Using the Sirius Wheat Calculator to manage wheat quality - the Canterbury experience.

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Abstract

Building on our growing experience of using the Sirius Wheat Calculator for optimising nitrogen and irrigation management for yield, we changed our emphasis to test the Calculator's ability to predict yield and protein changes under different nitrogen application timings. Five experiments were established in growers' fields around Canterbury, providing a range of cultivars, soil types, and weather conditions. The calculator closely predicted grain protein content over all sites and rates of N. Yield trends were closely simulated, but yield was systematically over-estimated. Yield overestimation was most likely associated with either an underestimation of the drought response of wheat, or an overestimation of the water holding capacity of the soils at the experiment sites.

Additional key words: Decision support system, crop model, nitrogen management, grain protein, wheat.

Introduction

The Sirius Wheat Calculator (SWC) is an interactive decision support tool that incorporates the wheat simulation model Sirius (Jamieson *et al.,* 1998b, Jamieson & Semenov, 2000) into a framework for guiding the timing and amount of water application and nitrogen (N) fertiliser required by wheat crops. It uses cultivar and soil information, together with current weather and scenarios of future weather.

From growing season 2001, the SWC was tested on farms by farmers, and predictions of yield and protein content were compared with measurements made from experiments established in farmer crops. Here SWC management was compared to that of the grower, with the aim of maximising yield and minimising N input.

The system has been very successful, mostly because its accuracy established its credibility in the first year of operation (Jamieson *et al.,* 2003). As a result, in the second year of testing, farmer practice more closely resembled the SWC guided management than it had in the previous year. This was because the participating farmers were using the SWC for guidance, even though they made slightly different decisions from the researchers. So the SWC met two aims – close prediction of yield, and a change in farmer practise. It also meant that further tests of SWC versus grower practise were pointless. Accordingly, we decided to use the SWC to develop and test strategies to manipulate protein content whilst maintaining yield. This paper reports the results of that project.

Methods

Experimental sites consisting of nine plots (10 m x 2.5 m) were established in commercial wheat crops on five farms in Canterbury. At all sites soil mineral N (a required SWC input) was measured in mid-July to a depth of 80 cm, or shallower if sampling was limited by the occurrence of stony layers (Table 1). Soil water holding capacity varied among sites, mostly associated with the depth to underlying gravel layers.

Table 1. Soil type, depth of soil to gravels and mineral N (kg/ha) in that depth, for wheat trial sites in Canterbury.

Farm	Soil type	Depth (cm)	N (kg/ha)
Chertsey	Templeton shallow silt loam	50	85
Lincoln	Taitapu silt loam	70	82
Methven A	Mayfield	70	68
Methven B	Hororata stony silt loam	35	60
Sheffield	Lyndhurst silt loam	80	187

All crop management, except for N application in the experiment area, was by the farmer according to his management decisions for the surrounding crop. This meant that a different cultivar was sown at each site, and sowing dates ranged from mid-April to early June (Table 2). Two of the crops were irrigated, with six applications of 45 mm at the Chertsey site, and two applications of 30 mm at the Lincoln site.

Table 2. Wheat sowing date and end use of each wheat cultivar grown at five sites in Canterbury.

Farm	Cultivar	Sow date	End use
Chertsey	Claire[1]	3/06/03	Feed
Lincoln	Regency[1]	17/05/03	Milling
Methven A	Equinox	14/04/03	Feed
Methven B	Solstice	27/04/03	Feed
Sheffield	Centaur	15/05/03	Feed

1 Crop was irrigated.

At each site, there were three N treatments replicated three times in a randomised complete block design. All N was applied as urea (46 % N). Treatment 1 had no fertiliser N added, to determine the capacity of the soil to deliver mineral N to the crop. In the other two treatments the SWC was

Table 3. Application date for three Zadoks growth stages (GS) and the total amount of N applied at five sites in Canterbury.

	Nitrogen treatment application dates			
Farm	GS 31	GS 39	GS 65[1]	Total N applied[2]
Chertsey	8/10/03	12/11/03	9/12/03	250
Methven A	8/10/03	12/11/03	9/12/03	240
Lincoln	10/10/03	12/11/03	26/11/03	200
Methven B	8/10/03	12/11/03	9/12/03	250
Sheffield	22/10/03	12/11/03	16/12/03	100

1 This application date is for treatment 3 only

2 The total amount of N was divided by two (treatment 2) or three (treatment 3) to give application amounts.

used to estimate optimum N fertiliser amounts for each site, based on soil mineral N contents measured at each site (Table 1). In response to site variations, applied fertiliser N varied from 100 to 250 kg N/ha. This amount was split into either two or three applications that occurred around growth stage (GS) 31 and GS 39 (treatment 2), with an additional application at GS 65 (treatment 3 only) (Zadoks *et al.*, 1974, Table 3).

Soil samples were taken from each plot and analysed for mineral N, prior to the harvest of plots with a plot combine harvester. Yield, thousand grain weight and grain protein content were measured. Statistical analysis by analysis of variance used the entire dataset, and measured yields and protein concentrations were compared with predictions from the SWC.

Results

Yields

Measured yields ranged from 3.1 to 11.1 t/ha. Yield was increased by N application for the two irrigated sites, but no benefits were gained by adding N to the dryland sites (Table 4). The split of fertiliser had no effect on yield.

Table 4. Yield (t/ha) when no N was added (1), and where N was added in two (2) and three applications (3).

	Treatment		
Farm	1	2	3
Chertsey[1]	8.9	10.9	11.1
Lincoln[1]	6.6	9.5	9.2
Methven A	10.9	10.4	10.6
Methven B	3.1	3.6	3.6
Sheffield	6.8	7.1	7.1

LSD 5% (20 df) when comparing between farms = 0.45

1 = Irrigated

Protein contents

Grain protein ranged from 7.5 to an extremely high 16.7 %. N fertiliser lifted grain protein levels at all sites. Two applications significantly increased protein on the dryland sites (Table 5), compared to three applications. In contrast, with irrigation, three applications gave either higher protein (Lincoln site), or made no difference over the two applications (Chertsey).

Table 5. Protein (%) at 14 % grain moisture content when no N was added (1), and where N was added in two (2) and three applications (3).

	Treatment		
Farm	1	2	3
Chertsey[1]	8.1	11.8	11.5
Lincoln[1]	8.5	13.2	13.9
Methven A	9.0	13.2	12.7
Methven B	7.5	16.7	15.1
Sheffield	9.3	12.2	11.6

LSD 5% (20 df) when comparing within a farm = 0.35

1 = Irrigated

SWC predictions

The predicted yields were closely correlated with the experimental yields, but systematically overestimated them by approximately 2.5 t/ha. (Fig. 1). There were two exceptions (the no N treatment for Equinox and Claire), where the predicted yield was exceeded by the observed yield by approximately 2 t/ha. Grain protein predictions were very close to measured results given the range of measurements. Soil mineral N contents taken just prior to harvest were high, especially where late N was applied (Table 6).

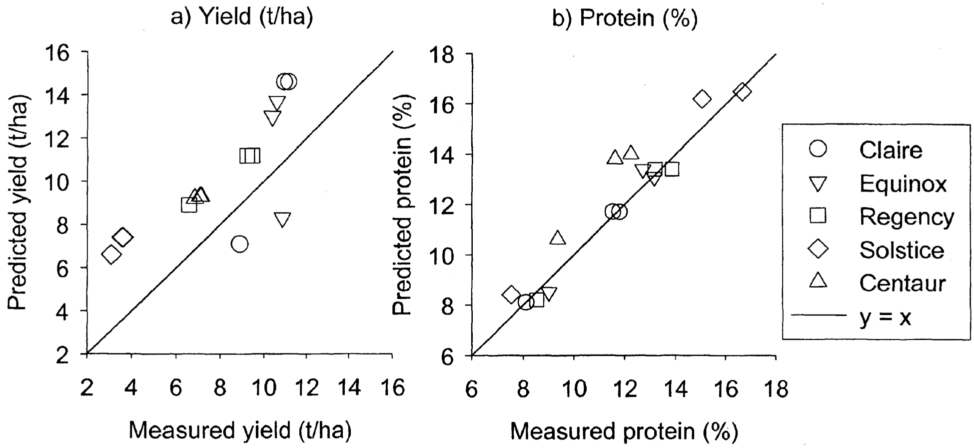

Figure 1. Comparison of mean (a) measured yields (t/ha) and (b) protein percentages (at 14% grain moisture contents) with predictions from the Sirius Wheat Calculator, from five wheat cultivars grown in Canterbury.

Table 6. Soil mineral nitrogen (kg/ha) taken just prior to wheat crop harvest from five sites around Canterbury.

	Treatment		
Farm	1	2	3
Chertsey	50.8	97.8	113.5
Lincoln	39.2	75.0	119.8
Methven A	48.9	62.5	78.9
Methven B	49.7	169.3	267.0
Sheffield	62.7	85.7	157.3

Discussion

The SWC predicted most of the variation associated with differences in site, cultivar and nitrogen supply under summer drought conditions. For the five sites, yield predictions averaged about 2.5 t/ha greater than measured results (Fig. 1a). Some bias is to be expected, as conditions such as shedding and poor establishment (identified at two sites) and the effects of disease are not accounted for by the Calculator, and will usually depress yield. However, the tendency in this experiment to overestimate yield differed from the earlier tests (Armour *et al.,* 2002), where there was much better agreement between measurements and simulations. A feature of the season was a hot, dry finish not experienced in previous tests. Lincoln rainfall for November, December and January was 36, 1 and 21 mm respectively, compared to long term means of about 60 mm per month. This provided a severe test of the system to simulate the effects of drought, and will make simulation accuracy dependent on the accuracy of the soil description, particularly those parameters that determine plant available water. The latter is the more likely cause of overestimation - the ability of Sirius to simulate terminal drought has been well-tested in the past (Jamieson *et al.*, 1998a).

The two exceptions (below the 1:1 line in Fig 1a), where the crops substantially out-yielded the estimates, were both from unfertilised treatments. The soil N determinations were limited by the depth available for sampling, and the SWC would have underestimated the soil N supply. To get the predicted yields to match the observed yield using the SWC required an extra 50 kg N/ha for the Chertsey crop, and to match the general overestimation required a further 30 kg N/ha. The N must have been available in the soil because most of it was harvested by the crop. The mismatch between observations and simulations reflected the difficulties in estimating the initial soil N supply when soils are difficult to sample to depth.

Simulations of the very lowest yielding crop gave substantial overestimates of yields. In this case the overestimation was associated with poor and patchy crop establishment. The tiller population was almost half that recorded at the other sites when N was added, and large gaps in the crop were evident. Even though yields were over-estimated, the calculator predicted little or no change in yield between the two different N treatments, as confirmed by the measured results.

SWC estimates of protein content were very close to observations, despite the errors in yield. The SWC even matched the extreme protein levels (Solstice, Fig.1b) where drought resulted in protein over 15 %. The SWC predicted differences in protein between the two and three split applications, although these were smaller than those measured.

The lower protein obtained from applying N in three applications (treatment 3) was most likely a result of the drought rather than N timing. Due to the lack of rain after flowering, the third application was not taken up by the crop. This was reflected in the high mineral N for this treatment measured at the end of the season (Table 6).

The current version of Sirius (Jamieson and Semenov, 2000) does not distinguish among cultivars on the basis of inherent differences in protein content – feed and bread wheat are assumed to have similar N pool sizes. As a consequence if they are grown in identical conditions and flower on the same day, they will have similar predictions for grain protein contents. We are currently working with French and Danish colleagues on refinements of Sirius that will take account of cultivar differences (Martre *et al.,* 2003).

Conclusions

The SWC allied with soil N tests has proved to be a very useful tool for calculating the amount of N fertiliser. Used with some planning of N timing, it shows potential to be used for managing quality. The results in a season with very dry conditions during grain fill emphasised the importance of accurate soil descriptions, and suggest that conservative users would be better to use descriptions that under- rather than over-estimate soil water holding capacity. The difficulty of measuring initial soil N was also again highlighted. This may be overcome when soil mineral N supply can be estimated from simulations of recent crops, rather than by direct measurement.

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References

Armour, T., Jamieson, P.D. and Zyskowski, R.F. 2002. Testing the Sirius wheat calculator. *Proceedings Agronomy Society of New Zealand* 32:1-6.

Jamieson, P.D., Porter, J.R., Goudriaan, J., Ritchie, J.T., van Keulen, H. and Stol W. 1998a. A comparison of the models AFRCWHEAT2, CERES-Wheat, Sirius, SUCROS2 and SWHEAT with measurements from wheat grown under drought. *Field Crops Res.* 55:23-44.

Jamieson, P.D., Semenov, M.A., Brooking, I.R. and Francis, G.S. 1998b. Sirius: a mechanistic model of wheat response to environmental variation. *European Journal of Agronomy* 8:161-179.

Jamieson, P.D. and Semenov, M.A. 2000. Modelling nitrogen uptake and redistribution in wheat. *Field Crops Research* 68: 21-29.

Jamieson, P.D., Armour, T. and Zyskowski, R.F. 2003. On-farm testing of the Sirius Wheat Calculator for N fertiliser and irrigation management. Proceedings 11th Australia Agronomy Conference, 2-6 Feb. 2003, Geelong, Victoria. Australian Society of Agronomy. ISBN 0-9750313-0-9.

Martre, P., Jamieson, P.D. Porter, J.R., and Triboi, E. 2003. Modélisation des Interactions Carbone-Azote dans les Grains de Blé Tendre. Poster at "Intégration de processus à l'échelle de la plante entière: Interactions entre les gestions de l'azote, du carbone et de l'eau. Bilan et perspectives." Ecole-Chercheur du réseau d'écophysiologie de l'arbre, INRA, 12-16 May 2003, Saint-Flour, France.

Zadoks, J.C., T.T. Chang, and C.F. Konzak. 1974. A decimal code for the growth stages of cereals. *Weed Research* 14:415-421.