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POTENTIAL OF MIXED INTERCROPPING FOR ENHANCED BREWING QUALITY OF MALTING BARLEY (HORDEUM VULGARE) UNDER ORGANIC GROWING CONDITIONS IN NORTH-WESTERN GERMANY

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Abstract: To assess the effect of intercropping on malting quality a field trial with spring barley (*Hordeum vulgare*) and legume (pea) as well as non-legume (camelina and linseed) intercrops in two additive seeding ratios as well as sole cops was established in 2017 at the organic experimental station of University of Applied Sciences Osnabrück in North-Western Germany. Two tested malting barley cultivars (cv. Marthe and cv. Odilia) showed different performance, but all variants achieved brewing quality. Results after two years indicate that linseed and camelina were able to limit protein content. For best land-use efficiency of malting barley production intercropping with linseed showed best results. Mixed intercropping can help to promote internal efficiency loops and is therefore a promising sustainable intensification strategy for more resilient future crop production under changing climate conditions.

Introduction: The demand for high quality organically grown malting barley is increasing. The main goal of producing malting barley is to achieve high and stable yields with a defined protein content. Within the framework of organic farming this is challenging, since nutrient uptake is unpredictable and strongly related to the weather conditions during the growing season (Pang and Letey 2000). Whereas in general organic grown spring cereals achieve good qualities, the nitrogen demand of malting barley is rather asynchronous with soil mineralisation. The idea to intercrop malting barley with a second crop could help to limit the nitrogen uptake in later growing stages. Mixed intercropping as simultaneous growing of more than one crop at the same time on the same field is known to provide further benefits as enhanced agrobiodiversity or improved resource use efficiency (Vandermeer 1989). Intercropping systems are, furthermore, more stable in yields over space and time (Reiss and Drinkwater 2018).

Material and methods: To evaluate the potential of intercropping on brewing quality parameters of malting barley within the framework of organic farming, a field trial was installed at the organic experimental farm “Waldhof” of University of Applied Sciences Osnabrück, Germany in 2017. In a randomised field trial three intercrops were tested for their potential to enhance malting parameters of two malting barley cultivars (Odilia, Marthe): camelina (*Camelina sativa*), linseed (*Linum usitatissimum* cv. Lirina) and pea (*Pisum sativum* cv. Rocket) as legume opponent were cropped in four mixing

ratios each (100:0; 90:50; 75:75; 0:100 as percentage of sole seeding rates for barley:intercrop). Cultivar Odilia was from bio-dynamic selection (Müller, Darzau) whereas cultivar Marthe came from conventional selection; both cultivars were used from certified organic propagation. The test site in Osnabrück (52.2780° N, 7.9875° E) was a Gleyic Cambisol with a sandy loam soil in the top layers and received 822 mm mean annual precipitation at 9.2 °C mean annual air temperature. Each of the 68 plots was 12 m² in size. The harvest was done in two steps: firstly, four randomly selected ¼ m² were hand-cutted and hand-threshed with a laboratory combine for exact determination of each intercrop. The main yield was estimated with a plot combine harvester; all post-harvest analyses were done with this material. Besides yield components (ears per m², grains per ear, 1000 grain weight) specific quality parameters for brewing were analysed (grain protein content, germination capacity, hectolitre weight, kernel size and shape).

Results: The yield results were diverse with significant effects of the barley cultivar (cv. Marthe > cv. Odilia) as well as between the intercrops, ratios and interactions (Fig 1A). The legume intercrop pea was able to increase grain protein content of barley (Fig 1B), but the main goal of malting barley intercropping was the other way-round: namely to achieve stable brewing quality in terms of low protein content under unpredictable nitrogen supply of organically managed fields. The idea of non-legume intercropping with malting barley was an increased nitrogen demand during the hardly controllable but usual peak during the later growing season through complementary niche differentiation to limit the barley nitrogen uptake. That was tendentially possible by cereal-non-legume intercropping (linseed > camelina) in all trial-years (2017 > 2018). In terms of crude protein content all variants fulfilled the malting barley requirements between 9.0 and 11.5 %, and cv. Odilia showed always significantly lower contents than cv. Marthe (Fig 1B). Camelina and linseed were able to reduce the protein content in both cultivars depending on the year. The germination capacity was furthermore with >96 % for all samples within the standard of the brewing industry with beneficial effects of all intercrops in high additive seeding rates. In terms of land equivalent ratios (LER) barley intercropping with pea was beneficial (LER >1) in 2017 (no data for 2018 due to failure of sole cropped pea plots) and intercropping with linseed seemed to be promising in 2018 whilst camelina's effect was less clear (Tab 1).

Table 1: Land equivalent ratios (LER) for the observed intercropping variants with two cultivars in two additive seeding ratios for two years.

			intercrop		
	seeding ratio	year	pea	camelina	linseed
cv. Odilia	90:50	2017	1.04	0.85	1.08
		2018	-	1.08	1.14
	75:75	2017	1.15	1.00	0.86
	2018	-	0.82	1.16	
cv. Marthe	90:50	2017	1.33	0.86	0.78
		2018	-	1.12	1.38

		18			
	75:75	2017	1.13	0.84	0.96
	2018	-	1.07	1.34	

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Figure caption:

Figure 1: Mean annual grain yields (A) and protein concentrations (B) (N=4; +1 standard error of the mean error bars) of the two investigated barley cultivars as sole crop compared to intercropping. Different letters indicate significant differences between variants in 2017 (LSD-test, α=0.05), no significant differences in 2018.

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Discussion: Intercropping for improved quality is known from cereal-legume systems, e.g. for bread wheat (Jensen et al. 2015). Our trial showed the potential of improved brewing quality from cereal-non-legume intercropping, which is in line with observations by Heimler et al. (2004). Additional benefits of enhanced LER are widely confirmed for legume-cereal systems (Martin-Guay et al. 2018), but could also be realized with the non-legume partner in our trial. Since LER's>1 indicate increased resource-use efficiency, intercropping can be seen as a potential strategy for sustainable intensification of arable farming, but further (technical) improvements are necessary for large scale implementation (Lithourgidis et al. 2011). Beyond the current agro-technical limitations, mixed intercropping is a promising system for enhancing productivity and product quality and simultaneously promote a win-win situation for agro-biodiversity and further ecosystem services.

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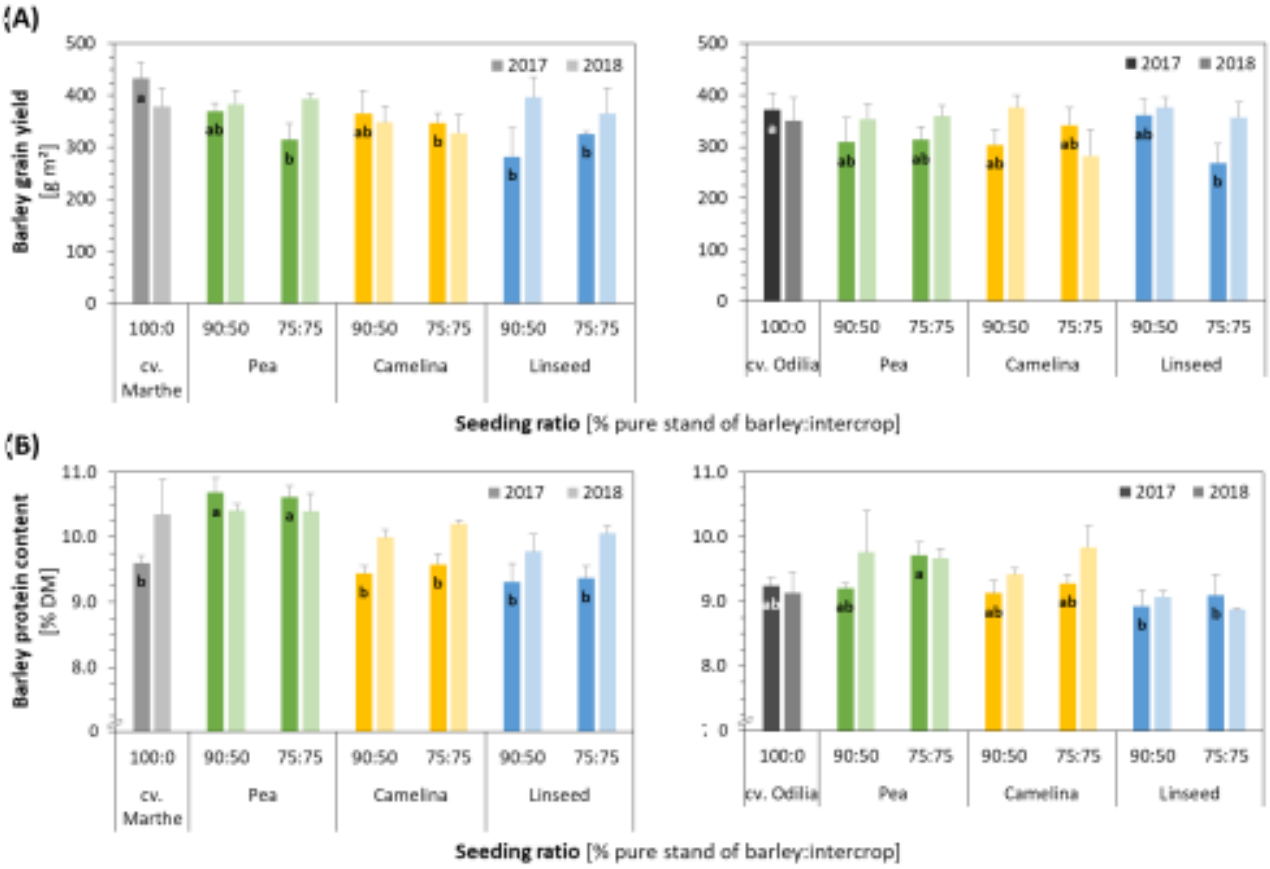
Image:



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