EXPLORING MANAGEMENT SCENARIOS FOR INTERCROPPING WINTER WHEAT AND RED FESCUE AS COVER CROP USING A STICS-MODEL

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1. Introduction

The use of cover crops in cropping systems has interesting agronomic and environmental effects, including protecting the soil against erosion, contributing to the control of weeds and diseases, providing the following crop with nitrogen and preventing nitrate leaching (Hartwig and Ammon, 2002). Cover crops are frequently sown after the harvest of a main crop, with subsequent destruction by chemical or mechanical techniques before the sowing of the following main crop. The introduction of a living cover crop during a cash crop growth cycle (relay intercropping) and its maintenance after the cash crop harvest may help to preserve biodiversity, increase soil organic matter content and carbon sequestration (Teasdale et al., 2007) and provide other ecosystem services such as natural pest regulation or nutrient recycling, by increasing useful biotic interactions within the agroecosystem (Hartwig and Ammon, 2002). However, when the cash crop and the cover crop are intercropped during the cash crop growth cycle, they generally have to compete for the same resources, which may decrease cash crop yields and returns (Carof et al., 2007a). In this study, we analyzed the impact of various approaches to managing a red fescue cover crop in a winter wheat crop in terms of light, water and nitrogen competition, using the STICS crop model (Brisson et al., 2009) adapted for wheat/fescue intercropping (Shili-Touzi et al., in press), in order to find the best compromise between competitive effects and facilitative effect (biomass accumulation and radiation interception). .

2. Materials and methods

The model used was an intercropping extension of the sole crop model STICS (Brisson et al., 2009) parameterized and evaluated using data obtained in two field experiments involving wheat and red fescue. The results of model evaluation are detailed in Shili-Touzi et al. (in press). The wheat/red-fescue model was then used to compare four management scenarios, in order to analyze the impact of the fescue cycle position on the agronomic and environmental performance of the system. Scenario 0 (Sc0) simulated wheat grown as a sole crop and was treated as the reference scenario. In scenario 1 (Sc1), we simulated fescue emergence one week after the harvest of the wheat crop (in July, precise date depending on wheat maturity), corresponding to a double-cropping system. In scenario 2 (Sc2), we simulated fescue emergence in the spring (18 March), corresponding to relay intercropping: wheat grown as a sole crop from October to March and then intercropped with fescue. In scenario 3 (Sc3), we simulated the simultaneous emergence of wheat and fescue (10 October), corresponding to full intercropping. In scenarios 2 and 3, fescue was not destroyed after wheat harvest, therefore remaining alive. These simulations were run over 35 years of climatic data (1970-2004) from Versailles (48°48'N, 2°04'E), to enable us to take climate variability into account in the scenario assessment.

3. Results and discussion:

Simulation results showed that wheat yield was not overly affected by fescue development in the intercropping system (Sc 2 and 3) in comparison with sole wheat yield (Sc 0 and 1) (Fig.1). The simulated yield for sole-crop wheat (Sc 0) varied from 7.60 to 10.9 t ha-1 (Fig. 1). Over the 35 years considered, intercropping fescue with wheat was predicted to result in a 0.52 t ha-1 lower wheat yield, on average, in (Sc3) than obtained for wheat as a sole crop (Sc0), with a high level of variability between years (Fig. 1a). If the fescue emerged in spring (Sc2), wheat yield losses did not exceed 0.5 t ha^{-1} (0.18 t ha-1 on average). No difference in wheat yield was predicted for (Sc 1) in comparison with (Sc1), in which the fescue was sown after wheat harvest and could therefore not affect wheat growth. Yield variability over time was similar for all four scenarios.

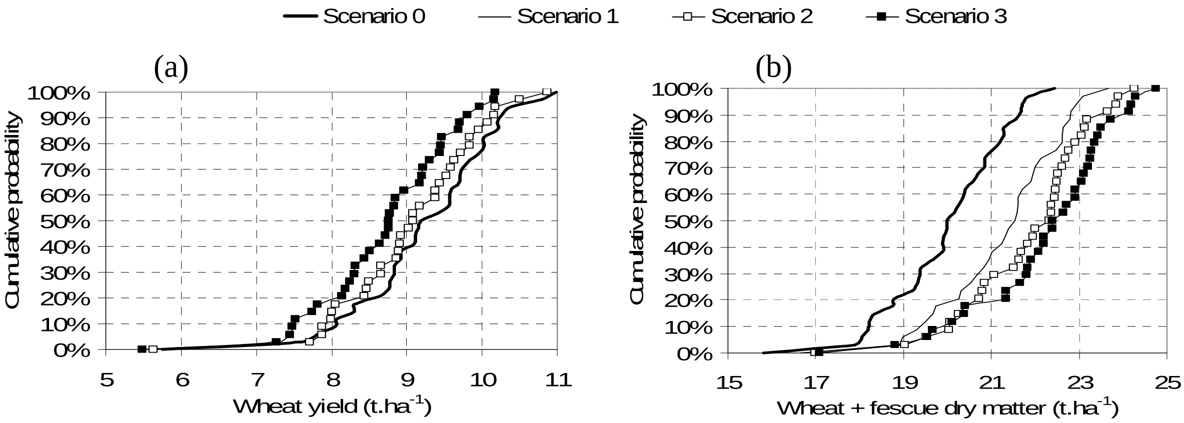

Figure 1. *Frequency analysis for managing scenario 0 (sole-crop wheat), 1 (wheat-fescue double cropping), 2 (relay intercropping) and 3 (full intercropping) over the 35 climatic years, for wheat yield (a),and wheat+fescue aerial dry matter (b).*

Simulations also demonstrated that the system was highly sensitive to the position of the fescue growth cycle, particularly in terms of dry matter production (Fig. 1b): overall dry matter production (wheat plus fescue) was greater than for sole-crop wheat, by 1.26, 1.84 and 2.19 t ha^{-1} on average for scenarios 1, 2 and 3, respectively. The difference between the scenarios is linked to differences in the timing of fescue dry matter production, which varied from 0.8 to 1.9 t ha^{-1} in Sc 1, from 0.5 to 1 t ha^{-1} in Sc 2 and from 1.5 to 2.5 t ha^{-1} in Sc 3, depending on the year (results not shown). These results are consistent with studies on the impact of the sowing date of a cover crop after the main crop (Dorsainvil, 2002) or of an intercrop (Launay et al., 2009). In the case of a cover crop introduced after the harvest (our Sc 1), Dorsainvil (2002) showed that the establishment of grasses (ryegrass in the studied concerned) was very slow if they were sown just after the cereal harvest, resulting in low levels of biomass production, principally due to water stress. In intercropping situations (our Scs 2 and 3) Launay et al. (2009) obtained results similar to ours for a pea-barley system, in which barley yields were 30% higher if barley was sown two weeks before pea. Advancing the sowing date of the fescue increases both competition effects (decreasing wheat biomass and yield) and facilitation effects (increasing total biomass and soil cover, decreasing the amount of solar radiation reaching the soil (data not shown)). It also increases the efficiency of radiation and nitrogen use (data not shown). The sowing date for the fescue is therefore a key technical choice determining the balance between competition and facilitation.

4. Conclusion

Agronomic performances of wheat intercropped with fescue as cover crop are slightly affected by competition in the short term, but may be improved in the long term by the facilitation processes induced by cover crops, such as nutrient recycling, increases in soil organic matter content and the improvement of soil structure.

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