CORE
Metadata, citation and similar papers at core.ac.uk
Provided by Organic Eprints

Pea-barley intercrops use nitrogen sources 20-30% more efficiently than the sole crops

H. Hauggaard-Nielsen[1], Ambus P.[1], Brisson N.[2], Crozat Y.[3], Dahlmann C.[4], Dibet A.[3], von Fragstein P.[4], Gooding M.[5], Kasyanova E.[5], Launay M.[2], Monti M.[6], Pristeri A.[6] and Jensen E.S.[1]

Abstract **- Field pea (*Pisum sativum* L.) and spring barley (*Hordeum vulgare* L) were intercropped and sole cropped to compare the effects of crop diversity on the use of nitrogen sources in European organic cropping systems. Across a wide range of growing conditions pea-barley intercropping showed that nitrogen sources were used from 17 to 31% more efficiently by the intercrop than by the sole crops. Intercropping technologies offers the opportunity for organic cropping systems to utilize N complementarity between component crops, without compromising total crop N yield levels. [1]**

INTRODUCTION

Nitrogen (N) input are required to balance N exported in products and losses from the farming system to maintain sustainability. Symbiotic N fixation from legumes like pea is the basic N input into organic systems. On the same time it is essential to make the optimal use of N derived from soil N mineralisation and when growing legumes in sole crop (SC) they will use soil derived N even though symbiotic derived N is sufficient. A practical application of ecological principles, such as diversity, competition and other natural regulation mechanisms through intercropping (IC) is regarded as a promising tool.

Intercropping, the simultaneous growth of more than one species in the same field is based on basic ecological principles such as diversity and competition (Willey, 1979). It has been shown in previous temperate pea-barley IC studies how pea and barley differ in their use of growth factors, like N in such a way that they can complement each other in both time (Jensen, 1996) and space (Hauggaard-Nielsen et al., 2001). Thus, the cereal IC (e.g. barley) efficiently exploit soil inorganic N sources while at the same time fixed N_2 from the legume IC (e.g. pea) enter the plant-soil-system (Jensen, 1996).

The aims of the present study were to determine the N productivity using additive or replacement pea-barley IC designs compared to SCs across Europe

[1] Risø National Laboratory, DK-4000 Roskilde, Denmark, (henrik.hauggaard-nielsen@risoe.dk). [2] INRA, F-84914 Avignon, France (Brisson@avignon.inra.fr), [3] Ecole Superieure Agriculture, F-49007 Angers, France (y.crozat@esa-angers.educagri.fr), [4] University of Kassel, D-37213 Witzenhausen, Germany (pvf@wiz.uni-kassel.de), [5] University of Reading, UK-RG6 6AT Reading, UK (m.j.gooding@reading.ac.uk), [6] University Mediterranea of Reggio Calabria, I-80061 Gallina, Italy (montim@unirec.it).

MATERIALS AND METHODS

The experiments was conducted in five different European regions: Denmark (DK-Tåstrup, 55°40'N, 12°18'E); United Kingdom (UK-Reading, 51°45'N 0°93'W); France (FR-Thorigné d'Anjou, 47°37'N 0°39'O); Germany (GE-Kassel, Hessian State Estate Frankenhausen, 51°25'N, 9°25'E) and Italy (IT-San Marco Argentano 39°18'N 21°12'E). It was a joint experiment of field pea (cv. Bacara) and spring barley (cv. Scarlett) employing an additive (100%pea + 50%barley; P100B50) and a replacement design (50%pea + 50%barley; P50B50) according to the recommended SC plant densities for the respective crops. Target plant densities were 300 and 90 plants m^{-2} for barley and pea, respectively. The same experimental layouts, field and laboratory methodologies, as well as the same pea and barley cultivars were used by all partners according to the planned protocol. The pre-history of all sites were 2 years of grass-clover mixtures followed by a winter cereal before the actual experiment was established. All sites were managed according to organic practise

Hand harvest ($1m^2$) took place at physiological maturity each year. Total N and natural abundance of ^{15}N were determined using an elemental analyser (CE Instruments EA 1110) coupled in continuous flow mode to an isotope ratio mass spectrometer (Finnigan MAT DeltaPlus).

RESULTS

Independent of year and regional growing conditions in each country pea SC (P100) accumulated the same amount of N in grain compared to the total P100B50 IC but significantly more than barley SC and the P50B50 (Table 1).

Table 1. Pea (P) and barley (B) grain N yield (g N m^{-2}) when sole cropped (100P and 100B, respectively; 100% of recommended density[1]) and when intercropped in two relative proportions; either additive (P100B50) or replacement (P50B50) design during 2003-2005 in the five different countries (n=60).

Cropping	DK	UK	FR	DE	IT	*Mean*
P100	6.7	8.3	9.1	14.1	15.7	*10.8*
B100	4.1	3.0	4.8	4.6	6.5	*4.6*
P100B50	6.4	8.5	8.8	11.3	14.2	*9.9*
P50B50	6.8	7.1	7.4	10.4	12.1	*8.7*
S.E.(D.F=33)	0.04	0.05	0.05	0.06	0.08	*0.005*[2]

[1]Recommended density for pea and barley SC was 90 and 300 plant m^{-2}, respectively; [2]D.F=206

In general barley IC is more competitive towards soil mineral N as compared to the pea IC counterpart, which forces pea to increase N_2-fixation to fulfil its N demand (data not shown). Surprisingly, pea SC took up significantly more total soil N as compared to barley SC, with intermediate values for the ICs (Fig. 1). Pea SC fixed the largest quantitative amount of N compared to the P100B50 IC with even less in the P50B50 IC independent of country.

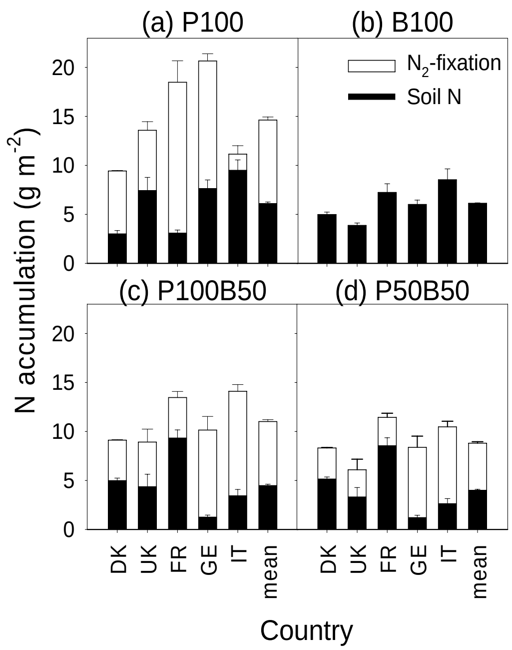

Figure 1. Pea (P) and barley (B) total nitrogen (N) accumulation when sole cropped (100P and 100B, respectively; 100% of recommended density1) and when intercropped in two relative proportions; either additive (P100B50) or replacement (P50B50) design during 2003-2005 in the five different countries. Values are mean (n=12) ± SE

Weak growth of barley due to e.g. water limitations (Italy, 2003) or pea aphid damages (Denmark and Germany, 2004) complicates general conclusions. However, barley was clearly the strongest competitor with larger proportions than expected (>0.5, independent of IC design. When raising the pea proportion in the additive design a suppression of barley increased the proportion of pea in the final total nitrogen accumulation (Table 2). A high proportion of pea in the IC had a positive impact on the total land equivalent ratio indicating greater complementarity.

.Discussion

The advantage in annual crop yields of 17 to 35% in ICs compared to SCs was attributed to competitive and facilitative N use production mechanisms. Pea increased its competitive ability for growth factors compared to barley when grown in additive compared to replacement design (Table 2). When raising the total density in the additive IC design a suppression of barley was achieved increasing the proportion of pea and thereby the total grain N yield (Table 1) to the same level as pea SC.

Table 2. Land equivalent ratio (LER)[1] for pea-barley and intercrops based on total crop nitrogen accumulation (Fig. 1). Values are the mean ± SE for each year (n=5) and total average (n=15)

Cropping	Year	L_p		L_b		LER	
P100B50	2003	0.8	±0.07	0.6	±0.12	1.4	±0.10
	2004	0.6	±0.09	0.7	±0.09	1.3	±0.10
	2005	0.6	±0.01	0.7	±0.05	1.3	±0.05
	Mean	*0.7*	*±0.04*	*0.7*	*±0.05*	*1.3*	*±0.05*
P50B50	2003	0.6	±0.04	0.6	±0.10	1.2	±0.08
	2004	0.5	±0.07	0.8	±0.07	1.2	±0.06
	2005	0.4	±0.04	0.9	±0.07	1.3	±0.07
	Mean	*0.5*	*±0.03*	*0.8*	*±0.05*	*1.2*	*±0.04*

[1]LER>1 indicate an advantage from IC in terms of the use of environmental resources for plant growth. LER of pea-barley IC = L_p+L_b where L_p=Y_{peaIC}/Y_{peaSC} and L_b= $Y_{barleyIC}/Y_{barleySC}$

Barley IC caused an increase of about 10-15% in the proportion of pea N_2 fixation ranging from only 55% in pea SC to about 70% when intercropped (data not shown). However, due to fewer plants per unit area (replacement) or increased interspecific interactions (additive) the quantity of N fixed was lower (Fig. 1), due to the strong competitive ability of barley (Hauggaard-Nielsen et al. 2001, Jensen 1996). Simplified 3-year N balance calculations showed negative N values across nations and cropping strategi (data not shown) indicating depletion of soil N resources in the long term, but when including pea and a SC or within a IC at a slower rate than barley SC.

Using the same field experiment soil and subsequent crop growth was sampled. N leaching assessments was performed using the crop model STICS (Brisson et al. 2003). The STICS modelling indicate that the often greater amount of soil inorganic N following pea SC compared to barley SC give rise to greater nitrate leaching in some regions and in others improved subsequent crop growth. Data interpretations are currently taking place.

Conclusions

Across a wide range of growing conditions pea-barley IC offer an opportunity to utilize N complementarity between component crops, including N_2-fixation input to the cropping system without compromising total grain N yield levels.

Acknowledgement

The presented data is a part of the EU shared cost project INTERCROP (see www.Intercop.dk) funded by the 5th Framework Programme of RTD, Key Action 5 - Sustainable Agriculture.

References

Hauggaard-Nielsen, H., Ambus, P. and Jensen, E.S. (2001). *Plant and Soil* **236:**63-74.
Brisson, N. et al. (2003). *European Journal of Agronomy* **18**:309-332
Jensen, E.S. (1996). *Plant and Soil* **182:**25-38.
Willey, R.W. (1979). Field Crop Abstracts **32**: 1-10.