Legume screening for cover crops: weed suppression, biomass development and nitrogen fixation

Hans Ramseier, Professor for Plant Protection & Ecological Infrastructure; Bern University of Applied Sciences HAFL, Zollikofen, Switzerland

1 Introduction and objectives of the project

1.1 Situation

Agriculture is faced with the enormous challenges of resource conservation. A more efficient use of light, water, nutrients and energy will be one of the great challenges of the future. Green manure/cover crops and mixed crops may be possible solutions. In order to improve the present situation, and to protect resources in a sustainable manner, great efforts in both research and application are crucial. The aim is to efficiently prevent nitrogen loss and selectively incorporate it in the farm system via the use of legumes.

Judiciously choosing plants and plant communities (including new ones) could result in greater importance of green manure/catch crops, if the potential of resource conservation can demonstrate its usefulness and convince farmers.

1.2 Possible solutions and objectives of the project

To evaluate and quantify the agronomic potential of approximately 30 legumes, with a view to developing mixtures for future intercropping. Special attention must be made to the following aspects:

- Efficient binding/use of nitrogen present in the soil after harvest
- Nitrogen bio-synthesis through the use of legumes
- Weed suppression through natural competition and allelopathy (excretion of inhibitors by certain plants)
- Prevention of erosion, reduction of structural damage
- Evaporation protection, shade
- Accumulation of organic matter
- Increasing biological activity and soil fertility

The first three points mentioned above were investigated specifically.

2 Materials and methods

2.1 Screening trial

The following plants were selected for the procedure to calculate the potential of nitrogen uptake, soil cover, and weed suppression of legumes:

1. *Lotus corniculatus* - Bird's-foot Trefoil
2. *Lupinus albus* – White lupin
3. *Medicago lupulina* – Black Medic
4. *Medicago sativa* – Alfalfa
5. *Melilotus albus* – Sweet clover
6. *Onobrychis viciifolia* – Sainfoin
7. *Trifolium alexandrinum* – Egyptian clover
8. *Trifolium hybridum* – Swedish clover
9. *Trifolium incarnatum* – Crimson clover
10. *Trifolium pratense* – Red clover
11. *Trifolium repens* – White clover

12. *Trifolium resupinatum* – Persian clover
13. *Trifolium subterraneum* – Subterranean clover
14. *Vicia faba* – Faba bean
15. *Vicia pannonica* – Hungarian vetch
16. *Vicia sativa* – Common vetch
17. *Lens culinaris* – Lentil
18. *Trigonella foenum-graecum* – Fenugreek
19. *Vicia villosa* – Hairy vetch
20. *Lathyrus sativus* – Grass pea / Chickling vetch
21. *Pisum sativum HARDY* – Pea variety HARDY
22. *Pisum sativum ARVIKA* – Pea variety ARVIKA
23. *Glycine max* – Soybean
24. *Lupinus angustifolius* – Blue lupin
25. *Trigonella caerulea* – Blue fenugreek
26. *Cicer arietinum* – Chickpea
27. *Terra nuda* – uncovered soil (control)
28. Lens culinaris – Lentil (Canadian variety)
29. Avena sativa – Oat
30. Phacelia tanacetifolia – Phacelia

In addition to 27 legume species, the non-legume species, spring oat and phacelia, were sown and used as reference, and one procedure served as control of uncovered soil.

These 29 plant species were sown as pure culture on the one hand in 2010 in Changins, and in Changins (Western part of Switzerland) and in Zollikofen (Bern) in 2011, and mixed with oats and phacelia, on the other (split plot enclosure). Trials were carried out three times each, resulting in 360 elementary plots per study site.
Trials with the pure cultures were mainly concerned with studying over-wintering (freezing and effect on the seeds of successive crops).

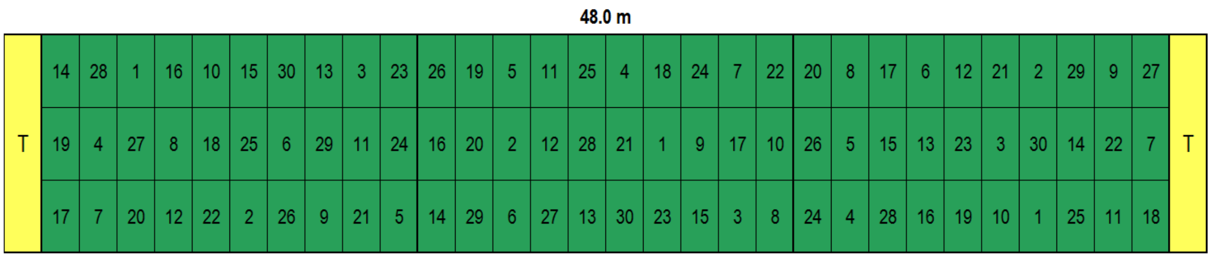

Illustration 1: Pure culture trial design. Each elementary plot measures 1.5 x 6m; T = Strips with oats bordering the remaining area.

In the split-plot trial, emergence and plant development data were collected until the first frost.

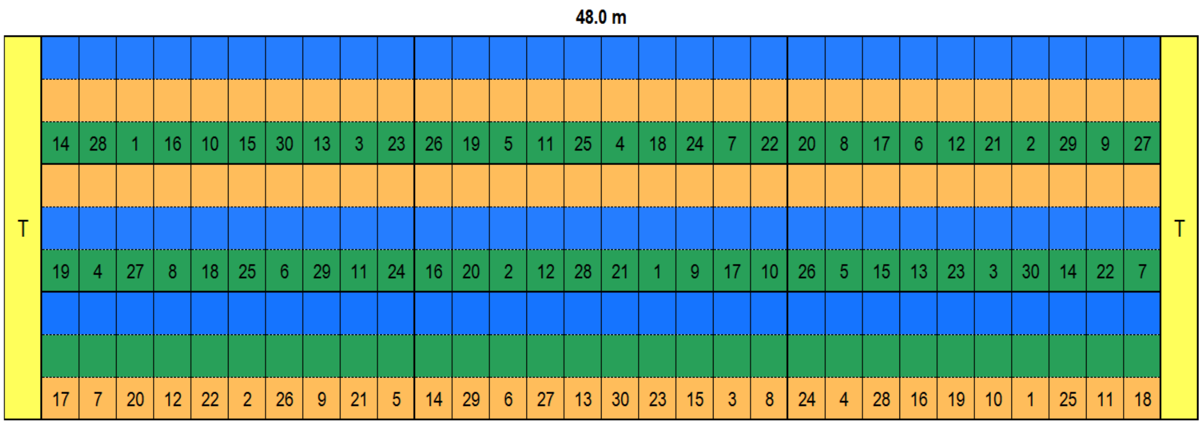

Illustration 2: Split plot trial design. Each elementary plot measures 1.5m x 18m (divided into 3 x 6m). Green = pure culture, blue = Phacelia-seed added, orange = oat seed added, T = strips with oats bordering the remaining areas.

After 25, 35, 45, 55, 65 and 75 ± 3 days, the speed of emergence and soil cover were examined. Weed suppression was measured in autumn and spring, and biomass production of the plants and weeds at the end of the vegetation period. The harvested samples were examined in the lab for N-, P-, K-, Ca- and Mg-content. At the end of the vegetation period, the plants were measured for height, and the portion of legumes (%) in the mixtures with oats and phacelia was determined. Further data was collected the following spring.

2.2 N-Fixation potential

To answer the question of how much atmospheric nitrogen is fixed by legumes, a pot trial was carried out in Zollikofen, using 20 legumes (3 repetitions). The plants were sown in pure sand and supplied with an N-free nutrient solution.
The Natural-N^{15}-abundance method was chosen to determine fixation performance. Here the ratio of the stable N-Isotope N^{14} and N^{15} in the plant was used, making it possible to differentiate the nitrogen available to the plants in the soil from the molecular nitrogen in the air. As in the field, phacelia and spring oat were used as reference plants.
The trial was planted and harvested at the same time as the field trials.

2.3 Effect on succeeding crops

In 2012 the development of the succeeding crop (sugar beets) were also examined in Zollikofen. The following data and observations were made:

- In addition to „Observations the following spring", under Chapter 2.1, the dominant surviving weeds were also determined.
- Emergence of the sugar beets (the number of emerging plants)
- Data on aphid and slug damage to the sugar beets
- Young plant development
  → height in cm in BBCH19 stage
  → plant propagation (measuring leaf spread) in cm in BBCH 19 stage
- Determining the biomass of the sugar beets on June 28th, separating leaf biomass and root biomass.

3 Selected results and discussion

3.1 Screening trial

3.1.1 Gross biomass

The gross biomass is composed of the tested plants and weeds in dt dry matter/ha (DM/ha).

The average amount of gross biomass produced varies a great deal, ranging from 11.9 dt DM/ha in the Bird's-foot Trefoil procedure to 62.6 dt DM/ha with the Faba bean. In the "uncovered soil" procedure, an average DM production rose from 9.8 dt/ha due to the weeds.
In a total of 7 procedures, the studies show a DM production of over 40 dt/ha: *Pisum sativum cv ARVIKA* (42.2dt), *Avena sativa* (43.8dt), *Lupinus albus* (44.0dt), *Vicia satia* (45.7dt), *Phacelia tanacetifolia* (47.0dt), *Pisum sativum HARDY* (52.1dt), *Vicia faba* (62.6dt).
The lowest DM production: control - uncovered soil (9.8dt), *Lotus corniculatus* (11.9dt), *Cicer arietinum* (16.3dt), *Trigonella caerulea* (16.4dt), *Medicago lupulina* (16.9dt).

3.1.2 Net biomass

Net biomass is obtained by subtracting weed biomass from the gross biomass.

Chart 1: Net biomass in three trials, Changins and Zollikofen in dt DM/ha. The different letters indicate statistically significant differences (p<0.5).

Plant species	Changins 2010		Changins 2011		Zollikofen 2011		average	SD[2)]
Uncovered soil	0.0	l	0.0	j	0.0	k	0.0	0.0
Lotus corniculatus	3.3	jkl	6.0	ij	4.3	jk	4.6	1.4
Onobrychis viciifolia	6.7	ijkl	14.1	fghi	10.1	ij	10.3	3.7
Cicer arietinum	17.2	gh	11.1	fghij	4.0	jk	10.8	6.6
Medicago lupulina	6.7	ijkl	10.2	ghij	15.9	ghi	10.9	4.6
Trifolium repens	11.2	hijk	9.7	hij	14.7	ghi	11.9	2.6
Trifolium hybridum	14.4	ghi	11.3	fghij	11.1	hij	12.3	1.9
Trigonella caerulea	4.4	jkl	14.7	fghi	21.5	efg	13.5	8.6
Trifolium pratense	11.0	hijk	14.0	fghi	16.1	ghi	13.7	2.5
Melilotus albus	10.1	hijk	17.2	fghi	15.7	ghi	14.3	3.8
Trifolium subterraneum	12.8	ghij	17.0	fghi	14.9	ghi	14.9	2.1
Medicago sativa	11.5	hijk	20.3	fgh	22.7	efg	18.2	5.9
Trigonella foenum-graecum	9.0	hijkl	38.4	cd	17.6	fghi	21.7	15.1
Lupinus angustifolius	9.9	hijk	36.5	d	21.2	efg	22.6	13.4
Lens culinaris cv.Canada	32.4	de	15.0	fghi	25.2	def	24.2	8.7
Vicia pannonica	35.2	de	19.0	fgh	20.0	fgh	24.7	9.1
Trifolium resupinatum	34.4	de	21.7	fg	26.1	def	27.4	6.4
Glycine max	2.0	kl	48.3	bc	34.1	d	28.1	23.7
Lens culinaris	40.5	cd	22.3	ef	32.0	d	31.6	9.1
Trifolium incarnatum	30.0	ef	32.7	de	32.5	d	31.7	1.5
Trifolium alexandrinum	31.7	de	32.4	de	31.9	d	32.0	0.4
Lathyrus sativus	NA[1]		39.9	cd	29.5	de	34.7	7.3
Vicia villosa	44.8	bc	35.7	d	32.3	d	37.6	6.5
Lupinus albus	21.5	fg	56.0	b	46.8	bc	41.4	17.9
Avena sativa	40.3	cd	36.0	d	48.2	bc	41.5	6.2
Pisum sativum cv.Arvica	52.7	ab	40.2	cd	33.3	d	42.1	9.8
Vicia sativa	54.0	a	35.4	d	43.9	c	44.5	9.3
Phacelia tanacetifolia	26.7	ef	52.3	b	55.0	ab	44.7	15.7
Pisum sativum cv.Hardy	53.6	a	55.2	b	44.6	c	51.1	5.7
Vicia faba	41.0	cd	74.5	a	62.7	a	59.4	17.0

[1]Not available [2)] = Standard deviation

The above chart shows that the best procedures in gross production are also the best procedures in net production. Procedures which produce over 40 dt DM/ha in gross production, show efficient weed suppression and also produce over 40 dt DM/ha via the sown plants. The Faba bean resulted in the highest values, at almost 60 dt DM/ha, which is very high when one takes into consideration that this biomass was produced within a relatively short period of time (beginning of August to the end of the vegetation period).

3.1.3 Growth and soil cover

Fast emergence and fast soil cover are important for fighting erosion and suppressing weeds.

Chart 2: The number of days needed to obtain 50% soil cover. Trial 2010 (Changins) and 2011 (Changins and Zollikofen). The different letters indicate statistically significant differences ($p<0.5$).

	Changins		Zollikofen			
Plant species	**2010**	**2011**	**2011 split plot**	**2011**	**average**	**SD[2)]**
Vicia villosa	11 g	18 defgh	21 bcde	22 cdefgh	18	4.9
Trifolium resupinatum	16 fg	23 cdefgh	21 bcde	21 defgh	20	3
Pisum sativum cv.Arvica	24 defg	16 h	20 bcde	20 efgh	20	3.5
Vicia sativa	20 efg	18 fgh	23 abcd	22 cdefgh	21	2.2
Lathyrus sativus	NA[1]	19 defgh	22 bcde	23 cdefgh	21	1.9
Lens culinaris	21 efg	21 cdefgh	21 bcde	22 cdefgh	21	0.7
Trifolium incarnatum	23 efg	23 cdefgh	20 cde	21 efgh	22	1.7
Pisum sativum cv.Hardy	28 cdefg	17 fgh	21 bcde	22 cdefgh	22	4.4
Phacelia tanacetifolia	35 cde	17 fgh	17 e	17 h	22	9
Lens culinaris cv.canada	25 defg	20 cdefgh	23 abcd	23 cdefgh	23	2
Lupinus albus	33 cdef	18 fgh	21 bcde	20 fgh	23	6.8
Trigonella caerulea	27 cdefg	21 cdefgh	22 bcde	21 defgh	23	3
Trifolium alexandrinum	25 defg	22 cdefgh	23 abcd	24 cdefg	24	1.1
Vicia pannonica	24 defg	24 bcdefgh	23 abcd	25 bcdefg	24	0.8
Cicer arietinum	27 cdefg	18 efgh	21 bcde	30 ab	24	5.4
Avena sativa	34 cdef	21 cdefgh	23 abcd	22 defgh	25	5.9
Medicago sativa	29 cdefg	27 bcdefg	22 abcde	21 defgh	25	3.7
Trifolium pratense	27 cdefg	29 bcd	22 bcde	25 bcdef	26	2.9
Vicia faba	37 cde	18 fgh	26 ab	23 cdefgh	26	7.9
Trifolium hybridum	30 cdefg	27 bcdef	25 ab	25 bcdefg	27	2.5
Medicago lupulina	36 cde	30 bc	21 bcde	21 defgh	27	7.4
Trifolium subterraneum	27 cdefg	34 b	24 abcd	24 bcdefg	27	4.7
Trigonella foenum-graecum	45 c	20 cdefgh	22 abcde	24 cdefg	28	11.4
Melilotus albus	35 cde	28 bcde	24 abcd	26 bcdef	28	5
Lupinus angustifolius	43 cd	26 bcdefgh	24 abcd	27 abcde	30	8.8
Lotus corniculatus	43 cd	NA[1]	25 ab	27 abcd	32	9.8
Trifolium repens	39 cde	54 a	25 abc	26 bcdef	36	13.5
Glycine max	89 a	17 gh	19 de	18 gh	36	35.6
Onobrychis viciifolia	68 b	49 a	27 a	28 abc	43	19.2

[1]Not available [2)] = Standard deviation

Some tested species cover the soil very quickly, that is, in approximately 3 weeks for 50% cover. These include Hairy vetch, Persian clover, Pea, Common vetch, Grass pea/Chickling vetch and Lentil. On the other hand, certain plant species require almost twice as long.

3.1.4 Soil cover, produced biomass and weeds

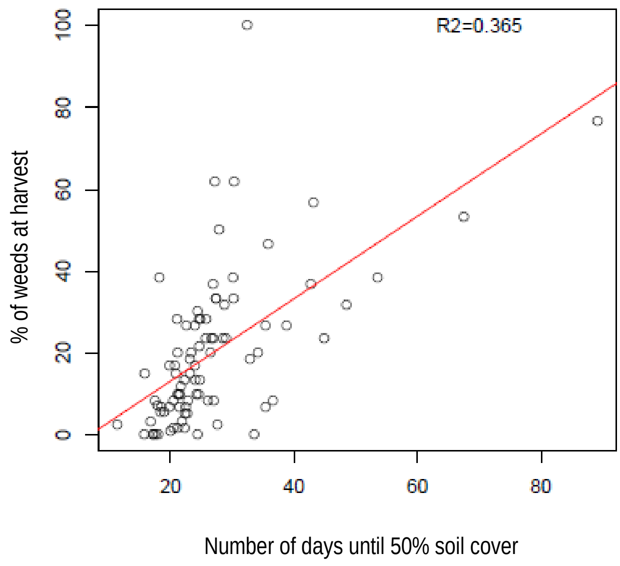

Illustration 3: Correlation between the number of days required for 50% soil cover and the % of weeds at harvest.

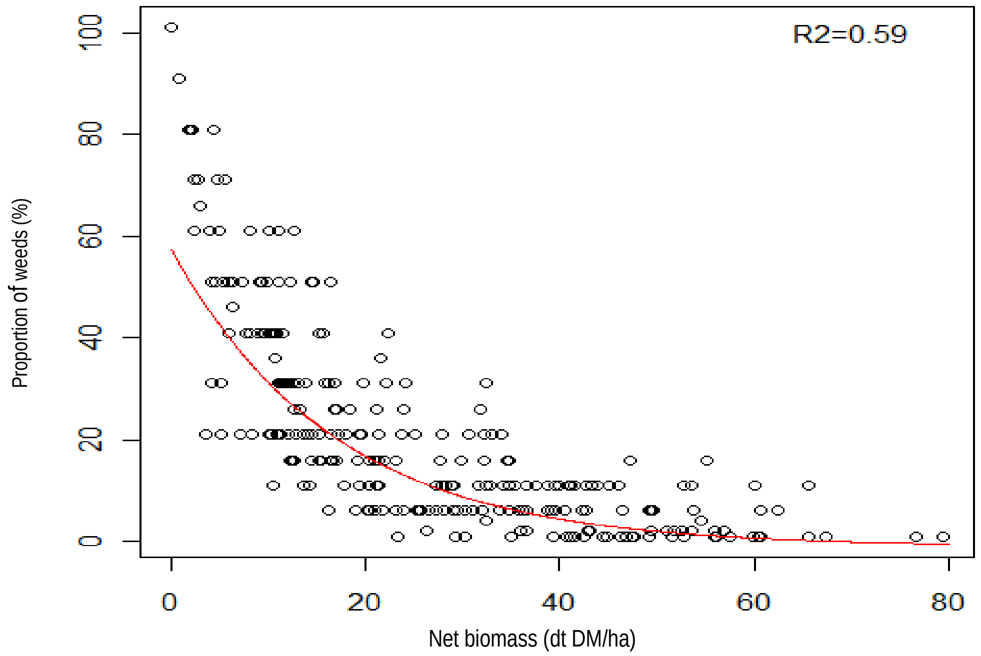

Illustration 4: Correlation between harvested biomass of green manure crops and proportion of weeds.

Illustration 5 indicates that there is a connection between the biomass of the green manure crop (net biomass) and the emergence of weeds. It is basically true that procedures with a high biomass production result in fewer weeds. There are exceptions, two of which are the Trigonella-species.

3.1.5 Amount of nitrogen in the above-ground biomass of the tested plants

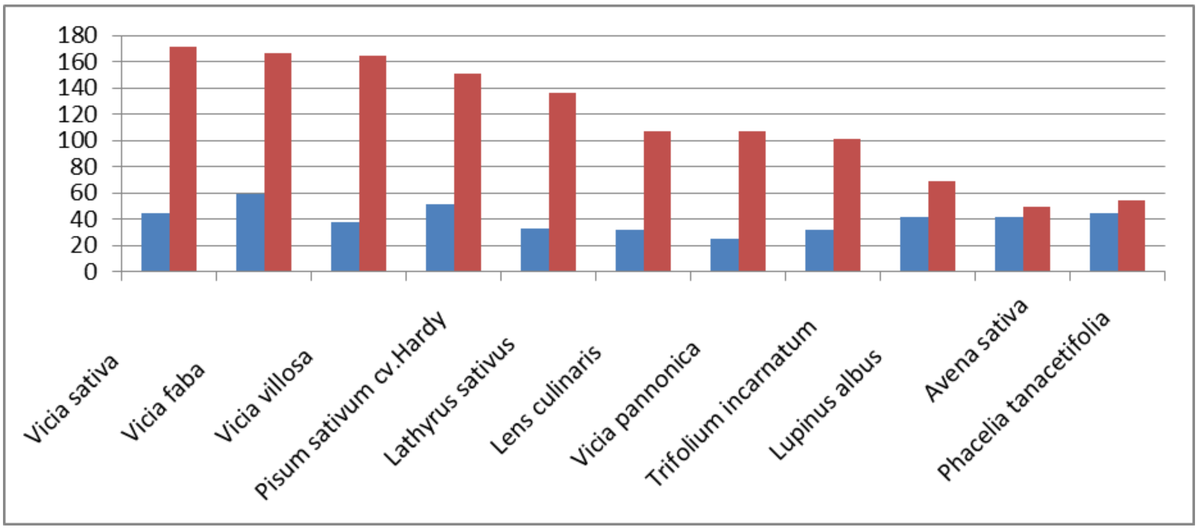

Illustration 5: Net biomass in dt DM/ha (blue columns) and the amount of nitrogen in kg/ha (red columns) in the above-ground biomass of a selection of tested plants in the trial.

The above graph demonstrates that in some cases, very high levels of nitrogen are present in the above-ground biomass. In the middle of 3 trials, 8 of the tested plants showed more than 100kg/ha nitrogen in the above-ground biomass. The three Vicia-species, Common vetch, Faba bean, and Hairy vetch even showed levels above 160kg N/ha. At this high level, one must consider whether a portion will not be washed away over winter. It is true that Oat and Phacelia produce high amounts of net biomass, but show considerably lower levels of nitrogen per hectare.

3.2 Biologically fixed nitrogen

With the help of the values obtained from the pot trial, a calculation could be made of how much nitrogen the planted legumes fixed from the air.

Chart 3 shows that several legume species fix no or practically no nitrogen from the air, probably because the specific rhizobia were absent and had to be inoculated. These include species which do not normally grow, or are not normally planted in Switzerland, such as Blue fenugreek *(Trigonella caerulea)*, Chickpea *(Cicer arietinum)* and Fenugreek *(Trigonella foenum-graecum).*
On the other hand, there are plant species which can fix high levels of nitrogen from the air. The 5 plants with the highest fixation performance showed levels clearly over 100 kgN/ha of fixed atmospheric nitrogen. The trials also indicate that under the climatic conditions of the Swiss Plateau area, considerable amounts of nitrogen can be added to the system through legumes used as green manure after cereal harvest. Many factors, which were not at all, or not completely covered in the trial, that is to say, included in the evaluations, could change the results. Most of the results, however, are similar or consistent with foreign studies. Unfortunately, however, it is impossible to estimate the ratio of N extracted from the ground to fixed atmospheric N, as the formation of rhizobia certainly changes when nitrogen is already present in the soil. Furthermore, only the above-ground biomass was tested in the studies: nitrogen present in the roots was not recorded.

Chart 3: Levels of fixed atmospheric nitrogen through the sown plants in the trial. Trial 2010 (Changins) and 2011 (Changins and Zollikofen). The different letters indicate statistically significant differences (p<0.5).

Amount of fixed Nitrogen from the air (kgNdfa/ha)								
Plant species	**Changins 2010**		**Changins 2011**		**Zollikofen 2011**		**average**	**SD[2)]**
Trigonella caerulea	1.1	ij	-25.0	h	-0.8	gh	-8.2	14.5
Cicer arietinum	4.4	hij	2.3	h	1.7	gh	2.8	1.4
Avena sativa	3.6	hij	8.5	gh	6.4	g	6.2	2.4
Trigonella foenum-graecum	12.7	ghi	28.0	efgh	6.3	g	15.7	11.1
Glycine max	7.5	hij	44.7	defgh	1.6	gh	17.9	23.4
Trifolium subterraneum	21.3	fgh	42.9	defgh	15.8	g	26.6	14.3
Melilotus albus	14.0	ghi	30.9	efgh	35.3	f	26.7	11.2
Lupinus albus	34.1	f	39.9	defgh	9.6	g	27.9	16.1
Trifolium repens	22.3	fgh	32.1	efgh	46.5	ef	33.7	12.2
Trifolium pratense	27.8	fg	36.3	defgh	37.5	f	33.9	5.3
Medicago sativa	19.5	fghi	25.2	fgh	62.2	de	35.6	23.2
Trifolium alexandrinum	59.5	e	36.3	defgh	58.7	de	51.5	13.2
Trifolium resupinatum	85.6	d	57.1	defgh	64.5	cde	69.1	14.8
Trifolium incarnatum	77.7	d	97.9	bcdef	57.6	de	77.7	20.1
Lens culinaris	104.6	c	50.0	defgh	80.9	c	78.5	27.4
Vicia pannonica	116.8	c	89.5	cdefg	74.7	cd	93.6	21.3
Pisum sativum cv.Hardy	109.3	c	116.1	bcd	101.5	b	109.0	7.3
Lathyrus sativus	Na[1]		152.4	bc	98.6	b	125.5	38.0
Vicia sativa	142.6	b	109.1	bcde	131.0	a	127.6	17.0
Vicia faba	112.6	c	175.1	b	130.6	a	139.4	32.2
Vicia villosa	175.0	a	170.6	b	100.1	b	148.6	42.0
[1]Not available [2)] = Standard deviation								

3.3 Effect on succeeding crops

Sugar beets (variety Robinson) were then sown on the trial plot in Zollikofen on 27.3.2012 (95‘000 pills/ha). On the basis of a soil analysis and precrop, fertilizer was added at 120 kg/ha K_2O, 46 kg/ha P_2O_5 and 52 kg/ha N.

3.3.1 Development of the young sugar beet plants as a function of green manure

With the development of the young plants (height and leaf blade), the „after-effect“of the green manure can be seen through improved soil structure, provision of nutrients and water supply. The results require cautious interpretation, however, as the trial lasted only one year and was held under difficult weather conditions.

Chart 4 shows that Common vetch and Hairy vetch delivered the best results and the best sugar beets developed. Alfalfa, White clover, both Trigonella-species and Grass pea/Chickling vetch and Egytian clover also performed well.

Chart 4: Growth height and plant spread of sugar beets in cm from selected procedures, recorded on June 5, 2012, Block Trial, Rütti Zollikofen, 2012

Species of plant	**Hight in cm**	**Rank**	**Leaf extent in cm**	**Rank**	**Rank sum total**
Common vetch	32.3	1	37.87	3	4
Hairy vetch	31.8	3	38.67	1	4
Alfalfa	31.7	4	38.40	2	6
White clover	31.7	4	36.67	7	11
Fenugreek	30.8	8	37.87	3	11
Blue fenugreek	31.6	7	37.73	5	12
Grass pea	31.7	4	34.53	10	14
Egyptian clover	30.8	8	37.47	6	14
Persian clover	30.6	10	35.33	8	18
Pea ARVIKA	29.7	14	34.00	14	28
Pea HARDY	30.4	12	32.80	20	32
Uncovered soil	27.3	23	34.00	14	37
Bird's-foot Trefoil	29.3	16	32.53	22	38
Soybean	27.8	22	33.60	17	39
Black Medic	28.1	21	33.30	19	40
Hungarian vetch	28.8	19	32.30	23	42
Crimson clover	28.5	20	32.20	24	44
Oat	26.8	24	32.70	21	45

On the other hand, there are species, such as Pea ARVIKA, Pea HARDY, Soybean and Hungarian vetch, which looked good in autumn, but delivered only moderate to poor results. It is difficult to find an explanation for this poor performance. One possibility could be the „cover“ formed by frozen plant matter, which prevented the soil from drying. Crismon clover and Oat showed the worst results, even worse than the uncovered soil. Possibly there was an allelopathic effect on the sugar beets.

3.3.2 Development of sugar beet biomass as a function of green manure

Chart 5: The development of root and leaf biomass of the sugar beets (an average of 5 beets/procedure) in kg DM. Selected procedures, in descending order according to root yield, recorded on June 28, 2012, Block Trial Rütti Zollikofen, 2012

Plant species	**kg root-DM**	**kg leaf-DM**
Hairy vetch	1.36 a	2.74 a
Eyptian clover	1.27 a	2.17 ab
Fenugreek	1.25 a	2.09 ab
Alfalfa	1.19 a	2.18 ab
Persian clover	1.19 a	1.91 ab
White clover	1.19 a	2.31 ab
Black Medic	1.18 a	1.89 ab
Blue lupin	1.18 a	2.12 ab
Grass pea	1.17 a	2.18 ab
Sainfoin	1.12 a	1.68 ab
Uncovered soil	0.97 a	1.47 ab
Blue fenugreek	0.96 a	1.76 ab
Pea HARDY	0.91 a	1.58 ab
Pea ARVIKA	0.90 a	1.72 ab
Oat	0.90 a	1.47 ab
Crimson clover	0.86 a	1.38 b
Hungarian vetch	0.84 a	1.89 ab

Root yield and sugar content of the sugar beets are certainly important for the farmer. Due to a shortage of funds (and labour), however, unfortunately neither the yield nor the sugar content were recorded in the autumn, which would no doubt have been more reliable and revealing than collecting data at the end of June. Nonetheless, conclusions can be drawn from the values obtained. The root yield shows mere tendencies, and no statistically significant values. Statistically speaking, the Crimson clover trial (lowest DM-yield) and Hairy vetch (highest DM-yield) were significantly different in leaf formation.
With few exceptions, the same procedures with Hairy vetch, Alfalfa, White clover and Fenugreek, showed the best root yields and young plant development. However, there are plants with good young plant development, but very poor root yield. For example, Common vetch, which, along with Hairy vetch, showed the best young plant development, slipped into the middle field in terms of root yield. The worst results, in both yield and young plant development were seen in the Oat, Crimson clover, and Hungarian vetch procedures. What is surprising is that root and leaf yield do not always conveniently correlate. Therefore, there are procedures (plants), such as Common vetch, which led to a high leaf yield with the sugar beets, and a relatively modest root yield. However the opposite was also observed: relatively modest foliage and a surprisingly high root yield, such as Persian clover and Black Medic.

4 Overall discussion and conclusions

On the whole, a very positive conclusion can be drawn. The trials have taken us forward significantly. Of the 27 tested legume species, we were able to identify some very interesting ones.
Plants which emerge quickly, cover well, and grow rapidly suppress weeds efficiently and can also form large amounts of biomass. On the basis of the trials, however, we cannot say which legume species are able to absorb especially much nitrogen present in the soil. The experiments have demonstrated that there are legumes which are in a position to fix atmospheric nitrogen very efficiently and in large quantities, especially the Vetch species, which can fix amounts significantly more than 100 kg N/ha within approximately 3 months in above-ground biomass. When one considers that about the same quantity can be found underground in the roots and nodules (which were not examined), this means an immense potential of fixing atmospheric N. Peas and Vetch are very efficient builders of biomass and therefore also enjoy a high potential for building organic matter („friable humus“). Of the 27 tested legumes, 10 formed more than 30 dt DM/ha of above-ground biomass, which is a very high level. When summing up the profit for the succeeding crop, the following species seem particularly interesting: Hairy vetch, Egyptian clover and Persian clover. Both Trigonella species and White clover are also of interest. With these species, the sugar beets tended to develop better than in uncovered soil. These species warrant further investigation. On the other hand, there seem to be plant species which suppress weeds well, can absorb and fix large quantities of N, such as Crimson clover; yet succeeding crops develop poorly. Oat, too, as reference plant, showed that, whereas it forms large quantities of biomass in the autumn and suppresses weeds well, the succeeding crop develops badly. On the basis of the tests, it can also be said that the future will lie not in single species but in mixtures. In this way various positive effects can be combined and negative effects eliminated.

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