**BREEDING FOR MIXED CROPPING AND ANTHRACNOSE RESISTANCE OF LUPINS**

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**Introduction**

In Switzerland, the organic sector has been trying to reduce the massive import of protein crops for feed by encouraging grain legume cultivation during the past years (Clerc et al, 2015). The main limiting factors of low yield stability and high weed pressure were successfully overcome through intercropping of peas and faba beans with barley and oats, respectively. Thus, the production of peas and faba beans grew continuously from 2010 to 2015 from 200t and 90t to 1170t and 560t, respectively (bioaktuell 2017). For more diversification of domestic grain legume cultivation and supply, FiBL has started field trials with blue (*Lupinus angustifolius*) and white lupins (*L. albus*) in 2014. The high risk of anthracnose, caused by the fungal agent *Colletotrichum lupini*, (Bondar) Damm, P.F. Cannon & Crous (Damm et al. 2012), is presently preventing white lupin cultivation in Switzerland, although organic feed mills are highly interested in domestically grown lots of this valuable plant protein source for food and feed.

The objectives of the study were (i) identification of suitable crossing partners for blue and white lupins, (ii) suitability of cultivars and breeding lines of blue and white lupin under organic growing conditions in Switzerland in mixed cropping systems, (iii) identification of genetic resources of white lupins with partial resistance against anthracnose, and (iv) development of a composite cross population and prebreeding material of white lupins with improved resistance.

**Material and Methods**

Four different lupin trials with plots of 7,5 m2 size in a randomized block design with three replicates were conducted from 2015-2017 on the biodynamic farm bioböhler in Mellikon/Rümikon (“high” Rhine valley, Kanton Aargau), Switzerland: Trial 1 testing 6-7 different crops as cropping partners with the blue lupin cv. Boruta; Trial 2 testing 8-12 different blue lupin genotypes in mixed cropping with summer oat cv. Buggy; Trial 3 testing 6-7 different crops as cropping partner with the white lupin cv. Feodora, Trial 4 testing 8 different white lupin genotypes in mixed cropping with summer oat cv. Buggy. Additionally, genetic resources and breeder’s lines of white lupin were tested for anthracnose resistance in single rows planted between spreader rows of the susceptible cultivar Amiga. 111 rows were sown in 2017 harvested from infected plants that had already been assessed and selected in 2015 and 2016, and 101 rows were sown in 2017 with new genetic resources.

**Results and Discussion**

Trial 1: For blue lupins, mixed cropping is beneficial as it reduces weed pressure and has a higher land equivalent ratio resulting in higher financial return than pure stands. Depending on the year, the cropping partners were very competitive and reduced the percentage of blue lupin below 30%. This was the case with oats and in 2015 and 2016, with barley in 2015 and 2017, and with wheat in 2017. Triticale proved to be the best partner over the three years. – Trial 2, blue lupin cultivars: the only determinated cultivar Boruta yielded less than the indeterminated types but was much more reliable concerning lodging resistance and homogenous ripening, allowing an earlier harvest than the indeterminated types. Trial 3: For white lupins, the mixtures tested to date had no yield benefits compared to the pure stands. In some cases, disease scores were slightly reduced in mixed cropping compared to the pure stands especially when the partner crops were below the lupin canopy (e.g., for triticale and the dwarf summer oat Buggy). Seed maturation was accelerated in mixed cropping with tall, vigorous oat cultivars. We will continue to test cropping partners for weed control in white lupins, e.g. low growing grass species. – Trial 4, white lupin cultivars: all cultivars and breeders’ lines were highly susceptible to anthracnose, which was most obvious in the more humid early summer of 2016. Yield differences mainly reflected the maturation regime, late ripening allowing more yield if conditions were favourable, but early ripening being the best escape from anthracnose. In the dry summer of 2015, the late maturating cultivar Energy was the best with a total (lupin + partner) yield of 4t/ha (of which 72 % were lupin seeds). In 2016 with high anthracnose incidence and overall low lupin yields, the early maturating cultivar Feodora with determinated growth had the highest total yield (1.3 t/ha), combined with the best lodging resistance. However, yield differences were small. In 2017, the early ripening but indeterminated cultivar Zulika showed high yield, but was prone to lodging. Genetic resources and breeder’s lines: Out of the 111 infected lines, two breeding lines from Chile and three genebank accessions continue to show lower disease score index by ≥ 1.25 compared with cv. Amiga . Of the 101 new lines, 8 were clearly superior to Amiga, but will have to be tested again in a subsequent year. Five of these were obtained from the genebank and three were breeding lines from Italy.

Development of a Composite Cross Population: Various genetic resources, including lines with improved resistance capacities, are crossed in a hierarchical order to generate a heterogenous composite cross population. The F2 of 10 single crosses between white lupins were bulked and multiplied in the field in 2017 to allow for natural selection against anthracnose.

**Conclusion**: For blue lupins, cultivation can be recommended in Switzerland especially in mixed cropping with triticale. In contrast, white lupins cannot yet be recommended due to the high risk of anthracnose, although yields can be very high in individual years. Our breeding goal for white lupin is an anthracnose resistant, early ripening, lodging resistant, low alkaloid cultivar. Only a small percentage of the genetic resources showed higher resistance against anthracnose than the commercial varieties. They will be used as parental lines for crossing schemes to establish a composite cross population. Artificial inoculation at the seedling stage will allow screening of a larger number of genetic resources for resistance. Mixed cropping could help reduce the late weed pressure in white lupin but further research is needed with less competitive crops or undersowing.

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