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Topic 4 - Innovation in Organic farming: "thinking out of the Box"

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ARE THE TRAITS OF WHEAT AND PEA CULTIVARS IN SOLE CROP PREDICTIVE OF THEIR BEHAVIOR IN MIXTURES? CONSEQUENCES FOR ADVISORS AND BREEDERS

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Abstract: In France, areas cultivated with cereals-legumes mixtures have been steadily increasing for 10 years, mainly in organic farming systems. For this management, little advice is available for varietal choice and there is almost no specific varietal selection. Farmers based their varietal choice on the traits of cultivars grown in sole crop, cultivars that have been selected for the dominant sole crop system. In these conditions, we can wonder if the traits observed in monoculture are predictive of those observed in mixture. Our study focused on eleven varietal traits and performances of wheat and pea, in sole crop and in mixture. Our results show that only half of the traits measured in sole crop are predictive of the traits in mixture and that the other traits such as yield cannot be predicted correctly by the values in sole crop. Varietal advice for mixtures cannot therefore be based only on the known cultivars traits grown in sole crop. Specific assessments must then be carried out in mixture in order to 1) specify the varietal key traits necessary for the success of a mixture, according to the objectives targeted by the farmer, and 2) to develop, in the future, selection programs specific to mixtures.

Introduction: In France, demand for organic wheat flour is higher than supply. Despite a farmers' interest in producing organic bread wheat, production is hampered both by the yield decrease and the low grain protein content (and hence the likely declassification of the batch into feed wheat). These two difficulties are mainly related to the lack of nitrogen availability during stem elongation.

French grain legume production has declined significantly over the last 20 years. Thus, pea areas decrease in sole crop is mainly due to yield instability, related to abiotic and biotic stresses effects, and to the high level of lodging before harvest, making it difficult to develop pea sole crops in organic farming (OF) systems.

Finally, weed control remains a challenge in OF, which sometimes may question the sustainability of organic field crops systems.

A solution to tackle these issues may be to grow wheat and pea in mixtures. It is still a minor practice but currently spreading in French OF. The cumulative yield of the mixture is generally higher and more stable than the average yield of the two crops (Bedoussac *et al.*, 2015). The interaction effects between both species result in a limited availability of water, nutrients and light resources for weeds (Verret *et al.*, 2017), a reduced development of diseases and pests (Boudreau, 2013) and a limitation of lodging since wheat is used as a tutor for pea. Finally the protein content of wheat grains is generally higher.

The choice of the wheat and pea cultivars that would be best suited to be mixed to ensure favorable effects of mixtures is under question. May it rely on varietal traits only assessed in sole crops? To what extent are traits and performances of a cultivar grown in sole crop predictive of the ones in mixtures? And finally, is it necessary for some of these traits to consider specific approaches to breed for adaptation to mixtures?

Material and methods: Nine trials were conducted in OF (*) or very low input systems (**) during the 2015/16 to 2018/19 seasons, in the Parisian Basin (Orsonville**), the north-west (Rennes *), the west (Couffé *), the southwest (Archigny *) and the center (Civray**) of France.

Six winter pea cultivars (Aviron, Balltrap, Enduro, Fresnel, Furious and Gangster) with contrasting phenological, architectural and productivity traits were sown both in sole (SC) and inter (IC) crops, the latter fully mixed on the row with a single winter wheat cultivar (Flamenko), chosen for its precocity and resistance to lodging. In IC, the pea and wheat cultivars were sown at 75% and 50% of the SC doses, respectively. The variables measured on pea cultivars on the two managements (SC vs. IC) in three to five different environments were the start and end of flowering dates, the height of the pea plants in the canopy at the beginning and at the end of flowering, the pea seeds yield.

Five bread winter wheat cultivars (Energo, Flamenko, Ghayta, Renan and Rubisko) with contrasting phenological, architectural and productivity traits were sown both in SC and IC on the row with a single winter pea cultivar (Aviron). In IC, the pea and wheat cultivars were sown at 50% and 100% of the SC doses, respectively.
The variables measured on wheat cultivars on the two managements (SC vs. IC) in three different environments were soil coverage, rated on a scale of 1 (bare soil) to 9 (fully covered soil), at three stages of canopy development (1 cm ear, 2 nodes, heading), the height of the wheat plants in the canopy at heading, the wheat grain yield and protein content.

For each environment, correlation coefficients were calculated between values observed in SC and in IC. Analysis of variance with two cross-factors were then performed in each environment to check for genotype and management effects and to determine if the impact of IC management depended on the cultivar. Finally, when the interaction between genotype and management appeared significant (5% threshold), multiple comparisons tests (Student, Newman and Keuls) were implemented separately for each management.

Results: The genotypes had a significant effect in almost all ANOVAs (37/41) and differences between cultivars in IC confirmed the importance of varietal choice for the success of the mixture.
The management factor had a significant effect in more than half of the ANOVAs performed, confirming the influence of the IC management on some varietal traits.

The genotype x management and management effects were not significant for the pea start and end of flowering dates and the wheat heading height. For these traits, the values in SC seem to be predictive of those observed in IC.

Wheat protein contents were significantly higher in IC than in SC. The R^2 values were high and there was no genotype x management interaction. The values of this trait in SC seem to be predictive of those observed in IC.

Soil coverages at the three stages were higher in IC than in SC. Values in SC seem to be predictive of those observed in IC at 1 cm ear and 2 nodes stages. At heading, the soil was entirely covered in IC, whereas it was incompletely covered, and at different levels, by the different cultivars in SC. The correlation between values in SC and IC was then very low.

Wheat yields were slightly lower in IC than in SC when these yields were relatively low and values in SC seem then to predict IC yields. When yields were higher, the loss of yield in IC was higher and the prediction from the SC results appeared less robust.

The pea heights were generally higher in IC than in SC, whatever the stage, confirming the tutor effect of wheat on pea. The prediction of SC towards IC was rather good at the beginning of flowering but weaker at the end of flowering, with more variable results depending on the environment.

For pea yield, values in SC did not seem to be predictive of those observed in IC. Again, the results were very variable depending on the environment.

Discussion: Over the eleven varietal traits studied, only half show SC values that were predictive of those observed in IC:
- traits known to be highly heritable: pea start and end of flowering dates, wheat height at heading stage,
- 1 cm ear and 2 nodes soil coverages, which are mainly related to wheat development at these stages.
For the five other traits, particularly yields, the varietal traits in SC were not predictive of those observed in IC.

The advice to farmers about varietal choice for wheat and pea mixtures cannot therefore be based only on the varietal traits observed in sole crop. It is therefore necessary to develop a specific cultivar assessment in mixture to properly advise farmers. An interesting approach is to look for the varietal key traits for each species essential for the success of the mixture, depending on the farmer's objectives. The definition of these key traits would make possible to develop specific selection schemes for mixtures. This work is under progress.

In our study, pea cultivars are grown in IC with only one wheat tester cultivar, Flamenko and wheat cultivars with a single pea tester cultivar, Aviron. We can wonder if the results obtained here would be maintained with other wheat and pea tester cultivars, with phenological, architectural and productivity traits completely different from those of the two testers studied. Likewise, seedling densities and ratios between species certainly have an impact on the results obtained, which further complicates the advice and selection for mixture.

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