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-795

FIELD BALANCES OF ORGANIC APPLE ORCHARDS IN TWO REGIONS OF GERMANY

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Preferred Presentation Method: Oral or poster presentation

Full Paper Publication: Yes

Abstract: Fertilizers used for organic apple production contain multiple nutrients with a nutrient composition that differs from that of the harvested products. Some plant protection agents also contribute to an input of nutrients. To gain information on the status of nutrient balances and to identify potential causes for imbalanced nutrient flows, a survey was conducted in two main apple growing regions of Germany. The current management was analysed based on field balances of apple orchards using data spanning a five-year period. The averages showed small surpluses of P (3 kg ha^{-1}), a deficit of K (-10 kg ha^{-1} a^{-1}) and stronger surpluses of N (26 kg ha^{-1}), Ca (36 kg ha^{-1}) and S (50 kg ha^{-1}). Base fertilizers had a liming effect, while some commercial fertilizers, pesticides and the offtake of harvest products had an acidifying effect. The severity and range of nutrient imbalances differed between the regions and was dependent on the kind of fertilizers (base or commercial) and pesticides used.

Introduction: Organic permanent cultures are a challenge for the nutrient management. Fertilizer options are either base fertilizers like composts and manure or commercial fertilizers like horn grit, feather meal, vinasse, etc. All these fertilizers contain multiple nutrient elements. Often, the nutrient demand of the crop differs from the nutrient composition of the fertilizers (Möller, 2018; Zikeli et. al., 2017). Additionally, there is a nutrient input of S, K and Ca with some plant protection agents used against fungal diseases. The analysis of anonymous soil samples from Southern German organic fruit orchards as a preliminary investigation of this survey showed high contents of P and K. These results led to further investigations on the current status of nutrient balances in organic apple orchards as presented in this study in order to improve the long term sustainability of the farming systems.

Material and methods: For the survey, farms were contacted via FÖKO e.V., a German umbrella organisation for fruit producers of different organic farming associations. A pre-test was done on a fruit farm to assess the practicability of the questionnaire. Participating farms were from the main apple growing regions in Germany, in Baden-Württemberg, South-West Germany (Stuttgart-Heilbronn (4), Lake Constance (6), South Baden (5)) and of the region Altes Land (4) in Northern-Germany, close to the city of Hamburg. From up to five orchards per farm data was collected on fertilizers and pesticide application as well as the yield of five consecutive years (2012 – 2016 for Southern Germany, 2014 – 2018 for

Northern Germany) based on the records of the farmers. The analysis of the nutrient input and output on field level was done on the elements N, P, K, Ca, Mg, S, Na and Cl. Therefore, plant protection agents containing these nutrients (fungicides mainly for control of *Venturia inaequalis*, containing S, K and Ca) were also included. For the calculation, specific values of nutrient contents of the fertilizers were used if available; otherwise, standard values were taken.

Results: The average field balances showed higher nutrient inputs than outputs for all the elements, except K with -10 kg ha^{-1} (Fig. 1). For P, Mg, Na and Cl the surplus was below 5 kg ha^{-1}, while higher values appeared for N (26 kg ha^{-1}), Ca (36 kg ha^{-1}) and S (50 kg ha^{-1}). Over two thirds of the N input came from commercial fertilizers, while the remainder were from base fertilizers. K and Ca were added by base and commercial fertilizers, as well as by the plant protection agents. The primary S input occurred by pesticides. The liming effect was negative overall, and was caused mainly by pesticides as well as by commercial fertilizers and removal of harvest products.

Figure 1: Nutrient input, output and field balance of German organic apple farms (n=18) in Stuttgart-Heilbronn (4), Lake Constance (6), South Baden (5) and of the region Altes Land (3).

Split between Northern and Southern Germany, differences could be seen in the average and the range of the values (Tab. 1). In Southern Germany the K balance was negative, while in Northern Germany it was slightly positive, with a higher negative minimum and a lower maximum. With Ca the minimum values were similar while the maximum was 5-fold higher in Southern Germany. A higher P surplus as well as a higher S application could be seen in Northern Germany. The results of the field balances for N were comparable in both regions whereas the Nitrogen use efficiency was higher in the South (34 %) than in the North (22 %). The acidifying effect was much higher in Northern orchards (Tab. 1).

Table 1: Nutrient field balances of German organic apple farms (n=18) in Stuttgart-Heilbronn (4), Lake Constance (6), South Baden (5) and of the region Altes Land (3).

	Southern Germany (n=15)			Northern Germany (n=3)		
	Mean (kg ha-1)	Min (kg ha-1)	Max (kg ha-1)	Mean (kg ha-1)	Min (kg ha-1)	Max (kg ha-1)
N	24,7	-5,8	50,1	33,4	-6,1	54,8
P	1,5	-4,8	8,2	9,0	-3,2	21,1
K	-13,4	-63,0	40,4	5,0	-18,0	29,3
Ca	40,2	-0,8	204,2	13,3	-1,2	38,6
Mg	3,1	-2,9	26,8	0,6	-0,8	1,9
S	45,9	18,8	92,8	72,2	38,9	92,1
Na	3,2	-0,6	16,7	3,7	0,0	8,6
Cl	3,6	-0,2	10,4	2,9	-0,3	9,3
liming effect	-50,3	-157,9	169,8	-146,9	-202,2	-75,3

Farms differed in their fertilization management. Those who primarily used base fertilizers (more than 30 % of the N input) showed higher field balances for all nutrients as well as lower nitrogen use efficiency (22 %) in comparison with farms using mainly commercial fertilizers (39 %, data not shown). Composts and manure show a liming effect, while commercial fertilizers have an acidifying effect.

Discussion: The results of the nutrient budgeting show that the current fertilization strategies do not lead to balanced nutrient flows. Organic fertilizers contain multiple elements with at least two main nutrients. None of these show a

composition comparable with the demand of apple trees. Consequently, a fertilizer application with regard to the N demand will lead to an over or undersupply of other nutrients. The application of base fertilizers results in an oversupply of Ca and Mg, while the use of commercial fertilizers leads to a K deficiency and especially a surplus of S. The K fertilizers permitted in organic farming even increase the imbalances, since they also contain S. Plant protection can be the reason of imbalances because of its major S input. The extent of the imbalances differs between the two regions and the kind of fertilizers and pesticides used. The nitrogen use efficiency was higher in commercial fertilizers similar to the situation in organic greenhouses (Zikeli et.al., 2017). Because of their higher efficacy, a more efficient fertilizer application with regard to the amount and point in time is possible by commercial fertilisers compared to base fertilizers. Further research will relate the results to the respective soil nutrient status.

References: Möller K (2018): Soil fertility status and nutrient input-output flows of specialized organic cropping systems: a review. Nutr. Cycl. Agroecosyst 112:2, 147-164.

Zikeli S, Deil L & Möller K (2017): The challenge of imbalanced nutrient flows in organic farming systems: A study of Organic greenhouses in Southern Germany. Agriculture, Ecosystems and Environment 244, 1-13.

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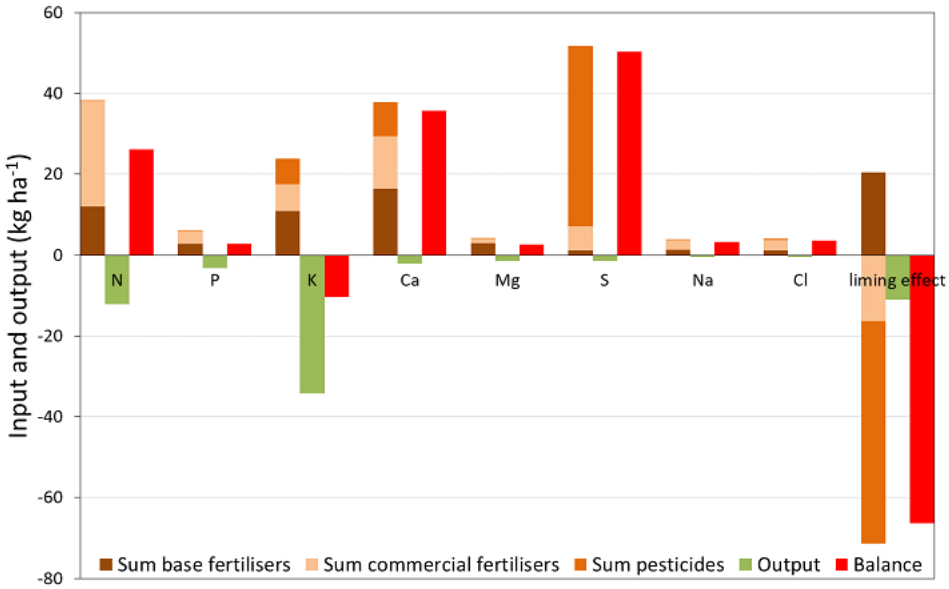

Disclosure of Interest: None Declared

Keywords: fertilization, field balance, nutrient input and output, nutrient use efficiency, organic apple production, sustainability