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Water Use Efficiency and Precipitation Use Efficiency of Crops in the Semiarid Prairie

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Abstract:
The importance of water use efficiency (WUE) in crop production, in the semiarid prairie, is based on the fact that the available water is the most limiting factor influencing crop production. This poster compares water use efficiency of four crop rotations from the Swift Current, SK, long-term rotation experiment: fallow-wheat-wheat (F-W-W), F-flax-W (F-Flx-W), continuous wheat (Cont W) and wheat-lentil (W-Lent). We found that, the WUE of flax and lentil averaged 50% and 64%, respectively, of wheat following wheat. The precipitation required per unit of produce from the complete cropping system (PUE) increased with cropping intensity on a yield basis (kg ha-1 mm-1): Cont W (4.8) > W-Lent (4.2) > F-W-W (4.1) > F-Flx-W (2.9) (opposite response to WUE) and when PUE was calculated on a dollars produced per rotation basis ($ ha-1 mm-1): W-Lent (1.0) was higher than the other two rotations (0.6 to 0.7).

Introduction:
Available water is the most limiting factor influencing crop production in the semiarid prairie.

Grain yields vary widely from year to year in response to the level of nutrients and available water (Campbell et al. (1997).

Reliable estimates of how management affects annual water use (WU), water use efficiency (WUE) and precipitation use efficiency (PUE) leads to improve management of crops

Objectives:
To compare and contrast WUE and PUE of a pulse and oilseed crop with wheat, and to explain any differences in terms of water distribution in the soil by the crops.

Materials and Methods:
We used the results of a 21-year experiment, conducted in the Brown soil zone at Swift Current, SK, to determine the influence of crop type on WUE and PUE.

Four crop rotations were compared:

- -Fallow-wheat-wheat (F-W-W),
- -F-flax-W (F-Flx-W),
- -Continuous wheat (Cont W) and
- -Wheat-lentil (W-Lent).

All rotations and crops received N and P fertilizer based on soil tests.

We used water measured in consecutive 0.3-m depth segments to 1.2 m in the soil, taken just prior to seeding and after harvest, and precipitation from seeding to harvest.

Tillage on summer fallow was performed two to five times with a heavy-duty cultivator and/or rodweeder.

All plots were soil sampled in early spring prior to seeding and after harvest each year from 1985 to 2005. Samples were taken with a Giddings soil corer (two cores per plot were bulked) from the 0- to 0.15- , 0.15- to 0.3- , 0.3- to 0.6- , 0.6- to 0.9- , and 0.9- to 1.2- m depths.

Precipitation and other weather parameters were measured at a meteorological site located 1 km west of the experimental site.

The amount of soil water used (WU) was calculated as the difference between spring soil water (0- to 1.2- m depth) and soil water measured soon after harvest of each crop, plus growing season precipitation.

Water use efficiency (WUE) = grain yield) WU.

Precipitation use efficiency (PUE) was calculated as grain yield of all crops in the rotation divided by the amount of precipitation received during the period from harvest of the previous crop to harvest of the crop in question(Campbell et al.1987; Nielsen et al. 2005).

Soil moisture in each 0.3 m depth and in the 0- to 1.2- m depth were analysed at seeding and at harvest, using a split plot design with year as main plot and treatment as sub-plot: (a) for crops grown on fallow, and (b) for crops grown on stubble. Similar analyses were performed on WU and on WUE.

Means and standard deviations were calculated for each rotation based on analyses for each year for PUE and PUE$. All data were analysed using the GLM of SAS (SAS Institute, Inc. 1985).

The least significant difference (LSD, $P<0.05$), for the factorial analysis of year(y), treatment (t) and y x t interaction, were calculated as outlined by Little and Hills (1978).

Results and Discussion:

Soil Water Distribution

Soil water in the profile was 14 mm greater following flax harvest than following wheat harvest (mostly located in 0.6- to 1.2- m depth), because flax produces less biomass and has shorter roots than wheat (Table 1a).

At harvest, wheat dried the soil to near the wilting point(154 mm), but flax and lentil left about 10 mm of available water in the profile (mostly in the 0.6- to 1.2- m depth), suggesting shallower rooting depths.

Over the 9-mo winter period about 58 mm of water was stored in the soil after wheat and 41 mm after flax. Wheat stubble conserved more overwinter water than flax because of its taller height and more dense stubble (Table 1b).

Lentil, with its much shorter stubble, conserved about 7 mm less water than wheat during winter.

About 11 mm more water was conserved during the 21-mo summer fallow period following wheat than after flax, and most of this difference in water was located in the 0.3- to 0.9-m depth (Table 1c).

Water Use and Water Use Efficiency

Lentil used as much water as wheat even though its biomass was much less. WUE for wheat grown on fallow averaged 8.11 kg ha -1 mm -1, and for wheat grown on stubble 6.9 kg ha -1 mm -1 (Figure 1).

WUE for wheat was also higher when it followed flax than when it followed wheat. The WUE of flax and lentil averaged 50% and 64%, respectively, of wheat following wheat.

Precipitation Use Efficiency (PUE)

The PUE increased with cropping intensity on a yield basis (kg ha-1 mm-1): Cont W (4.8) > W-Lent (4.2) > F-W-W (4.1) > F-Flx-W (2.9) (opposite response to WUE). When PUE was calculated on dollars produced per rotation basis ($ ha-1 mm-1): W-Lent (1.0) was higher than the other three rotations (0.6 to 0.7) (Table 2).

Conclusions:

WUE, as assessed through PUE on a dollar of production basis, increased with decreasing use of summer fallow and was greater for rotations that included pulse crops like lentil, or oilseeds like flax, than when monoculture wheat was used.

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Table 1a. Soil Water Distribution at seeding and harvest in crops grown on fallow (values[z] averaged over years)

	Spring				Harvest			
Depth (m)	F-(W)-W	F-(Flx)-W	Signif. Of F[y]	LSD (P<0.05) treat	F-(W)-W	F-(Flx)-W	Signif. Of F[y]	LSD (P<0.05) treat
0.0 - 0.3	71.0	71.1	y***		40.7	41.6	y***, y X t***	
0.3 - 0.6	72.0	66.2	y***, t***	2.9	34.1	35.7	y***,t*,y X t**	1.5
0.6 - 0.9	56.3	52.6	y***, t***	2.2	33.2	38.6	y***,t***,y X t**	1.6
0.9 - 1.2	54.9	53.6	y***		42.4	48.2	y**, t***	2.2
0.0 - 1.2	254.2	243.5	y***, t***	5.6	150.4	164.1	y***,t***,y X t**	4.1

[z] In this and subsequent tables and figures the values shown represent the rotation phases in parentheses.
[Y] In this and subsequent tables y = years and t = treatments. *, **, and *** denote significance at P < 0.05, P < 0.01 and P < 0.001, respectively.

Table 1b. Soil Water Distribution at seeding and harvest in crops grown on stubble (values[z] averaged over years)

Depth (m)	F-W-(W)	F-Flx-(W)	Cont. W	(W)-Lent	W-(Lent)	Signif. Of F[y]	LSD (P<0.05) treat
Spring							
0.0 - 0.3	68.0	64.5	71.1	64.5	72.5	y***,t***,y X t**	2.1
0.3 - 0.6	54.6	49.0	52.7	50.1	54.5	y***,t**	4.0
0.6 - 0.9	39.2	42.2	38.7	40.1	37.6	y***,t***,y X t**	2.2
0.9 - 1.2	46.3	49.3	45.3	45.8	42.8	y***,t***,y X t***	2.5
0.0 - 1.2	208.1	205.0	207.8	200.5	207.4	y***	7.6
Harvest							
0.0 - 0.3	41.7	39.8	43.2	41.7	40.2	y***,t***,y X t***	1.3
0.3 - 0.6	34.8	32.5	36.3	33.8	35.5	y***,t***,y X t**	1.7
0.6 - 0.9	38.6	32.7	34.7	33.1	37.6	y***,t***,y X t***	1.4
0.9 - 1.2	41.0	40.8	41.5	41.0	46.3	y***,t***,y X t***	1.9
0.0 - 1.2	151.1	145.8	155.7	149.6	159.6	y***,t***,y X t***	3.9

Table 1c. Soil Water Distribution at seeding on fallow (values^{z} averaged over years)

Depth(m)	(F)-W-W	(F)-Flx-W	Signif. Of F^{y}	LSD (P<0.05) treat
0.0 - 0.3	67.8	66.3	y***	
0.3 - 0.6	53.0	48.6	y***, t**	2.8
0.6 - 0.9	39.0	37.9	y***	
0.9 - 1.2	44.8	43.6	y*	
0.0 - 1.2	204.6	196.4	y***, t***, y X t*	5.0

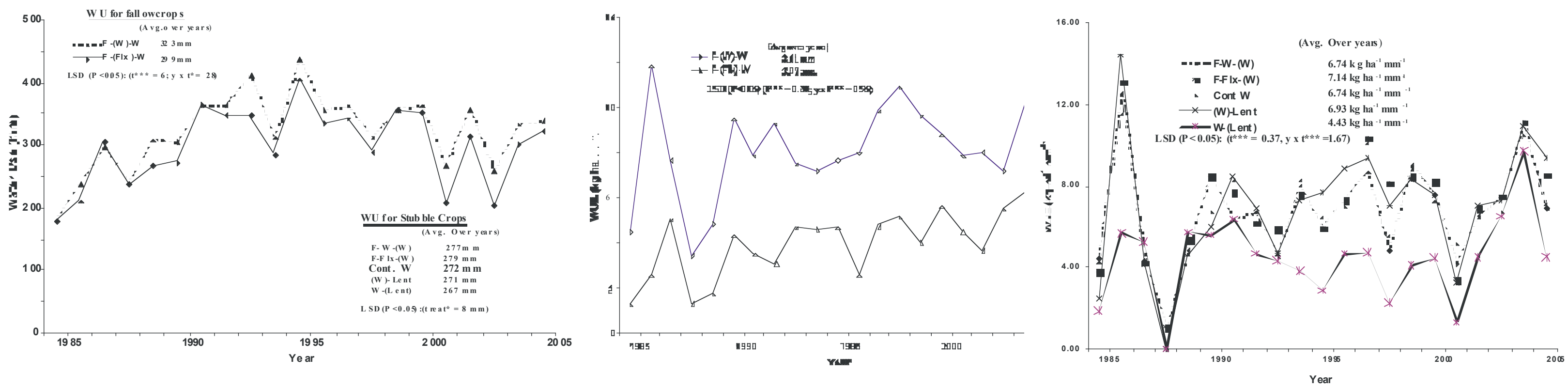

Figure 1.(A.) Water use from seeding to harvest for spring wheat vs. Flax in F-Crops-Crops rotations. (B.) WUE for spring wheat vs. Flax in F-Crop-Crop rotations. (C.)Water use efficiency for crops grown on stubble.

Table 3. Precipitation use efficiency (PUE) based on grain yield and dollars produced per rotation

Rotation	F-W-W	W-Lent	Cont W	F-W-W	W-Lent	Cont W
	-------------------kg ha^{-1} mm^{-1}-----------------			----------------------$ ha^{-1} mm^{-1}------------------------		
84-85			2.4			0.4
84-86		2.2			0.6	
84-87	3.9			0.6		
85-86			6.4			1.0
85-87		5.2			1.2	
85-88	2.7			0.4		
86-87			3.3			0.5
86-88*						
86-89	2.4			0.4		
87-88			0.0			0.0
87-89		2.7			0.9	
87-90	3.6			0.6		
88-89			4.0			0.6
88-90		3.6			0.9	
88-91	4.1			0.6		
89-90			4.2			0.7
89-91		4.2			1.1	
89-92	3.9			0.6		
90-91			6.2			1.0
90-92		5.0			1.1	
90-93	3.9			0.6		
91-92			5.5			0.9
91-93		4.2			1.0	
91-94	4.9			0.8		
92-93			3.2			0.5
92-94		3.4			0.8	
92-95	3.5			0.6		
93-94			6.2			1.0
93-95		4.0			0.9	
93-96	5.0			0.8		
94-95			4.8			0.7
94-96		4.6			1.0	
94-97	4.3			0.7		
95-96			6.0			0.9
95-97		4.7			1.0	
95-98	4.1			0.6		
96-97			6.3			1.0
96-98		4.8			0.9	
96-99	5.1			0.8		
97-98			4.2			0.7
97-99		3.8			0.9	
97-00	5.2			0.8		
98-99			6.3			1.0
98-00		4.8			1.1	
98-01	3.6			0.6		
99-00			5.5			0.9
99-01		3.7			0.6	
99-02	4.2			0.7		
00-01			3.6			0.6
00-02		3.0			0.9	
00-03	4.5			0.7		
01-02			4.5			0.7
01-03		5.5			1.2	
01-04	4.0			0.6		
02-03			5.2			0.8
02-04		6.2			1.7	
02-05	5.4			0.8		
Mean	**4.1**	**4.2**	**4.6**	**0.6**	**1.0**	**0.7**
SD	**0.8**	**1.1**	**1.7**	**0.1**	**0.2**	**0.3**

*** no yield under stubble crop due to drought in 1988**