

# Efficient use of Nitrogen fertilisers

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One of the cotton industry's goals is to ensure that inputs such as nitrogen (N) fertiliser are used efficiently. Nitrogen fertiliser prices have risen recently, as they are closely linked to oil prices. N fertiliser manufacture requires a high input of energy — natural gas is often used. So N fertiliser manufacture also contributes to our greenhouse gas emissions.



Many growers also wonder how efficiently the N fertiliser they apply is used.

This article reports on how the industry can undertake N efficiency benchmarking studies, what measurements are required and provides some background information on the efficiencies measured in some cropping systems experiments and in commercial cotton crops during the past season.

Growers cannot afford to under-fertilise with N (or other nutrients) and over-fertilising is wasteful of N, can reduce yield, delay harvest and add to greenhouse gas emissions. In making a decision on how much N fertiliser to apply, it is imperative to consider the amount of N in the seed bed at sowing and the crop rotation system, which dictates how much N will be come available through the season. The NutriLOGIC program can provide a good estimate of the N fertiliser required, based on soil nitrate-N levels determined in the winter prior to sowing.

Cotton crops derive most of their N from soil N, rather than the N fertiliser applied. Soil N is made available to the crop as organic materials in the soils are decomposed. In fallowed soil, small rates of N fertiliser may be required and following legume rotations, no fertiliser N may be required. The N fertiliser merely tops up what the soil cannot supply.

But large losses of N fertiliser can occur,

because most of our cotton-growing soils are medium to heavy clays that are prone to waterlogging following flood irrigation or heavy rain. N fertilisers can be used inefficiently under these conditions, as N can be lost through denitrification (particularly if the soil is waterlogged) and from leaching of nitrate-N into the subsoil beyond the crop's root zone.

High N fertiliser efficiency can be achieved through careful irrigation management, by maintaining well-aerated and well-structured soil and by matching N fertiliser applications to the crop's demand for N.

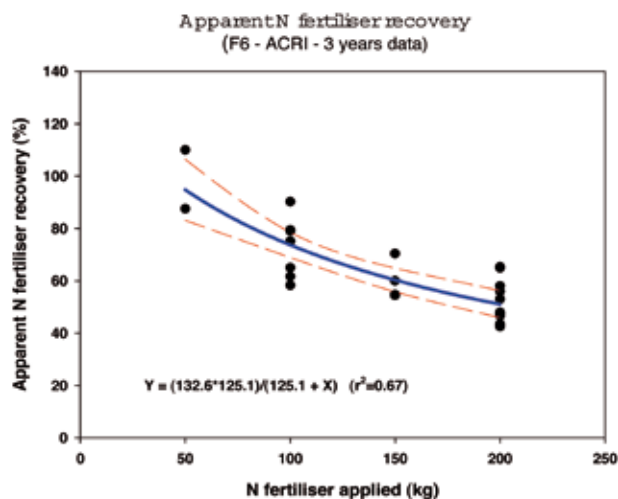
## DEFINITIONS

### Crop N uptake

This term refers to the quantity of N contained in the crop (the small amount of N in the root system is not normally included). Crop N uptake is determined at cutout, before leaves start to drop.

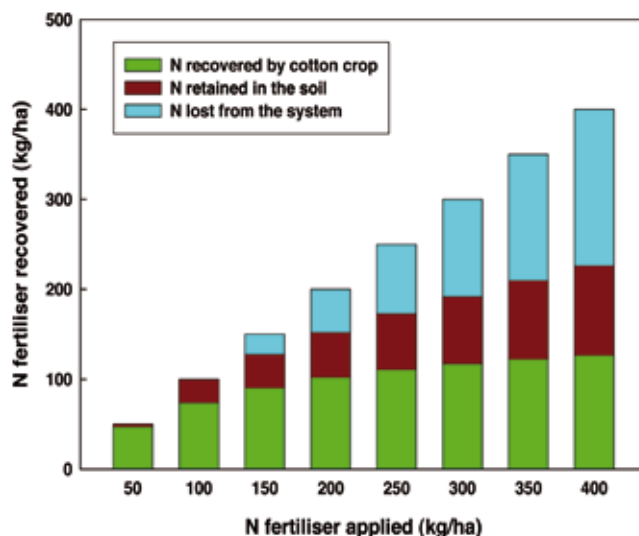
Cotton crops normally take up about 200 kg N per hectare. Measuring crop N uptake is a laborious and technical task. It requires sampling one square metre of crop (whole plants), drying, weighing, grinding and analysing the plant material for N content. But it is the most convenient way to assess how efficiently N is used by cotton crops, and also indicates whether the crop was under or over-fertilised with N. This

**FIGURE 1: Apparent nitrogen fertiliser recovery by cotton crops as influenced by the amount of N fertiliser applied**



Dotted lines represent the 95 per cent confidence intervals which indicate a close and significant relationship.

**FIGURE 2: The fate of N fertiliser applied to cotton crops growing in light-medium clay soil — losses will be greater from heavier soils**



measurement is needed to help growers and consultants manage N fertiliser inputs and provide alternative N fertiliser management practices where required.

### Apparent nitrogen fertiliser recovery (NFR)

This is the proportion of the applied N fertiliser that is taken up by the crop, expressed as a percentage. It is calculated by taking the difference in crop N uptake between fertilised and unfertilised cotton, divided by the rate of N fertiliser applied.

This measurement is taken after cut-out when the crop has accumulated almost all of its N. NFR is rarely measured in commercial fields as growers' are often reluctant to install small zero fertiliser plots. But the very small cost involved in potentially reducing yield within these plots is offset by the valuable information gained on the effectiveness of N fertiliser use.

### Crop nitrogen use efficiency (NUE)

This measurement indicates how effectively a crop produces lint yield from the N that it has accumulated. It is measured by dividing lint yield by the crop N uptake (that is, kg lint produced per kg N uptake). The crop NUE measurement does not discriminate between soil N or fertiliser N sources and therefore is independent of how much N fertiliser was applied. It indicates how efficiently the cotton crop uses all N sources available to it.

Generally, soils with naturally high N fertility will have poorer NFR and crop NUE, because the crop accesses most of its N from the soil and little N fertiliser is required.

### Determining benchmark levels for NFR and crop NUE

The data shown here are taken from cropping systems experiments where N rates (0 to 200 kg N per hectare) were applied to cotton grown after various rotation crops. These experiments provided a wide range of inherent soil N fertility levels, as some rotation systems had included several legume crops over the past decade. The range of N fertiliser rates chosen were sufficient in each rotation system to achieve maximum lint yield (yield decreased with higher N fertiliser application).



This defined the optimum amount of N fertiliser required. The economic optimum N fertiliser rate was identified as the rate beyond which it is no longer worthwhile to apply more N fertiliser (the extra yield produced did not pay for the extra N applied).

Crop N uptake and lint yield were measured in all plots to determine NFR and crop NUE. These data were collected over three seasons in which yields ranged up to 12 bales per hectare.

NFR was reduced as N fertiliser rates increased. Generally, small amounts of N fertiliser are used more efficiently, and higher rates less efficiently (Figure 1). The soil used here was light-medium clay. NFR is normally lower in heavy-textured (clayey) soil, as denitrification is more prevalent due to poorer aeration, particularly following flood irrigation which can produce waterlogging.

Normally, NFR in heavier clay soils would be 20–25 percentage units lower than the line displayed in Figure 1. Soil compaction produces a similar effect.

### Fate of fertiliser N

At higher N fertiliser rates, the soil and crop retain a smaller proportion of the N applied and a greater proportion is lost from the system through denitrification and leaching (Figure 2). Where there is a high level of native N in the soil, cotton crops make limited use of N fertiliser, especially when applied at high rates. If the line shown in Figure 1 was extrapolated to 400 kg N per hectare, the NFR would decline to only 32 per cent. This decline in NFR is illustrated in Figure 2, where at 400 kg N per hectare fertiliser N applied, only 128 kg N per hectare (32 per cent of the 400 kg N per hectare) are recovered by the crop.

Soil has a finite capacity to retain fertiliser N and when this is exceeded, N is lost from the soil/plant system (42 per cent of

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the 400 kg N per hectare applied in this example). These results have been confirmed by measurements of greenhouse gas emissions that are exacerbated by N fertiliser application in excess of the crop's N requirement (see Peter Grace's research in *Australian Cottongrower* October–November 2004, pp 8–10).

Cotton crops need to accumulate only 200–250 kg N per hectare to achieve the maximum yield. While cotton crops may accumulate in excess of 400 kg N per hectare, N uptake in excess of 250 kg N per hectare will not increase lint yield.

Crop NUE will be reduced in these cases. For example, where a crop can normally acquire 150 kg N per hectare from the soil N, application of 200 kg N per hectare will lead to a poor NFR of 25–50 per cent, as the crop will only need to accumulate 50–100 kg N per hectare from the fertiliser.

Crop Nitrogen Use Efficiency also showed a decline where higher N fertiliser rates were applied (Figure 3). Where N fertiliser is used efficiently, the crop NUE value will be close to 11.1 (+0.3) kg lint per kg crop N uptake. This value was derived from the three years of experimental data and is the point where the amount of crop N required was matched by that supplied from all sources (soil N + fertiliser N).

Larger values of NUE indicate that too little N fertiliser was applied or possibly that

**TABLE 1: Examples from last season**

Sites	N applied (kg/ha)	N uptake (kg/ha)	Lint yield (kg/ha)	Crop NUE	NFR (% of applied)
Farm A	0	183	1521	8.3	
	100	238	1603	6.7	55
	200	239	1080	4.5	28
Farm B	203	271	2910	10.7	
	241	409	2670	6.5	
Farm C	170	217	2180	9.9	

the crop was stressed. Values smaller than 11.1 indicate that excessive amounts of N fertiliser were applied or that possibly yield was reduced by poor growing conditions late-season or pest damage.

**COMMERCIAL EXPERIENCE**

During the 2005–06 season, a number of fields were sampled to indicate the range of values for crop NUE and NFR that growers achieved in commercial cotton crops. These fields may not necessarily be representative of the cotton industry at large.

At Farm A, the lack of response to N fertiliser was obvious and this was supported by the low values of crop NUE. N fertiliser recovery decreased as N rate increased — the relatively low values are indicative of the high clay content of this soil.

In fact, the second 100 kg N per hectare applied produced little extra N uptake by the crop and reduced lint yield, indicating very inefficient use of the additional N fertiliser.

At Farm B, in one field, high yields were achieved with moderate use of N fertiliser to achieve optimal crop NUE, while in an adjacent field on this farm, higher N fertiliser input produced greater crop N uptake and reduced lint yield, which reduced crop NUE substantially. Both fields had long fallows before this cotton crop.

At Farm C, the grower applied slightly more N than what was required at this site.

During the 2006–07 cotton season, many commercial cotton crops will be assessed in several valleys for crop nitrogen use efficiency and for N fertiliser recovery where zero N fertiliser plots have been installed. This will help provide benchmark values for crop NUE and NFR for future reference and grower comparison.

**How to improve crop NUE**

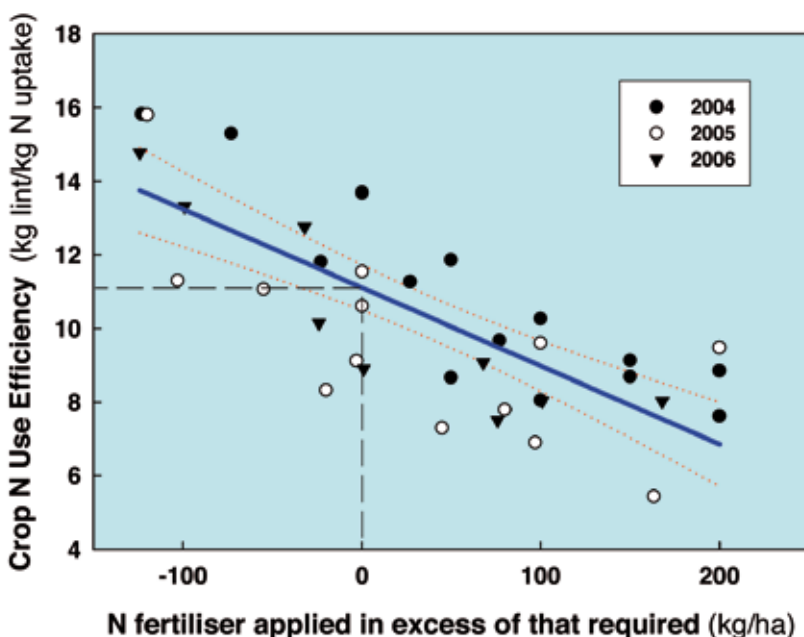
The data gleaned from the experiments and commercial fields over the past three years have indicated the ranges of N fertiliser use-efficiencies as benchmarks that the industry should aim for. High cotton yields are not necessarily achieved by applying higher rates of N fertilisers, but more commonly, through careful water, soil, pest and nutrient management.

High N fertiliser efficiency can be achieved through careful irrigation management, maintaining well-aerated and well-structured soil and by matching N fertiliser applications to the crop's demand for N. The revised NutriLOGIC program can provide a good estimate of the N fertiliser required, based on soil nitrate-N levels determined in the winter prior to sowing.

Aiming for high crop NUE makes economic sense. In many instances, lower N fertiliser inputs will achieve this, as well as reducing potential environmental problems, including greenhouse gas emissions.

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**FIGURE 3: Crop N use efficiency declines with N fertiliser application**



Dotted lines represent the 95 per cent confidence intervals which indicate a close and significant relationship.