EFFECT OF MOISTURE AND RATE OF NITROGEN ON NITROGEN DISPOSITION IN SOIL-PLANT SYSTEM

C. A. Campbell[1] and E. A. Paul[2]

INTRODUCTION

At the Soil Fertility Workshop held in 1976 we reported on some aspects of a study which was carried out at Swift Current in the summer of 1975 (Campbell et al. 1976; Davidson et al. 1976; Dyck et al. 1976). For those who might have missed last year's presentations, we will briefly outline the experimental procedure employed, but time will not permit us to reiterate the results reported at that time.

The study involved growing Manitou wheat on Wood Mountain loam (Mitchell et al. 1944) on stubble land in 15-cm diam., 120-cm deep lysimeters (Dyck et al. 1976, Fig. 6). We determined the accumulation of dry matter and N in tops and roots as a function of two moisture levels and seven rates of N (KNO_3) measured at five stages of development. Treatments which were sampled at maturity all received N^{15}-labelled fertilizer. The soil was sampled destructively. It was segmented into small sections and analyses for moisture, roots, NO_3, NH_4, Kjeldahl N, N^{15}, etc. were carried out. The soil contained 18 kg NO_3-N/ha in the top 60 cm at seeding.

The portion of the results which we wish to discuss today is concerned with the disposition of the fertilizer and soil N in the soil-plant system as elucidated by the N^{15} results. In order to keep this presentation as simple and as brief as possible, we have taken some liberties with the results by showing averages in several instances where interactions existed. Calculations related to the N^{15} results were done according to procedures outlined by Rennie and Paul (1971).

It may be recalled from last year's report that during the growing season of 1975 there was good soil moisture from seeding to about the tillering stage of growth; this was followed by a month of drought (< 1 cm of rain) lasting until about late flowering; followed by consistent rainfall (6 to 12 cm) to maturity (Campbell et al. 1976, Fig. 1).

---

[1]Research Scientist, Research Station, Research Branch, Agriculture Canada, Swift Current, Saskatchewan.

[2]Professor, Soil Science, University of Saskatchewan, Saskatoon, Saskatchewan.

RESULTS AND DISCUSSION

N-Uptake by Wheat

Plant uptake of N increased curvilinearly (concave downwards) with increasing rates of fertilizer N (Fig. 1). For example, plant N increased by 79% when 17.8 cm of water was added throughout the growing season. When 224 kg N/ha of fertilizer was applied, plant N increased by 89%. When both 17.8 cm of water and 224 kg N/ha of fertilizer were added, yield increased by 253%, from 53 kg plant N/ha to 187 kg N/ha.

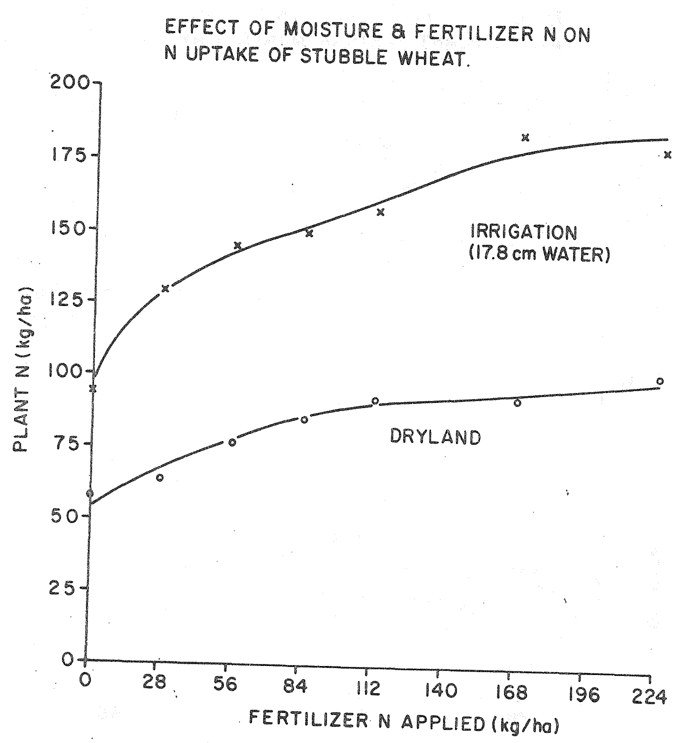

Fig. 1

Distribution of Total N Among Plant Parts

The N taken up was translocated efficiently and equally at all levels of fertilizer N under irrigated conditions (Fig. 2). There was an average of 7% more N left in the vegetative parts (roots 3%, straw 4%) under dryland than under irrigated conditions (Fig. 3). But there was an interaction between moisture and the rate of N applied with regards to their effect on N translocation from straw to grain (Fig. 2). This interaction suggested that some N present in the straw under dryland conditions was probably "denatured" during the prolonged drought which occurred between tillering and anthesis. This hypothesis was supported by the fact that translocation of N from straw to grain was impeded under dryland conditions at the higher fertilizer N rates where the rate of moisture use was directly proportional to rate of N application, i.e., the soils dried out much more rapidly at the higher rates of N (Campbell et al. 1976, Fig. 8).

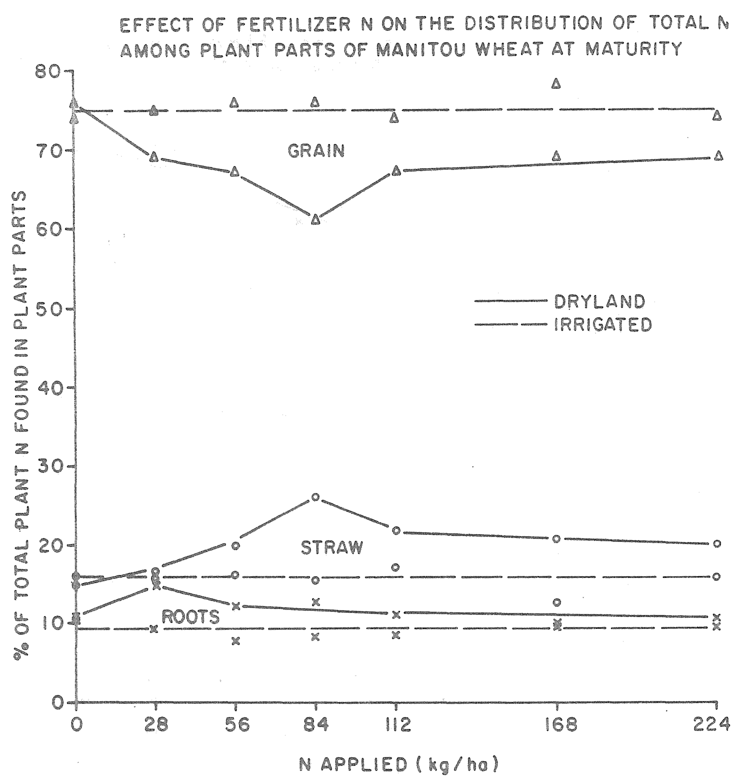

Fig. 2

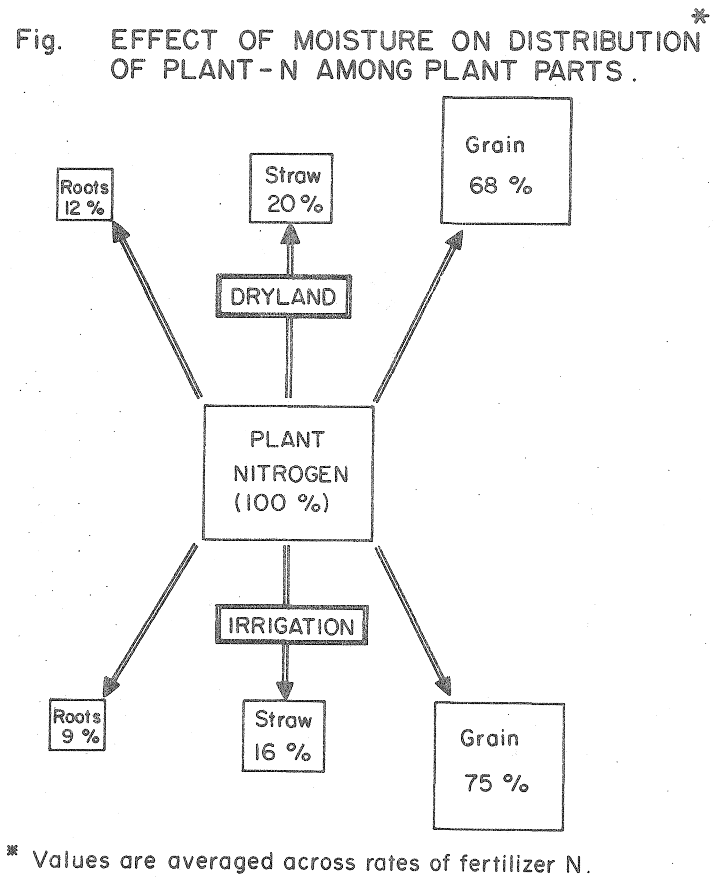

Fig. 3

<u>Proportion of Plant N Derived from the Fertilizer vs that Derived From the Native Soil N</u>

The proportion of the plant N (grain, straw, roots) which was derived from fertilizer N (%NDFF) increased with the rate of N application to a maximum at about 112 to 168 kg/ha and then levelled off or decreased slightly (Fig. 4). This response was not surprising since one might expect that the greater the rate of N application, the greater will be the concentration of fertilizer N in the pool of N in the soil, and therefore the more likely that the plant will absorb the fertilizer N as compared to native soil N.

Irrigation generally reduced the %NDFF in the above-ground parts (Fig. 4). This was no doubt due to the greater amount of net mineralization of native soil N brought about by the frequent wetting and drying under irrigation (data not shown).

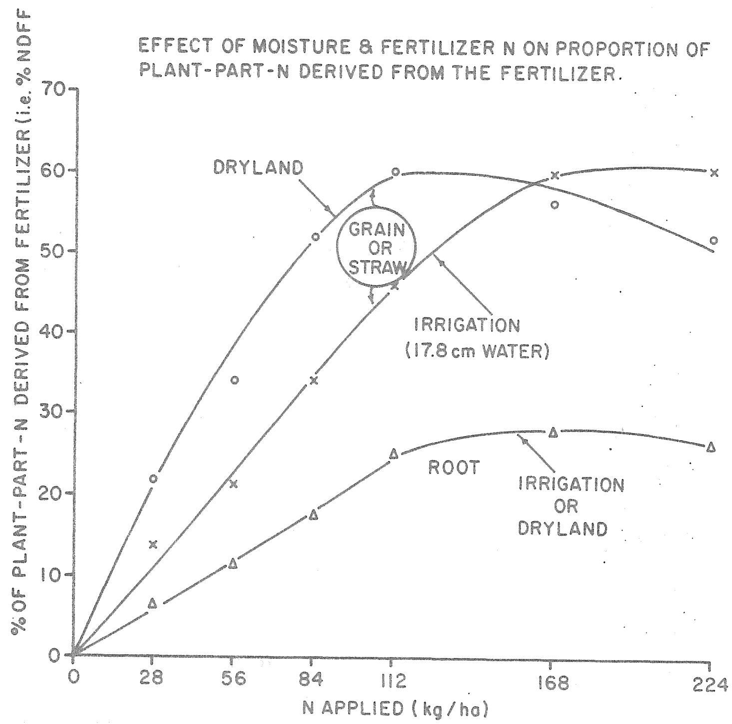

Fig. 4

The maximum %NDFF for above-ground parts occurred at a lower fertilizer N level under dryland (112 kg N/ha) than under irrigation (168 kg N/ha). This reflects the relative capacity of the plants grown under these two moisture regimes to incorporate the extra N into their tissue. For example, under the dryer conditions smaller plants were produced and these were gorged with fertilizer N at 112 kg/ha; above this level there was even a depressing effect of fertilizer rate on fertilizer N uptake. The latter may have resulted from an apparent priming of native soil N at high concentrations of soluble fertilizers (Laura 1974). This would tend to dilute the N pool in favour of native soil N and thus reduce the %NDFF.

Similar to the findings of the Soils Department, University of Saskatchewan (Paul et al. 1972) we found that the %NDFF was the same for straw and grain. We therefore agree with the University of Saskatchewan's conclusion that one should be able to estimate the N^{15} abundance for grain by measuring N^{15} abundance in straw and vice versa. The latter would save time, sample, and money. The %NDFF was considerably lower in the roots than in the above-ground parts (Fig. 4). Thus, root N^{15} abundance must be determined, especially if the sample is taken at maturity. The lower %NDFF in roots might be an indication that the N initially present in the roots was translocated to the tops and that most of the N present in the roots at maturity was N taken up from a pool of N now much lower in fertilizer N relative to native soil N. Some evidence in support of this hypothesis is found in the fact that roots lost dry matter (Fig. 5) and total N (Fig. 6) between shot blade and maturity (dryland), or anthesis and maturity (irrigated).

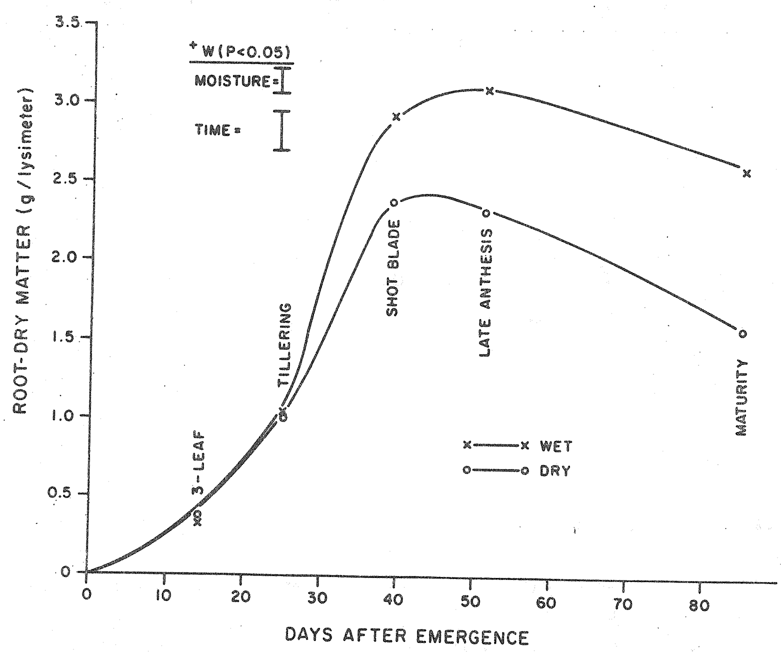

Fig. 5. Effect of water and growth stage on root-dry matter.

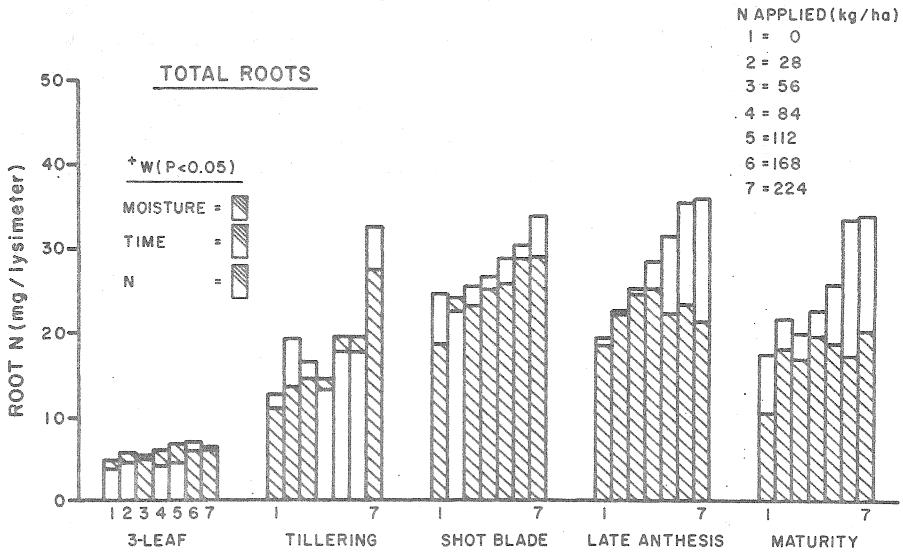

Fig. 6. Effect of moisture and N on root N accumulation.
(Cross-hatched = dryland; open area = irrigated)

The Proportion of the Fertilizer N That was Recovered by the Plant

The % of the applied fertilizer N recovered by the total plant varied from 30 to 64% under dryland, and 62 to 86% under irrigation (Fig. 7). The recovery was related to the influence of fertilizer N on dry matter production up to fertilizer rates of 84 kg N/ha under dryland conditions, and up to 168 kg N/ha under irrigation (compare Fig. 7 and dry matter graphs, Campbell et al. 1976). The decreasing parts of the curves (Fig. 7) reflect the fact that the N^{15} in fertilizer was increasing while N^{15} in plant remained constant under irrigation, or decreased under dryland (Fig. 4). The same explanation with regards to apparent priming of native soil N at the higher rates of fertilizer N is possible here again.

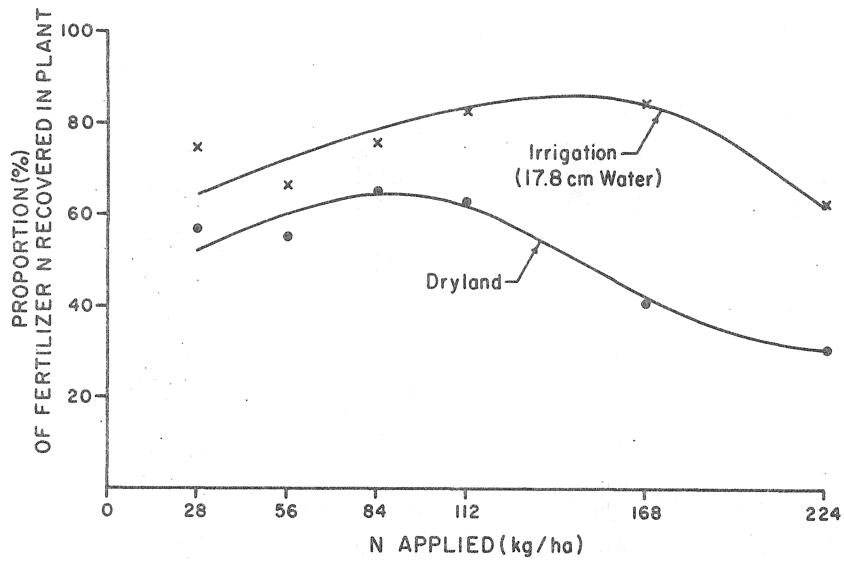

Fig. 7. Effect of moisture and N fertilizer on plant recovery of fertilizer nitrogen as determined by isotopic method.

Balance Sheet of Fertilizer N Distribution Throughout the Soil-Plant System at Maturity

There was considerably more of the fertilizer N left behind in the dryland soil (34.6%) than in the irrigated soil (15.4%); and there was much less fertilizer N recovered in the grain of dryland wheat (37.3%) than in the grain of irrigated wheat (58.3%) (Fig. 8). Both of these responses were directly related to dry matter production. Moisture had minimal effect on the average fertilizer N recovery in straw and roots. At the 1% level of probability the error in the average total recovery was ±6%. Thus the proportion of the fertilizer N that was not accounted for in the plant plus the soil (to 105 cm) was 7% for dryland and 4% under irrigation. These unaccounted for amounts were assumed to have been denitrified since leaching losses were minimal (as shown later). We can also assume that there was no effect of irrigation on denitrification in this experiment. Our watering technique had been planned with this objective in mind.

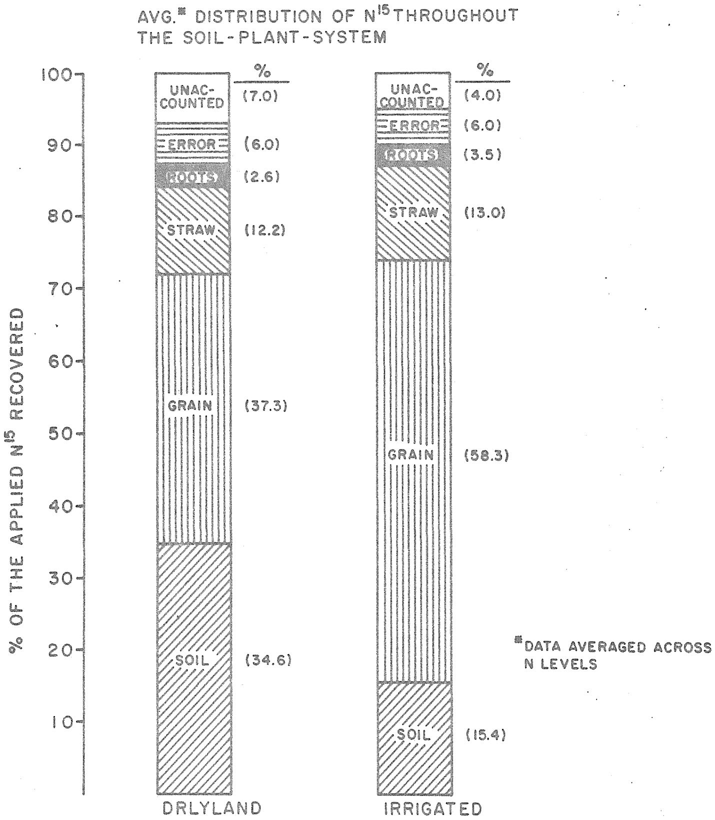

Fig. 8

The residual fertilizer N (soil N) was constant up to fertilizer rates of 112 kg N/ha under dryland and 168 kg N/ha under irrigation; then it increased sharply (Fig. 9). These results show the importance of not overfertilizing since the residual fertilizer N will remain in the soil and may later on be leached to the water table, especially if the soil is summerfallowed the year after the crop is grown. Thirty percent of the fertilizer N was left in the profile at rates of application up to and including twice the recommended fertilizer rate for dryland stubble wheat; at higher rates as much as 57% of the applied N was left in the soil. Only 15 to 21% of the fertilizer N was left in the soil under irrigated conditions.

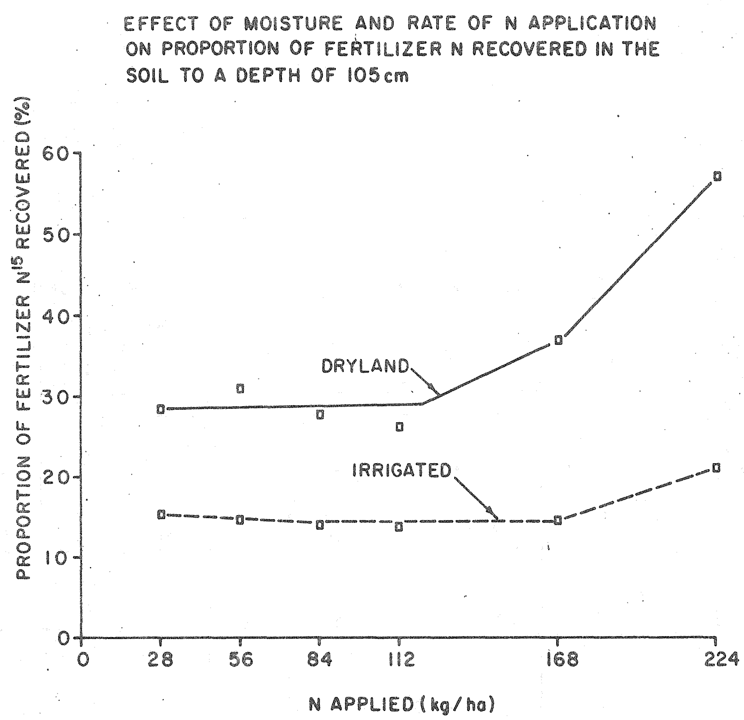

Fig. 9

Distribution of Residual Fertilizer N in the Soil Profile

At rates of fertilizer N equal or less than 112 kg/ha, 73% or more of the residual N was located in the top 30 cm of the soil profile under dryland conditions (Table 1). At higher rates of N >50% of the residual N was leached into the 30- to 60-cm segment by heavy rains which occurred between anthesis and maturity.

The plants had made more thorough use of the fertilizer N under irrigation thus very little residual N was left for leaching (Fig. 9); consequently, only at 224 kg N/ha was there appreciable movement of residual fertilizer N into the 30- to 60-cm segment (Table 1). There was an average of 4% of the residual fertilizer N located in the 60- to 90-cm segment and none below this depth.

TABLE I LOCATION OF RESIDUAL FERT. N IN SOIL PROFILE

N APPLIED (kg/ha)	DISTRIBUTION OF RESIDUAL FERT. N IN SOIL PROFILE (cm)							
	DRYLAND				IRRIGATION			
	0 to 30	30 to 60	60 to 90	90 to 105	0 to 30	30 to 60	60 to 90	90 to 105
	%							
56	89	10	1	0	80	15	5	0
112	73	13	13	0	78	19	2	0
168	43	54	2	0	86	8	5	0
224	17	81	0	2	51	46	2	1

CONCLUSIONS

It is a fallacy to assume that because wetter conditions provide greater potential for leaching, this will necessarily occur. The soil type, the rate and timeliness of irrigation, the rate of fertilization and the type of fertilizer N used, and the concomitant amount and rate of crop growth, will determine the amount and final distribution of the fertilizer N in the soil-plant-air continuum.

REFERENCES

Campbell, C.A., Davidson, H.R. and Hinman, W.C. 1976. Effect of N fertility and soil moisture on yield and nitrogen accumulation in Manitou wheat. pp. 102-113 *in* Proc. 1976 Soil Fertility Workshop, Saskatoon, Saskatchewan.

Davidson, H.R. and Campbell, C.A. 1976. The effect of N fertility on the rate of growth of spring wheat. pp. 93-101 *in* Proc. 1976 Soil Fertility Workshop, Saskatoon, Saskatchewan.

Dyck, F.B., Campbell, C.A. and McLaughlin, N.B. 1976. A macro soil coring device. pp. 86-91 *in* Proc. 1976 Soil Fertility Workshop, Saskatoon, Saskatchewan.

Laura, R.D. 1974. Effects of neutral salts on C and N mineralization of organic matter in soil. Plant Soil 41: 113-127.

Mitchell, J., Moss, H.C., Clayton, J.S. and Edmunds, F.H. 1944. Soil Survey Rep. 12. Univ. Sask., Saskatoon, Sask.

Paul, E.A., Rennie, D.A., Schappart, H.J.V. and McGill, K.S. 1972. Crop utilization and fate of fertilizer N in soil. pp. 79-132 *in* Soil Plant Nutrient Research Rep. No. M23, Dep. Soil Sci., Univ. of Sask., Saskatoon, Sask.

Rennie, D.A. and Paul, E.A. 1971. Isotope methodology and techniques in soil-plant nutrition and plant physiology. Sask. Inst. Pedol. Publ. No. 76. Univ. of Sask., Saskatoon, Sask.