What happens to fertiliser nitrogen?

Summary: High inputs of nitrogen (55 kg N/ha) at sowing in 1997 resulted in a yield loss of around 15%, compared to zero applied nitrogen. The crop with a high rate of nitrogen fertiliser produced more dry matter at flowering (+ 20%) compared to the zero nitrogen crop. The soil under the nitrogen fertiliser treatment was significantly drier at harvest compared to the zero nitrogen treatment, so it is highly likely that the crop under this treatment ran out of water at the end of the season. The extra nitrogen applied was not measurable in the soil at harvest. It is not known what has happened to this nitrogen - it was not leached (too dry), it could have been volatilised (into the air) or it could be transformed from available mineral nitrogen to unavailable organic nitrogen by soil microbes.

The crop yielded less than 33% of potential according to Water Use Efficiency principles. The yields were similar compared to the yields obtained in Trial 4 under the no cultivation treatments (crop affected by Pratylenchus). It is possible that high levels of root lesion nematodes (Pratylenchus) have played a role in limiting production.

The subsoil at the site was also extremely hostile to root growth. At depths of 40cm and deeper the soil contained boron and sodium at levels toxic to plant roots. It is suspected that these hostile conditions also played a part in limiting production.

Background: Nitrogen management is difficult to get right every year. Knowing how much and when to apply N are management issues which still have not been resolved. Putting all N requirements in the ground at sowing is a risky practice if it turns into a dry year, not putting out the requirements at sowing is a risky practice if it turns into a wet year because topdressing N has had very variable results. We initiated this trial to find out what happens to N fertiliser which is pre-drilled (ie. how much ends up in the plant and grain; how much is lost from leaching or water logging).

Aim: To determine what happens to pre-drilled N on southern Mallee clay-loam soils.

Methods: Two blocks of Frame wheat were sown on June 6, with Mallee Mix 1 at 80kg/ha. One block, **+N,** was pre-drilled with Urea at 120 kg/ha (55kg N/ha) The other block, **-N,** had no urea. Soil samples were taken to a depth of 0.9m for available soil water and nitrogen at sowing, flowering and harvest. Piezometers to record periods of waterlogging were installed but were not needed.

Results:
Water use, nitrate use and yield were measured. Using these measurements a picture of N and water use is presented.

Water use (reported as mm v/v)

depth cm	Soil water mm	Soil water - N mm		Soil water + N mm	
	Sowing	Harvest	Used	Harvest	Used
0-10	30	13	17	16	14
10-30	53	45	8	37	16
30-50	58	54	4	45	13
50-70	71	61	10	62	9
70-90	78	74	4	63	15

total	**289**	**248**	**43**	**222**	**67**

The soil profile under the +N treatment was dry (remaining soil water was not available to the plant), and it is highly unlikely that the crops used much water, if any, at depths greater than 40cm because of hostile soil conditions (see soil conditions below). The +N crop used 67mm of soil water, whereas the -N crop used 43 mm of soil water.

Yield and Water Use Efficiency

Treatment	Rainfall mm	Soil water used mm	Yield (t/ha)	WUE# (kg/mm/ha)
-N	190	43	0.90	7.3
+N	190	67	0.78	5.3

calculated as WUE = Yield (kg/ha) / (Growing Season Rainfall + Soil water used - Evaporation (110mm))

Yield was very low in this trial which was not only due to the lack of rain. The Water Use Efficiencies of the crops were about 1/3 of what is attainable. This could be due to later than optimum sowing (early June), poor subsoil conditions (inhibiting the uptake of water and nutrients deeper in the subsoil), or root diseases (see Trial 4, Pratylenchus results). The timing of rainfall could also have played a role, the +N crop was more advanced and the rain in late October may have been too late.

At flowering the dry matter of the -N crop was less (0.79 t/ha) compared to the +N crop (0.94 t/ha). This implies that growth rates, and therefore water use, was higher for the +N crop.

Soil available Nitrogen used (measured as soil nitrate)

depth cm	Sowing kg N/ha	- N treatment kg N/ha			+ N treatment kg N/ha		
		flowering	harvest	N used#	flowering	harvest	N used#
0-10	13	7	13	0	6	14	-1
10-30	39	19	26	13	36	22	17
30-50	36	15	3	33	56	11	25
50-70	3	5	2	1	6	10	-7
70-90	3	5	3	0	3	8	-5
total	**95**	**50**	**46**	**47**	**108**	**65**	**29**

(difference in kg N/ha between harvest and sowing)

Soil nitrates (kg N/ha) are reported for sowing, flowering and harvest for the -N (no urea) and +N (pre-drilled urea) plots, in the above table. The interesting observations are the soil nitrate values in the soil at flowering and harvest. In the +N treatment, the urea could be measured in the soil as elevated levels of soil available nitrogen (as nitrate) at flowering. At harvest the soil available nitrogen (nitrate) levels were much lower. This indicates that soil nitrate was 'lost' from the soil between flowering and harvest on the +N plot.

Treatment	N applied kgN/ha	soil N used kg N/ha	Yield (t/ha)	Protein %	N removed in grain kg N/ha	NUE# %
-N	6	47	0.90	15.0	25	47
+N	61	29	0.78	15.6	21	23

Nitrogen Use Efficiency = 100 x N removed in grain / (N applied at sowing + soil N used)

Note: the above calculations do not include a mineralisation factor. The estimate for mineralisation during the 1997 season was 29 kg of N/ha. If the expected mineralisation was included in the calculation then the Nitrogen Use Efficiencies would be less (30 and 13% respectively for the -N and +N treatments).

The +N treatment did not yield as well as the -N treatment. In addition, the nitrogen applied could not be accounted for at harvest. The +N crop had a low Nitrogen Use Efficiency. It is not clear where, or in what form, the applied nitrogen was at harvest. We can only speculate that the applied nitrogen was either volatilised (lost as ammonia in the air) or it was changed from the available form of nitrogen (nitrate) to the unavailable form (organic nitrogen) by soil microbes.

Soil chemical condition

The trials at Birchip in 1996 clearly demonstrated the hostile conditions for root growth in the subsoil. The soil at this site was again analysed to depth.

Depth	**pH water**	**EC* dS/m**	**Boron ppm**	**ESP# %**
0-10	8.0	0.24	3.2	7
10-20	9.1	0.31	9.5	16
20-30	9.3	0.55	22.4	26
30-40	9.3	0.73	21.8	32
40-50	9.2	1.04	11.8	36
50-60	9.1	1.23	24.9	37
60-70	9.0	1.42	18.0	38
70-80	8.8	1.78	26.6	40
80-90	8.8	1.76	25.0	8

* = Electrical conductivity (measurements of salt)
# = Exchangeable Sodium Percentage (measure of sodicity)

These results show the extreme nature of the subsoil. The electrical conductivity (measure of salts) restricts root growth at 0.9 dS/m, Boron at 15 ppm and ESP (sodium as a % of the cation exchange complex) at greater than 20%. The subsoil at this site at 30 to 40 cm is hostile to root growth.

Beside the toxic conditions in the subsoil the site was probably also affected by root lesion nematode (Pratylenchus). The results from Trial 4 clearly demonstrated the increased effect of the nematodes in the plots which were not cultivated compared to the long fallow treatment. The plot in this trial had not been fallowed.

Where has the Nitrogen gone?

- the applied nitrogen as urea was not measured in the soil as available nitrogen at harvest
- the applied nitrogen did not leach out of the profile
- the applied nitrogen did to some extent go into early growth (more dry matter at flowering) and the +N crop ran out of moisture during the end of the season and yielded less than the -N treatment (the soil under the +N treatment was drier than under the -N)
- the applied nitrogen did not go into yield or protein
- has the applied Nitrogen volatilised (into the air)?
- has the applied Nitrogen gone into the organic N pool through microbial action?

There are still many answers required before we can be confident on how to manage this important and expensive input to our farming systems. There is little chance that we can work out a profitable N management system if we do not know what happens to applied nitrogen in our cropping soils.

This site will be measured again in April to see whether summer rains have assisted in releasing some of the nitrogen applied as fertiliser in 1997, back to a plant available form.