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Title:

Reintroducing grain legume-cereal intercropping for increased protein production in European cropping systems

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Key words:

Pisum sativum, intercropping, N_2-fixation, soil N, protein production.

Summary:

The experiments demonstrated the potential of pea-barley intercropping as a means of introducing complementary N use by increasing the proportional input of pea fixed N_2, increasing the protein production and reducing weed problems in systems without herbicide use.

Introduction:

Motivations for reintroducing grain-legume-cereal intercropping to European cropping systems relate to the problems faced by intensive farming systems. During the eighties it has become evident that West European agricultural production systems (characterised by monocultures, nutrient surpluses, high external input of chemical fertilizer, pesticides and feed concentrates) are not sustainable in the long term. On the medium and long term this causes undesirable economic, ecological, environmental and social effects.

Reduction of external inputs and increases of home-grown feed together with a more efficient nutrient use from leguminous symbiotic dinitrogen (N_2) fixation (SNF) resulting in a reduction of nitrogen and mineral losses would be important goals to seek.

Grain legumes such as pea, faba bean, lupins and lentil are rich in protein (23% in average) compared to cereal grain crops. Nevertheless, grain legumes produced in Europe constitute only about 5% of the total protein used in European animal feed (1), the main protein source being imported soybean meal from North and South America. Besides being a valuable protein and energy source legumes are also beneficial to the agro-ecosystem due to their SNF ability. In addition, they are also known to have positive effects in the crop rotations, via recycled N-rich crop residues and the break-crop effect in cereals rich rotations, resulting typically in an extra tonne of wheat per hectare after grain legumes (H Pahl, this issue). However, yield variability in grain legumes is often observed due to their intolerance to water stress and harvest difficulties. Grain legumes are also known to be weak competitors for weeds and therefore less favoured in plant production systems that limit or exclude the use of herbicides (low-input farming).

Plant growth factors such as light, water and nutrients are more completely utilised and converted to crop biomass by intercropping, which is the simultaneous growing of two or more crop species in the same field. Due to agricultural intensification intercropping has disappeared from European farming systems. In the present paper we will present results from pea-barley intercropping field experiments. The objectives of these studies were to determine 1) advantages of pea and barley intercropping in low-input cropping systems, 2) utilisation of N resources and 3) effects of pea and barley cultivars on intercropping performances.

Materials and methods:

Three field studies were carried out at Risø National Laboratory, Denmark (55^{o}41'N, 12^{o} 05^{o}'E) on a sandy loam with 11% clay. The 25 year mean annual rainfall at Risø is 550 mm, mean annual air temperature is 8^{o}C with maximum and minimum daily air temperature of 16^{o}C (July) and -1^{o}C (February). Experiment 1 (3) in 1998, experiment 2 (4) in 1999 and experiment 3 (2) in 1984.

Determinate semi-leafless field pea (*Pisum sativum* L. cv. Focus) cultivar and a medium short spring barley (*Hordeum vulgare* L. cv. Otira) cultivar with high tillering ability and stem strength were grown in 1998 and 1999. In 1984 the field experiments included four pea cultivars and four barley cultivars differing in morphology, seasonal development, stem strength and resistance toward pests. In all experiments the intercrop establishment was based on replacement design.

The experimental plots (6.0 x 3.4 m) were laid out in complete randomised designs with pea sole crop (SC), barley SC and pea-barley intercrop (IC) as treatments with eight replicates in experiment 1 and three replicates in experiment 2 and 3. The actual plant densities counted three weeks after emergence were in average 80 field peas and 325 barley plants m^{-2}. Seeds were sown in the last week of April in experiment 1 and 2 whereas experiment 2 was sown in the first week of April. The intercrop design was based on the replacement principle, with mixed pea and barley grains sown in the same rows 15 cm apart in 0.5:0.5 ratios.

The utilisation of N resources and the influence of intercropping on SNF were studied in experiment 1 and 2 with ^{15}N isotope dilution technique using barley SC as the reference crop.

Results:

In experiment 1 and 2 grain yields of barley in intercrop and sole crop were almost equivalent and in addition about one t pea grain ha^{-1} was harvested in the intercrop (3, 4). Pea in sole crop and intercrop accumulated about 140 and 30 kg N ha^{-1} in aboveground biomass, respectively (Fig. 1). In the pea SC weeds accumulated approximately 80 kg soil N ha^{-1} whereas only 20 kg N ha^{-1} was accumulated in weeds of the barley SC and the pea-barley intercrop. The percentage of total aboveground N accumulation derived from N_2 fixation (%Ndfa) in pea SC increased from 40% to 80% during growth whereas pea IC had an almost constant %Ndfa of 85-90% (Fig. 2). The total amount of N_2 fixed was 95 and 15 kg N ha^{-1} in pea SC and pea IC, respectively. A significantly greater %N in seeds of the barley IC compared to SC grains was observed in experiment 2 and 3 (3;4).

The cultivar study showed that barley was usually the dominant species when intercropped with determinate pea cultivars, and that indeterminate pea cultivars are much stronger competitors and sometimes the dominant species (2). A leafless pea cultivar was not suited for intercropping and semi-leafless pea seemed to influence the barley ear emergence. Due to the superior competitive ability towards weeds, normal-leafed cultivars may be the most suited for intercropping in low-input systems.

Discussion

Because barley represses soil inorganic N uptake by pea (Fig. 2), pea-barley intercropping offers the potential of having a complementary N use. Barley took up almost similar amounts of soil N in SC and IC (Fig. 1). The greater competitive ability for soil N by barley was shown by %Ndfa values around 85-90% in pea IC from the tillering growth phase and throughout the experimental period. In experiment 1 there was no significant difference between pea SC and IC indicating that the high weed pressure that year were forcing pea SC to fulfil its major N demand by SNF. In pea-barley intercropping soil N sources are used efficiently by barley, which may partly explain the effect of intercropping on weeds.

Application of the ecological principle of competition, intercrops offered the opportunity to manipulate product quality. We measured a greater N content in the barley grains comparing SC and IC. It is usually difficult to increase the protein content of sole crop cereals because increased N-supply generally will increase also the dry matter yield and “dilute” the increased N uptake. one solution could be to supply N after flowering, but that is almost impossible using organic fertilizers. It was found that barley had a greater competitive ability for soil N than pea (3, 4, 5). Thus, it may result in a more than proportionate share of the soil N sources in legume-cereal IC systems because the relative increase in barley protein content is enhanced relatively more than the dry matters production. As a consequence protein content is increased.

Early pea growth is important for providing quicker, greater and more extensive soil coverage and thus improves pea competitive ability towards for growth resources. However, in order to withstand a large degree of complementary N use in the intercrop an improved pea growth should not compromise cereal N use, yield level and stability (5). One solution could be to create a better basis for selecting the most suited cultivars for intercropping. Breeding programs for sole cropping are not suitable to adapt a crop to growth in association with relatively different companions (2). Another solution may be to change the sowing strategy from sowing intercrop components at the same time in the same row to e.g. using relay intercropping strategies and/or non-regular spatial distribution of crops using newer sowing technologies. The key is how to improve early tillering growth in pea to improve the competitive ability towards weeds with an increased DM accumulation, increase N demand and thereby evolve a stronger sink increasing SNF. Normal-leafed cultivars seem to be the most suited for intercropping in low-input systems, the choice of barley cultivars was less important (2).

The experiments demonstrated several potentials of reintroducing pea-barley intercropping to European cropping systems when including current problems that conventional, specialised farms are increasingly confronted with. However, there is a lack of suitable cultivars and knowledge about key parameters determining co-existence and complementarity in intercropping systems.

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Figure captions:

Fig. 1: Total nitrogen (N) in aboveground crop biomass in sole crops (SC) and intercrops (IC) of pea and barley and weeds measured in 1998. Three harvests were conducted: at the tillering and post-flowering growth stage in barley and pea, respectively, after the elongation and in the pre-flowering growth stage in barley and pea, respectively, and at maturity. Values are the

mean (n = 8) ± SE. Each specific colour in the bar plot is associated to the single SE error bar in the diagram.

Fig. 2: Percentage N derived from fixation (%Ndfa) in sole cropped (SC) and intercropped (IC) pea measured in 1999. Values are the mean (n = 3) ± SE. Further explanations see figure 1.

Figures. Suitable for resizing to 7 cm x 7 cm

Fig. 1

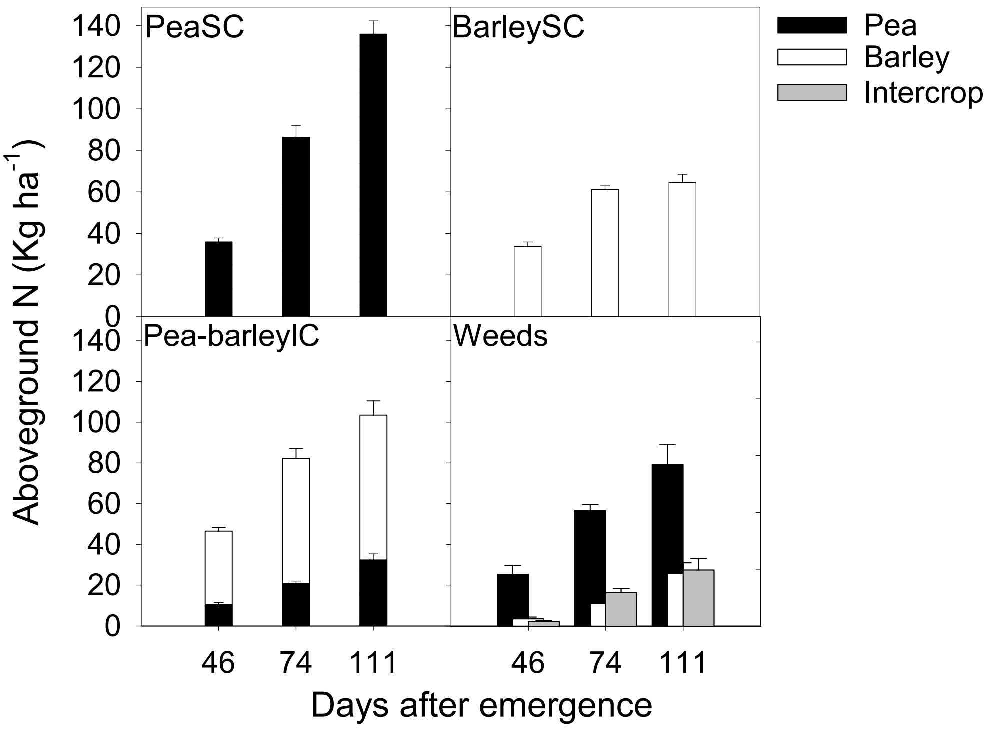

Fig. 2