# PROBLEMS WITH WHEAT GROWING IN HIGH WATERTABLE AREAS

by

Ary van der Lelij (1), Heather Percy (1) and Wayne Meyer (2),

High watertable situation may be caused by local infiltration or aquifer flow from other areas, e.g. rice fields or channels. Four issues are recognised:

1. How does wheat cope with higher watertables.
2. What are the resulting salinity effects.
3. What are the hydrogeological consequences of wheat growing in conjunction with rice.
4. Is artificial drainage a solution.

The first two issues are discussed on basis of results of an experiment at the CSIRO, DIFR, Griffith silo facility, and the third involves interpretation of soil physical and hydrogeological conditions in the irrigation areas.

## 1. Wheat and High Watertables

The experiment used three soil types and eleven soil cores. The Mundiwa clay loam soil was subjected to watertables at 0.5, 0.65, 0.8, 1.0, and 1.2 metres depth, and the Wunnamurra clay and the Yooroobla clay each to watertables at 0.6, 0.85 and 1.2 metres. The watertable was maintained from below and the water salinity was 1.55 S/m.

The idea for using fixed watertable depths was to simulate the relative differences in topographic height which occur in the landscape. Aquifer systems and groundwater flow cause relative differences in watertable depth, dependent on elevation. Superimposed on this there are all the other processes, including rainfall and irrigation, also affecting watertable behaviour. It is evident from piezometer readings in the district that the long term average level is affected by topography more than by the other factors.

The soil cores were initially non-saline with average EC1:2 of 0.03-0.04 S/m. Upward movement of water from the watertable was monitored. Irrigation applications were based on measured moisture depletion using a neutron probe. Salinity in the cores was measured at three levels using four electrode probes, and occasional sampling.

---

1 Dept. of Water Resources, Griffith, NSW
2 CSIRO, Div. of Irr and Fresh Water Res., Griffith.

Figures 1 and 2 give a picture of the upward movement, as measured and collated for weekly periods over two years. Peaks during the wheat growing seasons, and lows during the fallow period are evident.

A relationship of increased capillary rise to the rootzone with reduced depth to the watertable was found, particularly for the Wunnamurra clay soil. For the Mundiwa clay loam the relationship was not evident during the first year, but during the second season the effect was more apparent. The rate of upward movement is influenced by the frequency of irrigation, which was higher during the second season.

At the beginning of an irrigation interval the upward movement was found to be less than at the end, as expected. The wheat crop evidently benefits from the watertable condition where it is fresh and this may help increase the length of the irrigation interval.

Rainfall was excluded and the irrigation application never exceeded the moisture holding capacity, therefore there were no times during which leaching to deeper layers occurred.

The Wunnamurra clay, which recorded the highest upward movement, required less irrigation, particularly for the 0.6 metres watertable condition. Table 1 shows the relative proportion of plant water use derived from the watertable.

Table 1: Proportion of plant water use derived from watertable.

| Watertable Depth (m) | Wheat 1985 | Wheat 1986 | Sunflower 86/87 |
|---|---|---|---|
| Yooroobla Clay | | | |
| 0.60 | 27.0 | 22.7 | 28.3 |
| 0.85 | 0.8(*) | 3.0(*) | 8.8 |
| 1.20 | 2.3 | 2.7 | 7.0 |
| Wunnamurra Clay | | | |
| 0.60 | 47.8 | 43.6 | 15.1 |
| 0.85 | 28.4 | 22.6 | 34.1 |
| 1.20 | 8.8 | 9.8 | 17.3 |
| Mundiwa Clay Loam | | | |
| 0.50 | 13.0 | 5.1 | 5.5 |
| 0.65 | 7.1 | 4.0 | 6.5 |
| 0.80 | 10.2 | 1.2(*) | 7.6 |
| 1.00 | 10.5 | 1.6 | 9.6 |
| 1.20 | 8.1 | 1.8 | 13.5 |

**(*) Plants died.**

The results are in line with the work by Mason, Meyer, Smith and Barrs on the contribution of watertables to the growth of wheat, and similar effects recorded for Maize at Allan Irvins property during the seventies [3]. There may be a significant contribution to plant water use from the watertable. The apparent reverse behaviour of sunflowers for Mundiwa clay loam is interesting, and may be explained by the adopted method of irrigation management. The deeper watertable soil core received relatively less irrigation for its crop water demand, causing it to extract from deeper layers.

In all cores the watertable condition was induced from below and maintained at a constant level. This is probably more favourable than a watertable induced by local infiltration, which would increase waterlogging, or a fluctuating watertable, which would kill off some of the root system from time to time.

The yield of the wheat plants showed no relationship with the depth to the watertable for either soil the first or the second year.

## 2. Salinity Effects.

It would normally be expected that wheat would show a decline in yield as the soil salinity increases, in line with Maas and Hoffman [4]. These writers warn about interpreting yield/soil salinity relationships in high watertable situations, particularly where it is relatively fresh.

The cores were non-saline to start with to a depth of 1.35 metres. The volume of moisture in the cores was about 400 mm. This was gradually being replaced by the induced watertable, at a rate of less than 1 mm/week during fallow periods, and up to 20 mm/week for the highest watertable condition in the Wunnamurra clay.

There was no leaching, except from the surface horizon to lower layers of the rootzone and all upward movement represents the increased salinity in the soil above the watertable. The rate of salting was slow however, and it was calculated that for the 1985/86 management the time to replace all the moisture in the core by the saline groundwater would be 9 years for the Mundiwa soil, but only 1.5 years for the Wunnamurra clay, 0.6 m watertable.

---

3. **Mason, W.K., Meyer, W.S., Smith, R.C.G., and Barrs, H.E., 1983. Water Balance of Three Irrigated Crops on Fine Textred Soil of the Riverine Plain. A.J.Mgr. Res. Vol. 38 pp183-91.**
4. **Maas E.V. and Hoffman M., 1977. Crop Tolerance - Current Assessment. J. of Irr. and Dr. Div., ASCE, IR2.**

To minimise upward movement and the rate of soil salinisation it appears desirable to keep the watertable at 1.2 metres or deeper (Figures 1 and 2, Table 1). Even at that level upward movement may be significant, as evidenced by the sunflower crop in Mundiwa clay loam during 1986/87.

The yield of wheat during the second season did not show a significant relationship with the soil salinity in the top 0.6 metres. For the sunflowers after the second wheat crop the yield relationship is much more significant.

Salts had accumulated in the Wunnamurra clay, high watertable condition cores to levels above ECex 0.6 S/m (converted from EC1:2) during the second wheat season, apparently without affecting yield. This is mainly the effect of the crop being well watered at frequent intervals.

For Mundiwa clay loam it may take a long time for salinity effects to become apparent in irrigation areas after the watertable has risen to a new equilibrium level. In the field it is likely to be longer than in the experiment as winter rainfall would give some leaching of the surface horizons. The rainfall leaching would be least effective in very high watertable conditions, however with a watertable at 1.0-1.2 metres, which are common, periods well in excess of 9 years for the effects to be noticeable may be expected.

On the other hand the Wunnamurra clay appears much more susceptible to the salting process. Since these latter soils are often found in areas of lesser elevation, this is a worrying aspect.

Since high watertable conditions in many areas are quite recent, gradually worsening problems will affect future productivity of crops like wheat may be expected.

The time scale for problems to develop also depends on the irrigation regime, rotation with other crops, and aquifer characteristics, as well as the salinity of the groundwaterm which varies from as low as 0.5 S/m to 30 S/m across the Murrumbidgee Irrigation Areas.

## 3. Hydrogeological consequences of Irrigation Practices.

High watertables are caused by rainfall, seepage from channels and irrigation. The irrigation effect is determined by the intensity of the application across the landscape, and modified by soil type. In the MIA and Coleambally the application rate is in the order of 6-10 ML/ha, much of which is diverted to rice.

Tables 2 and 3 show that increased rice growing leads to a larger proportion of the area having a high watertable. The watertable distribution varies for seasons and is estimated for September and March in an average rainfall year [5]

---

5. van der Lelij, A. 1981. Tubewell Drainage Requirement associated with rice growing near Griffith, NSW. Proc. ANC -ICID Seminar on Drainage of Agr. Lands, Melbourne, May 1981.

Table 2: Distribution of September levels for different proportions of land under rice.

| Category | 36% rice (%) | 24% rice (%) | 17% rice (%) |
|---|---|---|---|
| within 1.0 metres | 34 | 15.6 | 6.4 |
| within 0.8 metres | 22 | 7.2 | 2.8 |
| within 0.6 metres | 12 | 3.2 | 1.1 |

Table 3: Distribution of March levels in non-rice area for different proportions of land under rice.

| Category | 36% rice (%) | 24% rice (%) | 17% rice (%) |
|---|---|---|---|
| within 1.0 metres | 48 | 38 | 20 |
| within 0.8 metres | 31 | 25 | 10 |
| within 0.6 metres | 20 | 15 | 5 |

The September average level is significantly correlated to the winter rainfall and the proportion of land under rice the previous year, i.e. there is a residual effect. The level of the watertable in March at any point is a significantly correlated to the time_average September level for that point (representing elevation) and the distance to the closest rice field.

Regression analysis of watertable distribution in an area near Hanwood for September suggests that the proportion of rice should be less than 28% to achieve an average watertable of 1.20 metres [2]. However even if rice was restricted to this proportion of the land, the watertable between rice fields would still be high in March, as shown by Table 3.

Rice growing is known to allow percolation throughout the ponding season. Even with clay soils this may be significant, rates of 30-2000 mm having been recorded over a rice season. The median is probably less than 100 mm for areas with high watertable conditions.

Section 1 suggests that careful irrigation management of wheat on clay soils results in no leaching, with a net upward movement to above the watertable, particularly during the period of peak growth. Leaching could only be expected when the soil is near saturation. Such periods could occur during the pre-sowing irrigation and early in the season, when the evaporative requirement of the crop is low. Leaching would also occur if the crop was over irrigated, but this may result in waterlogging loss of production.

The ability of wheat and safflower to extract moisture from deeper layers in the profile has also been demonstrated in the Lower Macquarie Valley, e.g. T.S Abbott et al [6]. This happens particularly when the plant water requirement exceeds the infiltration capacity of the soil. Figure 1 and Table 1 show that sunflowers, particularly when under-irrigated will extract moisture from layers deeper than 1.2 metres.

Over the whole landscape there is an imbalance which is being redistributed by groundwater movement through the underlying aquifer systems, forced by gradients related to topography and watertable depth. This imbalance may eventually result in increased salinity of depressed areas and the areas that are subject to less irrigation induced percolation.

It has been observed over many years that areas that are not irrigated end up with a salinity problem. From the above other areas that are irrigated at a less than average irrigation intensity are also at risk.

The idea that certain 'suitable' parts of farms may be set apart for rice, leaving other areas for other irrigated cropping is not supported for long term implementation. Very little land is completely suitable, or completely unsuitable, most land being in the intermediate category, having rice capability but not without restrictions. There is benefit in a system with crops grown in a rotational system.

Simulation models to describe the process of lateral movement in a situation with rice growing and irrigation of other crops are in the process of being developed. In these models the processes of capillary rise and the changes in soil moisture due to rainfall, irrigation and evapotranspiration are simulated, allowing the assessment of the percolation from rice fields, rainfall, other irrigation and channel seepage, and the groundwater flow between model cells for each time step.

These models are complex and require many calibration factors. Whilst early results are encouraging it is realised that further validation of algorithms used in the soil moisture routines against field experimentation is essential. This is being planned.

---

6. Abbott T.S. et al, 1987. Effect of deep rooting rotation crops on sodic grey clay. Proc. ASSS (Riv. Branch) Soils Conf, Deniliquin, May 1987.

The potential for such a model would be to estimate the rate of groundwater transfer between different parts of the irrigated landscape and the resulting salinity hazard. The resulting proportion of land requiring artificial drainage to maintain productivity is the ultimate objective.

## 4. Artificial Drainage

If watertable conditions are high and result in salinisation then artificial drainage may provide a solution.

Experience has shown that where the transmissivity in the aquifer is sufficiently high that drainage by aquifer pumping is feasible at reasonable cost. In many locations however the transmissivity is low ($<50$ m^2/day) and aquifer pumping becomes problematic.

Horizontal drainage is feasible if the soil at the level of the drains is sufficiently permeable. A survey of hydraulic conductivity in the Bilbul and Kooba areas showed that this is not the case in many instances [7]. In addition the cost of horizontal drainage is usually prohibitive when compared to the value of production of the current agricultural system. Presently the cost of a metre of 90 mm drain is about $ 5 and several hundreds of metres per hectare may be required.

In experiments with horizontal drainage in large area farms a hybrid system has been used, with spearpoints into the aquifer at about 9-12 metres depth relieving pressure into the horizontal collector drain at about 2 metres depth. The spearpoints may be installed cheaply and allow a wide drain spacing.

The main limitation to adoption of artificial drainage is the disposal aspect. Whilst alternative options for disposal are still being evaluated, no solution that would allow unlimited drainage is at hand. The Department of Water Resources has placed an embargo on further disposal from non-horticultural land until the evaluation process has been completed.

On-Farm evaporation areas have been suggested as another alternative. Two of these are currently being used on an experimental basis. The indications are that some seepage is taking place from these sites.

While artificial drainage is not showing promise on a large scale the emphasis has to be on irrigation management.

---

7. van der Lelij, A., 1984. Soil Permeability and Drainage Factors affecting Irrigation Water Quality in the Murrumbidgee Valley of NSW. Proc. ASSS. Symp. on Root Zone Limitations to Crop Prod. on Clay Soils. Griffith, Sept. '84.

FIGURE -1

CAPILLARY RISE FOR MUNDIWA CLAY LOAM

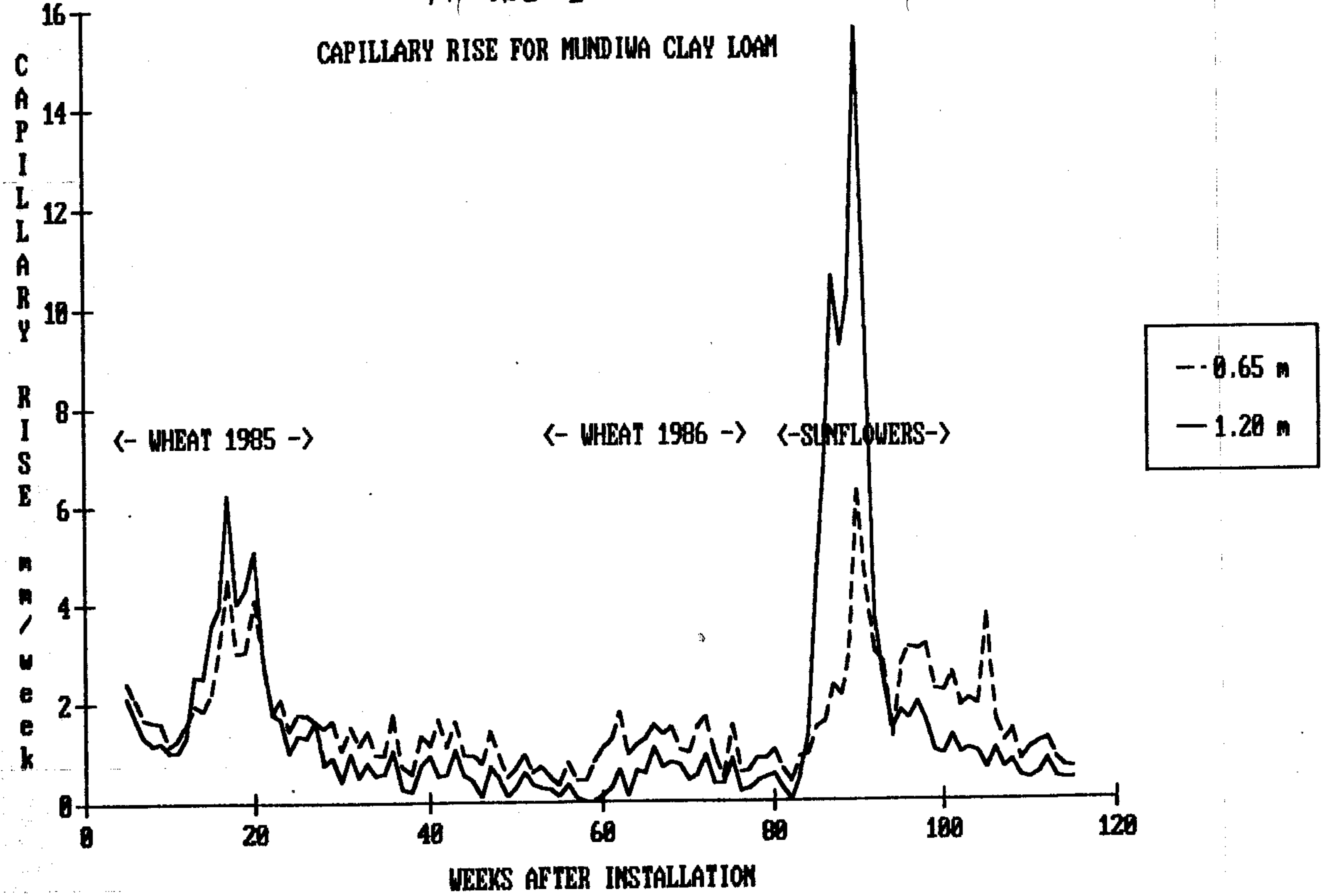

Figure 2 : Wunnamurra Clay - Capillary Rise.