

Final Report: Evaluation of yellow lucerne as a forage crop for northern Sweden

RJN Project 6/2021

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Lucerne experiment at Ås, September 2021. Photo: Lars Tirén

Summary

Yellow and hybrid lucerne are potential alternative forage species for Northern Sweden. They are generally more winter hardy than blue lucerne, and can also spread vegetatively via rhizomes. This project conducted field experiments in Northern Sweden to compare the yield and forage quality of 11 lucerne cultivars and one red clover cultivar. Two hybrid lucerne cultivars (Ludvig and Jögeva 118) and one yellow lucerne cultivar (Karlu) were higher yielding than other lucerne cultivars. Results in comparison with red clover were very site dependent. Where conditions were well suited to lucerne at Ås, most lucerne cultivars were higher yielding than red clover. Crude protein was similar among all cultivars. Digestibility was not different among lucerne cultivars, but harvest 2 digestibility was lower for lucerne than for red clover. There were differences between lucerne cultivars in terms of winter survival and persistence, and this was reflected in the abundance of weeds. A separate experiment sown in mix stands of Timothy grass and legume (red clover or lucerne) showed that lucerne could be a potential addition to seed mixes.

Introduction

Climate variability is a major concern for future agricultural production. Red clover (*Trifolium pratense* L.) is the main forage legume in northern Sweden but it is not very persistent. The main reason for the low persistence is winter survival, due to disease, ice, and cold. A decline in the plant population is often obvious in the third production year. Lucerne (*Medicago sativa* L.) is another forage that is widely cultivated in Europe, including in Sweden; however, there are many locations in Sweden where the climate or soil conditions are not suitable. Yellow lucerne (*Medicago sativa* ssp. *falcata* L.) is not widely cultivated, even in Southern Sweden, but has potential to be a future forage crop for northern Sweden due to its tolerance of stressors such as drought, cold and soil infertility (Araújo et al., 2015). Yellow lucerne also often has rhizomes, a low crown, and a branched fibrous root system (compared with blue lucerne which has a tap-root) (Garver, S., 1922). It is tolerant of acid soils and wet soils, longer-lived and more winter hardy than lucerne (Cui et al., 2019; Michaud et al., 2015). A related species is referred to in English as variegated lucerne (*Medicago x varia*) which often has a multi-coloured flower. The reality is that these perennial *Medicago* species interbreed, and hybrids exist. The overall aim of this project was to assess the potential of blue, yellow, and hybrid lucerne cultivars as alternative forage legumes in northern Sweden.

Materials and methods

Field experiment 1 - Monocultures

Lucerne cultivars and red clover were established in field experiments at 4 sites in northern Sweden: Röbbäcksdalen, Lännäs, Ås, and Öjebyn (Figure 1). Each site had three (Ås) or four (Lännäs, Röbbäcksdalen) replicates.

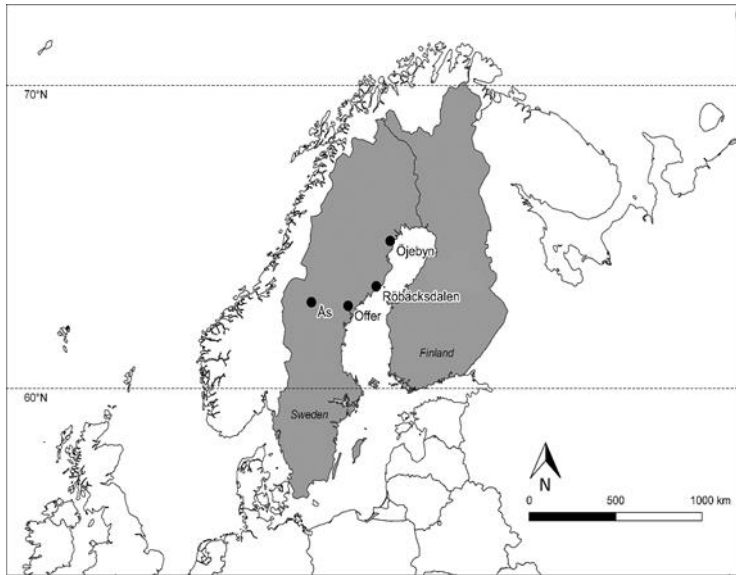


Figure 1 Experiment locations in northern Sweden. Map by Julien Morel.

The experiments included eleven cultivars of lucerne and one cultivar of red clover. All except one (Saaremaa kohalik) were commercially available cultivars of either blue lucerne, yellow lucerne, or a hybrid (Table 1), so for ease we refer to all 12 as cultivars. It is difficult to definitively place each cultivar in the category of blue, yellow, or hybrid, so classification was primarily based on how the cultivar is referred to by the breeders and in the scientific literature. The cultivars were diverse in their plant morphology, particularly in relation to the presence or absence of rhizomes. Two of the lucerne cultivars, Sholty and Don, are diploid, whereas the other lucerne cultivars are tetraploid.

Table 1 The tested red clover and lucerne cultivars.

	Cultivar	Species	Country of Origin
1	SW Yngve	<i>Trifolium pratense</i>	Sweden
2	SW Nexus	<i>Medicago sativa</i>	Sweden
3	Ludvig	<i>Medicago × varia</i>	Norway
4	Sholty	<i>Medicago sativa ssp. falcata</i>	United States
5	Don	<i>Medicago sativa ssp. falcata</i>	United States
6	Karlu	<i>Medicago sativa ssp. falcata</i>	Estonia
7	Juurlu	<i>Medicago sativa ssp. falcata</i>	Estonia
8	Saskia	<i>Medicago × varia</i>	United States
9	Ludelis	<i>Medicago sativa</i>	Denmark, France
10	Mezzo	<i>Medicago sativa</i>	France
11	Jögeva 118	<i>Medicago × varia</i>	Estonia
12*	Saaremaa kohalik	<i>Medicago × varia</i>	Estonia

*Not at all sites.

Experiments were sown in June or July 2020, with similar rates of live seed – seeding rates were adjusted for germination rate but not for hard seededness. Plots were fertilised with 30 kg P/ha and 60 kg K/ha at sowing, and again every spring.

Experiments were assessed for yield, plant density, plant height, botanical composition (visual), phenological stage, NDVI (Normal difference vegetation index), and chlorophyll content index.

Forage samples were collected for all sites and harvests and placed in storage. A selected set of samples (Lännäs 2021, harvests 1 and 2) were analysed for neutral detergent fiber (NDF), crude protein (CP), ash, and organic matter digestibility (OMD) using the rumen degradable organic matter (VOS) method (Lindgren, 1979).

At Röbbäcksdalen, the establishment of the field experiment was poor due to a problem with nodulation, likely caused by a low pH(CaCl₂) of 5.2. Note that this measurement was done by the Eurofins lab using NIRS (near infrared spectroscopy) and values are typically lower than for H₂O extractions. Rather than abandoning the experiment, fine lime (calciprill) was applied in autumn 2020, and inoculation was re-applied in autumn 2020 and summer 2021 by adding inoculum to a watering can and watering it onto plots. In June 2021 the soil was tested again using a desktop pH meter (Mettler) and pH(H₂O) was measured to be 5.9. Because of the poor growth in spring and early summer in 2021, and obvious signs of nitrogen deficiency, there was no first harvest at Röbbäcksdalen in 2021. Instead, the plots were cut back on 11-7-2021 and only a second harvest was taken.

Field experiment 2 – Lucerne and grass mixes

Early observations of the experiments in spring 2021 showed that the spring growth of lucerne was slow, which allowed weeds to establish in the plots. Therefore we decided to establish a new experiment with mixed stands of grass and lucerne. The experiment was sown in summer 2021, and used mostly the same cultivars as the monoculture experiment, with 12 entries and 4 replicates. The only difference in species treatments was that instead of Saareema kohalik, a mixture of Karlu and Jögeva 118 was used. Lucerne and red clover were sown at 500 live seeds/m². Timothy (*Phleum pratense*) cultivar Switch, was sown at 5 kg/ha. Plots were fertilised with 30 kg P/ha and 60 kg K/ha at sowing, and again every spring. In 2022, 50 kg N/ha was added after the first harvest, a low rate to favour growth of the legumes. In 2023, 30 kg N/ha was added in spring, 50 kg N was added after the first harvest, and 30 kg N was added after the second harvest.

Most of the management of the experiment was similar to that of the monoculture experiments, with some differences. Due to rapid establishment, the experiment was harvested once in the establishment year. Three harvests were taken in both production years. The first two harvests coincided with typical harvest times for a 3-cut system involving Timothy. The third harvest was taken late in the season when growth was judged to have finished. Botanical composition was determined visually, and also by

hand separating a sample of approximately 1 kg that was taken from the harvesting machine after harvesting each plot.

Samples were collected and saved for all harvests. A selected set of 60 samples was submitted for analysis, but the results were not completed at the time of writing this report. The sample set included Yngve, Nexus, Ludvig, Karlu, and Jögeva 118 for 3 harvests in 2023.

Glasshouse experiment – effect of pH on inoculation

This study was carried out by a Master student, Katarina Boström, with supervision by David Parsons and Göran Bergkvist. The aim of the study was to evaluate and compare the pH tolerance of blue and yellow lucerne.

A mineral soil and different rates of fast-acting lime (Calciprill) were used to create six treatments with $\text{pH}(\text{H}_2\text{O})$ 6.0-6.4 and $\text{pH}(\text{CaCl}_2)$ 5.1-5.4, at the start of the experiment. 60 pots containing inoculated yellow and blue lucerne cultivars were organized in a randomized block design in a greenhouse chamber. After 75-81 days the pots were harvested. Non-destructive measurements were made during growth and destructive measurements were made at harvest.

Results and Discussion

Field experiment 1 - Monocultures

General comments

The initial establishment was best at Lännäs and Ås. At Röbbäcksdalen the initial establishment was poor, due to a many plants failing to form nodules. The experiment at Öjebyn did not establish well (there were insufficient germinated seedlings), and was abandoned.

Although the Lännäs and Ås experiments established well, they were damaged by clover rot (*Sclerotinia trifoliorum*), with symptoms already clearly visible in spring 2021, especially in the red clover plots. This made them susceptible to weeds. In 2022, both experiments were sprayed with a selective herbicide, which reduced the harvest 2 yields. Both clover rot and herbicide may have affected the yields of red clover and lucerne during 2022. The experiment at Lännäs did not recover well after 2022, however it is not clear whether this was due to clover rot, herbicide damage, weeds or a combination of all of these. The experiment at Lännäs was not measured in 2023.

Spring density

Lucerne was slower than red clover to re-grow in the spring (see Figure 2), which possibly resulted in the lucerne spring density being under-estimated.



Figure 2 Assessing the field experiment at Lännäs on 28th of May 2021. The lucerne cultivars differ in their spring vigour, and are slower than red clover to re-grow. Photos: David Parsons.

At Ås (Figure 3) cultivars had a similar spring density in 2021 after the first winter. Karlu had a greater spring density than some other cultivars; however most cultivars were not significantly different to each other. The results for 2022 were quite different – all cultivars had lower spring density than the previous year, and for many lucerne cultivars it was a drastic reduction; however some of this difference may be due to differences between years in growth stage at the time of

assessment. The cultivars Yngve, Ludvig, Karlu, and Jögeva 118 had the greatest spring density. In 2023, Ludvig, Karlu and Jögeva 118 had the greatest spring density, with a similar pattern to 2022.

Spring density results at Lännäs were somewhat similar to Ås (Figure 3); however, in the first production year densities were lower than Ås, and Sholty already had a very low density. By the second production year spring density was greatest for Yngve, followed by Ludvig, Karlu, Juurlu, and Jögeva 118. All other cultivars had mean spring density of less than 10%.

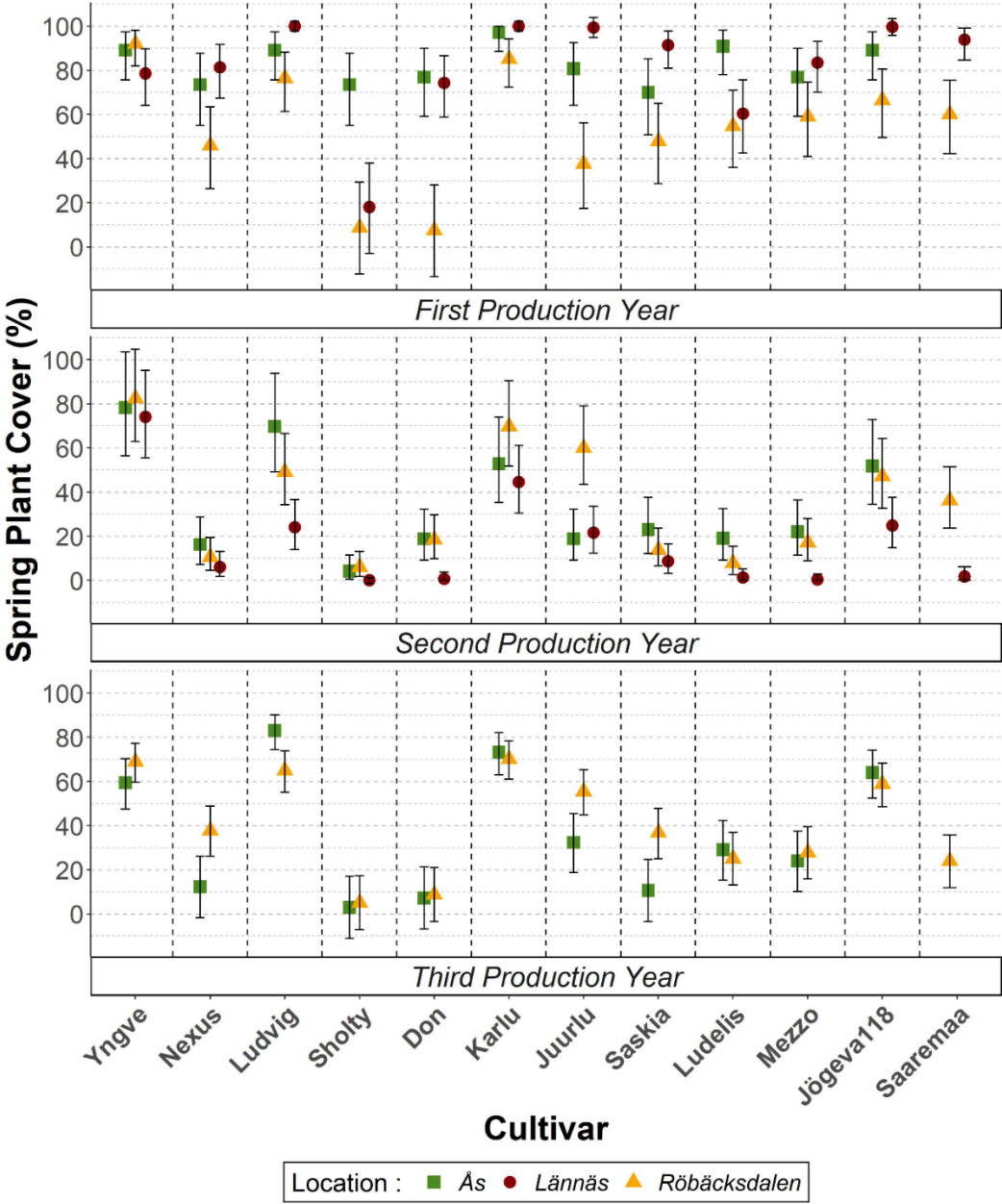


Figure 3 Spring density at Ås, Lännäs, and Röbbäcksdalen for each production year (2021-2023). Bars represent 95% confidence intervals, modified according to Tukey's test, and can be used for comparing means within production years and within sites.

At Röbbäcksdalen, the spring densities of many cultivars were already low in the first production year (Figure 3) due to the challenges with establishment. The cultivars with the greatest densities were Yngve, Ludvig, Karlu and Jögeva 118, a trend consistent with the other sites. The spring densities in 2022 and 2023 were similar to each other, with the same cultivars having the greatest densities (with the addition of Juurlu).

In summary, Yngve, Ludvig, Karlu and Jögeva 118 consistently had the greatest spring densities and were not significantly different to each other, with the exception that Ludvig had higher density than Yngve at Ås in the third production year. Spring densities will be measured at Ås and Röbbäcksdalen in 2024, and we hypothesise that the red clover is likely to have a lower spring density than previous years, whereas the best lucerne cultivars will maintain spring density. Additional figures are shown in the appendix, which use letters to distinguish significant differences between cultivars.

Autumn density

The most important autumn density measurement is in the establishment year, because it is a measure of initial establishment, and can be compared with density data from the following spring to assess the winter survival. At Röbbäcksdalen, autumn density was close to 100% and was not significantly different between cultivars. In contrast the spring density in 2021 was low. This suggests that the initial establishment was good, but the lack of nodulation in the establishment year meant that the plants were not healthy, decreasing winter survival. At Ås and Lännäs, establishment autumn density was close to 100% for most cultivars, but lower for Don and Sholty, possibly a result of hardseededness.

Subsequent autumn density values were collected but are not presented in this report. The data are not consistent due to the different harvesting times, which meant that the plots were at different growth stages in different years, making it difficult to consistently assess autumn density.

Annual yield

Yield results for the three production years are shown in Figure 4.

At Ås, there were differences in the first production year, with some cultivars (Nexus, Ludvig, Karlu, Ludelus, Mezzo and Jögeva 118) higher yielding than Yngve red clover. In the second production year the yield of red clover was lower than the previous year, likely due to disease pressure. Ludvig, Karlu, and Jögeva 118 were not significantly different to each other, but higher yielding than Yngve. Overall, yields were lower in the second production year, possibly due to the effect of herbicide use. In the third production year, lucerne yields were high again. By the third production year, the red clover had declined even further, and all lucerne cultivars with exception of Sholty and Don were higher yielding than red clover. Most lucerne cultivars had their greatest yield in the third production year, a trend which was opposite to that of red clover. Combined across years, yield was greatest for Karlu, Ludvig,

and Jögeva 118. Lucerne appears to be well suited to the Ås site – lucerne yields of more than 9 t/ha in the third production year are very promising.

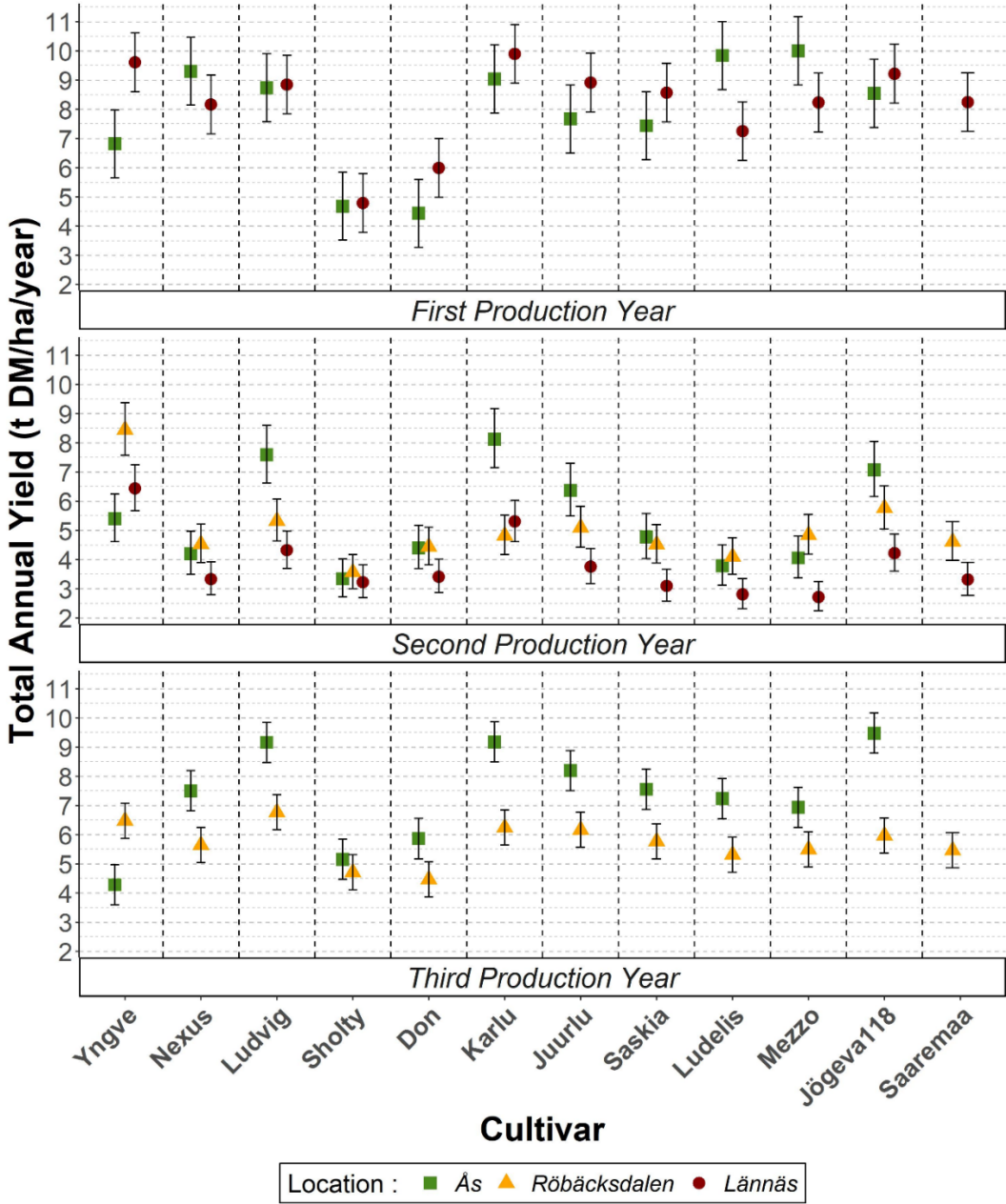


Figure 4 Dry matter yields (t.DM ha⁻¹ year⁻¹) at Ås, Lännäs, and Röbbäcksdalen for each production year (2021-2023). Bars represent 95% confidence intervals, modified according to Tukey’s test, and can be used for comparing means within production years and within sites.

At Röbbäcksdalen, there was no first harvest in 2021. The second-cut yields are not included in Figure 4, but are shown in the Appendix. In the second production year, red clover greatly outyielded all other cultivars. There were few yield differences between lucerne cultivars; however this does not give a complete view of the cultivars because some treatments had a lot more weeds in the plots than others. For example, averaged across all plots and harvests in 2022, Yngve had 2% weeds, Karlu had 19% weeds, Ludvig had 28% weeds and Nexus had 65% weeds (Table 2). In the third production year,

the red clover yield was lower than the previous years, but still greater than all lucerne cultivars. In contrast, most of the lucerne cultivars had greater yield than in the previous production year. Averaged across all plots and harvests in 2023, Yngve had 5% weeds, Karlu had 13% weeds, Ludvig had 9% weeds, Jögeva 118 had 19% weeds, and Nexus had 40% weeds. Based on the combination of good yield and lower weeds, Karlu, Ludvig, and Jögeva 118 were the best lucerne cultivars at Röbbäcksdalen. It is difficult to compare them to red clover due to the poor nodulation of the lucerne, and consequent effect on stand density.

Table 2 Estimated percentage of weeds at harvest, averaged over 2 harvests and 4 plots, at Röbbäcksdalen.

Species and cultivar	2022	2023
<i>Red clover</i>		
SW Yngve	2	5
<i>Blue lucerne</i>		
SW Nexus	65	40
Ludelis	78	57
Mezzo	76	51
<i>Hybrid lucerne</i>		
Ludvig	28	9
Saskia	67	41
Jögeva 118	31	19
<i>Yellow lucerne</i>		
Karlu	19	13
Juurlu	29	30
Sholty	86	94
Don	77	75

At Lännäs, most lucerne cultivars grew well in 2021, and there were few significant differences, with the exception of Sholty and Don being comparatively lower yielding. The pattern between cultivars was similar to that of Ås. The second production year results are not as useful due to problems previously described.

Yield by harvest

There were differences between cultivars in the distribution of yield between harvests. An example of this for Ås in 2021 is detailed in Table 3. For Ludelis, Mezzo, Jögeva 118 and Juurlu there was no difference in yield between harvests. The first harvest yielded 42% more than the second harvest for Yngve red clover, and 18% more for Karlu. The second harvest yielded greater than the first harvest for Nexus (+14%), Ludvig (+23%), Saskia (+55%), Sholty (+68%), and Don (+74%). Although these are the data for just one site and year, similar results were found for other years and locations. The differences in yield distribution mean that seed mixtures could be designed to have a more even distribution of yield between harvests, if desired. Plants will also perform differently when in competition with other species, so it is important to test new species and cultivars in mixtures.

Table 3 Dry matter yields (kg.DM ha⁻¹) at Ås for 2021. Values are least squares means. Different letters indicate significant differences ($P < 0.05$) between cultivars, within that harvest period, according to Tukey's test. Asterisks indicate a significant change between the two harvests ($P < 0.05$); ns means non-significant.

Species and cultivar	Harvest 1		Harvest 2		Time
<i>Red clover</i>					
SW Yngve	4021	ab	2832	c	*
<i>Blue lucerne</i>					
SW Nexus	3554	b	4042	ab	*
Ludelis	3944	ab	3736	ab	ns
Mezzo	3732	b	4090	ab	ns
<i>Hybrid lucerne</i>					
Ludvig	3331	bc	4090	ab	*
Saskia	2359	cd	3664	b	*
Jögeva 118	4309	ab	4274	a	ns
<i>Yellow lucerne</i>					
Karlu	4906	a	4163	ab	*
Juurlu	3712	b	3994	ab	ns
Sholty	1760	d	2956	c	*
Don	1634	d	2836	c	*
Standard error	299.6		170.4		
p-value	<0.001		<0.001		

Table 4 Autumn regrowth of different cultivars (4 replicates) in 2021 based on a rating of 1-3. Different letters indicate significant differences between cultivars ($P < 0.05$) according to Tukey's test.

Species and cultivar	2021	
	Vigour rating	
<i>Red clover</i>		
SW Yngve	3.0	a
<i>Blue lucerne</i>		
SW Nexus	3.0	a
Ludelis	3.0	a
Mezzo	3.0	a
<i>Hybrid lucerne</i>		
Ludvig	3.0	a
Saskia	3.0	a
Jögeva 118	2.0	b
Saaremaa kohalik	1.75	bc
<i>Yellow lucerne</i>		
Karlu	2.0	b
Juurlu	1.75	bc
Sholty	1.0	d
Don	1.25	cd
Standard error	0.129	
p-value	<0.001	

Autumn activity

To describe the differences between cultivars in the way in which they re-grow in autumn, we established a simple rating system from 0-3, which is depicted in Figure 5. The assessment was made at Röbbäcksdalen on 21/09/2021.

The results from Röbbäcksdalen (Table 4) show that three blue lucerne cultivars (SW Nexus, Ludelis and Mezzo) and two hybrid lucerne cultivars (Ludvig and Saskia) had higher autumn regrowth than other cultivars. In 2021 at Ås, selected cultivars were harvested a third time – these were the same cultivars that were scored with an Autumn regrowth rating of 3.

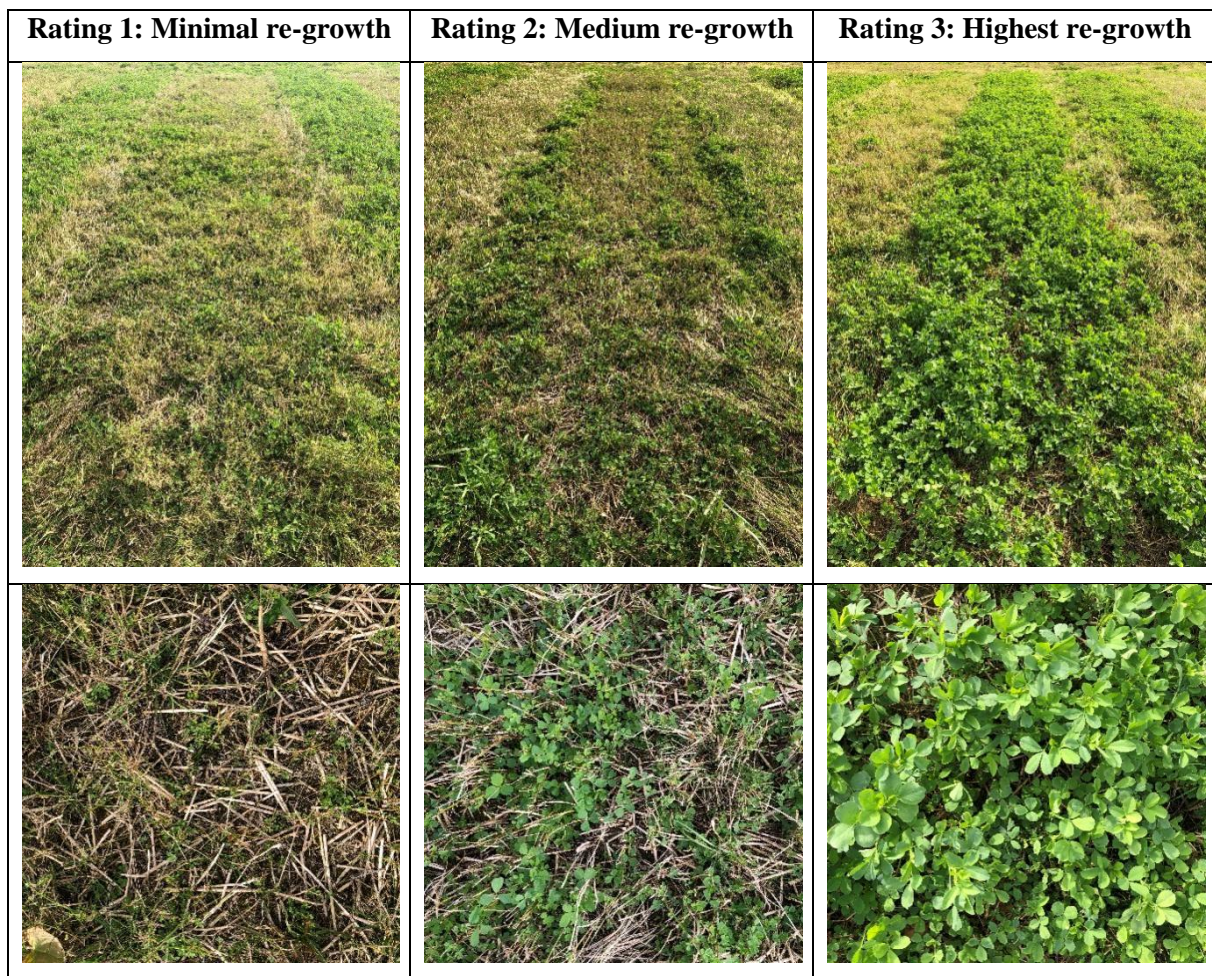


Figure 5 Autumn regrowth vigour of different lucerne cultivars (Pictures from left to right: Sholty, Jögeva 118 and Ludvig). Photos: Lin Tang.

Both production potential and persistence are traits of interest. Winter survival of lucerne is linked with dormancy. Plants which do not become sufficiently dormant early enough may be damaged by autumn frosts, and by subsequent winter stressors. Management is also a part of the equation, because plants respond to harvesting by using their root reserves to produce new growth, until photosynthesis can again provide sufficient carbohydrates. If harvesting occurs late in the season, and plants use their root reserves but are then unable to grow sufficiently to replenish root reserves, then this is likely to severely affect winter survival. This is an important research question for Northern Sweden, where the

winters are harsh and the growing season is short. It could be advantageous to have a cultivar with early dormancy that would coincide with timing of a (potentially later than normal) third harvest.

Forage quality

Forage samples were collected for all sites at all harvests. Samples from Lännäs at both harvests in 2021 were analysed for neutral detergent fibre, *in-vitro* digestibility (Table 5), ash, and crude protein (Table 6). For the 1st harvest, the red clover and one yellow lucerne cultivar (Juurlu) had a higher crude protein than another yellow lucerne cultivar (Don), but no other significant differences were found among other cultivars. There were no significant differences in crude protein among any cultivars at harvest 2. All cultivars had significantly higher crude protein content at the 2nd harvest than the 1st harvest. For *in-vitro* digestibility, at 1st harvest, there were no significant differences among any cultivars. At 2nd harvest, all but one (Sholty) had lower in-vitro digestibility than red clover. One hybrid lucerne cultivar (Saskia) and four blue lucerne cultivars had significantly lower in-vitro digestibility at the 2nd harvest than the 1st harvest.

Table 5 Neutral detergent fiber (NDF) and organic matter digestibility (OMD, VOS method) of all tested cultivars for Lännäs in 2021. Different letters indicate significant differences ($P < 0.05$) between cultivars, within that harvest period, according to Tukey's test. Asterisks indicate a significant change between the two harvests ($P < 0.05$); ns means non-significant.

Treatment	Cultivar	NDF (% DM)			OMD (% DM)		
		Harvest 1	Harvest 2	Time	Harvest 1	Harvest 2	Time
1	SW Yngve	38.4 ^a	36.8 ^b		84.3 ^a	78.2 ^a	ns
2	SW Nexus	38.7 ^a	44.2 ^{ab}	*	81.6 ^a	69.7 ^b	*
3	Ludvig	40.7 ^a	44.2 ^{ab}	*	78.3 ^a	69.1 ^b	ns
4	Sholty	37.2 ^a	40.1 ^{ab}	*	83.0 ^a	72.2 ^{ab}	ns
5	Don	42.3 ^a	45.5 ^a	*	77.8 ^a	69.8 ^b	ns
6	Karlu	41.3 ^a	45.5 ^a	*	78.3 ^a	69.9 ^b	ns
7	Juurlu	42.0 ^a	45.7 ^a	*	77.9 ^a	68.6 ^b	ns
8	Saskia	35.8 ^a	44.6 ^{ab}	*	82.4 ^a	68.8 ^b	*
9	Ludelis	35.9 ^a	44.6 ^{ab}	*	84.0 ^a	67.5 ^b	*
10	Mezzo	39.0 ^a	43.1 ^{ab}	*	79.7 ^a	68.7 ^b	*
11	Jögeva 118	41.2 ^a	46.7 ^a	*	76.8 ^a	66.2 ^b	*
12	Saaremaa kohalik	40.9 ^a	45.3 ^{ab}	*	78.6 ^a	69.5 ^b	ns
	Standard Error	2.38	1.73		0.694	1.52	

Table 6 Crude protein and ash concentrations of all tested cultivars for Lännäs. Different letters indicate significant differences ($P < 0.05$) between cultivars, within that harvest period, according to Tukey's test. Asterisks indicate a significant change between the two harvests ($P < 0.05$); ns means non-significant.

Treatment	Cultivar	Crude protein (% DM)			Ash (% DM)		
		Harvest 1	Harvest 2	Time	Harvest 1	Harvest 2	Time
1	SW Yngve	16.3 ^a	20.3 ^a	*	8.19 ^{ab}	8.30 ^a	*
2	SW Nexus	14.1 ^{ab}	18.1 ^a	*	7.68 ^{ab}	7.11 ^{bc}	ns
3	Ludvig	15.6 ^{ab}	19.0 ^a	*	8.00 ^{ab}	7.30 ^{abc}	ns
4	Sholty	12.8 ^{ab}	18.7 ^a	*	8.60 ^a	8.17 ^{ab}	ns
5	Don	11.4 ^b	18.3 ^a	*	7.85 ^{ab}	7.39 ^{abc}	ns
6	Karlu	14.5 ^{ab}	19.9 ^a	*	7.32 ^b	6.62 ^c	ns
7	Juurlu	16.0 ^a	19.5 ^a	*	7.92 ^{ab}	6.54 ^c	*
8	Saskia	14.8 ^{ab}	18.7 ^a	*	8.35 ^{ab}	6.94 ^c	*
9	Ludelis	14.2 ^{ab}	17.8 ^a	*	8.04 ^{ab}	7.30 ^{abc}	ns
10	Mezzo	13.3 ^{ab}	18.4 ^a	*	7.67 ^{ab}	7.11 ^{bc}	ns
11	Jögeva 118	14.5 ^{ab}	17.7 ^a	*	8.30 ^{ab}	6.59 ^c	*
12	Saaremaa kohalik	15.1 ^{ab}	19.8 ^a	*	7.60 ^{ab}	6.56 ^c	ns
	Standard Error	0.874	2.45		0.251	0.236	

Field experiment 2 – Mixed stands

The mixed grass-legume experiment was measured for two production years, and will be continued in 2024 and potentially beyond. The lack of weeds in the plots was noticeable, which is a contrast to the pure legume experiment. No plot was measured to have more than 1% weeds on a dry matter basis in any of the harvests. Examples of plots are shown in Figure 6.



Figure 6 Example plots from the grass/lucerne experiment before the second harvest (July 31st 2023). The left plot is Karlu, with lucerne height 80 cm and lucerne/grass yield 4020 kg/ha. The right plot is Ludvig with lucerne height 83 cm and lucerne/grass yield 4340 kg/ha. Photos: Nathan Berezyiat.

Spring density

The total (legume-grass) spring density (Figure 7) was greater than 95% for all treatments in the first production year, and greater than 90% for all except Yngve red clover in the second production year. The remaining percentage to add up to 100% is bare ground.

In the second year, Yngve had a greater legume plant density than all treatments except Ludvig, but more bare ground, due to a lower grass component. In the second production year, Don and Sholty had a lower legume density than all other treatments. The legume density of most treatments (except Yngve and Sholty) declined from the first to the second production year.

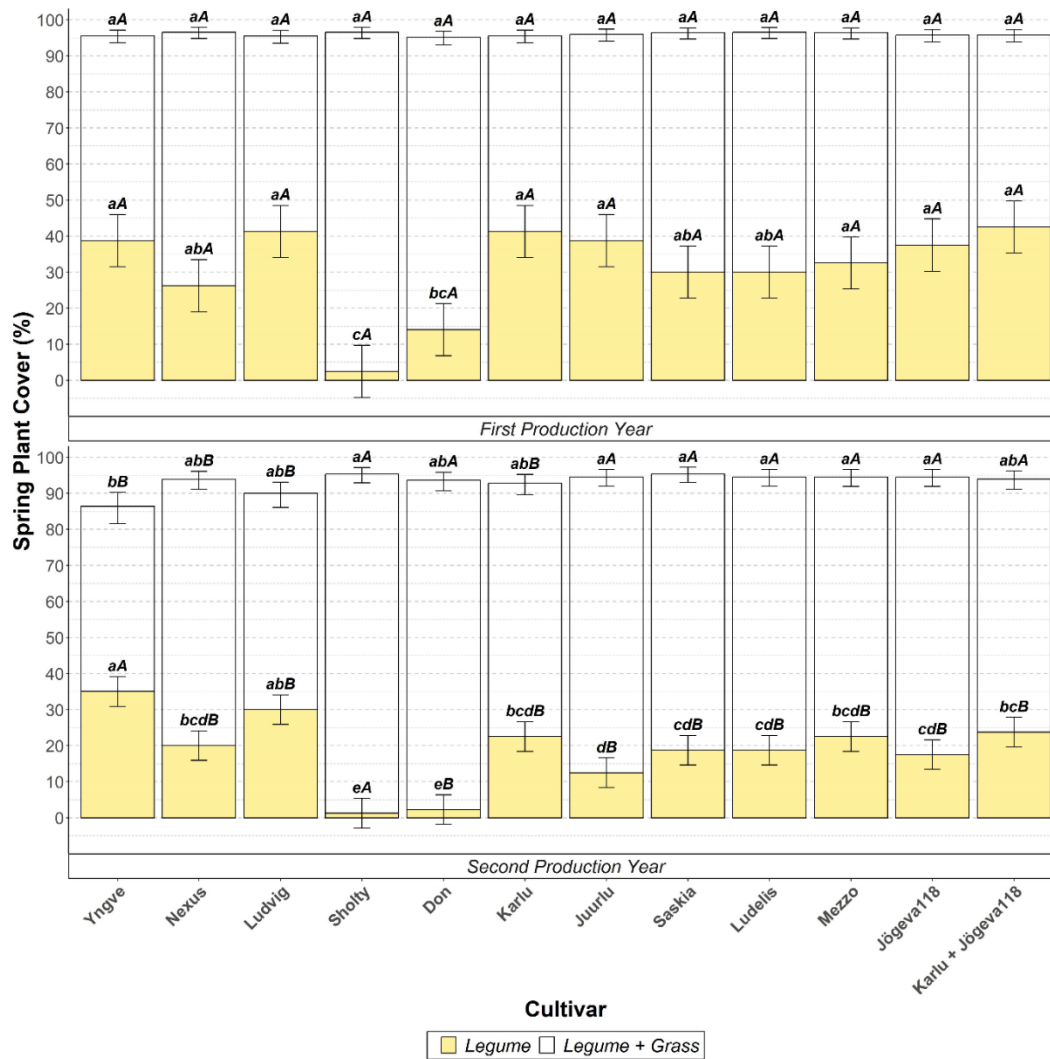


Figure 7 Spring density results for grass-legume plots during two production years (2022 and 2023). Bars represent 95% confidence intervals, modified according to Tukey's test. Clear columns represent total yields and coloured columns represent legume yields. Different lower-case letters indicate significant differences between cultivars ($P < 0.05$) for a plant type (legume or total) within a year, according to Tukey's test. Different upper-case letters indicate significant differences between years for a given treatment (legume or total).

Autumn density

Data were collected but not presented in this report. They are not consistent due to the different growth stages.

Legume dry matter yield

In the first production year the legume yield of Yngve was not significantly different to that of Karlu or Karlu + Jögeva 118 (Figure 8). All other treatments had a lower legume yield. In the second production year, the legume yield of Yngve was not significantly different to that of Ludvig, Karlu, or Mezzo. The yields of Yngve, and various lucerne cultivars were greater in the second than the first production year.

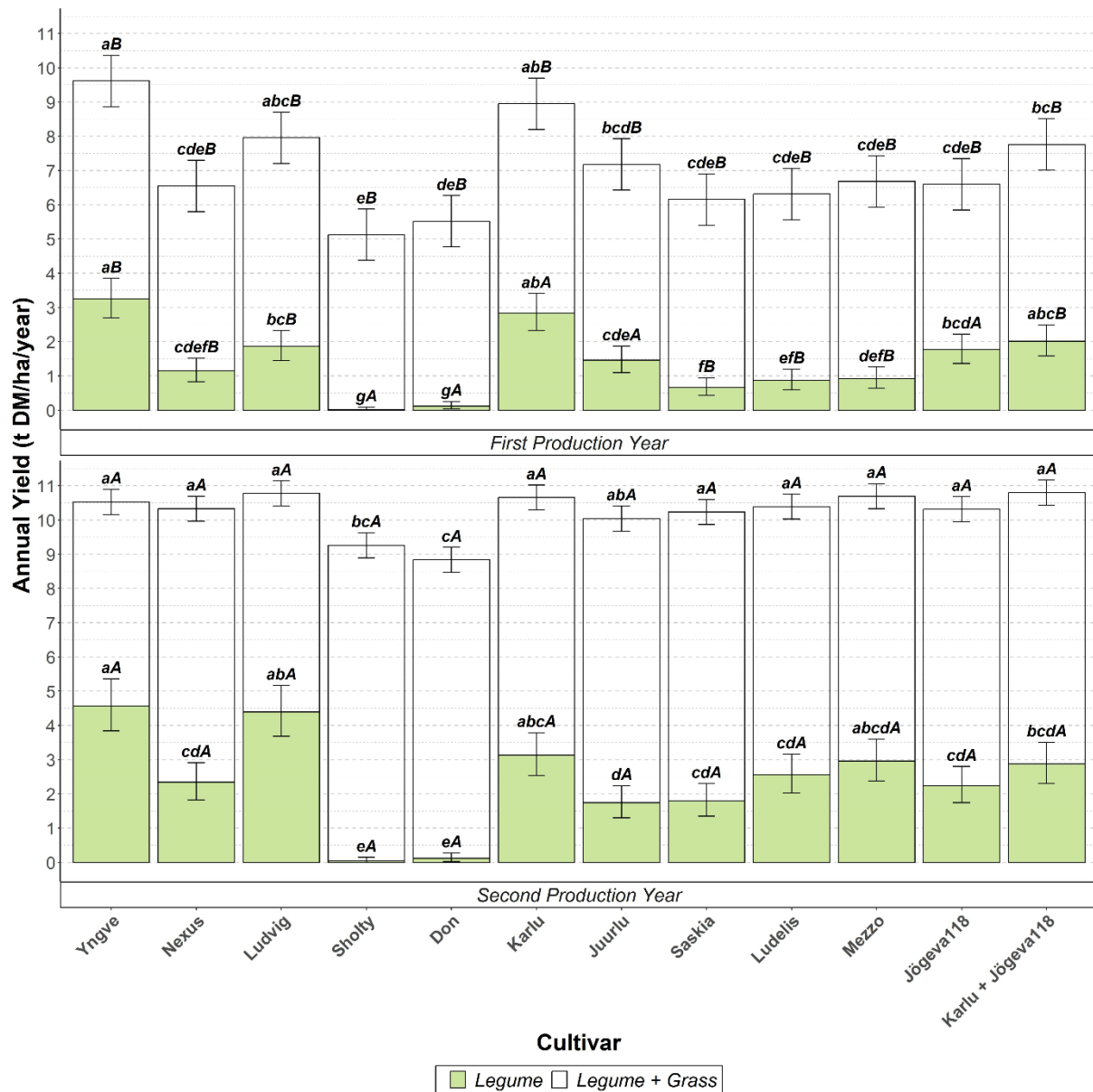


Figure 8 Dry matter yield results for grass-legume plots during two production years (2022-2023). Bars represent 95% confidence intervals, modified according to Tukey's test. Clear columns represent total yields and coloured columns represent legume yields. Different lower-case letters indicate significant differences between cultivars ($P < 0.05$) for a plant type (legume or total) within a year, according to Tukey's test. Different upper-case letters indicate significant differences between years for a given treatment (legume or total).

Total dry matter yield

In the first production year, there were differences in total dry matter yield – these reflected the legume yields. i.e. treatments with greater legume yield had greater overall yield (Figure 8). There were no significant differences in the grass component of the different treatments (statistical results not shown). This is potentially because the grass was constrained by available nitrogen. In the second production year there were fewer differences between treatments, and only treatments with Sholty and Don had lower total yield than others. This is likely because the nitrogen fertilizer rates were higher in the second year, and the grass was more constrained by competition with lucerne than by nitrogen.

These results show that swards with red clover or lucerne can yield higher than swards dominated by grass. If nitrogen is limiting then the difference in yield can be substantial.

In general, the yield results suggest that numerous lucerne cultivars can be grown in a mixed sward with Timothy.

Glasshouse experiment – effect of pH on inoculation

The pH(CaCl₂) ranged from 5.1-5.4 at the beginning of the experiment to 5.2-5.7 at the end of the experiment, which means that the pH(CaCl₂) was quite stable during the experiment. In contrast, the pH(H₂O) was 5.7 before lime addition, ranged from 6.0-6.4 at the beginning of the experiment, and 6.5-6.8 at the end of the experiment. We are not sure why the pH(H₂O) increased even in the pots that received no lime, and continued to increase during the experiment. As a result of the experimental pH levels, we were not able to observe clear pH stress in the plants. There was no effect on plant height or biomass (below or above ground). However there were significant effects of pH treatments on the number of nodules and the number of nodule clusters (colonies of multiple nodules) (Figure 9).

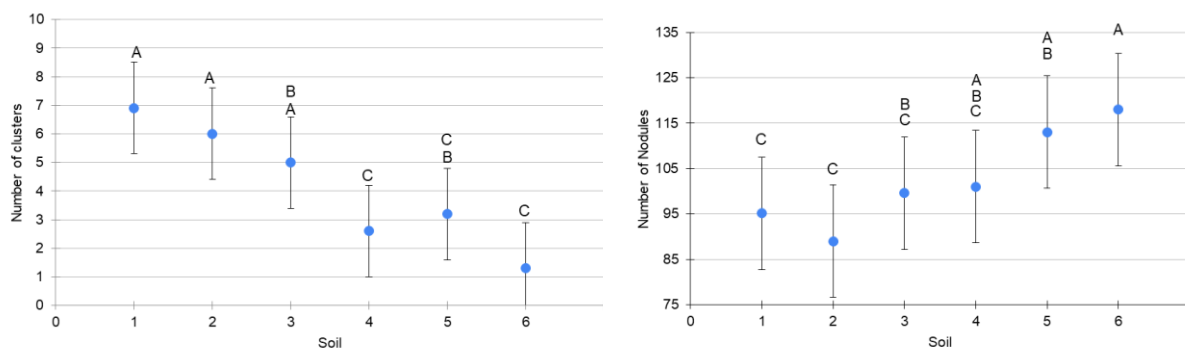


Figure 9 (a) Mean number of clusters for the soils. (b) Mean number of nodules for the soils. Soils with the same letter are not significantly different to each other. The error bars mark the 95% confidence interval.

The results highlight the pH-sensitive nature of the Rhizobia and indicate a nodulation trend, where nodules go from few but large at lower pH to small and many as pH increases. The results also confirm that the inoculum (Nitragin Gold) was compatible with both lucerne cultivars.

General Discussion

The results suggest that there are differences between lucerne cultivars that affect their establishment, winter survival and productivity. Ideally we are looking for cultivars with a good balance between survival and production.

The results so far suggest that selected hybrid and yellow lucerne cultivars could have the potential to be used as alternative forage species in Northern Sweden. However, they are not suitable for all locations, and further research is needed before they can be confidently recommended. General experience with these species suggests that sloped topography, with subsoils that are not acidic, are most suitable. Lucerne has potential for cultivation in locations where there is high clover rot pressure, such as Ås. In comparison with red clover, lucerne is slower to re-grow in the spring, potentially leaving it susceptible to weeds, and thus pairing with appropriate companion grasses is another important area of research. The grass-lucerne experiment at Röbbäcksdalen suggests that lucerne can grow well with Timothy; however testing it with other grass species and in more biodiverse swards would also be interesting.

The glasshouse study and the field studies in general suggest that the typical inoculant strain used in Sweden was adequate for nodulation of all cultivars. However, establishment is risky, particularly in locations where lucerne has not previously been grown, because of the critical process of nodulation, which can sometimes fail. To minimize establishment risk, we suggest the following practices: 1) Site selection (as mentioned above); 2) Suitable pH, approximately above 6 (in H₂O), however we cannot give exact recommendations; 3) Adequate nutrients, particularly P and K, determined through soil sample analysis before sowing; 4) Fresh inoculation of the seed, preferably including a process of seed coating.

Management of lucerne in autumn and its link with winter survival is a research question that requires further investigation. Harvesting late in the season can severely affect winter survival if the plants have not yet become dormant. A two-cut system will likely waste a lot of late-season growth, whereas a 3-cut system has the potential to negatively effect persistence, if clear management recommendations are not provided. The solution to this is matching the desired harvesting scheme with cultivars of a suitable dormancy type.

Recommendations for further research are as follows:

- Which soil types in Northern Sweden can support good yield and persistence of lucerne?
- For establishing lucerne, what pH level is adequate?
- How does lucerne perform when added to current commercial seed mixes? Can it be a useful component of biodiverse leys?
- In a 3-cut system, how can lucerne be managed to ensure persistence?

- Is there potential to breed new lucerne cultivars suited to Northern Sweden? Are there other interesting cultivars that we have not yet tested?
- Are there differences between lucerne species and cultivars in response to disease pressure?
- What are the implications for animal feeding of having more lucerne and less red clover in a silage?

Student involvement

Katarina Boström conducted her SLU Master thesis within the project.

International students were part of the project. Nathan Berezyiat (France) was strongly involved with the project in terms of data collection, data organisation, and statistical analysis. Camilla Destefanis (Italy) assisted with data collection.

International collaboration

A consortium on growing lucerne was established in 2020 by the project team, and includes Sweden (SLU), Finland (LUKE), Norway (NIBIO), and Iceland (Agricultural University of Iceland). The same cultivars were used in each country, and each organisation is assessing the experiments through obtaining their own funding. A publication is planned utilising the data from all countries.

Project outputs

- Master thesis, Katarina Boström. “Nodulation and biomass development of yellow and blue lucerne under pH stress”.
- Paper and poster, Vallkonferens, February 2023, “Utvärdering av gul- och hybridlusern som vallbaljväxter i norra Sverige”.
- Abstract and presentation, NJF conference, Iceland, September 2022, “Evaluation of yellow and hybrid lucerne as forage crops for northern latitudes”.
- Vallbrev article, December 2022, “Utvärdering av gul- och hybridlusern som vallbaljväxt i norra Sverige”.
- Scientific publications are planned.

Presentations

- Ämneskommitte Vall och Grovfoder, March 2021, “Utvärdering av gullusern som en potentiell framtida fodergröda”.
- NJF conference, Iceland, September 2022, “Evaluation of yellow and hybrid lucerne as forage crops for northern latitudes”.
- Field walk and presentation to farmers, Ås, August 2023.
- Presentation to Växadagarna, Umeå, January 2024, “Kan vi odla lusern i Norrland”.

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- The field stations involved in the experiments not only conducted the field work but offered their ideas and enthusiasm.
- Many additional people assisted with field work and sample management, including summer employees, international students and SLU staff (particularly Sanna Bergqvist and Brooke Micke).
- Göran Bergqvist assisted with student supervision.
- Seed was kindly supplied by DLF, Estonian Crop Research Institute, Lantmännen, Millborn Seeds, Naturcom, and NIBIO.

Scientific contributions to the project

David Parsons; project concept, application writing, project management, data collection, data management, statistical analysis, presentations, report writing. Lin Tang; project management, data collection, data management, statistical analysis, report writing. Mukhtar Ahmed; application writing, project management, data collection. Nathan Berezyiat; data collection, data management, statistical analysis. Linda Öhlund; project concept, project management.

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Appendix 1 – Additional Figures

Spring density

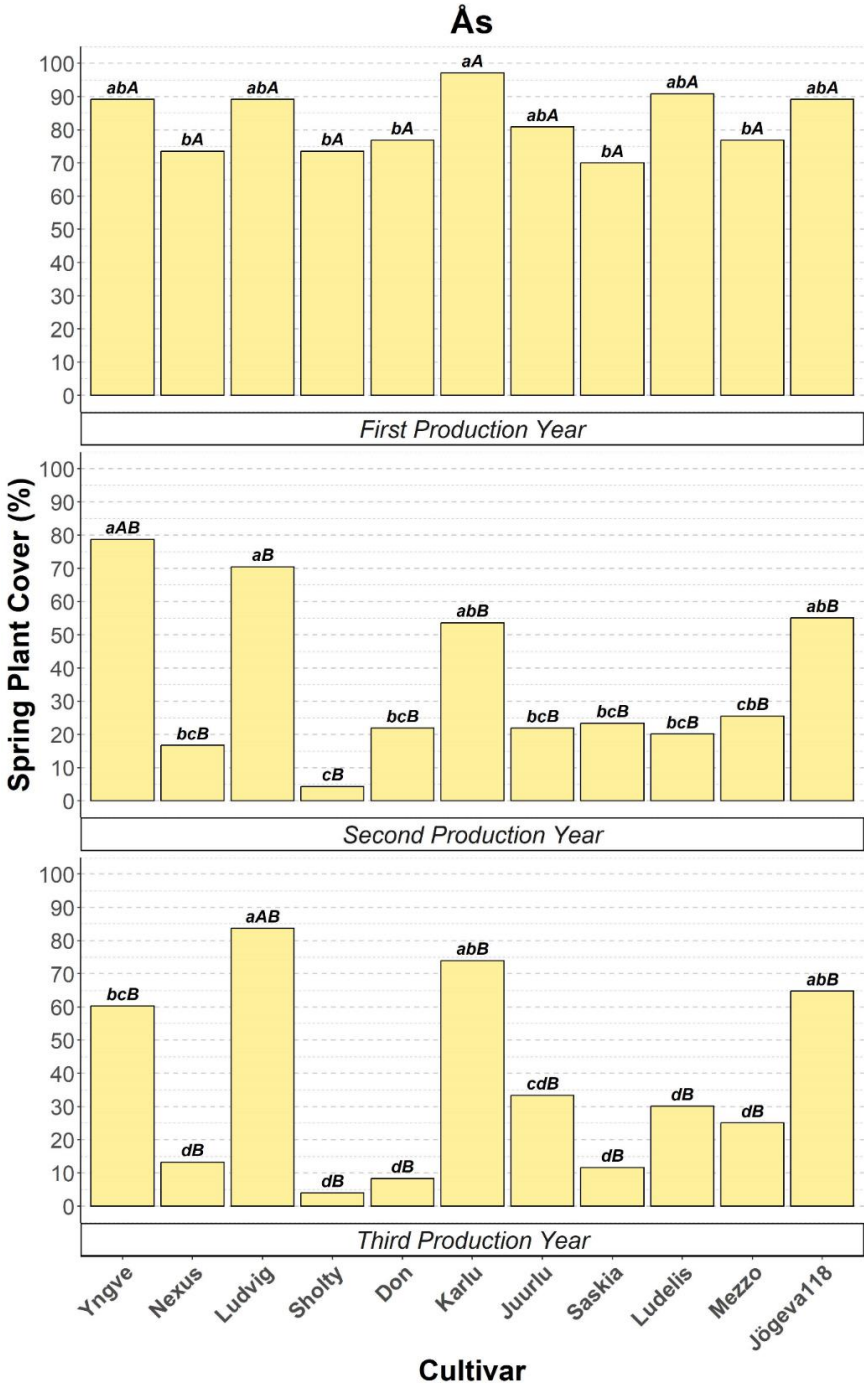


Figure 10 Spring plant density (%) of all tested cultivars at Ås for each year (2021-2023) and combined across years. Different lower-case letters indicate significant differences between cultivars ($P < 0.05$) within a year, according to Tukey's test. Different upper-case letters indicate significant differences between years ($P < 0.05$) for individual cultivars.

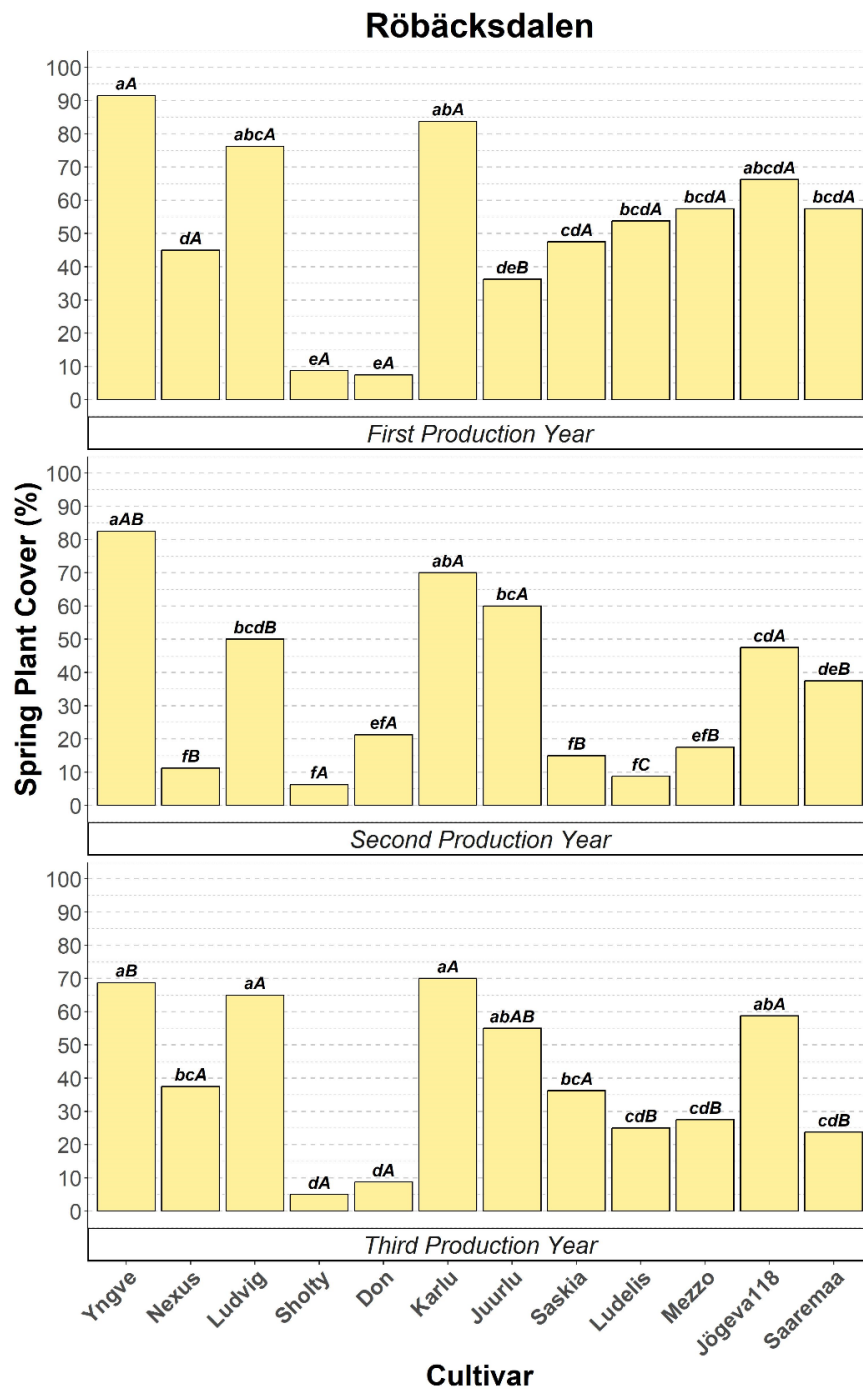


Figure 11 Spring plant density (%) of all tested cultivars at Röbäcksdalen for each year (2021-2023) and combined across years. Different lower-case letters indicate significant differences between cultivars ($P < 0.05$) within a year, according to Tukey's test. Different upper-case letters indicate significant differences between years ($P < 0.05$) for individual cultivars.

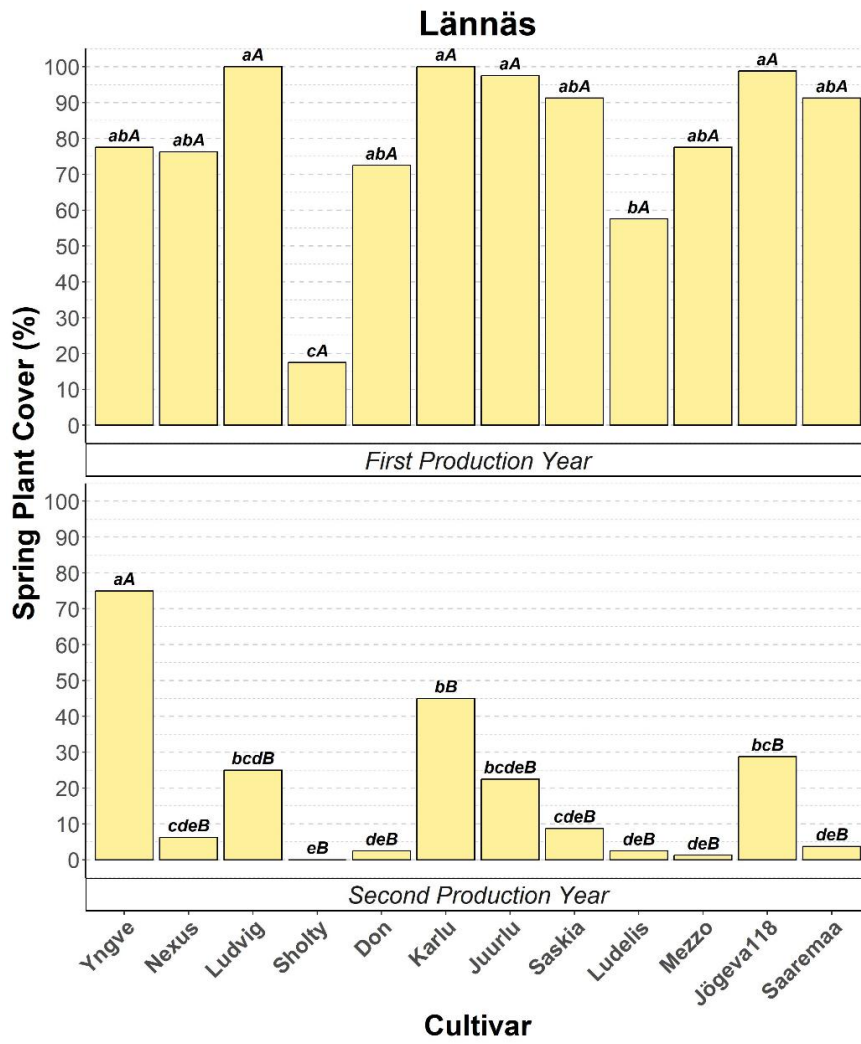


Figure 12 Spring plant density (%) of all tested cultivars at Lännäs for each year (2021-2022) and combined across years. Different lower-case letters indicate significant differences between cultivars ($P < 0.05$) within a year, according to Tukey's test. Different upper-case letters indicate significant differences between years ($P < 0.05$) for individual cultivars.

Dry matter yield

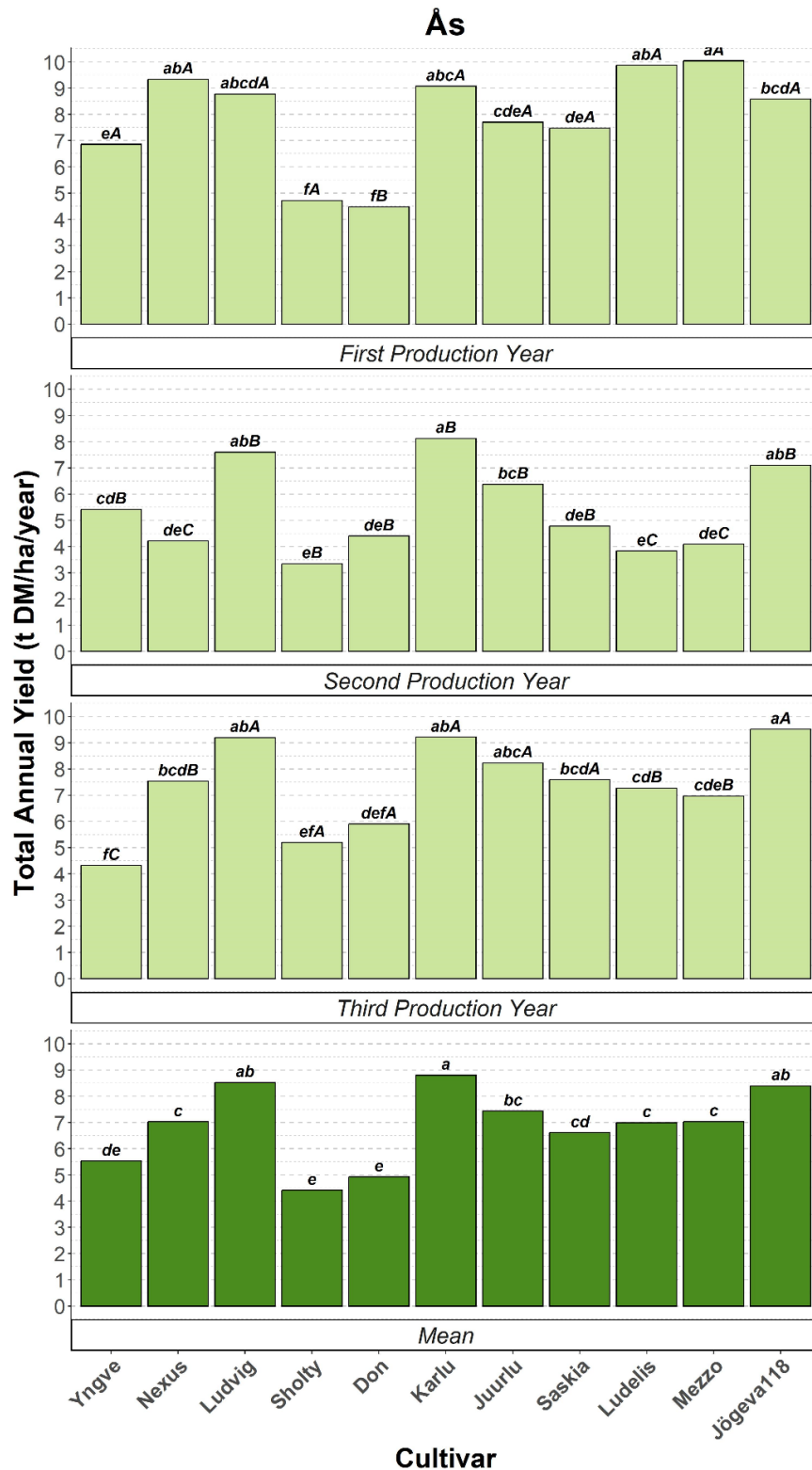


Figure 13 Dry matter yields ($\text{kg DM ha}^{-1} \text{ year}^{-1}$) at Ås for each year (2021-2023) and combined across years. Different lower-case letters indicate significant differences between cultivars ($P < 0.05$) within a year, according to Tukey's test. Different upper-case letters indicate significant differences between years ($P < 0.05$) for individual cultivars.

Röbäcksdalen

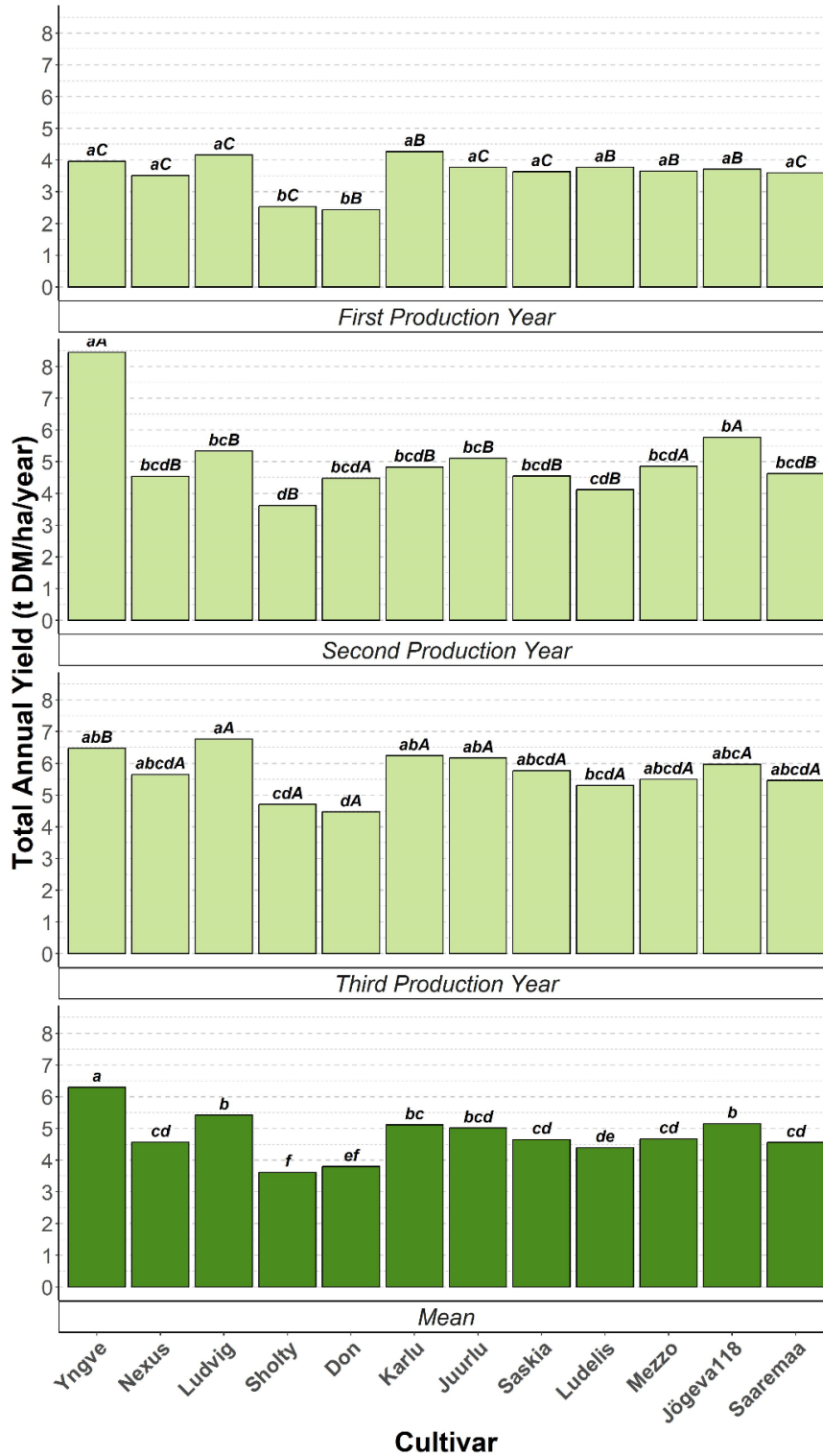


Figure 14 Dry matter yields ($\text{kg.DM ha}^{-1} \text{ year}^{-1}$) at Röbäcksdalen for each year (2021-2023) and combined across years. Different lower-case letters indicate significant differences between cultivars ($P < 0.05$) within a year, according to Tukey's test. Different upper-case letters indicate significant differences between years ($P < 0.05$) for individual cultivars.

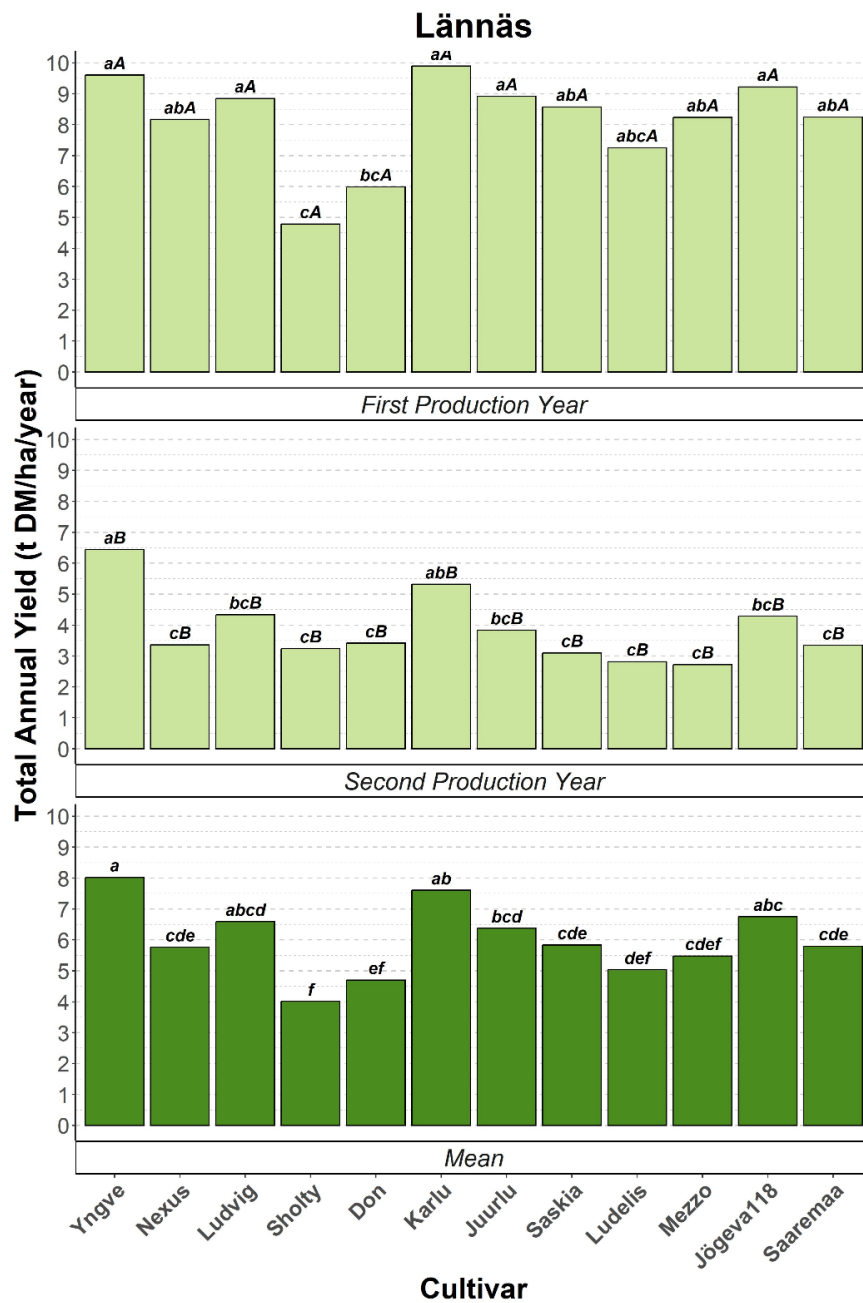


Figure 15 Dry matter yields (kg.DM ha⁻¹ year⁻¹) at Lännäs for each year (2021-2022) and combined across years. Different lower-case letters indicate significant differences between cultivars ($P < 0.05$) within a year, according to Tukey's test. Different upper-case letters indicate significant differences between years ($P < 0.05$) for individual cultivars.