SWISS FUTURE FARM

Annual Report 2021

About the farm

Farm size and structure

81 ha agricultural land

55 ha arable farming

20 ha permanent grassland

6 ha biodiversity area

Dairy barn

Cattle in Tänikon:

65 dairy cows

2/3 Brown Swiss, 1/3 Red Holstein and Holstein Frisian

Cow husbandry:

The farm provides the barns required for the various trials conducted by Agroscope and the Swiss Future Farm.

- Two sites with dairy barns: Emissions trial barn Waldegg & dairy barn Tänikon
- Cows are milked twice a day using a 2x5 herringbone milking parlour
- Breeding calves leave the farm after 3 weeks and spend the period until 4 weeks before the first calving on two partner farms and on the alpine pasture

Calf rearing:

- Single housing in igloos with access to exercise
- Milk freely available
- Breeding calves leave the farm after 3 weeks and spend the period until 4 weeks before the first calving on two partner farms and on the alpine pasture

Pig barn

Number of animals:	Number of spaces:
60 breeding pigs	120 fattening pens
1 boar	200 breeding pens
	18 farrowing pens

Objectives

The Swiss Future Farm makes modern precision farming technologies visible, tangible and understandable for sustainable and competitive agriculture:

- Practice-oriented field trials are carried out on site and presented to the public.
- Digital farm management is implemented in an exemplary and practice-oriented way in an agricultural environment.
- Research and development results are applied in agricultural practice.
- Innovative cooperation between private agricultural enterprises and public education and consulting.
- Tänikon as a meeting point for agriculture.

Partners

AGCO International GmbH
Leading manufacturer of high-tech solutions for farmers: Brands: Fendt, AGCO Grain & Protein, Massey Ferguson, Precision Planting, Valtra.

Arenenberg
Agricultural education and advisory center of the Canton of Thurgau with three research and pilot farms.

GVS Agrar AG
Market-leading importer of agricultural machinery in Switzerland. Import, sales and service for all AGCO brands.

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1 Field Trials

1.1 Robotic Planting Study in Corn

Study Contact

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Objective

The objective of this study was to investigate the agronomic performance, yield evaluation and vehicle ballasting in corn planted at different planting depths by use of an agricultural robotic solution which was electrically powered autonomous field robot Fendt Xaver Gen 3 (https://www.fendt.com/int/2-fendt-xaver).

Study Design

The study was carried out on the Swiss Future Farm (Switzerland) in 2021 season as a side-by-side strip trial. The following planting depths and vehicle weights were tested:

- 5.0 cm (230 kg)
- 5.0 cm (180 kg)
- 5.5 cm (180 kg)
- 4.5 cm (180 kg)

All trial strips were planted with two synchronously working Fendt Xaver robots with Precision Planting vSet seed meters and vDrive electric drives as part of the planting unit with a planted population of 90,000 seeds per hectare on 10th May 2021.

Crop care operations in the trial plot were conducted according to usual farm practice and with conventional tractors and implements for herbicide application (Banvel 4 S, 0.5 l/ha and Equip Power, 1.5 l/ha) and fertilization (Urea 46-0-0, 108 kg/ha).

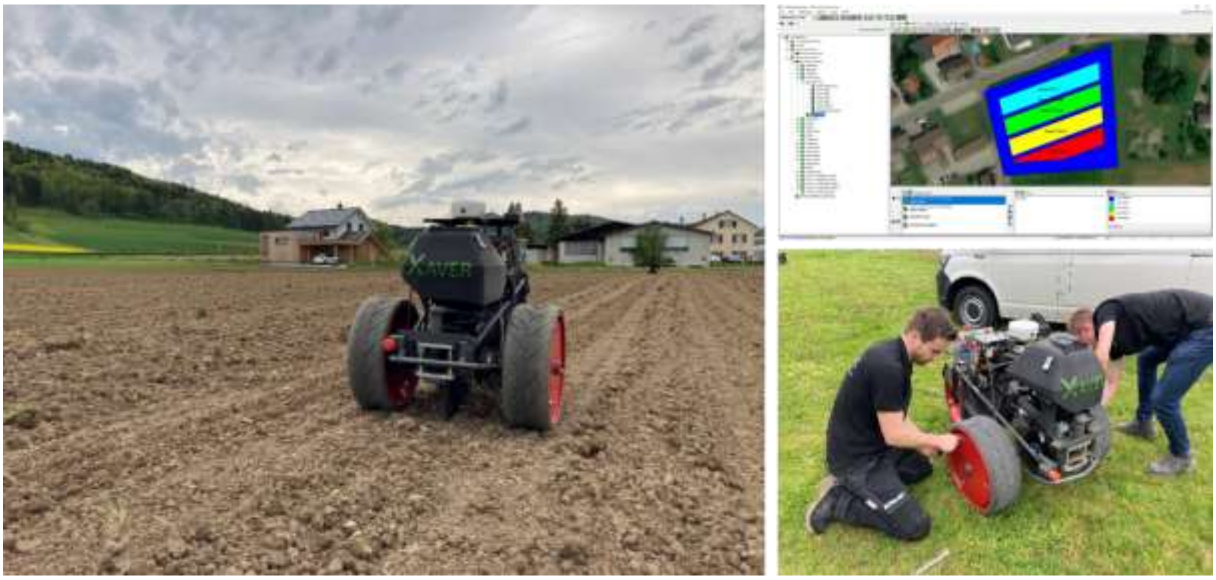

Figure 1. Fendt Xaver Gen 3 field robot planting the trial plot (left), trial design and plot planning in FMIS (top right), wheel weight installation for vehicle ballasting (bottom right).

Results

For a yield estimate, the trial was hand-harvested on an area of 1/1000 hectare for each treatment 137 days after planting. Corn harvested from the trial strip planted at standard planting depth of 5.0 cm and 180 kg vehicle weight provided the highest grain yield in the comparison with 11.1 tons/ha, whereas lower yield of 10.6-10.8 t/ha was found on the trial strips planted with higher vehicle weight (230 kg) and deeper (5.5 cm) or shallower (4.5 cm) planting depth (Figure 2).

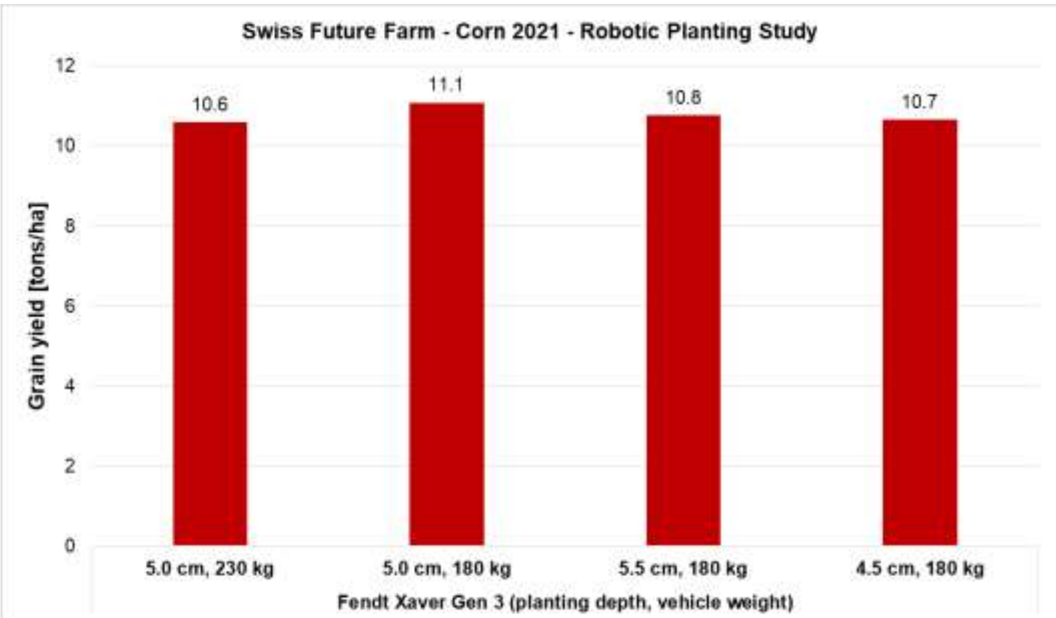

Figure 2. Grain yield estimate results at 14% moisture of the SFF 2021 Robotic Planting Study in corn.

However, yield difference between the planting depths and vehicle weight settings was in a range of <5%, and satisfying yield level (aiming for grain yield of 12.0 t/ha at 14% moisture) was achieved under the unfavorable local weather conditions for corn in 2021 that is comparable to the local average yield level of corn planted with conventional machinery. At the example of corn planting, these results show that field robotics solutions may be able to deliver agronomic performance that is comparable to conventional agricultural machinery. Future trials need to investigate the performance of robotic solutions for further field operations through the crop cycle, including tillage, crop care, and harvest.

Additional Observations

Growth stages of corn in the individual trial strips were measured in the established crop stand 54 days after planting using the Precision Planting POGO Stick and Research POGO App. The investigation of juvenile development shows that the trial strip planted with standard planting depth and higher vehicle weight (5.0 cm, 230 kg) had the highest share of further developed corn plants in the 8-leaves stage (V8), whereas corn planted with lower vehicle weight (180 kg) and deeper (5.5 cm) or shallower (4.5 cm) planting depth was slightly less developed, as indicated by the higher share of plants in growth stages V6 and V7 (Figure 3).

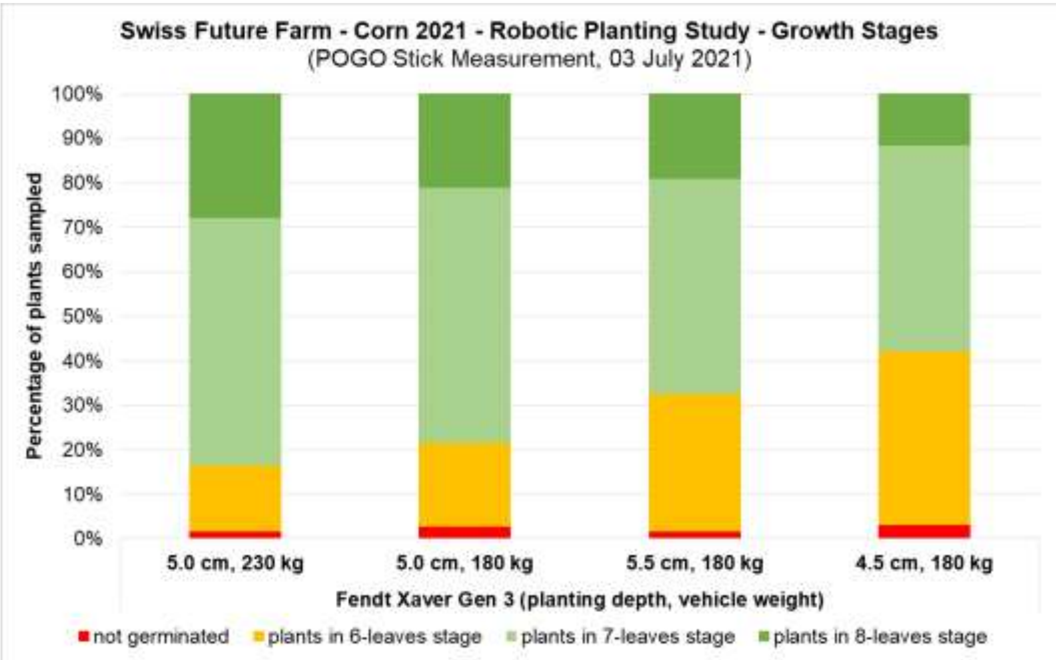

Figure 3. Assessment of crop development in the SFF 2021 Robotic Planting Study in corn.

Close to harvest date, we found crop development of the corn stand planted with the Fendt Xaver Gen 3 field robot to be comparable to the expected crop development using conventional planters (Figure 4).

Figure 4. Corn field planted with Fendt Xaver Gen 3 field robot on the Swiss Future Farm, photos taken close to harvest date on 25th September 2021.

Recommendations and Equipment Solutions

- vSet™ meters and vDrive™ electric drives for consistently good singulation and spacing accuracy.
- POGO Stick and Research POGO App enable digitalized crop measurements and evaluation of planter performance.

Figure 5. Precision Planting vSet seed meter (top left), Precision Planting vDrive electric drive (bottom left), Precision Planting POGO Stick (top right) and Research POGO App (bottom right) for crop measurements.

Payback

The highest revenue was obtained from corn planted at standard planting depth of 5.0 cm and 180 kg vehicle weight (4042 CHF/ha), which is 177 CHF/ha more revenue than with the lowest yield level in the comparison with 5.0 cm planting depth and 230 kg vehicle weight (Figure 6).

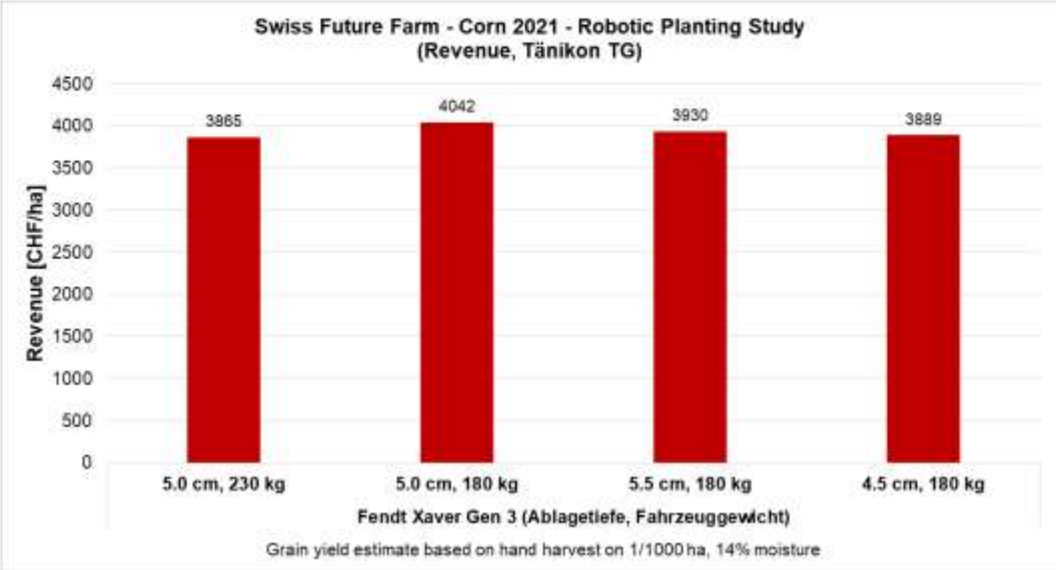

Figure 6. Revenue obtained from the SFF 2021 Robotic Planting Study in corn.

The assumptions on payback are based on the basic grain corn price of CHF 365.00/ton at 14% moisture (swiss granum 2021) excl. harvest, transport and drying costs.

1.2 Weed control strategies in silage corn: with herbicide, herbicide-reduced, and herbicide-free

Study Contact

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Objective

The aim of this study is to compare mechanical, herbicide-reduced and chemical weed control measures in silage corn in practical, 15 m wide trial strips. The trial serves as important illustrative material for farms that already practice herbicide-reduced or herbicide-free management in silage corn or would like to obtain information on this topic. In addition to the observable effects of the measures in the field, the costs of the individual methods are also directly compared. The trial was conducted for the first time in 2020. Based on last year's experience, the trial strips were adapted.

Study Design

The trial was carried out on the Mühlewiese field, which is characterized by low heterogeneity. The area has a slight slope on the west side, which is why the harrow treatments were arranged in the eastern part. Temporary grassland was the previous crop on the plot. The silage corn variety sown was KWS Amaroc with a seed rate of 90,000 plants/ha.

Figure 7 shows the division of the 15 m wide and 70 m long trial strips.

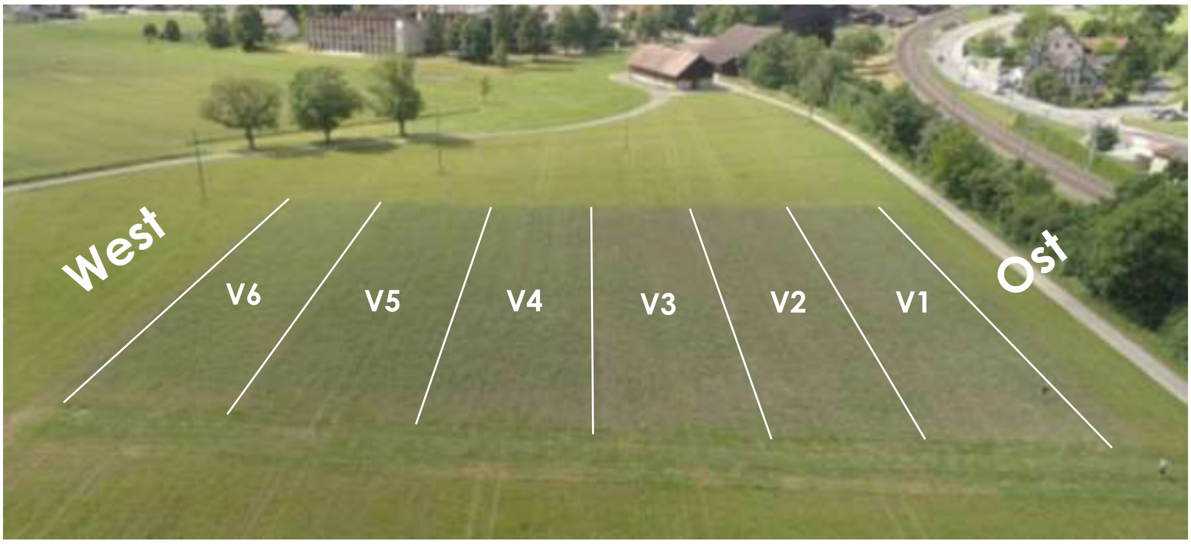

Figure 7. Arrangement of trial strips on the Mühlewiese trial field.

Table 1. Weed control measures per trial strip.

Trial strip	Blind harrowing	Harrow	Hoeing	Herbicide	Band sprayer	Cover crop
V1	Planned but not implemented	2x				
V2	Planned but not implemented	1x	1x			
V3	Planned but not implemented	1x	1x			
V4			1x		1x	
V5	Planned but not implemented	1x				1x
V6				1x		

Table 1 lists the weed control measures per trial strip.

Table 2. Field calendar for the Mühlewiese trial field.

Date	Field operations
10 May 2021	Slurry (36.8 m3/ha cattle slurry) Manure (11.7 t/ha of cattle manure) Plowing Rotary harrowing Planting (KWS Amaroc silage corn, 90,000 plants/ha)
04 June 2021	Harrowing Hoeing test aborted due to unfavorable conditions
14 June 2021	Herbicide application in treatment V6 Banvel 4S: 0.5l/ha Equip Power: 1.5l/ha
21 June 2021	Cover crop seeding with Persian clover (sown by hand) Harrowing Hoeing
22 June 2021	Fertilization (urea 46%: 108 kg/ha)
25 June 2021	Band spraying in treatment V4 Banvel 4S: 0.5 l/ha Equip Power: 1.5 l/ha
27 September 2021	Harvest

Overview of the field operations

Tillage and planting

On May 10, 2021, manure and slurry were applied to the Mühlewies trial field. Due to the threat of wet weather from the early morning of the following day, plowing, harrowing and sowing were carried out following fertilization in less than optimal conditions.

Figure 8. Tillage with plow and rotary harrow.

Blind harrowing

Due to the persistent rain until the end of May, the planned blind harrow pass on trial plots V1, V2, V3 and V5 could not be carried out.

Harrowing

On June 4, 2021, after a few sunny and warmer days, the field was open to traffic for the first time. The harrowing conditions were not favorable due to the non-optimal timing of tillage and planting, as well as the subsequent persistent rain, which led to a re-growth of the previous grassland. It was necessary to keep the tine tension low (strength 2 of 10), otherwise the soil would have been torn up too much, clods of soil would have been exposed and the corn plants would have been buried or uprooted. Weeds in the cotyledon stage could be well regulated with the harrow. However, against the grass tufts, the harrow showed no effect according to experience.

The second harrow pass took place on June 21, 2021. Compared to the first pass, the tine tension was increased to level 3 of 10. On June 22, there was already another rain period, so that the weeds could not dry out optimally.

Figure 9. First harrow operation on June 4, 2021.

Figure 10. Second harrow operation on June 21, 2021.

<u>Hoeing</u>

On June 4, a first hoeing trial was started on the trial plot. However, due to the long, preceding wet period and the poorly developed corn stand, only a marginal strip outside the trial was chopped on a trial basis. However, the chopping pass had to be interrupted again, as the chopped out tufts of grass carried away whole clods of soil and also corn plants. Furthermore, the clods of soil also clogged the chopping coulters.

Figure 11. Images of the first aborted hoeing attempt on June 4, 2021.

Figure 12. Pictures of the hoeing pass on June 21, 2021. The finger hoes in the right picture were dismantled because clods of soil were wedged in them.

On June 21, trial strips V2, V3 and V4 were hoed. In trial strip V3 it was planned to work with finger hoes in addition to the goosefoot coulters to also regulate weeds in the row. Weather conditions were optimal for a hoeing pass with a sunny 25 degrees in the afternoon. However, field conditions remained very challenging. The uneven and coarse soil kept causing the hoe to slip, and the camera had trouble guiding the row due to the very patchy corn stand. Hoeing with the finger hoes in trial strip V3 had to be aborted because the clods of soil got wedged in them and pulled the corn plants along and out. For this reason, only goosefoot shares were used for hoeing in all three trial strips. During the hoeing pass, the speed was 4 km/h.

Cover crop

In trial strip V5, Persian clover was undersown on June 21. The choice of Persian clover was intended to reduce the high costs of the previous year's cover crop seeding, as it is cheaper than the UFA Maisfix cover crop mixture chosen the previous year. Furthermore, after sowing the Persian clover, which should have been sown with the pneumatic fertilizer spreader as in the previous year, we wanted to dispense with the need to reed in the clover and thus save further costs. In the end, due to time constraints, we opted for hand seeding the clover undersow. The conditions were suitable for undersowing, as it was already raining again the day after sowing.

Herbicide application

The herbicide treatment served as a comparative method for mechanical weed control and was applied broadcasted in trial strip V6 on June 14 and as a band spray in the rows in trial strip V4 on June 25. The herbicides used were Banvel 4S (0.5 l/ha) and Equip Power (1.5 l/ha).

Weed infestation measurements

On July 12, 2021, a weed sampling was carried out in all experimental strips on the plot. For this purpose, an area of 1 m^2 was counted with three repetitions each. The results are summarized in Figure 13. The visual scoring of the strips can be seen in Figure 14. It can be seen that in all trial strips there was a heavy regrowth of the previous grassland. However, in trial strip V6, this was destroyed by the application of the herbicide. The grassland also had a suppressive effect on other weeds. This may be a reason for the low weed numbers in trial strips V2. It is also evident that clover growth could only be assessed in treatments V1 and V3. This reflects the poor development of the undersown Persian clover in trial strip V5. With the exception of the speedwell population, herbicide treatment in V6 was very effective because no other weeds were present in the counted scoring plots. Weed cover was highest in harrow trial strip V1. The diversity of counted weeds was also high in this treatment. This is not surprising, since the harrow application was very difficult due to the uneven conditions in the field.

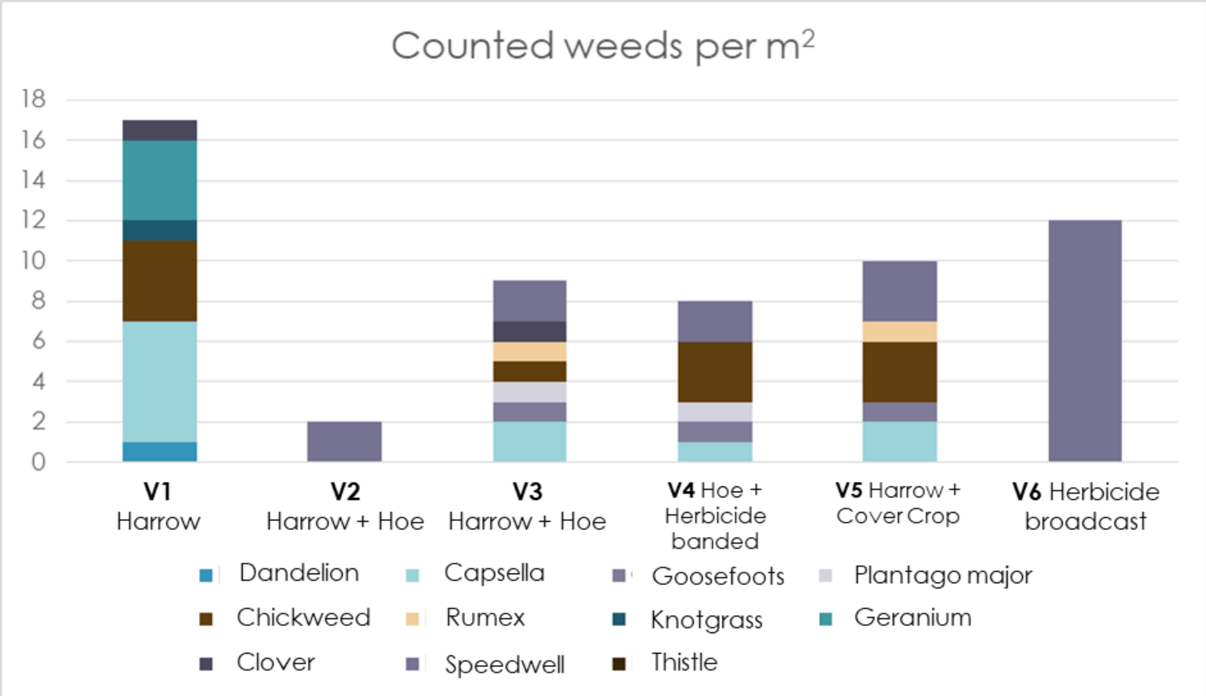

Figure 13. Results of the weed sampling of July 12, 2021.

V1: 2x Harrowing	V2: 1x Harrowing, 1x Hoeing	V3: 1x Harrowing, 1x Hoeing
		
V4: 1x Hoeing, 1x Herbicide banded	**V5: 1x Harrowing, Cover Crop**	**V6: Herbicide broadcast**
		

Figure 14. Stand images created during the July 12, 2021, weed infestation measurement after all treatments were completed.

Results

Silage Yield

The trial strips were individually harvested and loaded to trailers on September 27, 2021 in best weather and then weighed. DM yields in the trial strips ranged from 15.1 t/ha (trial strip V3) to 19.5 t/ha (trial strip V6). As in the 2020 trial year, the highest yield was obtained in the herbicide method followed by the harrow method. However, the differences between these two on the field edge and the rest of the treatments is very noticeable this year and could not be conclusively clarified. In 2020, the differences between the methods were much smaller. The 2021 yield was significantly lower than the yields (8.1% - 21.9%) of the previous year in all treatments (see Table 3). This is due on the one hand to the unfavorable cool and wet weather conditions in 2021 for corn cultivation and on the other hand to the less than optimal tillage and planting. The DM contents in 2021 were also below the values of the previous year (Figure 15).

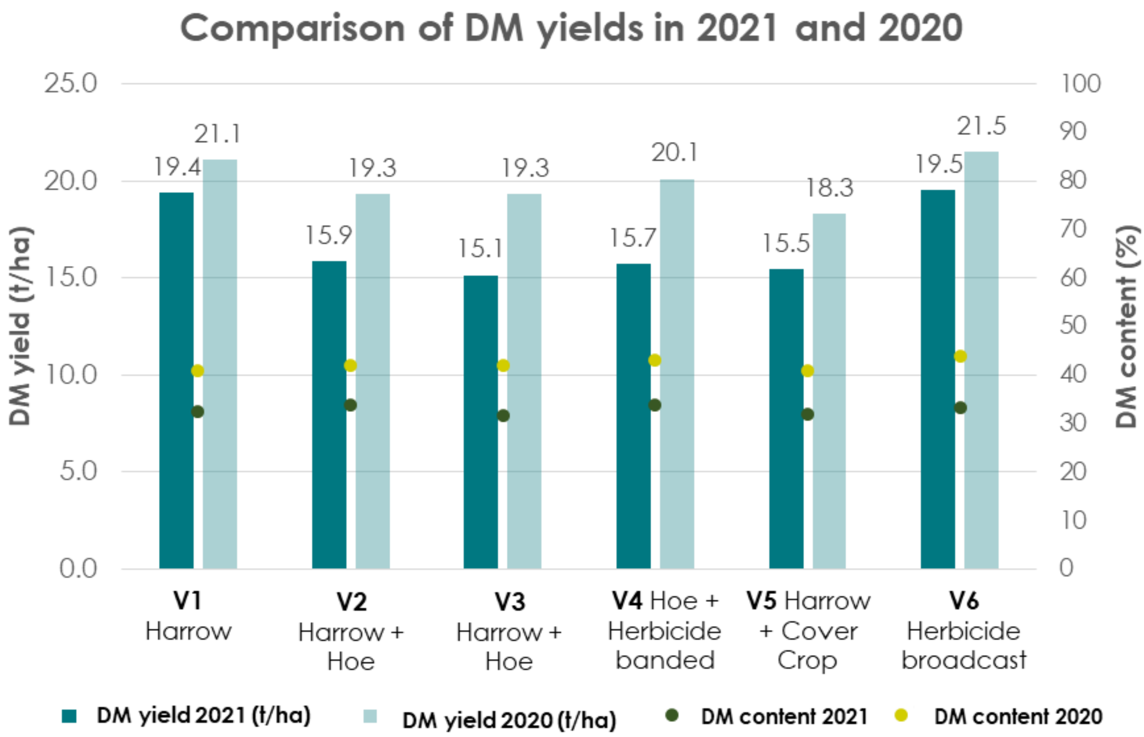

Figure 15. Comparison of DM yields (t/ha) and DM contents (%) between the years 2021 and 2020.

Table 3. Yield comparison 2020 and 2021 of the SFF trial on weed control in silage corn.

Comparison of DM yield (t/ha) 2020 and 2021						
	V1 Harrow	**V2 Harrow and Hoe**	**V3 Harrow and Hoe**	**V4 Hoe and Herbicide banded**	**V5 Harrow and Cover Crop**	**V6 Herbi-cide broadcast**
2020	21.1	19.3*	19.3*	20.1	18.3	21.5
2021	19.4	15.9	15.1	15.7	15.5	19.5
Yield difference 2021 (%)	**-8.1%**	**-17.6%**	**-21.8%**	**-21.9%**	**-15.3%**	**-9.3%**

*The V4 trial strip from 2020 was selected as the reference value for 2020, since it corresponds to V2 and V3 from 2021 in terms of the field operations carried out.

Operating costs

The process costs for weed control ranged from 123 CHF/ha in the harrow trial strip (V1) to 545 CHF/ha in the trial strip with band spraying (V4). In second place in terms of operating costs were trial strips 2 and 3, in which one harrow and one hoeing pass were carried out in each case. The herbicide trial strip followed in third place with one herbicide pass. Although the herbicide sprayer has twice the area efficiency of the hoe and similar area efficiency to the harrow, the majority of the costs (approximately 73%) in the herbicide trial strip are due to expenditures for the chemical inputs. The operating costs were calculated based on the guideline values of the 2021 machinery cost report (Gazzarin et al. 2021), since no meaningful cost statements can be made due to the trial structure with comparatively small areas. The area efficiency of the harrow was corrected from 7.18 ha/h to 4 ha/h compared to the specifications in the machine cost report. This estimate was made on the basis of empirical values on the SFF. All calculated costs include the machine, labor and input costs.

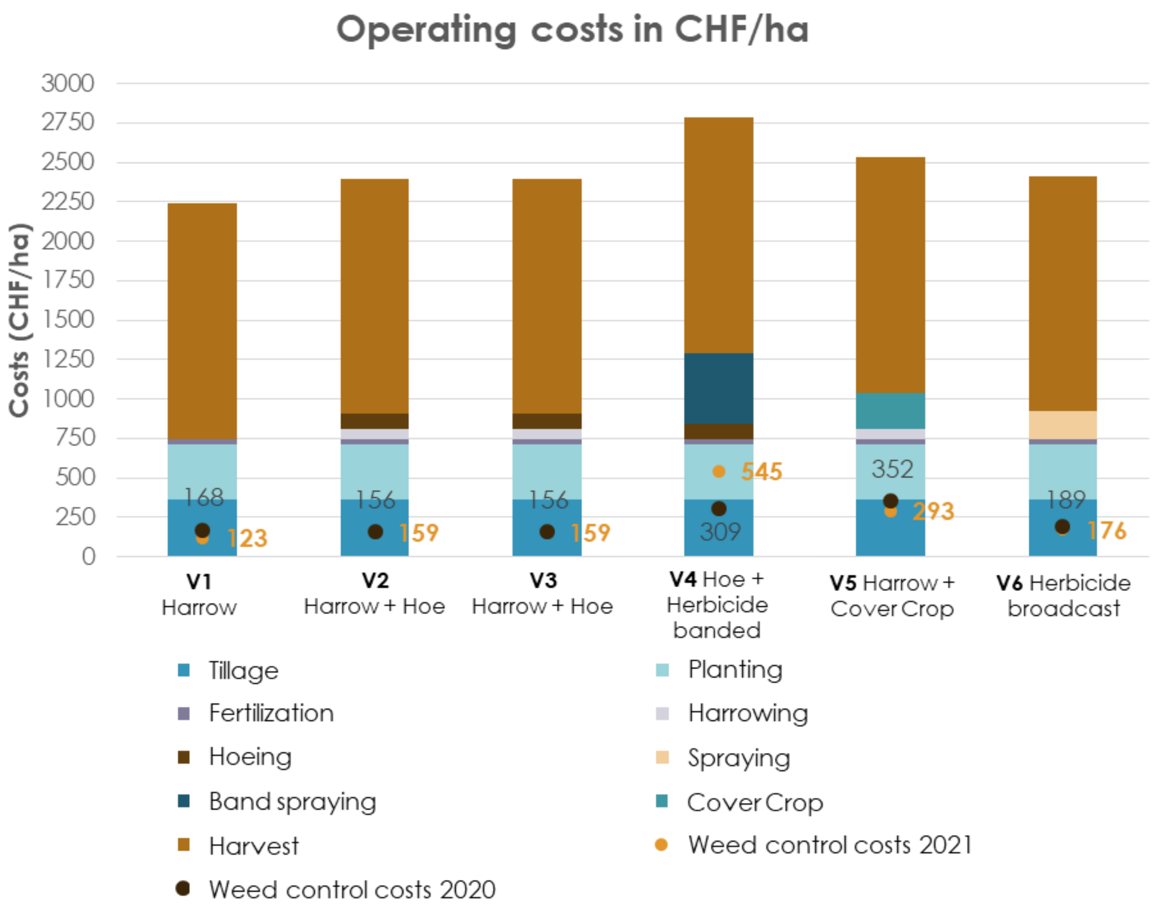

Figure 16. Operating costs 2021 in CHF/ha for all trial strips. The dots show the cost differences between weed control in 2020 and 2021.

Compared to the previous year, it is noticeable that the harrow costs are lower. This is due to the fact that no blind harrow pass could be made in 2021 because of the weather conditions. Treatments in trial strips V2 and V3 are in the same cost range as in 2020. In trial strip V4 (band spraying and hoeing), the costs in 2021 are 236 CHF higher than in 2020. The discrepancy comes from an adjustment in the area efficiency of the band sprayer. Based on the experience from 2020 and 2021, this area efficiency was adjusted downward to 0.25 ha/h. Although the undersowing was done by hand in 2021, a machine combination of tractor (Fendt 314) and harrow with pneumatic seeder (3 m) was used for the cost calculation. In 2021, the choice of Persian clover instead of the UFA Maisfix mixture for the undersowing reduced seed costs by 16 CHF/ha.

Contribution margins

Table 4 shows the contribution margins including machine, labor and input costs for all treatments. At 979 CHF/ha, the highest contribution margin was achieved in harrow trial strip V6. This is mainly due to the highest yield and the low operating costs in this treatment. Adding the payments by the Swiss subsidy program "Resource Efficiency Contribution" (REB) for not using herbicides, the figure is 1229 CHF/ha. In second place is the herbicide trial strip V6 with 877 CHF/ha.

It can be seen (see Table 5) that in 2021 all contribution margins are below the 2020 level. The most important factor for the difference is the lower yields and DM contents in 2021. Another factor is the higher harvesting costs in 2021. The smallest annual differences are found in trial strip V6 (herbicide treatment) and trial strip V1 (harrow treatment). Also this year, the cover crop and the band spraying treatment had the lowest contribution margin due to the high operating costs. The combination of harrow and hoe in trial strips V2 and V3 are competitive in terms of operating costs, but yields this year were significantly below those of trial strips V1 and V6.

Table 4. Contribution margin overview

	V1 Harrow	V2 Harrow and Hoe	V3 Harrow and Hoe	V4 Hoe and Herbicide banded	V5 Harrow and Cover Crop	V6 Herbi-cide
Fresh Mass Yield (t/ha)	59.7	46.8	47.8	46.7	48.6	58.8
Dry Matter Content (%)	33	34	32	34	32	33
Target price with corresponding dry matter content (CHF/t)*	CHF 56	CHF 58	CHF 54	CHF 58	CHF 54	CHF 56
Deliverables						
Revenue per ha	CHF 3'340	CHF 2'716	CHF 2'581	CHF 2'709	CHF 2'627	CHF 3'292
Costs						
Weed control	CHF 123	CHF 159	CHF 159	CHF 545	CHF 305	CHF 176
Tillage	CHF 364	CHF 364	CHF 364	CHF 364	CHF 364	CHF 364
Planting	CHF 348	CHF 348	CHF 348	CHF 348	CHF 348	CHF 348
Fertilization	CHF 36	CHF 36	CHF 36	CHF 36	CHF 36	CHF 36
Harvest	CHF 1'491	CHF 1'491	CHF 1'491	CHF 1'491	CHF 1'491	CHF 1'491
Contribution mar-gin 2 (incl. ma-chine, labor, inputs costs)	**CHF 979**	**CHF 319**	**CHF 184**	**-CHF 75**	**CHF 95**	**CHF 877**
Contribution mar-gin 2 incl. REB subsidies of 250 CHF/ha**	**CHF 1229**	**CHF 569**	**CHF 434**	**CHF 175**	**CHF 345**	**CHF 877**

**AGRIDEA Indicative prices 2021, **Resource Efficiency Contribution (REB) subsidy payments for herbicide-free weed control*

Table 5. Comparison of contribution margins 2020 and 2021 without payments by subsidy program "Resource Efficiency Contributions" (REB).

Comparison of contribution margin 2020 and 2021 (without REB subsidies)						
	V1 Harrow	**V2 Harrow and Hoe**	**V3 Harrow and Hoe**	**V4 Hoe and Herbicide banded**	**V5 Harrow and Cover Crop**	**V6 Herbicide broadcast**
2020	CHF 1'190	CHF 892	CHF 892	CHF 546	CHF 611	CHF 1'054
2021	CHF 979	CHF 319	CHF 184	-CHF 75	CHF 95	CHF 877
Difference 2021 (CHF) per ha	**CHF -211**	**CHF -573**	**CHF -708**	**CHF -621**	**CHF -516**	**CHF -176**

Conclusion and next steps

The difference in weather between 2020 and 2021 could not have been greater. While the spring and summer of 2020 provided the best conditions for corn planting and mechanical weed control, in 2021 the possible time windows for weed control were very scarce. For example, no opportunity for blind harrowing was found due to the persistent rain. Also, the wet and cool conditions resulted in widespread re-growth of the previous grassland and very slow corn development on the trial plot. Yields in 2021 were 8-21% below 2020 levels, but interestingly, in both 2020 and 2021, the harrow-only and herbicide-only trial strips proved to be the most profitable treatments with the highest contribution margins. In the future, it would be interesting to set up a larger-scale trial to obtain a more practical estimate of area performance when calculating operating costs.

References

Gazzarin et al. 2021: Maschinenkosten 2021, Agroscope Transfer 408 / 2021
Link:
https://www.agroscope.admin.ch/agroscope/de/home/aktuell/newsroom/2021/09-08_maschinenkostenbericht-2020/_jcr_content/par/columncontrols/items/0/column/externalcontent_531767590.bitexternalcontent.exturl.pdf/aHR0cHM6Ly9pcmEuYWdyb3Njb3BlLmNoLzAvQWpheC9FaW56ZW/xwdWJsaWthdGlvbi9Eb3dubG9hZD9laW56ZWxwdWJsaWthdGlv/bklkPTQ5OTQy.pdf

1.3 Tillage and Fertilization Study in Canola 2020-2021

Study Contact

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Objective

The aim of this study was to investigate the influence of a Triple Super Phosphate application of 46 kg P_2O_5/ha placed at a depth of 20 cm on plant growth in canola. The background of this trial is that, on the one hand, the attracting effect of the phosphate fertilizer should promote a deeper rooting of the soil by the canola roots, and on the other hand, the availability of the fertilizer in deeper soil layers remains high even in years with dry weather. Thanks to the use of guidance systems with RTK accuracy (2.5cm), it is possible to always place a fertilizer track between two subsequently sown rows of canola without any problems.

Study Design

The trial was set up at the Swiss Future Farm (Tänikon, Canton Thurgau, Switzerland) as a strip trial on the "Altkloster" plot. Tillage and combined deep fertilization with the Horsch Terrano, which was equipped with 40mm wide LD coulters ("low disturbance") and fertilizer inserter on the coulter, took place on August 25, 2020. 50% of the fertilizer (102 kg/ha Triple Super) was placed at 10cm depth and 50% at 20cm depth. On August 26, 50 plants of rapeseed of the variety "Tempo" per square meter were sown with the power harrow drill combination Horsch Express 3KR. The further plant protection measures in this crop were as follows:

- 27 Aug 2020: application of Basan Trio
- 01 Sep 2020: slug pellet application
- 21 Sep 2020: application of Cypermethrin (0.25l/ha) and Fusilade Max (1.5l/ha)
- 22.09.20 Applikation von Ammonsalpeter Mg S (24 %)

In order to make the investigated method comparable, the two treatments "Broadcast fertilization without deep loosening" and "Broadcast fertilization with deep loosening" were compared with the new method "Deep fertilization with deep loosening" described here. A total of seven trial strips, each 15 m wide and with three treatments, were laid out as shown in Table 6.

Table 6. Treatments of the SFF Tillage and Fertilization Study in Canola 2020-2021.

Trial strip no.	Treatment
1,7	Broadcast fertilization without deep loosening
3,5	Broadcast fertilization with deep loosening
2,4,6	Deep fertilization with deep loosening

Results and Discussion

Crop measurements were carried out on 26 October 2020. Root diameter, length and number of tips were measured. In addition, the dry matter (DM) content of root and plant was measured.

Figure 17. Measured plants from strip no. 7 (Broadcast fertilization without deep loosening).

Figure 18. Measured plants from strip no. 5 (Broadcast fertilization with deep loosening).

Figure 19. Measured plants from strip no. 4 (Deep fertilization with deep loosening).

It is clearly visible from the pictures that the roots from trial strip 7 (Broadcast fertilization without deep loosening) are smaller than those from both strips 4 and 5 with deep loosening. Figure 20 also shows the positive effect of deep loosening on root diameter and root length.

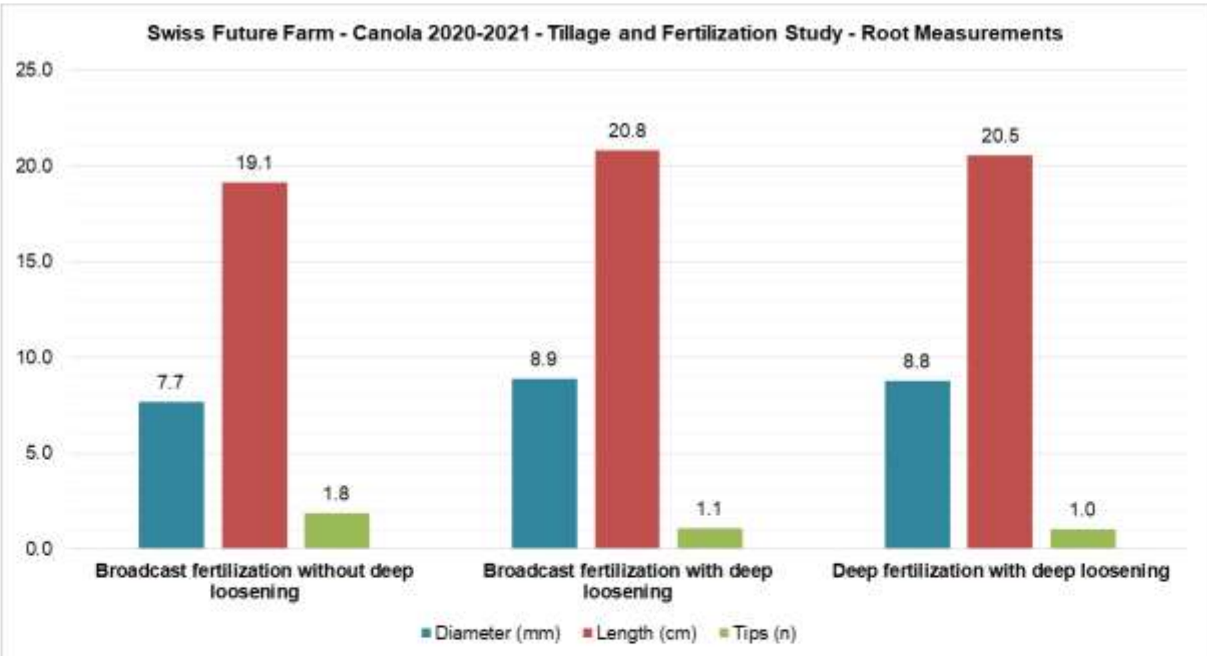

Figure 20. Root measurements of the three treatments.

The treatment without deep loosening differs noticeably from the other two with deep loosening. However, no clear difference can be observed between deep and broad fertilization in these two treatments. The result confirms the previous state of research, according to which canola benefits in root development from a deep pre-loosened soil. Purely in terms of root mass, however, no advantages of deep fertilization could be determined in the fall.

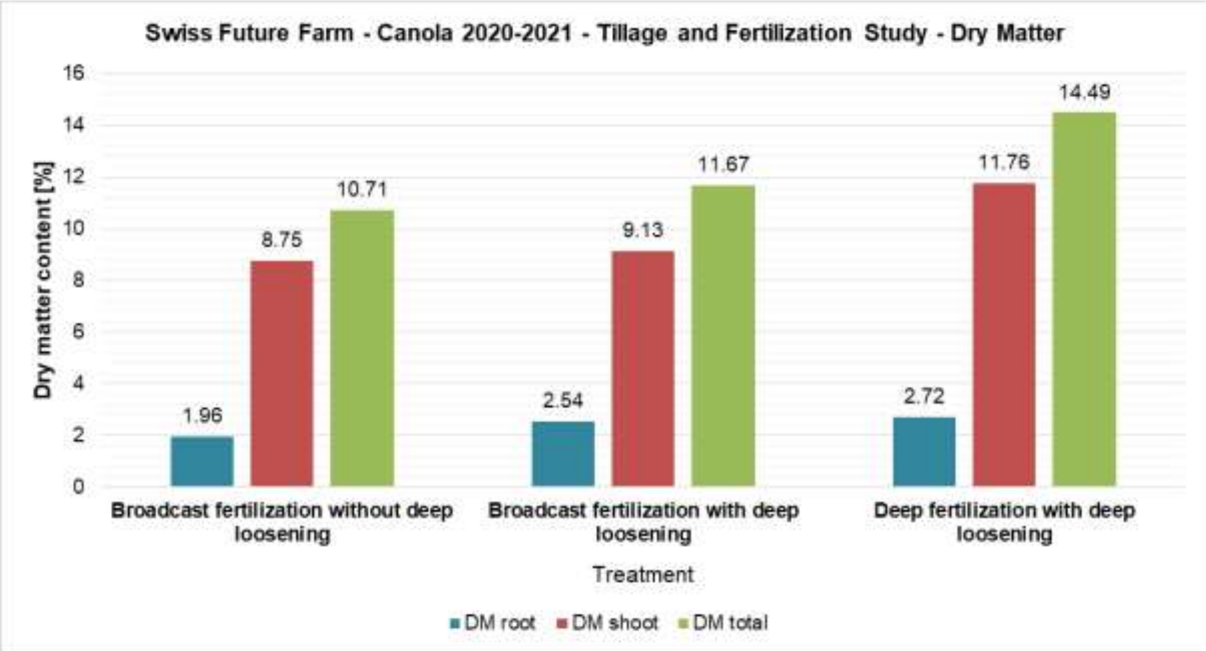

Figure 21. Results of dry matter measurement of root and shoot.

Figure 21 shows a clear difference between the method with broadcast fertilization with deep loosening and that with deep fertilization in combination with deep loosening. In the deep fertilization method, the shoot had on average 29% more DM content and the entire plant 24% more DM content than in the method with wide-area fertilization. This indicates a physiologically more developed plant, for which a better nutrient supply could be responsible. It can be assumed that these plants will have an advantage in spring development, but this would have to be investigated in more detail in a further trial year.

Due to the aggravating weather conditions for the 2021 harvest, no useful yield measurements could be taken at harvest.

Conclusions

In this experiment, the formation of the root seemed to depend mainly on the type of tillage and less on the type of fertilization. The higher DM content in the plant shows a physiologically more developed plant in the procedure with deep fertilization and deep loosening. In a further trial set-up, it would be useful to re-measure the plants in spring. In addition, any yield differences would be very interesting to see. Since temporary grassland seeding was preferred to canola in crop year 2022 due to the otherwise insufficient amount of forage, canola will not be planted on the SFF again until crop year 2023.

1.4 Planting Depth Study in Silage Corn

Study Contact

Nils Zehner, Swiss Future Farm, nils.zehner@agcocorp.com

Objective

The objective of this study was to evaluate yield in silage corn planted at variable planting depth. The settings were done with the unique Precision Planting SmartDepth™ Moisture Control based Precision Planting SmartFirmer™ soil sensor readings in comparison to uniform standard planting depth.

Study Design

The study was carried out on the Swiss Future Farm in 2021 as a side-by-side strip trial. The following planting depth settings were tested:

- Uniform standard planting depth: 5.1 cm
- Variable planting depth based on soil moisture (SM) measurements of Precision Planting SmartFirmer soil sensors and Precision Planting SmartDepth control with 3 increments: 3.8 - 5.1 - 6.4 cm planting depth:
    - SM > 40 % = 3.8 cm
    - SM 40 % - 30 % = 5.1 cm
    - SM < 30 % = 6.4 cm

The Precision Planting SmartDepth Moisture Control mode automatically adjusts planting depth according to the amount of moisture available to the seed measured by the SmartFirmer soil sensors in order to ensure consistent crop stand also under heterogeneous soil moisture conditions. The planted population was set to 90,000 seeds/ha for both planting depths, which is the regional standard planting rate for silage corn.

The trial was planted in a field with moderate heterogeneity of soil conditions in texture, moisture, and organic matter (Figure 22).

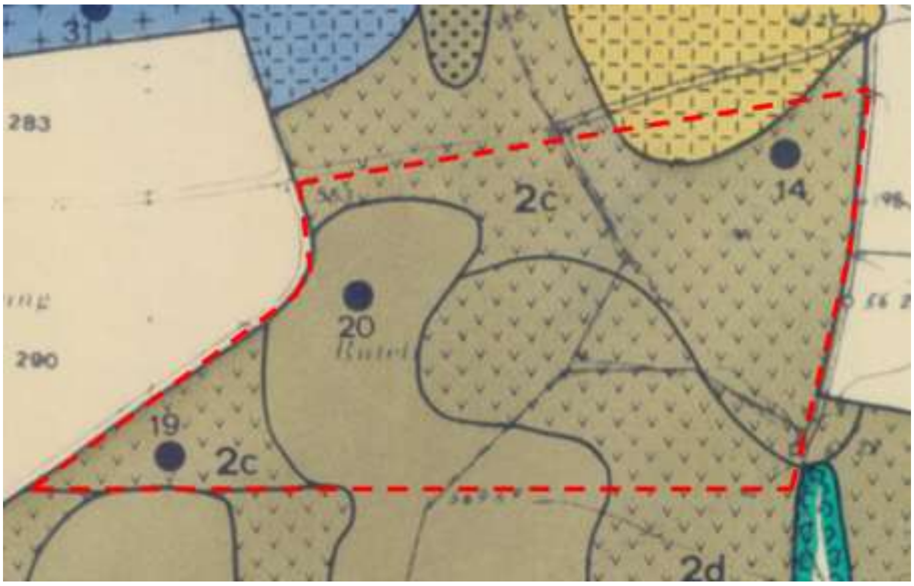

Figure 22. Soil zones in the trial field according to soil survey of 1977.

Properties of the soil zones are described in Table 7.

Table 7. Soil properties of the trial plot for the SFF 2021 Planting Depth Study in silage corn.

Soil zone	Soil type and properties
1d	Partially decarbonated, stagnogleyic brown earth, skeletal, slightly clayey loam and slightly sandy loam, damming moisture, good water storage, flat slope 16-20%
2c	Partially decarbonated gleyic brown earth, skeletally poor, slightly sandy and slightly clayey loam, slope moist, good water retention, valley location, 11-15% slope
2d	Partially decarbonated gleyic brown earth, skeletally poor, slightly sandy and slightly clayey loam, slope moist, good water retention, flat slope 16-20%

Planting date was 27th April 2021. Trial strips for each planting depth setting were planted across the different soil zones to enable full exposure to the heterogeneous soil properties.

Results

The trial was harvested 154 days after planting. Higher dry matter yield of 16.1 t/ha was obtained in the treatment planted with a variable planting depth with 3 increments while uniform standard planting depth resulted in lower dry matter yield of 15.7 t/ha (Figure 23).

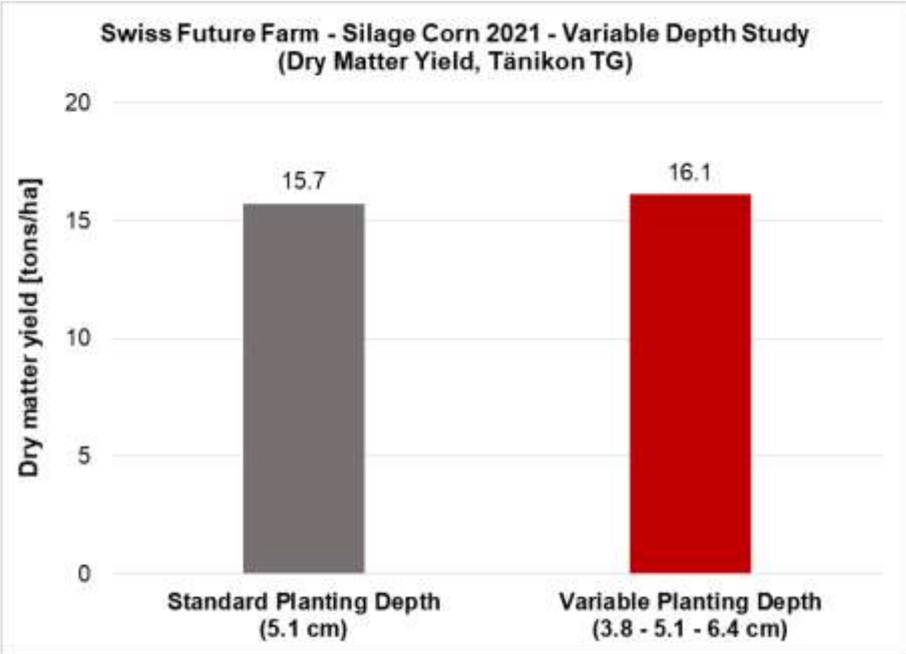

Figure 23. Dry matter yield results of the SFF 2021 Planting Depth Study in silage corn.

In our study, the yield increase that could be achieved due to the application of variable planting depth with Precision Planting SmartDepth amounted to 2.5% (with 3 increments at 3.8 - 5.1 - 6.4 cm planting depth) compared to uniform standard planting depth at 5.1 cm. These results indicate that increasing the planting depth in field zones with lower soil moisture appeared as a suitable approach considering the specific site's soils capability to improve yield.

Additional Observations

Mapping options of the Precision Planting 20/20 Gen 3 monitor allow for high-resolution visualization of as-applied planting depth for documentation of field operations and control of planter settings. The as-applied map of planting depths shows that the planting depth was adapted according to the readings of the SmartFirmer soil sensors and the increments defined for the Moisture Control mode of the planter in the respective Variable Rate trial strip (Figure 24). The changes in planting depth partially correlate to slopes or soil types and expected soil moisture differences found in the soil survey of this field.

Figure 24. Uniform standard planting depth (planter passes on top) and variable planting depths (planter passes on bottom) on the trial field of the SFF 2021 Planting Depth Study in silage corn shown in the Precision Planting 20/20 Gen 3 monitor.

Recommendations and Equipment Solutions

- Precision Planting SmartFirmer™ soil sensors measure soil moisture, soil temperature and organic matter in real time during planting and provide meaningful information on soil properties and field zones.
- Precision Planting SmartDepth™ automatically adjusts planting depth between a minimum and maximum depth while maintaining the soil moisture target based on SmartFirmer soil sensor measurements.
- Fendt VarioGuide with RTK ensures planter passes with maximum accuracy and operator comfort.
- Fendt Contour Assistant enables optimum wayline adaption to the contours of the field during planting.

Figure 25. Variable Depth Moisture Control mode in the Precision Planting 20/20 Gen3 monitor (left), Precision Planting SmartDepth gearbox for real-time adaption of planting depth according to soil moisture (top right), and Precision Planting SmartFirmer for measurement of soil moisture in the furrow (bottom right).

Payback

For silage corn planted at variable planting depth with Precision Planting SmartDepth control based on Precision Planting SmartFirmer readings, an additional revenue of 48 CHF/ha could be generated in comparison to planting with uniform standard planting depth at 5.1 cm (Figure 26).

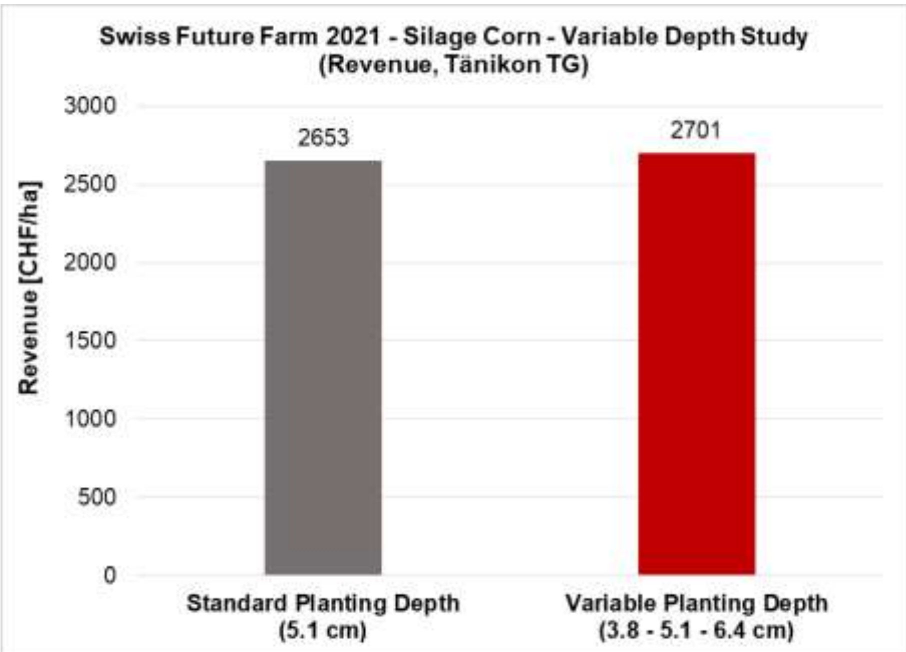

Figure 26. Revenue obtained from the SFF 2021 Planting Depth Study trial strips in silage corn.

Price calculations for silage corn based on the guidelines of the Swiss Farmers Association (SBV).

Silage corn price after harvest by seller: 65 CHF/ton fresh mass

Study Overview

Swiss Future Farm – Silage Corn 2021 – One-Year Planting Depth Study Nils Zehner, AGCO Agronomy and Farm Solutions Team, nils.zehner@agcocorp.com				
STUDY OVERVIEW	Location (Region) **Swiss Future Farm (EME)**		Improved Yield **3%**	
	Crop & Year **Silage Corn 2021**		Reduced Waste **-**	
	Study Type **Planting Depth**		Improved Operat. Efficiency **-**	
	Technology **Precision Planting SmartDepth**		ROI **48 CHF/ha**	

1.5 Human vs. machine: a test of the N-Tester Bluetooth and Yara Atfarm for Variable Rate fertilization

Study Contact

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Objective

In recent years, trials on Variable Rate fertilization in winter wheat have been carried out by Agroscope and ETH Zurich at SFF. In the three-year trial, it was shown that the use of drone technology in combination with soil information and expert knowledge resulted in an average N saving of 23 % while wheat yields remained constant. Furthermore, N use efficiency was improved by 13 %.

In addition to the research approaches described above, there are already commercial providers who promise optimized N use with sensor-based fertilizer recommendations. In contrast to Agroscope's methodology, most of these solutions do not incorporate any additional, advisory expert knowledge or soil information.
In the present trial, the N-Tester Bluetooth products were tested in combination with the Atfarm platform from the supplier Yara, and the resulting satellite- and sensor-based fertilizer recommendations were compared with the SFF farm manager's assessment in a strip trial. In line with the motto "human versus machine". The following questions were addressed:

- What is Yara Atfarm and the N-Tester Bluetooth and how can these products be used?
- How much nitrogen was used in total in the respective treatments (human and machine)?
- What yield was generated due to the treatments?
- Is the technology used suitable for use in Switzerland?

Study Design

The trial was conducted on the Schürpünt trial field (2.5 ha), which is characterized by low heterogeneity. Winter rapeseed was the preceding crop on the plot. As wheat variety, the forage wheat variety Mulan was selected, since there is a stored calibration curve for this variety for the sensor N-Tester Bluetooth used. 180 kg/ha were sown.

The historical soil map of Tänikon, which was drawn up by Agroscope at the Tänikon site in the 1970s, served as the basis for the study design (Figure 27). The trial strips were laid out so that the soil properties of the two plots were as uniform as possible. For this purpose, one tramline on the main road towards Aadorf (west side) and two tramlines towards Lützelmurg (east side) were excluded from the test plot and subsequent evaluation.

Figure 27. The soil zones are visible on the left side. The trial strips were laid out so that they all lie in the same soil zone as far as possible.

The "Machine" treatment comprises three tramlines on the west side. The "Human" treatment comprises three tramlines on the east side. In both plots there is a control plot as reference. The procedures differ with regard to fertilization as described in Table 8.

Table 8. The treatments for the SFF fertilization trial 2021 "Human vs. machine" at a glance.

	Human treatment (ME)	**Machine treatment (MA)**
1st fertilizer application in spring	Standard flatrate fertilization according to the assessment of the farm manager SFF	As in the ME method minus the measured N_{min} values (0-30 cm soil depth).
2nd and 3rd fertilizer application	Standard flatrate fertilization according to the assessment of the farm manager SFF	Determination of fertilizer quantity: • Yara N-Tester Bluetooth Determination of fertilizer distribution: • Satellite-based prescription maps on the at.farm platform

Technology Yara Atfarm and N-Tester Bluetooth

There are various tools on the market that are designed to support farmers in Variable Rate fertilization. Most products are satellite-based biomass viewers that show how biomass is distributed in the field. Often the NDVI is used as the biomass index for this purpose. This index is useful for distinguishing between healthy and diseased vegetation at early growth stages. However, when the plant canopy is closed, the NDVI shows saturation, so that it can usually no longer be used for the 2nd and 3rd fertilizer application (cf. Argento et al. 2020). Although the information on biomass distribution gives the farmer a good overview of the situation in the field, the decision on the amount of fertilizer to be applied as well as the strategy of distribution still lies with the farm managers. The Yara company goes a step further with its Atfarm product compared to most suppliers

Besides the NDVI, it offers with the N-Sensor view a satellite-based index that saturates later. Furthermore, Yara offers the N-Tester Bluetooth, hand-held sensor which can be

Figure 28. Use of the N-Tester Bluetooth for the determination of the 2nd fertilizer application on April 28, 2021.

used in the field to measure the relative amount of chlorophyll present (product information: https://www.yara.de/pflanzenernaehrung/tools-und-services/n-tester/; accessed Jan. 31, 2022). Yara has calibrated these chlorophyll values for diverse varieties to determine whether a plant is undersupplied or oversupplied with nitrogen. The N-Tester Bluetooth is paired with the smartphone and then the user must take measurements directly on the wheat leaf at at least thirty locations in the field to determine the chlorophyll content (Figure 28). The measured values are transmitted directly to the smartphone and, taking into account the amounts already fertilized and the N_{min} content, are combined to form a fertilizer recommendation with the optimum fertilizer quantity for the variety and conditions. This fertilizer rate can then be used as a baseline for the satellite-based biomass map. The package of N-Tester Bluetooth and satellite-based biomass maps tested in this trial costs users 395 euros per year (https://at.farm/de/preise; accessed 01/31/22).

Field calendar

Table 9. Field calendar for the Schürpünt trial field for the 2021 "Human vs. Machine" SFF fertilization trial.

Date	Field operation
25th August 2020	Tilage (cultivator)
11th September 2020	Tillage (spring tine harrow)
1st October 2020	Drill seeding with power harrow combination Mulan variety, 180 kg/ha
21st October 2020	Herbicide application 0.8 l/ha Herold Flex
2nd November 2020	31 m^3 cattle slurry (for all treatments)
9th March 2021	1st fertilizer application (tillering application): Mg ammonium nitrate 24 % N + 7 % S
10th March 2021	1st fertilizer application (tillering application): cattle manure
30th March 2021	Growth regulator: 0.7 l/ha CCC Herbicide application: 1.25 l/ha Othello
21st April 2021	Growth regulator: 0.5 l/ha Medax Fungicide application: 1.5 l/ha Kantik
28th April 2021	2nd fertilizer application (shoot application): Mg ammonium nitrate 27 % N + 2.5 % Mg
31st May 2021	Fungicide application: 1 l/ha Elatus Era Growth regulator: 0.7 l/ha Ethephon
29th July 2021	Harvest

Fertilization

Table 10 gives an overview of the fertilizer applied in the two trial variants. The entire experimental area (including control plots) was uniformly fertilized with 31 m^3 of cattle manure in the fall. The first fertilizer application in spring was on March 9. In the ME procedure, the amount of 60 kg N/ha given by the farm manager was divided into a part with 35 kg N/ha cattle slurry and a part with 25 kg N/ha Mg ammonium nitrate (24 % N + 7 % S). In the MA procedure, the N_{min} values measured in the subplot (22 kg N/ha) were subtracted from the 60 kg N/ha. In total, therefore, only 35 kg N/ha was applied as cattle slurry in the first application in plot MA. As a second fertilizer application, 60 kg N/ha were applied as ammonium nitrate (27 % N + 2.5 % Mg) without sub-area differentiation in the ME method. In the MA method, the amount of fertilizer to be applied was derived from 30 measurements distributed over the field using the Yara N tester. This procedure was repeated twice. In both replicates, the N tester recommended an N rate of 100 kg/ha. Since N utilization decreases with increasing N application (cf. Levy and Brabant 2016), corrective action was taken by the investigator and the recommended value of the N tester was corrected down to an N amount of 80 kg/ha to reduce the risk of possible N leaching.

Figure 29. Measurement with the N tester on 4/27/21 before the second fertilizer application in the machine (MA) treatment.

The third fertilizer application could no longer be carried out due to the unsuitable fertilization dates caused by the weather. Nevertheless, another measurement was carried out with the Bluetooth N tester on June 2. This measurement again indicated an N requirement of 100 kg N/ha.

Table 10 shows the total amounts of fertilizer applied in the human (ME) and machine (MA) treatments. With 146 kg N/ha, approx. 3.3 % less nitrogen per hectare was applied in the machine (MA) treatment than in the human (ME) treatment. However, this saving must be put into perspective, since the recommended fertilizer quantity in the machine (MA) method was reduced by 20 kg N/ha by the person responsible for the experiment during the second application due to the risk of leaching. Furthermore, the measurement with the N-tester at the time of the (not carried out) third fertilizer application showed again a N-recommendation of 100 kg/ha. Therefore, it can be assumed that the total N quantity in the machine (MA) treatment would have been higher than the quantities in the human (ME) treatment.

Table 10. Overview of fertilizer applications in the two treatments.

Application	Human (ME)				Machine (MA)			
	kgN/ha	**Fertilizer type**	**kg/ha m³/ha**	**Fertilizer distribution**	**kgN/ha**	**Fertilizer type**	**kg/ha m³/ha**	**Fertilizer distribution**
Fall	31	Cattle slurry	31	homo-geneous	31	Cattle slurry	31	homo-geneous
N_{min} Spring	0-30 cm: 15 30-60 cm: 10 60-90 cm: 10	N_{min} not included			0-30 cm: 22 30-60 cm: 14 60-90 cm: 8	N_{min} included		
1 (tiller-ing)	35 25	Cattle slurry Mg ammonium nitrate 24% N + 7% S	35 104	homo-geneous	35 0	Cattle slurry Mg ammonium nitrate 24% N + 7% S	35 0	homo-geneous
2 (shoot)	60	Ammo-nium nitrate 27% N + 2.5% Mg	222	homo-geneous	80	Ammo-nium nitrate 27% N + 2.5% Mg	296	homo-geneous, because at.farm was not available
3	Not applied	Not applied	Not applied	Not applied	Not applied	Not applied	Not applied	Not applied
Total kg N/ha	151				146			

The planned differentiation of the 2nd fertilizer application in the machine (MA) treatment by using satellite images on the Atfarm platform could unfortunately not be carried out, as the platform was undergoing a technical changeover at the time of the fertilization and, despite contacting those responsible at Yara, no satellite images were available for use in Switzerland.

In the meantime, it is now possible again to use satellite images for Switzerland via a small trick when specifying the federal state on the Yara Atfarm platform. This trick was used in the context of writing this trial report to retroactively calculate an application map for the fertilization date on 04/28/2021. A satellite image was taken for the area around Tänikon on 04/26/2021. This is shown in Figure 30 as NDVI (left image) and as N-sensor view (right image). In the N-sensor view, the already mentioned finer and later saturation gradation is noticeable. Furthermore, edge effects are visible on the western side of the field. In the trial design, field sections at the edges of the field were therefore not considered for the evalution.

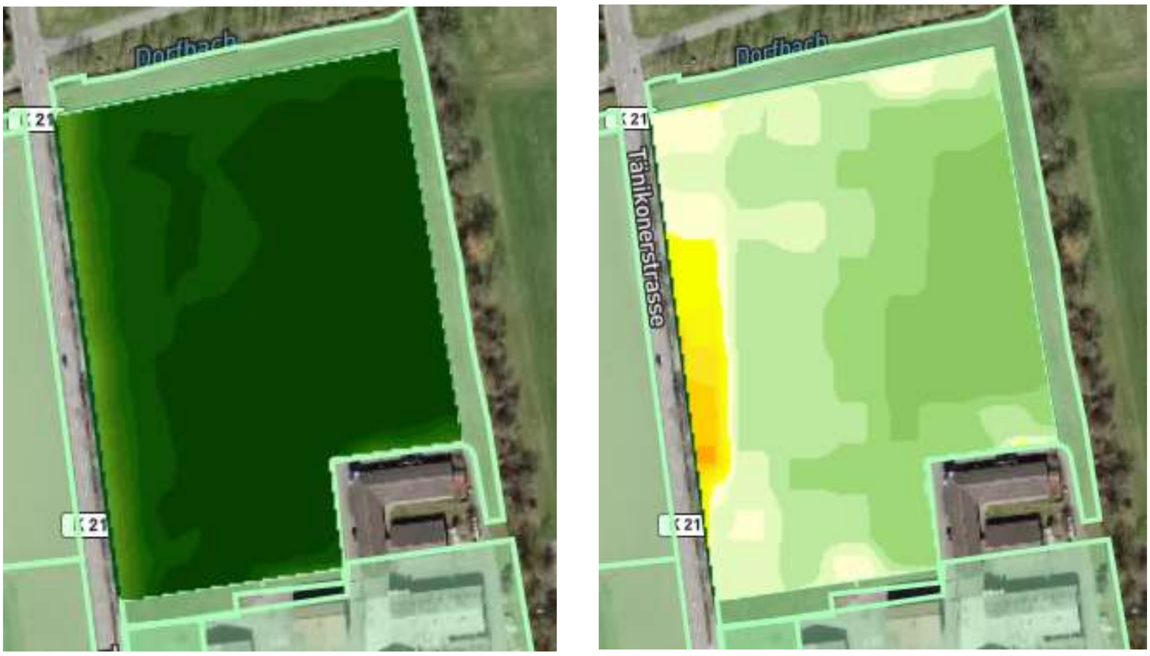

Figure 30. Retrospective comparison of the NDVI (left) and the Yara N-sensor view (right).

Figure 31 shows the zone map calculated by the platform based on the N-sensor index for generating an application map. The zone map is coarsely resolved and groups points with similar values into a subarea. In contrast, the raster map shown in Figure 32 generates one value per 20x20 m pixel. Since our emphasis in this experiment was to apply Variable Rate fertilization as practically as possible, we would have worked with the raster map. For this reason, no differentiation would have occurred in the machine (MA) subplot even with the inclusion of a prescription map.

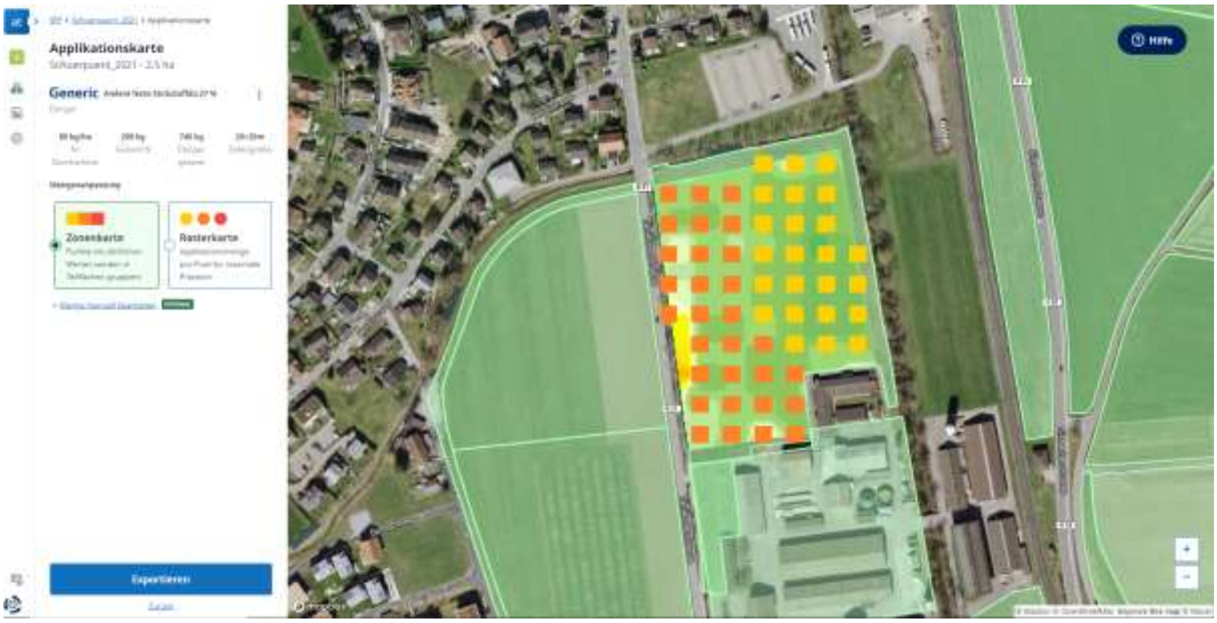

Figure 31. Zone map for Variable Rate fertilization on 28th April 2021.

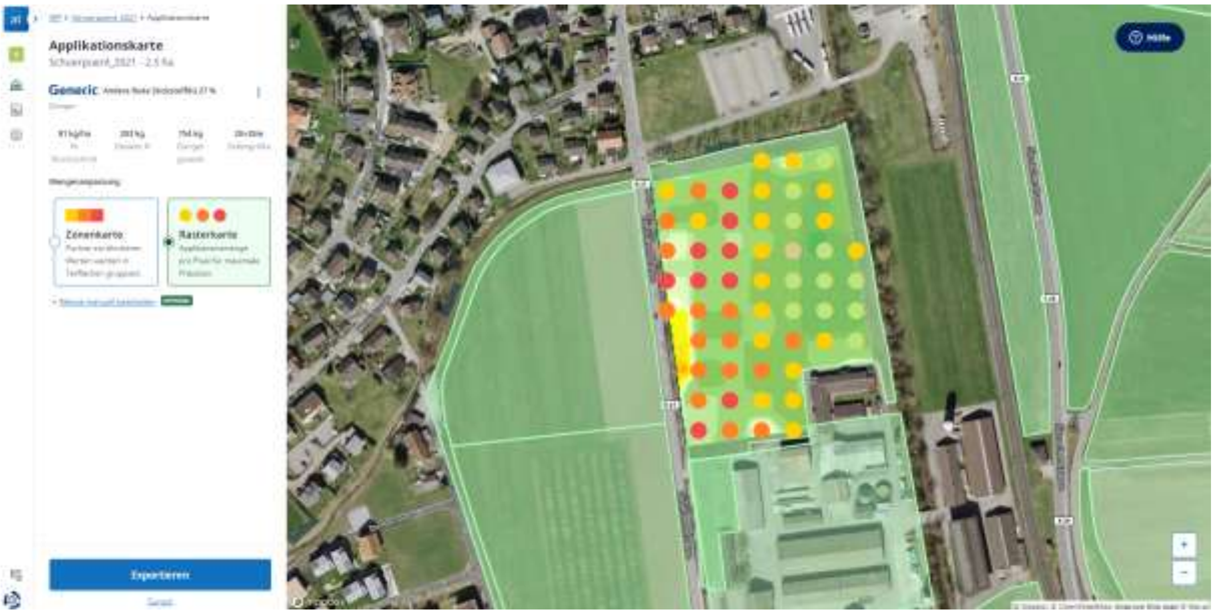

Figure 32. Grid map for Variable Rate fertilization on 28th April 2021.

Results

In the trial, the leaf mass yield (see Figure 33) was recorded on 2x1 m^2 each in the two trial strips and in the two control plots at the same time as the yield was recorded after the second fertilizer application on April 28, 2021 and at the time of the planned, but not implemented, third fertilizer application on June 1, 2021. The leaf mass yield in the two treatments is higher than the measured values in the control plot (with no fertilization) at both times. Further, the leaf mass yield in all procedures increases over time during the two measurement dates. At the time of the first measurement, the leaf mass weight is highest in the machine (MA) method with 4.87 t/ha. This result is surprising, because at the first fertilizer application in the human (ME) method, in addition to the 35 kg N/ha slurry (both methods), 25 kg N/ha were fertilized in the form of Mg ammonium nitrate. At the measurement on June 1, 2021, the leaf mass yield was highest in the human (ME) treatment with 6.25 t/ha. By this time, 151 kg N/ha had been fertilized in the human (ME) treatment and 146 kg N/ha in the machine (MA) treatment.

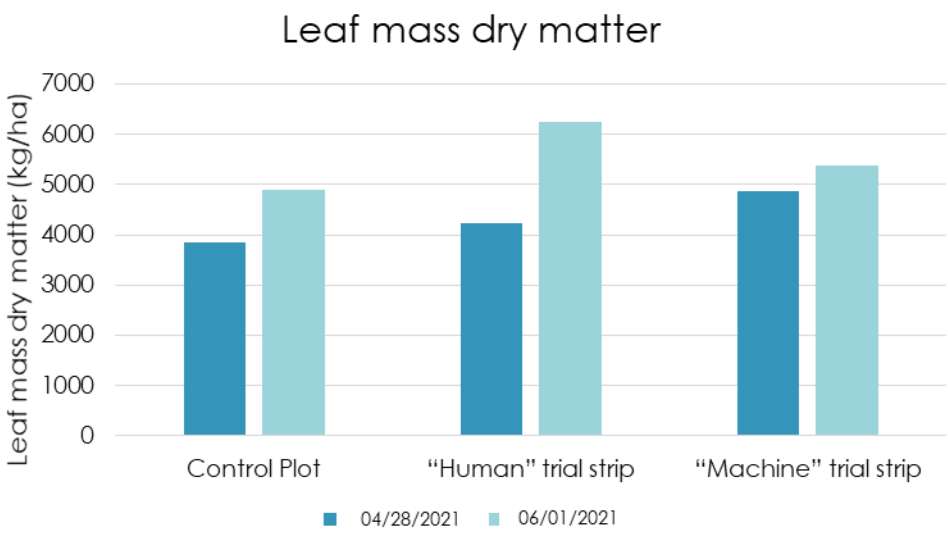

Figure 33. Determination of leaf mass in the trial strips at two measuring points of 1 m^2 each.

For the yield measurement for harvest on July 29, 2021, the trial plots (excl. headland and field edges) were harvested with a combine, loaded into trailers and weighed. The yields in the control plots were not collected separately due to their small size (4x6 m). Yields in the two trial strips were 78.5 dt/ha in treatment machine (MA) and 77.1 dt/ha in treatment human (ME), both above the field average of 74.7 dt/ha. The yields are summarized in Figure 34. Since a similar amount of N was fertilized in both treatments, the plot is homogeneous in the experimental sections, and the fertilizer was applied homogeneously in the machine (MA) treatment due to the unavailability of sattelite imagery service, it is not surprising that the yields are very close.

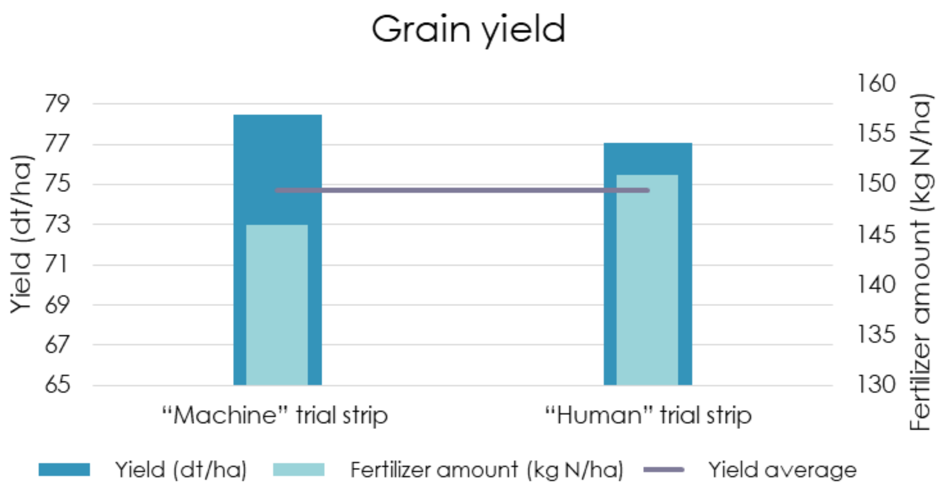

Figure 34. Applied N amounts and measured yield in the two trial strips at 12% moisture.

Findings on the application of the tested product in Switzerland

The aim of this trial was to test the N-Tester Bluetooth available on the market in combination with the Atfarm platform, on which current satellite biomass maps are provided, in practical use and to gather findings for application in Switzerland.

<u>N-Tester Bluetooth</u>

The use of the N-Tester Bluetooth in combination with the Yara Irix app (recently, the N-Tester can be used directly via the Atfarm app) initially presented a hurdle, as it did not establish a connection with an older iPhone 5S. With the Android smartphone WIKO Prime View available in the office, however, the connection worked immediately. The N-Tester was then registered in the app. The menu navigation in the app and the measurement in the field were self-explanatory and worked well. For the determination of the N undersupply or oversupply of the wheat, the N tester was calibrated for a large number of wheat varieties. For Switzerland, only the wheat varieties Mulan and Genius (Class I) are available. The Mulan variety was used for the trial. Although there is a calibration for the mentioned varieties, they are not optimized for Switzerland as a location with corresponding weather and sunshine hours. Furthermore, the software does not take into account existing legislative fertilizer restrictions in Switzerland. With these arguments, the high fertilizer recommendations, which the sensor recommended to us at the measurement dates on April 28, 2021 and June 2, 2021, can also be explained. From an experimental point of view, it would have made sense to apply the suggested 100 kg N at least on a small strip during the second fertilizer application. This would have to be taken into account when conducting the trial again.

Atfarm platform

The Atfarm platform has been available to users for several years as a free tool for displaying biomass differences and creating prescription maps. It was easy to use and offered a biomass index in addition to the NDVI, which saturated at later times. In spring 2021, there was a changeover on the platform, which resulted in a paid service. The use of the platform now costs 195 euros/year. In combination with the N-Tester Bluetooth, it is 395 euros/year (as of prices January 31, 2022). With the change, unfortunately, the availability of the service for Switzerland also fell away, so we could not include satellite images. For this reason, we also applied the fertilizer homogeneously in the MA method. As it turned out while writing this trial report and rechecking, the Atfarm services are still not officially available (the work-around is described above) for Switzerland. For this reason, they are not usable for Swiss farmers.

Conclusions

The multitude of new sensors and apps available on the market makes it difficult for farms to get an overview and to separate "the wheat from the chaff". With this strikingly designed trial on fertilization, a selected sensor was tested in combination with a web platform for site-specific fertilization. While the sensor N-Tester Bluetooth was convincing in practical handling, its usefulness for Swiss farms is unfortunately not given at present due to the lack of variety and location calibrations. Otherwise, the N-Tester would be an interesting tool to support the crop farmer in the decision-making process for the choice of fertilizer rates.

The Atfarm platform proved to be a good tool for generating prescription maps in recent years. With the platform changeover and the resulting loss of availability of the service for the application in Switzerland, the platform can no longer be used in this country. In the trial, this unfortunately had to be painfully realized when the services were suddenly no longer available in the spring. This clearly shows that the use of cloud services, in addition to all the advantages it offers, must always be thoroughly checked on country-specific requirements of the individual user.

References

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Levy L. und Brabant C. (2016): Die Kunst, den Stickstoffdünger für einen optimalen Ertrag und Proteingehalt von Weizen aufzuteilen. Agrarforschung Schweiz 7 (2): 80-87.

1.6 Three-Year Down Force Study in Sugar Beets

Study Contact

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Objective

The objective of this study was to apply different planter down force using the automatic down force control system DeltaForce™ and to evaluate the resulting yield in sugar beets.

Study Design

The study was carried out on the Swiss Future Farm (Switzerland) as a side-by-side strip trial from 2019 to 2021 with the following down force (DF) settings:

- Auto DF Standard (45 kg) = automatically readjusted down force with target value 45 kg
- Fixed DF (45 kg) = fixed down force set to 45 kg

All trial strips were planted at 3.8 cm planting depth and with a planting rate of 100,000 seeds per hectare, whereas down force applied by the Precision Planting DeltaForce system was changed between a fixed and an automatically adjusting setting, both with a target value of 45 kg. Planting dates for the study were in last week of March and first week of April.

Results

The trials plots were harvested in October or November in each study year. Automatic Standard DF yielded 81.7 t/ha had a slight advantage over Fixed DF which yielded 79.6 t/ha in the average of the study years (Figure 35). A yield increase of 2.6% can be generated when planting with automatic down force applied by Precision Planting DeltaForce instead of conventional fixed down force.

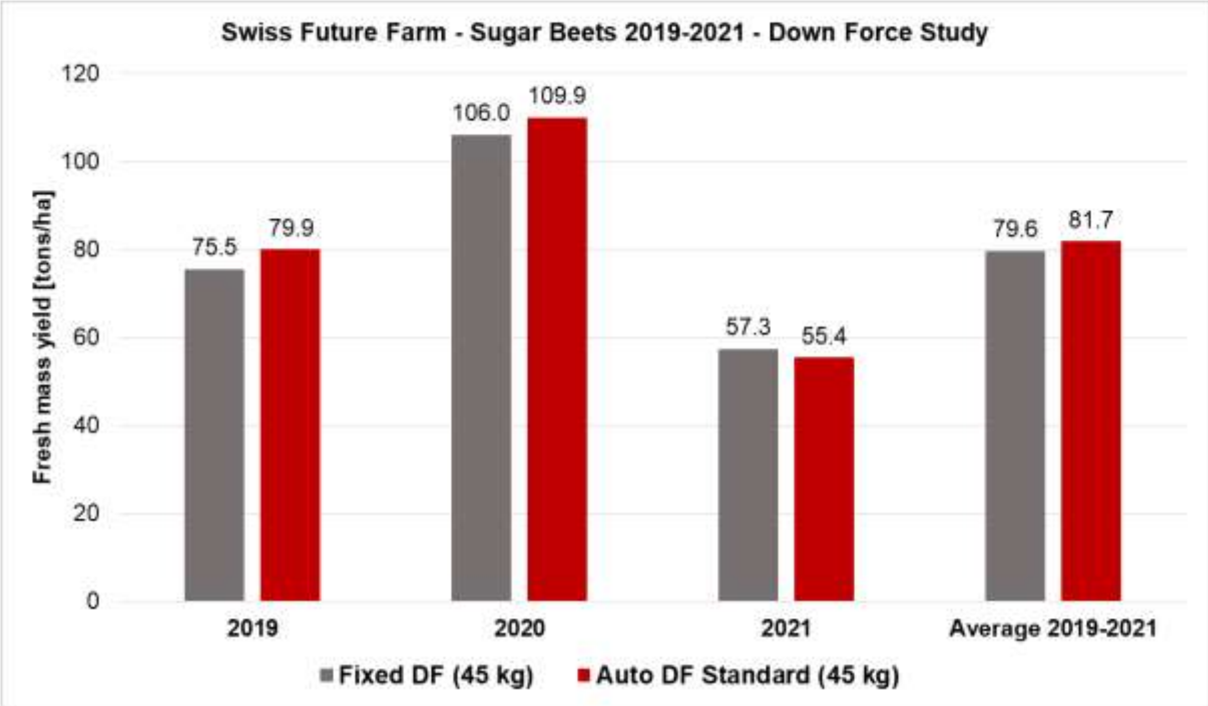

Figure 35. Fresh mass yield results of the Swiss Future Farm 2019-2021 Down Force Study in sugar beets.

The highest sugar content of 17.43% was obtained with Fixed DF settings, whereas Auto Standard DF had a lower sugar content of 17.28% on average (Figure 36).

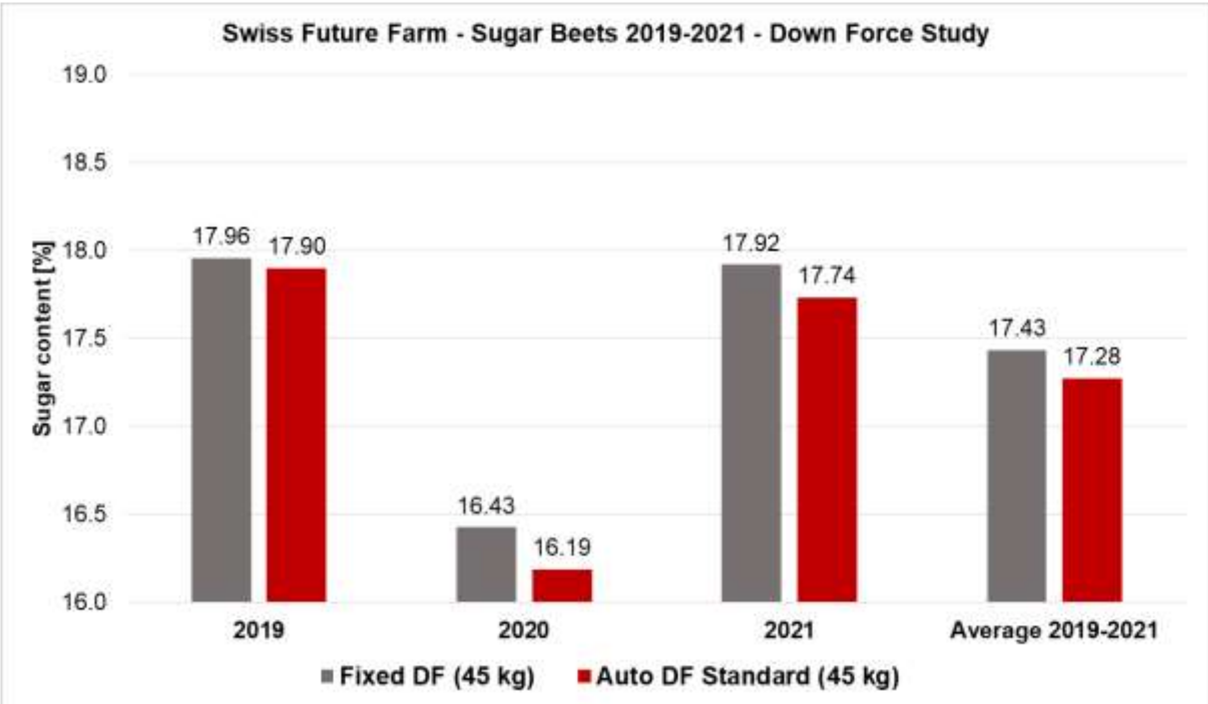

Figure 36. Sugar content results of the Swiss Future Farm 2019-2021 Down Force Study in sugar beets.

In the average of study years, Automatic Standard down force settings provided the highest sugar yield in the comparison with 12.4 t/ha, whereas slightly lower sugar yield of 12.2 t/ha was obtained from the trial strips planted with Fixed down force (Figure 37).

In our study, the increase in sugar yield that can be generated by planting with automatic down force applied by Precision Planting DeltaForce instead of conventional fixed down force amounts to 1.6%.

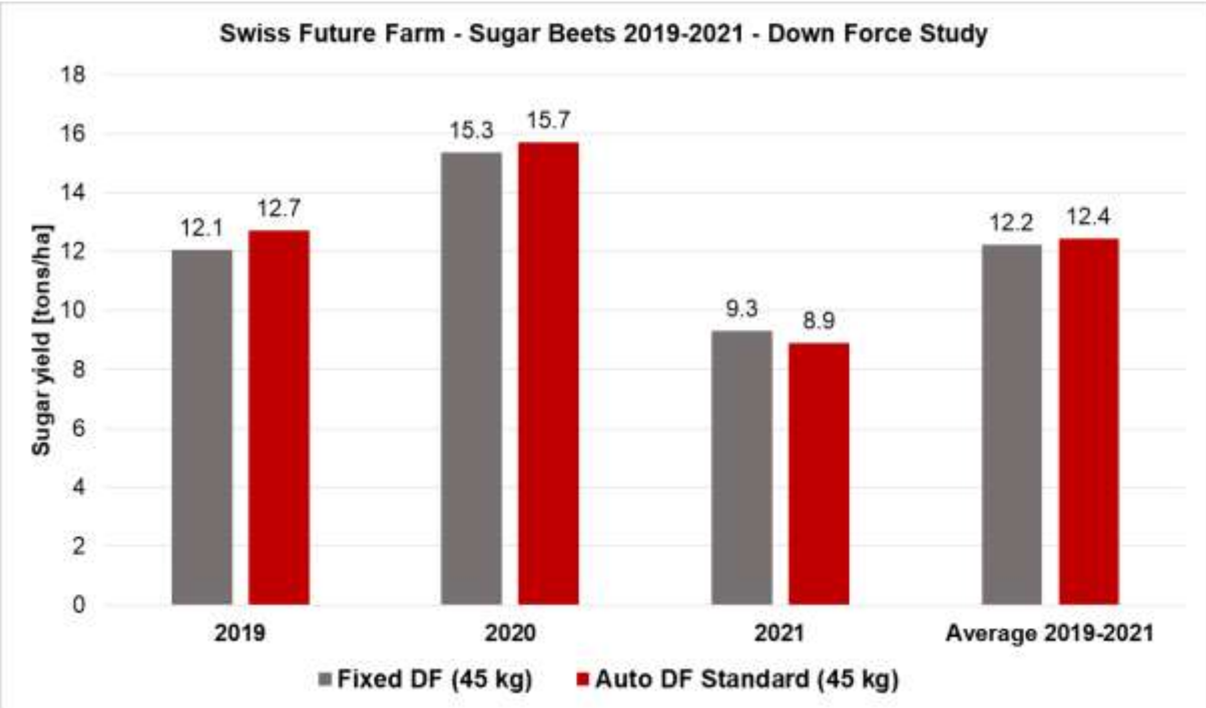

Figure 37. Sugar yield results of the Swiss Future Farm 2019-2021 Down Force Study in sugar beets.

Additional Observations

Sugar beets planted with automatic down force control with Precision Planting DeltaForce showed yield advantage over conventional fixed down force for study years 2019 and 2020, when the trial plot was located on fields with distinct soil heterogeneity indicated by the number of different soil zones recorded during a soil survey, whereas the 2021 trial plot was located in a field with homogeneous soil conditions (Figure 38).

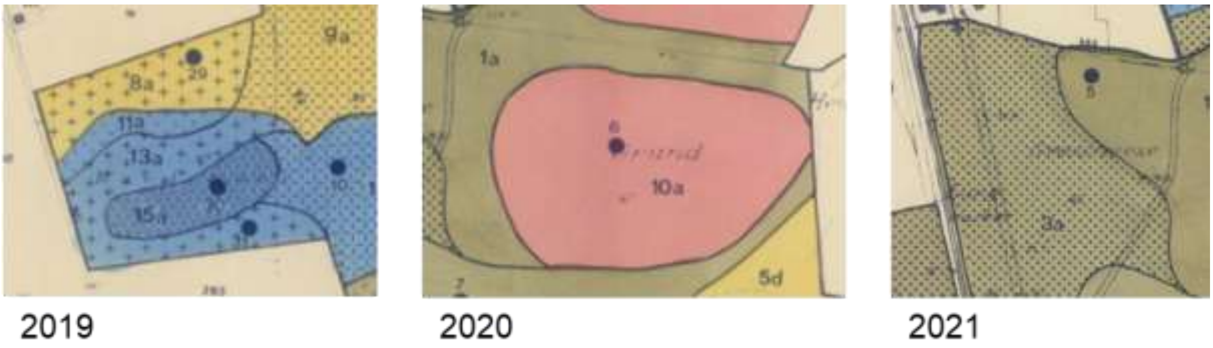

Figure 38. Soil zones in trial plots of the Swiss Future Farm 2019-2021 Down Force Study in sugar beets.

The soil types and properties are described in Table 11.

Table 11. Soil types and properties of the trial plots for Swiss Future Farm 2019-2021 Down Force Study in sugar beets.

Year	Soil zone	Soil type and properties
2019	8a	Gleyic brown earth, skeletal, slightly sandy loam and silty loam, good water storage.
2019	9a	Stagnogleyic calcaric brown earth, strongly skeletal, sandy loam and clayey silty loam, good water storage.
2019	11a	Partly decarbonated, browned gley, strongly skeletal, slightly sandy loam with a sandy base.
2019	13a	Partially decarbonated pale gley, skeleton poor, clayey soil and clayey loam, waterlogged.
2019	14a	Partially decarbonated pale gley, poor in skeleton, clayey loam with peat bedding, waterlogged.
2019	15a	Boggy, very pale gley, poor in skeletons, skeleton-rich subsoil, clayey loam and silty loam.
2020, 2021	1a	Partially decarbonated, stagnogley brown earth, skeletal, weak clay loam and weak sandy loam, stagnant moisture, good water retention, valley, 0-5% slope
2020	5d	Regosolian calcareous brown earth, skeleton-rich, slightly sandy loam and slightly clayey loam, fairly low water retention, flat slope 15-20%
2020	10a	Developed parabrown soil, skeletal, subsoil strongly skeletal, sandy loam and weak clay loam, very good water retention, valley, 0-5% slope
2021	3a	Alluvial, stagnogleyic brown soil, skeletally poor, weak sandy loam and weak clay loam, stagnant moisture, good water retention, valley floor, 0-5% slope

Recommendations and Equipment Solutions

- Automatic down force control with Precision Planting DeltaForce™ ensures consistent planting depth also under heterogeneous soil conditions.
- Using the Precision Planting 20/20 Gen3 monitor, planter settings are monitored and documented in high resolution. This will inform you, when adjustment of down force due to soil conditions is needed.
- Fendt VarioGuide with RTK ensures planter passes with maximum accuracy and operator comfort.
- Fendt Contour Assistant enables optimum wayline adaption to the contours of the field during planting.

Figure 39. Planter with DeltaForce down force control system on the trial plot.

Payback

In an overall consideration of the study years, the additional total revenue due to planting with automatic down force using the Precision Planting DeltaForce system in sugar beets is 52 CHF/ha (Figure 40).

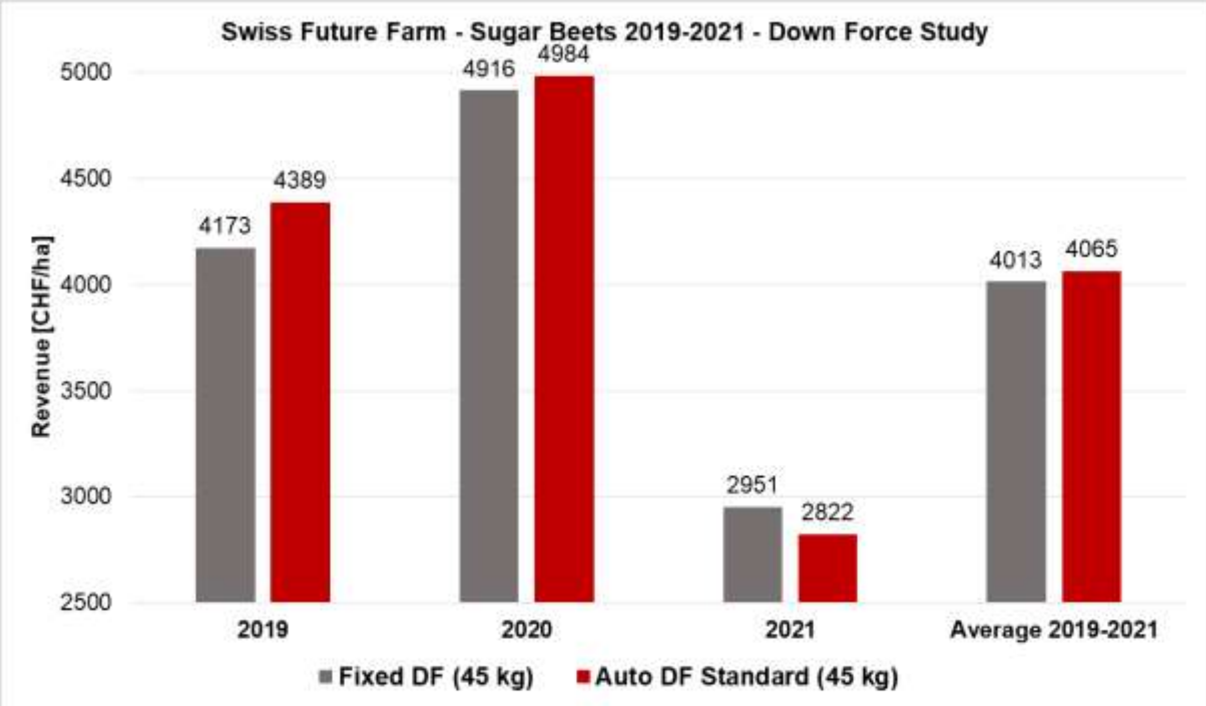

Figure 40. Revenue obtained from the Swiss Future Farm 2019-2021 Down Force Study in sugar beets.

The assumptions on payback are based on the conditions in the Swiss Sugar Beet Growing and Delivery Agreement 2021 between Schweizer Zucker AG and the Swiss Sugar Beet Growers Association.

Sugar beet basic price: CHF 45.00/ton

Surcharge or deduction per ton sugar beet per 0.1 % sugar content:

- <15%: - CHF 0.35
- 15.0-16.0%: CHF 0.00 (basic price without surcharge or deduction)
- >16%: + CHF 0.35

Study Overview

	Swiss Future Farm – Sugar Beets 2019-2021 – Three-Year Down Force Study Nils Zehner, AGCO Agronomy and Farm Solutions Team, nils.zehner@agcocorp.com			
STUDY OVERVIEW		Location (Region) **Swiss Future Farm (EME)**		Improved Yield **2%**
		Crop & Year **Sugar Beets 2019-2021**		Reduced Waste **-**
		Study Type **Down Force**		Improved Operat. Efficiency **-**
		Technology **Precision Planting DeltaForce**		Mehrerlös **52 CHF/ha**

1.7 Three-Year Liquid Fertilizer Study in Sugar Beets

Study Contact

Nils Zehner, Swiss Future Farm, nils.zehner@agcocorp.com

Objective

The objective of this study was to compare yield of sugar beets planted with liquid starter fertilizer using Precision Planting FurrowJet™ and FlowSense™, and sugar beets planted without liquid starter fertilizer.

Study Design

The study was carried out on the Swiss Future Farm (Switzerland) as a side-by-side strip trial from 2019 to 2021. The following treatments were compared:

- No liquid starter fertilizer (control)
- Hasorgan 0-0-5 liquid fertilizer (applied with total 1.16 kg K_2O/ha)

Planting dates for the study were in last week of March and first week of April. All trial strips were planted at 3.8 cm planting depth at a rate of 100,000 seeds per hectare, with DeltaForce automatic down force control set to a target down force of 45 kg. Liquid starter fertilizer was applied during planting using Precision Planting's FurrowJet™ and FlowSense™ liquid fertilizer system.

Results

The trials plots were harvested in October or November in each study year. Fresh mass yield in sugar beets in the average of the study years marginally decreased with application of liquid starter fertilizer compared to no liquid fertilizer by 0.2% (Figure 41). Seedling emergence may have been decreased by the popup placement of the liquid fertilizer (directly with the seed) due to salt effects of the fertilizer in dry soil.

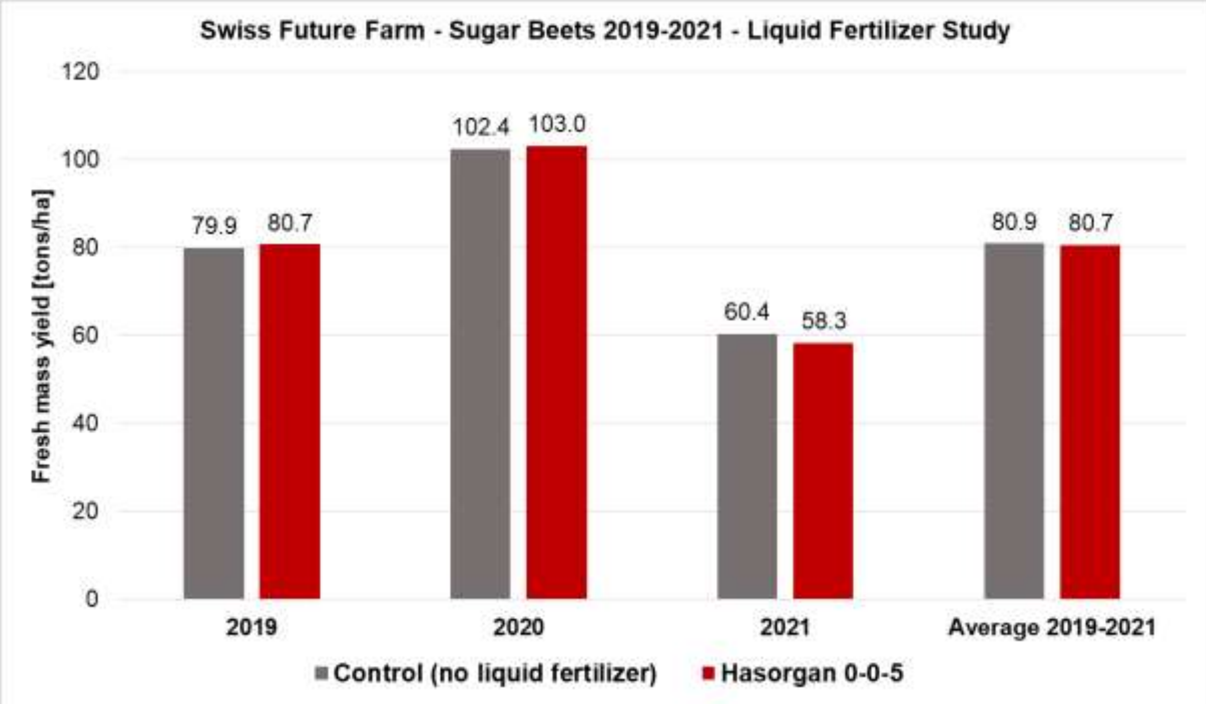

Figure 41. Fresh mass yield results of the Swiss Future Farm 2019-2021 Liquid Fertilizer Study in sugar beets.

In contrast, sugar content was 17.32% for the unfertilized control treatment and higher with 17.49% for trial strips with liquid starter fertilizer treatment in the average of study years, hence, an increase of sugar content of 0.17% could be achieved (Figure 42).

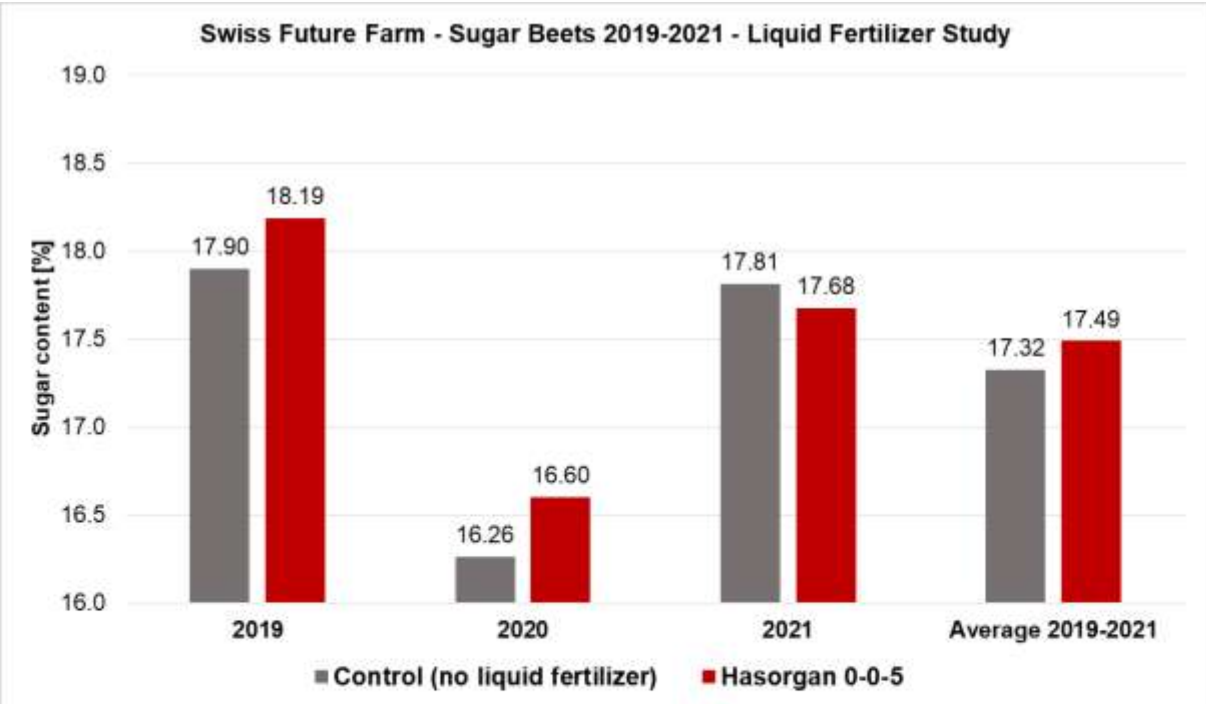

Figure 42. Sugar content results of the Swiss Future Farm 2019-2021 Liquid Fertilizer Study in sugar beets.

Sugar yield compared to the control treatment without liquid starter fertilizer of 12.3 t/ha was slightly higher for Hasorgan 0-0-5 with 12.5 t/ha on average (Figure 43).

Sugar yield increase that could be achieved due to the application of liquid starter fertilizer with Precision Planting FurrowJet compared to no liquid fertilizer in an average of the study years was 1.6%.

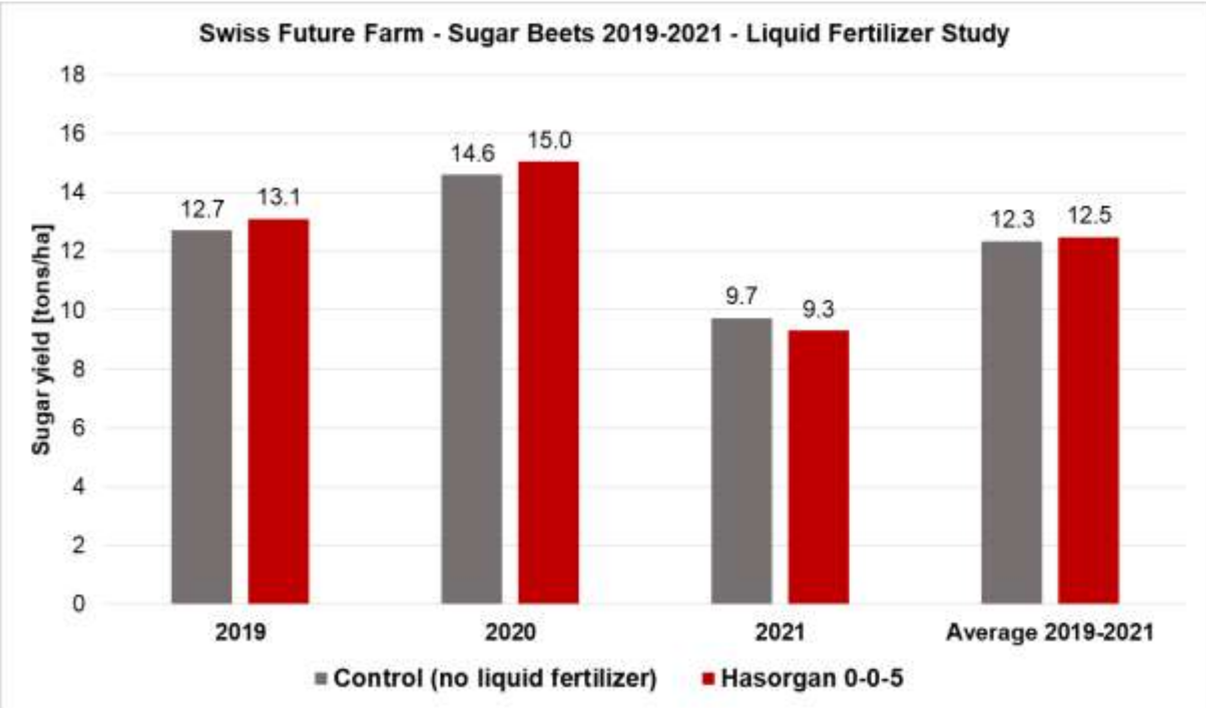

Figure 43. Sugar yield results of the Swiss Future Farm 2019-2021 Liquid Fertilizer Study in sugar beets.

Additional Observations

For the three study years, field emergence was measured twice during the trial in the growth period until the 6-leaf stage. Measurements are showing that in all study years no distinct differences in final field emergence could be observed between trial strips with and without liquid starter fertilizer application (Figure 44).

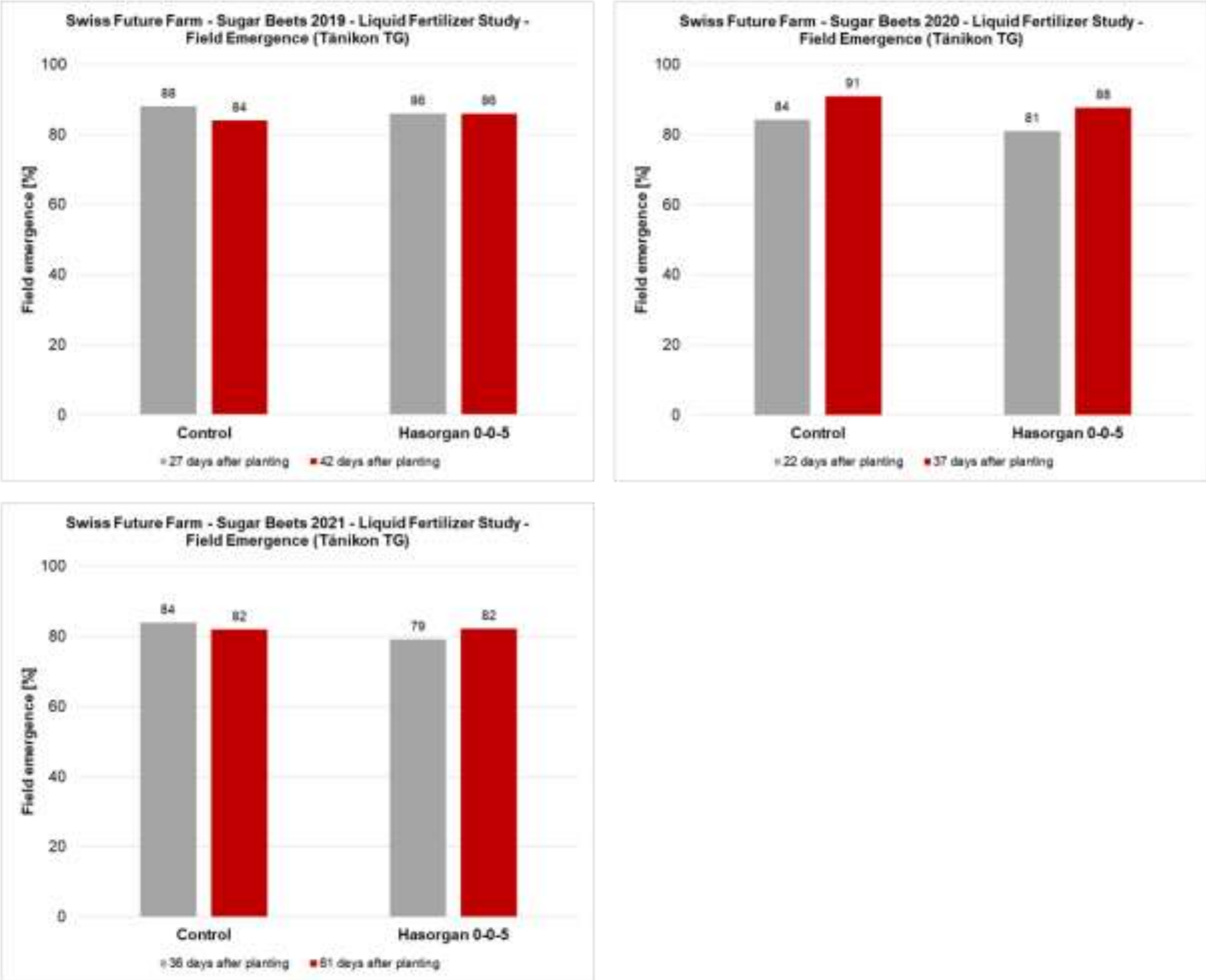

Figure 44. Field emergence results of the Swiss Future Farm 2019-2021 Liquid Fertilizer Study in sugar beets.

Recommendations and Equipment Solutions

- FurrowJet liquid fertilizer application system by Precision Planting enables exact placement of fertilizer in the trench and side walls of the seed furrow.
- Using the 20/20 Gen3 monitor, planter settings are monitored and documented in high resolution. This will help you to keep track of all planter settings and application systems.
- Fendt VarioGuide with RTK ensures planter passes with maximum accuracy and operator comfort.
- Fendt Contour Assistant enables optimum wayline adaption to the contours of the field during planting.

Figure 45. Precision Planting row unit equipped with FurrowJet liquid fertilizer system used for planting the trial plots.

Payback

In an overall consideration of the study years, the additional total revenue due to application of liquid starter fertilizer using the Precision Planting FurrowJet system in sugar beets on average was 76 CHF/ha (Figure 46).

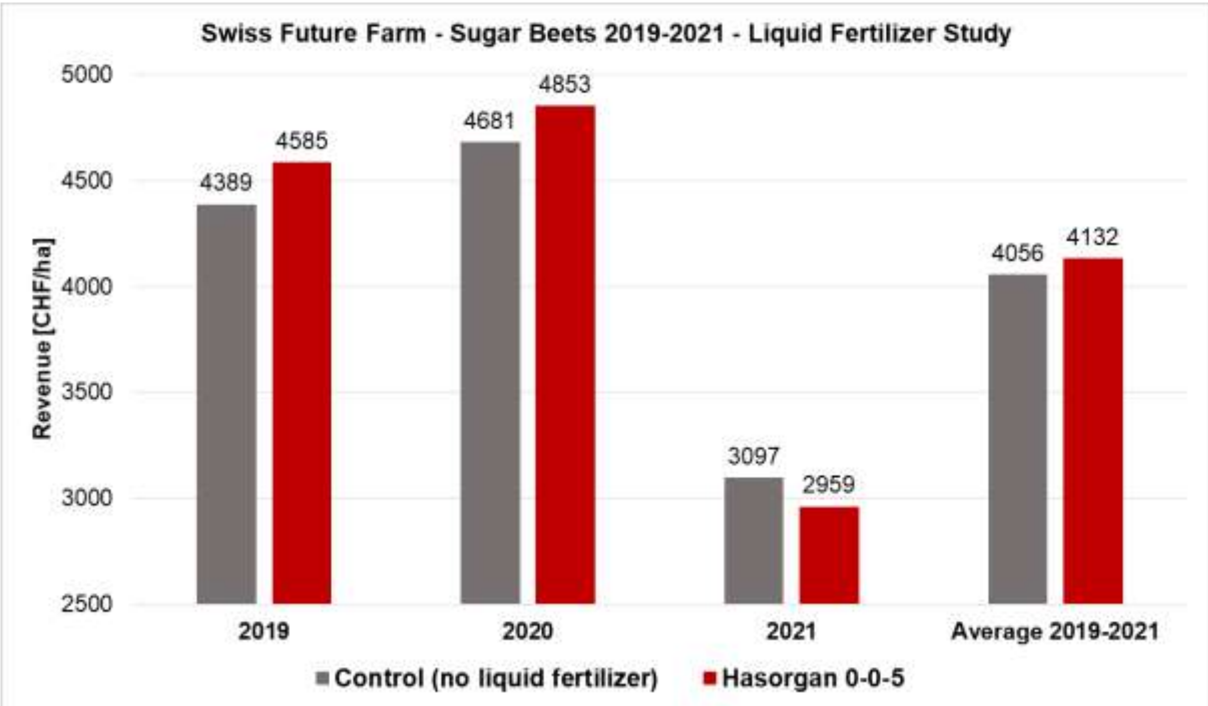

Figure 46. Total revenue obtained from the Swiss Future Farm 2019-2021 Liquid Fertilizer Study trial strips in sugar beets.

The assumptions on payback are based on the conditions in the Swiss Sugar Beet Growing and Delivery Agreement 2021 between Schweizer Zucker AG and the Swiss Sugar Beet Growers Association.

Sugar beet basic price: CHF 45.00/ton

Surcharge or deduction per ton sugar beet per 0.1 % sugar content:

- <15%: - CHF 0.35
- 15.0-16.0%: CHF 0.00 (basic price without surcharge or deduction)
- >16%: + CHF 0.35

Study Overview

<table>
<tr><td></td><td colspan="4">Swiss Future Farm – Sugar Beets 2019-2021 – Three-Year Liquid Fertilizer Study
Nils Zehner, AGCO Agronomy and Farm Solutions Team, nils.zehner@agcocorp.com</td></tr>
<tr><td rowspan="4">STUDY OVERVIEW</td><td>Location (Region)
Swiss Future Farm (EME)</td><td>Improved Yield
2%</td></tr>
<tr><td>Crop & Year
Sugar Beets 2019-2021</td><td>Reduced Waste
-</td></tr>
<tr><td>Study Type
Liquid Fertilizer</td><td>Improved Operat. Efficiency
-</td></tr>
<tr><td>Technology
Precision Planting FurrowJet</td><td>ROI
76 CHF/ha</td></tr>
</table>

1.8 Three-Year Planting Depth Study in Sugar Beets

Study Contact

Nils Zehner, Swiss Future Farm, nils.zehner@agcocorp.com

Objective

The objective of this study was to evaluate yield in sugar beets at different planting depths using a Precision Planting test planter with a DeltaForce™ down force control system.

Study Design

The study was carried out on the Swiss Future Farm (Tänikon, Canton of Thurgau, Switzerland) from 2019 to 2021 as a side-by-side strip trial. The following planting depths were tested:

- 2.5 cm (standard)
- 3.8 cm (slightly deeper)

In order to ensure consistent planting depth, all treatments were planted with DeltaForce automatic down force control set to a target down force of 45 kg and with a plant population of 100,000 seeds per hectare. Planting dates for the study were in last week of March and first week of April.

Results

The trials plots were harvested in October or November in each study year. Highest sugar beet yield in the average of the study years was obtained from the trial strips with deeper planting depth of 3.8 cm (81.0 tons/ha), whereas standard planting depth of 2.5 cm (74.4 tons/ha) provided lower yields (Figure 47).

The fresh mass yield increase in sugar beets that can be generated amounts to 8.9% when planting at 3.8 cm instead of 2.5 cm planting depth.

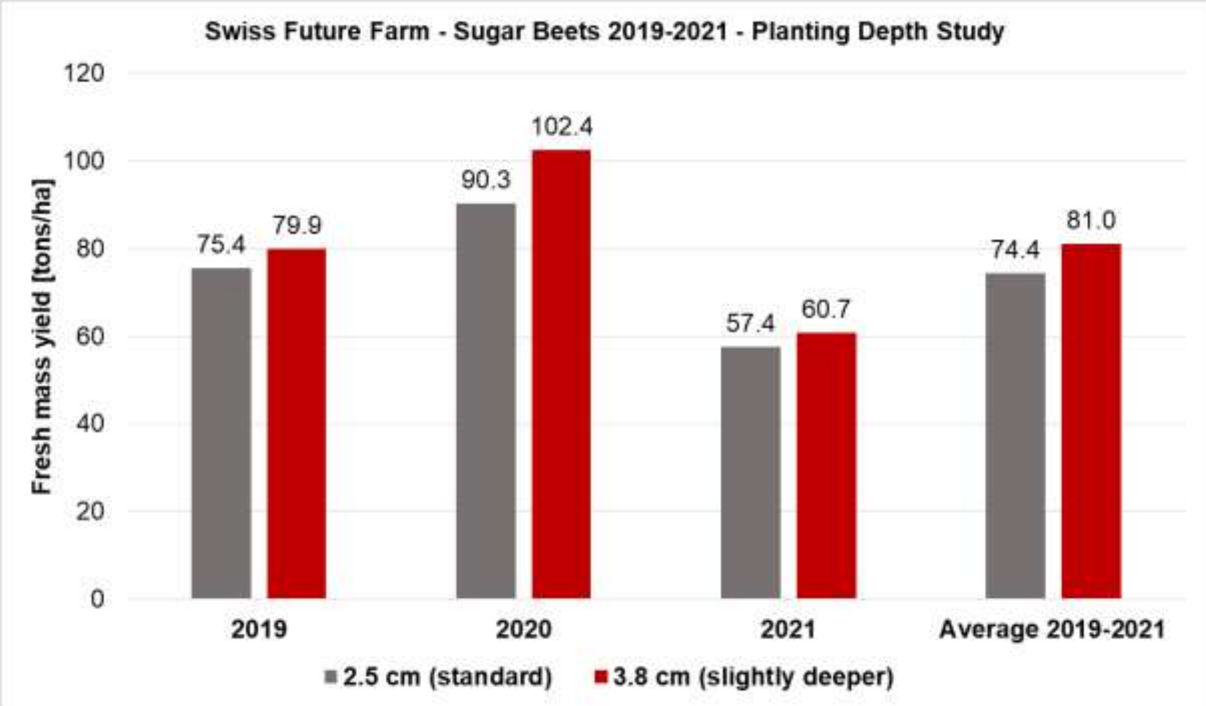

Figure 47. Fresh mass yield results of the Swiss Future Farm 2019-2021 Planting Depth Study in sugar beets.

Highest sugar content was obtained from sugar beets planted at standard planting depth of 2.5 cm (17.47%), whereas slightly deeper planting depth had lower sugar content of 17.28%, respectively (Figure 48).

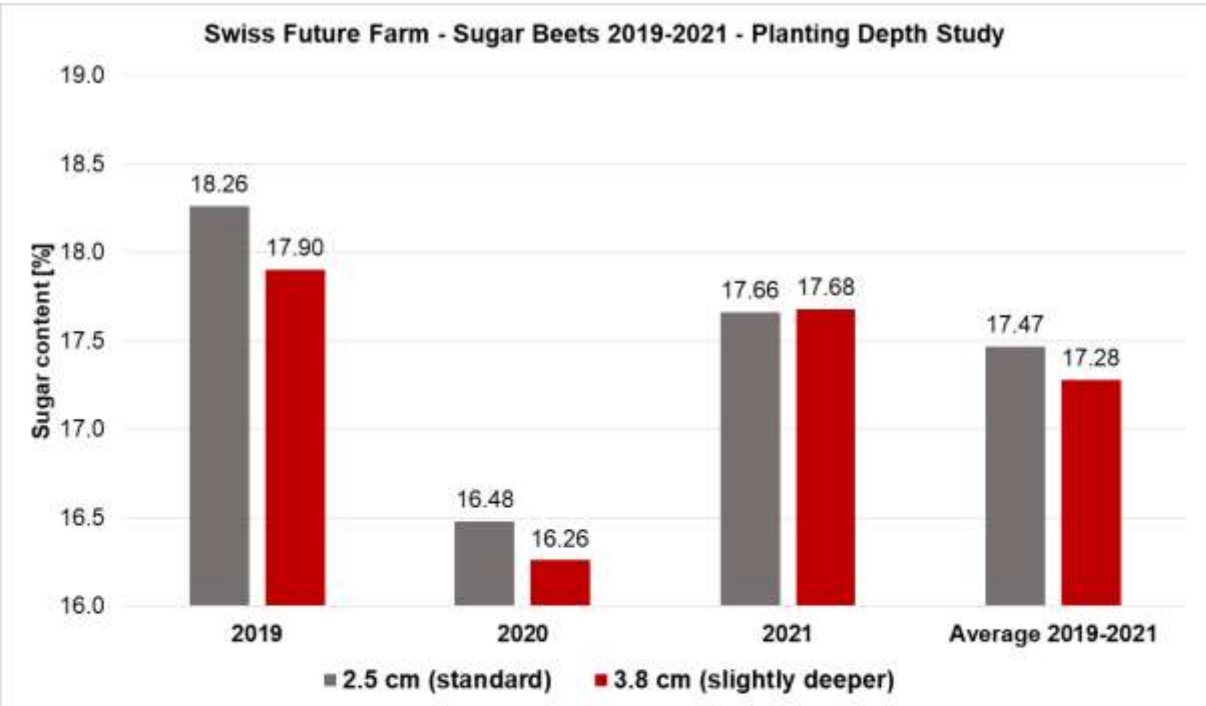

Figure 48. Sugar content results of the Swiss Future Farm 2019-2021 Planting Depth Study in sugar beets.

This may be due to lower impurities such as amino acids, potassium and sodium in sugar beets planted at 2.5 cm planting depth, as these impurities reduce the extractable sugar.

Highest sugar yield was obtained from the trial strips with 3.8 cm slightly deeper planting depth, whereas less sugar yield for 2.5 cm planting depth was found (Figure 49).

In our study, the increase in sugar yield that can be generated by planting at 3.8 cm instead of 2.5 cm planting depth amounts to 7.0% on average.

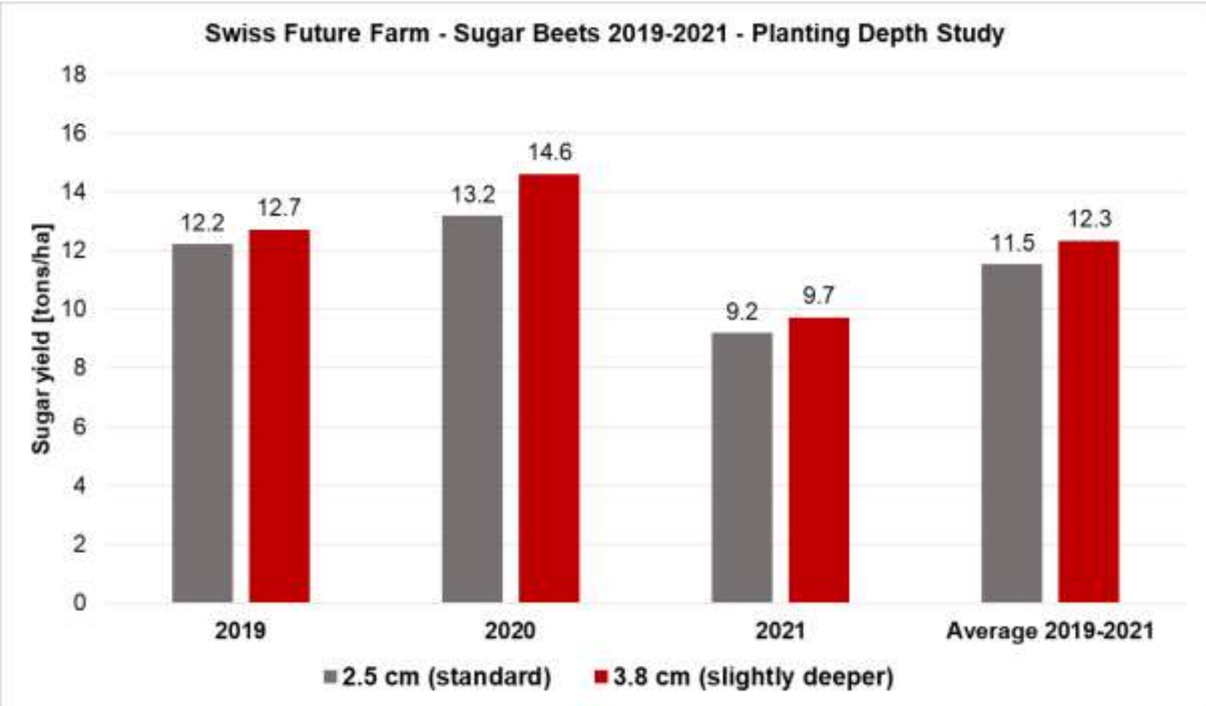

Figure 49. Sugar yield results of the Swiss Future Farm 2019-2021 Planting Depth Study in sugar beets.

Additional Observations

Yield advantage of sugar beets planted at 3.8 cm was evident in years with spring drought conditions. The year 2020 had a spring period with low precipitation during the planting period for sugar beets compared to the long-term average at the trial site (Figure 50). Slightly deeper planting depth (3.8 cm) compared to standard (2.5 cm) enabled to place the seed in sufficient moisture conditions during the crop establishment period and therefore provided better germination and emergence conditions.

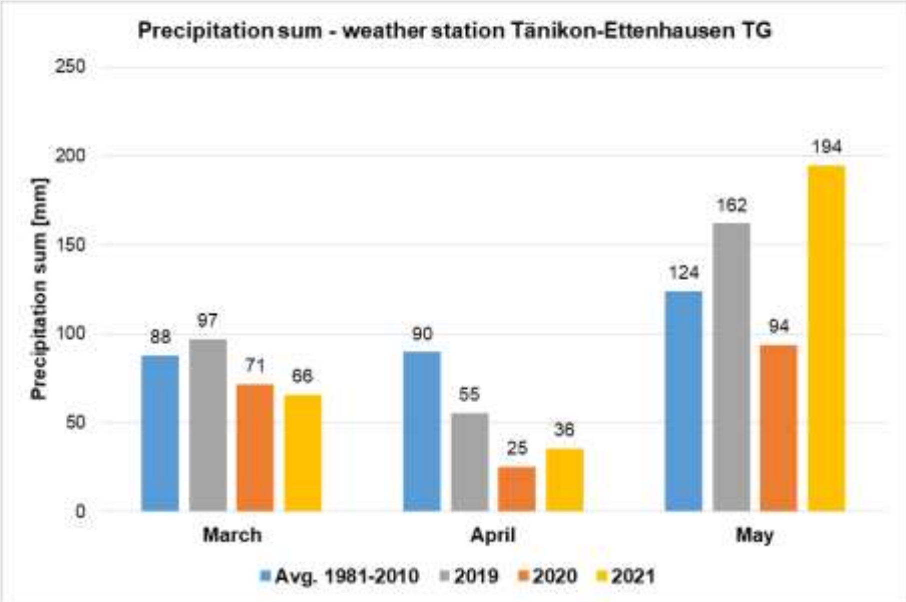

Figure 50. Precipitation during spring season at the trial location in Northeastern Switzerland in 2019-2021 compared to long-term average.

Recommendations and Equipment Solutions

- Slightly deeper planting depths for sugar beets of 3.8 cm (1.5 inch) compared to standard 2.5 cm (1.0 inch) places the seed in sufficient moisture conditions and enables better germination and crop establishment in dry planting periods.
- Fendt Guide with RTK ensures planter passes with maximum accuracy and operator comfort.
- Fendt Contour Assistant enables optimum wayline adaption to the contours of the field during planting.
- Automatic down force control with Precision Planting DeltaForce™ ensures consistent planting depth also under heterogeneous soil conditions.
- Precision Planting SmartFirmer™ soil sensors measure soil moisture, soil temperature and organic matter in real time during planting.
- Using the Precision Planting 20/20 Gen3 monitor, planter sensor parameters are monitored and documented in high resolution. This will inform you, when adjustment of planting depth due to insufficient moisture or temperature is needed.
- Precision Planting SmartDepth™ automatically adjusts planting depth between a minimum and maximum depth while maintaining the soil moisture target.

Figure 51. Precision Planting SmartFirmer for measurement of soil moisture in the furrow (left) and Precision Planting SmartDepth for real-time adaption of planting depth according to soil moisture content (right).

Payback

The highest revenue was obtained from sugar beets planted at slightly deeper planting depth of 3.8 cm (4048 CHF/ha), which is 263 CHF/ha more revenue than at 2.5 cm planting depth (Figure 52).

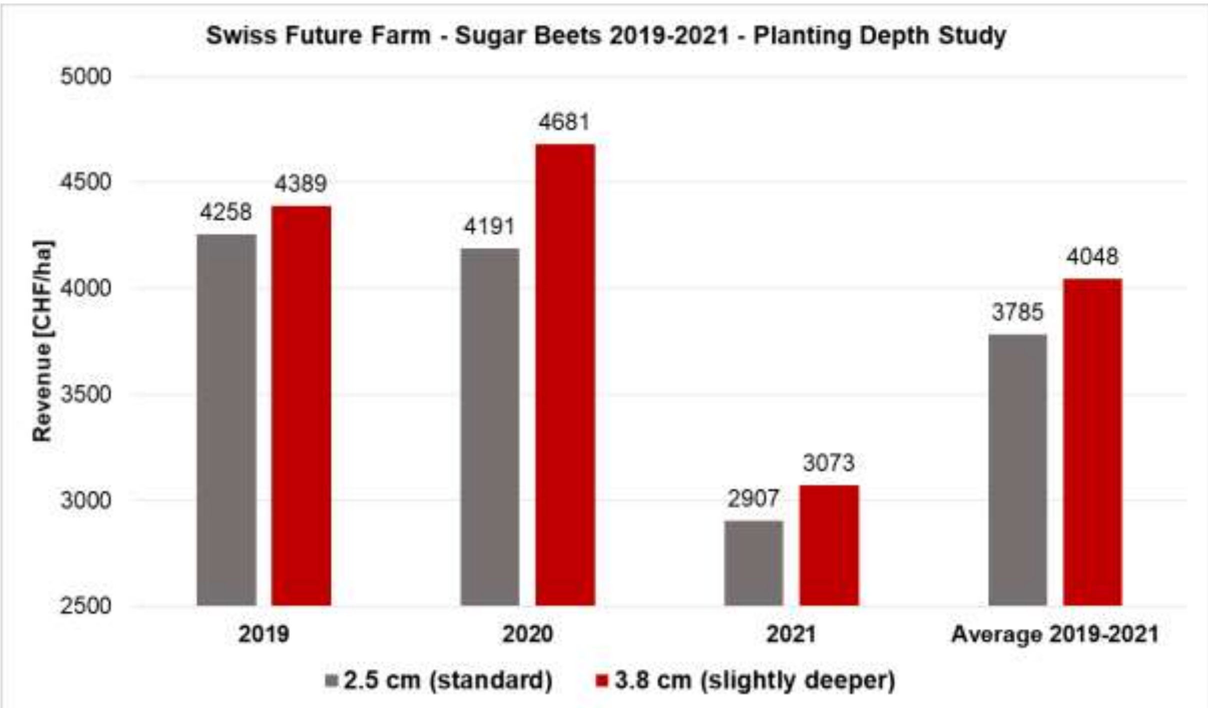

Figure 52. Revenue obtained from the Swiss Future Farm 2019-2021 Planting Depth Study trial strips in sugar beets.

The assumptions on payback are based on the conditions in the Swiss Sugar Beet Growing and Delivery Agreement 2021 between Schweizer Zucker AG and the Swiss Sugar Beet Growers Association.

Sugar beet basic price: CHF 45.00/ton

Surcharge or deduction per ton sugar beet per 0.1 % sugar content:

- <15%: - CHF 0.35
- 15.0-16.0%: CHF 0.00 (basic price without surcharge or deduction)
- >16%: + CHF 0.35

Study Overview

	Swiss Future Farm – Sugar Beets 2019-2021 – Three-Year Planting Depth Study Nils Zehner, AGCO Agronomy and Farm Solutions Team, nils.zehner@agcocorp.com			
STUDY OVERVIEW		Location (Region) **Swiss Future Farm (EME)**		Improved Yield **7%**
		Crop & Year **Sugar Beets 2019-2021**		Reduced Waste **-**
		Study Type **Planting Depth**		Improved Operat. Efficiency **-**
		Technology **Precision Planting DeltaForce**		ROI **263 CHF/ha**

2 Projects

2.1 „Smart-N“ consulting project

The consulting project "Smart-N" is the first project within the framework of the Experimental Station Smart Technologies in Agriculture in the application region Schaffhausen and Thurgau. The experimental station is a consortium of the Agroscope Research Station, the cantons of Thurgau and Schaffhausen, and the AGRIDEA advisory center with the aim of testing the digitalization possibilities in agriculture for the benefit of resource- and climate-friendly management and to further develop them specifically for use in practice. As a pilot project, the Smart-N project aims to bring sensor-based, site-specific nitrogen fertilization into practice using winter wheat as an example. To this end, satellite-based fertilization recommendations for fertilization in winter wheat will be used on three farms in the cantons of Thurgau and Schaffhausen from 2022 and compared with fertilization according to the corrected standard of the GRUD method and the standard farm method. A total of seven additional farms will be added in 2023 and 2024. The basis for the Smart-N project comes from the findings on site-specific fertilization, which were developed by Agroscope at the Swiss Future Farm between 2018-2021. In the Smart-N, the Swiss Future Farm acts as a consultant in the area of application of the technologies.

Further information on the Experimental Station Smart Technologies in Agriculture and the Smart-N project:
https://www.agroscope.admin.ch/agroscope/de/home/ueber-uns/standortstrategie/versuchsstationen/versuchsstation-smarte-technologien.html

3 Public Relations

3.1 Public visitor program at the SFF

Despite the Corona-related difficulties, we were again able to welcome around 1000 people to Tänikon in 2021 as part of our visitor program. In addition to excursions by companies and associations, we were once again able to welcome numerous students from various Swiss agricultural schools and students from universities such as HAFL, ZHAW and HEPIA to Tänikon in 2021.

For the general public, we organized the digital scavenger hunt "From Grain to Roll" during two summer vacation weeks of the cantons TG and ZH. On an educational trail about the production of grain and related experiments on the SFF, participants were able to collect points at various posts on the SFF. After completing the post run, the participants were allowed to pick up a well-deserved spelt roll at the Rüedi bakery in Aadorf. The spelt for future Aadorfer-Brötli is currently being grown on an SFF plot together with einkorn and forest perennial rye for use in the Rüedi bakery from 2022.

Figure 53. SFF Holiday Program "From Grain to Roll".

3.2 SFF Field Visit on 24th June 2021

The SFF Field Visit on 24th June 2021 took place at the Swiss Future Farm in collaboration with the advisory team of the Arenenberg, IP-Suisse and Regiomalz.

In the field, three posts provided information on the following topics:

- Weed control without herbicides in wheat: impact on yield, quality, and protiability
- New findings from the 2021 wheat variety trial
- Do new technologies in sugar beet planting impact yield? What is the optimum planting depth?

Due to the announced thunderstorm, the fourth post on malting barley cultivation in Switzerland was moved inside. Here, the young team from Regiomalz reported on their plans to open the first Swiss malting plant in eastern Switzerland. Furthermore, the interim results of the Arenenberg malting barley variety trial at the Swiss Future Farm were presented and watered with the kind support of Regiomalz.

Figure 54. After the presentation of Regiomalz on the potential of malting barley, the evening ended convivially.

3.3 Innovation Forum Food Industry

On December 03, 2021, the second edition of the Innovation Forum Food Industry Tänikon took place for the first time as a physical event on site in Tänikon on the topic of *Smart Solutions for Sustainable Food*.

The aim of the annual innovation forum is to network researchers, companies and agricultural producers along the entire value chain.

In the morning, representatives from research and industry gave presentations on environmentally relevant aspects of food production. In further presentations, possible applications of modern digital technologies were presented. In addition to robotics solutions for field cultivation, the frozen food producer Verdunova AG reported on digitalization as a fine-tuning instrument in process optimization. In the afternoon, a good hundred participants went on a tour of the Swiss Future Farm and learned more at the stations of the Swiss Future Farm, Agroscope, OST and the startup promotion of the Canton of Thurgau.

The next event will take place on Thursday, December 8, 2022, in Tänikon.

Figure 55. Nicolas Helmstetter from GVS Agrar AG informs about robotics in field cultivation (left). Representatives of OST present their slope-compatible mowing robot (right).

More information can be found on the following website:
https://innovationsforum-ernaehrungswirtschaft.tg.ch

4 Training and Education

4.1 Knowledge transfer activities

Program for agricultural schools in Switzerland

This year, in addition to the Arenenberg learners, we were pleased to welcome students from the Liebegg, Wallierhof and St. Gallen agricultural schools to the SFF. In half-day excursions, information was provided on the Swiss Future Farm projects as well as on the topics of the steering system and ISOBUS and on the emissions test barn in collaboration with researchers from Agroscope.

Figure 56. Students from Liebegg and Wallierhof during the excursion to the Swiss Future Farm as part of the elective module "GPS".

Module Smart Farming BF30

In 2021, the module "BF30 Smart-Farming" was successfully carried out for the first time together with Strickhof and the St. Gallen Agricultural Center. The module was attended by 25 participants, who gained insights into the areas of guidance systems, ISOBUS, sensor technology in arable and livestock farming, Geographical Information Systems and Farm Management and Information Systems in this basic module.

Impulse Course of the Canton of Thurgau's Promotion of Gifted and Talented People (BFF)

In the impulse course of the BBF of the Canton of Thurgau at the SFF in Tänikon, the participating students from the 5th to 7th grade were able to immerse themselves in the world of Smart Farming during an afternoon. The afternoon started with a theoretical part on the topic of "Digitalization in crop production". Afterwards, the students learned about the Smartbow sensor in the barn and were able to make suggestions for improvements to this sensor. Finally, the students were allowed to take the tractor and guidance system for a spin.

Smart Farming block in Master module Agroecology and Food Systems of ZHAW

On November 4, 2021, a module day in the Zurich University of Applied Sciences (ZHAW) master's module Agroecology and Foodsystems on the topic of Smart Farming was held for the first time at SFF. During the excursion, students gained a broad insight into practical farming and its challenges as well as the application of digital technologies in outdoor and indoor farming. For optimal learning success, the program was divided into theoretical and practical parts.

5 Links

5.1 Websites

www.swissfuturefarm.ch

www.swissfuturefarm.com

www.agcocorp.com

www.bbz-arenenberg.ch

www.gvs-agrar.ch

www.fusesmartfarming.com/de

www.agrar-landtechnik.ch

www.precisionplanting.com

eu.precisionplanting.com

www.agroscope.admin.ch/agroscope/de/home/themen/wirtschaft-technik/smart-farming/swiss-future-farm.html

5.2 Social Media

https://www.instagram.com/swissfuturefarm

https://www.facebook.com/swissfuturefarm

https://www.youtube.com/channel/UCzsEm9mMLs0X_lT3MoaCJXQ

6 Edition Notice

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