## 1.5 Nitrogen Management under Irrigated Conditions

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### INTRODUCTION

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.

Recovery of applied fertilizer-N vary widely and is dependent on the climatic conditions, the extent of leaching, and N losses due to denitrification, among other factors. The efficiency of fertilizer-N can also be affected by time of application. In most studies, the total fertilizer recovery, plant and soil, did not reach 100% and the difference between the amount of N applied and the amount of N recovered was attributed to leaching, runoff, denitrification and volatilization.

the acetylene blockage method. Measurements were taken just before the irrigation occurred, and 4, 7 and 10 h after irrigation. Denitrification rates were determined from soil cores taken from the top 10 cm. Each treatment was sampled twice.

At harvest, plants were dried at 60°C until constant weight, weighted and analyzed for total N, including $NO_3^-$ and $NO_2^-$. Plants were dried, weighed and threshed, and seed and straw analyzed for total N and atom % $^{15}N$. In 1988 soil samples were taken to a depth of 120 cm (15 and 30 cm increments) and analyzed for total N and atom % $^{15}N$.

## 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 1.5.2). 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.

Table 1.5.2 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 $^{15}N$.

However, the differences were not significantly different at the 5% probability level. The 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 1.5.3). 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.

Table 1.5.3 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 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 1.5.4).

Table 1.5.4 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.

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 1.5.5). 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 1.5.6). 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 1.5.5 Total N accumulation in canola (Westar) as affected by N application at Outlook, 1988.

| N applied kg/ha | Days after planting | | | | |
|---|---|---|---|---|---|
| | 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 1.5.6 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 $^{15}N$.

Similar results were found for soft wheat and durum and the application of 100 kg N-fertilizer/ha increased total N accumulation (Table 1.5.7). 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) (Figure 1.5.1). 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

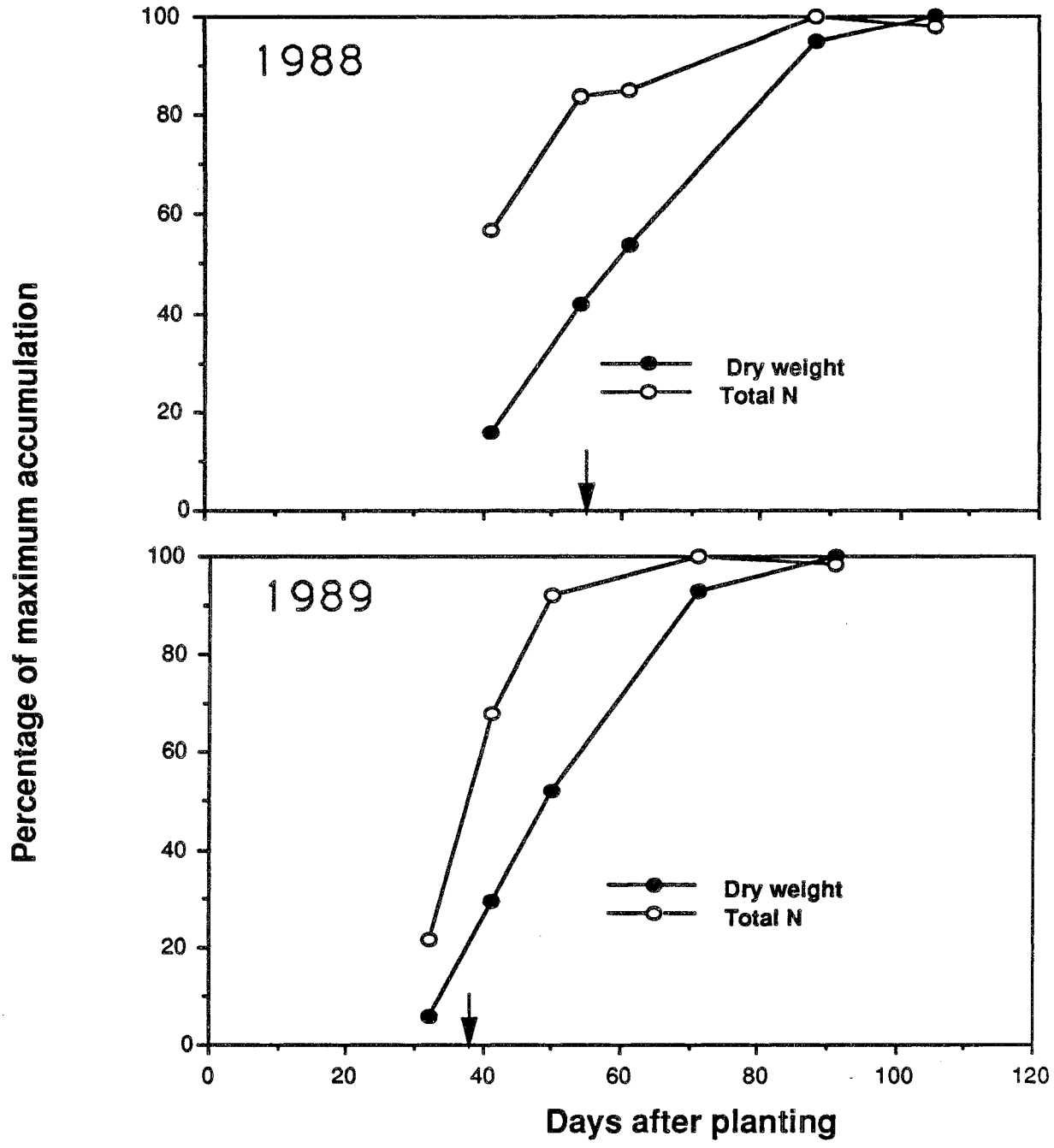


Figure 1.5.1 Dry matter and total N accumulation in canola. (Arrow indicates time of second split-N application)

Table 1.5.7. 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 $^{15}N$

durum and soft wheat (Figure 1.5.2). 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

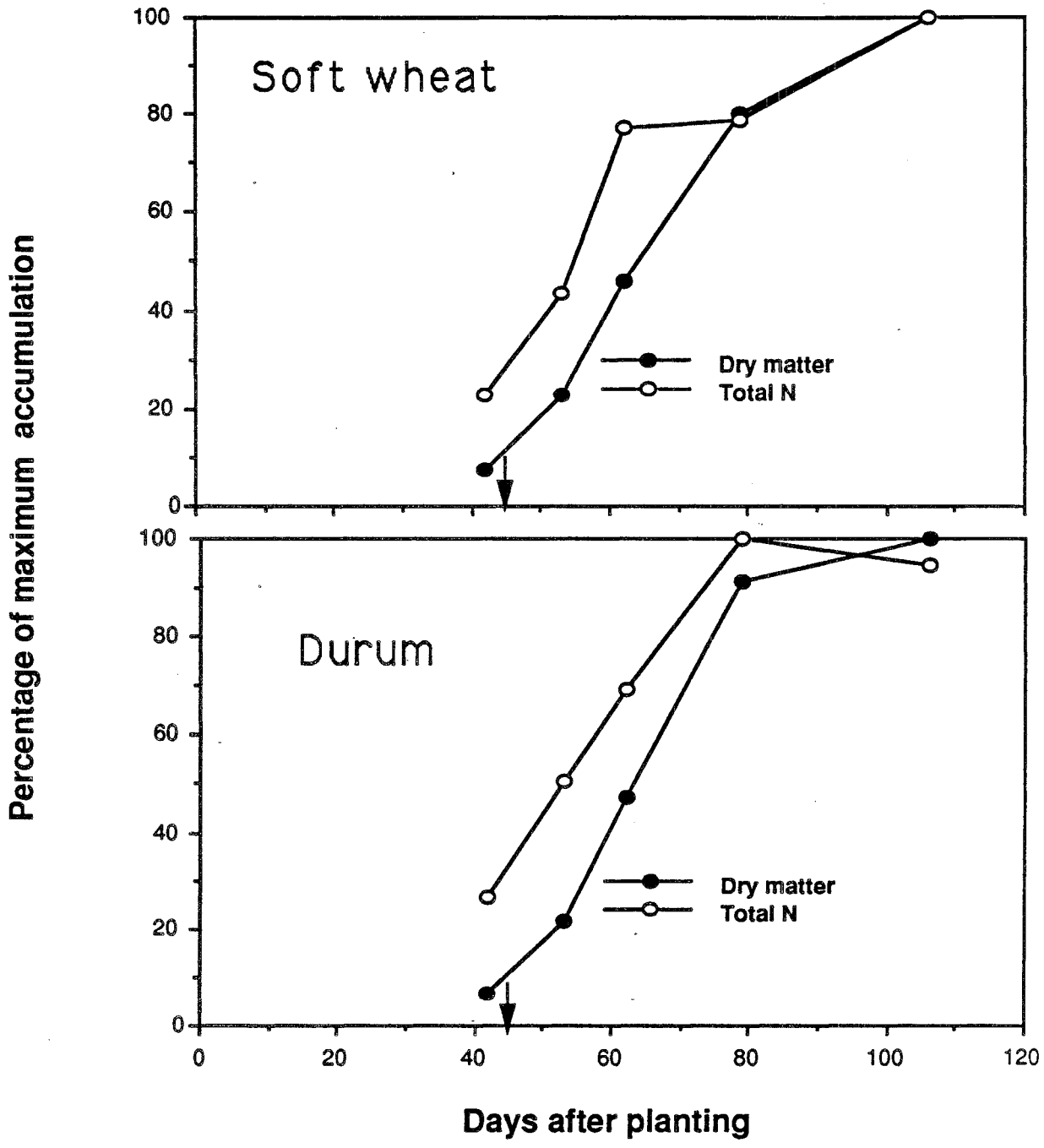


Figure 1.5.2 Dry matter versus total N accumulation in soft wheat and durum. (Arrow indicates time of second split-N application)

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.

Total yield of durum at Birsay was not affected by N application and ranged from 12,000 to 13,000 kg/ha (Table 1.5.8). In contrary, total yield at Outlook was affected significantly by N application and ranged from 4,213 to 6,951 kg/ha. Grain yield followed a similar pattern as total yield at both sites. However, at Outlook a much more favorable harvest index was found as compared with Birsay and the grain yield of fertilized durum at Birsay was on average 36% higher as compared with springwheat at Outlook. Total dry matter of fertilized durum was 104% higher as the fertilized springwheat at Outlook.

The recovery of fertilizer-N in 1988 in grain ranged from 25.2 to 29.0% (Table 1.2.9). The form of N applied, i.e. U or UAN, had no effect on the fertilizer use

Table 1.5.8 Total yield and grain yield of durum and springwheat at Birsay and Outlook, Saskatchewan, 1989.

| | Total (kg/ha) | | | Harvest index |
|---|---|---|---|---|
| | Total | Grain | Straw | |
| | | ***Durum (Birsay)*** | | |
| Control | 12833 | 4693 | 8140 | 0.37 |
| Urea | 13203 | 3634 | 9569 | 0.28 |
| AN | 13741 | 4176 | 9665 | 0.30 |
| LSD (P <0.05) | NS | NS | 884 | 0.07 |
| CV (%) | 3.7 | 14.1 | 5.6 | 12.8 |
| | | ***Springwheat (Outlook)*** | | |
| Control | 4213 | 2064 | 2149 | 0.49 |
| Urea | 6951 | 2937 | 4014 | 0.42 |
| AN | 6193 | 2765 | 3428 | 0.44 |
| LSD (P <0.05) | 1605 | NS | 799 | 0.03 |
| CV (%) | 16.0 | 18.5 | 14.4 | 3.9 |

Table 1.5.9 Nitrogen fertilizer recovery in soil and plant (Westar) at Outlook, 1988.

| Treatment | | Percent N recovered | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| kg N/ha | Form of N | Plant | | | Soil (cm) | | | | Plant and Soil |
| | | Straw | Grain | Total | 0-15 | 15-30 | 30-60 | Total | |
| 75* + 75 | Urea | 6.4 | 25.2 | 31.6 | 33.9 | 4.6 | 0.4 | 39.0 | 70.6 |
| 75* + 75 | UAN† | 7.8 | 35.7 | 43.5 | 31.9 | 4.3 | 1.6 | 37.8 | 81.3 |
| 150* | Urea | 6.9 | 29.0 | 35.9 | 33.5 | 4.2 | 1.7 | 39.4 | 75.3 |
| 150* | UAN | 8.2 | 28.4 | 36.6 | 25.0 | 7.1 | 3.5 | 35.6 | 72.2 |
| LSD (P <0.05) | | NS | NS | NS | NS | NS | 2 | NS | NS |
| CV (%) | | 39.9 | 21.6 | 21.7 | 37.1 | 64.4 | 67.7 | 35.7 | 12.7 |

* Indicates labelled $^{15}N$ fertilizer.
† Urea-ammonium nitrate mixture.

efficiency. The total % FUE in the crop, grain plus straw, was 37% and was independent of the form of N applied. The recovery of fertilizer-N in the soil was between 35 and 39% and was largely found in the top 15 cm. Almost no fertilizer was found below 30 cm. The total % FUE in the crop and soil was between 72 and 81%, suggesting a loss of approximately 19 to 28% of the applied fertilizer N. Potential mechanism of losses might have been denitrification or volatilization.

In 1989, the overall % FUE recovery in canola was 27%, which appears to be lower as the recovery found in the previous year (Table 1.5.10). The two cereals, durum and softwheat, showed an average % FUE of 42 and 43%, respectively. The application of 100 or 200 kg N/ha did not significantly affect the recovery of the fertilizer-N. The application of the second split of N, which was not labelled with $^{15}N$, appears to decrease the % FUE of the first application of N. At time the second split-N was carried out, canola and the cereals were accumulating N and the available soil N pool would have been diluted

Table 1.5.10 Fertilizer use efficiency of durum, soft wheat and canola at Outlook, 1989.

| Crop | Treatment | Form of N | Grain | Straw | Total |
|---|---|---|---|---|---|
| | | | % FUE | | |
| Durum | 100 | AN | 37.6 | 8.2 | 45.7 |
| Durum | 100+100 | AN | 30.1 | 8.4 | 38.5 |
| Durum | 200 | AN | 31.1 | 10.4 | 42.7 |
| LSD (P <0.05) | | | NS | NS | NS |
| CV (%) | | | 15.1 | 18.9 | 17.5 |
| Soft wheat | 100 | Urea | 35.6 | 8.7 | 44.3 |
| Soft wheat | 100+100 | Urea | 25.0 | 8.6 | 33.6 |
| Soft wheat | 200 | Urea | 37.8 | 13.3 | 51.1 |
| LSD (P <0.05) | | | NS | 2.3 | 11.2 |
| CV (%) | | | 18.7 | 13.2 | 15.1 |
| Westar | 100 | Urea | 22.1 | 5.8 | 31.5 |
| Westar | 100+100 | Urea | 15.5 | 6.4 | 21.9 |
| Westar | 200 | Urea | 20.9 | 7.9 | 28.7 |
| LSD (P <0.05) | | | NS | NS | NS |
| CV (%) | | | 36.3 | 20.4 | 22.5 |

by the second split N application. As the plant makes no distinction during uptake between $^{14}N$ and $^{15}N$, a decrease in % FUE of 100 + 100 kg N/ha as compared with 100 kg N/ha application would be anticipated.

At Birsay and Outlook total N accumulation followed similar pattern as total yield. The highest total N was found at Birsay, 200 kg N/ha, which was approximately the double of the amount of total N found in Outlook (Table 1.5.11). N application increased significantly at both sites total N accumulation. Whereas the % N derived from fertilizer-N was higher at Outlook as compared with Birsay, the FUE at both sites were very comparable and where close to 22%. However, the recovery was lower as found at the Irrigation Centre where durum and softwheat showed an average FUE of 42 to 43%. At present time, no apparent reason is available for the lower % FUE at the two farmer's field.

Table 1.5.11 Total N and percent fertilizer use efficiency of irrigated durum and springwheat.

| Treatment | N/ha | kg N/ha | | | % Ndff | | % FUE | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Grain | Straw | Total | Grain | Straw | Grain | Straw | Total |
| | | | | ***Durum (Birsay)*** | | | | | |
| Control | 0 | 108.0 | 31.1 | 139.1 | | | | | |
| Urea | 200 | 106.9 | 83.0 | 190.0 | 16.7 | 19.7 | 9.1 | 8.0 | 17.2 |
| AN | 200 | 123.6 | 76.7 | 200.3 | 29.9 | 29.0 | 18.6 | 11.1 | 29.7 |
| LSD (P <0.05) | | NS | 17.7 | 42.8 | 3.8 | 7.8 | 2.1 | 2.2 | 4.1 |
| CV (%) | | 15.5 | 16.0 | 14.0 | 9.2 | 18.7 | 8.7 | 14.0 | 10.1 |
| | | | | ***Springwheat (Outlook)*** | | | | | |
| Control | 0 | 52.2 | 7.1 | 59.3 | | | | | |
| Urea | 200 | 89.3 | 14.0 | 103.3 | 41.1 | 41.8 | 18.4 | 2.9 | 21.3 |
| AN | 200 | 85.8 | 12.3 | 98.1 | 44.5 | 44.3 | 19.3 | 2.7 | 22.0 |
| LSD (P <0.05) | | 23.6 | 2.4 | 25.7 | 2.3 | NS | NS | NS | NS |
| CV (%) | | 18.0 | 12.7 | 17.1 | 3.1 | 5.4 | 16.3 | 8.3 | 15.1 |

Losses of N due to denitrification at Outlook were insignificant before irrigation, increased to a high of approximately 50 g N/ha/day 3 h after irrigation and decreased again to low levels 10 h after irrigation (Figure 1.5.3). At Birsay, N losses before the irrigation were already significant and increased to 10 to 12.5 kg N/ha/day 3 h after irrigation and decreased to approximately 5 kg N/ha/day. The lowest N losses were found in the unfertilized treatments but the large variability made the differences non-significant. It is apparent from this study that the concentration of nitrate was not the limiting factor of the denitrification but rather the moisture condition of the soil. If the soil moisture content reaches its field capacity an anaerobic condition is created which subsequently enhances denitrification. Apparently, the conditions for denitrification were more favorable at Birsay

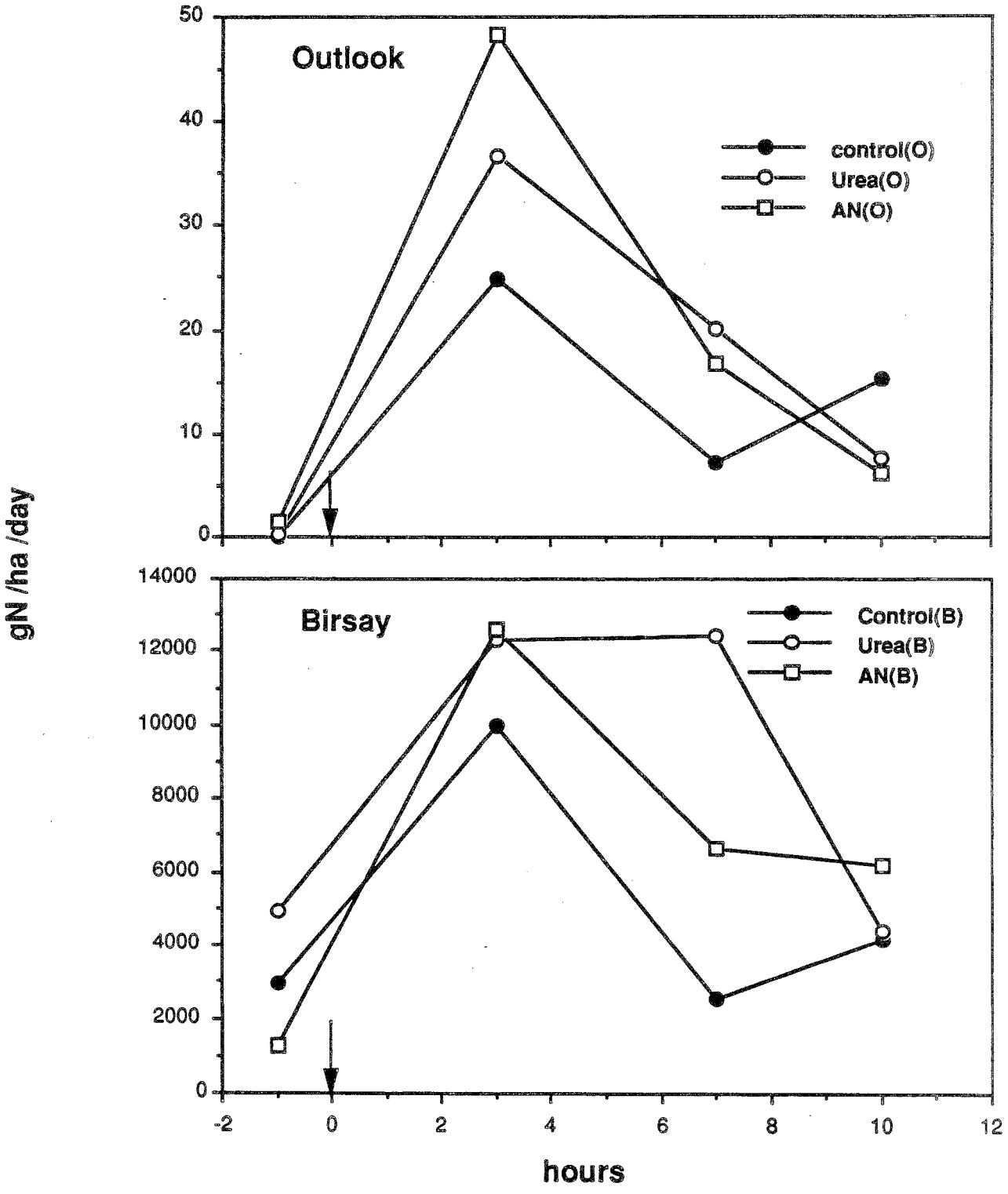


Figure 1.5.3 Denitrification rates as affected by N application and irrigation. (Arrow indicates initiation of irrigation)

(loam-clay) than at Outlook (sandy). It has yet to be determined which are the major factors at Birsay contributing to such high levels of denitrification.

## CONCLUSIONS

(1) Split N application did not enhance grain yield by canola, soft wheat and durum.

(2) Fertilizer use efficiency ranged from 21 to 43%.

(3) Significant N losses due to denitrification were observed at the site which had high water and N inputs.