Estimating nitrogen supply and cereal crop yield in organic crop production

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Implications

Hitherto it has been difficult for farmers to predict the effects of various sources of nitrogen (N) supply in organic farming, since these vary greatly in quality and thus in effect on crop yield. This has limited the planning of organic farming crop rotations and the application of manure and other mobile N sources to the crops, since the effect on crop yield would not easily be estimated. Here we used data from long-term organic crop rotation experiments in Denmark to determine the contribution of various N sources to yield of winter wheat and spring barley. The results showed consistent effects of N in soil organic matter, in organic matter applied to soils, in catch crops, in applied manure and of weed pressure. This opens the possibility for building a simple tool for crop rotation planning that will allow the effects of such crop rotations to be assessed in terms of cereal crop yields, and likely also yield of other non-legume cash crops. Such a tool can be used for strategic planning of crop rotations in organic arable farming taking into account the prehistory of the site as well as the possibilities of N supply through manure or measures to control weeds.

Background

Several studies have demonstrated that crop yield of cereals in organic arable farming is mainly constrained by availability of N and from competition by weeds (Olesen et al. 2007, 2009). Crop N supply for non-legume crops in organic farming depends on several sources, many of which are in organic form. The various forms of N are assumed to contribute differently to crop N uptake and N yield. However, so far it has shown difficult to estimate the contribution from each factor in a way that allows the information to be used for strategic planning of crop rotations and their management. In this study we used data from a long-term organic crop rotation experiment in Denmark to estimate the contribution of various N sources to yields of winter wheat and spring barley.

Results and discussion

The N uptake in grain of winter wheat and spring barley was estimated from data from 2006 to 2009 in crop rotation experiment at three locations (Jyndevad, Foulum and Flakkebjerg) in Denmark. Total N in the soil at onset of the experiment contributed about 0.0036 kg N in grain per kg N in top 25 cm of the soil for both crops. The amount of organic N input in above-ground residues and manure prior to the cereal crop contributed about 0.20 kg N per kg N in annual organic N inputs. Since the average period of inputs was about 10 years, this means a grain yield of about 0.02 kg N per kg N in accumulated inputs since the start of the experiment. The N in the above-ground of an incorporated catch crop prior to spring barley contributed 0.37 kg N per kg N in catch crop. The effect of manure application varied between locations and crops. For winter wheat the effect of ammoniacal N in the manure on grain N yield was 0.17, 0.55 and 0.39 kg N per kg NH_4-N for Jyndevad, Foulum and Flakkebjerg, respectively. For spring barley the effect of ammoniacal N in the manure on grain N yield was 0.58, 0.47 and 0.42 kg N per kg NH_4-N for Jyndevad, Foulum and Flakkebjerg, respectively. Weeds were found to reduce crop N update by 0.52 kg N per % dry matter in weeds at anthesis in winter wheat and by 1.06 kg N per % dry matter in weeds at anthesis in spring barley. The regression equations explained 69 and 73 % of the variation in grain N of winter wheat and spring barley, respectively. The results of grain N yield translated very well into grain dry matter yield with coefficients of determination of 0.99 for both crops.

The results show the relative contributions of various sources of N to crop yield. The smallest contribution (compared with the stock size) comes from native soil N. However, this stock of N is large and may vary considerably between fields, and should thus be taken into account. The amount of organic matter applied over the past 10 years contributes about 5 times as much in proportion of the amount of N present than native soil N, which indicates a faster mineralization of this of pool of soil organic N compared with native soil N. The contribution of N from freshly incorporated N in catch crops is much higher, which probably reflects the low C/N ratio of this material, which therefore releases a high amount of mineral N. The most variable contributions were from N in manure, in particular for winter wheat. Since the manure was applied in slurry and mostly injected to the spring cereals prior to sowing, this resulted in little ammonia volatilization for the spring cereals, and therefore consistent effects on crop yield. The low N use efficiencies of manure for winter wheat at Jyndevad and Flakkebjerg may be attributed to ammonia volatilization following surface application of slurry using trail hoses. The effect of weeds varied between cereals with the largest reduction for spring barley, which may partly be an effect of the generally smaller yields in spring barley compared to wheat, but may also reflect a smaller competitiveness of barley compared with wheat.

Materials and methods

An experiment on organic arable crop rotations was conducted at three sites in Denmark from 1997 to 2009 (Olesen et al. 2000; Askegaard et al. 2011). The experiment included three factors in two replicates: 1) Grass-clover green manure crop (with and without), 2) catch crop (with and without), and 3) animal manure (with and without). Four year crop rotations were used, and all crops in the rotations were represented every year. The experiment was placed at three sites with different soil and climatic conditions: Jyndevad (sand), Foulum (loamy sand) and Flakkebjerg (sandy loam). Where manure was applied this corresponded to about 40-60% of the recommended rates in conventional farming. Grain yields were determined for each plot by combine harvester. Samples of above-ground biomass dry matter were taken in each plot at ear emergence in the cereals, and the samples were separated into cereal, catch crop and weeds for assessing weed pressure. Samples of above-ground dry matter was also taken before cutting of the grass-clover at maturity of the main crops and in early November in catch crops and weeds to determine the amount of N being returned to the soil in residues. The harvested grain N yield in winter wheat and spring barley was related to a number of variables using multiple linear regression: 1) total N in the top 25 cm of the soil at onset of the experiment, 2) annual organic N inputs in crop residues and manure to the soil since onset of the experiment, 3) total N incorporated in spring in grass-clover or catch crops, 4) ammoniacal N in the manure applied, and 5) percentage of weeds in the crop at anthesis. Dry matter grain yield is then subsequently calculated from the grain N yield using a quadratic function.

References

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