Organic World Congress 2020 | FRANCE
SEPTEMBER 21ST TO 27TH, 2020 IN RENNES
AT THE COUVENT DES JACOBINS • RENNES MÉTROPOLE CONFERENCE CENTRE
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OWC 2020 Paper Submission - Science Forum

Topic 3 - Transition towards organic and sustainable food systems

OWC2020-SCI-1098

DOUBLE CROPPING, PLANT-BASED FERTILIZATION AND WINTER PLANT COVER IN VEGETABLE PRODUCTION FOR SUSTAINABLE INTENSIFICATION – A SYSTEM'S APPROACH

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Preferred Presentation Method: Oral or poster presentation

Full Paper Publication: No

Abstract: The global agenda asks for high and efficient food production in a sustainable way. A major part of the solution is a significant increase in vegetable consumption, which asks for an implementation of sustainable intensification in organic farming production of open-field vegetables. The aim of this study was to advance the design of cropping systems and their nitrogen management to achieve high yielding systems, while limiting nitrate leaching. A 5-year crop rotation trial was designed, including double cropping, plant-based fertilisers, catch crops, green manures and plough-free controlled traffic farming. The system was compared to a more standard organic crop rotation, fertilised by liquid manure. Crop yields, root growth, plant and soil nitrogen pools, soil microbial activity and nitrate leaching potential were studied in two years. Results showed that yields calculated per area were maintained for each crop, and increased for the season in the double-cropped system for at least two out of four fields of the rotation. Effects on soil nitrogen availability and leaching potential were ambiguous. Soil microbial activity, measured as potential nitrogen mineralisation and enzymatic activity, increased by more than 15% in the double-cropped compared to the standard system in the crop rotation. In conclusion, yields and soil fertility increased in the double-cropped system fertilised by plant-based sources and managed by plough-free controlled traffic farming. However, the high soil fertility asks for an increased focus on winter plant cover to avoid high leaching losses and to align to the principles of sustainable intensification.

Introduction: The global agenda as stated by the UN sustainability goals and the EAT-Lancet Commission asks for high and efficient food production in a sustainable way (Willett et al. 2019). The goal is a substantial reduction of the impact on climate, environment and biodiversity and a major part of the solution to the global challenges is a significant increase in vegetable consumption. This asks for implementation of sustainable intensification in organic farming production of open-field vegetables (Kremen and Miles 2012; Willett et al. 2019).

The intensive production methods used in, for example, Danish high-value crop production put high demands on the soil as a functional service to provide proper conditions for crop growth in terms of soil tilth and availability of nutrients and

water. These demands are highly contrasted by the fact that most high-value crop production deteriorates soil quality due to very intensive tillage, and low inputs of organic matter and fertilisation by use of conventional liquid manure. Thus, there is a strong need to find new ways to increase harvested yields, independent of fertilisers of animal origin by using services provided by a diverse crop rotation and a fertile soil.

Recent research has documented innovative tools for organic high-value cropping systems by intercropping of vegetables and catch crops for building up soil fertility and reducing nitrate leaching (Xie et al. 2017). Such potential beneficial effects should also be investigated for partial intercropping, so called double cropping, of two yielding crops with the aim to extend the growth season. In addition, research has shown the potential of on-farm production of plant-based fertilisers (cut-and-carry) of up to 500 kg N ha^{-1} per season to replace animal manure as fertiliser (Sørensen and Grevsen 2016). Finally, positive effects of plough-free controlled traffic farming were recently documented for vegetable yields, root growth and nitrogen availability (Hefner et al. 2019). Combining these innovative single-year methods into a multi-year crop rotation for increasing soil fertility, yields and sustainability represents a novel approach to organic crop production. This asks for investigation with a system's approach, which aligns to farmers' practice, but disables a full factorial statistical design.

The hypothesis is (i) an intensive double-cropped organic crop rotation fertilised by plant-based fertilisers, including optimised winter plant cover and plough-free controlled traffic farming will improve vegetable yields, soil fertility and reduce nitrate leaching compared to a standard crop rotation.

Material and methods: A 5-year organic crop rotation trial was designed, including double cropping, plant-based fertilisation and plough-free controlled traffic farming in combination with a winter plant cover whenever possible. The winter plant cover consisted of catch crops and green manures, which were also used for the production of plant-based fertilisers. The system was compared to a more standard organic crop rotation including ploughing and fertilisation by conventional liquid manure. The trial was established in 2016 at AU-FOOD, Aarslev; DOUBLECROP Field 1: Full season clover. Field 2: Pointed cabbage + summer cabbage + cereal/legume catch crop. Field 3: Celeriac + spinach catch crop. Field 4: Lettuce + leek + winter rye catch crop. Field 5: Onion + lettuce + undersown legume. Plant-based fertilisers of seeds, silaged and fresh green manures were applied for fertilisation and tillage was conducted by harrowing. STANDARD Field 1: Barley + undersown clover. Field 2: Winter cabbage + cabbage stalk catch crop. Field 3: Celeriac. Field 4: Leek. Field 5: Lettuce + lettuce. Fertiliser was applied in the form of conventional liquid pig manure, and tillage was conducted by ploughing and harrowing. Crop yields, root growth (minirhizotron method, Hefner et al. 2019), crop nitrogen and soil mineral nitrogen, potential nitrogen mineralization and soil enzymatic activity (β-glucosidase, dehydrogenase) were studied in 2017-2019.

Results: Results showed that yields calculated per area were maintained or increased for each crop, except for celeriac in 2019, and increased when counted as sales units in the double-cropped system for two out of four vegetable crops in 2018 and 2019 (Figure 1). Effects on soil nitrogen availability and leaching potential were ambiguous, sometimes showing higher and sometimes lower pools of soil mineral nitrogen (results not shown). Potential mineralisation increased under the double-cropped system by 20 to 40% and soil β-glucosidase activity by 4 to 30% from 2018 to 2019 (Figure 2).

Discussion: Vegetable yields were in general maintained or increased in the double cropping system – especially with a commercial perspective of counting marketable units instead of marketable yields per area. Soil fertility was indicated to

increase based on measurements of potential mineralisation and soil enzymatic activities. However, with the increase of soil fertility an increased risk of nitrate leaching was indicated. Therefore, in future implementation at farms, attention is needed to the winter plant cover to ensure recycling of soil mineral nitrogen in double-cropped systems fertilised with plant-based sources and managed by plough-free controlled traffic farming. This is to avoid increase of leaching losses, which will conflict with the principles of sustainable intensification.

Acknowledgement: The DoubleCrop project was supported by the RDD3 and GUDP programme (ICROFS and Danish Ministry of Food and Agriculture).

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Figure captions

Figure 1. Vegetable yields in sales units per area in the double-cropped and standard organic cropping systems in 2018 and 2019. Bars show standard errors, n=3.
Figure 2. Soil activity of β-glucosidase in April, 3 weeks before; and in May, 3 weeks after spring fertilisation in the double-cropped and standard organic cropping systems in 2018 and 2019. Bars show standard errors, n=3.

Image 1:

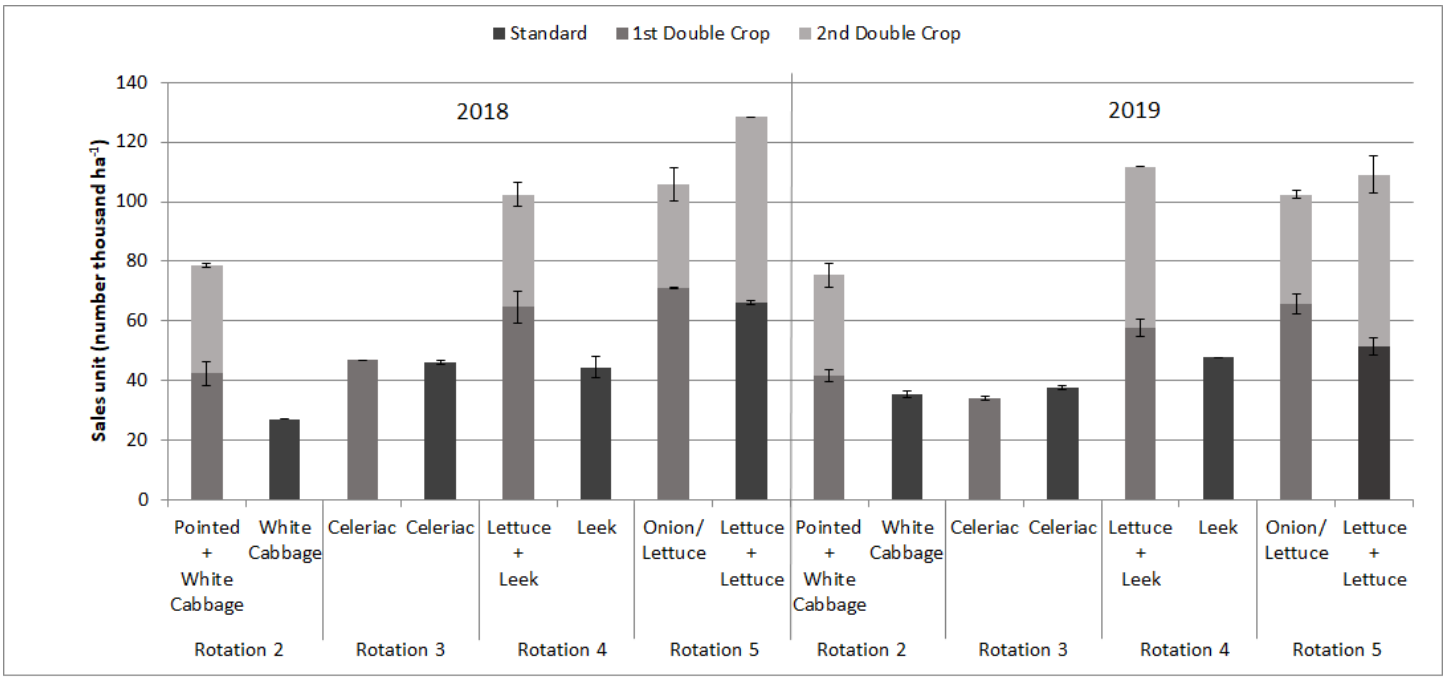
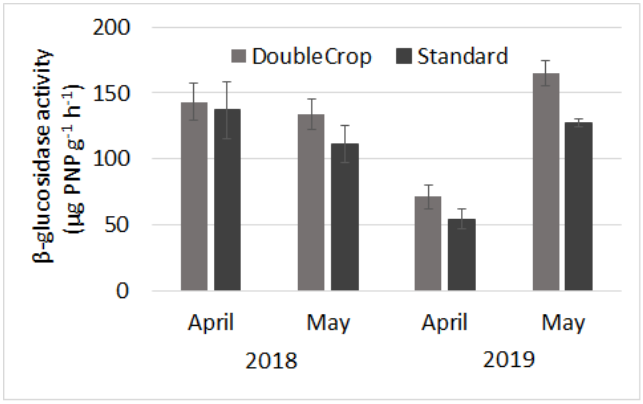


Image 2:



Disclosure of Interest: H. Kristensen: None Declared, J. Soerensen: None Declared, M. Hefner: None Declared, R. De Visser is consultant for: organic vegetable producers

Keywords: Keywords: cut-and-carry fertilisation, intercropping, nitrogen mineralisation, root growth, soil fertility, vegetable yield