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Suitability of Different Cover Crop Mixtures and Seedlings for a New Tree Row Management in an Organic Orchard

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Abstract In organic orchards disadvantages within the tree row weed management include tree damages, soil structure disturbance and humus erosion due to bare soil.

As a solution to this problem the Sandwich system was developed at the Research Institute of Organic Agriculture (Frick, CH). Hereby the tree row is planted and strips right and left of the tree row are hoed mechanically.

Grasses, legumes and grasses-legume mixtures were tested to identify suitable species for the tree row. *Lolium perenne* L., different *Festuca* species and subspecies, *Poa pratensis* L., *Trifolium pratense* L., Swiss and imported (i.e. European) ecotypes of *Lotus corniculatus* L. and *Medicago lupulina* L. were chosen. Additionally seedlings of *Potentilla reptans* L. and the allelopathic *Hieracium pilosella* L. were planted.

Evenness, plant height and vegetation cover were monitored over one vegetation period. *L. perenne* turned out to be dominant; *M. lupulina* was more competitive as an imported ecotype whereas the reverse was shown for the Swiss ecotype of *L. corniculatus* in species-poor mixtures.

The establishment of *P. reptans* was higher (nearly 100%) compared to *H. pilosella*. Both species showed the lowest height and due to these results future orchard tree row management research should focus on low-growing, stolon-building species.

Keywords Sandwich system · Tree row management · Cover crops · Organic orchard · Weeds · Allelopathy

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Eignung diverser Einsaatpflanzen und -mischungen für ein neues Konzept der Baumstreifenbegrünung im biologischen Obstbau

Zusammenfassung Bei der Beikrautregulierung im biologischen Obstbau innerhalb des Baumstreifens können Baumverletzungen, massive Eingriffe in die Bodenstruktur und die durch einen unbegrünten Boden erhöhte Gefahr der Humusabtragung auftreten.

Um dem entgegenzuwirken, wurde am Forschungsinstitut für Biologischen Landbau (Frick, CH) das Sandwich-Verfahren entwickelt. Bei diesem kombinierten Hack- und Begrünungsverfahren wird der Baumstreifen begrünt und rechts und links der Begrünung gehackt.

Um geeignete Begrünungspflanzen und -mischungen für den Sandwich-Baumstreifen zu identifizieren, wurden Gräser-, Leguminosen- und Gräser-Leguminosenmischungen aus *Lolium perenne* L., verschiedenen *Festuca*-Arten und -Unterarten, *Poa pratensis* L., *Trifolium pratense* L. und Schweizer und importierten (europäischen) Ökotypen von *Lotus corniculatus* L. und *Medicago lupulina* L. angepflanzt. Zusätzlich wurden Setzlinge von *Potentilla reptans* L. und der allelopathischen *Hieracium pilosella* L. angelegt. Die Gleichmäßigkeit des Auflaufs, Wuchshöhe und der Deckungsgrad wurden über eine Vegetationsperiode untersucht. *L. perenne* war sehr dominant, *M. lupulina* war als importierter Ökotyp konkurrenzstärker, *L. corniculatus* ist als Inlandökotyp in artenarmen Mischungen konkurrenzstärker.

H. pilosella zeigte nach einer Vegetationsperiode einen geringeren Deckungsgrad als *P. reptans* (beinahe 100 %). Beide zeigten im Gegensatz zu allen anderen Mischungen die niedrigste Wuchshöhe. Aufgrund der erzielten Ergebnisse sollten sich zukünftige Untersuchungen im Bereich

der Baumstreifenbegrünung auf die Eignung niedrigwüchsiger Ausläufer bildender Arten richten.

Schlüsselwörter Sandwich-System · Baumstreifenmanagement · Begrünung · Biologischer Obstbau · Beikräuter · Allelopathie

Introduction

The tree row weed management in any orchard is of major importance because it affects the vegetative and generative productivity of fruit trees.

To maximize and sustain the output of an orchard weeds in the tree row have to be controlled efficiently. There are many approaches in conventional and organic agriculture to this problem (Fischer 2002; Granatstein 2007; Himmelsbach and Kleisinger 1995a, b). If herbicides are not an option (as in organic agriculture) the tree row is either kept open mechanically, covered with mulches (such as straw or bark mulch), synthetic plastic covers or the tree line is completely planted with grass mixtures. However, all techniques have drawbacks. Material and equipment costs are high for the first three options and the high potassium deposition of the mulch technique increases the risk of bitter pit.

Though a complete vegetation cover increases the floristic and faunistic diversity (Altieri and Schmidt 1986; House and Brust 1989; Wyss 1996) and balances soil parameters like soil temperature and water availability it also competes for nutrients and water with the tree leading to less vegetative and generative growth (Glenn and Welker 1991; Hornig and Bünemann 1995; Merwin and Stiles 1994).

If the tree row is mechanically cleared of vegetation the nutrient and water competition is minimized. Nevertheless machine-induced tree damages are common and can lead to bacterial infections. In addition the weed removal adjacent to the trunk is usually insufficient and these clusters have to be eliminated manually (in organic agriculture) or by the use of herbicides (in conventional agriculture) (Himmelsbach and Kleisinger 1995a).

The Sandwich system which can be applied in organically and conventionally managed orchards as an efficient tree row management technique seeks to minimize the disadvantages of a planted (maintenance of a complete tree row vegetation cover) and a mechanically hoed tree row. The Sandwich system was developed at the Research Institute of Organic Agriculture (FiBL) in Switzerland (Schmid and Weibel 2000; Schmid et al. 2004). Hereby the tree row is planted and two approx. 30 cm wide strips right and left of the tree row are hoed. During a three-year trial no differences in leaf and fruit nourishment compared to the mechanical method were detected. The stem diameter was even 11% higher (Schmid et al. 2004) but the vigor of the tree apparently depends highly on the choice of the tree row plant species (Stefanelli et al. 2009).

A tree row vegetation cover should be persistent, competitive against weeds, establish quickly, be low-input, low-cost and low-growing (less than 25 cm to minimize the occurrence of voles which might damage the tree stem and roots). Though the degree of competition differs among varieties the choice of suitable assorted species which fulfill the demands cited above remains a major problem (Neilsen et al. 1999). The tree row in the Sandwich system is usually planted with *Hieracium pilosella,* an allelopathic, low-growing species but it has been reported to lack a quick establishment on limestone-rich soils.

Therefore new and different mixtures have been tested in this study to identify different species which may fulfill the demands of a tree row vegetation cover. We chose different legumes and grasses and combined them to test their suitability and influence on the performance and productivity of the fruit tree. Since it is an inherent value in organic agriculture to prefer native species over foreign ones a comparison of Swiss and imported (i.e. European) low-growing legume ecotypes has been carried out to assess the establishment of the presumably better adapted (and more expensive) Swiss ecotypes in relation to the cheaper European ecotypes. All mixtures were compared to the establishment of seedlings of *H. pilosella*, *Potentilla reptans* (which is an abundant weed in the study area) and a spontaneous vegetation variant as a control where the natural vegetation was left to grow. The results presented here summarize a one-year trial. The overarching goal was to check several new cover crop mixtures for their suitability. Therefore, nutrition and fruit quality data were neglected.

Material and Methods

Site Situation

The experimental orchard is situated in Frick, Switzerland (380 m NN, 900 mm precipitation p.a.). The apple trees were planted in autumn 2006.

The main components of the soil are 47% clay and 4.1% organic matter (Wyss and Weibel 2006). The pool of macronutrients like phosphorous, magnesium, potassium and calcium was identified as "sufficient to available" (Wyss and Weibel 2006). Only four rows of the apple orchard were used for this study (two rows variety Ecolette, two rows variety Opal).

One row consisted of 54 fruit trees and 53 tree row sections (1.5 m × 0.4 m per tree row section). At the beginning of April and in mid-May 2007 20 kg/ha manure were applied.

Height and Evenness

The plant height was determined in four randomly chosen tree row sections per variant on 14.05.07. The same tree row sections were measured again on 12.07.07. The evenness of every seed mixture was estimated over three tree sections (4.5 m × 0.4 m) during each vegetation survey. It was estimated on a scale from 1 (very uneven) to 6 (very even).

The effect on the vegetative growth of the tree was estimated by measuring the stem diameter 25 cm above ground on 14.05.07 and 11.09.07.

Vegetation Survey

Table 1 lists the composition of all ten variants; the spontaneous vegetation variant (= control) is not listed. The mixtures were distributed randomly in each of the four repetitions and planted over three tree distances. The planting took place on 18./19.04.07. *Trifolium pratense* was only available as a Swiss ecotype (indicated by an "i", European ecotypes are indicated by an "a"). *Potentilla reptans* and *Hieracium pilosella* were planted on 9./10.05.07 (four seedlings per tree row section). The installation of the Sandwich strips was delayed until July due to heavy rainfalls after a very long dry period (April–June).

Over the summer of 2007 four vegetation surveys were performed: 14./16.06.07, 11.07.07, 31.07.07 and 1.09.07. During each survey the same tree row section was examined.

To estimate the establishment of the vegetation cover in each variant (in %, including weeds) a 25 × 50 cm cover grid subdivided into 50%, 10%, 2% sections was used. Due to the formation of several vegetation storeys values higher than 100% were included.

Statistical Analysis

The program JMP 5.0 (SAS Incorp.) was used for the statistical analysis. Means were compared using the Tukey-Kramer HSD test.

Results

Plant Height

The average height of the mixed variants (i.e. legumes and grasses) and the grasses variant reached about 10 cm in May 2007 (Fig. 1). The seedlings of *H. pilosella* and *P. reptans* had just been planted a few days ago and were therefore not evaluated. The height of the legume mixtures (i-Leg. and a-Leg.) did not reach up to 5 cm. In the spontaneous vegetation plots (Spont.) no vegetation had grown yet.

In July, the height of all mixtures exceeded the maximum height of 25 cm after which the chance of tree damages by voles is heavily increased. Only the seedlings (P.r. and H.p.) did not grow higher than 25 cm. The maximum height was 12 cm in the *P. reptans* plots.

Table 1 List of all mixtures, their species composition and price. i = Swiss ecotype, all other legumes are European ecotypes. The spontaneous vegetation variant is not listed

	Grasses + Swiss legumes (Gr. + i-Leg.)	Grasses + European legumes (Gr. + a-Leg.)	Grasse + *L. corniculatus* (Gr. + L. c.)	Grasses + *T. pratense* (Gr. + T. p.)	Grasses + *M. Lupulina* (Gr. + M. l.)	Grasses (Gr.)	Swiss legumes (i-Leg.)	European legumes (a-Leg.)	*H. pilosella* (H. p.)	*P. reptans* (P. r.)
L. perenne L.	X	X	X	X	X	X				
P. pratensis L.	X	X	X	X	X	X				
F. guestfalica BOENN. ex. RICHB.	X	X	X	X	X	X				
F. rubra L.	X	X	X	X	X	X				
F. rubra rubra L.	X	X	X	X	X	X				
T. pratense (i) L.	X	X		X			X	X		
M. lupulina L. *(a)*		X						X		
M. lupulina (i) L.	X				X		X			
L. corniculatus L. *(a)*		X						X		
L. corniculatus L. *(i)*	X		X				X			
H. pilosella L.									X	
P. reptans L.										X
Price in € (kg)	21.00	15.00	22.00	37.50	8.50	6.00	21.00	13.00	0.01	–

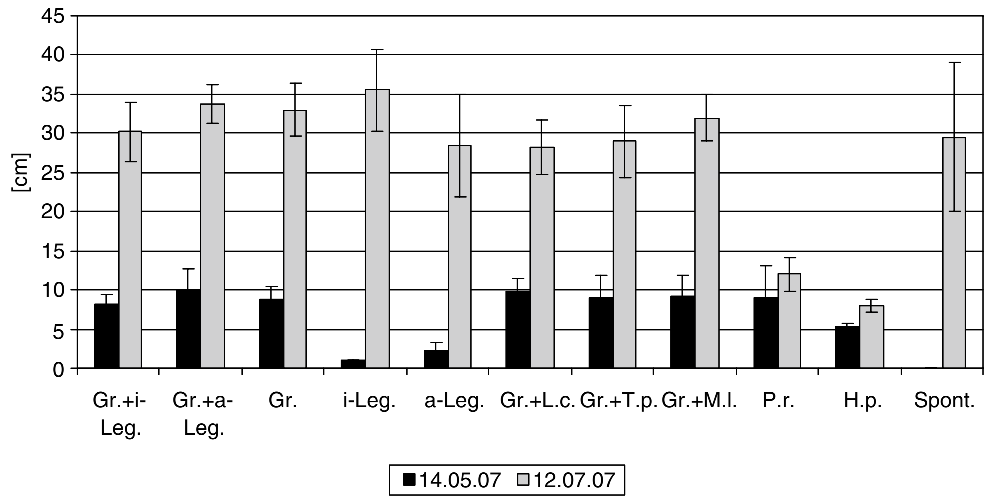

Fig. 1 Mean plant height on 14.05.07 and 12.07.07

Evenness

Grasses Variant

The grasses variant started with an evenness of 4.5 which rose to almost 6 in the last survey (Fig. 2). It showed a relatively quick and even establishment which did not differ significantly from most other variants (exceptions are *H. pilosella* and the spontaneous vegetation variant).

Grasses-Legume Mixtures

The grasses-legume variant (Gr. + a-Leg.) gained the highest value of all variants in the first survey and reached the highest value of evenness in the second which was significantly higher compared to all other variants. The mixed variants reached an evenness of 4. Of all mixtures only the values for the Swiss legumes (i-Leg.) and the grasses-*M. lupulina* variant were lower. The grasses-*T. pratense* variant reached higher values in the second survey (statistically not significant).

However, all grasses-legume mixtures reached the highest value of evenness after the second or third survey.

Swiss and European Legume Ecotypes (i-Leg. and a-Leg.)

The Swiss legume variant (i-Leg.) showed a less even distribution than the European legume variant in the first survey. This is reverse in the second but over all four surveys no significant differences occurred between the two ecotypes.

Seedlings (Potentilla reptans, Hieracium pilosella) *and Spontaneous Vegetation Variant*

The evenness of the *P. reptans* variant was significantly higher than the values for the *H. pilosella* variant. *H. pilosella* did not show a gain in evenness until the last survey. The values for the evenness of *P. reptans* on the other hand increased and showed a very even distribution in the last survey. The maximum value gained by the spontaneous vegetation variant was four in the last survey. It is significantly lower compared to all other variants.

Survey of the Tree Row Vegetation Cover

Grasses

L. perenne was very dominant (Fig. 3, 4); the minimum cover was 54% in the grasses-*T. pratense* variant. The highest value was gained in the grasses variant, followed by the grasses-*M. lupulina* variant and the grasses-*L. corniculatus* variant. The different *Festuca* species and subspecies built a less dense cover. The highest cover was obtained in the grasses variant (4%); values for all other variants were much lower. *Poa pratensis* could not be identified in any tree row section.

Legumes

Trifolium pratense gained a much higher cover in most variants than the other legumes. The grasses:legume ratio was significantly lower compared to the grasses-*M. lupulina* variant and the grasses-*L. corniculatus* variant (Fig. 4). By comparing the grasses-Swiss ecotype legume variant (Gr. + i-Leg.), the grasses-European ecotype variant (Gr. + a-Leg.) and the pure legume variants (i-Leg., a-Leg.) it is evident that *M. lupulina* gained a significantly higher vegetation cover than the Swiss ecotype of *M. lupulina*. The Swiss ecotype of *L. corniculatus* showed a higher cover but these differences were only statistically significant in comparison to the pure legume variants (i-Leg., a-Leg.).

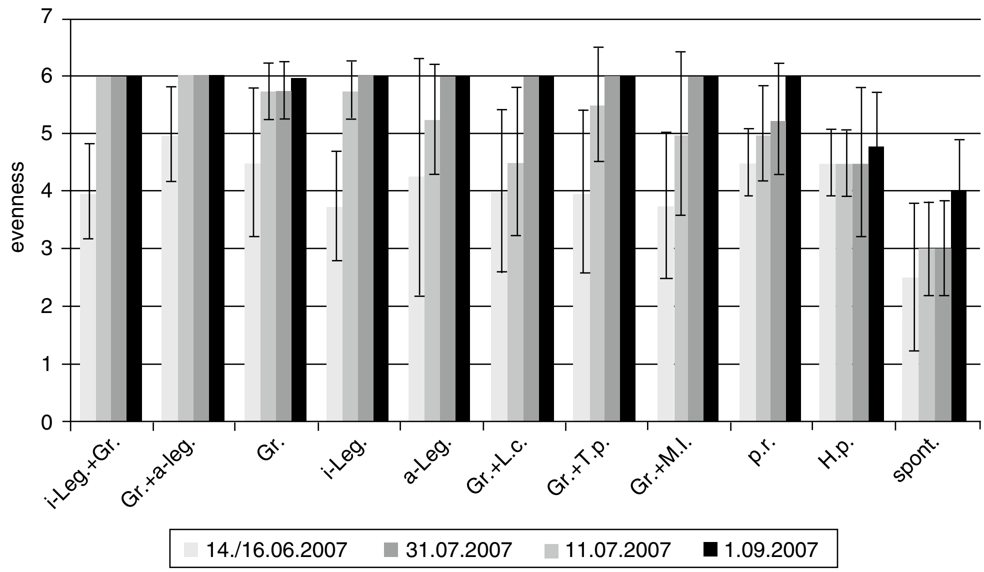

Fig. 2 Survey of the evenness of vegetation ground cover over one vegetation period (June–September 2007). The Tukey-Kramer HSD test ($p<0.05$) shows significant differences in the comparison of means. Variants connected by different letters are significantly different

Variants				Least Sq Mean
Gr.+a-Leg.	A			5.750
Gr.	A	B		5.500
Gr.+i-Leg.	A	B		5.500
Gr.+T.p.		B		5.375
a-Leg.	A	B		5.375
i-Leg.	A	B		5.375
Gr.+M.l.	A	B		5.188
P.r.	A	B		5.188
Gr.+L.c.	A	B		5.125
H.p.		B		4.563
Spont.			C	3.125

Seedlings and Spontaneous Vegetation Variant

H. pilosella established—like the spontaneous vegetation variant—a cover of 51% whereas *P. reptans* established a cover of 66% (Fig. 4). In addition to that, plots planted with *P. reptans* had a lower share of weeds than those planted with *H. pilosella*.

Stem Diameter

The spontaneous vegetation variant (Spont.) had the highest gain in stem diameter followed by the grasses-*T. pratense* variant (Fig. 5). The grasses-*L. corniculatus* variant and the grasses variant showed the lowest increment. All other variants are settled between these two groups. The differences

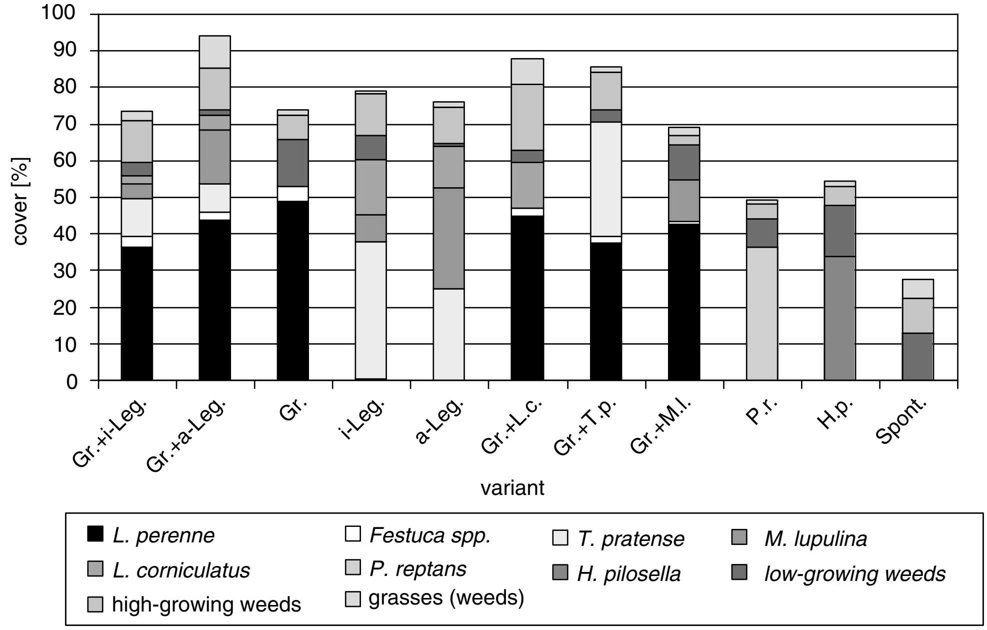

Fig. 3 Means of the ground cover after the first survey

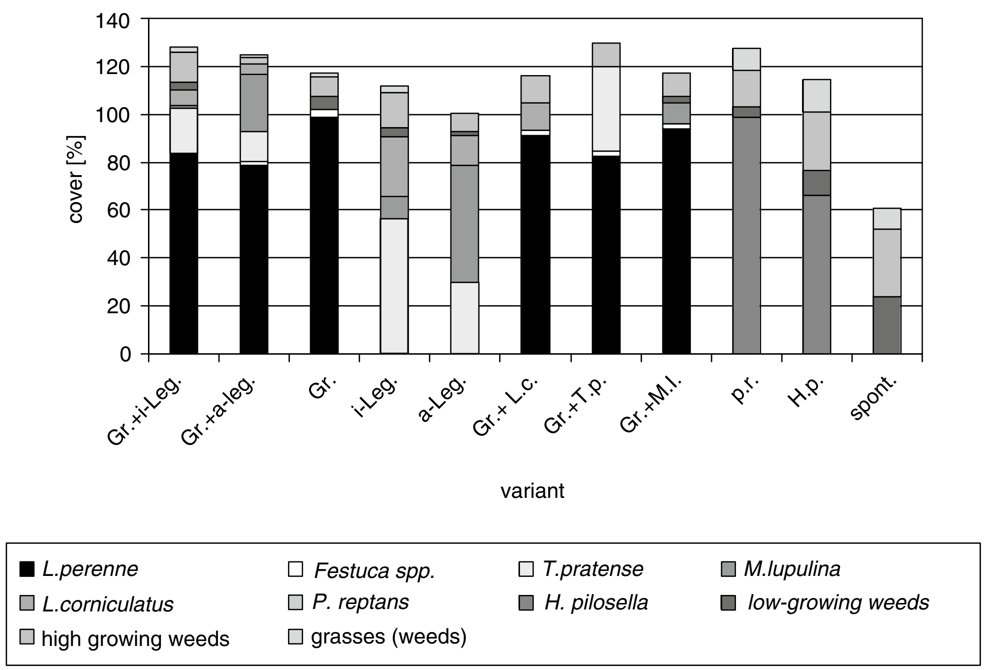

Fig. 4 Means of the ground cover after the last survey (September 2007)

among the variants are not statistically significant. The high standard deviation in some variants must be noted.

Discussion

Following the results from Fig. 1 it is obvious that the height of all variants except for the seedlings was too high for an eligible tree row vegetation cover. Both ecotypes of the low growing legumes (*M. lupulina* and *L. corniculatus)* grew much higher than predicted by the seed retailer. *L. perenne* was very dominant and showed a quick establishment, shading smaller and slower-growing plants. Therefore only the seedlings are suitable for a low-growing ground cover.

When the vegetation cover is considered this remains only true for *P. reptans*. The vegetation cover of *H. pilosella* (less than 70%) is—similar to the spontaneous vegetation variant—much too low. The release of allelopathic components from *H. pilosella* roots was not powerful enough to compete against the quick weed establishment.

Exact reasons for the dominance of *L. perenne* are difficult to find. The amount of seeds of all other grasses was four times higher than that of *L. perenne.* The very dry weather conditions towards the end of April 2007 may have been

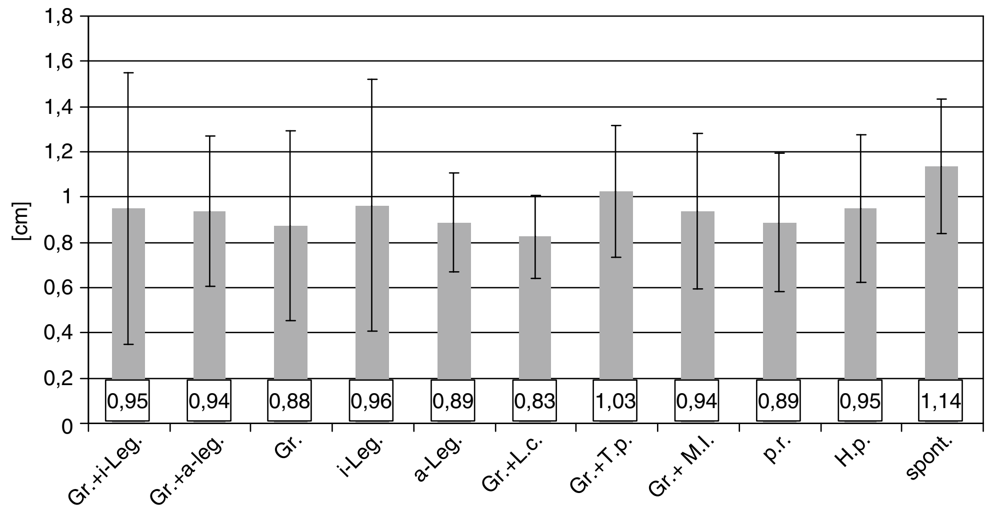

Fig. 5 Gain in stem diameter from May–September 2007

a reason: the soil was not moist enough to support the germination of all seeds. In the case of *Poa pratensis* this must not necessarily be the reason because it is a very drought-enduring grass (Hegi 1964). It is more likely that the sowing took place too late and an earlier date would have been more beneficial for the germination and establishment of other grass species than *L. perenne*.

Since all the variants are artificial combinations which do not necessarily occur in a natural environment, the lack of one or several competitors of *L. perenne* may be an explanation for its dominance. This cannot be limited to one species in particular because of the complex interactions in a plant community (Wilmanns 1998). It therefore remains a general problem of all cover crop mixtures. However, any cover crop mixture should contain several species: the biodiversity is higher and if one species becomes infested with bacteria or fungi other species can fill the void (Merwin and Stiles 1994).

The analysis of the two legume ecotypes shows that Swiss ecotypes are generally not better adapted than other European ecotypes. This differs from species to species but in this case the European ecotype of *M. lupulina* fulfilled the demands of a good tree row vegetation cover much better than the Swiss ecotype. The data for *L. corniculatus* showed only statistically significant differences in the pure legume variants among the ecotypes. Nevertheless, the Swiss ecotype of *L. corniculatus* is better suited as a cover crop than the European ecotype.

Since *T. pratense* was only available as a Swiss ecotype, it cannot be included in this comparison. It had the highest share of legumes compared to the other two grasses-legume variants and showed the second highest gain in stem diameter. From all this, a better competition ability can be deduced which results in a positive effect on the vegetative growth of apple trees. This may in particular be attributed to the low share of grasses which—as depicted in Fig. 5—caused a lower gain in stem diameter. These results should be considered preliminary for the time being due to the thin data record of only one vegetation period. Therefore only trends may be deduced from these data.

It is however important to consider the overall effect of the understory (and tree row) management on several trophic levels and the whole orchard ecosystem (House and Brust 1989; Mathews et al. 2002). Though the vegetative tree growth may (temporarily) fall behind those of trees subjected to a different understory management, factors associated with a planted tree row like faunistic diversity and a minimized pest risk may contribute considerably to the long-term health of the whole orchard.

Conclusions and Further Research

It has become obvious that spontaneous vegetation does not fulfill the demands of a functional tree row vegetation cover: the cover is too low, the height too high and the establishment very uneven. A controlled greening is more likely to result in an even vegetation distribution because the seed distribution can be controlled but other parameters such as height and cover must not necessarily comply.

Among all tested species *P. reptans* seems to be the most promising. It is locally well adapted and should be tested in other regions as well. In addition, more data need to be collected to examine the persistence of this variant.

All other variants cannot be recommended without further modifications. The share of *L. perenne* should be minimized. Another possibility is to replace it with another less competitive grass which shows a good establishment.

H. pilosella established too slowly which may have been due to imperfect soil conditions. Ecotypes which tolerate soils with a high fraction of limestone should be cultivated. Other *Hieracium* species which are more tolerant of limestone-rich soils like *H. humile* and *H. glaucum* should be tested as potential tree row plants in those areas. It is not known whether these species are allelopathic but their potential suitability should be tested. In general, the research towards allelopathic species suitable for a tree row vegetation cover should be fostered because these species can be regarded as an efficient tool for weed control (Anaya 1999; Macías et al. 2007).

Ideas for future experiments in the realm of understory management can be taken from other areas where low growing, persistent plants are needed. Common plants in rooftop greening are *Satureja montana* spp. *illyrica* (Host.) Nym., *Thymus serpyllum* L. em. MILL., *Cerastium arvense* L. and *Gypsophila repens* L. (Anonymous 2007; ZinCo 2005).

They all meet the same demands as those used in tree row vegetationmanagement but the height of these species may increase once fertilizer is applied to the field which is not common in rooftop greening.

As mentioned above, not all data can be statistically backed up. It may be possible that variants which show a neutral or negative effect on the vegetative tree growth after one vegetation period (e.g. the grasses variant) may catch up with the other variants since the young trees have to get used to the competition the greening might have caused.

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