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Increased yield and yield stability in variety mixtures of spring barley

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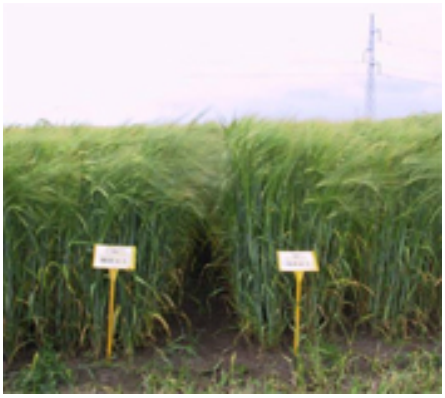

Breeding during the last 50 years has focused on developing genetic uniform crops/varieties for farmers to be able to produce homogeneous products for the market. However, despite quite intensive testing of varieties, predictions of performance of varieties are difficult - especially within organic growing systems, where pesticides and chemical fertilizers cannot be applied to stabilize the yield (Østergård et al., 2005b).

Genetic diversity is a way to stabilize yield using the potential of the crop for self regulation. Especially for selfing crops like barley where nearly all plants in a field are genetical identical, specific tools have to be applied to ensure genetic diversity. Among these tools is the use of variety mixtures, which have been used at varying extent in wheat and barley for many years (Finckh et al., 1999).

Variety mixtures have so far been studied mostly under conventional farming conditions and with focus on reducing disease severity by combining varieties with different disease resistance genes. To improve the performance of mixtures especially under organic conditions we need more information on the ability of different varieties to complement and compensate for each other under a range of different environmental conditions.

In the DARCOF II BAR-OF project, six variety mixtures are studied in organic as well as conventional growing systems in the period 2002 to 2005. The focus has been on competitive ability of the component varieties in addition to their disease resistance. The study is included in a European Network on sustainable low-input cereal production focusing on varietal characteristics and crop diversity **(SUSVAR - COST 860)**, initiated in 2004. The following is based on papers presented at two SUSVAR workshops (Østergård, 2005; Østergård et al., 2005a).

Certification of variety mixtures in Denmark

In Denmark, official regulations for certification of variety mixtures of spring barley have been practiced during the last two decades with the purpose of controlling disease development in the crop. In the latest set of regulations from 2003 (Anonymous, 2004), the requirements for certification of a mixture are:

- the mixture consists of 3 or 4 component varieties from Danish or EU variety lists in equal weight

- the average disease severity of mildew, leaf rust, scald and net blotch of the varieties in the mixture is below a certain level depending on the year (based on information from the previous year)
- the varieties have at least medium ranking for grain yield
- the max difference in ripening date between varieties is 5 days
- the max difference in culm length between varieties is 15 cm

As average over the last three years, 9% of the certified organic spring barley seed has been sown as variety mixtures whereas the number for conventional seed is 6% (based on information from Danish Plant Directorate). In addition, the farmer may himself mix seed before sowing, so the total area of mixtures grown is not known.

Studies of six variety mixtures

In 2002, six 3-component variety mixtures of spring barley were constructed based on information from official variety testing. The mixtures consisted of altogether 14 mostly high-yielding varieties **(Table 1)**. The mixtures were made according to official certification requirements with respect to disease resistance and date of ripening. However, larger differences between component varieties than accepted according to the rules for culm length were introduced. Also, the variety Culma was an older variety with lower yield. The mixtures were combining malting and fodder varieties, as the purpose was to study the interaction between varieties expected to have different weed competitiveness.

Each year the mixtures were composed of untreated or treated seeds from conventional multiplication of the component varieties in equal weight proportions taking into account differences in seed germination. The seed for mixtures and the pure stands were from the same seed batches.

Field trials on three locations

The six mixtures, as well as their components, were included in large variety trials in the years 2002-2005 (Jensen & Deneken, 2002, 2003, 2004, 2005). Here, only data from 2002-2004 are considered. In this period, the field trials were conducted in experimental research fields at three Danish locations: Flakkebjerg, Foulum and Jyndevad.

Different growing systems were studied, e.g., organic conditions (i.e., no pesticide application, weed harrowing or grass-clover undersown, and low input of organic fertiliser such as slurry) or conventional conditions (seed treatment, use of herbicides for weed control and synthetic fertiliser according to local standards, however, without use of fungicides). All together, data were collected in five to six different environments in each year 2002 to 2004. Many different disease- and growth characteristics were assessed; here, we will consider only grain yield.

Variety mixtures yielding better than their components

The mixtures performed differently which was expected as they were selected to vary with respect to intra-specific competition **(Table 2)**. The mixtures Mix1 and Mix4 were ranking well above the official standard in most environments, in some environments even somewhat better than all their component varieties (for both mixtures, in 7 out of 17 environments). Further, Mix1 was among the ten best varieties in the official variety testing in all years.

Within each environment, rank values of grain yield of the 20 mixtures and varieties were calculated (‘1’ is assigned to the highest yield in the environment and ‘20’ to the lowest yield). In general, mixtures had a better ranking than that of all component varieties (9.8 compared to 10.7).

Better yield stability in mixtures

The environmental variance of absolute yield as well as yield rank values over these very different environments (i.e., the average variation between environments for each variety) was the lowest for mixtures **(Table 3)**. This is interpreted in the way that mixtures having a relative high yield in one environment tend to have a relative high yield in other environments. Likewise, mixtures having a relative low yield in one environment also tend to have a relative low yield in other environments. Therefore, mixtures can be considered more stable than the component varieties.

This characteristic of variety mixtures has been used for several years in the official variety testing of barley in Denmark, where the official standard is a 4-component variety mixture with one component replaced each year.

Good mixing ability of good weed competitors

The grain yield of each mixture was in most cases higher than the average of its components (denoted positive mixture effect) when considering the mean over environments **(Table 2)**. In average, mixtures produced significantly more (0.9 hkg/ha) than the average of their components. Mix1 and Mix4, in addition to Mix5, showed the largest effect.

Both Mix1 and Mix4 included two component varieties with high weed competitiveness. The third mixture with this characteristic was Mix5. This mixture showed a significant mixture effect, however, its yield was only medium. One of its component varieties, Fabel, yielded rather low in many environments and this was to some extent compensated by the other components in the mixture. The variety Fabel was also included in Mix6 where the mixture effect was positive, but not significantly so.

Based on these results, one may suggest that 3-component mixtures should include more than one good competitor, however, this needs to be confirmed by other studies.

Mixture effects varies with environments

The average mixture effects **(Table 2)** are hiding large variation between environments **(Figure 1)**, which has to be understood. Much knowledge is available about how to combine mixtures to control disease, however, we do not have the final solution for how to combine varieties when also other biotic and abiotic factors are largely uncontrolled. With this information, variety mixtures will be profitable crops for many purposes in future sustainable agriculture.

The final mixture data from the BAR-OF variety trials (2002-2005) are now being analysed and so is data from other BAR-OF trials including variety mixtures: trials focusing especially on weed control by mechanical weeding (Preben Klarskov Hansen) and trials focusing on nutrient uptake (Ingrid Thomsen and Niels Erik Nielsen). In the nearest future, also data from many published and unpublished trials will be collected among SUSVAR participants to form the basis for different meta-analyses clarifying associations between mixture effects, component varieties and environments.

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