On-farm testing of the Sirius Wheat Calculator for N fertiliser and irrigation management

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Abstract

The Sirius Wheat Calculator is an irrigation and nitrogen scheduling decision support system (DSS) based on a wheat simulation model. It estimates yield and economic impacts of variations in management and weather. The system was installed with 10 farmers for their evaluation during the 2001/02 wheat season in Canterbury. Feedback from the farmers during the season led to substantial improvements to the DSS during the project. On five of the farms, experiments were conducted to compare the performance of crops whose nitrogen fertiliser management was decided according to farmer best practice, those where N management was decided using the calculator, and those where no fertiliser N was used. The calculator accurately predicted both absolute yield and response to management variations in most cases. The exceptions were where disease severely limited crop production (one farm) and where the depth of soil to the underlying stony layer was insufficient to allow adequate sampling of soil mineral N (one treatment on one farm). Even in these cases the calculator was useful in assessing the cost of the disease, and the value of the mineral N unaccounted for. The reaction to the calculator amongst the farmer group has been enthusiastic. They all want to continue in an enlarged project and have provided very good feedback on the usefulness of the system as it stands, and on desirable futures features. Their advice will lead to modifications in the calculator for the next release.

Key words

Triticum aestivum, takeall, simulation modelling.

Introduction

Irrigation and N fertiliser are significant costs in wheat production and, in combination, have the potential to cause adverse environmental impacts through leaching of mineral N into aquifers. Hence, much time and effort has been spent in developing methods of assessing demand for and effects of both water and N in crop production. This has been much more straightforward for water than for N, because the sources, sinks and consumptive use of water are well understood, easily calculated, and the data needed for the calculations are often readily available. On the other hand, although the size of the main plant sink for N can be readily calculated, soil mineral N can come from several sources (1). The sizes of the non-fertiliser pools are not always easy to calculate, depend to some extent on history and, for various reasons, not all soil mineral N can be extracted (2,3). The dynamics of N in the system is understood, if not always adequately parameterised, so that the rise in the availability and use of simulation models (4,5,6) provides some hope of improving recommendations for N management.

The Sirius Wheat Calculator is a new DSS based on the wheat simulation model Sirius (7). Sirius accurately simulates the effects of restrictions in water supply (8) and N (9). Although Sirius was developed initially as a scientific tool for testing hypotheses about plant growth processes, it is robust and simple enough to be tailored as a DSS. Importantly, most of its development has been in a modern computer language (C++) so that software modifications to produce the DSS have been straightforward. The purpose of the project reported here was to provide such tests by comparing model-directed management against the best practices of skilled wheat growers. Such a test also provided an avenue of feedback from the DSS users to the developers, so that that the DSS could be tailored towards the real needs of the growers.

Methods

A draft version of the Sirius Wheat Calculator, developed in the six months prior to commencement of the project, was installed on the computers of 10 farmers in mid-Canterbury in July of 2001. On five of the farms, experiments were set up within a wheat field already sown by the farmer. These consisted of three treatments replicated three times in a randomised block design. The treatments were:

1. N fertiliser applied according to farmer best practice as decided by the participating farmer. This treatment is designated “farmer”

2. N fertiliser applied according to decisions made in conjunction with the wheat calculator. This treatment is designated “model”

3. No N fertiliser. This treatment was designed to test the ability of the system to supply N to the crop. This treatment is designated “nil”

Actual application amounts and dates are given in table 1.

Table 1. Nitrogen fertiliser application dates and amounts.

	Evans	Lepoutre	Lilley	Williamson	Wright
"Farmer" treatment					
1st date applied	8-Oct	8-Nov	8-Nov	25-Sep	8-Oct
kg N/ha	120	92	90	76	32
2nd date applied	31-Oct			8-Oct	23-Oct
kg N/ha	120			92	69
3rd date applied				12-Nov	19-Nov
kg N/ha				58	69
Total N: kg/ha	240	92	90	226	170
"Model" treatment					
1st date applied	26-Sep			8-Oct	23-Oct
kg N/ha	90			90	60
2nd date applied	8-Nov	8-Nov	12-Nov	12-Nov	19-Nov

kg N/ha	150	46*	170	100	40
Total N: kg/ha	240	46	170	190	100

* In this case the model recommendation was actually no N fertiliser, so 46 kg N/ha was applied to provide a treatment different from the control.

Plots 2.5 m x 10 m were marked out within the crop and isolated with herbicide strips (Glyphosate applied with a weed wiper). At the time of set-up, augured soil samples were taken to 90 cm or to the gravel layer, whichever was shallowest. Mineral N was measured in each layer (0-15, 15-30, 30–50, 50–70, and 70-90 cm) and total N was measured in the upper two 15 cm layers. N fertiliser was applied as urea according to the treatments at each site. At intervals through the season the soil under the crop was sampled to the initial measurement depth and soil mineral N measured. Crop yield and seed weight from the plots were measured at maturity.

Experimental Results

Treatment yields at 14% moisture varied from 4.5 to 14.3 t/ha. On all but one farm, and one treatment on another farm, predictions of yield from the calculator were very close to those observed in the plots, and response to applied N fertiliser was accurately predicted (Fig. 1). One of the exceptions (Williamson site) was associated with a severe Take-all (*Gaeumannomyces graminis var. tritici*) infection that reduced yields substantially, and predictions exceeded measured yields by more than 2 t/ha when no N fertiliser was added, and by more than 5 t/ha when N fertiliser was added (Table 2). The other exception was where measured yield without added N exceeded calculated yield by about 5 t/ha (Evans site, Table 2). In this case sampling of soil N was severely restricted because the depth to stones was only 30 cm and apparently not all of the soil N was accounted for in the calculations. With these outlying plots excluded, the model accounted for 81% of the variation in wheat yield over a two-fold range (Fig 1.), and the root mean square error (RMSE) of predictions over these 11 treatments x farm combinations was 0.9 t/ha.

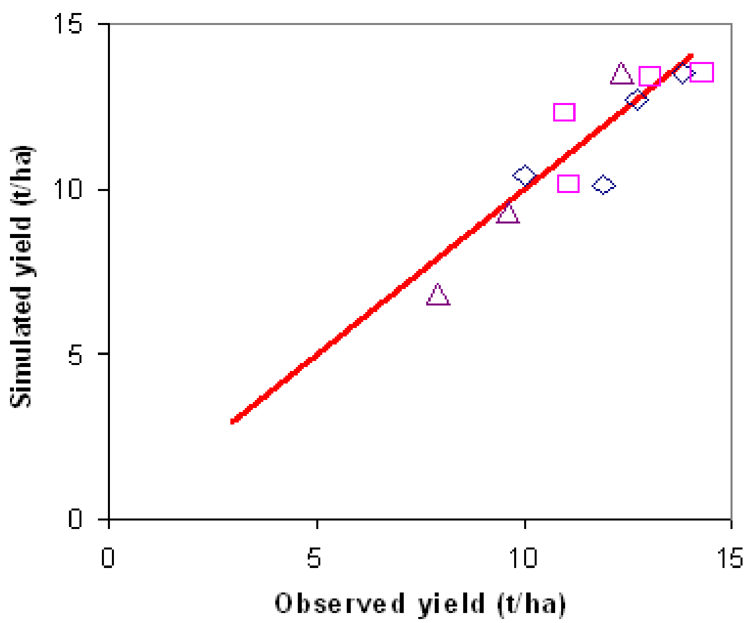

Figure 1. Comparison of yields predicted by the calculator with those measured in plots managed according to farmer best practice (diamonds), by using the model (squares) and with no added N (triangles). The solid line is Y=X.

Table 2. Treatment yields (t/ha) according to method of management. Numbers in parentheses are Wheat Calculator estimates of yield. Paddock yields were estimated by the farmers.

Site	Farm	Model	Nil	LSD 5%	Paddock	Notes
Evans	12.7 (12.7)	13.1 (13.4)	10.5 (5.4)	0.70	11.0	
Lepoutre	13.8 (13.5)	14.3 (13.5)	12.3 (13.5)	3.31	11.0	
Lilley	10.0 (10.4)	11.0 (12.2)	9.6 (9.5)	1.35	9.0	
Williamson	7.8 (13.3)	7.2 (13.2)	4.5 (6.9)	1.23	7.8	Take-all
Wright	11.9 (10.1)	11.1 (10.1)	8.0 (6.8)	1.68	9.4	

Statistical analysis of the results showed no significant differences between the yields of the plots that were managed according to “farmer” or “model” treatments (Table 2). In other words, the calculator guided management was at least as good as that of the best wheat farmers in Canterbury. In all but one case, there was a significant increase in yield associated with added N fertiliser.

Discussion

An important factor in the acceptance of a computer based DSS is that the results are credible. The very close correspondence of simulated with measured yield (Fig. 1) established that credibility, so that the participating farmers were much more interested in using the calculator to explore the effects of varying management than they were in testing its accuracy. Even in those cases where there was a large discrepancy between simulations and measurements, the reasons were clear and credible, and the simulations still yielded valuable management information. For instance, on the Evans property, the Nil plots yielded substantially more than the calculator estimate (Table 2), based on the measured mineral content of 45 kg N/ha in the upper 30 cm of soil. This was because the nature of the soil profile meant that sampling was very shallow, and we estimate that about 85 kg N/ha was undetected in the stony layers. At other sites where sampling was deeper, the total mineral N was two to four times the amount in the upper 30 cm. Although this N would have cost only about $68/ha to apply, its end-of-season value was that of about 5 t/ha of crop, or $1250/ha. Similarly, the financial loss associated with disease at the Williamson property could be calculated as the value of the difference between measured and simulated yields, i.e., 6 t/ha valued at about $1500/ha.

The farmer’s usual practice at the Lepoutre site was to apply substantial amounts of fertiliser as “insurance”. The measured mineral N content to 90 cm was 265 kg/ha. The calculator indicated that no N was required, so in this case the Nil treatment in Tables 1 and 2 is the calculator recommendation. The farmer was reluctant to risk taking the advice of the Calculator, and applied 138 kg N/ha in three applications, but a communication lapse meant neither of our treatments matched his. The mean yield across all plots of 13.5 t/ha exactly matched the Calculator prediction. The difference in gross margin between calculator recommendation and farmer practice was the cost of the fertiliser, or $110/ha.

The Wright site was at an altitude of 340 m, but Lincoln (altitude 11 m) was the closest weather site. The altitude alone will mean the site is about 3˚C cooler than Lincoln. Simulations using unadjusted Lincoln weather data gave predictions for growth stages, particular GS30 and anthesis, that were about two weeks earlier than observed at the site, and yield predictions that were low (Table 2). When the minimum and maximum temperatures of the Lincoln weather files were reduced by 3˚C, then the predicted and observed growth stages matched within a few days, and yield predictions improved dramatically, to within 0.2 t/ha for the plots with added N, and to within 0.6 t/ha for the Nil treatment.

Conclusions

The Sirius Wheat Calculator has proved to be an accurate predictor of crop performance in well managed wheat crops. Management of N fertiliser using the DSS calculator recommendations proved at least as good as the best management practices of some of the most experienced wheat farmers in Canterbury. Even so, the farmers made their decisions on better information than they usually have available. Knowledge of the mineral N content through a substantial portion of the root-zones meant that their own management was probably better than normal. The positive feedback from the farmers involved in the project has already led to substantial changes to the program, and more are planned to address their wish-lists for the future. The continuation of this project will inevitably involve some farmers whose skills are not as advanced as our first test group, and we are hopeful that by using the calculator they will substantially improve the performance of their wheat crops.

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