Managing crops, animals and crop disease in mixed-farming systems based on dual-purpose wheats

PROJECT DETAILS

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PROJECT TITLE: MANAGING CROPS, ANIMALS AND CROP DISEASE IN MIXED-FARMING SYSTEMS BASED ON DUAL-PURPOSE WHEATS
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Summary

This project has shown that:

a. grazing does not increase the spread of Wheat Streak Mosaic Virus (WSMV) in wheat crops. Disease control measures, therefore, should concentrate on management of the crop and the primary vector, wheat curl mite (WCM).

b. young sheep grazing winter wheats grow faster if supplemented with magnesium (Mg) and sodium (Na). Practical supplementation guidelines are provided, however, fertilising wheat with Mg is not an economic way of supplementing animals.

c. a major way for crops to recover from grazing is by increased photosynthetic rates in grazed wheat. The results are captured in a computer model which will allow better prediction of the effects of grazing on grain yields.

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Conclusions

The following conclusions are drawn from project results. All have repercussions for the management of dual-purpose crops in mixed farming systems.

1. The grazing process itself does not contribute to the spread of WSMV in a crop. The infectivity of the virus in saliva was essentially zero, though why this is so remains unclear. The project results indicate that reduced infectivity does not relate to the presence of urea in ovine saliva. These findings show that producers can sow dual-purpose wheats without fear of WSMV spread due to grazing. Their disease control measures should be concentrated on controlling the primary vector (wheat curl mite) and on crop hygiene measures such as eradicating summer host plants for the mite. The potential profits from using dual-purpose wheats in mixed farming systems can thus be realised.

2. Relative to the needs of young stock, wheat forage is marginal for Mg, very high in potassium (K) and low to very low in Na. The resultant high dietary K/Na ratios reduce gut absorption of Mg. As a result, young sheep given Mg and Na supplements while grazing wheat grow 20-30% faster, a response which can be valued at $20-45 million annually in New South Wales (NSW) alone. Equally large responses to supplements have since been recorded in other southern states, so that Australia-wide, the value of supplementation would be much higher. The uptake of supplementation by producers has already been very rapid in South East (SE) Australia and equivalent responses have been shown in young cattle.

3. Direct supplementation of animals is the preferred strategy. Use of fertilisers to increase crop Mg content is less reliable and more expensive. Livestock grazing oats or canola do not need Mg/Na supplements, but further work is needed to define the response with barley.

4. The development of a computer package which models wheat recovery from grazing will allow better prediction of the effects of grazing on potential reductions in grain yields. This can then allow producers to compare the penalty of reduced grain yields with the potential gains in livestock production. In practice, the model will be incorporated into existing decision-support tools such as those in the APSIM or AUSFARM families.

Recommendations

The following recommendations are made.

1. Decisions about whether or not to sow long-season wheats for grazing do not need to consider the possible effects of grazing on the spread of Wheat Streak Mosaic Virus (WSMV). Control of this disease in crops should instead concentrate on controlling the primary vector, the wheat curl mite, and on crop hygiene issues such as the control of host plants upon which the mite has ‘over-summered’. This is particularly important in seasons in which rainfall patterns have permitted a very early sowing.
2. Young sheep and cattle grazing winter wheat must be supplemented with Mg and Na. A practical way to do this is with a 1:1 mix of CausMag® (magnesium oxide (MgO)) and granular salt, offered to allow an intake of 20g/day per sheep or six to eight times that for cattle.

3. Supplementation should be directly to the animals as the manipulation of forage Mg levels using fertilisers is expensive, short-lived and unreliable.

4. Preliminary results, plus the mineral content of the crops, suggest that there is no need to supplement livestock grazing oats or canola; the response when grazing barley requires further work.

5. The computer package developed within the project can be used to predict the effects of grazing on grain yields and thus evaluate the overall economic response to dual-purpose use.

Outcomes

The economic outcome of the project should be improved profitability from the use of dual-purpose wheats in mixed farming systems, arising in three ways:

1. Demonstration that grazing does not spread WSMV removes the fear that grazing of long-season wheats will, in itself, increase the incidence of this disease. It means that producers can sow dual-purpose wheats without fear of this effect. They should concentrate their disease control measures on controlling the primary vector (wheat curl mite) and on crop hygiene measures such as eradicating summer host plants for the mite. The potential profits from using dual-purpose wheats in mixed farming systems can thus be realised.

2. Young sheep given Mg and Na supplements while grazing wheat have consistently grown about 20-30% faster. This extra liveweight gain is worth 10-15 times the supplement costs. Given that wheat grazing has been valued at $100-150 million annually in NSW alone (F. McRae, NSW DPI, personal communication), such supplement responses can be valued at $20-45 million annually in that state alone. Equally large supplement responses have since been recorded in other southern states, so that Australia-wide, the value of supplementation would be much higher. The technology will not require great extension effort to achieve uptake, because the uptake of supplementation by producers has already been very rapid in SE Australia, due to the cheapness and obvious economic benefit of supplementing.

3. The development of a computer package which models wheat recovery from grazing will allow better prediction of the effects of grazing on potential reduction in grain yields. This can then allow producers to compare the penalty of reduced grain yields with the potential gains in livestock production.

Combined, these benefits mean that producers can more confidently incorporate dual-purpose wheats into previously ‘all-pasture’ systems. This will not only increase income but also provide the cash flow needed, for example, to apply lime at sowing and thus address problems associated with soil acidity. The positive environmental effects of this are harder to quantify in monetary terms but would be an additional benefit from the project.

A social consequence of the results from this project, as well as closely related project CSP0085 (dual-purpose canola grazing), will be to provide cash-strapped farming families with more options and greater flexibility of management in mixed farming systems.

Achievements/Benefits

Work within the project can be subdivided into three sections.

Section 1: Investigation of possible salivary transfer of Wheat Streak Mosaic Virus (WSMV)

Prior to the project, a common grower perception was that the incidence of WSMV was worse in grazed dual-purpose crops. This was a major concern, because it was a disincentive for producers to adopt dual-purpose crops. An important way in which sheep could increase WSMV incidence would be by transmitting infective virus from plant to plant in saliva. This was investigated under indoor conditions, in preference to artificially infecting field crops, because of quarantine concerns with the latter approach.

Experiment 1 (2008): Six housed sheep were allowed to consume WSMV-infected wheat followed by a further seven meals of uninfected wheat over 24 hours. The hypothesis was that this would allow salivary transmission of WSMV to the uninfected wheat. Saliva samples were taken from all sheep over the course of the 24 hours. All ‘grazed’ wheat was allowed to grow on under glasshouse conditions, to see if WSMV symptoms developed. The presence of virus in saliva was monitored as ribonucleic acid (RNA) via reverse-transcription polymerase chain reaction (RT-PCR). Virus was detected in only a few samples, usually at 24 hrs. Because of the extreme sensitivity of RT-PCR, it was possible these were ‘false positives’. This view was
supported by the fact that no WSMV symptoms were detected in any 'grazed' plants.

Experiment 2 (2008): Five young sheep were housed indoors in individual pens and maintained on a diet of lucerne chaff. At 09:30 hr on day 1 of the experiment, and before animals were fed, three saliva samples were taken from each sheep using cotton swabs. One swab was dipped into celite and rubbed onto the leaves of three wheat seedlings (cv. Sunbrook®). The second and third saliva samples were retained for later assay for virus by RT-PCR and enzyme linked immunosorbent assay (ELISA), respectively. Four of the animals were then offered WSMV-infected wheat seedlings growing in seedling trays. The fifth sheep was offered uninfected wheat. When wheat seedlings had been ‘grazed’ to nearly level with the potting mix, seedling trays were removed and saliva samples were taken again and processed as described above. At 10:00 hr, all sheep were given 800g (air dry) of lucerne chaff. Saliva samples were then taken at 17:00 hr and at 10:00 hr the next morning. Wheat plants which had been inoculated using the saliva samples were transferred to a glasshouse and allowed to grow back from ‘grazing’.

In none of the saliva samples collected did either assay present evidence of virus presence. Plants inoculated with the sap of WSMV-infected plants (‘positive control’) developed WSMV symptoms, indicating that inoculation procedures were satisfactory. However, no virus was detected in any plants inoculated with saliva, nor did symptoms develop.

Experiment 3 (2008): These results, together with some earlier work from the NSW Department of Primary Industries (DPI), suggested that the infectivity of WSMV was greatly reduced or eliminated in ovine saliva. The third experiment investigated whether this was due to urea, a normal constituent of ovine saliva which, at higher concentrations, has also been used to denature viruses. Primary virus extracts were prepared from fresh wheat leaf tissue in 0.02M phosphate buffer. Urea solutions were prepared in the same buffer and mixed with primary virus extract, to give final urea concentrations in the mixtures of 5M, 2.5M, 1M, 500mM, 250mM, 100mM, 25mM, 10mM, 5mM, 2.5mM and 1mM. Samples of all the above mixtures were then inoculated onto leaves of wheat plants (cv. Sunbrook). These were allowed to grow for a further two weeks to allow virus replication and symptom development. Any visible symptoms on day 14 were scored on a scale of 0-4 (0 = healthy; 4 = severe or lethal symptoms). Four samples (two plants per sample) were also collected from new leaves and virus concentration determined using ELISA.

Virus-free urea solutions had no effect on plants, but virus extract without urea caused severe symptoms, indicating satisfactory infectivity and inoculation procedures. A 5M urea /WSMV-infected sap mixture greatly reduced symptom development; at urea concentrations of less than100mM, there was little effect of urea on the infectivity of the virus or symptom manifestation. At urea concentrations similar to ovine saliva (1-5 mM), symptom development was not significantly different from the ‘no urea’ treatment. These results confirm that the infectivity of WSMV is greatly reduced in ovine saliva, however, this reduction does not seem due to the urea content of ovine saliva. The reason for the greatly reduced infectivity remains unidentified but the practical import of the results is that it is unlikely that sheep spread WSMV by the salivary route during grazing. In a research paper prepared from these data (Muhammad et al. 2010), it was concluded that grazing by livestock does not increase the incidence of WSMV. The perceived extra incidence in grazed crops may relate to these being sown earlier and thus exposed to over-summered primary vector in early autumn.

Section 2: Mineral supplements for growing lambs grazing dual-purpose wheat

Earlier reports indicated that growing lambs grazing dual-purpose wheat grew 25-50% faster when supplemented with either Mg (as MgO), Na (as NaCl) or a combination of both (Dove et al. 2007; Dove and McMullen 2009). These results are summarised in Table 1.

Table 1. Summary of the growth responses of young sheep grazing dual-purpose wheats, to direct supplementation with Mg, Na or both (values are % increase in growth compared with un-supplemented animals).

<table>
<thead>
<tr>
<th>Supplement</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg (as CausMag®)</td>
<td>-</td>
<td>24%, 25%</td>
<td>-</td>
</tr>
<tr>
<td>Na (as salt)</td>
<td>-</td>
<td>25%, 37%</td>
<td>18%</td>
</tr>
<tr>
<td>Mg + Na</td>
<td>54%</td>
<td>-</td>
<td>31%</td>
</tr>
</tbody>
</table>
The marginal to low Mg content, very high K content and extremely low Na content of the forage of Australian wheats result in very high K/Na ratios in the rumen of sheep consuming wheat forage. This in turn significantly reduces Mg absorption. The responses in Table 1 thus represent responses to Mg or Na as such, together with an effect of Na on Mg absorption brought about by reducing the rumen K/Na ratio. Consumption by sheep of the 1:1 CausMag®:salt supplement reduces the dietary K/Na ratio from about 2,000 to about seven, a value close to that typical of many pasture species, and to the value implied by animals’ daily K and Na requirements.

Although supplements are cheap, direct supplementation of animals still involves the labour cost in feeding once or twice a week. The indirect ‘supplementation’ of animals with Mg by fertilising the crop with MgSO₄ or by ‘dusting’ it with MgO may be a cost-effective, labour-saving way of supplying Mg. This was investigated in 2008.

An April-sown crop of Mackellar wheat was grazed in July and August by Merino hoggets. Prior to grazing, the wheat forage had a very high K content (2.9% dry matter (DM)) and a low Na content (0.015% DM); mean Mg content was 0.16% DM, slightly above the requirement of growing sheep (0.12% DM). Forage Mg content was manipulated by applying 70kg Mg/ha to the crop as MgSO₄ (7 days before grazing) or MgO (1 day before grazing). These treatments greatly increased forage Mg ‘content’ at the start of grazing to 0.27 and 0.51% DM, respectively. Seven days into grazing, the Mg ‘content’ of MgO-dusted forage fell to a level similar to MgSO₄-fertilised wheat; thereafter, both treatments contained 0.17-0.24% Mg, well above requirement level. Over the first 14 days, animals grazing on MgSO₄-fertilised wheat grew 49% faster (P<0.05) and those on MgO-treated wheat 18% faster (P<0.05) than those on unfertilised wheat. The difference between the two Mg treatments was also significant. However, as grazing progressed, treatment differences in weight gains progressively declined. Over the entire 37 day period, lambs grazing untreated wheat grew at 168g/d, MgSO₄ animals 178g/d and MgO animals 169g/d. These liveweight gains were not significantly different.

These responses were much less than those observed with direct supplementation (see Table 1 above) and were also much more expensive because the MgSO₄ fertiliser is applied as MgSO₄.7H2O which contains only 10% Mg. The above application thus resulted in an ‘indirect supplementation’ cost of 50-60 cents/sheep/d, compared with 1-2 cents/sheep/d for direct supplementation.

In 2009, a further grazing trial was conducted to investigate whether Mg and Na supplementation (1:1 CausMag:salt, to appetite) was required for sheep grazing oats, barley or canola. Supplementation did not lead to significant increases in liveweight gain in animals grazing any of these crops. The work in this section of the project has thus defined the best-bet supplement to use (a 1:1 mix of CausMag® and salt) and has demonstrated that this is required by sheep when grazing wheat, but not when grazing oats or canola. There was a small response when grazing barley (Dove et al. 2012) which needs further investigation.

Section 3. Studies on the recovery of the wheat crop from grazing; derivation and calibration of a new wheat grazing model. WHTGRAZ

This section comprised soil water, crop growth and phenology measurements by Kelman and Dove, as well as the grazing experiments and modelling studies conducted by Matthew Harrison, a PhD student with the project. Grazing studies: In parallel with the animal measurements in 2008, Kelman and Dove also measured the effect of grazing on the growth and development of the wheat post-grazing. In the 30 day period after grazing, the biomass accumulation in grazed Mackellar wheat was only 59% that of ungrazed crop (60.1 v. 102.0kg DM/ha/day). However, between mid-September and anthesis (24 October), the grazed crop grew much faster (126.6kg DM/ha/day) than ungrazed (76.9kg DM/ha/day) so that at anthesis and at harvest, there was no difference in the biomass of grazed and ungrazed crops, and grain yields did not differ (grazed 3.37t/ha; ungrazed 3.30t/ha). These trends in biomass accumulation imply differences in physiological processes in grazed and ungrazed crops, an aspect which was also investigated in the studies by Harrison. His first field trial (2007) examined the effect of grazing frequency and intensity on the phenology, growth and ultimate yield of Mackellar wheat. In summary, grazing at 67.3 dry sheep equivalents (DSE)/ha for 31 days or at 33.7 DSE/ha for 62 days significantly reduced canopy leaf area index but also resulted in significantly increased photosynthetic rates post-grazing in young, fully expanded leaves. Increasing the intensity or length of grazing reduced soil water use in the dry period following grazing. Grain yields were not reduced by any of the grazing treatments (see Harrison et al. 2011a, b, c).

In summary, results showed that the fraction of incident light intercepted by grazed crops was reduced to only 10-20% compared with 95% in ungrazed crop. This did not significantly affect the rate of biomass accumulation in either cv. Mackellar or cv. Naporoo. The rate of leaf photosynthesis in grazed plants of both varieties continued to increase for up to
three weeks post-grazing and remained elevated until anthesis. This suggests that grazed plants were compensating for defoliation by increased rates of carbon fixation.

Model development and calibration: The development of the new wheat-grazing model, WHTGRAZ has now been completed. The model was calibrated with the time-courses of leaf, stem and kernel dry matter, leaf area and volumetric soil water measured during the 2007/2008 field experiments, as well as soil water, phenological and specific leaf area parameters. By inserting daily weather variables into WHTGRAZ, the model simulates daily growth of above- and below-ground dry matter of the crop. More importantly, the grazing of winter wheat crops can be simulated, allowing the response and recovery behaviour to be critically analysed. Simulations have shown that the model framework has a very good ability to predict regrowth behaviour. For example, over a range of grazing regimes, growing seasons and wheat varieties, WHTGRAZ simulations accounted for around 90% of the observed variation in leaf area indices, a key driver of crop growth. A regression comparison of predicted and observed leaf area indices did not differ from the 1:1 line. This high accuracy of WHTGRAZ simulations means that a great degree of confidence can be placed in model output. The power of WHTGRAZ lies in its ability to integrate the multi-trophic components of the system and thus allow identification of the many interactions that occur over the soil-plant-atmosphere continuum. The next logical step in this process is, therefore, to use the model to study the effect of alternative grazing regimes. These simulations will not only reveal the final effect of grazing on grain yields but will enable explanation of why grazing causes the crop to respond in a given manner. Alternative scenario testing will provide the solutions to many pertinent questions, such as how grazing affects water- and radiation-use efficiency. In the broader sense, WHTGRAZ can be used as a tool for identification of the most appropriate grazing regime, evaluating the trade-offs between dry matter and grain versus animal production.

Other research
Based on the results of the current project, the following areas emerge as research opportunities.

1. The reason for the greatly reduced infectivity of WSMV in ovine saliva remains unknown. There is also no data on the impact of cattle grazing on WSMV spread, though work in USA suggests there is little effect. Both aspects need urgent attention in order to provide producers with clear guidelines regarding the interactions between crop hygiene, mite control and livestock grazing.

2. In relation to mineral supplementation, results to date provide useful advice to growers and advisers grazing cereals with growing sheep. However, the mineral supplementation of lactating ewes grazing dual-purpose cereal has not been examined and should be addressed urgently, particularly in relation to the possible need for calcium (Ca). Similarly, there is very little data regarding mineral supplementation of cattle grazing cereals, though in this case results from the USA should be useful. On-farm trials by FarmLink and by commercial outlets (e.g. Landmark) indicate responses in cattle are similar to those in sheep. This aspect needs examination under controlled experimental conditions.

3. The current project and its predecessor (CSP009) investigated the use of dual-purpose cereal. The use of dual-purpose canola is similarly being explored within project CSP00085 (Kirkegaard et al.). There is a need to extend such work to mixed grazing systems involving pasture, canola and cereal and to conduct simulation studies to evaluate pasture/canola/wheat grazing systems. This will be pursued within a new project commencing 1/07/2009.