Final Project Summary

Project title	Agronomic, economic and environmental analysis of dual-purpose wheat cultivars for bioenergy		
Project number	RD-2010-3741	**Final Project Report**	SR34
Start date	October 2010	**End date**	October 2014
AHDB Cereals & Oilseeds funding	£37,500	**Total cost**	£75,000

What was the challenge/demand for the work?

Concerns about climate change and energy security are driving the development of biofuels, which are transport fuels produced from plant material. One type of biofuel, second generation biofuels (SGBs), are made from materials such as crop residues. In the UK, the biggest potential source of feedstock for these biofuels is wheat straw. This straw tends to have a low value and supply currently exceeds demand. This means that a considerable amount of straw is chopped and incorporated into the soil. Should biofuel production from crop residues begin in the UK a new market for wheat straw will develop. This may increase the price of straw and encourage a greater number of farmers to supply straw. There may even be a possibility of farmers starting to manage their wheat crops to maximise profit from the sale of wheat straw. This could be through selecting cultivars with greater straw yields.

This project investigated the use of dual-purpose cultivars (DPCs) that are optimised for the production of both grain and straw. Based on work from another AHDB Cereals & Oilseeds studentship project (Project code: 3690) four key cultivar traits were associated with the DPCs: grain yield, straw yield, straw digestibility (i.e. the ease at which the straw can be converted into a biofuel), and lodging susceptibility. Increasing digestibility could lower the costs of producing biofuels and/or increase the yield of biofuel from a set amount of straw. Lodging was considered an important trait as there are possible trade-offs with the other traits with a potential reduction in lodging resistance resulting from increases in digestibility and straw yield.

The three main aims of this project were:

1. To identify potential candidate cultivars that could be used as DPCs
2. To quantify the benefits DPCs might provide
3. To determine whether farmers be willing to grow DPCs should the price of straw increase

How did the project address this?

The experimental work involved five main components:

1. A field experiment was conducted to quantify plant component biomass, plant

characteristics associated with lodging susceptibility, and straw digestibility. This was conducted for three cultivars with and without the plant growth regulator chlormequat, and with various nitrogen fertiliser application rates.
2. An economic model was used to quantify the value of straw and determine how gross margins of a wheat crop are influenced by increases in straw yield and digestibility.
3. A logistic model was developed to investigate how increases in straw yield and digestibility can influence the area of wheat required to supply a set demand for feedstock for biofuel production, and how this impacts on the transportation costs.
4. A life cycle assessment (LCA) was conducted to quantify the environmental emissions (e.g. greenhouse gas emissions, water pollution) of the supply of straw for biofuel production, and the impact of straw yields and digestibility on these environment emissions.
5. A farmer survey was used to investigate the current and potential future supply of wheat straw.

What outputs has the project delivered?

Field experiments

Combining the results from this field experiment with previous work (AHDB Cereals & Oilseeds project code: 3690) there were no cultivars that stood out as suitable candidates for use as DPCs. Results for individual cultivars were very variable making it difficult to differentiate among the cultivars. The application of chlormequat led to an overall reduction in straw yield but this was not a consistent effect. Additional N application did not influence traits but it is unclear whether the additional N was available to the plants due to the timing of application and the weather during this period. Lodging susceptibility varied with cultivars and decreased when chlormequat was applied. Digestibility also varied with cultivar but the differences among the cultivars was minor. There were no clear patterns in trade-offs between the key traits.

Economic analysis

The analysis suggests a minimum acceptable selling price for wheat straw of £31.38 tonne^{-1} will be required due to the costs of fertiliser and straw collection costs. Increasing the straw yield and digestibility adds value to the overall wheat gross margin but this increase is low and can be negated by relatively minor reductions in grain yield. This means any potential increase in lodging susceptibility from increased straw yields or digestibility could outweigh the increased income from these improved traits.

Logistics analysis

Increasing the straw yield across the supply area for a biorefinery reduces the distances needed to collect a set amount of straw. Increasing digestibility lowers the amount of straw required to meet a certain biofuel production level. This decreases the supply area and the number of journeys

required to collect the straw. Therefore, increasing straw yield and digestibility leads to cost savings for transporting straw, with increasing straw yield being the most important of the two factors.

Life cycle assessment

Overall emissions were lower in the current LCA than in results in the literature. This suggests that some studies have overestimated the emissions from biofuel production. Depending on the assumptions of the LCA model, increasing straw yield and digestibility can lower the environmental emissions associated with biofuel production; however, these reductions are relatively small. Assumptions of allocation (i.e. how the environmental emissions are shared between the grain and straw) have a large impact on the extent of the emissions.

Farmer survey

From the survey, 55% of all wheat straw was chopped and incorporated in 2012. Farmers wanted, on average, £91 tonne^{-1} for straw before they would start to manage their wheat crop to increase straw yields. At £100 tonne^{-1}, 45% of farmers who currently incorporate straw would sell their straw and 50% would start using management practices to increase straw yield. The most popular management practice for increasing straw yield was selecting cultivars with higher straw yield.

Who will benefit from this project and why?

It is hoped that stakeholders in the biomass supply chain, such as crop breeders, growers and biofuel producers, will benefit from the results of this project. The project provides a foundation for further work into the development of DPCs.

Due to the relatively high costs of converting straw into biofuel, stakeholders in the biomass supply chain are likely to be interested in finding ways in which costs can be reduced. Increasing straw yield and digestibility has the potential to reduce transport costs which could benefit biofuel processors and possibility farmers if the costs savings are passed on. It is possible that environmental benefits can be achieved through growing DPCs. As the purpose of SGBs is to reduce greenhouse gas emissions, growing cultivars that can help to lower these emissions would be of interest. Although there are limits on the greenhouse gas emissions from biofuel production, there does not appear to be any financial benefits to biofuel producers to have greenhouse gas emissions any lower than the maximum allowed emissions. Therefore, there is no financial incentive to reduce emissions beyond a certain point. But if these limits are decreased, DPCs can provide a possibility of lowering emissions to meet these requirements.

Currently, there is no SGB production in the UK so there is limited potential for the growing of DPCs. It is unclear if there are currently grown cultivars that could be used as DPCs. Breeding new

cultivars to show these traits could be one option. However, the farmer survey found that farmers would want £90 tonne^{-1} before they would manage their wheat crop for increased straw yield; this suggests that it would be a risky investment for plant breeders given that straw price is currently about half that amount.

Although not identified in the field experiments, it is suggested that increased straw yield could lead to increased lodging susceptibility. The increased risk of lodging might dissuade farmers from growing these cultivars. This could be the reason why farmers want such a high price before managing for straw yield. If plant breeders can develop a cultivar with higher straw yield that does not come at the expense of increase lodging susceptibility, then farmers might be willing to grow these cultivars. Chlormequat application decreases lodging risk but this investigation did not find a significant decrease in straw yield resulting from its use. This means that farmers can continue to use chlormequat without compromising their straw yields.

If farmers do want to grow these cultivars then it is suggested that farmers are provided information on straw yields. The survey found that AHDB Recommended Lists were important for cultivar to 88% of respondents. Therefore, these recommended lists would be a good medium to provide this information.

If the challenge has not been specifically met, state why and how this could be overcome

It is not possible to conclude whether it is or isn't worthwhile to develop DPCs. Partly that's because of the lack of a SGB industry in the UK and only very limited data on how increasing digestibility influences the conversion of straw into biofuel. The project did not identify any cultivars as candidates for use as DPCs. The yields in the field trials were very variable and being able to differentiate among the cultivars and treatments would require a greater number of field experiments. As digestibility is not measured in cultivars and straw yield tends to be seen as a negative, it is likely those cultivars that could fit the role as DPCs do not make it through the crop breeding process. Because of this, it will be difficult to identify cultivars from among currently grown cultivars and the development of a DPC is likely to require a dedicated breeding programme.

The project attempted to determine whether there would be interest in growing DPCs through quantifying potential benefits and through surveying farmers. Due to the limitation of a postal survey the survey results only give a modest insight into farmer willingness to grow DPCs. A more in depth study is required, perhaps including interviews or focus groups to understand the barriers to the growing of DPCs.

The LCA did not model the biofuel conversion process and it is unclear how increasing digestibility influences the conversion stage; in the model it was assumed that biofuel yield would increase but

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it might be that biofuel yield is the same but the input requirements are reduced. Therefore, further work is required to better link straw digestibility and the biofuel conversion process, both in terms of environmental emissions and costs.

How have you benefited from this studentship?
This studentship has given me the opportunity to learn a number of different experimental methods. It has allowed me to present my work at the AHDB student symposium, where I have been able to learn about other students' research and the work of AHDB Cereals & Oilseeds in general. I am currently writing a number of academic papers based on the results of my investigation. This has given me a good foundation for progressing into an academic career.

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