Irrigation Scheduling of Pulse Crops

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INTRODUCTION

Fababean (*Vicia faba* L.), pea (*Pisum sativum* L.) and lentil (*Lens culinaris* Medik) are annual grain legumes, otherwise known as pulse crops. Pulse crops fix part of their own nitrogen supply, act as break crops in cereal rotations and provide a foodstuff high in protein. These crops respond to additional water application and seem well suited to irrigated production. Expansion of production of pulses in the irrigated areas of Saskatchewan has been limited by agronomic problems leading to yield fluctuation and economic uncertainty.

Irrigation scheduling is an important area of irrigated crop management. The aim of the irrigator is to obtain maximum yield of marketable product from a given quantity of applied water. It is important for the grower to recognize critical growth stages when maximum yield response to irrigation will occur.

Annual legumes have moisture sensitive stages and will respond in terms of yield and quality to irrigation (Salter and Goode 1967). The critical problem is to decide when to irrigate to prevent water stress induced yield reductions. Studies of moisture sensitive stages of annual legumes have indicated differential responses to soil moisture conditions depending on whether seed yield or vegetative growth is the criterion of plant response (Salter 1962 ; Jones 1963). Generally, it is agreed that leguminous crops are particularly sensitive to moisture stress during flower and pod development (Salter and Goode 1967).

There is limited data on irrigation scheduling of pulse crops in Western Canada and Saskatchewan in particular. With this in mind, the following study was undertaken to evaluate the response of pulse crops to irrigation at critcal growth stages.

MATERIALS AND METHODS

This study was conducted at the Saskatchewan Irrigation Development Centre at Outlook, Saskatchewan in 1982, 1983 and 1990.

The soil was a Bradwell vfsL developed on sandy glacial lacustrine deposits. These soils are well drained and are classified as Class I soils for irrigation (Canada Department of Agriculture 1964). Soil samples representative of the study area were taken prior to plot establishment each year (Table 1).

A randomized complete block design was used for each crop. The crops and varieties used each year were as follows : Fababean-Outlook 1982 and 1983, Aladin 1990 ; Pea-Tara 1982 and 1983, Express 1990 ; Lentil-Eston. Five water treatments were replicated four times (Table 2). The plots were seeded in mid-May each year. All crops were inoculated prior to seeding and additional phosphorus fertilizer was seed placed to ensure adequate phosphate levels were available. Weed control was adequate using recommended herbicides supplemented by hand weeding.

The experiment was conducted using flood basins. In 1982 and 1983 each plot was seeded separately with small dykes around the outside edges to contain the applied water. In 1990, the entire area for each crop was seeded and then plots were delineated with the use of steel border strips.

Soil moisture content was measured in each plot each year to a depth of 120 cm using a neutron probe. The 0-15 cm depth was done gravimetrically. Soil moisture measurements were taken at seeding, harvest and various intervals during the growing season.

The actual scheduling of irrigations was determined with tensiometers. Irrigation water was applied when 50% of the available water was depleted. Enough water was applied to fill the soil profile to field capacity to a depth of 120 cm.

Yield samples were collected from each treatment. Grain samples were cleaned and weighed and a sub-sample submitted for nitrogen analysis. Protein was calculated using the factors of 5.03 for fababean, 5.25 for pea and 4.91 for lentil (Sosulski and Holt 1980). In 1990, measurements were obtained of seed size and other plant growth characteristics.

RESULTS

I. Yield

Table 3 shows the effect of witholding irrigation on the yield of the three pulse crops for each of three years. In 1982, results were too variable to detect differences in yield for pea and lentil, while the fababean dryland treatment was significantly lower yielding than all other treatments. In general, yield levels for all three crops were relatively low in 1983. This indicates that prolonged hot dry weather reduced the yield potential of these cool season grain legumes. As expected, in both 1983 and 1990, dryland treatments were significantly lower yielding than all full irrigation treatments for all three crops. Treatment yield can be explained in terms of the timing of irrigation and rainfall in relation to the stage of crop development and the growth habit of the individual crops (Table 3).

Fababean

For fababean, treatment D was significantly higher yielding compared to treatments A, B, and C in 1983 and A and C in 1990 (Table 3). This indicates that fababean is sensitive to moisture stress at all stages. Additional 1990 data show the effect of irrigation on the components of yield, seed weight and the number of seeds per square meter (Table 4). Treatments B and D had similar effect on yield, number of seeds and seed weight. For treatment B, water was witheld on June 28 (Table 3). Between June 28 and July 2, precipitation of almost 50 mm was recorded. Treatment B, therefore, was not effective as a limitation to yield and should be considered equivalent to treatment D.

Treatments A and C, however were significantly lower yielding than both treatments B and D but for different reasons. Treatment A caused significantly lower numbers of seeds per square meter compared to treatment D but no difference in seed size. Treatment C resulted in a large reduction in seed number per square meter(significantly less than even treatment A). Yield compensation for treatment C occurred in the form of significantly larger seed size compared to all treatments except dryland.

Treatment C coincided with late bloom/early pod fill. Stress during this growth stage reduced the number of seeds by causing flower or young pod abortion. Resumption of irrigation and late July rainfall allowed seeds of treatment C and the dryland treatment to reach full potential seed weight. The yield limitation of treatment A (vegetative growth stage) may have been caused by a reduction in the number of fertile early flowers or restriction of branching from basal nodes.

Pea

Relative to fababean, pea showed less sensitivity to moisture stress. Treatment C alone resulted in significantly lower yield than the fully irrigated treatment in both 1983 and 1990 (Table 3). The timing of this treatment coincided with very late bloom / mid pod fill in 1990. Moisture stress at this stage caused a significant reduction in the number of seeds per square meter compared to treatment A. This indicates shortening of the effective flowering period (Table 4). Although seed size was not different for treatment C compared to D, it was significantly reduced compared to treatment B. The pea crop required a shorter season than the fababean crop. Therefore, unlike fababean, the pea crop was unable to benefit from late July rainfall and was unable to compensate for flower abortion by producing larger seeds.

Stress at early to mid-flowering in 1990 (treatment B) resulted in significantly larger seed weight but no reduction in seed number or yield (Table 4). This treatment received late June and early July rainfall and was therefore ineffective in causing moisture stress. The larger seed size does indicate that flowering ended relatively early, like treatment C. Unlike fababean, the dryland pea treatment received no benefit from late July rainfall and showed no yield compensation in the form of larger seeds.

Lentil

Lentil yield was less sensitive to moisture stress compared to fababean and pea. In all three years, treatment A yielded as high as or higher than all other irrigation treatments (Table 3). Witholding irrigation throughout the entire vegetative stage had no detrimental effect on yield potential.

In 1983, treatments D and C were equivalent because only two irrigations were applied during the entire growing season (Table 3). Moisture stress during mid pod-fill (treatment B in 1983) caused a significant reduction in yield compared to all other irrigation treatments. In 1990, treatment C corresponded with mid pod-fill but resulted in no yield reduction. In 1990, late July rainfall was adequate for maintaining yield potential. Treatments C and D, which were the same in 1983, were significantly lower yielding than treatment A. It was observed, however, that the lentil canopy for these two treatments was 25-30% taller than that of treatment A. This may be an indication of excess vegetative growth. A taller denser canopy can lead to yield reduction through foliar disease buildup. In 1983, however, the yield reduction in the fully irrigated treatments was more likely due to rapid cutoff of the growing season. Extremely high temperatures occurred during the first two weeks of August. This would limit yield potential in mid to late pod fill.

There was some evidence of yield compensation in 1990 for treatment B (similar to the pattern for pea). Treatment D had significantly higher seed number per square meter compared to treatment B, but had significantly reduced seed weight. There is some evidence, therefore, that treatment D caused a prolongation of flowering and pod fill in 1990.

II. Total Water Use

Table 5 shows the total water use for the three pulse crops for each of the three years. The maximum daily water use is shown for the fully irrigated treatment (treatment D). Total water use was directly related to the amount of water applied for all three crops.

Fababean

Fababean is a long-season crop which has an indeterminate growth habit resulting in high water use late into the growing season. As a result, fababean is a high water use crop. This is clearly evident from the results for this study where total water use for the fully irrigated treatment was in excess of 600 mm in 1982 and 1983 and 574 mm in 1990.

In 1983 a high evaporative demand due to extreme heat in August resulted in treatment D requiring an additional water application to prevent moisture stress during pod fill. As a result, treatment D had a much higher water use than the other treatments. As well, the high evaporative demand resulted in a high maximum daily water use. In 1982 and 1990 evaporative demand was lower resulting in reduced maximum daily water use compared to 1983 (Table 5). These results concur with Elston and Bunting (1978) who observed that, in legumes, when water is freely available the rate of evapotranspiration depends upon meteorological conditions.

Total water use was also found to be linearly related to yield (Figure 1). The greater the water use the higher the yield. Similar results were observed in southern Alberta (Krogman et al 1980). Obviously, large amounts of water are required to obtain high fababean yields.

Pea

Pea, a cool season crop with an indeterminate growth habit, is capable of growing for an extended period of time and requires a stress period to terminate growth. Total water use depends on the length of the growing season as well as growing conditions. In 1982, cool moist growing conditions maintained a long period of vegetative growth resulting in a higher total water use than in either 1983 or 1990. The high evaporative demand in August of 1983 resulted in a shorter vegetative growth period and thus lower total water use. In 1990, the variety Express was grown. It matures earlier than Tara, and is much shorter, therefore, its water use is reduced. Maximum daily water use also indicated a higher evaporative demand in 1983 and 1990 than 1982 (Table 5).

Lentil

Lentil, like pea, also has an indeterminate growth habit and requires a stress period to terminate growth. Total water use depends on the availability of water and growing conditions. In 1982 total water use was high with excessive vegetative growth and late maturity a result of the cool moist growing conditions. Total water use in 1983 and 1990 was more in line with the value of 400 mm that has been considered adequate for lentil production in Egypt (El Gibadi and Badawi 1978). In 1983 treatment C and D were identical since they received the same number of irrigations. Irrigation applications were terminated in early August of 1983 and 1990 to prevent the excessive vegetative growth and late maturity experienced in 1982.

III. Seed % Protein

Table 6 shows the effect of withholding irrigation on the protein content of the three pulse crops for each of three years. Moisture level and N-fixation are generally highly correlated leading to increased protein content with increased moisture supply (Sprent 1972).

The opposite effect was observed in most cases in the present study. High NO3-N levels present in the soil at seeding (Table 1) may have had an overriding effect on N-fixation.

Fababean

Fababean protein content did not display a consistent treatment effect. Generally, in 1982 and 1983, the dryland treatment had a significantly higher protein content than the irrigation treatments. In 1990, there was no significant differences. These results are contrary to the results reported by Krogman et al (1980) who observed increasing protein content with increasing moisture supply.

Pea

Pea protein content did not show any significant differences in 1982 and 1990. In 1983 treatments A and D were significantly lower than the other treatments.

Lentil

Lentil protein content did not show any significant differences due to irrigation treatment in 1982 and 1983. In 1990 the dryland treatment was significantly lower in protein than any of the irrigation treatments.

CROP COMPARISONS

The average results for total water use, maximum daily water use, yield and protein content for each crop over the three years of this study are presented in Table 7.

Pea had the highest average yield in all treatments followed in turn closely by fababean, then lentil. The yield of the fully irrigated treatment for fababean was similar to that of pea. Lentil yields were lower in all irrigation treatments than for fababean or pea but were similar to fababean for the dryland treatment. Both pea and lentil produce high relative yield under dryland conditions.

Fababean exhibited the greatest water use in all irrigation treatments. The water use for the fully irrigated treatment for fababean was 615 mm while for pea and lentil the values were similar at 477 and 486 mm respectively. Lentil values may be high due to extended growth and thus higher water use in 1982. The maximum daily water use was highest for fababean at 9.8 mm/day followed in turn by pea at 8.3 mm/day and lentil at 7.7 mm/day.

Fababean produced the highest protein percentage at 22.5 to 24.1% followed by lentil at 21.0 to 21.8% and pea were lowest at 20.5 to 21.2%.

DISCUSSION

Effective irrigation scheduling requires that plant indicators like critical moisture stages be used as a guide to the timing of irrigation, while knowledge of soil moisture storage and movement capability be used as guide to the amount of irrigation. All three pulse crops in this study have an indeterminate growth habit. This means that there is considerable overlap between the flowering and pod filling growth stages. Any moisture stress that reduces the number of seeds produced per square meter has the potential to reduce yield. Maximum yield is achieved by ensuring that the number of seeds per square meter is maximized. For indeterminate grain legumes, this means prolonging flowering. Compensation for potential yield decrease due to moisture stress may occur in the form of increased seed weight. This is possible only if additional moisture stress and disease development do not limit the duration of the pod filling stage once the effective flowering period has ended.

Results from this experiment suggest that the ability to compensate for yield limitation caused by moisture stress can vary depending on the crop. Fababean is a large-seeded, long season crop. Yield limitation due to moisture stress can occur from the mid-vegetative stage to the end of pod fill. Moisture stress until mid-pod fill will reduce the number of seeds per square meter. Compensation for yield can occur (increase seed size) if moisture is not limiting to the end of pod fill. In 1990, treatment C seed weight was 18% greater than the fully irrigated treatment.

For pea, vegetative moisture stress is of less concern. Most pea varieties are more indeterminate than fababean (more possibility for branching). However, moisture stress during mid-flowering and early pod fill can reduce yield by reducing the number of seeds per square meter. Like fababean, stress at this growth stage will cause early termination of flowering. New pea vareties with more determinate growth habit are likely to be even more sensitive to moisture stress at this stage.

In the lentil crop, irrigation during the vegetative stage may actually be detrimental by causing a delay in flowering. The Eston type lentil is short season relative to pea and fababean. Moisture stress at any time beyond mid pod fill may reduce yield by causing a rapid reduction in the number of pods set on secondary and tertiary branches, especially if this coincides with a period of high temperature. Compensation for potential yield loss by increased seed weight may be less important in lentil than in pea and fababean.

The most effective irrigation schedule for each of these three pulse crops is the one that will prolong flowering. A prolonged reproductive period will maximize the overlap between the flowering and pod-filling growth stages.

SUMMARY AND CONCLUSIONS

Fababean, pea and lentil can be grown successfully under irrigation conditions but careful management is required. Fababean will produce large yields provided moisture stress does not develop. Fababean has a high water requirement and production should not be considered unless sufficient moisture is available. Pea can also produce large yields under irrigated conditions with less water than the amount required for fababean. Moisture stress during the flowering-pod fill period has the potential of producing yield reductions. This was clearly evident in 1983. Lentil also responds to irrigated conditions. Irrigation during flowering-pod fill was shown to be a critical period especially during hot, dry, moisture-stress inducing conditions evident in 1983. Irrigation during the vegetative period maybe detrimental to final yield. Irrigation of lentil must be terminated by August 1 to induce a stress period to terminate growth. Where limited water is available, lentil production is feasible provided that moisture stress is prevented during the flowering-pod fill period.

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Table 1. Analysis of soil samples from plot area.

Year	Depth (cm)	pH	1:1 Conductivity (dS/m)	NO3⁻-N	P	K	SO4⁻-S
				---------kg/ha†	-------		
1982	0-15	7.7	0.9	76	26	270	24+
	15-30	7.8	0.9	51			24+
	30-60	7.9	1.1	60			24+
1983	0-15	8.2	0.2	21	25	265	21+
	15-30	8.0	0.7	62			40+
	30-60	8.2	0.8	114			80+
1990	0-15	7.8	0.6	24	45	347	24+
	15-30	7.9	1.3	62			24+
	30-60	8.0	1.7	120			48+

† kg/ha = ppm X 2 for 15 cm depth and ppm X 4 for 30 cm depth.

Table 2. Intended water scheduling treatments.

Water treatment	Timing	Growth stage
A	Missed first irrigation	Vegetative
B	Missed second irrigation	Flowering
C	Missed third irrigation	Late flowering - early pod fill
D	Received all irrigation	
E	Dryland	

Table 3. Mean yield of fababean, pea and lentil in response to irrigation treatments for experiments conducted for three years at Outlook, Saskatchewan

	Crop and year								
	Fababean			Pea			Lentil		
Water treatment †	1982	1983	1990	1982	1983	1990	1982	1983	1990
	Yield ‡ (kg/ha)								
A	4936 a	2712 b	4299 b	4270	3702 a	4578 a	2516	2860 a	3652 a
B	4078 a	2801 b	4702 a	4947	3346 ab	4536 a	2309	2150 c	3391 a
C	4444 a	2391 b	4302 b	5103	3125 bc	3910 b	2385	2462 b	3505 a
D	4705 a	3560 a	4696 a	4864	3535 a	4545 a	2753	2544 b	3620 a
E	2627 b	1406 c	2155 c	5275	2822 c	2702 c	1989	2081 c	2071 b
LSD (0.05)	910	568	295	NS#	377	485	NS	293	430
	Date of withheld irrigation								
A	Jul 15	Jun 23§	Jun 15	Jul 5	Jun 23	Jun 15	Jul 1	Jun 17	Jun 15
B	Jul 26	Jul 19§	Jun 28	Jul 24	Jul 18	Jun 28	Jul 23	Jul 18	Jun 28
C	Aug 18	Jul 29§	Jul 17	Aug 6	Jul 29	Jul 17	Aug 5	none	Jul 17
D	none	none	none	none	none	none	none	none	none
E	all	all	all	all	all	all	all	all	all
Total number of possible irrigations	4	5	4	3	3	3	4	2	3

† Irrigation treatments as follows: A - first irrigation missed; B - second irrigation missed; C - third irrigation missed; D - no irrigation missed; E - dryland.

‡ Yield values within columns followed by the same letter are not significantly different at P = 0.05

§ Treatments A, B, and C did not receive a fifth irrigation

NS-not significant

Table 4. Effect of irrigation on yield, number of seeds per square meter and seed weight for fababean pea and lentil grown at Outlook, Saskatchewan in 1990

	Crop‡								
	Fababean			Pea			Lentil		
Water treatment†	Yield (kg/ha)	Seeds/m^2	Seed weight (mg)	Yield (kg/ha)	Seeds/m^2	Seed weight (mg)	Yield (kg/ha)	Seeds/m2	Seed weight (mg)
A	4299 b	1220 b	353 b	4578 a	1822 a	251 b	3652 a	10787 ab	34 a
B	4702 a	1295 ba	363 b	4536 a	1680 ab	271 a	3391 a	9771 b	35 a
C	4302 b	1026 c	421 a	3910 b	1600 b	245 bc	3505 a	10235 ab	35 a
D	4696 a	1387 a	340 b	4545 a	1786 ab	255 b	3620 a	11446 a	32 b
E	2155 c	514 d	408 a	2702 c	1134 c	238 c	2071 b	5879 c	36 a
LSD (0.05)	295	97	27	485	200	15	430	1300	2

†Irrigation treatments as follows: A - first irrigation missed; B - second irrigation missed; C - third irrigation missed; D - no irrigation missed; E - dryland.

‡Values within columns followed by the same letter are not significantly different at P = 0.05

Table 5. Total water use of fababean, pea and lentil for the irrigation scheduling experiment conducted for three years at Outlook, Saskatchewan

	Crop and year								
	Fababean			Pea			Lentil		
Water treatment†	1982	1983	1990	1982	1983	1990	1982	1983	1990
	Total Water Use (mm)								
A	541	468	491	453	364	393	555	270	408
B	533	467	495	454	358	384	534	281	401
C	550	468	499	479	360	392	552	355	404
D	630 (8.0)‡	642 (12.7)	574 (8.7)	541 (7.7)	433 (8.5)	456 (8.7)	614 (7.3)	367 (7.3)	478 (8.4)
E	353	223	259	374	226	239	399	194	248
	Date of witheld irrigation								
A	Jul 15	Jun 23§	Jun 15	Jul 5	Jun 23	Jun 15	Jul 1	Jun 17	Jun 15
B	Jul 26	Jul 19§	Jun 28	Jul 24	Jul 18	Jun 28	Jul 23	Jul 18	Jun 28
C	Aug 18	Jul 29§	Jul 17	Aug 6	Jul 29	Jul 17	Aug 5	none	Jul 17
D	none	none	none	none	none	none	none	none	none
E	all	all	all	all	all	all	all	all	all
Total number of possible irrigations	4	5	4	3	3	3	4	2	3

†Irrigation treatments as follows: A-first irrigation missed; B-second irrigation missed; C-third irrigation missed; D-no irrigation missed; E-dryland.

‡Maximum daily water use-mm/day

§Treatments A, B, and C did not receive a fifth irrigation

Table 6. Mean seed % protein of fababean, pea and lentil in response to irrigation treatments for experiments conducted for three years at Outlook, Saskatchewan

	Crop and year								
	Fababean			Pea			Lentil		
Water treatment†	1982	1983	1990	1982	1983	1990	1982	1983	1990
	% Protein ‡								
A	21.1 b	22.3 b	24.1	20.2	20.3 b	21.2	22.8	19.4	21.8 a
B	22.4 b	22.1 b	24.2	21.6	20.9 a	21.0	22.7	20.5	21.5 a
C	20.2 d	22.6 b	24.8	21.0	21.7 a	19.5	22.8	20.6	21.6 a
D	20.5 cd	22.8 b	24.6	20.8	20.3 b	20.6	22.7	20.7	22.1 a
E	21.6 ab	24.8 a	25.7	21.3	21.4 a	20.9	22.3	20.2	20.4 b
LSD (0.05)	0.8	0.8	NS#	NS	0.9	NS	NS	NS	1.0
	Date of withheld irrigation								
A	Jul 15	Jun 23§	Jun 15	Jul 5	Jun 23	Jun 15	Jul 1	Jun 17	Jun 15
B	Jul 26	Jul 19§	Jun 28	Jul 24	Jul 18	Jun 28	Jul 23	Jul 18	Jun 28
C	Aug 18	Jul 29§	Jul 17	Aug 6	Jul 29	Jul 17	Aug 5	none	Jul 17
D	none	none	none	none	none	none	none	none	none
E	all	all	all	all	all	all	all	all	all
Total number of possible irrigations	4	5	4	3	3	3	4	2	3

† Irrigation treatments as follows: A - first irrigation missed; B - second irrigation missed; C - third irrigation missed; D - no irrigation missed; E - dryland.

‡ % protein values within columns followed by the same letter are not significantly different at P = 0.05

NS-not significant

§ Treatments A, B, and C did not receive a fifth irrigation

Table 7. Three year average total water use maximum, daily ET, seed yield and seed % protein for the pulse crop irrigation scheduling experiment.

Crop	Water treatment	Total water use (mm)	Max. daily ET (mm/day)	Seed yield (kg/ha)	Seed protein %
Fababean	A	500		3982	22.5
	B	498		3860	22.9
	C	506		3712	22.5
	D	615	9.8	4320	22.6
	E	278		2063	24.1
Pea	A	403		4183	20.6
	B	399		4276	21.2
	C	410		4046	20.7
	D	477	8.3	4315	20.5
	E	281		3600	21.2
Lentil	A	411		3009	21.3
	B	405		2617	21.5
	C	437		2784	21.7
	D	486	7.7	2972	21.8
	E	280		2047	21.0

Figure 1. Relationship between fababean yield and total water use