LEGUTEC – MECHANICAL WEED CONTROL IN SOYBEAN CULTIVATION IN LUXEMBOURG

EVALUATION REPORT

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LeguTec

Sustainable and resource-efficient protein production using various mechanical weed control methods in grain legume cultivation, using soybean as an example

Project duration: 10/2017 – 09/2020

Coordination

IBLA
Institut fir Biologësch Landwirtschaft an Agrarkultur Luxemburg a.s.b.l.

Project partners

Lycée Technique Agricole

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GEOCOPTIX

Organic farm „An Dudel" Emering, Sprinkange;
Organic farm Mehlen, Manternach,
Organic farm François, Hostert

Funding

LE GOUVERNEMENT DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Agriculture, de la Viticulture et du Développement rural

ŒUVRE Nationale de Secours Grande-Duchesse Charlotte

carried out with the support of the King Baudouin Foundation and the National Lottery

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PIET VAN LUIJK
Produits agricoles - Aliments bétails

Content

Acknowledgement

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1. Introduction

Soybean (*Glycine max* (L.) Merr), a member of the family *Leguminosae*, has a protein content of about 40 % and a very high biological value due to an optimal amino acid composition, making it one of the most important feed protein sources in animal nutrition (Hahn et al., 2013). The high content of the two essential amino acids lysine and methionine in soybeans is particularly important for monogastric animals such as pigs and poultry (Bernet et al. 2016). As a protein plant, soybeans have a number of positive properties for use in agriculture: the cultivation of soya expands and loosens crop rotation, increases agrobiodiversity, improves soil fertility through the ability to fix nitrogen, and thus contributes to savings in nitrogen fertilizers (Köpke et al., 2010; Nemecek et al., 2008).

Being one of the EU-states that signed the European Soya Declaration (2017), Luxembourg aims to promote the regional cultivation of soybeans and other protein crops. The decisive factor is the current dependency on imports from mainly North and South America. Far more than 60 % of the required amount of soybean is imported (Bernet et al. 2016), which causes various environmental and social problems (Beste et al. 2011). Due to the large-scale cultivation of soya as a monoculture in the producing countries and the associated intensive use of chemical-synthetic plant protection products, in particular glyphosate in conventional cultivation, there is a strong loss of biodiversity as well as soil erosion and health hazards to the population. The high global demand for soybean meal as fodder also leads to strong land pressure, with rainforests being cleared to make way for soybean cultivation areas, which in turn leads to a loss of biodiversity. There is also the risk of mixing with GMO soya and the long transport routes have a negative impact on CO_2 emissions.

In times of climate change, the widespread degradation of our natural resources and the increasing incidence of degenerative diseases, alternatives to these practices must be identified. One solution is a sustainable meat production, especially for monogastric animals, in combination with an increase in the fodder autarky of regional farms. The local, pesticide-free cultivation of grain legumes can cover at least part of the protein requirement for animal production. This can reduce dependence on imported soya and the associated negative environmental and social impacts and thus contribute to climate protection.

Thanks to breeding of new varieties with very early maturity, soybean cultivation is nowadays possible under low temperature conditions - an opportunity to introduce soybean production in Luxembourg and thus increase its protein autarky. However, the organic cultivation of soybean is demanding and in addition to the currently not yet guaranteed further processing in Luxembourg (e.g. toasting as one heat treatment possibility) there are above all knowledge gaps in efficient and sustainable mechanical weed control techniques (Zimmer et al., 2016).

The aim of this project is to contribute to a regional and sustainable agriculture while excluding chemical treatments and including a mechanically treated legume crop into the crop rotation; resulting in the national environmental protection and water conservation as well as help to support less international ecological and environmental damages. The best possible mechanical weed control method for soybean cultivation has to be derived in order to promote sustainable and resource-efficient protein production in Luxembourg and to increase the protein autarky of the Luxembourgish farmers. The best method will be given regarding the success of weed control, practicability and profitability. The results can then be transmitted and applied to further grain legumes. The next generation of farmers, the students at the Lycée Technique Agricole will learn how to handle the weed control in soybean cultivation mechanically. Therefore, they will be involved into the field trial in Bettendorf from the beginning on as a part of their lectures. All in all, the communication and demonstration of mechanical weed control possibilities as well as the disseminations will not only be given to interested parties in Luxembourg, but will be spread transnational, especially into the Greater Region where comparable agricultural conditions are present.

LeguTec is a joint project of the Institut fir Biologësch Landwirtschaft an Agrarkultur Luxemburg a.s.b.l. (IBLA), Lycée Technique Agricole (LTA), Geocoptix GmbH and Wolff-Weyland SA.

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2. Material and methods

2.1 General experimental design

LeguTec consists of three study sites on organic farms spread over Luxembourg, while each site is designed as one-factorial-exact-trial. In addition, one experimental area of the *Lycée Technique Agricole (LTA)* in Bettendorf is designed as an on-farm trial. The following three organic farms have been selected: Organic farm Patrick François in Hostert, organic farm Alex Mehlen in Manternach and organic farm "An Dudel" of Marc Emering in Sprinkange (see Figure 1).

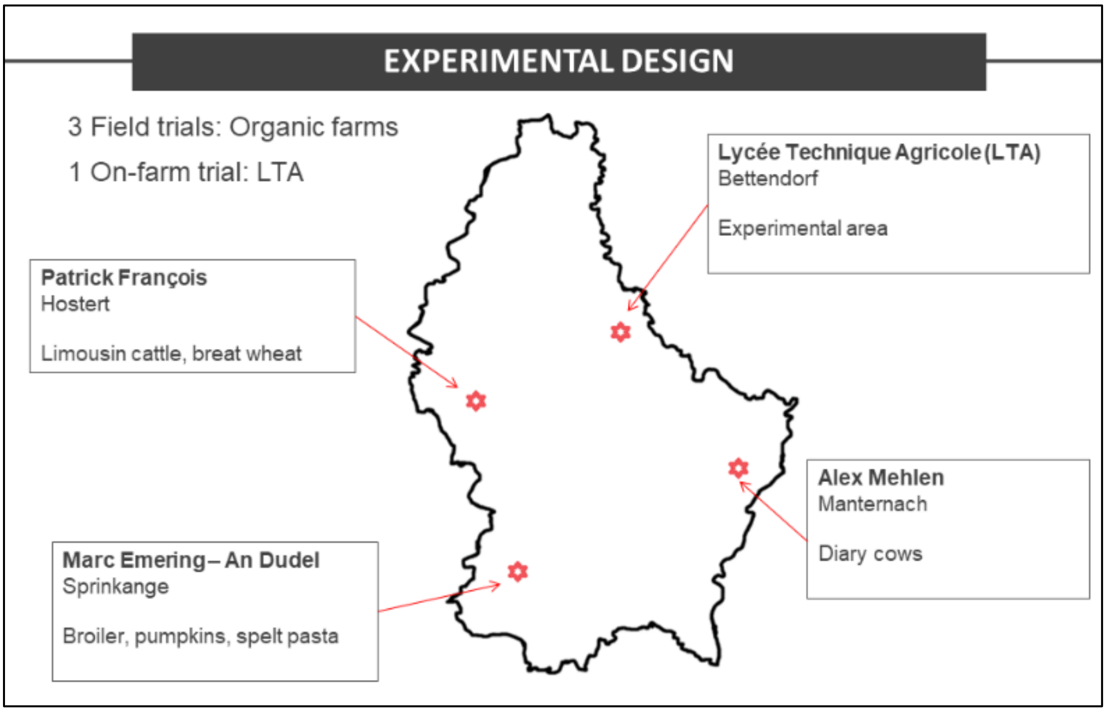


Figure 1: Locations of the study sites in Luxembourg. The main agricultural production of the farmers is given.

The three organic field trials are set as randomized complete blocks consisting of five different systems of mechanical weed control that are going to be tested and compared: 1) harrowing, 2) hoeing with interrow cultivator with duck foot shares, 3) hoeing with interrow cultivator with duck foot shares and finger weeder, 4) a flexible system, a combination of treatment 1 and 3, while the decision is made according to the actual site and weather conditions and 5) intercropping of soybean and camelina in combination with harrow. A negative control, where no weed control is administered, and a positive control, where all weed is taken out of the plots by hand, are considered as well. The treatments are set in four replicates (see Figure 2).

Weed harrowing is done with the machinery of the respective farmer, whereby the uniform harrow width is six meters. Hoeing is carried out with a technique of the manufacturer Hatzenbichler, which includes duck foot shares with the attachment element finger weeder. The three meters wide hoe is provided by the agricultural engineering company Wolff-Weyland SA, as well as the 24-row, mechanical seed drill of the manufacturer Amazone. Sowing, harvesting and the operations with the hoe are carried out in cooperation with the technical staff of the LTA. The weed control dates will be best performed according to common practice criteria such as weather and plant development.

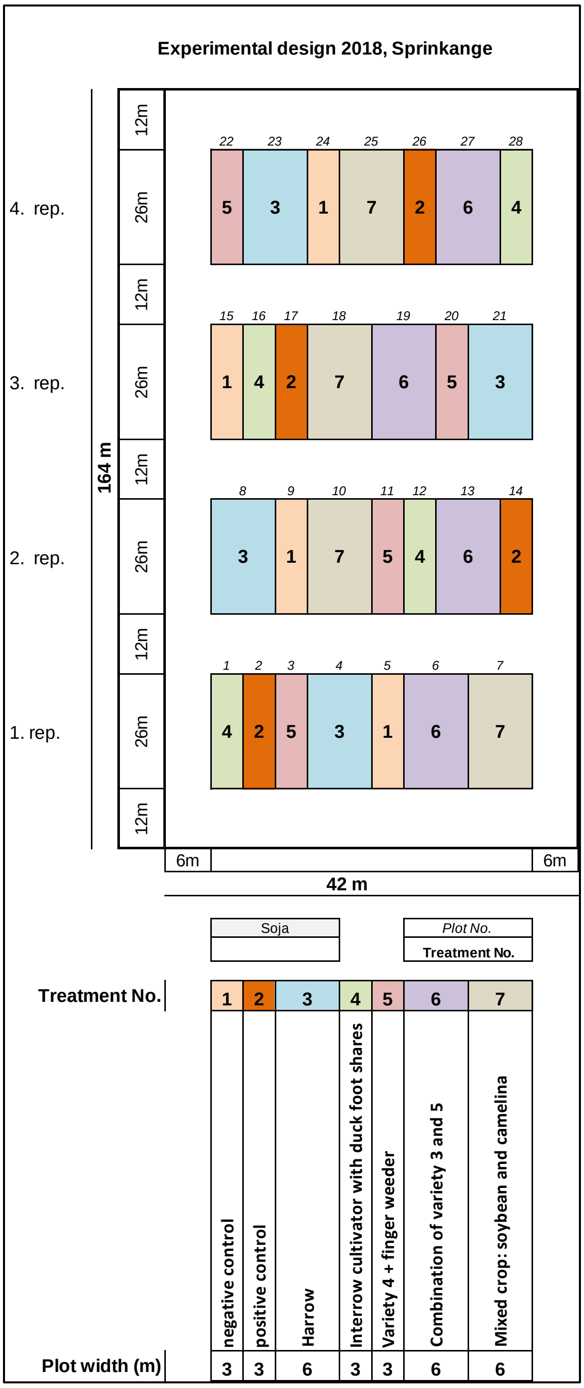


Figure 2: Experimental design of LeguTec study site Sprinkange.

During the vegetation period, the emergence and the regulation of weeds (weed control efficiency) by the various weed regulation methods is accurately recorded and documented, both manually and by aerial photographs of the project partner Geocoptix GmbH.

The plant damages, health and the workload of the single runs are noted. At harvest, the yields and yield structures are determined, followed be the protein yields. Table 1 lists an overview of the surveys and assessments which are collected in the entire course of vegetation in both of the years.

Table 1: Overview of the surveys and assessments in the project LeguTec along the two vegetation periods 2018 and 2019.

Date	**Kind of survey/assessment**
Sowing	Soil analysis (basic analysis and N_{min})
Emergence	Number of plants per meter
Pre and post mechanical weed control	• Number of plants and branching • Cover of plants and weeds [%] • Number and kind of weeds • Workload per run and machine • Plant damages (after Vanhala et al., 2004) • Plant and weed biomass (prior to first run) [g/m^2]
Flowering	• Chlorophyll content (measured with SPAD) • Plant health • Plant height [cm] • Number of plants and branching • Cover of plants and weeds [%] • Number and kind of weeds • Plant and weed biomass [g/m^2]
Harvest	• Number of plants and branching • Cover of plants and weeds [%] • Number and kind of weeds • Plant and weed biomass [g/m^2] • Plant height [cm] • Yield [dt/ha] and yield structure • Humidity [%], thousand seed weight [g], hectolitre weight [kg/hl] of harvested soybeans • Protein content of soybeans [%] • Soil analysis (basic analysis and N_{min})

The single assessments take place in pre-defined areas in each plot. For each plot, 9 fixed subplots with an area of 1 m^2 and a 12 m^2 harvest plot are marked to ensure elevations along the vegetation period at the same position. Figure 3 exemplary shows the subdivision of each plot for the treatments 4 and 5.

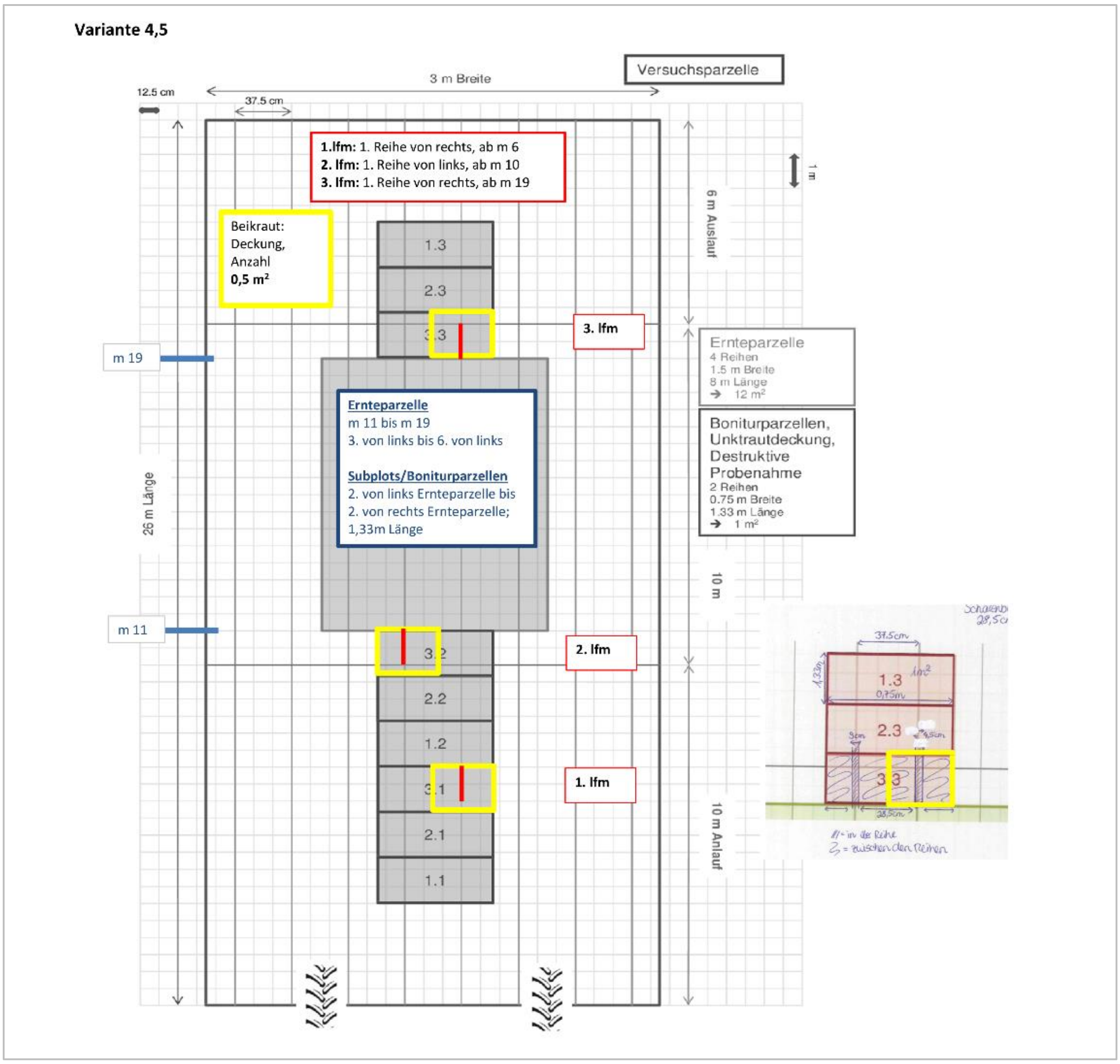


Figure 3: Exemplary scheme of the subdivision of each parcel into its subplots (yellow), the meter for counting the plants (red) and the harvest parcel (blue).

Within three subplots (3.1, 3.2, 3.3) cover (%) and weed species are determined at the different times with the help of a score frame (see Figure 4) measuring 0.5 m². The number of soya plants is also counted in these subplots per running meter. The destructive sampling of the biomass takes place in the remaining subplots.

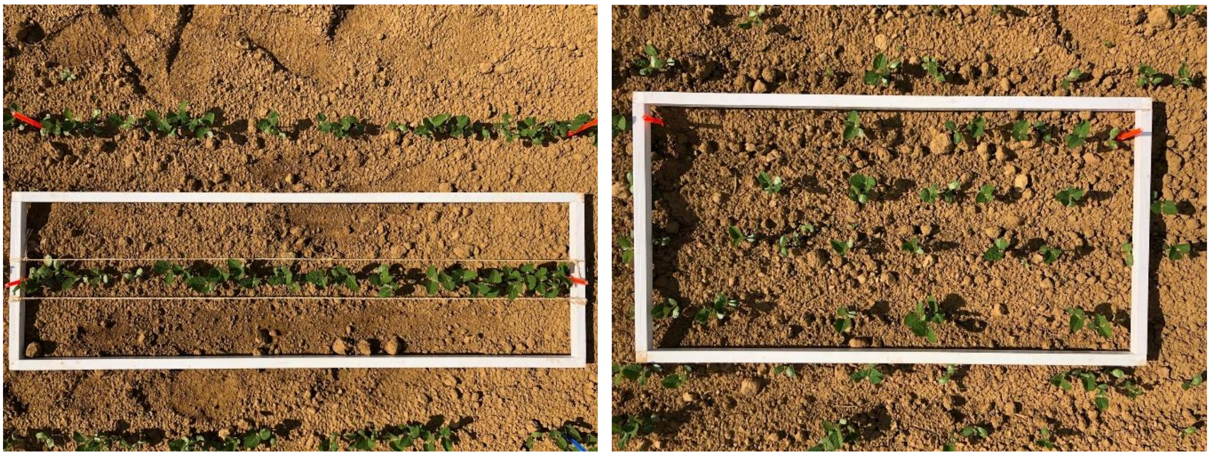


Figure 4: Score frame for the row-dependent treatments (left) and the row-independent treatments (right).

Within 1 to 3 days after each weed control the post assessment will take place including the additional parameter of soya plant damages. The assessment takes place according to Vanhala et al., 2004 on a scale of 1-100%.

The chlorophyll content is measured at flowering with a *SPAD 502 Plus Chlorophyll Meter*. For this purpose, 10 measurements within a subplot are averaged. For each plot the mean SPAD value within the three subplots is determined.

Before and after each weed control, as well as at flowering and harvest, the manual assessments are complemented with drone-supported aerial photographs. The project partner Geocoptix GmbH flies over the respective test field by means of unmanned flight systems. The aim is to perform weed detection and quantification before and after the respective mechanical weed control and to determine the efficiency of the respective treatment. In addition, possible stress symptoms caused by damage to the soya plants are to be identified. Different flight and camera systems were used for this purpose: On the one hand, a Micasense RedEdge-M, a multispectral camera which records 5 channels in the optically reflective spectral range (B-G-R-RE-NIR). A small quadrocopter (DJI Phantom 4 Pro) with a total weight of 2.2 kg serves as the flight system. On the other hand, a highly sensitive thermal camera (TeAx ThermalCapture Fusion Zoom) is used on a DJI S900. In both flight systems, the test fields are flown over in a chessboard pattern and photographs are taken at regular intervals.

The first processing step after the image data collection is the radiometric calibration of the aerial photographs. This corrects the influence of the atmosphere and the position of the sun on the images and allows the comparison of image data taken at different times. After the radiometric correction, the images are subjected to photogrammetric evaluation and distortion-free orthomosaics are calculated.

The on-farm field trial in Bettendorf consists of the following treatments: a) harrow, b) interrow cultivator, c) interrow cultivator with finger weeder, d) combination of harrow and hoe and e) chemical weed control. This area is managed independently by the students of the LTA in consultation with the teaching staff and is thus used for teaching and demonstration purposes. In the on-farm experiment, the harvest parameters yield, moisture, thousand grain weight and hectolitre weight are recorded.

2.2 Experimental design 2018

The choice of the study sites on the three organic farms in Luxembourg was already made in 2017, taking into account the criteria that the soybean fits into the crop rotation and that the location of the sites is relatively homogeneous with as little slope as possible. Based on the soil samples taken, it was decided to fertilize the areas with lime and phosphorus to create ideal conditions for the soybean plant, which has its optimum growth range at a pH value in the weakly acidic to neutral growth range (pH 6.5 - 7) (Recknagel, et al., 2018). The target phosphorus content in the soil should be 10-12 mg/100 g dry soil to counteract the phosphorus removal of about 1.5 kg/dt soybeans (Hahn et al., 2013). The lime (carbonic acid lime 95, dry) was provided by the company MUELLERKALK DE. The primary cultivation, the necessary fertilization as well as the seedbed preparation and the creation of a false seedbed were carried out by the respective farmer after consultation with IBLA. Table 2 provides an overview of the study sites in 2018, the characteristics and data on the treatments carried out, the assessment dates and other important key figures.

Table 2: Key figures of the test locations in the LeguTec project as well as data of the work steps carried out. Temperature and precipitation are given as a 7-year average. The development stage of the soy plant is indicated in brackets with the aid of the BBCH scale according to Munger et al., 1997.

LeguTec		Manternach (Mehlen)	Hostert (Francois)	Sprinkange (Emering)	Bettendorf (LTA)
Study site	**Year of investigation**	**2018**			
	FLIK number	P0158691	P0761342, Schlag 2	P0915621	P0893423
	area field (ha)	0.69	0.74	0.69	1.05
	m a.s.l.	281	464	336	188
	Ø-Temp (°C)	10.7	9.1	9.7	9.7
	Ø-precipitation ∑ (mm)	688.4	920.9	681.2	849
	CHU (crop heat unit)	2972	2708.8	2647.6	2740.3
	Soil type	sandy-clayey brown earth from dolomite	stony-loamy and sandy-cleyey brown earth and luvisols	clayey brown earth	Valley soils
	Soil parameter				
	soil extraction date	Sep.16	Feb.18	Nov.17	Jan.18
	pH (CaCl2)	6.1	5.3	6.3	7.4
	K_2O	14	23	14	12.5
	P_2O_5	8	11	6	15.5
	MgO	20	13	10	24
	Na		1	1	1
	previous crop	Triticale	winter wheat	spelt	winter grain
	intercrop		sunflower	summer oat	
Primary cultivation	**Plough**	21.02.	26.03.	24.02.	20.03.
Fertilizer	**Liming date**	12.04. (spring-tooth harrow)	06.04. (rotary harrow)	23.04. (spring-tooth harrow)	-
	Amount of lime (kg)	800	1500	800	-
	Phosphorus date	12.04. (spring-tooth harrow)	13.04. (harrow)	23.04. (spring-tooth harrow)	11.04.
	Amount of phosphorus (kg)	120	80	160	100
Sowing	**False seed-bed**	12.04.	13.04.	(23.04.) 15.05. (spring-tooth harrow)	13.04.
	Inoculation + sowing	23.04.	24.04.	(26.04.) 17.05.	20.04.
	Inoculant	Biodoz Soja			
	Seed rate (seeds/m²)	65			
	Sowing camelina	18.05. (BBCH 11)	27.05. (BBCH 11)	27.06. (BBCH 13)	-
	Amount of camelina (kg/ha)	5.8	4.9	3.6	-
Mechanical weed control	**Blind harrowing**	27.04. (BBCH 05)	28.04. (BBCH 05)	21.05. (BBCH 05)	-
	Harrowing 1	18.05. (BBCH 11)	25.05. (replicate 1 and 2), 27.05. (replicate 3 and 4) (BBCH 11)	25.06. (only treatment 7) (BBCH 13)	09.05.
	Hoeing 1			22.06. (BBCH 13)	
Assessments, drone flight	**Assessment, flight 1 PRE**	18.05. (BBCH 11)	25.05. (BBCH 11)	20.06. (BBCH 13)	-
	Biomass 1	18.05. (BBCH 11)	26.05. (BBCH 11)	22.06. (BBCH 13)	-
	Assessment, flight 1 POST	19.05. (BBCH 11)	28.05. (BBCH 11-12)	25.06., 27.06. (Var.7) (BBCH 13)	-
	Assessment flowering	14.06., 15.06. (BBCH 65)	03.07., 04.07., 05.07. (BBCH 69)	12.07., 13.07. (BBCH 65)	-
	Biomass 2 (flowering)	15.06. (BBCH 65)	09.07., 10.07., 11.07. (BBCH 70, 71)	16.07. (BBCH 65)	-
	SPAD measurement, flight flowering	15.06. (BBCH 65)	09.07. (BBCH 70)	13.07. (BBCH 65)	-
	Plant height	14.06. (BBCH 65)	06.07. (BBCH 69)	13.07. (BBCH 65)	-
	Biomass 3	23.08. (BBCH 65)	31.08. (BBCH 97)	13.09. (BBCH 97)	-
	Assessment, flight harvest	22.08. (BBCH 97)	29.08. (BBCH 97)	12.09. (BBCH 97)	-
Harvest	**Harvest date**	24.08. (BBCH 99)	04.09. (BBCH 97)	17.09. (BBCH 97)	12.09. (BBCH 99)

Thanks to the warm and constant weather from March to April, the sowing could already take place in the middle of April; for our regions relatively early. At Sprinkange, however, the sowing had to take place again a month later, as it became apparent after emergence that the sowing was not homogeneous, due to a problem with the seed drill.

After consultation with experts, the choice of variety fell to the Merlin variety of the ripening group 000 (very early ripening), which had been stable in yield over the last few years, in order to increase the probability of a safe ripening (Recknagel, et al., 2018). Merlin had already proven itself as a variety in previous trials in Luxembourg. With a seed strength of 65 germinable grains per square meter and a prior necessary vaccination with the inoculant BIODOZ Soya from the manufacturer DeSangosse, the soybean was placed at a depth of 4 cm with the 24-row Amazone seed drill (see Figure 5).

Due to the different mechanical weed control techniques, the row spacing of the soybean plants is dependent on the treatments, with 12.5 cm for treatments 1, 2, 3, 7 and 37.5 cm for treatments 4, 5 (see Figure 2).

Figure 5: Vaccination of the soybean (left, photo: IBLA), view of the seed in Sprinkange from above (center, photo: Serge Heuschling) and blind harrowing in Sprinkange (right, photo: IBLA).

Mechanical weed control started at all the sites with a harrowing run, the so-called blind harrowing, performed in a time window of up to 4 days after sowing in all the harrow treatments (see Figure 5). Since the soybean plants grow slowly and show a slow youth development, already germinated weeds can be exposed or spilled in this way (Bernert, 2016). As soon as the first pair of leaves is fully developed, the culture can for the first time be harrowed or hoed with slight zinc pressure (see Figure 6).

Due to the low weed pressure at Manternach, the hoe was used without the finger weeder in all the hoeing treatments, as the risk of damage to the plants was higher than the expected benefit. On the Hostert experimental site, however, the finger weeder was used directly in combination with the duck foot shares, as an above-average weed pressure was found here right from the start (see Table 3). Due to a rain event, the test field in Sprinkange was not passable at this development stage of the soy plant and the time for weed regulation had to be postponed. Since the crop was already in BBCH stage 13, a decision was made against a harrow pass in treatment 3. The harrow was only used in treatment 7, as camelina had to be sown and also harrowed.

Table 3: Overview of the methods used in the treatments on the study sites in 2018; 1=negative control, 2=positive control, 3= harrow, 4=hoe, 5=hoe and finger weeder, 6=combination, 7= intercropping.

	2018	**Manternach**							**Hostert**							**Sprinkange**						
	Treatment / **Method**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1. date	**Blind harrowing**			x			x	x			x			x	x			x			x	x
2. date	**Harrowing**			x				x			x				x							x
	Duck foot share				x	x	x					x	x	x					x	x	x	
	Finger weeder												x	x						x	x	

On all study sites, the combination (treatment 6) was decided against the use of the harrow, but for the use of the hoe, as this seemed to be visibly the more effective treatment.

At the Manternach site, the weed pressure remained low even after the harrowing and hoeing operations and the culture closed the rows relatively quickly, so that no further mechanical use was necessary. Since the weed control in Sprinkange was already late, no further run was possible here either. In Hostert, the rows also closed relatively quickly and, moreover, the weather did not allow the machine to be used again before flowering, which would have been a particular advantage at this location with its strong weed pressure.

Figure 6: Mechanical weed control with harrow (left), hoe with duckfood shares (middle) and hoe with finger weeder (right).

From June onwards, the soybean plants were in full bloom and the next assessments were carried out. In addition to biomass, cover and plant numbers, the chlorophyll content and plant height were measured.

Due to the drought from the time of flowering, the soybean had to be harvested relatively early. In Manternach the plant went into emergency ripening and some of the pods cracked. Therefore, threshing was already carried out there on 24th of August. The Hostert and Bettendorf sites followed and the harvest was completed on 17th of September with the Sprinkange site. The plot harvester of the agricultural school threshed out the respective harvest plots and the remaining crop was harvested by the combine harvester of the respective farmer (see Figure 7). In addition to the yield structure, various harvest parameters were collected at harvest (see Table 1) and a partial milled sample was sent to the ASTA laboratory to determine the protein content.

Figure 7: Harvesting the soybeans with the plot harvester (left and middle) and the combine harvester of the farmer Marc Emering in Sprinkange (right, photo by Nikos Zompolas).

3. Project progress

3.1 Project status and activities carried out

The LeguTec logo and a first roll-up were designed by the project partner Wolff-Weyland SA at the start of the project. The practical execution of the experiments, the drafting of the assessments and the experimental plan took place in consultation with experts of the *Research Institute for Biological Agriculture Switzerland (FIBL)* and the *Department of Ecological Agricultural Sciences* of the University of Kassel. Expert opinions were also obtained at the Soybean Conference in Rastatt, which took place the 6th and 7th of December 2017. This conference was also used as a contact point for IBLA, for further training in the field of soybean and to gain insight into current and similar soybean projects. An exchange of views and advice on the project design made it possible to come into contact with experts and build up a network. This also resulted in IBLA's membership in the German Soybean Promotion Association (*Deutscher Sojaförderring e.V.*).

After a large part of the preparation and planning had been carried out at the end of 2017 and beginning of 2018, the project LeguTec could start with the internally organized kick-off meeting of the individual partners. The kick-off meeting on 16.02.2018 was attended by representatives of the partners Geocoptix GmbH, Wolff-Weyland SA, LTA and IBLA as well as the farmers involved in the project to discuss joint agreements, fine-tuning and clarification of responsibilities. On the agenda was the signature of the "Contrat d'étude" by the project partners as well as the signature of the agreement between partner farmers and IBLA.

The following information material and promotional activities have subsequently been produced for the project to date:

- a project leaflet (see Appendix 1),
- specially designed snack soybeans as a giveaway for the project (see Appendix 2),
- a poster with a brief description of the project (see Appendix 3),
- information signs on each of the test fields, as the sites are easily accessible and located along cycle paths.

The article "Soybean made in Luxembourg" was published on 12.01.2018 in the column Kloertext of the Letzebuerger Journal (see Appendix 4). The project was presented to experts at a colloquium at the University of Kassel, Department of Organic Agriculture in Witzenhausen on 19th of February 2018. Practical suggestions for the experimental design resulted from the subsequent discussion. The project was presented to the public for the first time as part of the conference “Legume Day” on the 2nd of March 2018 in Ettelbrück, organised by IBLA.

On the 8th of June 2018 IBLA together with the LeguTec project partners organized an official field visit on the LeguTec study site at the organic farm Mehlen in Manternach. A large audience of more than 200 visitors, among them Her Royal Highness the Hereditary Grand Duchess, as well as the Minister of Agriculture Mr. Fernand Etgen, the President of the Oeuvre Nationale de Secours Grande-Duchesse Charlotte Mr. Pierre Bley, and a large number of farmers and other interested parties were able to inform themselves about the project and the status of the weed control methods. The audience was led past various stations and informed about the project details by the project partners. The students of the agricultural school were involved in the field inspection and presented the test site Bettendorf (see Figure 8). With this event LeguTec met with great public interest. A large number of articles in regional magazines (Allianz, Alcovit), radio reports (including RTL and radio100,7) and a TV report on RTL confirm this (see Appendix 5).

Figure 8: Official field visit at the study site Mehlen in Manternach.

The project was also in the focus of the IBLA stand at *Foire Agricole Ettelbrück*. With an exhibition of the hoeing technique used in the project, poster information materials as well as the demonstration of the drones by Geocoptix GmbH the visitors could inform themselves. As a special guest we could welcome His Highness the Grand Duke on the IBLA stand, where he informed himself about the LeguTec project. A children's studio, to which various school classes were able to register, provided playful knowledge about the chicken and linked its feeding with the soybean and thus with the LeguTec project. The photographer Nikos Zompolas chose the project LeguTec for a competition of the association Etika and accompanied the IBLA team during the vegetation period with the work on the three study sites. The photos shown in Appendix 6 are the first results of his work. A postcard from Etika with brief information about the project as well as a picture during the assessment in Hostert is the result of this competition (see Appendix 7).

As part of a field visit to organic soybean cultivation in Wallonia, Belgium, on 21st of September in Nalinnes, an exchange of experiences took place with the local specialists (forfarmes, SCAR, BioWallonie, Wallonie research CRA-W and Province de Liège Agriculture). At the "Semaine de la machine agricole", which was organized by the project partner Wolff-Weyland SA (18.10.-22.10.2018), LeguTec presented itself to the public with an information stand and showed first results.

On the 8th of February 2019 this year's Legume Day, organised by IBLA, took place in Ettelbrück. In the focus of soybean cultivation, more than 100 interested participants informed themselves about the possibility of cultivating soybean in Luxembourg. First results of the project LeguTec were presented together with the project partners Geocoptix GmbH and students of the agricultural school.

3.2 Conference participations and previous publication

The first results were presented on 17th and 18th of October 2018 at the legume conference "2e Rencontres Francophones sur les Légumineuses" in Toulouse in the form of a poster presentation. Further results were presented also on a poster at the Soybean Conference 2018, which took place on 23rd to 24th of October in Würzburg, Germany, at the international conference ICOAS 2018 (6th International Conference on Organic Agriculture Sciences) from 7th to 8th of November 2018 in Eisenstadt, Austria (see Appendix 8) and at the 15th Science Conference on Organic Agriculture (WiTa) in Kassel, Germany (see Appendix 9). The first publications from the mentioned participations in international conferences and meetings are listed below:

Leimbrock, L.; Rock, G.; Diederich, R.; Krier, R.; Reiland, G; Stoll, E.; Zimmer, S. (2018): LeguTec – Mechanical weed control in soybean cultivation in Luxembourg. ICOAS, 7.-8. November 2018, Eisenstadt, Austria. Book of Abstracts, p. 80.

Leimbrock, L.; Altmann, G.; Rock, G.; Diederich, R.; Krier, R.; Reiland, G; Stoll, E.; Zimmer, S. (2018): Désherbage mécanique dans la culture du soja bio au Luxembourg. RFL2, 17.-18. Oktober 2018, Toulouse, France. Livre des Résumés, p. 215.

Leimbrock, L., Rock, G., Diederich, R., Krier, R., Reiland, G., Stoll, E., Zimmer, S. (2019): LeguTec – mechanische Beikrautregulierung im Sojaanbau in Luxemburg. 15. Wissenschaftstagung Ökologischer Landbau, Kassel, Germany. 06.-08. March 2019, p. 84.

3.3 First results

The 2018 season initially offered ideal conditions for soybean cultivation. Due to a warm spring, sowing was possible relatively early at the end of April. Growing weather was present right up to flowering so that the plants could develop well. From flowering onwards, unfavourable conditions with hot temperatures and far too little rainfall followed until the harvest. Figure 9 shows the temperature curve for Reckange measuring station near the Sprinkange test site and highlights the low precipitation in July and August.

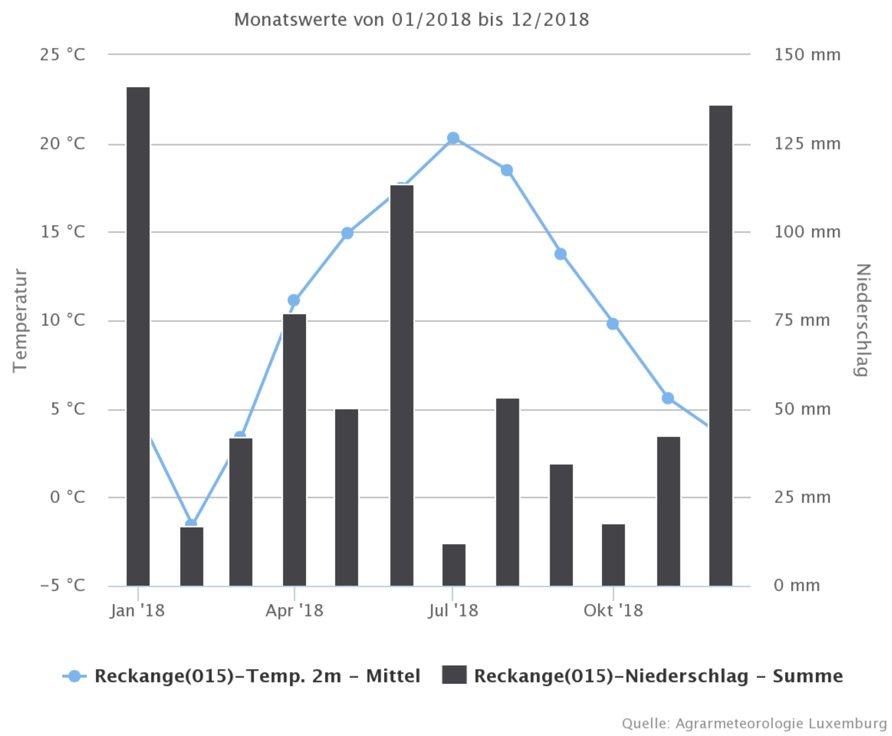


Figure 9: Temperature (blue line) and precipitation (black blocks) curve for the study site Sprinkange in 2018 (agrimeteo.lu)

At the experimental site in Manternach, the plants reached emergency ripeness due to drought. 15 % of the pods had cracked and opened just before harvest, which is also reflected in the yield.

3.3.1 Yield, weed biomass and protein content

At the Sprinkange study site, the combination treatments show the highest yield among the regulation methods with 14.1 dt/ha. The lowest yield in the harrowing treatment is 10.3 dt/ha. The two treatments differ significantly in their yields. The positive control is with a yield of 16.2 dt/ha and the negative control with 12.7 dt/ha. The experimental site Hostert shows the lowest yields with 7.5 dt/ha each in the harrow and intercropping treatments. The combination achieves the highest yield among the regulation methods with only 10.4 dt/ha. However, the differences are not statistically significant. The positive control is at a yield of 15.5 dt/ha and the negative control at 6.7 dt/ha. In Manternach, the highest yield of 14.8 dt/ha was harvested in the treatment hoeing with finger weeder and the lowest in the harrowing, whereby the treatments do not differ significantly from each other. Here, the positive control shows a yield of 13.6 dt/ha and the negative control 11.8 dt/ha (see Figure 10 and Figure 11).

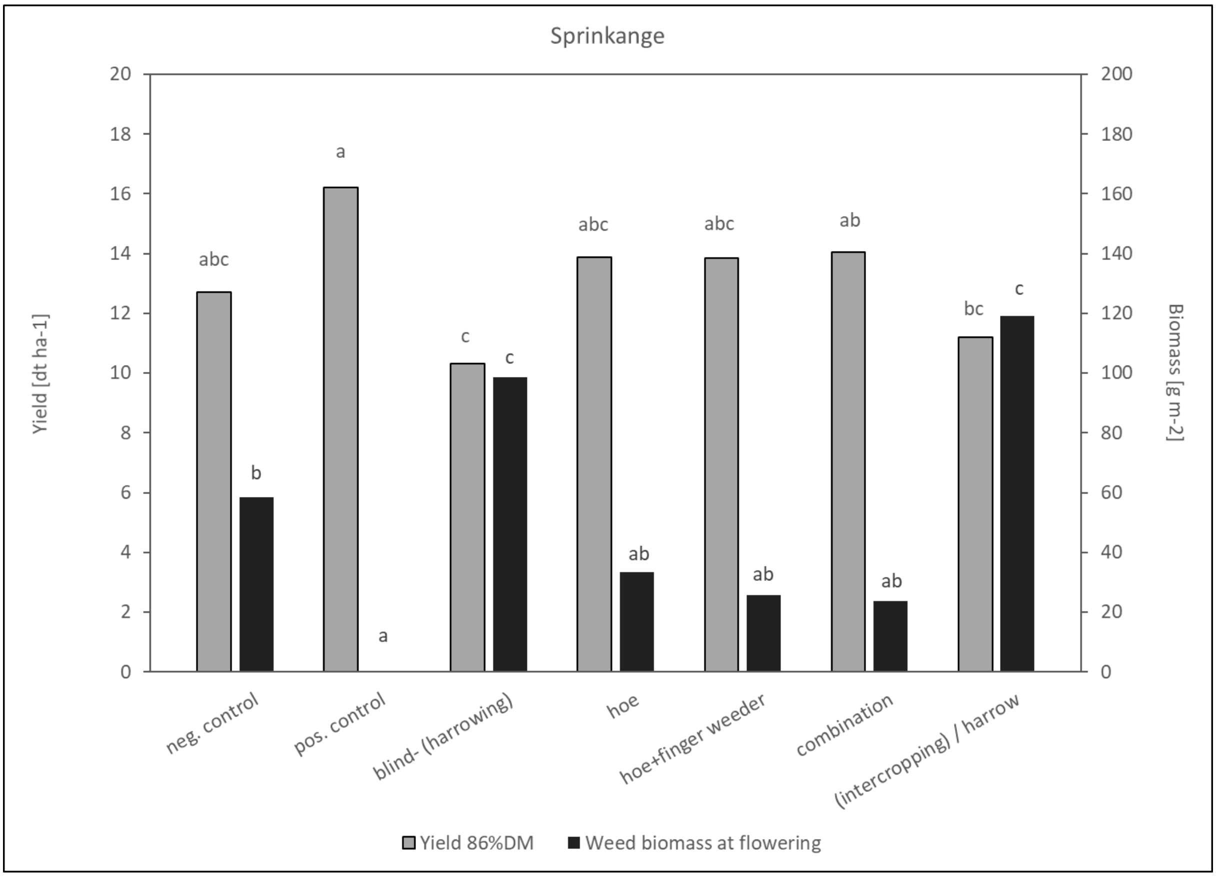
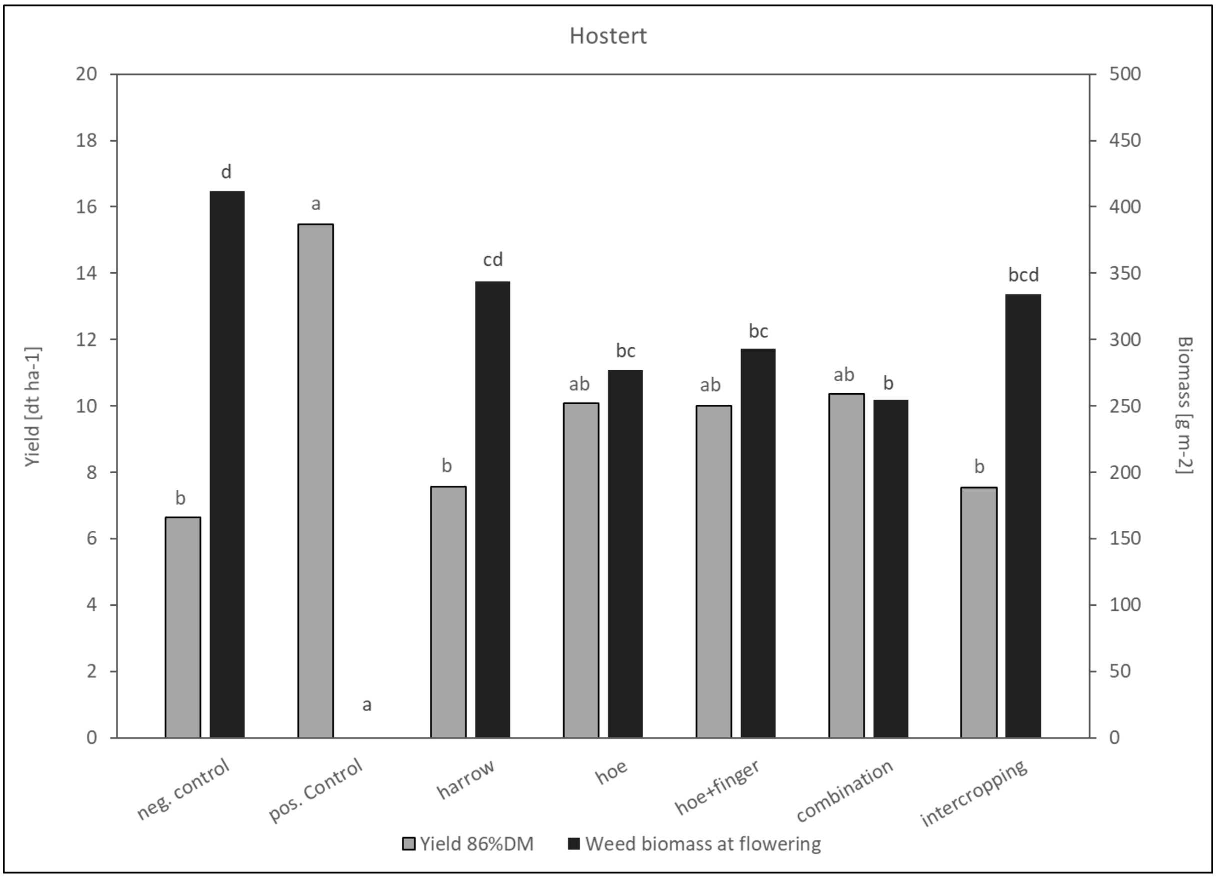


Figure 10: Yield [dt ha-^{1}] and weed biomass at flowering [g m-2] of the study site Sprinkange depending on the various weed control techniques; Yield (n=4), biomass (n=12); different letters indicate significant differences (ANOVA, TukeyHSD, p<0,05).



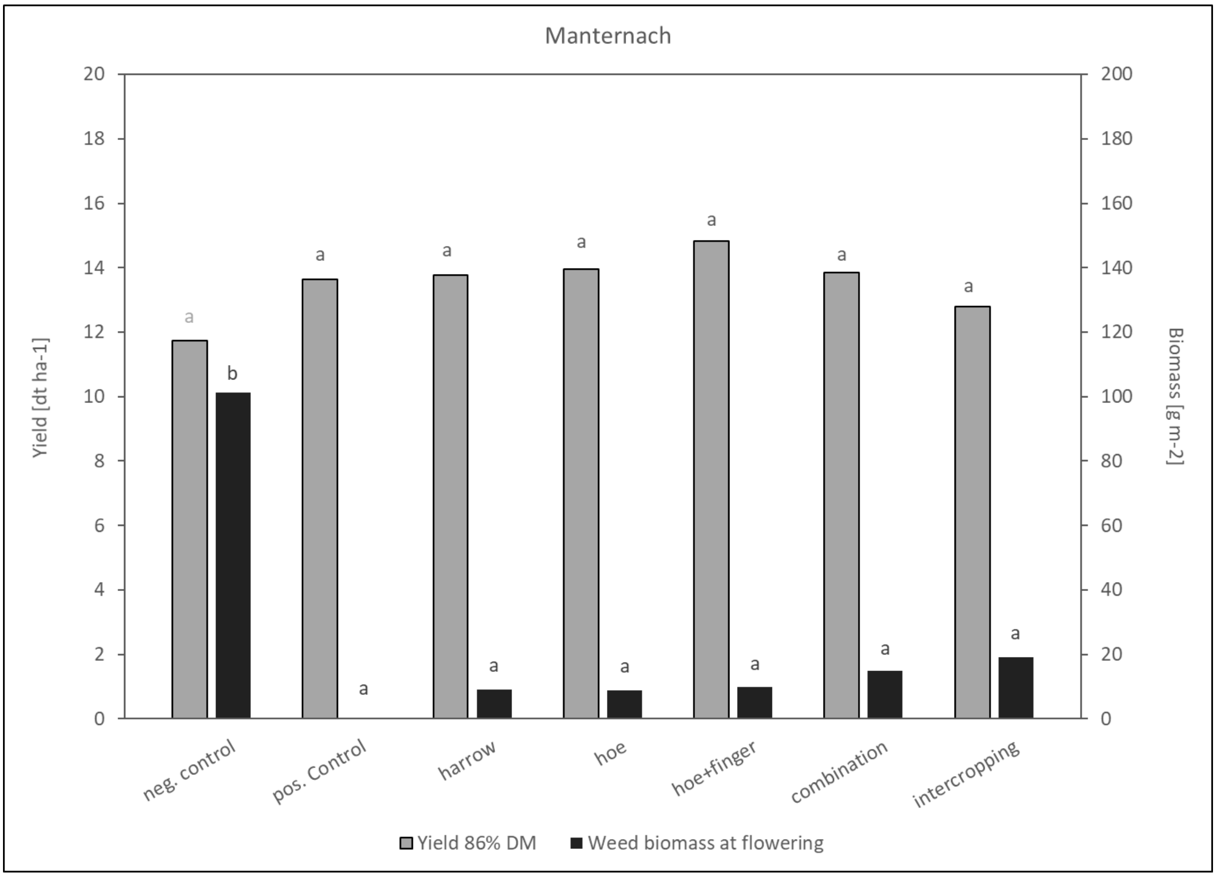


Figure 11: Yield [dt ha-^{1}] and weed biomass at flowering [g m-2] of the study sites Hostert and Manternach depending on the various weed control techniques; Yield (n=4), biomass (n=12); different letters indicate significant differences (ANOVA, TukeyHSD, p<0,05).

The weed biomass at flowering is lowest in Sprinkange in the combination treatment with 23.6 g/m² and highest with 119.1 g/m² in harrowing (intercropping) treatment. The harrow method, in which only blind harrowing was used, also shows a significantly higher biomass than the negative control. The hoeing treatments all differ significantly from the blind harrow and harrow (intercropping) methods. Hostert shows significantly higher biomasses. With 254 g/m² the lowest biomass is found in the combination treatment and with 344.1 g/m² the highest biomass is observed in the harrow method. Here, too, the harrowing and combination treatments show significant differences. As with the yield, Manternach shows no significant differences in biomass within the individual treatments.

Yield and weed biomass at flowering show significant correlation (Pearson correlation, $p<0.05$) with $r = -0.72$ (Sprinkange) and $r = -0.86$ (Hostert). For the Manternach site, however, there is no significant correlation between the two parameters.

The development of weed biomass is shown in Figure 12 as an example for the Hostert site. After field emergence, the weed control methods do not yet show any significant differences. However, it can already be seen here that the weed pressure in Hostert is high from the beginning on. At flowering, as already described above, the combination and harrow treatments differ significantly from each other, in favour of the combination method and at the time of harvest, the biomasses in the variants are equally high. Only the negative control differs significantly.

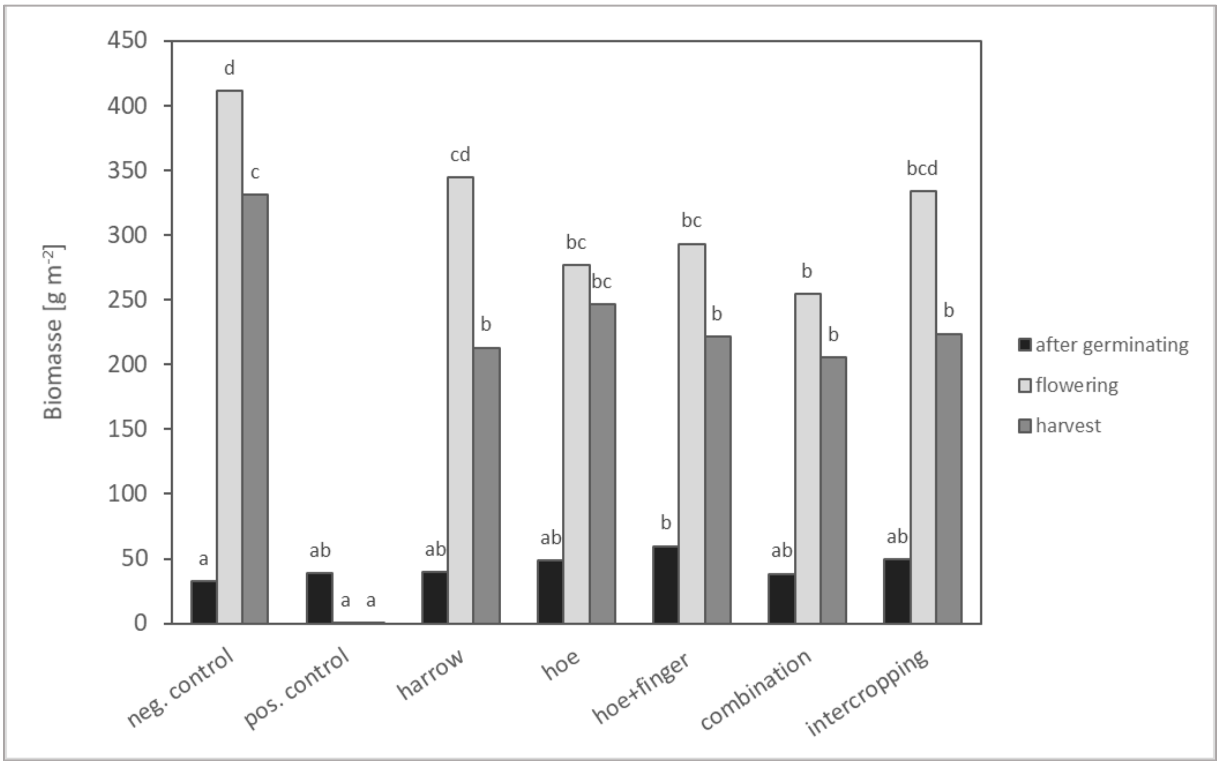


Figure 12: Development of weed biomass [g m-²] from time after field emergence to flowering and harvest (n=12)of the study site Hostert; different letters indicate significant differences (ANOVA, TukeyHSD, p<0.05).

The protein contents of the soybeans are shown in Table 4. There are no significant differences between the individual treatments. While the protein contents in Manternach range up to 40 % in the hoeing treatments and up to 39 % in Hostert, only a maximum protein content of 32 % in the harrow method was analysed in Sprinkange.

Table 4: Raw protein content in % in the different treatments. The analyses were carried out in the ASTA laboratory. On all three sites there are no significant differences (same letters) between the treatments (ANOVA, TukeyHSD, p<0.05).

	Raw protein content [%]		
Treatment	Manternach	Sprinkange	Hostert
neg. control	39.48 a	31.27 a	38.45 a
pos. control	38.88 a	30.85 a	37.79 a
Harrow	39.76 a	32.96 a	38.56 a
Hoe	39.70 a	30.36 a	39.15 a
Hoe + finger weeder	40.36 a	29.55 a	38.33 a
Combination	40.49 a	28.25 a	39.68 a
Intercropping	39.20 a	31.05 a	38.43 a

With regard to the number of germinated plants and plant losses after weed control, there are no significant differences between the treatments at the individual experimental sites.

3.3.2 Aerial survey

The first results of the unmanned aerial survey consist in the creation of so-called orthomosaics (distortion-free aerial maps, see Figure 13). For each of the locations, the raw data were processed radiometrically for each overflight date (Figure 15) and further processed into orthomosaics (Figure 14). The first Level 2 products consist of a sub-area-specific estimation of the biomass.

Figure 13: Orthomosaics as overview pictures of the 3 locations. Left: Manternach, top right: Hostert, lower right: Sprinkange .

Figure 14: Detailed view of the test field including the reference grey wedge for radiometric correction of the data.

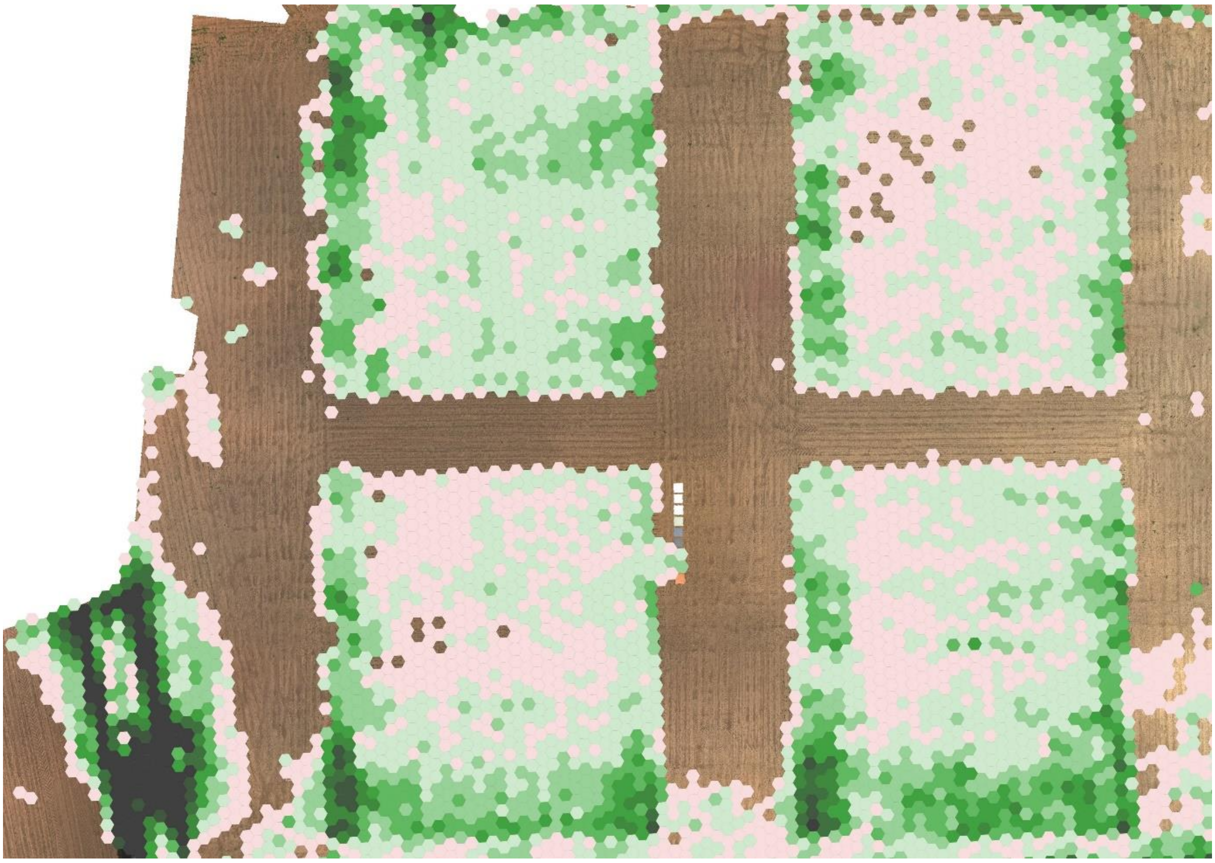


Figure 15: Biomass estimation as the first Level 2 product. Exemplarily presented at the site Manternach.

3.3.3 Discussion

The study sites Sprinkange and Hostert show significantly higher yields and less weed after blind harrowing with subsequent hoeing with duck foot shares and finger weeder (combination treatment) than with harrowing. This was also visually visible after the first runs. At the Manternach site the weed pressure was low from the beginning on, so that good weed control was possible in all treatments. The harrow also worked well here. On the area in Hostert where weeds were abundant from the beginning, there was a tendency towards weed control in favour of the hoe. However, it became clear here that it is not sufficient to apply the appropriate weed control measure, but that good continuous management of the cultivated areas in terms of crop rotation and weed pressure is essential.

Due to the late second sowing in Sprinkange, there were deficits in the development of soybean plants. Weed control was not possible until late because the heavy soil did not allow it earlier. Therefore, it was only harrowed in the intercropping cultivation with camelina in order to incorporate the seeds after sowing. However, the harrowing has led to a further stimulation of the growth of the weeds, which becomes visible in comparison to the negative control. In the harrow treatment, a harrow was deliberately omitted, as it was already apparent that this would only stimulate further weeds under the given site conditions. As only blind weeding was used here and at the time of flowering the weed biomass was significantly higher than in the negative control, the opposite effect can be seen that blind weeding has already stimulated weed growth. The low protein content in Sprinkange compared to the other sites could be a sign of the delayed development due to the dryness and point to the reduced activity of the nodule bacteria or also a sign of the previous silting up and the reduced supply of oxygen for the plant and bacteria. However, it is also possible that the pre-vaccinated seeds itself, because the second seed was not re-vaccinated, did not have the vaccination intensity as with an additional vaccination. An indication of this would also be the insignificant differences in yield in the negative control to the other treatments. This indicates that the pre-vaccinated seed should also be additionally vaccinated to ensure that the nodule bacteria can form sufficiently and that the nitrogen can be stored in the plant. This is also shown by experiments on ready-to-use vaccinated seeds by the Bayerische Landesanstalt für Landwirtschaft LfL (Aigner, 2014).

Since camelina is sown to the soybean only later in the stage of the first developed leaf, it could not accumulate in Hostert due to the high weed pressure and in Sprinkange due to the following dryness. Only in Manternach it had the possibility to germinate due to a precipitation event shortly after sowing. Whether the intercropping with camelina can be a future concept for soybean cultivation in Luxembourg will have to be seen in the next study year.

The drought following flowering has led to yield losses at all the study sites. The open pods in Manternach were a clear sign that the soybean had to go into emergency ripening here. An early harvest was therefore necessary.

In summary and based on the initial results it can be said that the yields tend to be higher in the hoeing treatments than in the comparative harrowing treatments and thus the weed control success is higher there. However, further data evaluation is necessary in order to relate all parameters, from the yield structure to the soybean biomass, the chlorophyll content and the distribution of weed species and to be able to make more detailed and conscientious statements.

4. Perspective and interim conclusion

With regard to the next project year, study sites have already been selected and farmers are being accompanied in the preparation of the fields. After the future area had been cultivated, Phacelia or oats were sown as intercrops. The sites are now be prepared and are ready for the next season to be sown. The further project schedule is shown in Figure 17.

The good cooperation between the project partners and especially with the farmers involved enables a practical experiment procedure. Flexible planning and spontaneous, weather-related assignments worked without any problems in the first year of the study. The great interest on the part of the public and the farmers shows the topicality of the project and confirms the implementation of the project in soybean culture.

The increased interest in regional soybean cultivation due to the LeguTec project prompted Bio-OVO to launch a new project. BIO-OVO is an eggs producer association and has set itself the goal of increasing its protein self-sufficiency by increasing the proportion of soya in its feed rations from regional sources. Together with the project partners IBLA, SCAR Scrl, Wolff-Weyland SA, Lycée Technique Agricole (LTA) and Piet van Luijk Sàrl, a conclusive concept for national soybean production was developed: From the accompaniment and advice of the seed, mechanical weed control (required technology) over the harvest up to the cleaning, drying, storage, preparation and further processing in the feed rations for the BIO-OVO laying hens (see Figure 16).

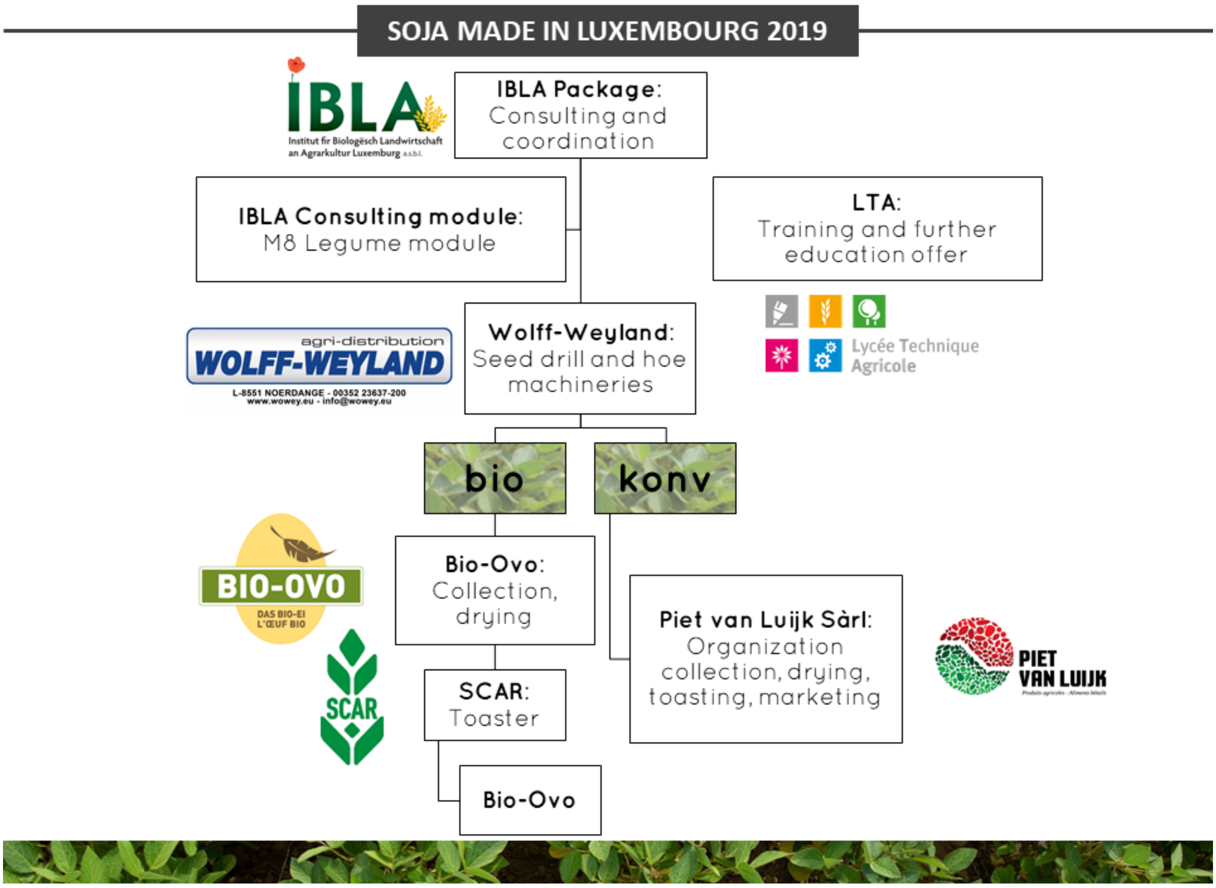


Figure 16: Overview of the new project of Bio-OVO, which was developed from the increased public interest in the context of LeguTec.

Nr.	Mile-stones	Tasks	2017			2018												2019												2020								
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	Experimental design																																					
		Selection of study sites																																				
		Selection of machines																																				
		Experimental design and time planning																																				
		Handbookl of methods																																				
		Order of seeds																																				
		Selection of soybean incolant and order																																				
		Kick-Off Meeting																																				
2	Preparation of field trials																																					
		Measure study sites																																				
		Soil samples for soil analysis (at sowing and harvesting: basic analysis + Nmin)																																				
		Fertilization (liming, phosphorus)																																				
		Seedbed preparation (Falsches Saatbett)																																				
		Weighing seeds																																				
		Seeding																																				
3	Mechanical weed control																																					
		Blind harrowing																																				
		Harrow																																				
		Interrow cultivator with duckfoot shares (IC) and IC + finger weeder																																				
		Manual weeding																																				
4	Assessment and valuation																																					
		Emergence of soybeans																																				
		Weed cover - valuation before and after each mechanical weed control run																																				
		Crop damage - number of plants before and after each mechanical weed control run																																				
		Plant diseases at flowering																																				
		Chlorophyll content at flowering																																				
		Weed cover at flowering																																				
		Weed cover at harvesting																																				
		Sampling for evalutaion of weed biomass (BBCH 32, at flowering and at harvesting)																																				
		Sampling for yield																																				
		HEB-Index (population height at harvest / population height at flowering)																																				
		Tendency to laying down at harvesting																																				
5	Harvest																																					
6	Yield parameters																																					
		HLG (hectolitre weight)																																				
		TKG (thousand seed weight)																																				
		moisture content																																				
	Quality parameters																																					
		Protein content																																				
7	Evaluation of results																																					
		Evaluation																																				
8	Communication																																					
		Field visits, communication									8.6.	29.6.																										
		Reporting																	28.2.			1.5.																30.9.
		Publication of results, dissemination																																				

Figure 17: Project schedule LeguTec.

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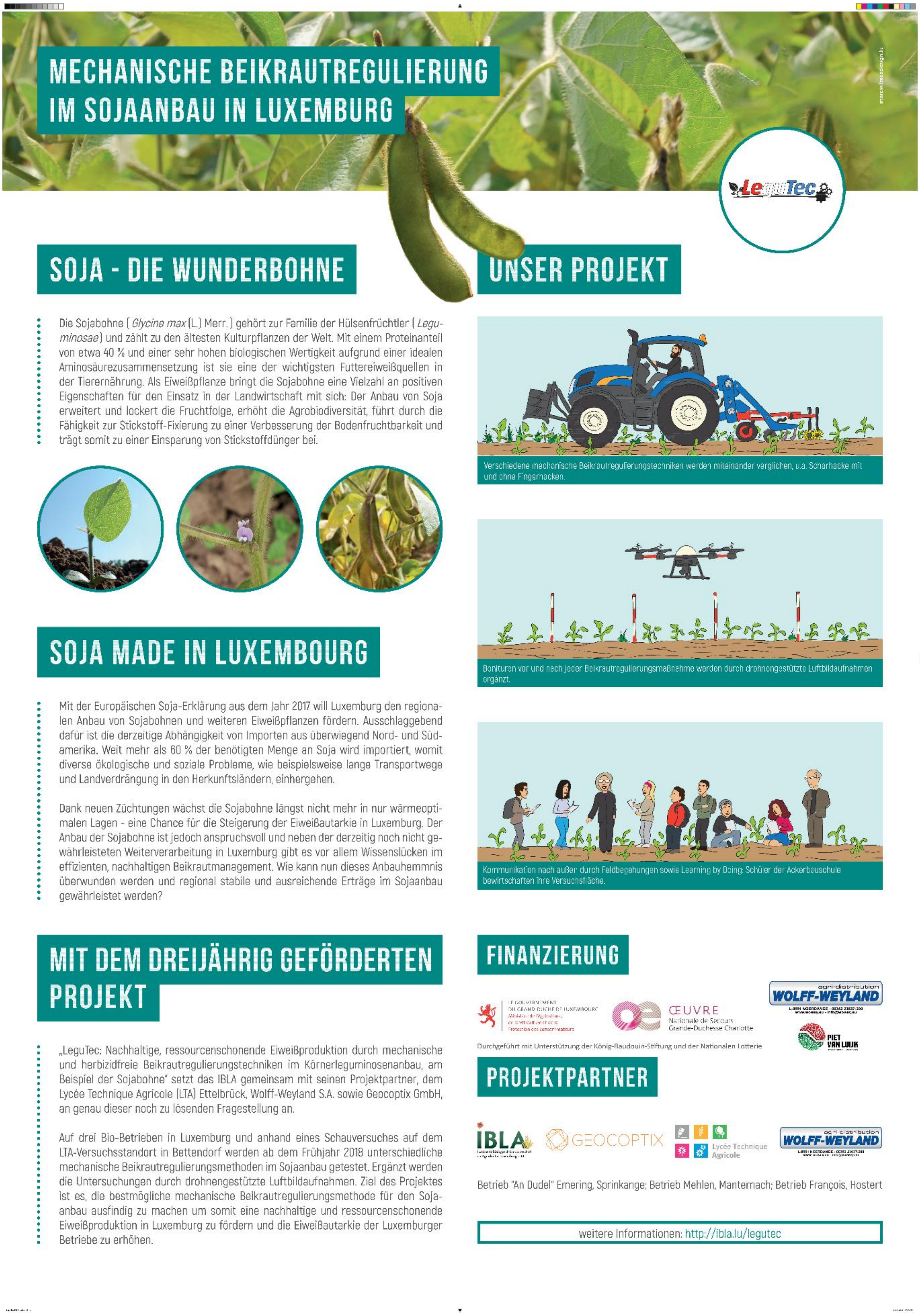
Appendix

Appendix 1: LeguTec leaflet.

Appendix 2: Snack soybeans LeguTec.



MECHANISCHE BEIKRAUTREGULIERUNG IM SOJAANBAU IN LUXEMBURG

SOJA - DIE WUNDERBOHNE

Die Sojabohne (*Glycine max* (L.) Merr.) gehört zur Familie der Hülsenfrüchtler (*Leguminosae*) und zählt zu den ältesten Kulturpflanzen der Welt. Mit einem Proteinanteil von etwa 40 % und einer sehr hohen biologischen Wertigkeit aufgrund einer idealen Aminosäurezusammensetzung ist sie eine der wichtigsten Futtereiweißquellen in der Tierernährung. Als Eiweißpflanze bringt die Sojabohne eine Vielzahl an positiven Eigenschaften für den Einsatz in der Landwirtschaft mit sich: Der Anbau von Soja erweitert und lockert die Fruchtfolge, erhöht die Agrobiodiversität, führt durch die Fähigkeit zur Stickstoff-Fixierung zu einer Verbesserung der Bodenfruchtbarkeit und trägt somit zu einer Einsparung von Stickstoffdünger bei.

SOJA MADE IN LUXEMBOURG

Mit der Europäischen Soja-Erklärung aus dem Jahr 2017 will Luxemburg den regionalen Anbau von Sojabohnen und weiteren Eiweißpflanzen fördern. Ausschlaggebend dafür ist die derzeitige Abhängigkeit von Importen aus überwiegend Nord- und Südamerika. Weit mehr als 60 % der benötigten Menge an Soja wird importiert, womit diverse ökologische und soziale Probleme, wie beispielsweise lange Transportwege und Landverdrängung in den Herkunftsländern, einhergehen.

Dank neuen Züchtungen wächst die Sojabohne längst nicht mehr in nur wärmeoptimalen Lagen - eine Chance für die Steigerung der Eiweißautarkie in Luxemburg. Der Anbau der Sojabohne ist jedoch anspruchsvoll und neben der derzeitig noch nicht gewährleisteten Weiterverarbeitung in Luxemburg gibt es vor allem Wissenslücken im effizienten, nachhaltigen Beikrautmanagement. Wie kann nun dieses Anbauhemmnis überwunden werden und regional stabile und ausreichende Erträge im Sojaanbau gewährleistet werden?

MIT DEM DREIJÄHRIG GEFÖRDERTEN PROJEKT

„LeguTec: Nachhaltige, ressourcenschonende Eiweißproduktion durch mechanische und herbizidfreie Beikrautregulierungstechniken im Körnerleguminosenanbau, am Beispiel der Sojabohne" setzt das IBLA gemeinsam mit seinen Projektpartner, dem Lycée Technique Agricole (LTA) Ettelbrück, Wolff-Weyland S.A. sowie Geocoptix GmbH, an genau dieser noch zu lösenden Fragestellung an.

Auf drei Bio-Betrieben in Luxemburg und anhand eines Schauversuches auf dem LTA-Versuchsstandort in Bettendorf werden ab dem Frühjahr 2018 unterschiedliche mechanische Beikrautregulierungsmethoden im Sojaanbau getestet. Ergänzt werden die Untersuchungen durch drohnengestützte Luftbildaufnahmen. Ziel des Projektes ist es, die bestmögliche mechanische Beikrautregulierungsmethode für den Sojaanbau ausfindig zu machen um somit eine nachhaltige und ressourcenschonende Eiweißproduktion in Luxemburg zu fördern und die Eiweißautarkie der Luxemburger Betriebe zu erhöhen.

UNSER PROJEKT

Verschiedene mechanische Beikrautregulierungstechniken werden miteinander verglichen, u.a. Scharhacke mit und ohne Fingerhacken.

Bonituren vor und nach jeder Beikrautregulierungsmaßnahme werden durch drohnengestützte Luftbildaufnahmen ergänzt.

Kommunikation nach außer durch Feldbegehungen sowie Learning by Doing: Schüler der Ackerbauschule bewirtschaften ihre Versuchsfläche.

FINANZIERUNG

Durchgeführt mit Unterstützung der König-Baudouin-Stiftung und der Nationalen Lotterie

PROJEKTPARTNER

Betrieb "An Dudel" Emering, Sprinkange; Betrieb Mehlen, Manternach; Betrieb François, Hostert

weitere Informationen: http://ibla.lu/legutec

Appendix 3: Poster LeguTec in the formats A0 and A4.

KLOERTEXT - SOJA MADE IN LUXEMBURG

LAURA LEIMBROCK
Forschung und Entwicklung,
„Institut fir biologesch Landwirtschaft an Agrarkultur a.s.b.l." (IBLA)

Landwirtschaft von Importen unabhängiger machen

In der Ernährung unserer Nutztiere spielen Eiweiß liefernde Futtermittel eine wichtige Rolle. Der klassische Eiweißträger ist die Sojabohne, welche als Sojaschrot Schweinen, Geflügel und Rindern gefüttert wird. Der Bedarf an Futtersoja ist jedoch in unseren Regionen weitaus höher als das Angebot. Daher ist Europa abhängig von Importen aus überwiegend Nord- und Südamerika, welche ökologische und soziale Probleme mit sich bringen: Gentechnisch verändertes Soja, Monokulturen mit hohem Pestizideinsatz, Abholzung von Regenwäldern und Landverdrängung. Eine Frage beschäftigt unsere Landwirte und Konsumenten daher seit einigen Jahren: Gibt es Möglichkeiten, sich von diesen Importen unabhängiger zu machen, um eine regionale Wertschöpfungskette zu gewährleisten?

„Soja ist eine Wunderbohne! Mit einem Proteinanteil von etwa 40 Prozent und einer sehr hohen biologischen Wertigkeit ist sie eine wertvolle Körnerleguminose. Dank neuen Züchtungen wächst sie längst nicht mehr nur in wärmeoptimalen Lagen. Ihre Vielzahl an positiven Eigenschaften machen sie nicht nur als Eiweißlieferant für den Einsatz in der Landwirtschaft interessant. Der Anbau von Soja erweitert und lockert die Fruchtfolge, führt durch die Fähigkeit zur Stickstoff-Fixierung zu einer Verbesserung der Bodenfruchtbarkeit und zudem zu einer Einsparung von Stickstoffdünger. Das Kultivieren der Sojabohne ist jedoch anspruchsvoll, und neben der noch nicht gewährleisteten Weiterverarbeitung in Luxemburg gibt es vor allem Wissenslücken im effizienten, nachhaltigen Beikrautmanagement, Wie kann dieses Anbauhemmnis überwunden werden und regional stabile und ausreichende Erträge im Sojaanabau gewährleistet werden?

Mit dem dreijährig geförderten Projekt ‚LeguTec: Nachhaltige, ressourcenschonende Eiweißproduktion durch mechanische Herbizid freie Beikrautregulierungstechniken im Körnerleguminosenanbau, am Beispiel der Sojabohne' setzt das IBLA mit seinen Projektpartnern, dem Lycée Technique Agricole (LTA) Ettelbrück, Wolff-Weyland S.A, sowie Geocoptix UG, an dieser Frage an. In drei Bio-Betrieben in Luxemburg und anhand eines Schauversuches am LTA werden ab dem Frühjahr 2018 unterschiedliche mechanische Beikrautregulierungsmethoden im Sojaanbau getestet. Ergänzt werden die Untersuchungen durch Luftbildaufnahmen. Ziel des Projekts ist es, die bestmögliche mechanische Beikrautregulierungsmethode für den Sojaanbau ausfindig zu machen, eine nachhaltige und ressourcenschonende Eiweißproduktion in Luxemburg anzukurbeln und die Eiweißautarkie der Luxemburger Betriebe zu erhöhen. Finanziert wird das vielversprechende Projekt von der ‚Oeuvre Nationale de Secours Grande-Duchesse Charlotte' und dem ‚Ministère de l'Agriculture, de la Viticulture et de la Protection des consommateurs' und unterstützt durch Sponsoring von Wolff-Weyland S.A..

Die Eiweißversorgung werden wir nie vollständig selber decken können. Wir können aber neben einem verbesserten Grünlandmanagement und Feldfutterbau einen bedeutenden Beitrag zur Reduzierung der Eiweißlücke leisten. Die steigende Verwendung von heimischer Soja in Luxemburg kann die ökologischen und sozialen Probleme in den Exportländern mindern und gleichzeitig ökologische Vorteile für unsere Landwirtschaft bringen."

Weitere Infos unter www.ibla.lu

„Ein steigender Anbau von heimischer Soja in Luxemburg bringt Vorteile für unsere Landwirtschaft"

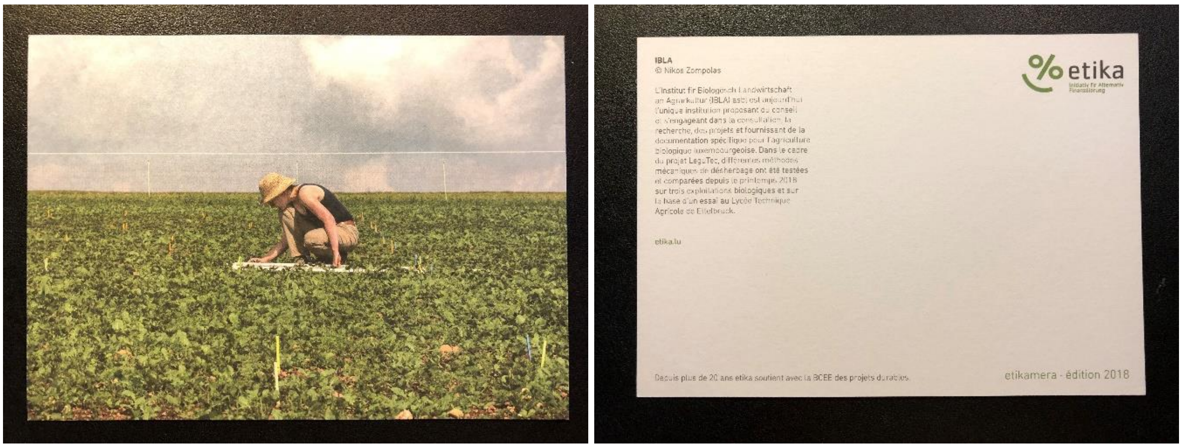
Appendix 4: Article about LeguTec in the Letzebuerger Journal, 12.11.2018.

Institution	**Titel of report**	**Link**	**Kind of report**	**Date**
Oeuvre Nationale de Secours Grande-Duchesse Charlotte	LeguTec- Soja made in Luxembourg	https://www.oeuvre.lu/legutec-soja-made-in-luxembourg/	report	18.06.2018
100,7	Soja: eng Wonnerboun?	https://www.100komma7.lu/article/aktualiteit/soja-eng-wonnerboun	radio	12.06.2018 - 11:30
RTL	PISA- De Wëssensmagazin Am Replay: Modernen Akerbau Roboter um Feld, Soja-Comeback an zu Lëtzebuerg an e Rise-Gras aus Asien.	http://tele.rtl.lu/emissiounen/pisa-de-wessensmagazin/emissioun/1191951.html	TV-report	09.07.2018
Le Quotidien	Soja: vers une solution « Made in Luxembourg »	http://www.lequotidien.lu/a-la-une/soja-vers-une-solution-made-in-luxembourg/	article	09.06.2018

Letzebuerger Journal	„Soja made in Luxembourg“	http://www.journal.lu/article/soja-made-in-luxembourg/	article	08.06.2018
RTL	Invité vun der Redaktioun (8. Juni) Stéphanie Zimmer iwwer Soja aus Lëtzebuerg	http://radio.rtl.lu/emissiounen/den-invite-vun-der-rtl-redaktioun/1191467.html	radio	08.06.2018
RTL	VIDEO: Soja zu Lëtzebuerg	http://tele.rtl.lu/emissiounen/de-journal/3126987.html	TV-report	08.06.2018
Gouvernement.lu	Offiziell Feldbegehung a Virstellung vum Projet "LeguTec“ zu Manternach um Betrib Mehlen	https://gouvernement.lu/lb/actualites/toutes_actualites/articles/2018/06-juin/08-legutec.html	report	08.06.2018

Appendix 5: List of previous media articles about the LeguTec project.

Appendix 6: First photos submitted by photographer Nikos Zompolas.



Appendix 7: Postcard from etika about LeguTec. Photo by Nikos Zompolas as result of a competition at etika.

LEGUTEC: MECHANICAL WEED CONTROL IN SOYBEAN CULTIVATION IN LUXEMBOURG

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Introduction

Soybean (Glycine max (L.) Merr.) has a protein content of about 40 % and a very high biological value due to an optimal amino acid composition, making it one of the most important feed protein sources in animal nutrition (Bernet et al. 2016). Being one of the EU-states that signed the European Soya Declaration (2017), Luxembourg aims to promote the regional cultivation of soybeans and other protein crops due to the current dependency on imports from mainly North and South America (>60 %). However, the organic cultivation of soybean is demanding and there are above all knowledge gaps in efficient and sustainable mechanical weed control techniques (Zimmer et al., 2016).

Aim
The aim of the project is to investigate the efficiency of the selected mechanical applications, taking into account plant losses, crop and weed biomass and cover along the growing season as well as yield.

Material and methods

- **Design**: one-factorial-exact-trial with 4 replicates on three organic farms (see Fig. 1) spread over Luxembourg in 2018
- **Treatments**: five mechanical weed control methods in soybean cultivation plus control plots:
  t.1 Negative (no weed control) and **t.2** positive (manually) control plot
  t.3 harrow,
  t.4 interrow cultivator with duck foot shares,
  t.5 interrow cultivator with duck foot shares and finger weeder,
  t.6 a flexible system (treatment 3 and/or 5)
  t.7 mixed cropping: soybean and camelina in combination with harrow.
- **Pre-treatment**: blind harrowing in treatments 3, 6 and 7
- **Sowing**: variety Merlin, inoculant BIODOZ Soja, seeding rate 65 seeds/m2 seeding date end April-mid May, row distance 12,5 cm (harrow) and 37,5 cm (hoeing)
- **Assessments**: before and after each run, at flowering and at harvest
- **Dissemination**: on-farm field trial at agricultural school (LTA)

Results and discussion

- First results in yield and weed cover along vegetation period 2018 are presented in Figure 2.
- Manternach: high yields but no significant differences due to very low weed cover. Weed cover signficant higher in t.7 than in t.4 and t.5.
- Sprinkange: significant higher yield and lower weed cover in flexible system (t. 6) than in harrow treatment (t. 3).
- Hostert: very high weed pressure from beginning on: significant highest in t.7 and t.3; highest yield in t.6 and lowest in t.7 and t.3 but no significant differences.
- No significant differences in plant number after emergence and no significant differences in plant losses after treatments (not shown here).

Conclusion

- Yields in hoeing treatments higher than in harrowing treatments, but no significant differnce within hoeing treatments.
- Drought leads to low yields in Manternach: 15 % of pods were open at harvest.
- Hostert: low yields due to high weed pressure from the beginning on ↔ management decisive.
- Camelina germinated only in Manternach, earlier sowing necessary.
- Further results will complement the study.

	Manternach	Sprinkange	Hostert
altitude [m]	281	336	464
temp (°C)	9.8	9.7	9.1
precipation (mm)	617	681	921
sowing	23.04.2018	17.05.2018	24.04.2018
harvest	24.08.2018	17.09.2018	04.09.2018

Fig. 1: Characteristics and location of the study sites in Luxembourg. The three study sites Manternach, Sprinkange and Hostert are the three organic farms and the location Bettendorf is the experimental site of the agricultural school LTA.

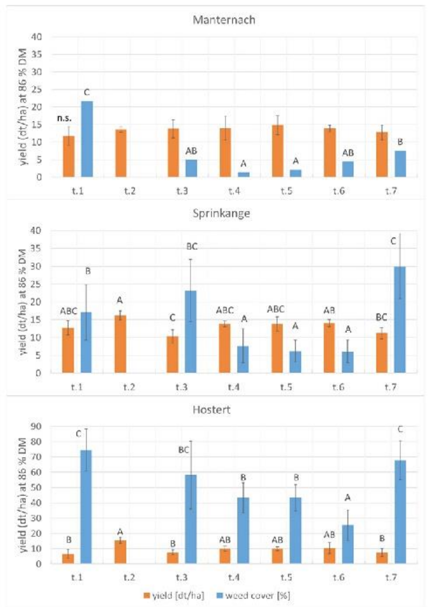

Fig. 2: Yield [dt/ha] and weed cover [%] at flowering of the three study sites as a function of the different treatments; yield (n=4), cover (n=12); different letters = significant differences (ANOVA, Tukey-test resp. Games-Howel-test, p<0,05).

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European Soya Declaration (2017) European Soya Declaration: Enhancing soya and other legumes cultivation. Available at: https://www.bmel.de. [Accessed 10 June 2018].
Zimmer S, Haase T, Piepho HP, Stoll E, Heidt H, Bohn T, Heβ (2016a): Evaluation of grain legume cropping systems for animal fodder potential and impacts on subsequent wheat yield under less favourable soil condition in organic agriculture in Luxembourg. Journal für Kulturpflanzen, DOI: 10.5073/JFK.2016.06.02.

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Appendix 8: Poster presentation at ICOAS2018.

LEGUTEC: MECHANISCHE BEIKRAUTREGULIERUNG IM SOJAANBAU IN LUXEMBURG

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[2]Geocoptix GmbH, Max-Planck-Straße 6, D-54296 Trier, Deutschland, www.geocoptix.com
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Hintergrund

Mit einem Proteinanteil von etwa 40 % und einer sehr hohen biologischen Wertigkeit aufgrund einer idealen Aminosäurezusammensetzung ist die Sojabohne (*Glycine max* (L.) Merr) eine der wichtigsten Futtereiweißquellen in der Tierernährung (Bernet et al. 2016). Mit der Unterzeichnung der Europäischen Sojaerklärung (2017) hat sich Luxemburg zum Ziel gesetzt, den regionalen Anbau von Sojabohnen und anderen Eiweißpflanzen zu fördern. Grund dafür ist die derzeitige Abhängigkeit von Importen aus hauptsächlich Nord- und Südamerika (>60 %). Jedoch ist der Anbau anspruchsvoll und es gibt Wissenslücken im effizienten, nachhaltigen Beikrautmanagement in Luxemburg (Zimmer et al., 2016).

Ziel des Projekts ist es, die Effizienz der ausgewählten mechanischen Systeme unter Berücksichtigung von Pflanzenverlusten, Pflanzen und Unkrautbiomasse und Deckung zu untersuchen.

	Manternach	Sprinkange	Hostert
Höhe (m ü. NHN)	281	336	464
Temperatur (°C)	9.8	9.7	9.1
Niederschlag (mm)	617	681	921
Saat	23.04.2018	17.05.2018	24.04.2018
Ernte	24.08.2018	17.09.2018	04.09.2018

Abb. 2: Versuchsstandorte in Luxemburg. Auf den Bio-Betrieben in Manternach, Sprinkange und Hostert befinden sich die Exaktversuche und in Bettendorf der On-Farm Versuch auf den Versuchsfeldern der Ackerbauschule LTA.

Material und Methoden

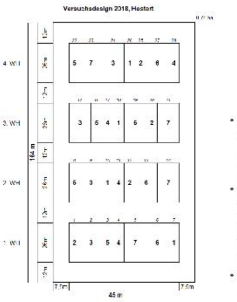


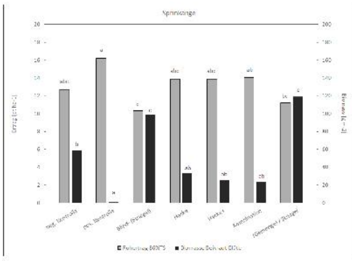
Abb. 1: Versuchsaufbau des Standortes Hostert.

Variante		Parzellenbreite
1	negative Kontrolle	3
2	positive Kontrolle	3
3	Striegeln	6
4	Hacken zwischen Reihen	3
5	Hacken zwischen und in der Reihe	3
6	Kombination 3+5	6
7	Mischkultur Soja/Leindotter	6

- **Design:** einfaktorieller Exaktversuch in vierfacher Wiederholung auf drei Bio-Betrieben in Luxemburg (s. Abb. 1 und Abb. 2)
- **Saat:** ab 20.04.2018, Sorte Merlin, Impfmittel BIODOZ Soja, Saatstärke 65 K/m², Saatbreite 12,5 cm (Hacke) und 37,5 cm (Striegel); Blindstriegeln in Variante 3, 6, 7
- **Kommunikation:** On farm Versuch der Ackerbauschule (LTA)

Ergebnisse und Diskussion

- Rohertrag und Beikrautbiomasse zur Blüte zeigen signifikante Korrelation (Pearson-Korrelation, $p<0,05$) mit $r = -0,72$ (Sprinkange) und $r = -0,86$ (Hostert)
- Sprinkange: signifikant höhere Erträge und geringe Beikrautbiomasse in Kombination als in Striegelvariante (s. Abb 3)
- Hostert: sehr hoher Beikrautdruck von Beginn an: am signifikant höchsten in den Striegelvarianten (7 und 3); höchste Erträge in Kombinationsvariante, niedrigste in Striegelvarianten (n.s.)
- Manternach: keine sign. Unterschiede in Biomasse und Ertrag a.G. sehr geringem Beikrautdruck; 15% der Hülsen frühzeitig aufgeplatzt
- Keine signifikaten Unterschiede in der Zahl der aufgelaufenen Pflanzen und Pflanzenverluste (hier nicht gezeigt).



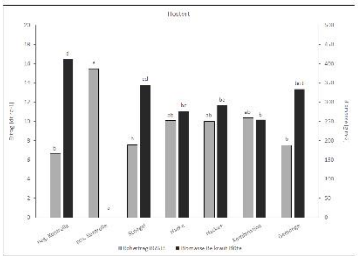


Abb. 3: Ertrag [dt ha⁻¹] und Biomasse des Beikrauts zur Blüte [g m⁻²] der Standorte Sprinkange und Hostert in Abhängigkeit der verschiedenen Beikrautregulierungsvarianten; Erträge (n=4), Biomasse (n=12); unterschiedliche Buchstaben bedeuten signifikante Unterschiede (ANOVA, TukeyHSD, $p<0,05$).

Abb. 4: Beikrautregulierung mit dem Striegel (links), der Scharhacke und den Fingerhacken (Mitte) und nur mit der Scharhacke (rechts).

Fazit

- Erträge generell in Hackvarianten höher als in Striegelvarianten, aber keine signifikanten Unterschiede innerhalb der einzelnen Hackvarianten
- Geringere Beikrautbiomasse zur Blüte in Hackvarianten und besonders in Kombinationsvariante -> Regulierungserfolg
- Trockenheit nach Blüte von Jun-Aug: hohe Ertragsverluste
- Hostert: geringe Erträge a.G. hohem Beikrautdruck von Anfang an -> Management des Standortes ausschlaggebend
- Erstes Versuchsjahr -> Saison 2019 wird weitere Aussagen zulassen

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European Soya Declaration (2017) European Soya Declaration: Enhancing soya and other legumes cultivation. Available at: https://www.bmel.de. [Accessed 10 June 2018].
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Appendix 9: Poster presentation at the conference WiTA in Kassel, March 2019.

Imprint

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