neutron probe readings taken prior to and after such events.

RESULTS AND DISCUSSION

Irrigation/seed yield production functions

Rainfall at the different sites was drastically different over the four years (Table 1). This provided an excellent range of conditions from drought to above average precipitation to develop production functions.

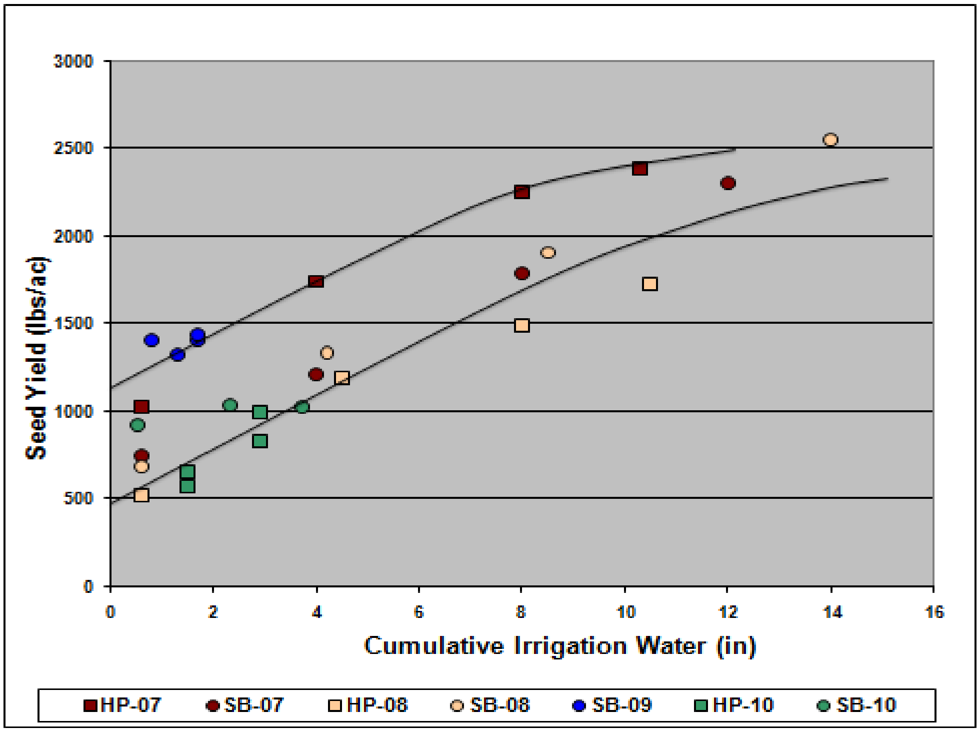
Table 1. Growing season precipitation (mid-April to harvest).

Location	2007	2008	2009	2010	30 yr avg.
	------------------------------inches------------------------------				
Alliance	5.7	6.6	---*	6.4	8.3
Scottsbluff	2.6	5.3	12.4	9.3	8.0
Sidney	10.5	7.5	15.1	9.6	8.6

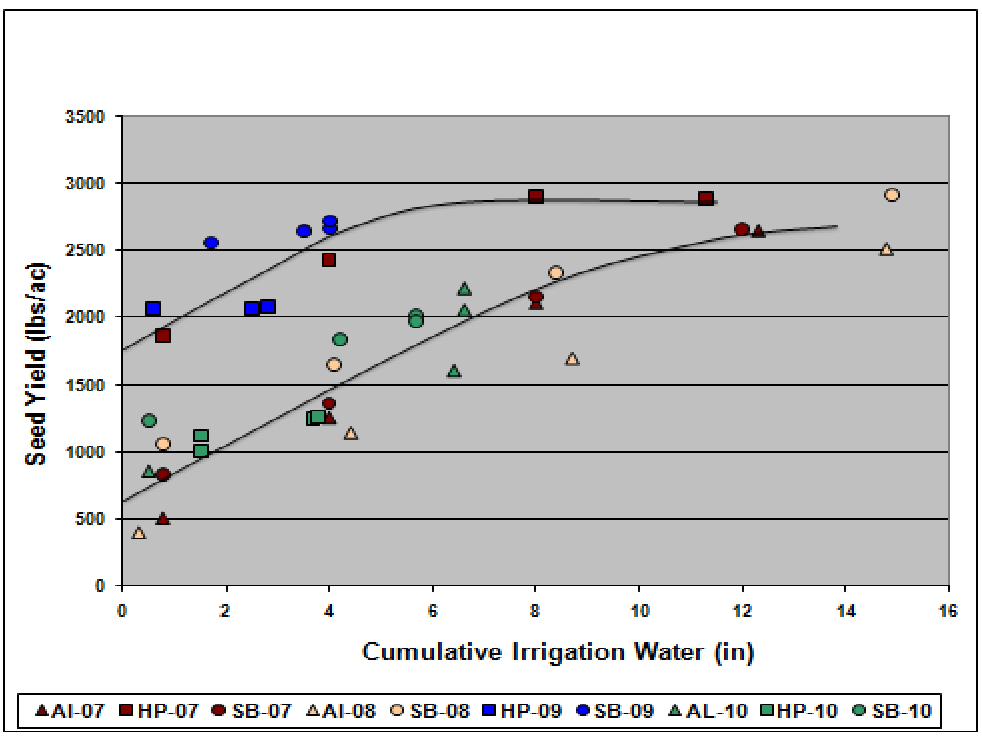
*lost to hail.

Irrigation versus seed yield production functions for camelina and canola are depicted in Figures 1 and 2, respectively. Data for Sidney camelina (2009) and canola (2008) are not reported due to significant crop losses from downy mildew (*Peronosporaceae*) and adverse harvesting conditions, respectively. Data for Alliance canola (2009) is not reported due to severe crop loss from hail. Seed yield for both camelina (Fig.1) and canola (Fig. 2) increased curvilinearly in response to increases in cumulative irrigation. The data suggest that at least two (2) functions can be fitted to the data, herein referred to as upper and lower production functions. In general, for both crops, location years associated with the upper production functions are characterized by relatively high amounts of precipitation and/or stored soil moisture during the growing season whereas years associated with the lower production functions are characterized by relatively low precipitation and/or stored soil moisture.

Seed yields for the upper and lower camelina production functions increased linearly, at the rate of 150-160 pounds per acre per inch of irrigation, until cumulative irrigation amounts of approximately 8 to 10 inches were applied, respectively. Thereafter, the respective functions predict incremental seed yield increases of 50 to 70 and 80 to 100 pounds per acre for each additional inch of irrigation. Maximum seed yields of 2390 and 2560 pounds per acre were produced at the respective maximums of cumulative irrigation water for each function.



Seed Yield (lbs/ac)
Cumulative Irrigation Water (in)
HP-07
SB-07
HP-08
SB-08
SB-09
HP-10
SB-10



Seed Yield (lbs/ac)
Cumulative Irrigation Water (in)
Al-07
HP-07
SB-07
Al-08
SB-08
HP-09
SB-09
AL-10
HP-10
SB-10

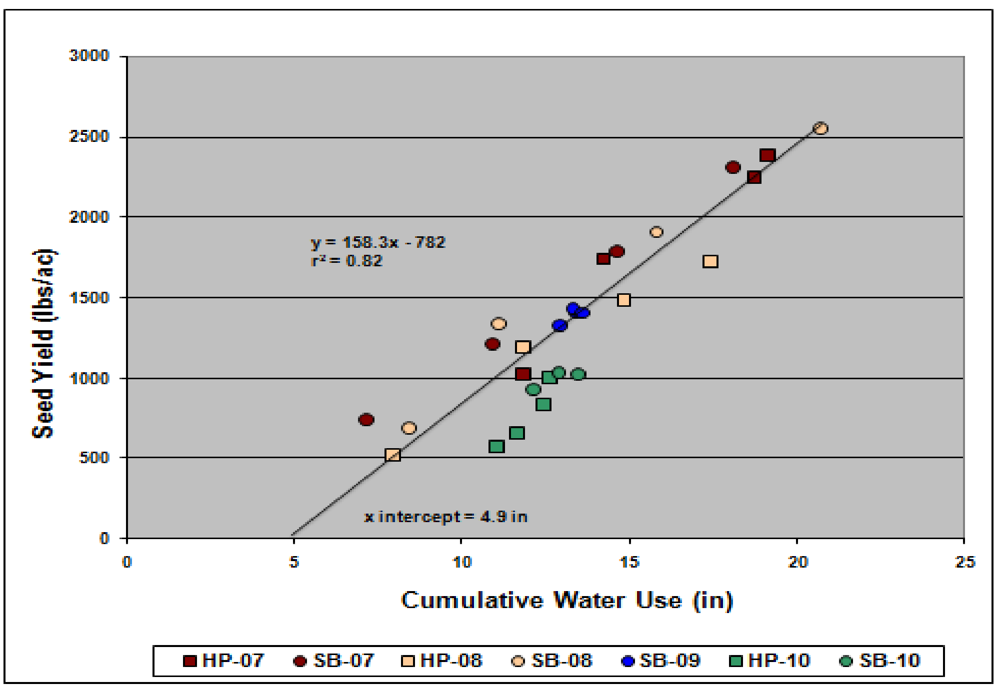
Data for both camelina functions exhibit “plateaus” in seed yield at or near the respective maximums of cumulative irrigation water. These “plateaus” are significant since they represent the cumulative irrigation water required to meet full evapotranspiration crop demand. Based on water use data (Figure 3) and phenology data (not shown), these “plateaus” correspond to a total water use of 18 to 20 inches when stored soil water, rainfall and irrigation are considered.

Seed yields for the upper and lower canola functions increased linearly, at the rate of 200 to 220 pounds per acre per inch of irrigation, until cumulative irrigation amounts of 4 and 8 inches were applied, respectively. Thereafter, corresponding incremental seed yield increases of 20 to 30 and 80 to 100 pounds per acre for each additional inch of irrigation are predicted. Maximum seed yields of 2900 and 2930 pounds per acre were produced at the respective maximums of cumulative irrigation water for each function.

As with camelina, “plateaus” exhibited by both canola production functions indicate that full evapotranspiration crop demand was attained at or near the respective maximums of cumulative irrigation water. Figure 4 shows these “plateaus” correspond to a total water use of 20 to 22 inches when stored soil water, rainfall and irrigation are considered.

Water Use/Seed Yield Production Functions

Figures 3 and 4 present water use versus seed yield functions for camelina and canola, respectively. Each function is described by a linear regression, the slope and x-intercept corresponds to a water use efficiency and threshold water use value.



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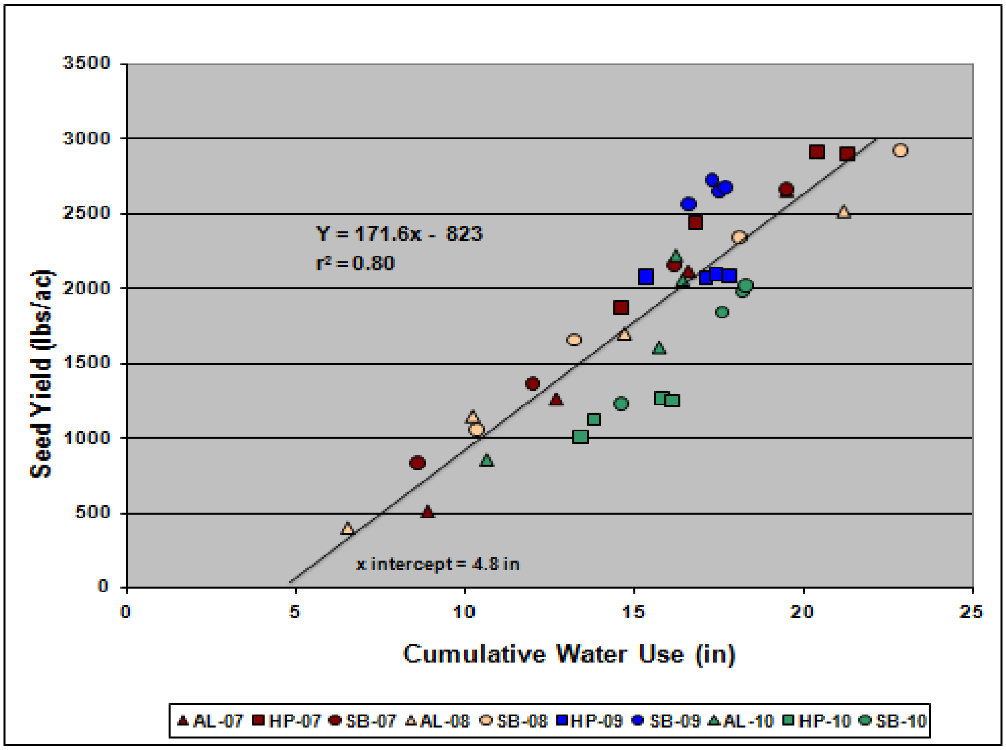


The water use/seed yield production functions for camelina and canola predict water use efficiencies of 158 and 172 pounds of seed for each inch of cumulative water use, respectively. In addition, the corresponding production functions predict threshold water use values of 4.8 and 4.9 inches or, in other words, approximately 5 inches of cumulative water would be required for any production of camelina or canola seed.

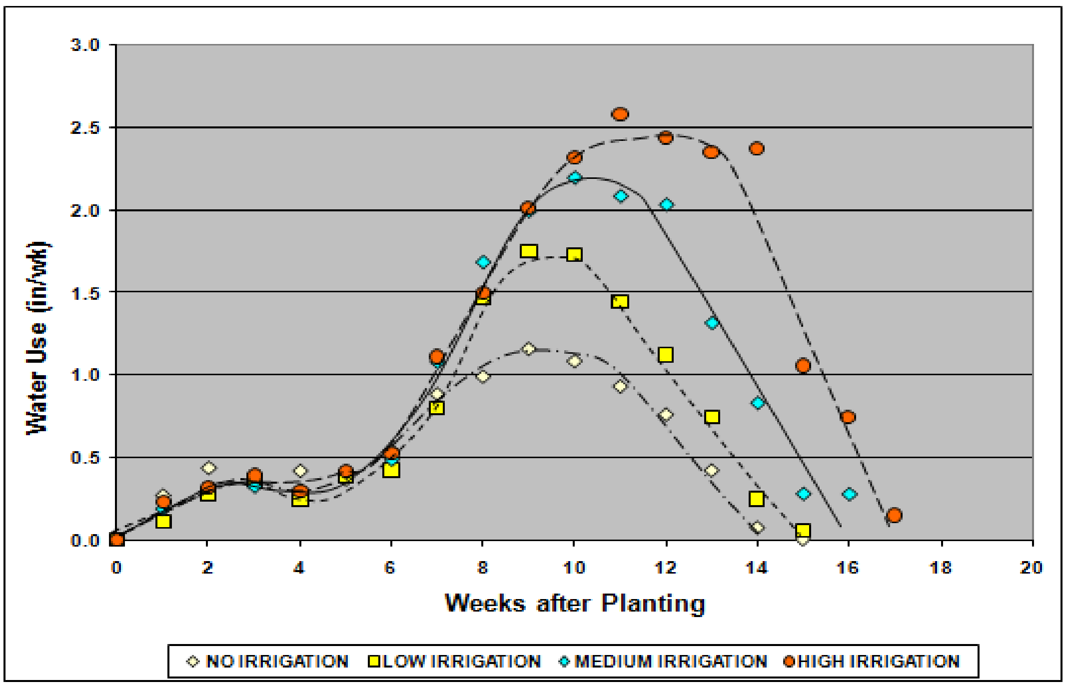
Camelina seed yields ranged from 520 to 2560 pounds per acre with 8.1 and 20.7 inches of cumulative water use, respectively. On the other hand, canola seed yields ranged from 400 to 2930 pounds per acre with 6.5 and 22.9 inches of cumulative water use, respectively.

Nielsen (1997) reported a water use/seed yield production function for canola that predicted a threshold water use of 6.2 inches and a water use efficiency of 175 pounds of seed per acre for each inch of water use. These reported values were based on soil moisture contents to a depth of 65 inches and a maximum water use of 20.5 inches.

Growing Season Water Use

The effect of the different irrigation levels was highlighted well for both canola and camelina during the 2008 (very dry) season. Figure 5 shows the effect of different irrigation levels on the extent and duration of crop ET as affected by water stress for camelina. The true dryland treatments advanced through flowering and seed fill more rapidly than well-watered treatments (data not shown) and the maximum water use varied considerably as did the time period of high water use. Maximum water use approached values for corn during the hot and dry conditions of 2008. Maturities were significantly different due to water effects.

In contrast, 2009 was an above average rainfall year and there was no significant difference between any of the irrigation levels for water use, crop development, maturity and yield (Figure 6). Disease did limit yields even though fungicide was applied to control downy mildew. Weekly water use was maximized near 1.7 inches per weeks versus a higher value in a dry year.



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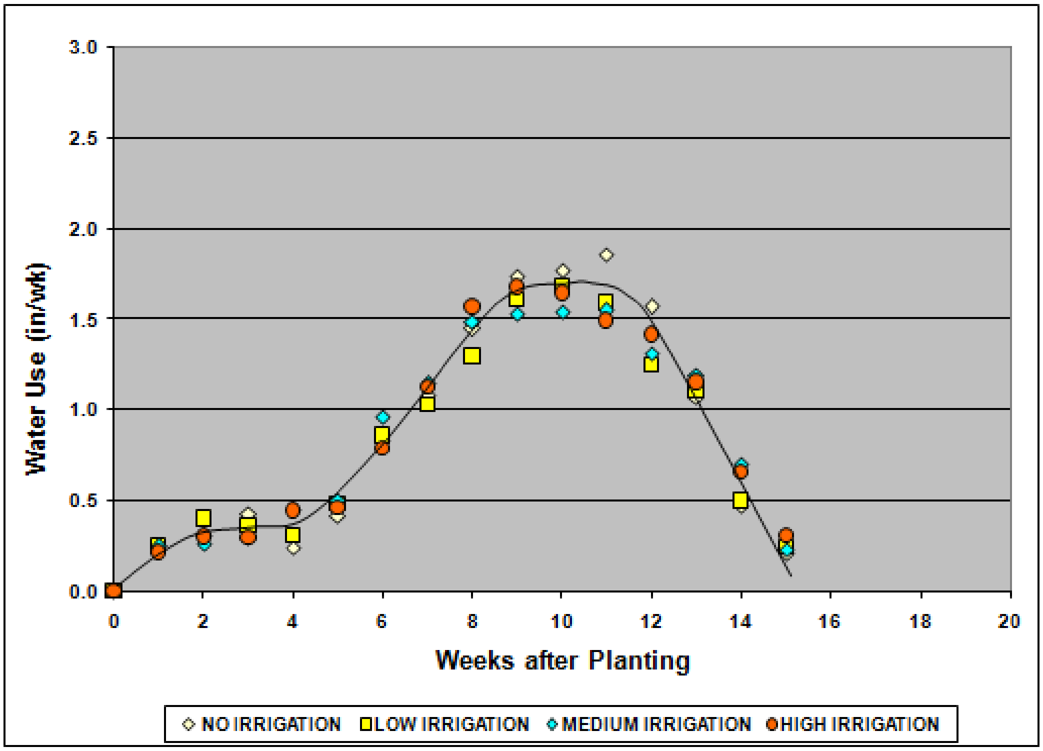

Conclusions

Camelina seed yields produced typical curvilinear responses to increasing irrigation. In drier years the full irrigation requirement ranged from 11 to 13 inches whereas 6 to 8 inches of irrigation produced optimum yields in wetter years. Maximum ET for fully irrigated camelina in dry years approached 2.4 inches per week for a total water use of 18-20 inches, when stored soil water, rainfall and irrigation are considered. Maximum seed yields of 2300 to 2500 lbs/ac are attainable with current cultivars. Non-irrigated yields ranged from 500 to 1200 lbs/acre. Soil water was extracted from at least 4 feet. Canola has a higher yield potential than camelina with maximum seed yields of 2900 to 3000 pounds per acre. This is likely a result of more years of genetic improvement in canola versus camelina. Non-irrigated yields ranged from 700 to 1900 lbs/acre. In drier years the full irrigation requirement ranged from 11 to 13 inches whereas 6 to 8 inches of irrigation produced optimum yields in wetter years. Maximum ET was similar to camelina, however, canola showed soil moisture extraction to at least the 5 foot level. Both crops required a minimum of 5 inches of ET to produce the first pound of seed. Our research did not show major differences in drought tolerance or water productivity (172 vs. 160 lbs/inch for canola vs.

camelina.) Both crops need sufficient soil moisture for germination and stand establishment. Stress during the reproductive stage can significantly reduce yield. Data suggest that spring camelina and canola would be suitable crops for biofuel production with limited water supplies in the northern High Plains.

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