A COMPARISON OF ROOTING PATTERNS IN SPRING AND WINTER WHEAT

K. J. Gross, M. H. Entz and D. B. Fowler
Crop Development Centre, University of Saskatchewan,
Saskatoon, Saskatchewan

INTRODUCTION

The most severe growing season drought period in Saskatchewan usually occurs in July and early August. Most of the growth of winter wheat has already occurred by the end of July and, as a result, this period of stress is usually avoided (Fowler et al, 1986). Consequently, this factor is believed to be of primary importance in giving winter wheat its characteristic ability to outyield spring wheat (Fowler, 1983).

Many measurements of plant characteristics and responses have been taken in order to determine differences in the growth of wheat that may contribute to yield. This research has included comparisons of the root growth and water extraction of spring and winter wheat. The objective of this study was to compare the rooting patterns and soil moisture depletion patterns of spring and winter wheat grown under the environmental conditions experienced in Saskatchewan.

MATERIALS AND METHODS

Field experiments were conducted in 1986 at three locations; Outlook, Goodale, and Clair. Two varieties of winter wheat (Norstar and Norwin) were seeded in the fall of 1985 at a rate of 90 kg/ha using a small plot disc-press seeder with 22.86 cm spacings. Thirty kg/ha of phosphate was applied with the seed while rates of 0 and 90 kg/ha of ammonium nitrate were broadcast by hand in the spring of 1986. Two varieties of spring wheat (Katepwa and HY320) were seeded with the same seeder at the same rate at the end of April in 1986. Again ammonium-nitrate was applied by hand at the same rates that were used with the winter wheat.

The plots were laid out in a split-block design with five replicates, one of which was used as a root wash block. A neutron probe was used to measure soil water depletion over the growing season. The probe measured the soil water in 20 cm increments starting at 10 cm in depth and continuing to a depth of 130 cm. The amount of moisture in the top 10 cm of soil was determined gravimetrically.

A partial excavation technique called the profile wall method (Bohm, 1979) was utilized to expose the roots of both spring and winter wheat. The trench was positioned transversely to the rows in the block in order to show variation within and between the plots. The profile wall was smoothed using a flat-bottomed spade and a profile knife. Roots were then exposed by removing a soil layer approximately 1.3 cm thick from the working face of the profile. This was accomplished by spraying water on the face at 276 kPa (40 psi) using a teejet nozzle on a hand-gun hooked up to a water pump. Once the roots were exposed, pictures were taken of the roots at night in order to improve contrast between the light colored roots and the darker soil. The roots were illuminated by a light source consisting of three 400 Watt bulbs.

Slides of the profile wall were analyzed later on a screen which consisted of a 3x3 grid pattern. Using a technique modified from Tennant (1975), the following formula was employed to compare the rooting patterns of spring and winter wheat:

$$\text{ROOT DENSITY (intercepts/cm grid)} = \frac{\text{(NUMBER OF INTERCEPTS)}}{\text{(grid size)(\# of grid lengths counted)}}$$

Four washes were conducted at each site based on physiological stage of development. That is,

1) first wash: winter wheat - tillering; spring wheat - 3 leaf,

2) second wash: winter wheat - anthesis; spring wheat - tiller,

3) third wash: winter wheat - harvest: spring wheat -anthesis

4) fourth wash: spring wheat - harvest.

Statistical analysis of data from the profile wall method was conducted using locations as replicates since only one trench was dug at each site at a given date. Statistical analysis of the neutron data used the four replicates at each site.

RESULTS AND DISCUSSION

Profile wall method of root measurement.

In a semi-arid environment such as Saskatchewan, water usually is the limiting factor with respect to growth and yield. Thus, the ability of a crop to produce an extensively branched, deeply penetrating root system is very important in order to make the most of the available soil moisture. Previous studies have indicated that utilization of early season moisture is important for maximum yields on the Canadian prairies (Fowler et al, 1986). In this study winter wheat rooted earlier and more prolifically in the spring than did spring wheat (see Figure 1). Winter wheat had approximately 16% more roots in the uppermost soil layer on May 30. This difference would allow the winter wheat greater access to the soil water reserves which are present at this time of year. Another point of interest is the similar numbers of roots in the 10-30 and 50-70 cm depths respectively. There are two reasons for this occurrence:

1) Studies have shown that by the time the fourth leaf on the shoot has developed, the roots may exceed 30 cm in length (Russel, 1977). Due to the early seeding of the spring wheat in this study, greater differences would probably have been observed if a root washing would have occurred earlier in the growing season.

2) Both habits were under high moisture stress during this period of growth (see Table 1). However, as winter wheat was at a later physiological stage of development, the lack of moisture affected its development more severely.

TABLE 1

COMPARISON OF PRECIPITATION AND EVAPORATION PATTERNS
FOR 1986 AND THE LONG TERM AVERAGE: PARKLAND AREA

Time Period	Wynyard 1986 Evap. mm	Wynyard 1986 Precip. mm	Wynyard 1986 E/P	Yorkton 25 Year Mean Evap. mm	Yorkton 25 Year Mean Precip. mm	Yorkton 25 Year Mean E/P
May 1-15	96.2	45.2	2.1	80.9	18.8	4.2
May 16-June 3	207.2	4.8	43.2	134.0	31.2	4.2
June 4-June 27	118.8	35.6	3.3	171.4	52.6	3.2
June 28-July 11	181.9	65.7	2.7	108.1	34.5	3.1
July 12-July 23	89.6	26.8	3.3	86.4	24.0	3.6
July 24-Aug. 8	100.4	19.2	5.2	110.4	11.8	9.3

Source: Environment Canada

FIGURE 1. Winter and Spring Wheat Root Growth.
May 30, 1986

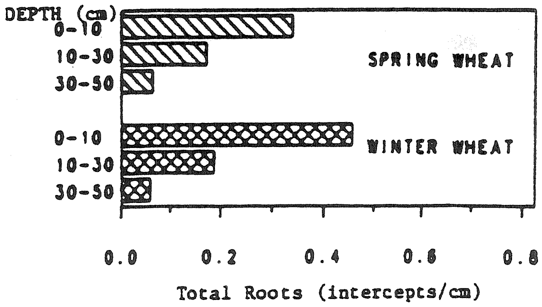


FIGURE 2. Winter and Spring Wheat Root Growth.
June 22, 1986

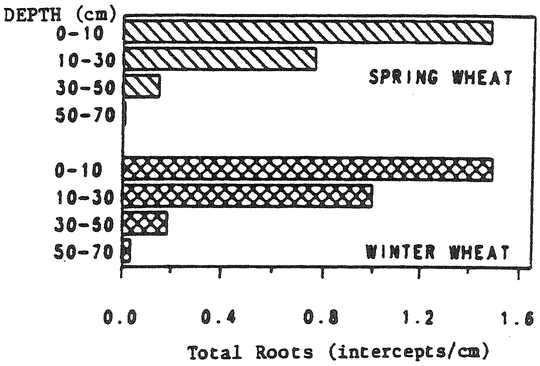
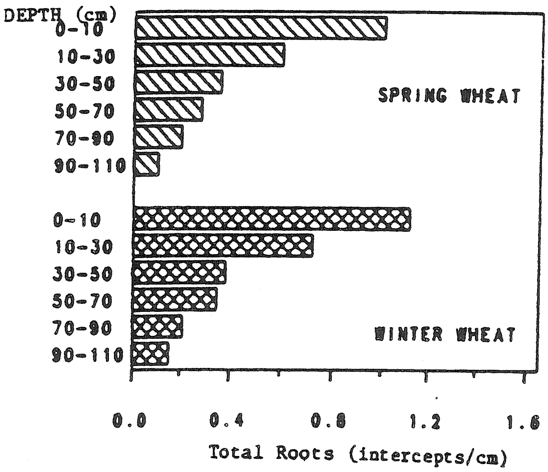


FIGURE 3. Winter and Spring Wheat Root Growth.
July 13, 1986



The next sampling period occurred when the winter wheat was at anthesis and the spring wheat was at the tillering stage. At this date (June 22 was the average time of washing between the three sites - see Figure 2) a new trench was dug and root observations were repeated. Several trends are illustrated from Figure 2;

1) There were more roots at each depth than there were at the previous date,

2) Most of the roots from both spring and winter growth habits occur in the top 30 cm of soil and this correlates well with results from other studies (Garay et al, 1983),

3) The two growth habits had rooted more deeply,

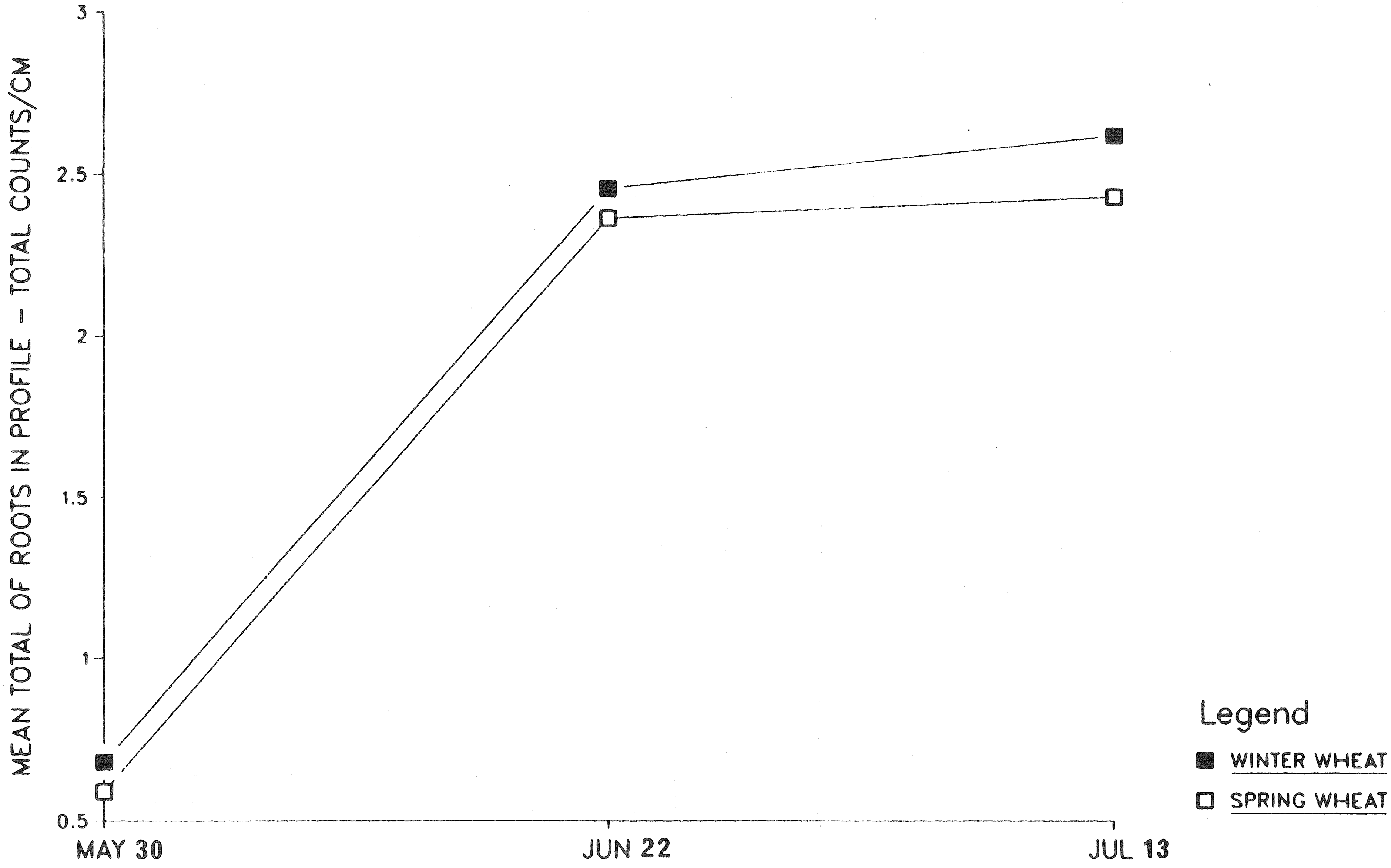
4) The advantage winter wheat held over spring wheat at this date was no longer in the first depth but occurred in the form of more roots/cm in the three lower depths.

5) The two growth habits achieve near maximum root proliferation relatively early in the growing season (Figure 4).

Figure 2 also illustrates the greater root proliferation of winter wheat at depth, most notably in the 10-30 and 50-70 cm depths respectively. This is of some importance since lower roots become more vital as the surface soil layers dry out (Welbank et al, 1973).

Finally, Figure 3 shows the number of roots in the soil profile at the various depths prior to the harvest date of winter wheat and anthesis of spring wheat. The figure indicates how similar rooting patterns of the two growth habits were by this time in the growing season. Although the rooting patterns were

FIGURE 4
1986 ROOT WASH STUDY
INCREASE OF ROOTS OVER THE GROWING SEASON



similar, it may be important to note that winter wheat still held a slight advantage with respect to root number at various depths.

The number of roots in the top two depths appeared to have decreased since the prior washing date. Several reasons may account for this phenomenon:

1) Roots in these layers were dying back due to lack of moisture in these zones (see Figures 5 and 6).

2) Although root systems are genetically controlled they are sensitive to the soil environment (Hurd et al, 1973). Thus, as a different sample area was studied to record these values, the variability of the soil may have played a role.

3) Roots generally begin to die back after anthesis.

These observations suggest that there are differences in the rooting patterns of the two growth habits. Field observations also supported these conclusions. However, total rooting differences were not significant when analyzed statistically. A comparison of the intercepts/cm at each depth has yet to be done. High variability of the data did not allow detection of differences between the mean number of roots totalled over depths for spring and winter wheat. This appears to be a common problem with root studies (Irvine, 1978; Cholick et al, 1977) and indicates that greater replication is required to detect differences (Schuurman, 1965). The fact that 1986 was an abnormal year with respect to precipitation (Table 1) could also have been a factor in masking differences between spring and winter wheat.

Table 1 indicates that from May 15 - June 3 the amount of precipitation that occurred was down drastically from the twentyfive year average. This resulted in a tenfold increase in stress (note the E/P values) over what normally occurs during this period. This increase in stress early in the growing season undoubtably restricted growth as a result the differences in rooting patterns between the two habits probably decreased.

Water Extraction Technique.

The neutron probe was used to measure soil moisture content thereby giving an indication of root activity (Cholick et al, 1977). That is, the presence of roots are correlated with soil moisture depletion. Since the amount of roots/cm of soil is important when evaluating the use of soil water by plants (Smika et al, 1982), this study used the neutron probe technique to compliment the profile wall method.

Figure 5 illustrates the amount of water (in cm of water/cm of soil) in each of the top three depths. This figure is made up from data combined from the three locations. It is interesting to note that although the soil water content of both habits is quite similar, there was a significant difference at Clair between the water use of spring and winter wheat for the first depth. The ability of the neutron probe to identify these differences is partly due to replication at each site that was not possible with the profile wall technique.

It is apparent that the water content of the surface soil (0-10 cm depth) was depleted quite early in the growing season (see Figure 6). This indicates not only an increase in evaporation from these surface layers, but also shows that the

FIGURE 5. Indication of Root Growth by Water Extraction. Comparing Spring and Winter Wheat. May 15, 1986

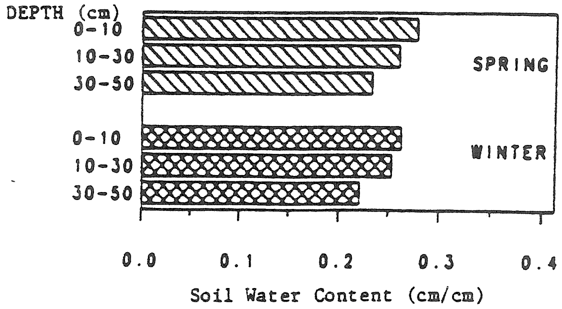


FIGURE 6. Indication of Root Growth by Water Extraction. Comparing Spring and Winter Wheat. May 30, 1986

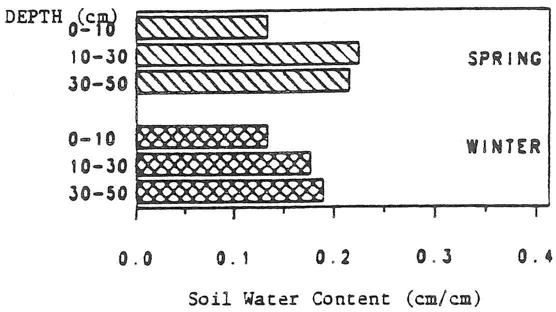
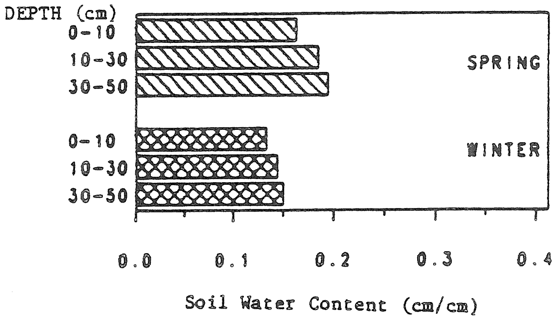


FIGURE 7. Indication of Root Growth by Water Extraction. Comparing Spring and Winter Wheat. June 20, 1986



roots have proliferated in this area and, as a result, used the available moisture.

Figure 6 also indicates greater rooting activity by winter wheat at the two lower depths as shown by the difference in soil water content when compared to spring wheat. Statistical analysis at this date showed significant differences between spring wheat and winter wheat with respect to soil water content in the second depth at all three sites. In addition, the third depth was proven to have shown differences in water content between spring and winter wheat at Outlook.

Finally, Figure 7 shows the further depletion of water in the lower depths as the growing season progressed. This coincides with the increased root growth in these zones shown by the profile wall technique. Clair and Outlook showed signifecant differences in the soil water content between the two habits in all three depths at this date. This diagram presents only the three depths for reasons of simplicity. Also, with the exception of depth four at Outlook, these three soil zones were the only depths at which significant differences were achieved. Schuurman (1959, cited in Hurd) had results similar to these even though he found roots below these soil zones. He conjectured that as long as the water supply is plentiful nearer to the surface, roots will not take moisture from below this area. However, this is not necessarily the only reason for this phenomenon as our studies indicated that there was water depletion below this zone, but the water use by the two growth habits in those zones was not significantly different.

Water-use efficiency and Yield Components.

Moisture availability during the growing season is one of the major factors limiting crop productivity on the prairies. Thus, it is important that a crop growing in such an area have the ability to make efficient use of the moisture that is available. As winter wheat establishes early, it begins to use water as much as two to three weeks before spring wheat at a time when the prevailing climate is cooler (Fowler et al, 1986). This results in the higher water-use efficiency (WUE) of winter wheat (see Table 2). It follows that the greater root distribution of winter wheat at this time of year will allow it to make more efficient use of the available water.

The relationship between grain yield and water use has been shown to be a positive one (Steppuhn et al, 1986). This positive relationship is illustrated in Table 2. The difference in yields were due mainly to significant differences in 1000 kernal weight and tiller number. There were also very significant differences in percent protein at all three sites, while Total Water Use (TWU) was signicantly different at Clair and Goodale. WUE values at Goodale and Outlook appear to be quite low, this is likely due to rainfall that occurred late in the growing season and was therefore relatively unavailable for crop use.

CONCLUSION

Earlier research has pointed out that winter wheat roots much deeper than does spring wheat (Black et al, 1981). However, due to the relatively short growing season and dryland conditions

Table 2

YIELD COMPONENTS AND WATER USE EFFICIENCY OF THE WHEAT VARIETIES

SITE	VARIETY	YIELD COMPONENTS: TILLERS (#/m^2)	SEEDSPER TILLER	1000 KERN. WT.	YIELD (kg/ha)	PROTEIN (%)	PROTEIN YIELD (kg/ha)	TWU (**)	WUE (*)
Clair	Spring:								
	Katepwa	365	18.96	31.8	2122	17.1	362.7	29	73.1
	HY320	353	15.90	42.3	2277	14.1	318.8	29	79.6
	Winter:								
	Norstar	461	19.33	31.1	2723	13.2	358.4	18	151.4
	Norwin	475	14.22	30.1	1994	13.5	266.3	17	116.2
Goodale	Spring:								
	Katepwa	176	20.65	29.3	1042	18.5	192.9	31	33.7
	HY320	150	22.85	41.4	1385	16.2	222.1	31	45.4
	Winter:								
	Norstar	277	20.97	24.3	1323	14.7	195.1	24	54.6
	Norwin ***	-	-	-	-	-	-	-	-
Outlook	Spring:								
	Katepwa	163	31.48	28.6	1425	16.5	233.4	29	49.9
	HY320	139	31.87	33.0	1462	15.3	219.5	29	50.4
	Winter:								
	Norstar	161	42.43	27.1	1496	14.4	214.0	26	57.4
	Norwin	309	25.28	27.8	1868	13.6	252.4	29	65.5

* Water-use efficiency in kg/ha/cm
** Total water-use: May 13 - Harvest
*** Norwin was winterkilled - poor stand.
Note: Values may be rounded off to the nearest decimal.

this is not the case in Saskatchewan. This study shows that the yield advantage of winter wheat is probably due to the fact that early in the growing season it roots deeper and more extensively than does spring wheat. This enables winter wheat to use the early season stores of moisture more efficiently (Fowler, 1985).

Although the spring wheat roots as deeply as winter wheat by anthesis; by this time the soil has lost the greater part of its moisture reserves. Thus, the lower yield of spring wheat is likely at least partially due to its poor WUE in the early part of the growing season.

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