THE PATTERN OF SUBSOIL WATER USE IN AUTUMN-SOWN KOPARA WHEAT

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ABSTRACT

Autumn-sown Kopara wheat was monitored throughout its period of greatest crop growth (from the double ridge stage until near the end of grain-filling) for its subsoil water extraction pattern. Weekly neutron probe readings were taken for the partial soil depths of 25-50 cm, 50-75 cm, 75-100 cm and the total 25-100 cm profile zone and, by the subtraction of successive readings, the weekly subsoil water use was obtained.

Treatments of nitrogen (applied at tillering), irrigation (at approximately mid-anthesis and again 14 days later) and two sowing rates were imposed in an attempt to obtain as much variation as possible in the pattern of subsoil water uptake. This was only partially successful as the site soil variability was much greater than anticipated. A gradual change in the water extraction pattern occurs throughout the reproductive phase of non-irrigated plots. Initially the shallowest measured zone was the largest supplier of water while the deepest zone provided least water but, by grainfilling, the situation was reversed. Each profile had a similar trend over the season. The shallowest zone attained any given level of water usage first, followed by the middle and then the deepest zones. Once irrigation was supplied, the water extraction pattern quickly changed. Whereas non-irrigated plots had more water being taken from the deepest zone, the irrigated treatments had the greatest loss from the shallowest profile.

Additional Key Words: Irrigation, nitrogen, sowing rates, neutron probe

INTRODUCTION

Prior to this experiment, autumn-sown wheat crops at Lincoln had been monitored for soil water only using gravimetric methods. Because of the physical limitations of this procedure, only the top 20 cm soil layer had been regularly sampled (Dougherty *et al.*, 1974; Scott *et al.*, 1973, 1977).

The major advantage of the neutron probe method is that once an access tube is placed there is no further disruption of the soil. Therefore soil water content can be determined *in situ* on a relatively undisturbed soil volume. Repeated readings may be taken over time and several depths can be sampled on each occasion allowing quick and easy calculation of the subsoil moisture levels.

Plant water uptake relates closely to root distribution hence root spread, density and depth are important in defining the rooting volume (Wiersum, 1966). Water extraction or uptake is controlled by the plant rate of water loss, the extent and efficiency of the root system, the soil water potential, and the hydraulic conductivity of the soil (Kramer, 1969). In moist soil, Kramer (1959) considered that the transpiration rate was controlled by plant factors such as leaf area and structure, extent of stomatal opening and by such environmental factors as humidity, temperature, solar radiation and wind. As water vapour is given off, gradients of water potential are generated in the plant causing more water from the soil to be taken in by the roots.

The objective of this paper was to monitor the pattern of subsoil water uptake through the period of greatest crop growth and how this was affected by the imposed treatments.

MATERIALS AND METHODS

The experiment consisted of a 3 x 2 x 2 factorial with 2 replicates of each treatment. The three treatments and their levels were as follows:

Nitrogen	N0	None
	N1	45 kgN/ha
	N2	90 kgN/ha
Irrigation	I0	None
	I1	Irrigated
Sowing Rate	S0	250 viable seeds/m^2
	S1	500 viable seed/m^2

These treatments were selected to simulate management practice and hence to test whether they caused any variation in subsoil water utilization from the measured profile zone.

The site soil type was a Templeton silt loam complex (Cox *et al.*, 1971) and the previous ground cover was a six year old lucerne stand. A basal application of 250 kg/ha superphosphate was drilled in with the Kopara seed at sowing on 16 June 1977. Plot size was 1.5 m wide by 50 m long with buffer plots between each treatment plot. Ammonium nitrate was broadcast at the start of tillering on 23 August. Irrigated plots were serviced by a microtube trickle system delivering 1.88 litres/m^2/hr and was applied first on 29 November (3 days before mid-anthesis) and again 14 days later, the amounts being 73 and 47 mm respectively. Disease, pest and weed levels were kept to a minimum using suitable preventative chemical controls.

Soil water was monitored at weekly intervals using a neutron moisture meter. The tubes were inserted during late August and probe readings taken from 15 September onwards, at the depths of 25, 50, 75 and 100 cm. These readings were then converted into millimetres of water by integrating the spline function joining consecutive depths so that the total water content within the three partial (25-50, 50-75, 75-100 cm) and total (25-100 cm) profile zones was obtained. Weekly water consumption was obtained by the subtraction of volumes of successive weeks.

No attempt was made to distinguish or measure downward drainage which was assumed to be small in relation to the transpirational use (Hillel, 1972). Similarly, the top 25 cm of soil was not monitored due to the difficulty of distinguishing between water lost by soil evaporation and that of plant transpiration.

RESULTS

It was only from 6 October that the majority of partial profile volumes (25-50, 50-75, 75-100 cm) recorded a water loss. Before this date heavy rainfall in September (Table 1) caused water volumes to rise in many of the profiles indicating water content possibly in excess of field capacity. Prior to the first irrigation being applied (29 November), only one significant difference in water use between treatments occurred and this was for the 3 November reading when, in the 25-50 cm profile, the plots which had received the highest rate of N removed more water (Table 2).

TABLE 1: Lincoln College monthly rainfall data (mm) for the trial.

	1941-1970 average mm	1977 mm
May	76	74
June	58	72
July	58	137
August	56	52
September	46	104
Total:	294	439
October	48	21
November	53	29
December	58	49
Total:	159	99

TABLE 2: Water extraction (mm) for the 25-50 cm profile in the nitrogen treatment for the period 28 October to 3 November.

Nitrogen Level	mm
N0	4.78 b
N1	6.38 ab
N2	7.72 a
C.V. %	25

Values followed by the same letter are not significantly different ($p < 0.05$).

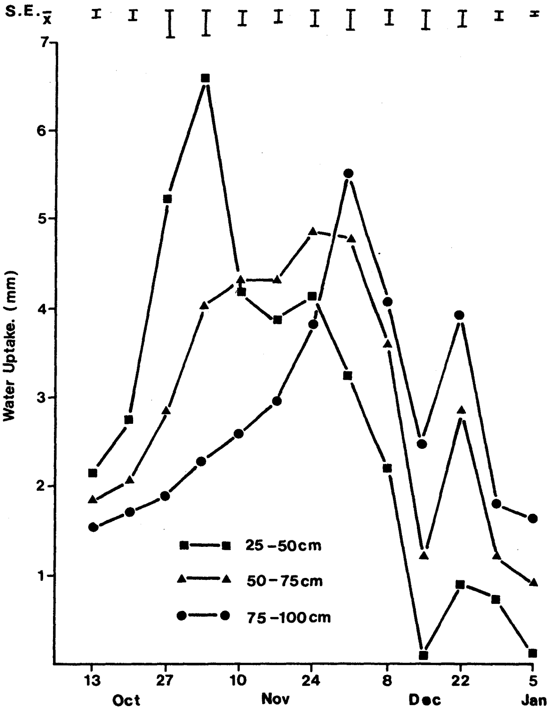

Figure 1: Average weekly uptake of water (mm) for all non-irrigated plots for the three (25-50, 50-75, 75-100 cm) soil profiles.

Throughout the experiment, sowing rate caused no significant differences in water extraction. The N treatment caused significant differences on only 6 occasions (3 November and 1, 8, 15, 22 and 29 December) and these were all for various partial zones. The total profile zone (25-100 cm) was not influenced at all by the use of N. Once irrigation commenced it caused many significant differences in water status. Immediately following an irrigation application, the profiles in the irrigated plots had more water entering, otherwise the significant differences were due mainly to the irrigated treatment plots having more water removed compared to the non-irrigated ones. These results have been published elsewhere in full (Dalgliesh, 1981).

Figure 1 presents the average weekly consumption of water for all non-irrigated treatments. Between the three partial profiles, differences in the rate of water removal varied over time. The trend was for the shallow (25-50 cm) zone to initially display the greatest volume removed. Then, as that level declined, the middle (50-75 cm) zone replaced it as the main water source. Correspondingly as water was removed from the middle zone, the deepest (75-100 cm) zone became the most important layer. This zone, in common with the other two, declined in water uptake after

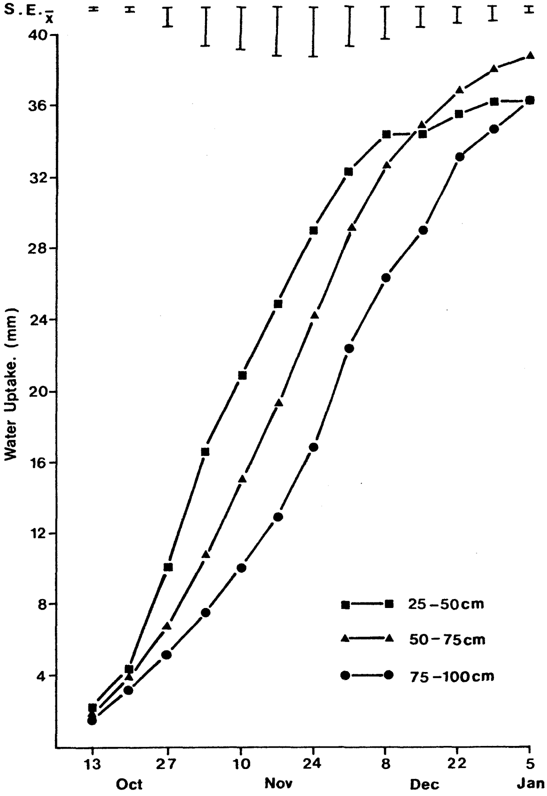

Figure 2: **Average cumulative weekly uptake of water (mm) for all non-irrigated plots for the three (25-50, 50-75, 75-100 cm) soil profiles.**

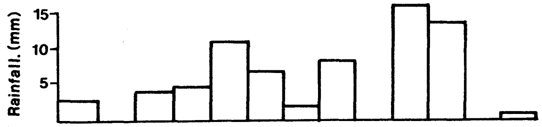

Figure 3: **Total weekly rainfall (mm) from 6 October to 5 January.**

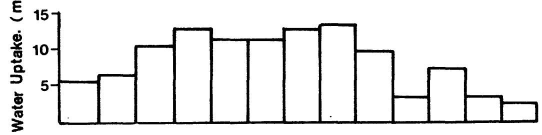

Figure 4: **Average total weekly uptake of water (mm) for all non-irrigated plots for the total soil profile (25-100 cm) from 6 October to 5 January.**

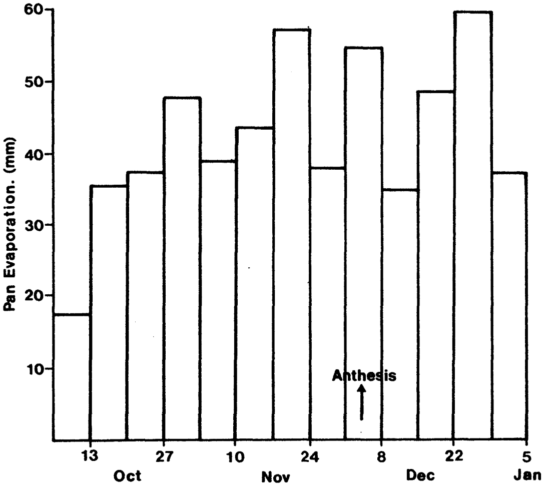

Figure 5: **Total weekly raised pan evaporation (mm) for Lincoln College Metrological Station from 6 October to 5 January.**

TABLE 3: **Total water removal (mm) for all non-irrigated plots for the three individual and total profile zones between 6 October and 5 January.**

	Profile (cm)			Total
	25-50	50-75	75-100	25-100
Start (mm)	72.67	72.41	73.80	218.88
Finish (mm)	36.35	33.49	36.80	106.64
Difference (mm)	36.32	38.92	37.00	112.24
% water used	50.0	53.7	50.1	51.3

anthesis. Figure 2 is the average cumulative total for each profile zone and shows that each zone supplied a similar amount of water. Weekly rainfall totals throughout the soil monitoring period are shown Figure 3, the average weekly water consumed by the total (25-100 cm) profile zone is given in Figure 4 and the Lincoln College Meteorlogical Station raised pan evaporation totals are produced in Figure 5. Figure 6 compares the average weekly water uptake between the irrigated and non-irrigated treatments for the last three weeks monitored. The calculated quantities of water removed during the recorded period for the non-irrigated plots are in Table 3.

DISCUSSION

A feature of these results were the high coefficients of variation obtained (Dalgliesh, 1981) due to large differences recorded between plots with the same treatment. This variation was attributed to the textural complexity of the soil and its resultant effect on water holding capacity (Anon., 1968; Hart 1978) and it was generally greater within individual profile zones than over the whole profile

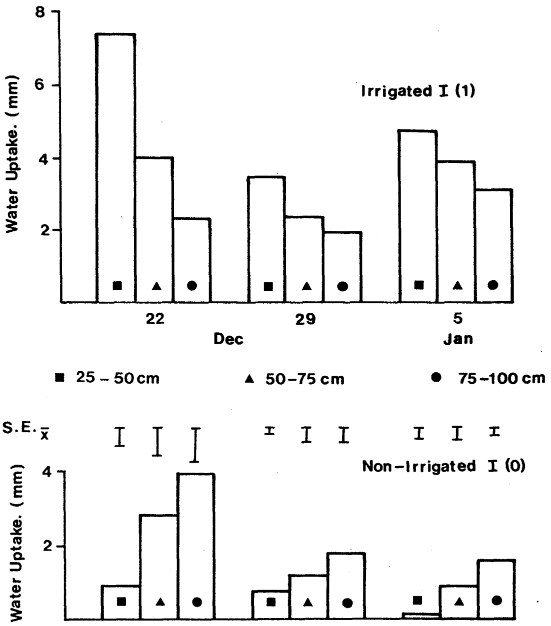

Figure 6: Average weekly water (mm) uptake for the non-irrigated (I0) and irrigated (I1) treatment means for the three (25-50, 50-75, 75-100 cm) soil profiles for the last three weeks monitored.

total. This indicates that the plant water extraction pattern was an integrated function of the whole rooting depth rather than being dominated by specific arbitrarily determined soil profile zones.

Soil water storage is largely dependent on the annual depletion and recharge cycle. Rainfall data over the winter months of this trial was 50% higher than the long term average (Anon., 1973, Table 1) and neutron probe readings in late September showed that all subsoil profiles had reached or exceeded field capacity. Plant water demand is low before the double ridge growth phase as little biomass is produced and soil, air temperatures and solar radiation levels are also still relatively low at this time. All these conditions favour root development near the soil surface rather than subsoil penetration (Evans, 1973).

It was throughout stem elongation when biomass accumulation was accelerating that the monitored profiles showed water depletion occurring faster than natural recharge. Reicosky *et al.* (1972) noticed that as the dry matter production increased so did the demand for water, and root and shoot growth were found by Lupton *et al.* (1974) to be highly correlated over this phase. Throughout this period less rainfall was recorded (Table 1) than the long term average. In unsaturated soil conditions, plant water extraction depends mainly on continued root growth into unexploited moisture reserves of the soil profile (Pearson, 1966). Initially the shallowest measured zone was the largest supplier while the deepest provided least but by grainfilling the situation was reversed (Figure 1). This pattern of soil water utilisation is in agreement with the findings of Hurd & Spratt (1975). As water is removed from the uppermost layer, the gradient in water potential between soil and root decreases and hydraulic conductivity of the soil declines reducing the water flux. As the level of water in the surface diminishes, a gradual change in extraction pattern occurs to the deeper layers. Each profile trend was very similar in the rate of cumulative water absorption (Figure 2) with the shallowest attaining any given level of water usage first, followed by the middle profile and then the deepest. This held true until 8 December after which water removal from the 25-50 cm profile noticeably declined (Figure 2).

Summation of the water extracted each week from the three partial profiles (Figure 1) gives the total weekly profile of water utilization (Figure 4). The average total weekly uptake increased until 3 November, fell slightly for the next two weeks and then rose again for the following two. The first decline could be explained by higher rainfall and lower pan evaporation (Figures 3, 4, 5) placing a temporarily decreased dependence on subsoil water. Previous research with autumn-sown wheat at Lincoln (Scott *et al.*, 1973) indicated that by early December the topsoil 25 cm could be near wilting point. This layer would include the oldest and most suberised roots. Reicosky *et al.* (1972) demonstrated that these roots could still absorb water if it was readily available while Kramer (1933) showed that plants could take up water even through dead root systems. Thus, the roots in the top 25 cm soil layer absorbed and utilized rainfall replacing and conserving water available from the deeper subsurface zones. The importance and volume of water supplied from the topsoil layer to the wheat was not determined in this experiment.

The second decline in the amount of water removed each week from the total profile happened just after anthesis but it cannot be explained in the same way as it coincided with a period of high pan evaporation and no rainfall (Figures 3, 4, 5). This reduction in water uptake was probably related to the cessation of root growth known to occur at that time (Hurd, 1968; Connor, 1975). There is also the possibility that water was being taken up from below the 100 cm subsoil level. As the hydraulic conductivities of the soil above the 100 cm depth decline, the roots could penetrate deeper for higher water potential levels. After the very wet winter, the soil below 100 cm would have been at saturation capacity and this could be a ready source of water for deep root exploitation even though the last three months of the year were drier than normal (Table 1). Kmoch *et al.* (1957) demonstrated that winter wheat roots can extract water from as deep as 2.4 m.

Following the use of irrigation the water extraction pattern in the three profile zones was markedly changed. Whereas non-irrigated plots were removing more water from the deepest profile zone, the irrigated plots had their greatest loss from the shallowest profile (Figure 6). This trend continued for three weeks, until testing stopped, and would be due to the irrigation raising water potential gradients more in the surface profiles than the deeper ones.

All profiles were dried to around 50% of their total water (Table 3). This was about the expected maximum since the neutron probe measures total soil water which includes capillary and hygroscopic water (Gardner, 1965). In normal situations only capilliary or plant available soil water can be used and this portion generally amounts to about half the combined total (Dagg, 1967). Theoretially, Table 3 indicates that approximately all the plant available soil water was removed from the measured profile depths. This demonstrates the importance of root penetration into deeper soil layers for the purpose of extracting water, especially when considering that in the last month monitored, the shallowest to deepest partial profile zones had a total of 1.9, 6.2 and 9.9 mm of water removed respectively (Figure 2).

It is obvious that further improvements could be made to obtain more information from this type of study. Longer access tubes are essential to encompass the plants complete rooting depth. An attempt should be made to estimate water removal in the top 0-25 cm soil profile even though considerable problems would be encountered (Painter, 1977). But the most important requires finding another site if small, but *real*, differences caused by the treatments are to be detected. Ideally the soil used should have a uniform profile so the soil physical parameters do not vary with depth or between sampling sites.

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