Field Crops Research xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Yield components and nitrogen use in cereal-pea intercrops in Mediterranean environment

Michele Monti, Antonio Pellicanò*, Carmelo Santonoceto, Giovanni Preiti, Aurelio Pristeri

Department of Agriculture, University Mediterranea of Reggio Calabria, Loc. Feo di Vito, 89122 Reggio Calabria, Italy

ARTICLE INFO

Article history:
Received 15 May 2016
Received in revised form 5 July 2016
Accepted 22 July 2016
Available online xxx

Keywords:
Intercropping
Yield components
Nitrogen use
Straw nitrogen content
Pea

ABSTRACT

Intercropping is a cropping practice with the potential to increase the sustainability of the agricultural systems. Field pea has been largely studied in intercrop with wheat and barley in Northern and Central Europe whereas much less research has been carried out in semiarid environments of Southern Europe.

A two-year field experiment was conducted in Southern Italy with the aim to assess yields and yield components and N use of field pea and four different cereals – wheat, barley, oat and triticale – grown in additive and replacement intercrop.

The cereal was the dominant partner in intercrop, strongly outcompeting pea. Cereal height and biomass yield and intercrop density affected yield component parameters of pea causing a severe reduction of number of pods per plant and death of pea plants.

Pea yields were generally lower in intercrop than in sole crop. Consequently, nitrogen accumulation in intercrop and Land Equivalent Ratio (LER) N yields-based values resulted negatively affected. LER values were highest in barley-pea intercrops for both grain and straw nitrogen yields. Cereal grain and straw N content increased in intercrop compared to the sole crop while pea grain N content was reduced.

The results of this study indicate that cereal-pea intercropping can be a way of improving the grain and straw quality of the intercropped cereal and reducing N inputs into agricultural systems compared with the sole cropping. The choice of the companion cereal and the intercrop density should, however, be carefully evaluated in drought-prone environments like those of Southern Europe.

1. Introduction

Intercropping – described as the simultaneous cultivation of two or more species on the same area of land (Vandermeer, 1989) – is a cropping practice with the potential to increase the sustainability of the agricultural systems in temperate areas (Wezel et al., 2014) and to help deliver sustainable and productive agriculture (Lithourgidis et al., 2011). The rationale behind intercropping is that, due to complementarity in plant growth resources use (i.e. light, water and mineral nutrients), the different species intercropped do not compete for the same ecological niches resulting in an improved use of the resources compared to the corresponding sole crops (Willey, 1979a).

Field pea (*Pisum sativum*) is largely grown in Europe and is one of the most commonly used grain legumes as an intercrop in wheat or barley cropping systems. When pea was intercropped with wheat or barley, results showed an increase in total intercrop grain yields compared to the sole crops (Bedoussac and Justes 2010a; Jensen, 1996), greater land productivity (Bedoussac and Justes 2011; Hauggaard-Nielsen and Jensen 2001; Hauggaard-Nielsen et al., 2006) and reduced weed pressure (Corre-Hellou et al., 2011). In cereal-legume intercrops, advantages of intercropping versus sole cropping are often assumed to arise from the complementary use of N sources by the intercrop components. The cereal is more competitive than the legume for soil inorganic N due to its deeper and faster root system (Hauggaard-Nielsen et al., 2001a) and forces the legume to increase its reliance on symbiotic N_2 fixation (Bedoussac and Justes, 2010a; Hauggaard-Nielsen et al., 2009a; Jensen, 1996). The complementary use of N sources makes cereal-legume intercrops particularly suited to low-nitrogen-input systems and under those conditions intercropping shows the highest yield increase compared to pure stands (Bedoussac and Justes, 2010a; Ghaley et al., 2005; Naudin et al., 2010). Pelzer et al. (2012) found that yields of wheat-pea intercrops managed with low inputs resulted close to those of conventionally managed cereal crops. Cereal-legume intercropping can also be a way of improving the

* Corresponding author.
E-mail address: antonio.pellicano@unirc.it (A. Pellicanò).

http://dx.doi.org/10.1016/j.fcr.2016.07.017
0378-4290/

grain quality of the intercropped cereal compared with the sole cropping. When pea was intercropped with wheat (Bedoussac and Justes 2010a; Gooding et al., 2007; Naudin et al., 2010) or barley (Knudsen et al., 2004) the N content of the intercropped cereal was greater than that of the respective cereal sole crop. Furthermore, Naudin et al. (2010) demonstrated that no-fertilised wheat-pea intercrops could produce wheat grains with protein content not significantly different from sole cropped fertilised wheat. If the grain quality of the components grown in intercrop has been largely investigated, conversely, the quality of intercrop residues has been an aspect only marginally explored. Neugschwandtner and Kaul (2015) observed a higher N content in the residues of both oat and pea grown in intercrop compared to that of the respective sole crops, however there is still little literature published on this aspect.

Despite its potential benefits, the adoption of the intercropping practice in agricultural systems of developed countries has faced huge competition from large-scale, intensive monocrop farming. The delivery of multiple ecosystem services and products becomes therefore important to increase the interest towards this agronomic practice (Brooker et al., 2014). Cereal-legume intercrop residues, for instance, can find application in the bioethanol industry where cereal straw has gained interest as a low-cost material for the fermentation (Petersson et al., 2007) and the addition of legume biomass can have a positive effect on ethanol yields (Thomsen and Hauggaard-Nielsen, 2008). Cereal-legume intercrop residues can have also the potential to improve the synchrony between the rates of N supply to crop and crop demand for N (Hauggaard-Nielsen et al., 2009b).

Wheat- and barley-pea intercrops for grain production have been broadly studied in Northern Europe environments on spring sowing (e.g. Ghaley et al., 2005; Hauggaard-Nielsen et al., 2001b; Hauggaard-Nielsen et al., 2006) and at lower latitudes on winter sowing (e.g. Bedoussac and Justes 2010a,b; Corre-Hellou et al., 2006; Naudin et al., 2010; Pelzer et al., 2012). Limited research, in contrast, is available on wheat- and barley-pea intercrops on winter sowing for grain production in drought-prone Mediterranean environments of Southern Europe where severe terminal drought and heat stress can limit yields of drought sensitive crops, i.e. pea. Furthermore, other small grain winter cereals widely adopted in the agricultural systems of Southern Europe, such as oat and triticale, have been only marginally studied in intercrop with grain legumes. For instance, triticale is well adapted to the Mediterranean environment and modern varieties are considered as a viable alternative to durum wheat (Motzo et al., 2015).

If yield components of cereals and grain legumes have been widely examined in sole cropping conditions, very little research, instead, has been carried out to investigate how the main yield-determining traits of those crops are affected when intercropped. Actually, an understanding of the yield components of crops grown in mixture is a key component in developing intercropping systems (Neugschwandtner and Kaul, 2014). If the yield components influenced by the intercropping were closely identified, the findings may assist the selection of appropriate genotypes to be used in intercrops thus contributing to the adoption of this agronomic practice. The aim of this study was to assess four small grain cereal-pea intercrops grown in winter season in a typical Mediterranean environment of Southern Italy with focus on (i) yield and its components, (ii) grain and straw N content, (iii) nitrogen use of cereal–pea intercropping systems as compared to pure stands of both components. The four intercrop combinations were arranged in two intercrop density designs; a 50:50 replacement design and a 100:50 additive design with the cereal sown at full sole crop density and the legume at half of the sole crop density. In the additive design, the cereal was considered as the main crop and the pea was used as a tool to increase the sustainability of continuous cereal monocropping (i.e. biological N fixation and weed control) and to improve the quality of the grain and straw mixture (N content) without affecting cereal yields.

2. Materials and methods

2.1. Experimental site

The experiment was carried out on a clay loam (36% clay, 24% silt and 40% sand) classified as a "Typic Haploxeralfs" (USDA) on the experimental farm of the *University Mediterranea* in Reggio Calabria in Southern Italy (38°10′ N, 15°45′E, 232 m a.s.l.) over two growing seasons (2006/07 and 2007/08). The soil (0–30 cm depth) contained 1.95% organic matter, 1.12‰ total N (Kjeldahl), 12.31 ppm P (Olsen), 372.58 ppm K and had a pH of 7.15.

The previous crop on the experimental site was sole crop of barley. At sowing, soil samples (0–60 cm) were taken and soil was sieved to <4 mm particle size before analysis. NH_4^+-N and NO_3^--N in 2 M KCl soil extracts were determined colorimetrically by using a Flow Injection Analysis System (FIAS 400 PerkinElmer, Inc., CT, USA) equipped with an AS90 Autosampler (PerkinElmer) and linked to a UV/Vis spectrophotometer Lambda 25 (PerkinElmer). Inorganic soil N was 47.3 ± 4.0 and 35.3 ± 3.13 kg ha^{-1} respectively in the first and second cropping season. 84 kg ha^{-1} of $Ca(H_2PO_4)_2$ (Superphosphate) were incorporated into the soil at sowing. No N fertilization was provided. Crops were sown in the third decade of December in both years. No chemical weed control was undertaken and all treatments were kept free of weeds by hand as much as possible. There was a slight asynchrony among the different species in regards to the full physiological maturity stage. Harvesting was therefore organized according to such a criteria that the crops were harvested at their physiological maturity in sole crop and at full maturity of the last maturing species in intercrop. Harvest took place at pea physiological maturity for pea sole crop (last week of May in both years), and at cereal physiological maturity (Zadoks 92) for both cereal sole crops and intercrops (first week of June in both years).

Air temperature and rainfall during the experimental period are shown in Fig. 1. Air temperature regimes were similar for the two years and in line with the 20-year mean of the experimental site. February in the second season was colder than in the previous one and the minimum daily air temperature dropped to 4 °C. In both seasons, air temperature started increasing constantly from March onwards. The rainfall during the growing seasons (December–June) was 400 mm and 226 mm in the first and second seasons respectively versus the 20-year mean for the same period of 394 mm. The first season was affected by a wet winter (especially March) that was then followed by a sharp increase in the air temperature in April. In the second season, in contrast, the autumn was wet before sowing whereas the crops received much less rainfall from the emergence afterwards compared to the previous year.

2.2. Treatments and experimental design

Durum wheat (W) (*Triticum turgidum* spp. *durum*) cv. Valbelice, Triticale (T) (*Triticum x Secale*) cv. Trica, oat (O) (*Avena sativa*) cv. Argentina, barley (B) (*Hordeum vulgare*) cv. Gotic and a tall, semi-leaf-less, medium early and indeterminate growth pea (P) (*Pisum sativum*) cv. Hardy were grown as (1) sole crop (WSC, TSC, OSC, BSC, PSC), (2) replacement (W50P50, T50P50, O50P50, B50P50) and (3) additive (W100P50, T100P50, O100P50, B100P50) cereal-legume binary intercrop (IC). The sole crops were sown with planned density of 400 seeds m^{-2} for wheat and triticale, 300 seeds m^{-2} for oat and barley and 90 seeds m^{-2} for pea. In intercrop each species was sown in alternate rows at half of its sole crop densities in the replacement design and at full (cereal) and at half (pea) of its sole crop density in the additive design. On the individual rows, the