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Sowing ratio and N fertilization affect yield and yield components of oat and pea in intercrops

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ABSTRACT

Intercropping is of increasing interest in sustainable arable farming systems in temperate regions. This study was determined to assess the influence of sowing ratio and N fertilization on yield and yield components of oat (*Avena sativa* L.) and pea (*Pisum sativum* L.) in intercrops. A two-year field study was carried out on a fertile soil in eastern Austria with oat and pea sown in three substitutive sowing ratios and at different nitrogen levels. Oat was the dominant partner in the mixtures, strongly outcompeting pea. N fertilization increased the competitive ability of oat. Total grain yields were generally lower in intercrops than in pure stands; thus oat–pea intercrops failed to achieve a yield advantage. Sowing ratio and fertilization affected yield component parameters of oat and pea compared to the corresponding pure stands. Oat in intercrops used available environmental resources for increasing panicles plant^{-1} and grains panicle^{-1} whereas harvest index and grain weight of pea were negatively affected in the mixtures. In conclusion, oat–pea intercrops could no achieve higher grain yields than corresponding pure stands on a fertile soil.

1. Introduction

Field crop mixtures are extensively grown in traditional agricultural systems of developing countries (Biabani, 2009). There is also an increasing scientific interest in intercropping systems in temperate regions for developing sustainable farming systems for forage (Anil et al., 1998; Begna et al., 2011) or grain production (Aufhammer et al., 2004; Kübler et al., 2008). Advantages of intercropping have been attributed to greater long-term yield stability, a more efficient utilization of finite resources such as light, nutrients and water, and reduced weed, insect and disease pressure (Musa et al., 2010). Intercropping cereals and pea can result in higher yields, better land use efficiency and enhanced economic benefits compared with their respective monocrops due to a more efficient use of available environmental resources (Lithourgidis et al., 2011). Intercropping may result in a higher protein yield and a higher nutritive value of harvested grains for ruminants (Micek et al., 2012), an increased proportion of N derived from symbiotic N_2 fixation and improved soil fertility due to N accumulation (Ghaley et al., 2005). Intercropping of faba bean (*Vicia faba* L.) with maize (*Zea mays* L.) was found to alleviate the inhibitory effect of N fertilization on legume nodulation and N_2 fixation thus improving the productivity of this intercropping system (Li et al., 2009). The complementary use of soil and atmospheric N sources is of special interest in low input systems. In barley–pea intercrops, the competition by barley (*Hordeum vulare* L.) for soil mineral N increased pea' N portion derived from N_2 fixation (Corre-Hellou et al., 2006). Complementarily, legumes save the soil N pool due to their symbiotic N_2 fixation and their lower N fertilizer demand compared to other crops, which is called the "N-sparing effect" (Chalk et al., 1993). Pea–oat intercrops have been found to be superior to intercrops of pea with wheat or barley regarding grain and protein yields (Lauk and Lauk, 2008) and weed suppression (Šarunaite et al., 2013).

The aim of this study was to assess oat–pea intercrops grown on a fertile soil in temperate conditions of eastern Austria as affected by sowing ratio and N fertilization with focus on (a) yield, (b) yield components and (c) overall productivity (land equivalent ratio) of intercropping systems as compared to pure stands of both crops.

2. Material and methods

2.1. Environmental conditions

The experiment was carried out in Raasdorf (48°14′ N, 16°33′ E) in eastern Austria on the experimental farm Gross-Enzersdorf of BOKU University in the years 2010 and 2011. The soil is classified as a chernozem of alluvial origin and rich in calcareous sediments (pH 7.6, silty loam, 2.2–2.3% organic substance). The mean annual temperature is 10.6 °C, the mean annual precipitation is 538 mm

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Table 1
Long-term average monthly temperature and precipitation (1980–2009) and deviations during the 2010 and 2011 growing seasons.

	Temperature (°C)			Precipitation (mm)		
	Mean	Deviations		Mean	Deviations	
		2010	2011		2010	2011
March	5.8	0.5	0.5	38.5	−33.3	−10.1
April	10.7	0.2	2.6	35.3	23.1	−2.8
May	15.6	−0.3	0.3	56.1	58.6	−12.5
June	18.5	0.7	1.7	72.3	11.4	−8.0
July	20.8	1.8	−0.5	59.1	12.8	−4.3

(1980–2009). Table 1 shows the long-term average monthly temperature and precipitation (1980–2009) from April until July and the deviations during the 2010 and 2011 growing seasons. The temperature was generally higher in 2011 than in 2010 (except for July). Monthly precipitation in 2010 was well above average during the growing season from April until July whereas the experimental year 2011 was comparatively dry.

2.2. Experimental treatments and measurements

Pure stands of oat (cv. Effektiv) and pea (cv. Lessna) were established with 350 (oat) and 80 (pea) germinable seeds m^{-2}, respectively. Three oat–pea intercropping mixtures were sown simultaneously in replacement series consisting of the following sowing ratios (%): 75:25, 50:50 and 25:75. The nitrogen fertilizer calcium ammonium nitrate (CAN, 27% N) was applied at two fertilization levels (6 and 12 g N m^{-2}, corresponding to 60 and 120 kg N ha^{-1}) complemented by an unfertilized control. Fertilizer was applied in two equal splits, right after sowing and at end of tillering of oat, on May 2, 2010, and on May 5, 2011. The experiments were in a randomized complete block design with three replications.

Individual plots had an area of 15 m^2 (10 m × 1.5 m) and comprised 10 rows at 12.5 cm spacing. Seedbed preparation was done with a tine cultivator to a depth of 20 cm. Sowing was performed in one pass-over with an Oyjard plot drill at a depth of 4 cm on March 19, 2010, and on March 14, 2011. The preceding crops were winter barley (2010) or spring barley (2011). Soil mineral N at sowing was 158 (March 24, 2010) or 168 (March 16, 2011) kg N ha^{-1} (at 0–0.9 m depth). Sufficient contents of K and Mg and a high supply with P were determined by Mehlich III soil extraction procedure (Zbíral, 2000) in the arable layer (at 0–0.3 m depth) (2010: 275 (K), 232 (Mg) and 155 (P) mg kg^{-1}; 2011: 264 (K), 233 (Mg) and 151 (P) mg kg^{-1}). Mechanical hand weeding was performed throughout the experiment; plants were sprayed against pests (grain aphid (*Sitobion avenae*) and pea aphid (*Acyrthosiphon pisum*)) when necessary (with Decis®).

Plants were harvested manually by cutting on the soil surface at full ripeness on 1.2 m^2 per plot on July 21, 2010, and on July 19, 2011, and dried at 70 °C for 3 d. Plant samples were divided into component species, which were further used to determine yield components including grain and straw yield, harvest index, number of panicles m^{-2} (oat) and thousand kernel weight (TKW). Subsequently, numbers of grains $panicle^{-1}$ (oat) and grains m^{-2} were calculated.

Land equivalent ratio (LER) indicating possible yield advantages of intercrops was calculated according to Mead and Wiley (1980) as follows:

$$LER = \frac{Y_{1.2}}{Y_{1.1}} + \frac{Y_{2.1}}{Y_{2.2}}$$

where $Y_{1.1}$ and $Y_{2.2}$ are the crop yields for crop 1 and crop 2 grown in pure stands and $Y_{1.2}$ and $Y_{2.1}$ are the yields of the crops grown in mixture. A LER > 1 shows a yield advantage of the intercropping system whereas and a LER < 1 indicates a yield disadvantage. The LER is the sum of the partial LERs of the individual crops in the mixture. Partial LERs indicate the relative competitive abilities of individual crops in the mixture.

2.3. Statistics

Statistical analyses were performed using SAS version 9.2. Analysis of variance (PROC GLM) with subsequent multiple comparisons of means were performed. Means were separated by least significant differences (LSD), when the *F*-test indicated factorial effects on the significance level of $p < 0.05$.

3. Results

3.1. Above-ground dry matter, grain and straw yield

Above-ground dry matter, grain and straw yields of oat were significantly increased by N fertilization whereas no influence of N fertilization was observed on these parameters for pea (Fig. 1a, c and e). Total grain yields were generally lower in intercrops than in both pure stands, total straw yields were higher in intercrops than with pea in pure stand. Oat was the dominant partner in the mixtures strongly outcompeting pea. Decreasing ratios generally impaired the grain yields of both crops. In any case, grain yield of oat just slightly decreased with decreasing share in the intercrops whereas pea grain yields were strongly affected. E.g. with a share of 50% in the mixture the grain yields of oat decreased by 27% (2010) or 22% (2011) whereas the pea grain yields decreased by 91% (2010) or 83% (2011) compared to the corresponding pure stands. Oat has dominated pea even in the treatments sown with 25% oat seeds and 75% pea seeds, achieving a grain yield share of 70% (2010) or 50% (2011) on the total grain yields (Fig. 1b, d and f).

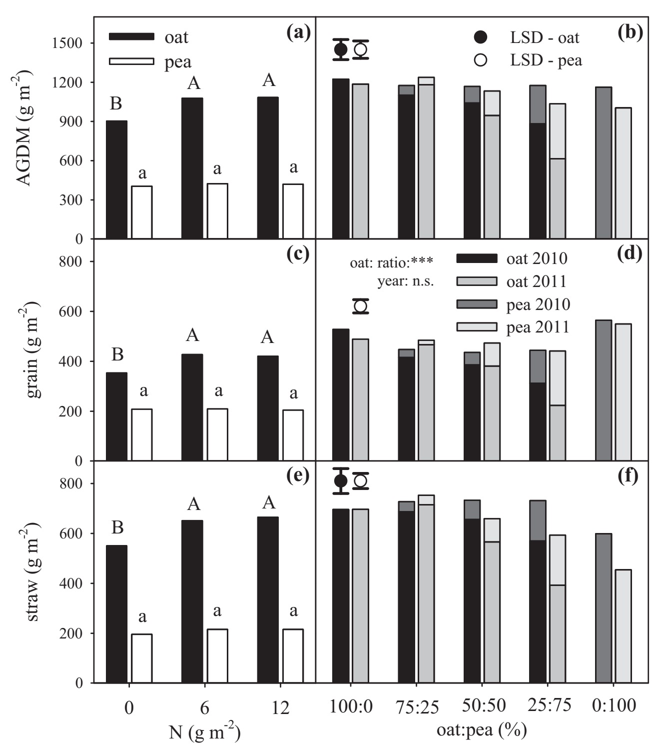

Fig. 1. (a and b) Above-ground dry matter (AGDM), (c and d) grain yield and (e and f) straw yield depending on N fertilization (main effect) and sowing ratio × year (interaction). Different letters indicate significant differences, error bars are LSD ($p < 0.05$).