RESPONSE OF IRRIGATED CROPS TO SPLIT-N APPLICATION

G.D.W. Swerhone, C. van Kessel and N.J. Livingston
Department of Soil Science, University of Saskatchewan, Saskatoon

Abstract

The efficiency and benefits of split N applications by cereals and oilseed was evaluated at the Irrigation Farm at Outlook. In 1988, canola (Westar) received 0, 75 + 75, or 150 kg N/ha in the form of urea (U) or urea-ammonium nitrate (UAN). In 1989, durum (Kyle), soft wheat (Fielder) and canola (Westar) received 0, 100, 100+100, or 200 kg N/ha in the form of U or ammonium nitrate (AN). Plants were harvest five times during the growing season. In 1988, the second N application occurred at 54 days after planting. In 1989, the second N application for durum and soft wheat occurred at 45 days after planting (Feekes 7) and 38 days after planting for canola.

In 1988, unfertilized canola showed a grain yield of 1832 kg/ha, whereas the application of 150 kg N increased grain yield to 3012 kg/ha. Split-N application, however, did not increase grain yield as compared with canola fertilized with 150 kg N/ha at time of seeding. No significant differences in grain yield between U and UAN fertilized canola were found.

In 1989 canola, durum and soft wheat responded strongly to N fertilizer. Unfertilized durum showed a grain yield of 2267 kg/ha, whereas durum fertilized with 200 kg N/ha showed a grain yield of 3952 kg/ha. Grain yields for unfertilized and fertilized soft wheat were 2981 and 5358 kg/ha, respectively. N fertilization increased grain yield of canola from 1049 to 1890 kg/ha. However, no differences in grain yield were found between crops that received all fertilizer-N at time of seeding and crops that received half of its fertilizer-N 38 days after planting.

It was found that most of the N required for crop growth was taken up early in the growing season. It appears that N should be available soon after seeding and that under Saskatchewan growing conditions the time frame during which the second split N application can be carried out successfully is short or, perhaps, even non-existent.

Introduction

Irrigation not only increases crop yields in dry areas but also provides the means to apply N fertilizers at various times during the growing season. While several researchers have shown that split N applications increase yields (Bigeriego et al., 1979), others have not found such a beneficial effect or have obtained results that were not conclusive enough to derive definitive recommendations (Deibert et al., 1979; Russelle et al., 1981). Nevertheless it is generally accepted that fertilizer use efficiency of split N applications is higher than that obtained when all the N is applied at the time of seeding (Bigeriego et al., 1979; Deibert et al., 1979; Russelle et al., 1981, 1983) and that it is economically beneficial to supply the plant with additional N-fertilizer during the growing season. Split N application should be timed to coincide with the period when a crop has its highest N demand. For example, in wheat additional N fertilizer should be applied at the 'boot' stage (Spratt, 1974). While N applications enhance vegetative plant growth at early stages (Bigeriego et al., 1979), this does not necessarily translate into higher seed yield. Increased vegetative growth can have significant effects on the partitioning of water use between soil evaporation and transpiration and consequently on water use efficiency (Siddique and

Sedgley, 1987). Irrigation scheduling in turn may be effected as well as the amount of N lost through leaching.

In Saskatchewan, farmers with access to irrigation apply all the fertilizer-N for cereals and oilseed crops at time of seeding. The highest N uptake per day for cereals and oilseed, however, occurs when the seedling has established itself and has formed an extensive root system. Although at present time it is largely unknown at what stage of plant development the maximum N uptake under Saskatchewan conditions occurs, it is likely the maximum N uptake will not occur within four weeks after seeding.

Applying fertilizer-N at a later stage during the growing season may have various advantages. Application the fertilizer-N at time of the highest N demand for the crop will reduce N losses caused by leaching, as a more extensive root system has developed which enables to assimilate fertilizer-N at a higher rate. This in turn would increase the fertilizer use efficiency. Furthermore, if the amount of available N after four weeks became insufficient to support optimum growth, the second application of N will increase the available soil-N pool which in turn would increase plant growth. The disadvantage will be the extra labour involved.

Materials and Methods

In a two year experiment, 1988 and 1989, canola (Westar) and in one year experiment durum (Kyle) and soft wheat (Fielder) were grown under irrigation at the Outlook Irrigation Centre, Saskatchewan. In 1988 canola received 0 N, 75 kg N/ha of urea at planting and 75 kg N/ha of urea at 54 days after planting (DAP), 75 kg N/ha of urea at planting and 75 kg N/ha of urea at 54 days after planting (DAP), 75 kg N/ha of UAN at planting and 75 kg N/ha of UAN at 54 days after planting (DAP), 75 kg N/ha of UAN at planting and 75 kg N/ha of UAN at 54 days after planting (DAP), 150 kg N/ha of urea at time of seeding, or 150 kg N/ha of UAN at time of seeding. In 1989 canola received 0, 100 kg N U at time of seeding, 100 kg N U at time of seeding, plus 100 kg N-U at 38 DAP, or 200 kg N U at time of seeding. Soft wheat received similar amounts of U but the second application occurred 45 DAP (Feekes 4-5 growth stage). Durum received similar amounts of N but in the form of AN and the second split of N also occurred at 45 DAP. The experiment was laid out as a randomized complete split plot design with crop as the main plot treatment and fertilizer rate as the split plot treatment. Irrigation water was applied through drip lines, spaced at 0.5 m. Crops were harvested five times during the growing season (Table 1). Dimensions of individual harvest plots measured 3.0 by 2.0 m. The second application of fertilizer-N was carried out through the drip lines.

After harvest, plants were dried at 60°C until constant weight, weighed and analyzed for total N, including NO_3^- and NO_2^- (Bremner and Mulvaney, 1982). If necessary, plants were dried, weighed and threshed, and seed and straw analyzed for total N.

Results and Discussion

The application of N increased total yield of unfertilized canola (Westar) in 1988 of 6652 kg/ha to a maximum of 9651 kg/ha (Table 2). Grain yield at final harvest was increased by N fertilization from a low of 1832 kg/ha to the maximum of 3012 kg/ha observed after the application of 150 kg N/ha split between time of seeding and 54 DAP. However, the differences were not significantly different at the 5% probability level. The

Table 1. Seeding and harvest data of various crops grown in 1988 and 1989.

Crop	N applied kg/ha	Form of N†	Seeding date	Days after planting: Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5
			1988					
Canola (Westar)	0		May 13	41	54	61	88	105
Canola (Westar)	75*+75	U	May 13	41	54	61	88	105
Canola (Westar)	75+75*	U	May 13	41	54	61	88	105
Canola (Westar)	75*+75	UAN	May 13	41	54	61	88	105
Canola (Westar)	75+75*	UAN	May 13	41	54	61	88	105
Canola (Westar)	150*	U	May 13	41	54	61	88	105
Canola (Westar)	150*	UAN	May 13	41	54	61	88	105
			1989					
Durum	0		May 9	42	53	62	79	106
Durum	100*	AN	May 9	42	53	62	79	112
Durum	100+100*	AN	May 9	42	53	62	79	112
Durum	200*	AN	May 9	42	53	62	79	112
Soft wheat	0		May 9	42	53	62	79	97
Soft wheat	100*	U	May 9	42	53	62	79	106
Soft wheat	100+100*	U	May 9	42	53	62	79	106
Soft wheat	200*		May 9	42	53	62	79	106
Canola (Westar)	0		May 30	32	41	50	71	91
Canola (Westar)	100*	U	May 30	32	41	50	71	91
Canola (Westar)	100+100*	U	May 30	32	41	50	71	91
Canola (Westar)	200*	U	May 30	32	41	50	71	91

* ^{15}N labelled fertilizer

† AN = ammonium nitrate; U = urea

Table 2. Total dry matter and grain yield of canola (Westar) as affected by N application at Outlook, 1988

N applied (kg/ha)	Total weight (kg/ha)					Grain weight (kg/ha)	
	Days after planting						
	41	54	61	88	105	88	105
0	1432	4080	4704	7406	6652	1752	1832
75* + 75 urea	1690	4285	4853	8443	8407	2374	2641
75 + 75* urea	1532	4478	4559	10354	9028	2558	2852
75* + 75 UAN	1678	4575	5108	10842	9143	2736	2789
75 + 75* UAN	1591	4809	4899	8810	9651	2229	3012
150* urea	1363	4397	4762	9284	9127	2054	2763
150 UAN	1544	4779	5193	9191	9698	2491	2854
LSD (P <0.05)	NS	NS	NS	NS	NS	NS	NS
CV (%)	22	15	15	16	23	28	22

* Indicates labelled ^{15}N

form of N-fertilizer applied, i.e. urea or a mixture of 50% ammonium nitrate and 50% urea, showed no effect on total yield and grain yield. Time of N-fertilizer application, i.e. 100% at time of seeding or 50% at time of seeding and 50% during the growing season, appeared to have no effect on yield.

In 1989, N application increased total yield of Westar canola (Table 3). Total grain weight increased at 71 DAP after the application of 100 or 200 kg N/ha but at final harvest the increase became non-significant. Applying 50% of the N-fertilizer at time of seeding and 50% at 38 DAP did not increase total yield and grain yield.

Similar results were found for durum and soft wheat where N fertilizer significantly increased total yield and grain yield but the application of 50% of the N-fertilizer at time of seeding and 50% at 45 DAP (Feekes 4-5) did not increase total yield and grain yield (Table 4).

Total N accumulation in canola in 1988 was affected by N application at 61 and 88 DAP but the increase became non-significant at final harvest (Table 5). Overall, the increase in total N was independent of the form of N fertilizer applied or applying all the N at time of seeding or split in two equal portions at time of seeding and during the growing season. In 1989 the total N accumulation in canola was increased by 100 kg N/ha and further increased after the application of an additional 100 kg N/ha (Table 6). Only at final harvest canola fertilized with 200 kg N/ha at time of seeding or split equally at time of seeding and at 38 DAP showed significantly higher total N accumulation as compared with canola fertilized with 100 kg N/ha at time of seeding.

Table 3. Nitrogen fertilizer recovery in soil and plant (Westar) at Outlook, 1988.

Urea-N applied (kg/ha)	Total weight (kg/ha)					Grain weight (kg/ha)	
	Days after Planting						
	32	41	50	71	91	71	91
0	203	982	1576	4327	755	3521	1049
100*	352	1725	2996	6543	1333	5070	1546
100+100*	355	1466	2858	6697	1024	6648	1746
200*	396	1944	3445	6097	1209	6573	1890
LSD (P <0.05)	NS	430	1091	1399	340	1972	NS
CV (%)	30	18	25	15	20	23	31

* Indicates labelled ^{15}N fertilizer

Similar results were found for soft wheat and durum and the application of 100 kg N-fertilizer/ha increased total N accumulation (Table 7). An additional 100 kg N-fertilizer/ha further increased total N accumulation although not significantly above the total N accumulation of soft wheat and durum fertilized with 100 kg N/ha. Applying N-fertilizer in a split application mode did not alter the amount of N accumulated in both cereals tested.

The second application of N-fertilizer should be carried out before the highest crop demand for N occurs. Nitrogen accumulation occurs earlier as total dry matter accumulation. This is particularly apparent for canola (Westar) (Fig. 1). Although in 1988 canola accumulated 16% of the maximum dry matter at 41 DAP, it accumulated already 57% of its total N. In 1989, a somewhat similar early N accumulation occurred for canola (Westar) and where at 34 DAP Westar had accumulated 22% of its total N but only 6% of its total dry matter. This makes for a narrow time frame during which a split-N application can be carried out. Somewhat similar early N accumulation occurred for durum and soft wheat (Fig. 2). At 42 DAP durum had accumulated 24% of its total N but only 7% of its total dry matter. For soft wheat those number were 23 and 8% for total N and dry matter, respectively. However, total dry matter and total N accumulation became more synchronized during the rest of the growing season as compared with the N and dry matter uptake curves of Westar. Although this would made the practice of applying split-N applications for durum and soft wheat more feasible, split-N applications did not result in higher yield for both crops.

The duration of the growing season in Saskatchewan is approximately 100 days. A large majority or all of the N uptake for the three crops tested occurred within 60 DAP. Although not measured in this experiment, the total N accumulation during the 20 days will be small. Therefore, it is during those remaining 40 days that most of the N uptake takes place. This time period might be too short to be able to increase yield through a split-N application.

Table 4. Total dry weight and seed yield of durum and soft wheat crops at Outlook, Saskatchewan, 1989.

Crop	N applied kg/ha	Form of N†	Total weight (kg/ha) Days after planting 42	53	62	79	106	Grain weight (kg/ha) 106
Durum	0		362	1285	2398	5492	6422	2267
Durum	100*	AN	725	2289	5062	9711	10649	3763
Durum	100+100*	AN	639	1989	4407	8294	11684	3563
Durum	200*	AN	765	1968	4956	9321	11236	3952
LSD (P <0.05)			NS	NS	1301	2335	2061	795
CV (%)			31	26	19	18	13	15
Soft wheat	0		454	1624	3149	5744	6464	2981
Soft wheat	100*	U	937	2867	5770	10025	12493	5471
Soft wheat	100+100*	U	666	3031	5112	8231	12056	5001
Soft wheat	200*	U	914	2719	5426	8604	12823	5358
LSD (P <0.05)			268	692	1255	1487	1289	726
CV (%)			22	17	17	12	7	10

* ^{15}N-labelled fertilizer

† AN = ammonium nitrate; U = urea

Table 5. Total N accumulation in canola (Westar) as affected by N application at Outlook, 1988

N applied	Days after planting				
kg/ha	41	54	61	88	105
	kg N/ha				
0	ND†	88.0	64.8	76.4	70.2
75* + 75 urea	73.4	118.3	107.0	123.3	118.4
75 + 75* urea	ND	128.3	100.6	148.4	127.5
75* + 75 UAN	87.8	120.2	107.3	157.3	129.5
75 + 75* UAN	ND	133.8	118.7	139.3	135.8
150* urea	67.8	144.2	121.8	133.5	158.5
150 UAN	70.9	131.1	112.8	119.1	129.3
LSD (P <0.05)	NS	NS	28.7	32.2	NS
CV (%)	23	26	18	17	28

*Indicates labelled ^{15}N
†Not determined

Table 6. Total N of canola as affected by N application at Outlook, 1989

Urea-N applied (kg/ha)	Total weight (kg/ha)					Grain weight (kg/ha)	
	Days after Planting						
	32	41	50	71	91	71	91
0	7.7	21.8	28.0	54.9	43.1	24.2	33.9
100*	16.1	50.1	72.5	90.6	69.7	44.6	54.1
100+100*	17.1	44.1	88.0	91.8	97.9	37.9	67.7
200*	21.7	68.3	103.2	100.6	98.8	44.4	72.1
LSD (P <0.05)	7.5	16.8	29.2	27.0	27.4	12.5	26.9
CV (%)	29.9	22.7	25.0	20.0	22.1	20.7	29.5

* Indicates labelled ^{15}N

Table 7. Total N accumulation of softwheat and durum as affected by N application at Outlook, 1989

N applied kg/ha	Days after planting					
	42	53	62	79	106 grain	106 total
	kg N/ha					
				Softwheat		
0	15.5	31.8	45.9	52.8	56.9	64.9
100*	32.5	61.6	109.7	112.3	113.6	142.1
100+100*	28.4	77.0	105.3	99.0	116.6	157.1
200*	33.3	72.3	111.5	96.9	123.8	165.5
LSD (P <0.05)	11.1	17.7	33.1	21.0	19.6	24.5
CV (%)	24.4	18.3	22.3	14.5	11.9	11.8
				Durum		
0	14.0	28.8	43.2	48.4	45.3	59.6
100*	29.1	60.1	82.2	120.8	87.3	105.6
100+100*	26.6	62.0	104.0	108.5	85.6	112.7
200*	32.2	60.7	93.8	115.7	106.4	141.1
LSD (P <0.05)	14.8	20.6	30.0	36.4	26.8	41.3
CV (%)	36.3	24.3	23.2	23.1	20.7	24.7

*Indicates labelled ^{15}N

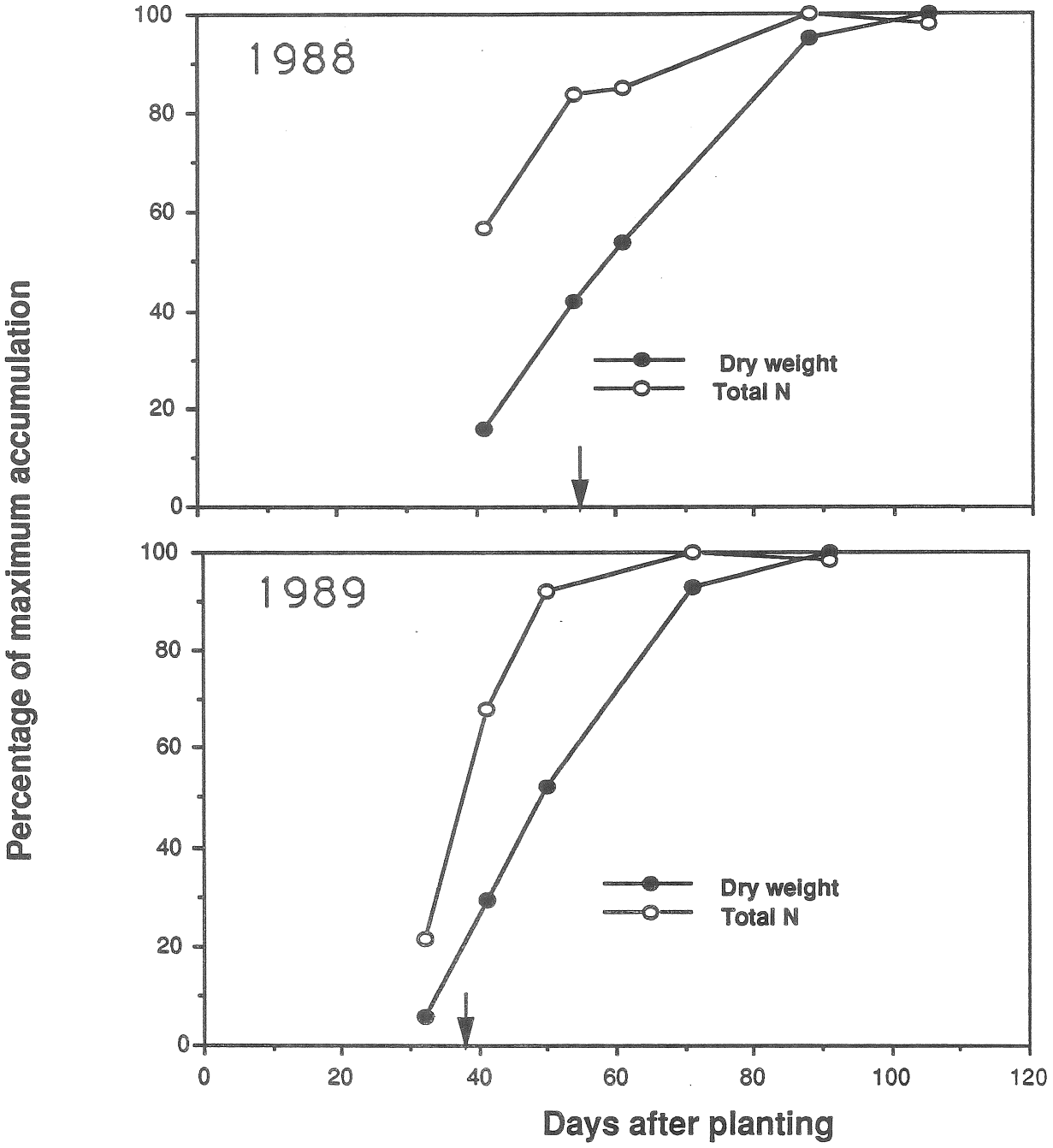

Fig. 1. Dry matter and total N accumulation in canola
Arrow indicates time of second split-N application

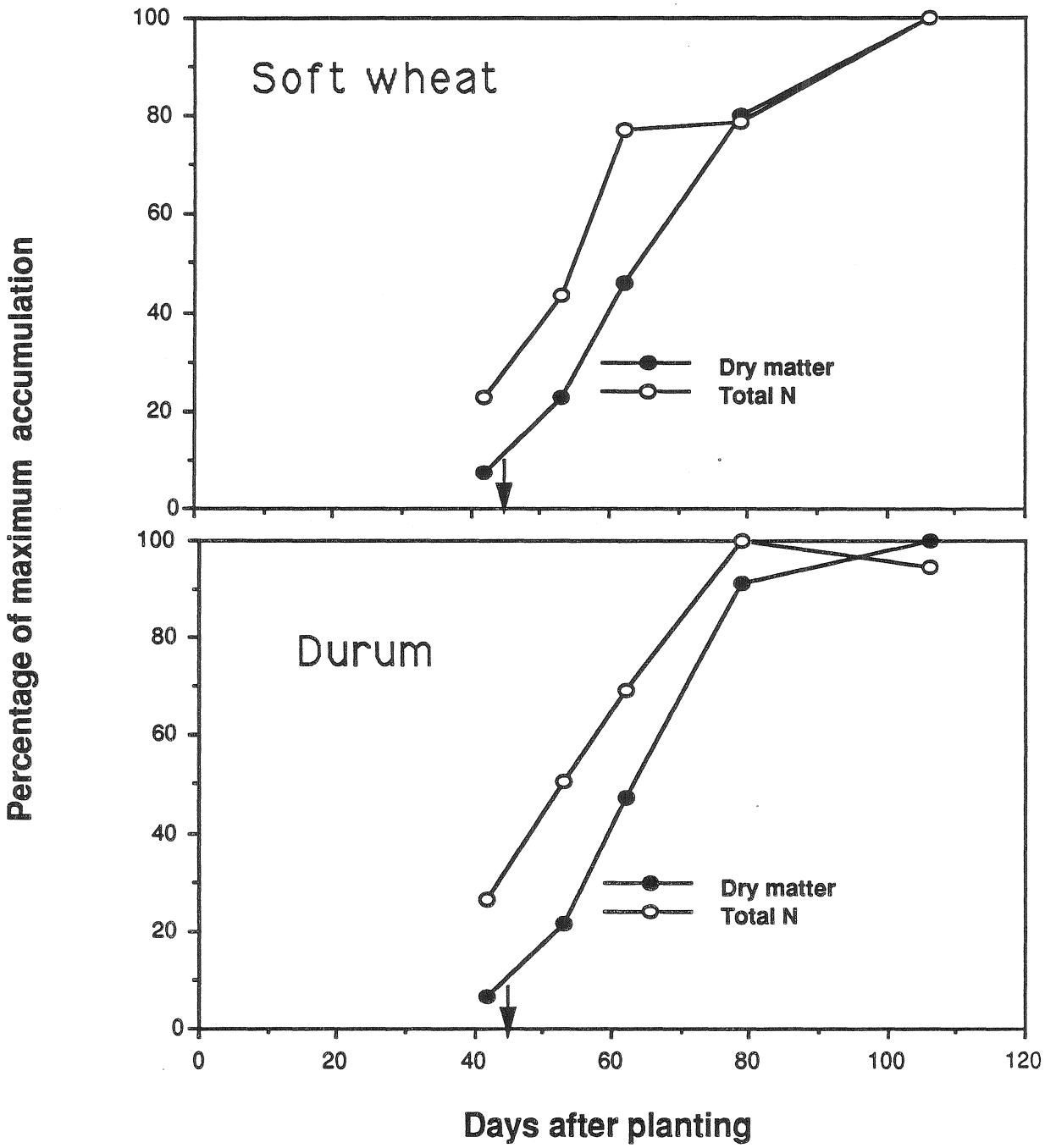

Fig. 2. Dry matter versus total N accumulation in soft wheat and durum
Arrow indicates time of second split-N application

Acknowledgements

Financial support was provided by the Saskatchewan Water Cooperation. The technical assistance of Brent Zettl and Kevin Komarnicki were crucial for the completion of the experiment. The typing skills of E. Farkas are as always highly appreciated.

Literature Cited

Bremner, J.M. and C.S. Mulvaney. 1982. Nitrogen -Total. *In* A.L. Page, R.H. Miller and D.R. Keeney (ed.). Methods of soil analysis. Part 2, 2nd ed. Agronomy 9:595-624.

Bigeriego, M., R.D. Hauck and R.A. Olson. 1979. Uptake, translocation and utilization of ^{15}N-depleted fertilizer in irrigated corn. Soil Sci. Soc. Am. J. 13:528-533.

Deibert, E.J., M. Bigeriego and R.A. Olson. 1979. Utilization of ^{15}N fertilizer by nodulating and non-nodulating soybean isolines. Agr. J. 71:717-723.

Russelle, M.P., E.J. Deibert, R.D. Hauck, M. Stevanovic and R.A. Olson. 1981. Effects of water and nitrogen management on yield and N-depleted fertilizer use efficiency of irrigated corn. Soil Sci. Soc. Am. J. 45:553-558.

Russelle, M.P., R.D. Hauck and R.A. Olson. 1983. Nitrogen accumulation rates of irrigated maize. Agron. J. 75:593-598

Spratt, E.D. 1974. Effect of ammonium and nitrate forms of fertilizer-N and their time of application on utilization of N by wheat. Agron.J. 66:57-61.

Siddique, K.H.M. and R.H. Sedgley. 1987. Canopy development modifies the water economy of chickpea (*Cicer arietinum L.*) in South-western Australia. Aust. J. Agric. Res. 37:599-610.