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HARVESTING OUR FERTILISERS FROM THE SEA - AN APPROACH TO CLOSE THE NUTRIENT GAPS IN ORGANIC FARMING

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Abstract: Organic production in Europe is currently dependent on the input of fertilisers derived from conventional agriculture, such as farmyard manure, slurry and fertilisers derived from slaugther residues. A significant part of the nutrient flows in our food systems goes in one direction, from land to sea, via sewage and leaching. Harvesting marine organisms for fertilisation or utilising residual materials e.g. from fish industry as fertilisers, may close such nutrient gaps and promote active cycling of nutrients. At NORSØK, we are studying the use of algae fibre from seaweed (rich in potassium (K), magnesium and sulphur) and fishbones (rich in nitrogen (N), phosphorus (P) and calcium) as fertilisers. In a pot experiment with ryegrass (11 treatments, 4 replicates, 5 harvests), high yields were produced with fishbones, and the short-term N availability was much higher than for mineral N fertiliser. The same result was confirmed in a field experiment with dried poultry manure as control treatment (1 fertilisation level, 5 fertilisers, 4 replicates, random block design), and an outdoor pot experiment (2 fertilisation levels, 5 fertilisers, 4 replicates, random block design). Plants with a long period of nutrient uptake benefited from algae fertiliser. However, seaweeds contain significant amounts of arsenic (As), and easily available K may impact a balanced mineral content in the food or feed products. Excess P in the fishbones may cause eutrophication of this fertiliser is applied to cover N demands of the crop. Research is needed to make a well-balanced commercial fertiliser.

Introduction: Many commercial fertilisers are used in organic farming. E.g. in Norway, 118 products were permitted for use in certified organic growing in 2019. Organic gardeners often apply compost, e.g. from household waste, (conventional) animal manure and/or green waste to cover the plants' need for nutrients, especially nitrogen (N). Over time, this commonly leads to high levels of soil phosphorus (P), which is not environmentally sound. On the other side, organically managed soils are often depleted in P and other minerals, especially in arable farming systems, but also in milk production (Cooper et al. 2018). Organic farming is currently dependent on the input of animal manure and other animal-derived fertilisers, commonly derived from conventional production. This weakens the integrity of organic farming and is questioned due to animal welfare and environmental footprint. A significant part of the nutrient flows in our food systems go from land to sea, via sewage. Harvesting, or utilising available residues from seaweed, fish and other marine organisms for fertilisation may close such nutrient gaps and promote active cycling of nutrients. This paper present results from pot and field experiments with algae fibre and fish bones as fertilisers.

Material and methods: Fertilisers made from marine ingredients are rarely used in Norwegian agriculture, in spite of historical traditions and a significant marine industry. For our study, we searched for residual materials from marine industry which were locally available in the region around Tingvoll, Norway. We have worked with algae fibre, which are residues from extraction of liquid fertilisers from knotted wrack (*Ascophyllum nodosum*) which grows wild and is collected along the Norwegian coast. The extracts are produced at Algea AS, Kristiansund, and residual algae fibre is currently mixed into compost in a local waste treatment plant. Further, we have worked with fish residues, which are mainly bones from cod *(Gadus morhua)* and saithe (*Pollachius virens*), grinded and conserved with formic acid. This material was achieved from Fjordlaks AS in Ålesund, a company producing clipfish. The residues, here called fishbones, is a leftover sediment when grinded mass has been subject to hydrolysis during storage, and the layers of fish oil and soluble proteins have been removed to be utilised as feed in aquaculture. This sediment is currently disposed of as residual waste and usually incinerated.

Pot experiment with ryegrass, 2018

Dried and fresh fishbones without formic acid conservation, and dried and fresh algae fibre were tested separately in an indoor pot experiment with annual ryegrass (*Lolium westerwoldicum*) in 2018, with calcium nitrate and unfertilised soil as control. Drying occurred at 105 °C. Fertilisers were mixed with a sandy soil with medium to low P concentration, and plants were harvested five times (4 replicate pots per treatment, 600 g soil per pot). At each harvest, the amount of aboveground dry material was recorded. We aimed at applying the same amount of N with each fertiliser, corresponding to 300 or 600 kg N per hectare.

Combined field plot and pot experiment with oats and leek, 2019

In 2019, fresh algae fibre and fish bones conserved with formic acid were used, separately or mixed, in a combined outdoor pot and field plot experiment located next to each other and using the same soil. The plot experiment comprised 5 fertiliser treatments with one fertilisation level: Fishbone (FB), algae fibre (AF), mixed FB and AF where 30% of N came from AF and 70% from FB; dried poultry manure (PM) and soil with no fertilisation. The experimental crop was oats (*Avena sativa* L.). The pot experiment had the same fertilisers plus calcium nitrate, and all fertilisers were applied in two levels, comprising 13 treatments in 4 replicates. The experimental crops were oats and leek (*Allium porrum* L.), and each pot contained 9.7 kg sieved soil. In both experiments, experimental units were randomly distributed within 4 blocks. In field plots, we aimed at applying 160 kg N/hectare. In the pot experiment, we aimed at applying 80 or 160 kg N/hectare in oats, and 160 or 320 kg N/hectare for leek. The plants were harvested at the aboveground maximum dry matter production stage, in late July for oats and late August for leek. Yields of aboveground fresh and dry matter (DM) were recorded. In all experiments, nutrient concentrations in soil and plants were analysed.

Results: Pot experiment with ryegrass, 2018

Application of fishbones increased the yields of ryegrass significantly. Converted to yields of dry matter (DM) per hectare, on average for the two N levels, fishbones gave 10.9 tons per hectare, whereas non-fertilised soil (control) gave 7.2 tons. Calcium nitrate gave 8.6 and algae fibre 8.5 tons. We found no significant effect of drying the fertiliser materials. Algae fibre gave a high uptake of potassium (K), hence decreasing concentrations of magnesium (Mg) and calcium (Ca) in plant material. In spite of high concentrations of arsenic (As, 33 mg/kg DM) in AF, and a large application of material (up to 4 g of dry fibre per pot), the concentrations of As in plant material were below the detection limit.

Combined field and pot experiment with oats and leek, 2019

The yields of oats in the field plots were significantly increased with application of fishbones. On average, 4.8 tons of DM per hectare were produced, as compared with 2.7 tons with no fertiliser application (control). For algae fibre applied alone, the yield level was equal to the control. With poultry manure, the yield level was 3.8 tons, and with combined AF+FB it was 4.4 tons per hectare. In the pots with oats, calcium nitrate increased the growth only slightly. Poultry manure and algae fibre both gave about 50% higher DM yields than the unfertilised control. Best results were achieved with FB and FB+AF, which both increased aboveground DM production by about 180% with low level of fertilisation, and more than 200% with high fertilisation.

A positive effect of combining AF+FB was also found in leek. The yield level was generally low as compared with commercial growing of leek, where a leek for sale should have a fresh weight of about 200 g (roots removed). However, we achieved very clear differences in growth with different fertilisation. With no fertiliser (control), the fresh weight of leek was 4.4 g per plant. Calcium nitrate decreased the yield slightly to 3.4 g (both application levels), whereas poultry manure gave leeks weighing 8.3 g with low and 9.8 with high application. With AF only, yields were 21.6 and 30.3 g per plant. FB alone gave 29.4 and 34.5 g per plant. AF+FB gave the maximum yield, with 27.5 g per plant for low and 42.1 g for high application of fertiliser.

Whereas in oats grown in pots, the concentration of DM only varied between 24% (no fertiliser) and 26% (AF), algae fibre decreased the amount of DM in the leeks. The value was 17% with no fertiliser, and about 11% with AF only. Highest values of DM were obtained with application of FB only, about 19%.

As was also found in the indoor pot experiment, no plant samples from field pot or plots contained arsenic (As) above the limit of detection.

Discussion: Several experiments at NORSØK have shown that crop plants grow vigorously with application of fishbones to the experimental soil. This may be due to a high proportion of mineral N in this material, since analyses show that close to 100% of the total N in the fishbones is ammonium. Possibly, the N in the fishbones may occur in organic molecules which are converted to ammonium during the analytical procedure, and which are taken up by the plants very easily (Dion et al. 2018). The very rapid growth effect, much faster than for calcium nitrate which also is expected to give a rapid response, may point in this direction. However, it may also be due to easily available P, and further study is required to explain this effect in more detail. The effect of algae fibre on plant growth is long-term (Ahuja & Løes 2019). Combining algae fibre, fishbones and possibly other materials into a balanced, complete fertiliser is an important field of study. Fertilisation with marine residues obtained from Norwegian industry partners have given positive results so far. Hence, harvesting nutrients from the sea seems to be a useful strategy for organic farming to close existing nutrient gaps.

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