Alternative Crops in Wheat Country: Yield Response to Available Water

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Introduction

Water drives crop production in the Dry Prairie, where wheat is king. As producers move toward a more market-based economy, incentives become greater for exploring other crop options. What are legitimate oilseed and pulse crop options for the Dry Prairie? Certainly alternative crops must complement wheat in extended rotations and 'cropping system' water use strategies must be compared. However, in this paper our intent is to explore a limited dataset to compare yield-water relationships of alternative crops to that of wheat.

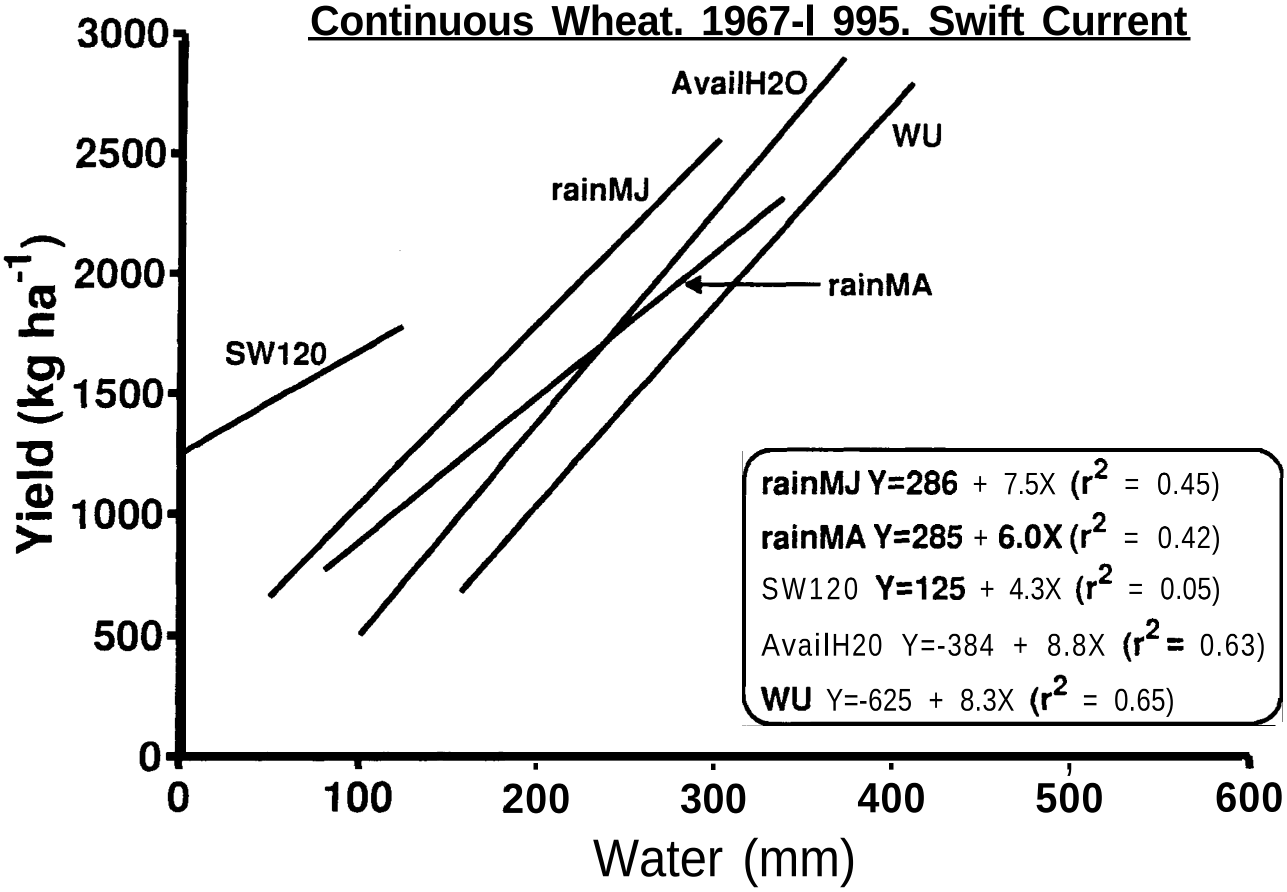
The focus question for this paper is: "How does wheat yield response to water compare with oilseed/pulse yield response in the semiarid prairie?" To illuminate this focus question, more specific questions must be addressed:

1. What is the best measure of water we can use to relate to yield?
2. Does yield response differ for fallow vs. stubble cropping?
3. Are oilseeds/pulses more (or less) responsive to water than wheat?

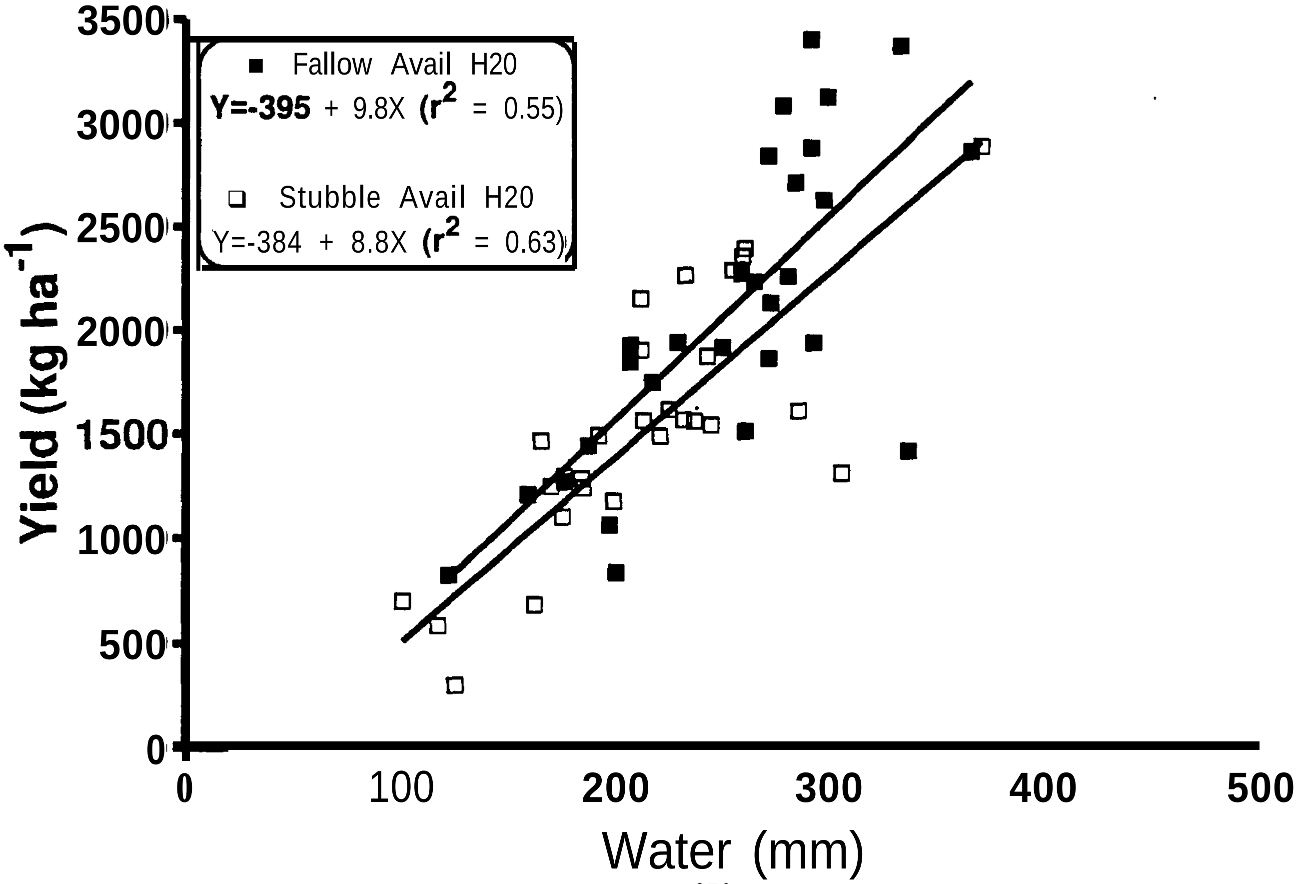
1. Best measure of water to relate to yield?

The most appropriate measure of water we can use to relate to crop yield should probably account for both available water and evapotranspirative demand. The fertilized continuous wheat (cv. Leader/Lancer) treatment in the Old Rotation study at Swift Current (1967-95) will be used to compare different measures of water availability. Producers often use the soil water status at seeding to help them decide whether or not to recrop (i.e., flex-cropping). If we assume that the theoretical lower limit of available water for wheat is -40 bars, then the spring soil available water to 120-cm soil depth (SW 120) can be calculated. However, the long term results from the Old Rotation suggest that available spring soil water alone is not predictive of wheat yield in the semiarid prairie, because it only explained about 5% of the variation in continuous wheat yields (Fig. 1). The crop ultimately depends on growing season rainfall. Total rainfall from 1 May to 3 1 July (rainMJ) is the simplest measure of water, explaining about 45% of the variation in continuous wheat yields (Fig. 1). However, total rainfall does not take into account rainfall distribution which can be equally as important. For example, in 1970 most of the growing season rainfall came in one week in June and the drought-stressed wheat did not respond as one might expect based on total growing season rainfall. Combining SW120 and rainMJ to estimate total available water explained 63% of the variation in wheat yield (Fig. 1). However, when 1970 is deleted from the dataset this increased to 74%. The best estimate of crop available water involved measuring crop water use to 120-cm soil depth (WU 120) by taking the difference between seeding and harvest, and adding in growing season rainfall.

Fig 1. Yield Response to Water
Continuous Wheat. 1967-I 995. Swift Current



Fia 2. Wheat on Fallow vs Stubble! 1967-1995, Swift Current



The latter explained 65% of the yield variation in continuous wheat (Fig. 1). The above methods of measuring available water focus only on the 'supply' side of the water-yield relationship. The 'demand' side can be estimated by determining evaporative demand, e.g., pan evaporation (PE), and deducting growing season water used to 120-cm soil depth (WU 120). As expected, this inverse relationship explained the greatest amount of variation in continuous wheat yield, e.g., kg/ha = 3274 - 3.74 (PE-WU120); $r^2 = 0.74$. Although the inclusion of the demand side for water increases the predictive power of continuous wheat yield, because pan evaporation, or the weather data variables to calculate potential evaporation, are not commonly available at specific sites, this paper will focus on the relationship of yield to water supply.

2. **Does yield response differ for fallow vs. stubble?**

There is some suggestion that yield response to available water may differ for stubble vs. fallow seeded crops because the greater stored soil water of fallow has the potential to act as a 'buffer', reducing chances of crop failure during intermittent drought periods. This is clearly an important consideration for oilseed and pulse crop production. If the yield response to available water on fallow vs. stubble differs, it will influence the producer's decision in choosing whether to seed on fallow or stubble. The evidence from our Old Rotation study, comparing both wheat and flax grown on fallow and stubble clearly shows the yield response does not differ (Figs. 2, 3, 4). This suggests that the total amount of water available to the crop is more important than what proportion is stored in the soil, consistent with the observation that stored soil water, by itself, is not predictive of wheat yield (Fig. 1). Does this observation hold for other crops? Preliminary results from Scott and Swift Current suggest that this generally may not be the case. For example, field pea yields, as a % of wheat yields, have been higher when grown on stubble compared with fallow. The opposite trend has occurred for Oriental mustard.

3. Are oilseed and pulse crops more or less responsive than wheat?

Some producers are of the opinion that oilseed and pulse crops are more sensitive to drought stress than wheat. If this is true, then the converse may also be true, i.e. that oilseed and pulse crops are more responsive to available water than wheat. Thus, on a graph of oilseed, pulse. and wheat yields vs. available water, while the Y-intercepts may differ, the slopes would tend to be steeper for the oilseed and pulse crops.

Regression analysis allows an estimate of rate of increase in yield per unit of available water which is simply a modified calculation of water-use efficiency (WUE) where the Y-intercept is allowed to be something other than 0. If the assumption of a linear relationship holds, then it is expected that the Y-intercept will be negative, or conversely, the X-intercept positive, which simply means there is some threshold amount of water required to produce the first. unit of yield: a biological reality. In contrast to our opening premise, our regression results showed that wheat is more responsive to available water

Fig 3. Wheat vs Flax on Fallow. 1967-1995, Swift Current

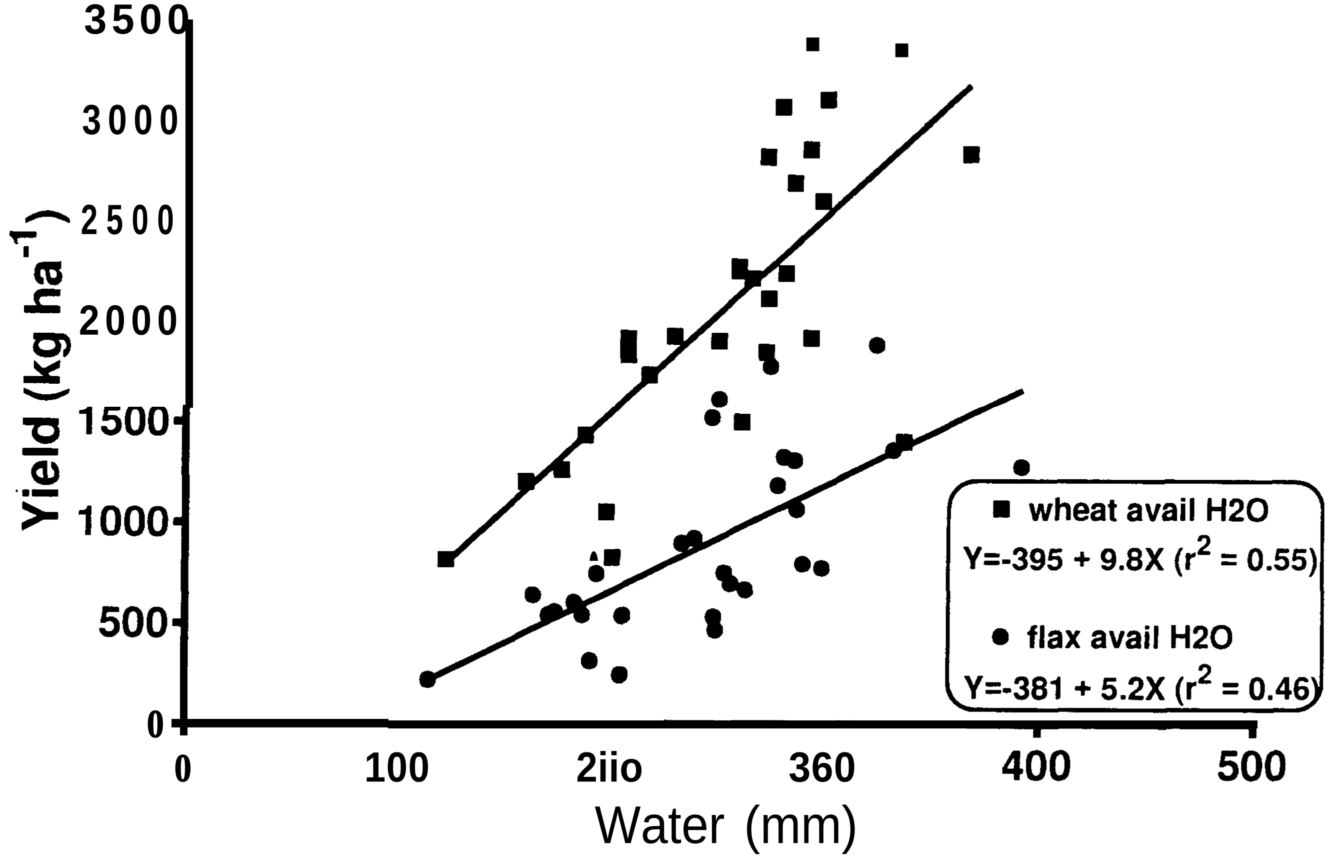
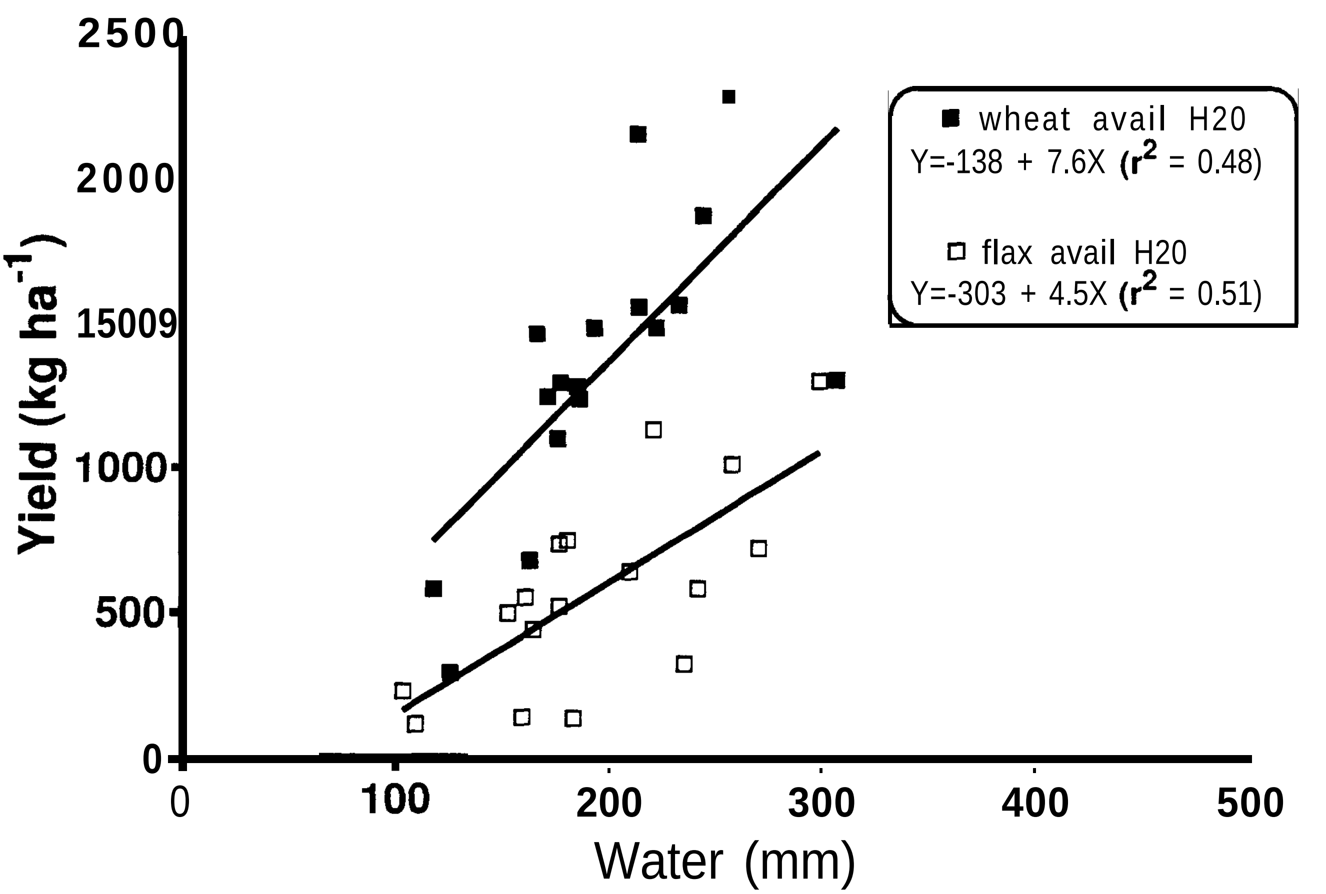


Fig 4. Wheat vs Flax on stubble, **1967-l 984. Swift** Current



than the oilseed and pulse crops (Figs. 3,4,5,6), with the notable exception of field pea (Fig. 6). If the alternative crops were less repsonsive to available water than wheat, then can we say that they were more drought tolerant? Support for this contention comes from a limited dataset comparing oat and wheat yields at Scott. Oat is known to be less drought tolerant than wheat. The regression equations were, kg oat/ha = -1970 + 20.2 (mm Available water), r^2=0.81; and, kg wheat/ha = -324 + 11.3 (mm Available water), r^2=0.53. The steeper slope of the oat regression served as an indication of lesser drought tolerance, just as the flatter slopes for the alternative crops regressions presented here indicate greater drought tolerance.

If the alternative crops are compared to wheat on a proportional basis, however, where both the Y-intercepts and slope coefficients are used to calculate yields of alternative crops as a % of wheat yields, the opposite results were obtained. High, medium, and low water classes were set by picking the mean available water for both fallow and wheat stubble, and setting the high and low water situations as plus and minus one standard deviation from the mean. This would be expected to represent the range from upper to lower extremes in available water for 19 of 20 years. In the high moisture situation, the yield of flax and lentil, relative to wheat, increased relative to the low moisture situation. In other words, on a proportional basis, as water availability decreased, the relative yield response of flax and lentil decreased, indicating lesser drought tolerance than that for wheat.

Table 1. Flax and lentil yields as % of wheat yields at low, medium, and high available water.

Crop	LOW	Medium	High
	------------ %	of Wheat yield	------------
Flax on fallow (N*=29)	42	45	47
Flax on stubble (N= 18)	37	44	‘47
Lentil on stubble (N= 16)	61	63	64

* N = number of years included in analysis.

An important aspect of yield response to available water is concerned with the consistency or stability of the response over time and space. The coefficient of variation (CV) for yield provides a measure of the relative variability of response for each crop. Evidence from the Old Rotation study showed the yield response of wheat over time to be more stable than that of flax or lentil (Table 2). The CV's were elevated for the wheat vs. lentil comparison because of the inclusion of 1988, a year of complete crop failure for both crops, in a relatively small dataset. Additional evidence from a limited but more recent combined dataset from collaborative alternative crop studies at

Fig 5. Wheat vs Lentil on stubble. **1979-1995, Swift Current**

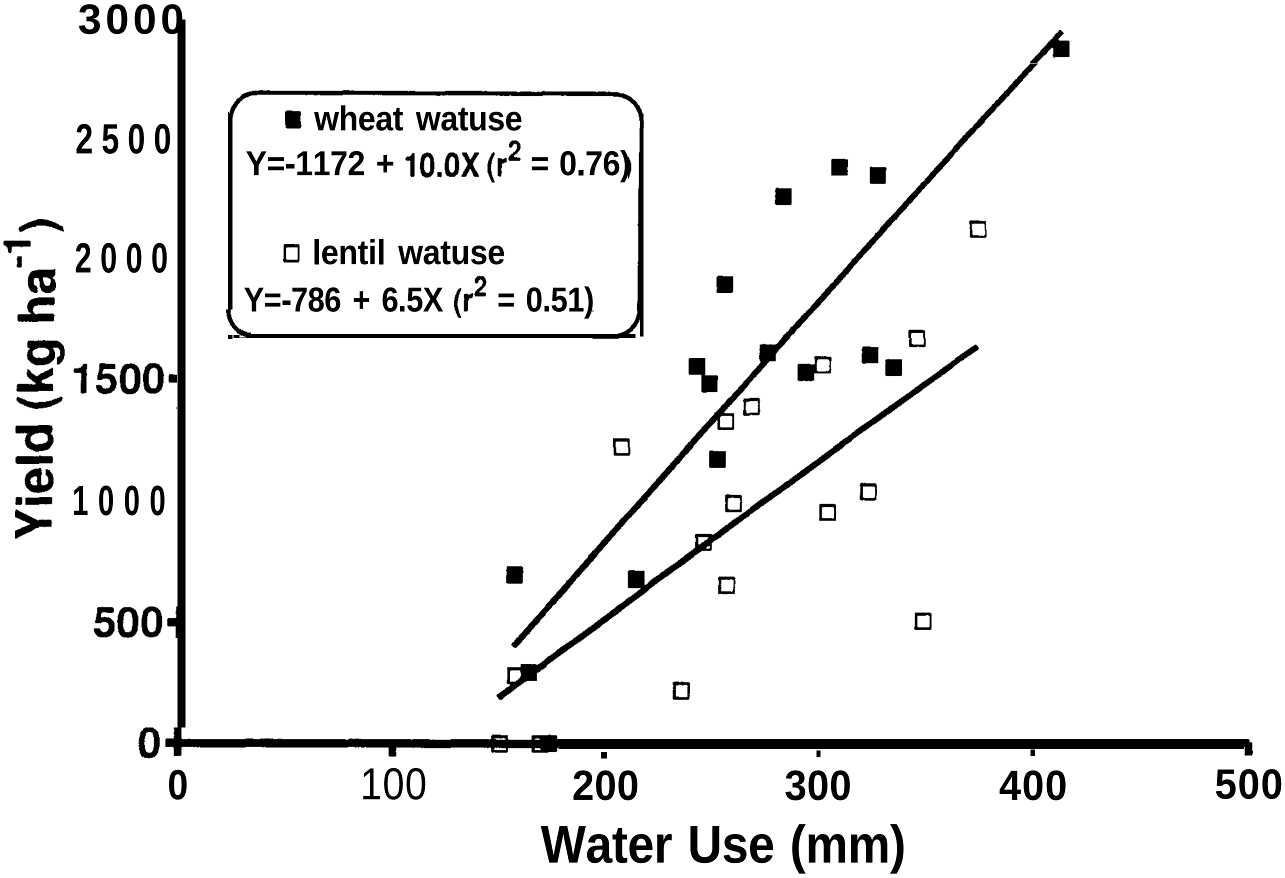
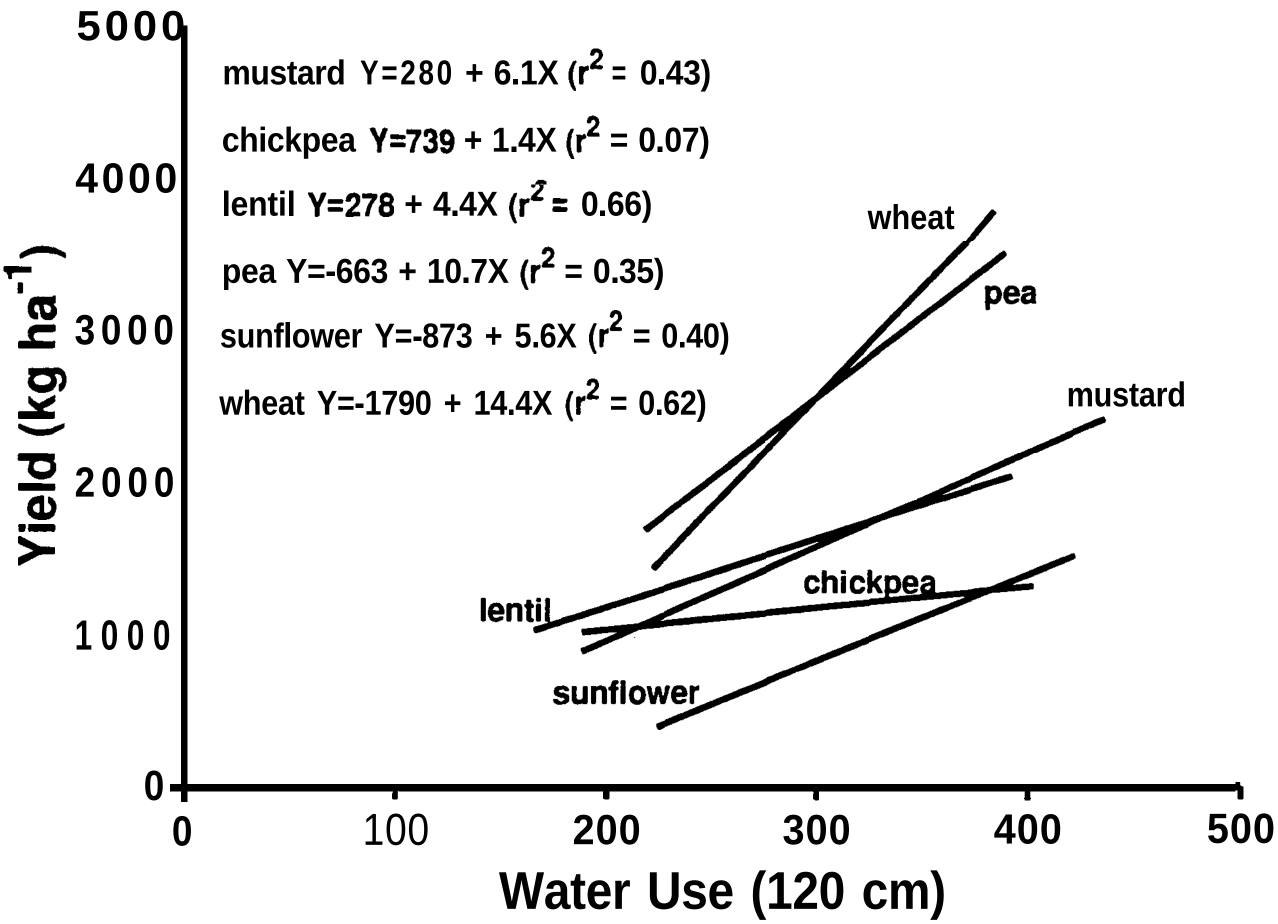


Fig 6. Alternative Crops. Scott and Swift Current. **1990-1995**



Scott and Swift Current, showed that the variability of yield response over time and space was not as clear (Table 3). Lentil appeared to have the lowest CV but note that when the 1993 data from Scott was included, where lentil suffered major disease losses (indirectly related to high available water), this CV jumped from 24 to 4 1. Chickpea also appeared to have a low CV, but as disease inoculum increases it may behave similarly to lentil because high available water situations would often result in low yields, increasing the CV. If water is the main limiting factor to crop production, then it can be argued that the consistency of yield response to available water is greater for wheat as compared to the alternative crops presented here. However, higher CV's aren't necessarily an indication of more variable response to available water. Other factors such as excessive temperatures or pests also affect yield, and, perhaps more importantly, crop management for alternative crops is less well developed than for wheat. This last factor alone can contribute to higher CV's as has been previously demonstrated for canola.

Table 2. Yield variability of alternative crops compared to wheat in the Old Rotation studv at Swift Current.

Comparison	years	Yield (kg/ha)	CV*
Flax on fallow	1967-95	890	51
Wheat on fallow	1967-95	2090	35
Flax on stubble	1967-84	580	60
Wheat on stubble	1967-84	1340	38
Lentil on stubble	1979-95	920	67
Wheat on stubble	1979-95	1490	53

CV = standard deviation/mean yield.

Summary

Based on linear regression analyses of yield response to available water, alternative crops appear more drought tolerant (i.e., less responsive to available water) than wheat, with the notable exception of field pea. However, if alternative crop yields are reported on a proportional basis relative to wheat, then the alternative crops appeared somewhat less drought tolerant. Regardless, it appears that the alternative crops examined here were not especially sensitive to drought stress, compared with wheat. It is unclear whether the greater variability of yield response for alternative crops is related to available water or other factors, such as crop management.

It is obvious that alternative crop yield relationships with climatic factors, principally water availability, are not well understood for the semiarid prairie. With a stronger knowledge base in this area, perhaps yield risk maps could be developed to assist producers with alternative cropping choices in non-traditional areas of production. Crop response to rainfall distribution during the growing season, as opposed to the total amount. needs to be better understood if we are to properly assess production risk due to drought. Critical water and temperature stress periods for alternative crops are not well understood for the semiarid prairie and effects on yield have not been quantified. Differential patterns in water use by alternative crops would be useful information for planning efficient water utilization strategies from the cropping system perspective. This information is likely tied closely to rooting characteristics for alternative crops, again an area where little is known that can be applied directly to cropping systems in the semiarid prairie. All information relating crop yield response to available water must be pooled to manage the 'whole-farm' for improved water-utilization strategies. Very little of this information is currently available for the semiarid prairie. This is truly unfortunate. Knowledge of alternative crops yield response to available water is vital to ensuring the agronomic viability and economic sustainability of diversified cropping systems in the semiarid prairie.

Table 3. Yield variability of alternative crops compared to wheat for combined site-years at Scott and Swift Current.

Comparison	N*	Yield (kg/ha)	CV**
Lentil	23	1610	24
Wheat	26	2640	30
Chickpea	19	1180	32
Mustard	26	1590	38
Field Pea	30	2510	43
Sunflower	24	1010	52

* N = number of site-years in analysis.
**CV = standard deviation/mean yield.

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List of Figures.