Alternate Crops in Dry Environments

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Introduction

The identification and development of alternate crops to replace some of the wheat and summerfallow area of the dry prairie is critical to ensuring economic survival. Reducing summerfallow frequency is also critical to conserving the soil resource of the region (Brown and Dark Brown soil zones). Research at Scott and Swift Current since the early 1990's has been directed towards addressing this issue.

Objectives of these activities were to evaluate performance of several cereal, oilseed and pulse crops at these sites over a limited number of years. The data would also be used to assess responses of each crop to moisture and temperature conditions. This information would then be used to predict how each might perform in future, including relative yielding ability and yield variability or risk. It was also recognized that the datasets could be used to identify management practices that could enhance crop performance.

Because it is difficult to obtain an adequate sampling of growing season conditions, we utilized three dates of seeding in latter years. This provided more than one sampling of climate for each year. We then used correlation and regression analyses to relate crop performance to climate.

Materials and Methods

Experiments were conducted at Scott (Dark Brown soil zone) and Swift Current (Brown soil zone). However, the focus of this paper is on the Scott data., and the materials and methods described herein apply to Scott only.

A split plot (crops as main plots) RCBD was used for the seeding dates experiment and a simple RCBD used in 1990 and 1991, all with four replicates.

Seeding at recommended rates for each crop was done in early, mid and late May of 1993 to 1997 and mid May only of 1990 and 1991 Herbicide damage was incurred on the early seeded treatments in 1994, and data from this seeding date was disregarded. Nitrogen and phosphate fertilizers were applied at rates based on soil tests for all crops except pulses, which received phosphate only. Pulses were inoculated with appropriate rhizobial inoculant just prior to seeding. Pesticides were applied according to best management practices to maintain plots relatively pest free. Fungicide application to pulses in 1993 was too late to prevent some yield loss.

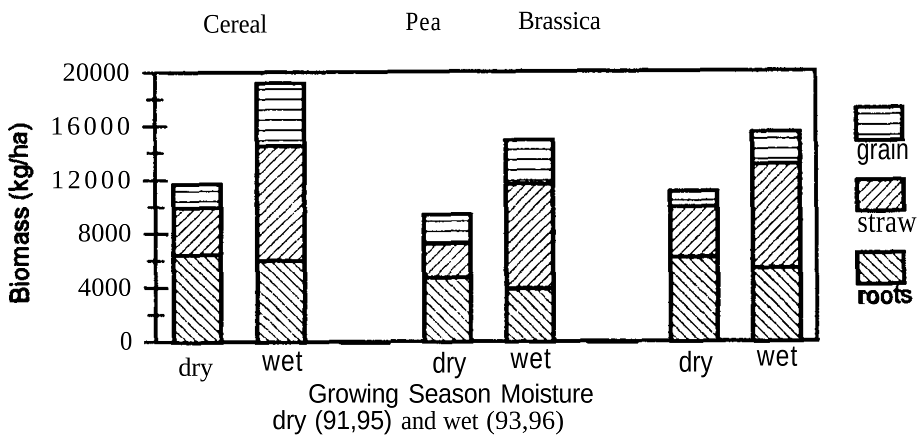

Figure 1. Partitioning of biomass to roots, straw and grain for cereals, pea and *brassica* oilseeds.

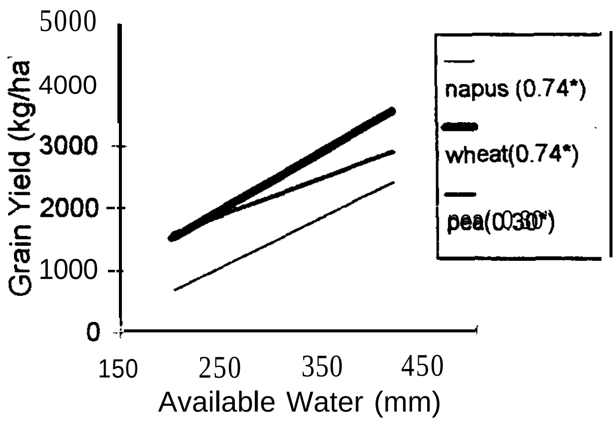

Figure 2. Yield : water relationship for wheat, pea and argentine canola at Scott. (R^2 values in brackets)

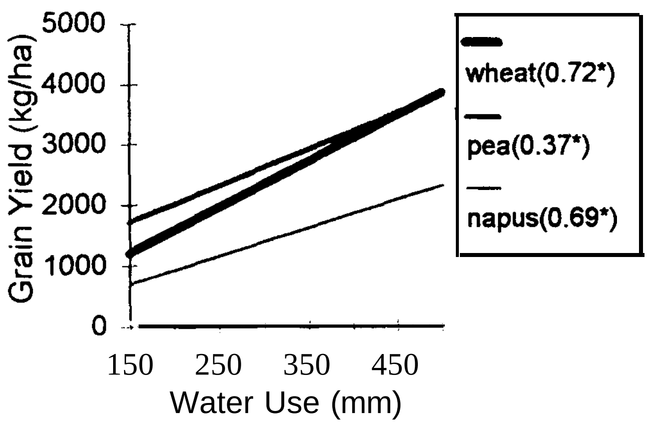

Figure 3. Yield water relationships for wheat, pea, and argentine canola at Swift Current. (R^2 values in brackets)

Gravimetric soil moisture to 90cm depth was determined prior to seeding and after harvest each year. Precipitation was measured at 2 sites within 0.5 km of the experiment and temperature at a site within 5 km.

After seeding, crop growth staging was done at weekly intervals on all crops.

Biomass production was measured on $2m^2$ areas per plot harvested at physiological maturity. Grain yield was measured by direct harvesting the crop at IO- 15% seed moisture content. Straw yield was calculated by difference. Root biomass was measured (199 1, 1993, 1995, 1996 only) on washed and screened root material recovered from two 5cm x 20cm x 30cm deep soil cores from each plot. Grain, straw and root yields were expressed on an oven dry basis (near zero moisture). Nitrogen contents (Kjeldahl) of each component were determined. Because most samples were from only a small area, error was so large that significant crop, year or seed date differences could not be detected. However, due to similarities for the 2 driest (1991 and 1995) and 2 wettest (1993 and 1996) years, and for the cereals, Brassica oilseeds and pea and lentil data was grouped for these crops and years.

From this data, water use efficiencies were calculated and simple or multiple regressions of straw and grain yield or water use efficiencies with available moisture (spring soil moisture plus May 1 – August 3 1 precipitation) and/or mean temperatures during flowering (for oilseed and pulse crops) were performed.

Data reported here focuses on wheat, Argentine canola and pea at the Scott site.

Results and Discussion

The seven years of study provided a reasonably balanced sampling of moisture and temperature conditions (Table 1). Available spring soil water, May 1 to August 31 precipitation and total available water each had several instances where values were near, substantially above or below long term normals. Similarly, mean daily temperatures for the growing seasons evaluated were not seriously skewed in favor of higher of lower than normal values.

Root biomass at O-3Ocm depth was greater for cereals and Brassica oilseeds than for pea, but differences were relatively small (Figure 1). Because sampling was done only at 30cm depth, the data is insufficient to evaluate whether or not rooting capacity would make one group of crops better able to extract water from the full soil profile.

Root biomass for the 2 dry years tended to be slightly higher than for the 2 wet years, although differences were not statistically significant.

Root biomass as a proportion of total biomass for all crops was greater for the dry years than wet years (data not shown). This was more a reflection of greater straw and grain biomass production in wet years than greater root biomass production in dry years. Similar observations (Richards and Thurling 1978) have been made for proportioning of root, straw

Table 1. Growing season precipitation and temperatures, and available spring moisture (to 90cm depth) at Scott.

Year	Spring Soil Moisture (mm)	May 1 -Aug. 31 Precipitation (mm)	Total Available Water (mm)	Mean Daily Temperature (°C)	
				May – June	July - Aug
1990	53	219	272	13.0	16.5
1991	76	195	271	13.4	18.8
1993	176	243	419	11.9	14.5
1994	166	170	336	12.9	16.5
1995	102	106	208	13.4	15.8
1996	75	224	319	11.4	17.3
1997	91	121	202	13.2	17.8
Long Term	110	159	269	12.1	16.5

and grain biomass with and without imposed drought on Brassica species. This result suggest that all crops did a reasonably good job of diverting sufficient assimilate to ensure that root growth was adequate to make effective use of the moisture available to the crop.

Correlation analyses revealed strong relationships between the amount of water available to the crop (spring soil water plus May to August 3 1 precipitation) and both grain and straw yield of Argentine canola, wheat and pea (Table 2). Available water responses differed between crops with wheat and pea showing similar responses, but Argentine canola being somewhat less responsive (Figure 2). At Swift Current, correlations were based on water use (soil water used plus precipitation from seeding to harvest). Although the relationships were based on a somewhat different water variable (Figure 3), similar relationships developed between grain yield and water for the three crops.

Table 2. Relationships between the supply of available water and grain and straw yields, and water use efficiencies (WUE).

Crop	Relationship	R^2	P
Argentine canola	Grain Yield = 9.15 Available Water - 1210	0.74	0.000
	Straw Yield = 25.6 Available Water - 666	0.49	0.002
	Grain WUE = ,015 Available Water + 0.34	0.39	0.009
	Straw WUE = ,001 Available Water + 23.0	.00	1.000
Wheat	Grain Yield = 11.3 Available Water - 870	0.74	0.000
	Straw Yield = 32.1 Available Water - 3906	0.67	0.000
	Grain WUE = .012 Available Water + 4.71	0.22	0.063
	Straw WUE = .025 Available Water + 11.5	0.07	0.3 11
Pea	Grain Yield = 8.04 Available Water - 157	0.30	0.014
	Straw Yield = 30.6 Available Water - 4270	0.60	0.000
	Grain WUE = 37.6 Available Water - 4067	0.03	1.000
	Straw WUE = .046 Available Water + 1.72	0.28	0.036

Grain water use efficiency (grain yield/available water) of Argentine canola, but not wheat or pea was significantly and positively related to available water. This would suggest that canola uses water more efficiently to produce grain as the supply of water increases. This would also suggest that the crop is relatively better adapted to wetter climates than wheat or pea.

Pea showed a weak relationship between straw water use efficiency and available water. This may be an indication that pea uses water preferentially to produce straw under higher moisture conditions, or conversely that less water is devoted to straw production under drier conditions.

Yield responses to date of seeding were quite variable over years (Table 3), particularly for canola and pea. In general, early seeding of canola produced yields equal to or greater than later seeding. When averaged over years, there was a significant linear effect of seeding date on yield. Yield declined with delayed seeding.

Table 3. Influence of date of seeding on yield (kg/ha) of wheat, Argentine canola and pea at Scott, SK, during 4 years.

Seeding Date	1993	1995	1996	1997	Mean*
Wheat					
- early May	3370ab	1380	2300b	1750a	2200
- mid May	3590a	1340	2740ab	1800a	2370
- late May	3030b	1480	3060a	1300b	2200
Argentine canola					
- early May	3220a	760	1710	740a	1610
- mid May	2170b	750	1690	760a	1340
- late May	2100b	970	1600	320b	1250
Pea					
- early May	2690a	990	3200b	1590a	2120
- mid May	2290ab	1260	4100a	1580a	2310
- late May	1907b	1230	3000b	1080b	1820

· **No** *significant effects for wheat, significant linear effects for canola, significant cubic effects for pea.*

For wheat, averaged over years, seeding date had little effect on yield. However, during 1993, mid May seeding was significantly higher than late May, while late May seeding increased yield over early May in 1996.

Pea yield was generally similar or lower for late May seeding compared to early or mid May. When analysed over all years, there was a significant cubic effect of seed date on grain yield, indicating that yield increased then decreased as seeding was delayed from early to mid and late May.

Yield responses to seed dates suggest that for canola and pea in particular, yield was responding to something other than just water. Published reports (Nuttall, et al, 1992) indicate that canola and pea are sensitive to temperatures at early reproductive stages (flowering and early seed set).

To evaluate this further, the relationships between temperatures during several crop growth stages and yield were examined. Wheat and pea yields were not well correlated to any temperature function. The duration of flowering for pea was quite variable, ranging from 8 to 29 days, and did not appear to be related to either temperature or moisture. Duration of flowering for canola was less variable (19 to 36 days). For canola, mean temperatures from start to finish of flowering were significantly and negatively correlated to grain yield. This temperature function was also negatively related to available water, since drought is normally associated with heat. Multiple regression analysis provided a more objective overview of the role of both water and temperature as determinants of canola yield. The relationship can be expressed as follows;

Argentine canola yield = 5.1 x available water – 237.8 x Temperature + 3703 R^2= 0.83

Where available water is precipitation from 1 May to 31 August plus available soil water at 1 May, and temperature is mean daily temperature (^{0}C) from start to finish of flowering.

Argentine canola yield increased by 5.1 kg/ha for each mm of water (2.3 bu/ac/inch) and decreased by 238 kg/ha (4.2 bu/ac) for each degree rise in mean temperature during flowering in the range of 12 to 18.5 degrees. This relationship helps to explain seeding date responses by canola since delaying seeding from early to late May typically exposes the crop to progressively higher temperatures during flowering.

Conclusion

Both wheat and pea are well adapted to dry environment of the semi-arid prairie. The yield responses were similar at both low and high levels of available moisture.

The negative effect of high temperatures and increasing water use efficiencies at higher available water levels suggest that this crop would be more risky than wheat or pea

The temperature and water yield model needs further validation, particularly against datasets from locations in the Brown soil zone. If it can be validated, it could prove useful for predicting relative yield and yield variability using long term meteorologic data from a large number of sites in the semi-arid prairie. This could prove to be a very valuable tool for predicting the performance of this crop relative to wheat. Generation of risk maps and predicting the merits of manipulating seeding dates in improving performance are also feasible.

If this exercise proves productive, it is reasonable to expect that similar models can be developed from the details we have for other Brassica oilseeds.

References:

Nuttall, W. F., Moulin, A. P., and Townley-Smith, L. J. 1992. Yield responses of canola to nitrogen, phosphorus, precipitation and temperature. Agron. J. 84: 765-768.

Richards, R. A. and Thurling, N. 1978. Variation within and between species of Rapeseed *(Brassica campestris* and *B. napus)* in response to drought stress. 1. Sensitivity at different stages of development. Aust. J. Agric Res. 29. 469-477.