Influence of undersown White clover (Trifolium repens L.) on organic Leek (Allium porrum L.)

Ehsan Ebrahimi

Norwegian University of Life Sciences
Department of Plant and Environmental Sciences (IPM)
Master Thesis Agroecology 60 credits 2012

Acknowledgment

First and foremost, I would like to thank Professor Peter von Fragstein und Niemsdorff, my supervisor and teacher at University of Kassel for giving me the opportunity of working in this experiment and for his unique and sincere supervision. He has patiently supported me throughout the project and his pieces of advice have improved my understanding and knowledge about the project and the field of study.

I would like to enunciate my appreciation to Professor Tor Arvid Breland, for all his supports during the project. His Pieces of advice were always helpful.

I would like to dedicate my appreciation to the University of Kassel and Norwegian University of Life Sciences (UMB) and also every person who has contributed to the completion of this MSc. thesis successfully.

I am particularly grateful to my friend, Mr. Alireza Bagheri for his tireless supports to solve my difficulties in the data analysis and I would like to thank Ms. Saeedeh Behrooznia for her sincere cooperation in editing the thesis. I dedicate my special thanks to all the employees and students for their help during the establishment of this project on university farm.

Last but not least, I would like to thank my parents for their great support during my studying and for their great love which was the main motivator in my life.

Preface

This thesis is a result of cooperation between a master student of Agroeoclogy from Norwegian University of Life Sciences (UMB) with University of Kassel in Germany. The field work has been done on university farm in Frankenhausen in Germany. The topic has been offered by University of Kassel based on scientific approach for a master thesis in agroecology. This experiment was held under the supervision of Professor Peter von Fragstein und Niemsdorff from University of Kassel and also Professor Tor Arvid Breland form UMB. The topic: *“Influence of Undersown White Clover (Trifolium repens L.) On Organic Leek (Allium porrum L.)”* wisely chosen to cover some of the main agroecological aspects like biodiversity, nitrogen fixing and sustainability in vegetable production as one of the main branches in European agricultural system.

Summary

Leek fields with open canopy are unprotected to weed suppression and nutrient leaching during their growing period. Intercropping can be an alternative way to conventional production on bare soil or as a mono-crop system. Intercrop has positive effect on weed management and nutrient support for main plant and even further plant in field. Respectively, this experiment has been designed based on undersown (US) management to increase sustainability based on agroecological rules. So the experiment concocted to evaluate the influence of US management in combination of different treatments with early sowing of clover as US simultaneously leek and late sowing of clover 48 days after transplanting of leek in the field and also cutting or not cutting of clover in treatments with clover and in some treatments leek transplanted on bare soil and in some treatments US have sowed without leek.

The yield attributes like diameter and dry matter (DM) were influenced by the date of sowing of US and also cutting management of clover. Treatments with late US as well as treatment without US but with hand weeding (HW) show the best diameter in both harvest which indicate a positive relation between field density and diameter size. These trends were followed by total DM per hectare in the first harvest but in the second harvest the differences between treatments were not significant. The results illustrated that DM% was not affected by field density. In this case, treatments which spend more time with US indicates better DM% compared with others. Although these differences were not significant in first harvest but in second harvest treatment with early US and with cut displayed better DM% and had positive relation with treatments with early US and without cut and also with treatment without US but without HW. Application of US and US management didn't have significant effect on leek height and also nutrient content of DM.

This experiment was invaded by animals during winter. After monitoring of field it is understood that destruction of field has a method and it is believed that animals have special trend to eat leeks. Analysis of leek size indicates that treatments with early US were destroyed more than other treatments. In other words, animals preferred to eat the plots were clover were existing in for longer time. It is thought that animal has priority for eating the leeks as well. Treatments with more density were their first option for eating and then they have continued with other plots.

Table of content

List of figures, tables and charts

Abbreviation

EU	European Union
DSB	Federal statistical office of Germany
EC	European commission
DAT	Days after transplanting
FM	Fresh matter
DM	Dry matter
TDM	Total dry matter
US	Undersown
HW	Hand weeding
ANOVA	Analysis of variance
DF	Degree of freedom
N	Nitrogen
P	Phosphorus
K	Potassium
$P \leq 0.01$	1% probability level
$P \leq 0.05$	5% probability level

1. Introduction

The world demands for food and agricultural products have increased during last centenary which cause a lot of pressure on agricultural section to produce food for increasing world population. Using chemical amendments such as manure as well as pesticides and herbicides consumption have created new issues for environment and agro-ecosystems. On the other hand, loss of biodiversity in monoculture systems beget new problem in farm systems. During the next 50 years, global agricultural expansion threatens worldwide biodiversity on a huge scale (Hole et al. 2005, p. 1). Prediction of around 9 billion for human population (UN, 2003) could result in a further one billion hectares of natural habitat being converted to agricultural fields mainly in developing countries. But then a twofold increase for water demand and a threefold increase in pesticide usage together with doubling or trebling of nitrogen and phosphorus inputs will endanger the biodiversity and sustainability in future (Hole et al. 2005, p. 1). Productivity of ecosystems in the long-term is implied by sustainable agriculture and it also implies the ability of agro-ecosystem to produce high quality foods and environmental benign. Increasing the amount of input applied in agro-ecosystems albeit has increased the yields but has diminished the quality of production and also natural capital. Then again, there is increasing awareness about environmental aspects which is related to agriculture and the truth that our present food consumption method may blemish the sustainability in ecosystem (de Backer et al. 2009).

Loss of biodiversity began debate over sustainability for current intensive farming system, which includes water pollution, soil erosion, food safety and chemical pesticides and herbicides use. In Europe these fears have started a growing public concern and governmental, and European Union (EU) support for agricultural systems that use less intensive practice, such as organic farming. The certified organic lands and in conversion areas within EU increased from 0.7 million ha in 1993 to 3.3 million ha in 1999, which is 24.1% of global organic land areas (EU, 2002) (Hole et al. 2005, p. 2). The Federal Statistical Office of Germany (DSB) reported that in 2005 782.5 (1,000 hectare) of 17024 (1,000 hectare) total agriculturally used areas were used for ecological farming which is 4.5% and this statistics in 2006 were 861.2 of 16954.3 total agriculturally used areas which was 5.07% and showed 0.57% growth.

Vegetable production in open field, where several crops are harvested per year, is associated with intensive use of chemical fertilizers and pesticides compared with other kind of plant production (Müller-Schärer 1996, p. 1). Intercropping is considered as a defined technique which can intensify and diversify the cropping system in time and space attributes (Biabani, 2008 & Francis, 1986). Competition between crop species is one the factors which influence yield and quality of crops in intercropping system. Biabani et al (2008) has reported in some areas, such as Iran, where the environmental condition often causes some stress including drought, intercropping provides a broad tolerance by different cultivars which may have a significant effect in total yield stability. Crop density is an important parameter affecting competition between intercrop and weeds. The crop cultivars, weed species composition, spatial arrangement, herbivores and soil conditions are other factors which might affect competition in intercrop system. On the other hand, farmers will accept such system which yields and quality are almost the same as in the sole cropping regimes. However, labor efficiency and mechanization possibilities should be considered as well introducing intercrop system as an adoptable system with high-technology for farmers and vegetable producers in developed countries (Baumann 2001). Also, concerns about interference between the vegetable crop and the intercrop have prevented development of intercropping vegetable production systems (Müller-Schärer 1996).

Leek fields are vulnerable to weed interference and nutrient leaching during its vegetation period, because of open canopy up to harvest. Intercropping in leek fields can be an environmentally alternative to conventional production on bare soil, which demands herbicide use (Müller-Schärer 1996). Emphasizing on pest suppression quality and weed management, potential of intercropping is more interesting these days rather than productivity of crop. Therefore, it is mentioned as a tool for weed and pest management in organic farming systems. Considering that market demand for organic vegetable production is increasing, there is an increasing need for non-chemical methods for weed and pest management techniques to reduce the application of herbicides and pesticides (Baumann 2002). From the other point of view, mechanical weed management as a technique might damage the plant especially when they are small and by using just tillage before planting or transplanting complete weed control in somehow is impossible. Intercropping specially for transplanted leeks is a non-chemical method which has a significant effect on weeds especially in early growing period (Melander 2001). In general, researches shows that Leeks in mono-crop system are better host for pest compared with intercrop system (den Belder 2000).

Also, Intercropping has been suggested to reduce and control weeds and to prevent soil erosion and leaching of mobile nutrition such as nitrates (Müller-Schärer 1996). Previous researches indicate that nitrogen (N) uptake in plants is often greater by intercropping system compared with mono-crop regimes which have been claimed because of yield increase but then, it is difficult to determine if better nutrient uptake was consequence of or the effect of better biomass production (Baumann 2001b).

Although there are some potential disadvantages in intercropping system which have limited its application for small-scale and low-input agricultural regimes which are related to use of machineries for agricultural process mainly when the component crops have different planting pattern or other agricultural requirements (Biabani 2008). Also, intercropping may have a negative impact on plant growth by interfering with availability of nutrients and light for the plant (Müller-Schärer 1996).

In leek production weed management constitute one of the main parts in production costs. Reducing in crop vitality, bulb diameter, plant height and leaf production caused by weed invasion show, there is a big concern about weed management in organic leek production (Sadeghi 2010). On the other hand, in organic farming regimes, weeds are controlled with different method most of which are labor, time and intensive resource. Hence, managing weeds is needed to avoid spending a lot of time and finance (Uchino et al. 2012). As it mentioned before, weed control with mechanical means is not effective enough, and moreover it can create damage on soil structure or increase the risk of frosting. Even though, manual weeding retrained by labor numbers is costly. To avoid these problems, prevention of weed growth is an alternative. Previous researches are reported somehow to reach that goal such as, reducing seed soil bank or reduce the competitive ability of weed with main crop (den Hollander et al. 2007a, p. 1). Also, den Hollander et al. (2007a) mentioned that the amount of established weed seedling is reduced when the soil early covered by cover crop therefore the harmful effect of weeds is reduced. In other words, US cover crops can alleviate weed infestation by rapid occupation of open niches between the rows and main crop, which prevents weed seeds germination and consequently reduces weeds in field (den Hollander et al. 2007b). Nevertheless, reduction in main crop yield through competition between cover crop and main crop has been concerned (den Hollander et al. 2007a, p. 1).

Cover crop can play the role of main crop for some reasons like pest control or improving the soil quality especially in organic system where pesticides are not used (den Hollander et al. 2007a, p. 1). Also, Hole et al. (2005) illustrated undersowing and presence of clover – ryegrass in the crop rotation can limit the weed cover in organic farming regimes.

Organic vegetable productions need extensive farming system and plan to provide enough soil fertility and acceptable crop protection. Accordingly, different agricultural methods such as crop rotation, applying US and using compost should be considered. Francis (2009) reported the amount of 125 to 225 kg ha^{-1} of nitrogen over several years provided by the cover crop is depending on gathered biomass and mineralization of N and control or minimize losses of N to provide for main crop or storage in soil as organic matter is an objective for a good organic farming practice. Nitrogen transformation can occur via different ways from N-fixing plants. Death, decompose and mineralization of roots are some of the ways which are accepted these days but additionally, mycorrhizal activities in some plants should take into account (Murray & Clements 1998).

The *Rhizobium* bacteria can be considered as a good source of N in organic farming by its symbiotic association with legumes. Although the atmosphere can supply and renew N forever but, management of N as a dynamic nutrient is still a big challenge (Francis 2009). White clover (*Trifolium repens L.*) is known to have high ability to fix nitrogen biologically with help of *Rhizobium* bacteria and associate main crops with fixed N. Annual N that biological N fixing input to a grass-clover mixture can be up to 300-500 kg ha^{-1}, although Thorsted et al.,(2006) reported 150-300 kg ha^{-1} per year is more typical. However, this amount can be variable, depending on amount of clover, soil moisture and defoliation regime. High values of feeding quality for white clover, transmuted this plant as an interesting plant which is used as pasture in temperate areas, but more than that, the role of white clover as a cover crop for providing nitrogen in soil through association with *Rhizobium* bacteria which are able to fix N_2 from the atmosphere for plant usable form (Murray 2002) and also clover as a cover crop role in gathering soluble nutrient is vitally important. This plant by its fast growing period and storage of nutrient in leaves until tillage plays a good role to avoid leaching of nutrients (Kroeck & Langer 2011).

Besides all the advantages of cover cropping, there are some disadvantages as well. For instants, cover crop can be a good host for some soilborn pathogens or changes the microbial activities and also might have abiotic disadvantages like decreasing physical factors in the soil (Wyland 1996).

Leek, *Allium porrum L.* is one of the important field vegetable crops in Europe (Müller-Schärer 1996). In Germany, 2399 hectare of 122454 hectare of vegetable production in total is allocated to leek during 2011. The total yield of leek in Germany at 2010 was 80 (1000 t) of 3148 (1000 t) total vegetable production and this statistic raised to 84 (1000 t) of 3379 (1000 t) total vegetable production in 2011 (Federal Statistical Office of Germany, 2012). Leek, like many other crops from *Allium* family, is a weakly competitive plant due to its slow primary growth and the open canopy during the growth period up to harvest. Consequently, there is a good place for weeds to continue emerging during the whole growing season, and high cost and effort is needed for weed management and subsequently quality and production losses (Baumann 2001b).

According to the above explained reasons, intercropping could be an alternative way for many of conservative agricultural systems which can increase soil quality and have large effect on weed management and nutrient supply for farm which are the main concerns in organic farming systems. In this study, intercropping between leek (*Allium porrum L.*) and white clover (*Trifolium repens L.*) as US is considered.

1. Objectives

Organic farming systems as a low-input farming regime, almost have limited access to nitrogen which affect the productivity of these systems. Therefore many of organic systems depend on biological N fixation to supply N for intercropped plant and /or for subsequent crop (Thorsted et al. 2006, p. 1). Some researches illustrate that cover crop sometimes inhibited the main crops due to the competition between main crop and cover crop. Therefore, there is a need to understand proper management of cover crop to have effective weed control (Uchino et al. 2012). Hence this study was planned to evaluate the influence of US white clover on growth parameters, yield and some other agroecological parameters of leek.

2. Hypothesis

Existence of US increases the N uptake and increases DM subsequently. Nevertheless, though other benefits of cover crop like weed management and providing good soil structure the quality of leek will be affected the positively. However Dry matter production are related to N uptake in the plant but luxury consumption of N shows that is possible to have nitrogen uptake without effect on dry matter content and even dry matter can increase without nitrogen uptake because of nitrogen dilution (Booij 1996).

3. Material and methods

3.1. Experimental site characteristics

The experimental field is located in teaching and research farm Frankenhausen near Grebenstein in Hessen, Germany (51° 27′ 0″ N, 9° 25′ 0″ E) with 249 meter (817 ft) above sea level. The average daily temperature is 8.5 C° (according to 30-yrs average: 1961-1990) while annual precipitation mean is 650 mm/a (according to 30-yrs average: 1961-1990). The field soil type is Haplic Chernozem (according to FAO classification), and leeks was transplanted in clay loam soil texture through on natural precipitation as irrigation source.

3.2. Experiment structure

The experiment was established at 10^{th} of July 2011. A randomized block design (RBD) with three replicates and 14 treatments were applied. In this experiment we evaluate three factors: factor A is date of sowing, factor B is management of undersowing and factor C is hand weeding management. The structure of all treatments in the field has been explained in Table 1; the structure of 6 treatments with leek and without leek has been displayed in Table 2. The soil was prepared by using plough at March 2011 and it was prepared for sowing in April by circular harrow. Besides that, mechanical weeding was done by rotavator for several times. The plot dimensions were 3 × 4m while the whole field was 21 × 28m. The first and second previous crops were grass clover and potato respectively. Leeks were transplanted with 10cm distance from each other. In order to ensure about better soil condition for availabilities of water and nutrition during growing season, rotavator applied two times, two days before transplanting on 10^{th} of July. The leeks were bought as transplants. The organic white clover seeds were closured at 06.2011 and applied 30 gram per row in two lines in both leek sides, and they were mixed with 30 gram dead seeds to be well strung and well distributed by hand sowing. The US was applied in two different times, first with transplanting on July 13^{th} and second was done on August 29^{th}, 48 days after the first undersowing. Four hand weeding were carried out in 24, 49, 65 and 80 days after transplanting (DAT).

During the experiment, two harvest have been done on 14^{th} of October and 6^{th} of December and in each harvest, growth parameters like fresh matter (FM), dry matter (DM), DM content, N content, K content, P content were measured; furthermore, soil sampling was done in each harvest as well however, one soil sampling has been done before planting. Because of high amount of damage by animals during winter third harvest on 21^{st} of March was canceled.

Table 1: The structure of factors and their variety in treatments

Date of Sowing (Days after planting)	Leek existence	Undersown (US) management	Hand weeding (HW)
0 (4*)	No (4)	Without US (2)	No (2)
47 (4)	Yes (6)	Without Cutting (4)	Yes (10)
		With Cutting (4)	

* Number of occurrence of this factor in the treatments

Table 2 *: The structure of treatments with leek and without leek and their codes

	All factors					
	HW					No HW
	With Cutting		Without Cutting		Without US	Without US
	Same date US	Late US	Same date US	Late US		
Leek	1231	2231	1221	2221	1211	1210
Without Leek	1131	2131	1121	2121	---	---
Fallow					1110-1	1110-2

* The explanation of codes are attached at the last page of thesis as an extra paper

3.3. Soil Sampling

The soil was sampled four times. The first soil sampling has been done before planting the leeks and three soil samplings have been done right after each harvest on 18^{th} October, 8^{th} December of 2011 and 21^{st} March 2012 but unfortunately because of high expenses and budget limit just first (before planting) and last samples were analyzed.

For each treatment three sub-samples were taken with a core sampler (Ø 4 cm) from 0-60 cm depth and pooled to give one sample per plot. Samples with same treatment have been mixed and at the end one sample per treatment have been sent to the laboratory. Total N content (kg ha^{-1}) and nitrate rate (mg) and ammonium rate (mg) were measured per treatment.

3.4. Yield and nutrient analysis

Yield attributes like leek height and diameter and also FM and DM weight were recorded after harvesting the leeks. Harvests have been done from two middle row of each plot from an area with 50 × 100 cm size which consist almost 10 plants. Samples of ten plants were collected from the mentioned area were cut and dried to constant weight at 60°C and 105°C and total dry matter (TDM) were measured. Total N content (%) were determinate by Kjeldahl method and P and K were calculated by Spectrophotometer and Flame photometer, respectively.

3.5. Monitoring

During the winter time, the field experiment was invaded by animals and was partly destroyed. Two monitoring session was held on February 2nd and March 22nd and the plots were monitored in case of destruction level and destruction trend. During this monitoring session, ten samples were collected from two middle rows of each plot. The size of each plant was compared with our base plant which was the biggest and visually most pristine plant. The Normal size was considered around 40 cm which is divided to 5 parts in 8 cm each and it is scaled as follows: [(0-8 cm) = 1, (9-16 cm) = 2, (17-24 cm) = 3, (25-32 cm) = 4 and (33-40cm) = 5]. The ten plants which were collected from plots were measured by this pattern and ranked from 0 to 5 by damaged that 0 means most damaged plant and 5 means least damaged plant. In addition, numbers of damaged leek per plot were counted. All the data were analyzed with software to define the differences.

3.6. Statistical analysis

Statistical analysis using SAS 16, MINITAB 16 and Microsoft Excel 2007 were carried out with three replications. Date of sowing of US, management of US and hand weeding were considered as three factors. The factor date of sowing of US (factor a) had two levels i.e., Same date undersowing and Late undersowing, the factor management of US (factor b) had three levels i.e., With Cut, Without Cut and Without US and the factor hand weeding (factor c) had two levels i.e., HW and No HW (Table 1 and Table 2). Mean comparison were directed using analysis of variance (ANOVA) test. Duncan's multiple range test ($P \leq 0.05$) and Fisher test ($P \leq 0.05$) were applied to estimate significant differences between the individual treatments. Considering that the set of data were not as the size that we expected because of animal damages in the last harvest, orthogonal analysis was applied for group comparison between the factors generally. For that aim, comparisons were done in three contrasts. Treatments based upon the existence of US were considered as contrast one, treatment based on date of sowing as contrast two and treatments based on US management (cut or without cut) as contrast three. After defining the contrasts with

Microsoft Excel 2007, with the help of SAS 16 comparisons between contrasts has been done. It has been observed that there was a trend between treatments in stem diameter, DM percentage and total DM, P≤ 0.05 according to analysis of variance (annex 2: Table 18, 8, 10). According to information in Table 18, 8 ,10 (in annex 2), DF for treatments is more than 1 and consequently DF for numerator in F test is more than 1, which means that F test in this experiment can be divided to F test with smaller DF to have more accurate results (Hoshmand 2006). Since 6 treatments were applied in this experiment, possible group numbers could be 5, but concerning that some of factors were not significant just 3 groupings were done. For more accurate understanding of the effects between treatments, orthogonal analysis was applied. For that aim some comparisons were designed (Table 3).

Table 3: Group comparison between treatments and their coefficient in first and second harvest based on orthogonal analysis

Treatment / Comparison group	Same date US + without US cut + HW (1221) *	Same date US + with US cut + HW (1231)	Late US + without US cut + HW (2221)	Late US + with US cut + HW (2231)	Without US + HW (1211)	Without US + without HW (1210)
1	1	1	1	1	-2	-2
2	1	1	-1	-1	0	0
3	-1	1	-1	1	0	0

* Treatment's code

Comparisons have designed for specific purposes:

1. Comparison between treatment with US and without US
2. Comparison between treatment which US has been sowed at same time with leek and two month later
3. Comparison between treatment which the clover have cut one time and were used as mulch or without cut

Table 4: Analysis of variance (mean square) for significant factors in group analysis

Source	DF	DM per plot (g m^2)	Diameter in first harvest	Diameter in second harvest
Treatment	5	309021.795 *	16.7222 **	14.7804 **
Error	10	34888.360	0.8722	1.1212

Mean Square with * and ** are significant in P≤ 0.05 and P≤ 0.01 respectively

4. Results

4.1. Yield attributes

4.1.1. Total dry matter and dry matter percentage

Analysis of variance for DM percentage shows a significant difference between treatments in the second harvest but in the first harvest a trend on some treatments was observed (Table 6).

Table 5: Analysis of variance (mean square) for DM percentage in first and second Harvest

Source	DF	DM % first harvest	P value	DM% second harvest	P value
Treatment	5	0.6701 $^{ns\ \#}$	0.1023	1.3923 *	0.038
Error	10	0.2683	---	0.3789	----

Mean Square with * is significant in P≤ 0.05 and “ns” are not significant, # P≤ 0.1

Application of US and different US management and also different date of sowing were not significantly changed DM (%) in first harvest (P=0.18 > 0.05) but difference between treatment in the second harvest was significant (P=0.05), but as the Table 6 show neither in second harvest which differences were significant nor in the first harvest which there was no significant difference between treatments, a strong differences was not observed (Table 6-B).

Table 6-A: Effect of US management on DM % in first harvest:

Treatment	Without US		Same day US	Late US
	HW	No HW		
- CUT	10.592 b	10.558 b	10.988 ab	10.743 b
+CUT	- - -	- - -	11.782 a	10.592 b

Means with the same letter do not differ significantly ($p \leq 0.05$, Duncan test)

Table 6-B: Effect of undersown management on DM % in second harvest:

Treatment	Without US		Same day US	Late US
	HW	No HW		
- CUT	14.95 b	15.73 ab	16.02 ab	14.98 b
+CUT	- - -	- - -	16.53 a	14.89 b

Means with the same letter do not differ significantly ($p \leq 0.05$, Duncan test)

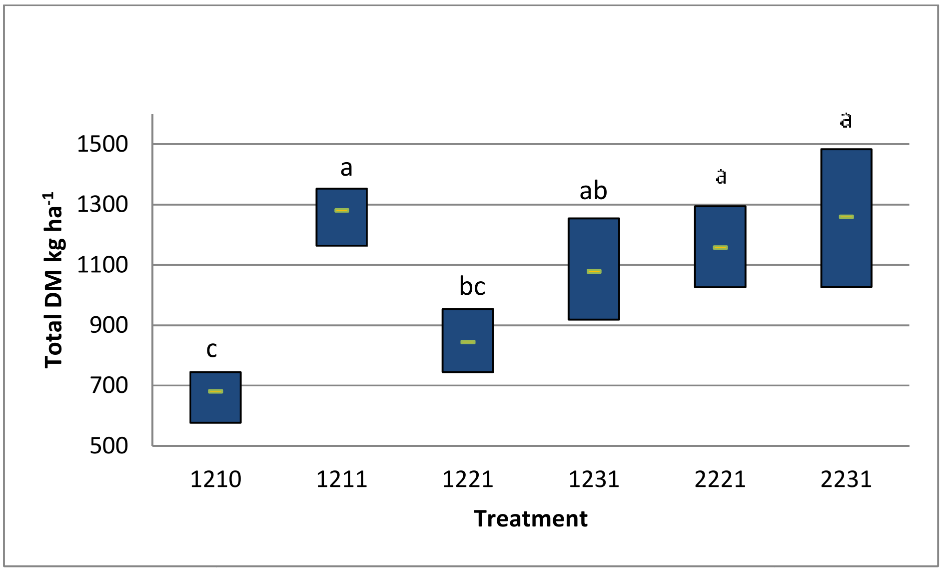
According to the Table 6, treatment with late US and US cut shows best DM% in both harvests which has positive relation with treatment with late US and US without cut in the first harvest and with also treatment without US and without HW in the second harvest. Besides all mentioned above, the results for DM (kg) per hectare followed different behaviors. Analysis of variance shows significant differences in concept of total DM in the first harvests.

Table 7: Analysis of variance (mean square) for DM per Hectare in first and second Harvest:

Source	DF	DM (kg) per Hectare first harvest	P value	DM (kg) per Hectare second harvest	P value
Treatment	5	173193.95 **	0.0047	680103.24 ns	0.1849
Error	10	24750.23	---	3616905.15	---

Mean Square with ** is significant in $P \leq 0.01$ and “ns” is not significant.

On the other hand, DM (kg) per hectare showed different results unlike DM (%). In the first harvest DM kg ha^{-1} was significantly different between treatments but in the second harvest no difference was observed (Table 8). Mean comparison based on Duncan test $p \leq 0.05$ illustrated that treatment which had no HW produced less dry matter (Table 8 & Figure 1).



Means with the same letter do not differ significantly (p≤ 0.05, Duncan test). (Explanation of codes is at the end of thesis)

Figure 1: Total Dry matter per hectare in first harvest

Table 8: Effect of US management on DM per hectare (kg) in second harvest:

Treatment	Without US		Same day US	Late US
	HW	No HW		
- CUT	2458.2 a	1334.5 a	1525.7 a	1686.1 a
+CUT	- - -	- - -	2110.2 a	2424.7 a

Means with the same letter do not differ significantly (p≤ 0.05, Duncan test)

4.1.2. Diameter and height

Stem diameter is one of the characteristics which define market quality for leeks. Intercropping by changing in density of field can have effects on diameter of leeks according to different reasons like increasing completion for nutrient and light. In this experiment diameter of leeks was measured. Leek diameters in both harvests were significantly affected (p≤ 0.01) by different treatments in this experiment.

Through applying Duncan method for comparing means in p≤ 0.05, it is identified that stem diameter for leeks in treatment without hand weeding is significantly less than other treatments in first harvest (Tables 9).

Table 9-A: Effect of US management on leek diameter (mm) average in first harvest:

Treatment	Without US		Same day US	Late US
	HW	No HW		
- CUT	18.33 a	13.25 d	14.66 c	17.66 a
+CUT	- - -	- - -	16.33 b	18 a

Means with the same letter do not differ significantly (p≤ 0.05, Duncan test)

Table 9-B: Effect of undersown management on leek diameter (mm) average in second harvest:

Treatment	Without US		Same day US	Late US
	HW	No HW		
- CUT	20.917 a	15.148 d	16.866 cd	20.667 a
+CUT	- - -	- - -	18.167 bc	20.333 ab

Means with the same letter do not differ significantly (p≤ 0.05, Duncan test)

Besides diameter of stem, leek height was measured in this experiment as a market characteristic and an ecological factor for leeks. Mean values differences for leek height were not significant in both harvests. The amount of P value were 0.27 > 0.05 and 0.22 > 0.05 respectively.

4.1.3. Nutrient content in dry matter

It has been observed that there was no considerable difference in nutrient content of DM with different treatments. Analysis of variance shows in both harvests there is no significant distinction (p≤ 0.05) with application of different treatments (Table 10).

Table 10-A: Analysis of variance (mean square) for percentage of N, P and K in Leek DM in first harvest:

Source	DF	First harvest					
		N %	P value	P %	P value	K %	P value
Treatment	5	0.0138 ^{ns}	0.6164	0.0024 ^{ns}	0.4824	0.0338 ^{ns}	0.3927
Error	10	0.0189	---	0.0025	---	0.0292	---

Mean Square with “ns” is not significant (p≤ 0.05)

Table 10-B: **Analysis of variance (mean square) for percentage of N, P and K in Leek DM in second Harvest:**

Source	DF	Second harvest					
		N %	P value	P %	P value	K %	P value
Treatment	5	0.0346 ns	0.4911	0.0016 ns	0.6680	0.0043 ns	0.9585
Error	10	0.0365	---	0.0024	---	0.0225	---

Mean Square with "ns" is not significant (p≤ 0.05)

4.1.4. Nutrient uptake

Different US management didn't show significant difference between treatments in case of nutrient percentage in DM but nutrient uptake were measured to identify the effect of different treatments on N, P and K uptake in the field. Analysis of variance for N shows that, in the first harvest there is a significant difference between treatments (P=0.014≤0.05). Based on information in Table 11, treatments with late US without or with cut and treatment without US but HW show the best N uptake in the first harvest. As Table 11 illustrates, 24.78 kg ha^{-1} was the highest amount that treatment without US and with HW could uptake nitrogen. This amount has positive relation with 24.243 and 24.018 kg ha^{-1} which was for treatments with late US and without cut and with cut respectively.

Table 11: **Effect of US management on N uptake for leeks in first harvest:**

Treatment	Without US		Same day US	Late US
	HW	No HW		
- CUT	24.78 a	13.504 c	16.513 bc	24.243 a
+CUT	- - -	- - -	20.94 ab	24.018 a

Means with the same letter do not differ significantly (p≤ 0.05, Fisher test)

At the second harvest, different N uptake between treatments were not significant (p=0.29 > 0.05). In case of P uptake the same pattern was followed. It is observed that in the first harvest deference between treatments was significant (p= 0.015 ≤ 0.05). In follow table difference between treatments has been presented.

Table 12: Effect of US management on P uptake for leeks in first harvest:

Treatment	Without US		Same day US	Late US
	HW	No HW		
- CUT	2.8482 a	1.6589 c	1.5401 c	2.7739 a
+CUT	- - -	- - -	1.8570 bc	2.6926 ab

Means with the same letter do not differ significantly (p≤ 0.05, Fisher test)

According to Table 12 treatments without US and with HW shows highest amount of P uptake which has a positive relation with treatment with late US and without or with cut. In second harvest the differences were not significant (p=0.68 > 0.05). The same pattern was followed for K uptake as well. The analysis of variance identify significant difference between treatments in first harvest (p=0.004 ≤ 0.05). Table 13 displays the differences between treatments and their relations.

Table 13: Effect of US management on K uptake for leeks in first harvest:

Treatment	Without US		Same day US	Late US
	HW	No HW		
- CUT	11.804 a	5.919 b	7.041 b	10.585 a
+CUT	- - -	- - -	6.554 b	10.993 a

Means with the same letter do not differ significantly (p≤ 0.05, Fisher test)

In line with the results in Table 13, the same trend was followed by leek in case of K uptake as well. Treatment without US and with HW shows highest amount of K uptake with 11.804 kg ha^{-1} which has a positive relation with treatment with late US and without or with cut and differences in K uptake with other treatments is so sharp and accurate. In second harvest there is no significant differences between treatments (p=0.315 > 0.05), (Table of analysis of variance for all nutrient uptakes is available in annex 2).

4.1.5. Group comparison of means

4.1.5.1. Group comparison for DM

In comparison 1, treatments with US and treatments without US were compared. Analysis of variance showed that treatments didn't have significant differences together (Table 14). In comparison 2 the results illustrated very strong effect by treatments ($P \leq 0.01$) in the case of date of sowing in TDM in the first harvest. In order to understand which group had more effect on DM, the mark of coefficients in each treatment in Table 3 and the mark of Q in Table 14 should be considered. If the marks are the same it means that DM was more under effect of these treatments (this method should be applied for all comparisons). Amount of Q illustrated that treatments 2221 and 2231 which both had late US had better effect on DM per plot (g m^2).

Table 14: **Analyses of group comparison for effect of 6 different treatments of leek on DM per plot (g m2) in first harvest:**

No.	Comparisons	DF	SSQ	Q
1	With US vs. Without US	1	38604.12 ^{ns}	1178.87
2	Same Date US vs. late US	1	264226.5 **	-1780.65
3	Cut vs. without cut	1	5146767 *	-7858.83

Mean Square with * and ** are significant in $P \leq 0.05$ and $P \leq 0.01$ respectively and “ns” are not significant

- $Q=\sum C_i T_i$, linear equation of comparisons which Ci is the coefficient of comparisons and Ti is the total of i^{th} treatment.

According to the above two designed comparisons, the third comparison was based on management of US by cutting. As Q mark in Table 14 and Table 3 show, treatments 1221 and 2221 which both were without cut had more positive effect on DM, compared with other treatments. After estimating the influence of US management on DM, diameter as one of the market factors of leek might be interesting.

Table 15: **Analyses of group comparison for effect of 6 different treatments of leek on diameter of stem in first harvest:**

No.	Comparisons	DF	SSQ	Q
1	With US vs. Without US	1	2.77 ^{ns}	10
2	Same Date US vs. late US	1	16.33 **	-14
3	Cut vs. without cut	1	3 **	6

Mean Square with ** are significant in $P \leq 0.01$ and “ns” are not significant

In comparison 1, no significant differences were observed between treatments but based upon the comparison 2; there was a significant difference when date of sowing was changed. According to Table 15, and Table 3, treatments 2221 and 2231 had the best effect on leek diameter in the first harvest. The mentioned treatments both had late US and the field were kept bare longer than treatments 1221 and 1231. The situation in comparison 3 was different and in the case of US cut management the superiority was for treatments 1231 and 2231 which both has treatment with US cutting.

Table 16: Analyses of group comparison for effect of 6 different treatments of leek on diameter of stem in second harvest:

No.	Comparisons	DF	SSQ	Q
1	With US vs. Without US	1	1.82 ns	8.09
2	Same Date US vs. late US	1	26.7 **	-17.9
3	Cut vs. without cut	1	0.7 ns	2.9

Mean Square with ** are significant in $P \leq 0.01$ and "ns" are not significant

In line with the results in Table 16, comparison 1 and comparison 3 did not show a significant difference between treatments. In the other word, existence of US and management of US by cutting did not create a significant difference in leek diameter in the second harvest or end of growing period but comparison 2, indicated that late sowing of US in had better effect on diameter in the second harvest as it was in the first harvest.

4.2. Soil chemical properties

During the experiment, two sets of soil sampling had been done. Considering that the samples were collected based on treatment and not replication, so in continue the observation of N contents are reported. Figure 2 shows the total amount of N before starting the experiment and after the last harvest.

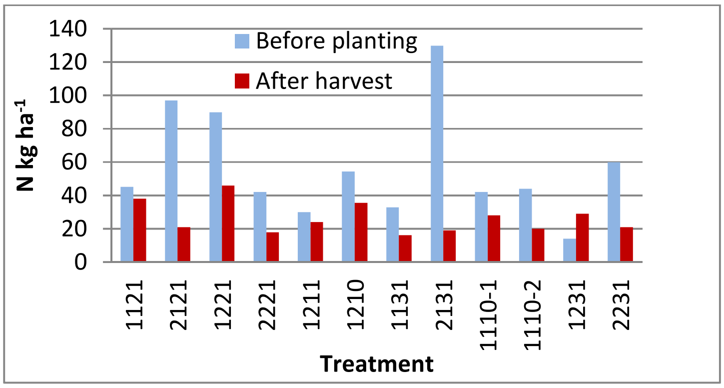
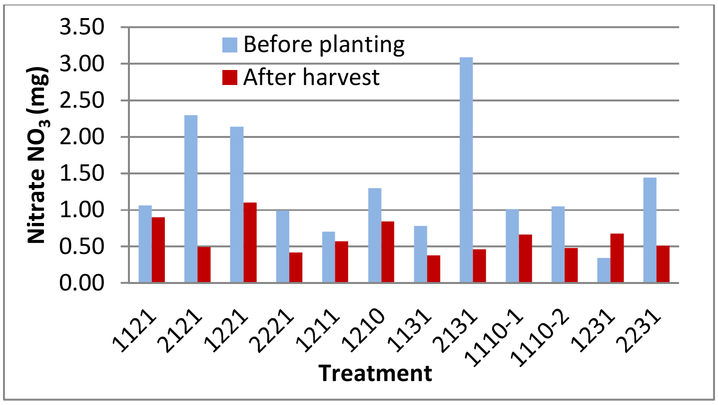


Figure 2: **Total N content before planting and after last harvest**

According to the figure, just treatment (1231) shows increasing in N content from 14 (kg ha^{-1}) to 29 (kg ha^{-1}) at the end of the experiment. The most reduction of N are in treatments 2131 from 130 to 19 (kg ha^{-1}) and treatment 2121 from 97 to 21 (kg ha^{-1}). In general, treatments with leek show less difference between these periods of time. Then, available N in form of NO_3 (nitrate) and NH_4 (ammonium) was measured and compared in Figure 3.

(A)



(B)

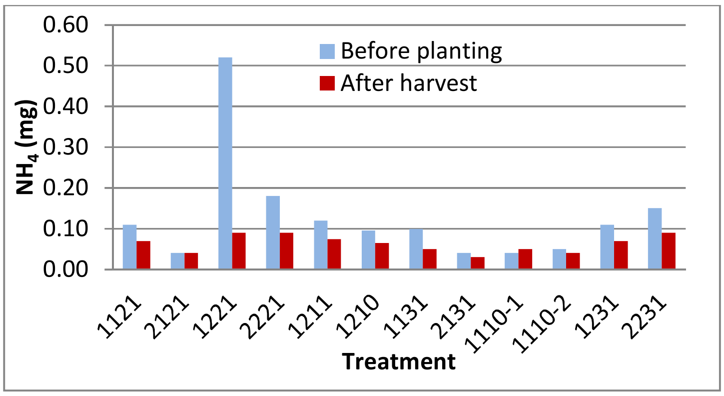


Figure 3: **Amount of nitrate (graph A) and ammonium (graph B) before planting and after harvest**

In line with the results in Figure 3, NH_4 level decreased dramatically after growing season for treatment 1221 from 0.52 to 0.09 mg and in treatment 221 also there is still high decrease in NH_4 rate between the sampling from 0.18 to 0.09 mg which is half of the amount from beginning.

4.3. Animal damage

During the winter time, the field was affected by animals. The amount of damage was considerable and destroyed the field in a way that the third harvest was cancelled. To estimate the level of damage, field experiment was monitored. Analysis of variance illustrates that the differences between treatments are significant $P \leq 0.01$ (Table 17).

Table 17: Analysis of variance (mean square) for animal trend in eating leeks:

Source	DF	Mean square
Treatment	5	1.2326 **
Error	12	0.0881

Mean Square with ** are significant in $P \leq 0.01$

As Table 17 shows there is a strong significant difference between treatments. In continue Figure 4 presents the difference between treatments.

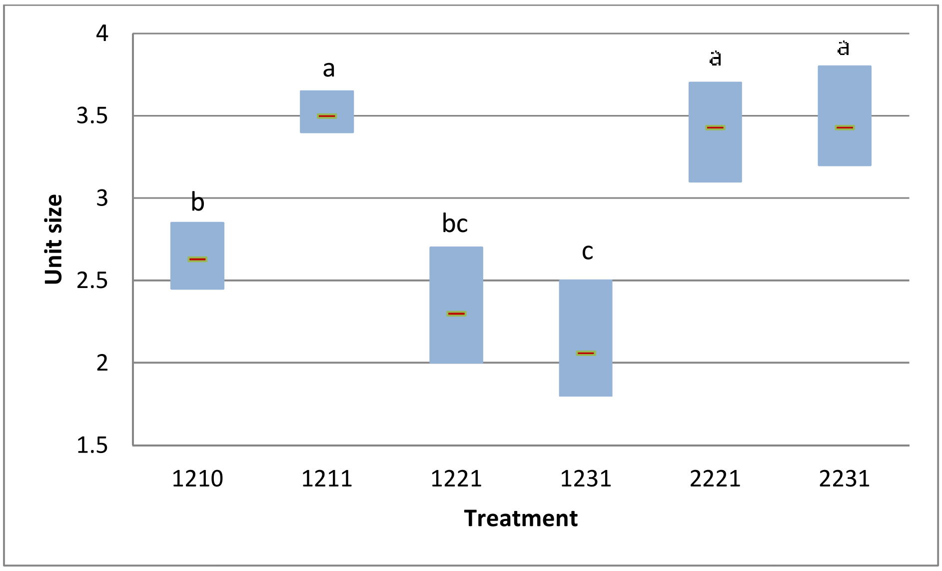


Figure 4: Influence of animal trend on yield damage in last harvest

In line with the results in this figure, the treatments with late undersowing and treatments without US were preferred by animals more and damaged more consequently. On the other hand treatments with clover and weed were affected less. It is thought that animals started by eating some plots before another. Observation indicates that plots which had treatments 1221, 1231 and 1210 were chosen by animal for eating first. The fallow figure describes the pattern of animals for eating leeks. For this figure number of leeks which damaged was counted in both monitoring.

	1	2	3	4	5	6	
G	1110	1110	1210	1210	1121	2121	G
F	1231	2231	1211	1211	1221	2221	F
E	1131	2131	1110	1110	1231	2231	E
D	1210	1210	2221	1221	1131	2131	D
C	1211	1211	2121	1121	1110	1110	C
B	1221	2221	2231	1231	1210	1210	B
A	1121	2121	2131	1131	1211	1211	A
	1	2	3	4	5	6	

Figure 5: Pattern of animal for eating leeks based on priority at first visit

High damage (66 to 100%) Slight damage (34 to 66%)

Very slight damage (up to 33%) Fallow

According to the chart above, all plots which had the treatments of 1231 and 1221 in all three replications had been damaged. Then again, plots with treatments 1211 and 2211 (which is the same with 1211 and there is just numeral difference) had less damage in the first invade.

	1	2	3	4	5	6	
G	1110	1110	1210	1210	1121	2121	G
F	1231	2231	1211	1211	1221	2221	F
E	1131	2131	1110	1110	1231	2231	E
D	1210	1210	2221	1221	1131	2131	D
C	1211	1211	2121	1121	1110	1110	C
B	1221	2221	2231	1231	1210	1210	B
A	1121	2121	2131	1131	1211	1211	A
	1	2	3	4	5	6	

Figure 6: **Pattern of animal for eating leeks based on priority at second visit**

High damage (66 to 100%)

Slight damage (34 to 66%)

Very slight damage (up to 33%)

Fallow

In the second visit, it was observed that animal started with plots which were damaged slightly before. Based on this monitoring and data analysis it is thought that, there might be sampling by animals for eating leeks.

5. Discussion

5.1. Yield attributes

It is observed that DM percentage showed different manner. In the first harvest no significant differences were observed but in the second harvest differences were significant.

According to Table 6 treatments with early US and cut showed the best DM% in the first and second harvest with 11.782 and 16.53 respectively although there was a relation between treatment without cut in both harvests with 10.988 for the first harvest and 16.02 for the second harvest and also relation with treatment without US and without hand weeding with 15.73. It is believed that treatments which had longer time with clover in the field displayed better DM percentage compared with other treatments and also the highest amount of DM% was for treatment with early US with cut. The reason might be the existence of more mulch and biomass in the field compared with other treatments, which consequently increase nitrogen fixation by increased in carbon level in the soil (Gardner et al. 1985).

In line with the results in Table 7, total DM per hectare showed different situation. Unlike DM%, in total DM in the first harvest showed significant difference between treatments but in the second harvest the difference was not significant. Figure 1, shows in the first harvest treatment without HW and treatments with early US showed less TDM compared with other treatments and also treatment with early US but with cutting displayed more DM compared with treatment without cut and it had a relation with treatments which had late US. This result obviously defines that during the critical stages of growing leeks; competition can affect main plant significantly and reduces the total DM, but based upon the Table 8, by passing time especially in winter differences in DM disappeared, but even in the second harvest treatments which had better DM in the first harvest, still showed more DM per hectare. Based upon these data, increasing the competition can affect total DM in early period of grows but in continue differences will be insignificant. It should be considered that the second harvest had been done during winter time which clovers and weed were almost inactive or destroyed so; lack of competition might be one of the reasons. These results were relevant with finding of Uchino et al. (2009) about the effect of date of sowing on yield production in maize and soybean intercropping which was higher in treatments with late undersowing of rye and hairy vetch and when the main crop was established.

Based on information in Table 10, there was no significant effect on nutrient content of DM between treatments. Considering that leek has low N uptake level, insignificancy between treatments can be justified. Booij et al. (1996) also reported less dependency of leek to nitrogen for DM support. These data showed same manner for P and K as well.

In line with the results, treatments which had fewer competitors could uptake more nutrient in the beginning of growing period, but by passing time, and growth of clovers, the level of uptake decreased consequently.

Importance of market quality created big concern for vegetable producers about the characteristics which are important for customers and market consequently. Attributes like height, diameter and the white part of the shaft are some of the main market elements that should be concern in leek production systems (Müller-Schärer 1996). In plant communities competition for ecological resources could be one of the main reasons for changing in plant characteristics. Intercropping by raising the competition creates ecological and physiological effects on the main plant. As it is mentioned in Table 18, differences between treatments were strongly significant in case of diameter in this experiment. According to Table 9-A, leek diameter was affected more in treatments in which HW was not done and the reason could be high competition with weeds. Based on the information on Table 9, mean square for treatment without hand weeding was 13.25 (mm) in the first harvest whereas the highest amount was for treatment without US but hand weeded was 18.33 and treatment with late undersowing and with cut was 18 and without cut was 17.66. Müller-Schärer (1996) also reported that weeds are most dangerous competitors for vegetables. In continue treatments with early US showed 14.66 and 16.33 (mm) for diameter which the biggest was for the treatment with US cut (Table 9-A). In the second harvest, treatments without US with hand weeding and late US still showed the largest diameter 20.917 and 20.667 (mm) respectively but they had relation with late US which was cut with 20.333 (mm). On the other hand, treatment with late US with cut showed a relation with treatment with early US with cut which was 18.167 (mm). In general treatment without US created the biggest diameter which was relevant with results that Baumann et al. (2001) and Bertschinger & Anderson (2004) exemplified by intercropping of leek and celery which declined the diameter by competition. In line with the results in Table 9-A and Table 9-B, treatments with US cut showed better diameter compared with treatments without cut and this difference was completely significant in the first harvest and in the second harvest some relations were observed. Superiority of diameter with US compared with treatments with weed existence demonstrated that competition in intercrop system was more productive than other dense situation. In support of this result Baumann (2001b) illustrated that increasing in leek density in intercrop system with celeriac plants, reduction on plant weight and diameter were not significant compared with increasing the density in mono-crop regime.

Leek height as one of the market factors for leeks was also considered in this experiment. Table 19 obviously displays that there were no significant differences on leek heights with different treatments even though treatment without hand weeding showed the highest amount in the first harvest with 361.97 (mm) and treatments with early US showed higher amount with 374.22 and 338.67 (mm) compared with other treatments. This behavior is almost happened in the second harvest as well (Table 20 & Table 21). In spite of this, Müller-Schärer (1996) reported that in intercropping leek with ryegrass (*Lolium perenne L.*) late sown treatments were taller.

5.2. Group comparison

For more accurate results, the F test was divided to smaller DF. Grouping had focused on US management. Comparison between all treatments with US and without US didn't show a significant difference in general. These results illustrated that difference between all treatments which had US with or without HW did not have significant and relevant differences with all treatments with US and other management. Based on the next comparison, it was thought that applying of US itself could not be effective on DM, diameter and etc but management of US could cause differences between treatments (Table 3). The second comparison was showed that late undersowing of clover positively could affect the DM in first harvest. Treatments with late undersowing 2231 and 2221 were more successful treatments in that case. Comparison 3, indicated that treatments without cut in US are more successful. Based on these results, the treatment 2221 was the best treatment in the case of DM production in first harvest. It is believed that in short term, less competition can support the DM but after establishment of the plant the differences are not significant.

In the case of leek diameter in both harvests first comparison was not significant. This clearly indicates the importance of US management on further parameters. Also, the comparison 2, illustrated that treatments with late undersowing were more successful compared with early undersowned treatments, But unlike previous finding in comparison 3 for DM, treatments with cut clover showed better diameter effect compared with treatment which clover remained in the field. Comparison 3 in the second harvest didn't show significant difference in diameter. It was thought that after establishment of leek cutting didn't create a significant effect on the diameter of stem. The treatment 2221 responded better to all US managements in the case of DM production and treatment 2231 showed bigger diameter size in consequence of US management. However treatment 2221 was the one which could cover more factors in comparisons in the cases of DM production and diameter size.

5.3. Soil chemical properties

Treatment 1231 with early US and cut was the only treatment which showed increase in N and NO_3 after harvest. The main difference of this treatment with other treatment was in date of US which means that clover remained in the field as much while clover was growing however the highest levels of N after harvest were observed in treatments 1221 with 46 kg ha^{-1} which had early US without cut. According to figure 2, treatments with early US and without cut for clover showed more N level after harvest and this level of N was close to the treatments without leek and treatment with leek but with cut for early US. This result might be because of less dependency of leek to nitrogen for producing DM (Booij et al. 1996). In other point of view Wyland (1996) indicates that cover crop can improve the nutrient dynamics by increasing in microbial activities in top layer of the soil.

A big fall in amount of nitrate was observed before planting and after harvest. Treatments 2131 and 2121 showed this drop between two samplings. Concerning that these two treatments had no leeks; this fall in nitrate level might be because of leaching effect during winter time. Treatment 1231 showed increase in level of nitrate after harvest compared with before planting. In this treatment cutting was done in the middle of growing season and clover used as mulch in the field. Applying clover as mulch might cause an increase for rate of nitrate in soil and also increase in the rate of carbon (C) improved the N-fixation in clover (Gardner et al. 1985). Murray and Clements (1998) also mentioned that death decomposition is one of the accepted ways for nitrogen transformation. In general, treatments in which application of US was early display better nitrate content in the field. These data compared with data about nutrient uptake indicates that plots with early US are better for next yield in the field because treatments with early US showed less nutrient uptake but more nitrate level in the soil.

In line with the results in Figure 3-B, ammonium rate in the soil showed different manner. Treatment 2121 and 2131 displayed a small amount of decrease before planting and after planting. In both treatments US was sowed late and this time was close to winter time. It is thought that lack of time for enough fixations might be a reason for satiability of ammonia in the soil before planting and after harvest. But then, in treatment 1221, in which clover had a proper time for fixation; high level of decrease in NH_4 was observed. It is believed that differences in ammonium use between treatment 1221 and 1231 refers to cutting which has been done for treatment 1231 and decreased the level of fixation in this treatment. In line with the results in ammonium level and nutrient uptake level, indicate that late US can increase nutrient uptake in the beginning of the growing period and also keep the ammonium level for next yield during winter.

5.4. Animal damage

Based upon the data in Table 17, animal damages were significantly different for treatments. According to Figure 4, treatment with early US and with cut was damaged more than other and had relation with treatment with early US and without cut (1221), however treatment 1221 had relation with treatment 1210 which was without US and not HW. All results above indicate the level of damage for treatments. Also during the two monitoring, it was observed that animal had chosen some plots to eat first and then continued with others. As Figure 5 shows, plots which were held with treatments 1231 and 1221 were completely damaged in all replications in the first invasion. It was observed that plots with treatments 2210 and 1210 were destroyed in 2 replications while 1210 in the third replication and treatment 2231 and 2221 were damaged slightly in the two plots. Treatments 1211 and 2211 were partly damaged in just one replication. This behavior illustrated that animal had trend to start with leeks that which had been in plots with longer clover like early US and then plots with more biomass like plots with weeds. The animals were selective in this case because as the Figure 5 shows, they passed some plots to reach the target plot with interesting leeks (e.g. plot with treatment 2221 in section D4).

It was observed that in the second attack treatments 1211 and 2211 had delicate damage compared with other treatments. The animals in this phase started with plots which were slightly damaged in the first invade which were 2221 and 2231 and both treatments had late US. Based on the above finding it is believed that animals preferred to eat leaks which were grown in plots and treatments with more biomass content.

6. Conclusion

It is believed that DM percentage in organic leek under intercrop system is more impressed by density. It was observed that increase in density created an increase in DM%. Moreover, treatments which were longer time with clover as US showed better DM% in comparison with other treatments. According to that, in both harvests, treatments with early US with both cutting management indicated more DM% in comparison with other treatments and just in the second harvest treatment without US and without HW displayed the same manner as well. However total DM production was under the effect of competition and density negatively. In treatments with late US and with any kind of cutting management produced more DM with treatment with early US and without US cut. In this character, treatment without US but with HW and treatment with early US and with US cut showed positive relation however all of these differences were disappeared by starting the winter season and consequently in the second harvest. What mentioned above support our hypothesis that existence of US can affect DM positively. Diameter as one of the main market qualities of leek in response to increased density gives better results in intercropped cultures so, treatments with late US showed better quality. This result can support the hypothesis and also Baumann (2001b) reported a positive effect by increasing density in intercrop system compared with mono-crop system.

Late US can increase the nutrient uptake significantly during the beginning of growing period. In line with the results, in treatment 1221 with early US and without cut, N content in DM was displayed in highest amount. In treatment 1231 with early US and with cut, using US as mulch increased the amount of N in the soil after harvest in comparison with before planting. In general treatments with early US had better nitrate level compared with other treatments. In some plots a sharp drop was observed in N level before planting and after harvest which could prove the luxury consumption of N by plant. On the other hand existence of clover for long time could cause a sharp drop of ammonium level in the soil after harvest in treatment 1221.

In case of animal damage, it was believed that the animal priority of eating are treatments with older clover and at the second level they had preferred to use the treatments with more biomass like treatments with weed. The complex ecosystem and also the temperature of plot as well as the richness of leeks might be the reasons that animals applied for their choices.

List of references

Biabani, A., Hashemi, M. & Herbert, S.J. (2008). *Agronomic performance of two intercropped soybean cultivars*. International Journal of Plant Production. 2: 215–222.

Melander, B. & Rasmussen, G. (2001). *Effects of cultural methods and physical weed control on intrarow weed numbers, manual weeding and marketable yield in direct-sown leek and bulb onion*. Weed Research. 41 (6): 491–508.

Backer, E., Aertsens, J., Vergucht, S. & Steurbaut, W. (2009). *Assessing the ecological soundness of organic and conventional agriculture by means of life cycle assessment (LCA): A case study of leek production*. British Food Journal. 111 (10): 1028–1061.

Bertschinger, L. & Anderson, J. D. (2004). *Sustainability of horticultural systems in the 21st Century*. International Society for Horticultural Science, Belgium. ISBN: 978-90-66057-07-4.

Baumann, D.T., Bastiaans, L. & Kropff, M.J. (2001a). *Competition and Crop Performance in a Leek–Celery Intercropping System*. Crop Science. 41 (3): 764–774.

Baumann, D.T., Bastiaans, L. & Kropff, M.J. (2001b). *Competition and Crop Performance in a Leek–Celery Intercropping System*. Crop Science 41: 764–774.

Baumann, D.T., Bastiaans, L. & Kropff, M.J. (2001). *Effects of Intercropping on Growth and Reproductive Capacity of Late-emerging Senecio vulgaris L., with Special Reference to Competition for Light*. Annals of Botany. 87 (2): 209–217.

Baumann, D.T., Bastiaans, L., Goudriaan, J., Laar, H. H. & Kropff, M.J. (2002). *Analysing crop yield and plant quality in an intercropping system using an eco-physiological model for interplant competition*. Agricultural Systems. 73 (2): 173–203.

den Hollander, N.G., Bastiaans, L., Kropff, M.J. (2007a). *Clover as a cover crop for weed suppression in an intercropping design*. European Journal of Agronomy. 26 (2): 104–112.

den Hollander, N.G., Bastiaans, L., Kropff, M.J. (2007b). *Clover as a cover crop for weed suppression in an intercropping design*. European Journal of Agronomy. 26 (2): 92–103.

den Belder, E., Elderson, J. & Vereijken, P. F. G. (2000). *Effects of undersown clover on host-plant selection by Thrips tabaci adults in leek*. Entomologia Experimentalis et Applicata. 94 (2):173–182.

Francis, C. A. (1986). *Multiple cropping systems*. Macmillan; London: Collier Macmillan, New York. 383 pages. ISBN: 9780029486108.

Francis, C. A. (2009). *Organic farming. The ecological system*. WI: American Society of Agronomy; Crop Science Society of America; Soil Science Society of America, Madison. 355 pages. ISBN: 978-0-89118-173-6.

Gabriel, J.L., Muñoz-Carpena, R. & Quemada, M. (2012). *The role of cover crops in irrigated systems: Water balance, nitrate leaching and soil mineral nitrogen accumulation*. Agriculture, Ecosystems & Environment. 155: 50–61.

Gardner, F. P., Pearce, R. B. & Mitchell, R. L. (1985). *Physiology of crop plants*. 1st ed. Iowa State University Press, Ames. 327 pages. ISBN: 081381376X.

Müller-Schärer , H. (1996). *Interplanting ryegrass in winter leek: effect on weed control, crop yield and allocation of N-fertiliser*. Crop Protection. 15 (7): 641–648.

Hole, D. G., Perkins, A. J., Wilson, J. D., Alexander, I. H., Grice, P. V. & Evans, A.D. (2005). *Does organic farming benefit biodiversity?.* Biological Conservation. 122 (1): 113–130.

Hopkins, A. (2004). *Organic farming : science and practice for profitable livestock and cropping*. British Grassland Society, England. ISBN: 0905944844.

Hoshmand, A. R. (2006). *Design of experiments for agriculture and the natural sciences*. 2nd ed. Chapman & Hall/CRC, London. 437 pages. ISBN: 9781584885382.

Isik, D., Kaya, E., Ngouajio, M. & Mennan, H. (2009). *Weed suppression in organic pepper (Capsicum annuum L.) with winter cover crops*. Crop Protection. 28 (4): 356–363.

Kroeck, S. & Langer, J. (2011). *Crop rotation and cover cropping*. Chelsea Green Pub, farm. Rev. White River Junction, VT. ISBN: 9781603583459.

Wyland, L. J., Jackson, L. E., Chaney, W. E., Klonsky, K., Koike, S. T. & Kimple, B. (1996). *Winter cover crops in a vegetable cropping system: Impacts on nitrate leaching, soil water, crop yield, pests and management costs*. Agriculture, Ecosystems and Environment. 59 (1-2): 1–17.

Mennan, H., Ngouajio, M., Isık, D. & Kaya, E. (2009). *Effects of alternative winter cover cropping systems on weed suppression in organically grown tomato (Solanum lycopersicum).* Phytoparasitica. 37 (4): 385–396.

Tursun, N., Bukun, B. & Can Karacan, S., Ngouajio, M. & Mennan, H. (2007). *Critical Period for Weed Control in Leek (Allium porrum L.).* Hortscience. 42 (1): 106–109.

Murray, P.J., Dawson, L.A. & Grayston, S.J. (2002). *Influence of root herbivory on growth response and carbon assimilation by white clover plants*. Applied Soil Ecology. 20 (2): 97–105.

Murray, P.J. & Clements, R. O. (1998). *Transfer of nitrogen between clover and wheat: Effect of root herbivory*. European Journal of Soil Biology. 34 (1): 25–30.

Booij, R., Kreuzer, A.D.H., Smit, A.L. & von der Werf, A. (1996). *Effect of nitrogen availability on dry matter production, nitrogen uptake and light interception of Brussels sprouts and leeks*. Nederland Journal of Agricultural sciences. 44 (1): 3–19.

Sadeghi, S., Rhnavard A., Ashrafi Z.Y. (2010). *Responds of Leek (Allium porrum L.) to various weed management*. Journal of Agricultural Technology. 6 (3): 607–614.

Thorsted, M. D., Olesen, J. E. & Weiner, J. (2006). *Mechanical control of clover improves nitrogen supply and growth of wheat in winter wheat/white clover intercropping*. European Journal of Agronomy. 24 (2): 149–155.

Uchino, H., Iwama, K., Jitsuyama, Y., Yudate, T. & Nakamura, S. (2009). *Yield losses of soybean and maize by competition with interseeded cover crops and weeds in organic-based cropping systems*. Field Crops Research. 113 (3): 342–351.

Uchino, H., Iwama, K., Jitsuyama, Y., Ichiyama, K., Sugiura, E., Yudate, T. (2012). *Effect of interseeding cover crops and fertilization on weed suppression under an organic and rotational cropping system.* Field Crops Research. 127: 9–16.

Annex 1

Literature review

There are many advantages which suggested intercropping as a successful cropping system such as stability of yield, increasing biodiversity, more efficient use of natural recourses for crop growth and potential protection of crop against weeds, pests and diseases by filling free niches and increasing biodiversity and competition (Baumann et al., 2001). Baumann et al. (2000) have shown that intercropping with a higher light interception of crop canopy illustrating better results with respect to weed suppression in intercropped leek field compared with the same light interception of crop canopy. This result was also illustrated not only in biomass of weed but also the weed seed production was significantly decreased.

Increasing the leek density in mono-crop system showed a significant reduction in plant weight and pseudostem diameter but, same increasing in leek density were not significantly affected in intercrop system with celeriac plants. And in the above mentioned experiment, leek reached the market quality for all intercrop systems. Intercropping have positive effects on quality parameters with light competition which caused leek to grow higher and make longer white stem, although the bleached part if stem tended to be longer in higher density of plants (Baumann 2001b).

Intercropping reduces the total yield due to competition between main crop and intercrop for recourses and even space but, reduction in intercropping by clover can be compensated in the rotation. In other words, Wolfe (2004) illustrated in vegetable-clover intercropping systems, it is worth considering to condone in deficiency of vegetable production against field efficiency and yield productivity in following crop however, Some studies show some vegetables like root and leaf beet have shown better responses to white clover in intercropping compared with onions and leeks (Hopkins 2004).

Cover crop is considered as an effective tool to suppress weeds. There are many aspects and factors which are important for choosing cover crops. Some cover crops are more effective on some special species but legume and cereal cover crops are used for different kinds of crops (Isik et al. 2009). Application of US cover crop for weed management aim is relevant to used for the crops which are not that much competitive. Slow growing crops like leek or onion which have been upright leaves are not able to cover the canopy to suppress weed growth adequately (den Hollander et al. 2007a, p. 93). As Isik et al. (2009) showed, at the regions with cold temperature, cover crops with high cold tolerance like ryegrass and Egyptian clover are more effective and can spread and establish rapidly.

Cover crop can cause many interactions in microbial situation in the soil. Some of these interactions are intricate, especially when cover crop enhancing a kind of pathogen activity while decreasing another kind at the same period of time. But Wyland et al. (1996) mentioned that it is thought the cover crop and organic amendment in general suppress the soil pathogens because of the changes that they beget in carbon (C) and N ratio. The mentioned author illustrated that cover crop in vegetable production was commercially profitable because of its effects on insects or disease which neither introduce nor increase viable amount of pathogens which threaten the main crop in the soil, and more importantly, winter cover cropping costs were small comparedg with conventional soil management in winter.

In agricultural fields, the surface layers of the soil have organic C and N and high microbial activities. These factors and some other abiotic factors like soil moisture and texture help the system to provide nutrient for plants. Agricultural activities and cultivation decline the soil organic matter which has a big effect on microbial activity. Applying cover crop with all its benefits like increasing microbial activities or adding nitrogen to soil is a good option to improve nutrient dynamics in top soil layer (Wyland 1996). The researchers showed sowing cover crop with high density right after distributing compost on the field can keep nutrient in compost for further metabolizing by the soil. Quick root developing system in cover crops might be a reason for that nutrient saving (Kroeck & Langer 2011). Gabriel et al (2012) have reported replacing intercrop fallow with cover crop can increase maintenance of inorganic N after post-harvest and also has positive effects on N use efficiency and reduces NO_3 leaching in humid areas. Low water use efficiency limits the application of cover crop in arid areas however, in semiarid regions which cover crop can establish properly because of irrigation, sustainability could increase because of consequent soil and nutrient conservation. Some recent studies on maize have reported that cover crop did diminish NO3- leaching during the early growth period of next maize season but not in the intercrop period (Gabriel et al. 2012).

Besides all the benefits of using cover crop, there are some disadvantages or potential problems in applying cover crops. Plowing time might be one of these problems. It is crucial to let cover crops to decompose for some weeks before planting a new crop in the area. The studies showed an allelopathic effect while the first decomposing happened in winter rye which was used as cover crop (Kroeck & Langer 2011).

Nitrogen is one of the components of soil organic parts and an essential part of living cells. Therefore, Organic farmers should know about N cycle to be able to do an effective N management and luckily N can supply by organic matters that can be grown on the farm itself (Francis 2009).

Nitrogen Fertilizer is mostly applyed to increase the soil fertility and total yield subsequently. But difficulties to define an exact amount for especial crop in a certain area may cause some issues. Broad range of nitrogen usage of a plant and in total, a farm, produces an economical demand to find optimum uses of nitrogen to produce a relevant yield in continue. On the other hand in conventional farming regimes, high utilization with nitrogen has negative effects on the environment due to high losses of nitrogen. Booij et al. (1996) reported that leek has low nitrogen uptake rate compared with some other vegetables like Brussels sprouts and also it is the same for relative growth rate. It might because of nitrogen demand in leek and less dependency of leek to nitrogen to support dry matter which causes less reaction to nitrogen supplies on the soil consequently. The author illustrated, adding high amount of nitrogen at transplanting, may cause risk of nitrogen leaching during growing periods especially in slow growing plants like leek. He also stated that 2.8-3.1 % is a minimum nitrogen concentration which is needed to have maximum dry matter in leek at any part of growing period. Considering that high amount of nitrogen are within the leaves, LAI could be a factor to estimate the nitrogen demand in each part of crop period. Leek use the major part of N during 5 to 7 weeks before final harvest, therefore High amount of N is required in this period. Furthermore, considering of small biomass production during first month of growth, there would be little amount of N is absorbed during early growth period (Baumann 2001b). Wolfe (2004) reported white clover in intercropping allows little release of accumulated N during the growing season and while it is still on the field and alive and in this case it is not a big assertive competitor (Hopkins 2004).

Müller-Schärer (1996) reported intercropping leek with ryegrass (*Lolium perenne L.*) has reduced the nitrogen leaching by allocating nitrogen in interplant specially in autumn and winter compared with bare plots. In the same research, the author illustrated that treatments with late sowing of interplant (ryegrass) were closer to the control treatment (without ryegrass) in yield production. The author reported late sown treatments were taller, thinner and the white part of the shaft was larger and nitrogen level was reduced as compared with control treatments. However, all the characteristics mentioned before are preferred by market for leek. Another research showed applying ryegrass as interplant reduced N leaching losses from 110 kg N/ha to 40 kg N/ha compared with bare fallow. Wyland et al. (1996) reported winter cover cropping decreased leaching of N and water from surface layer because of extensive rooting system in top layer which created by cover crop. The author also mentioned that other studies reinforced the idea that winter cover crops reduce NO^{3-}N leaching after harvest or in the areas with long rainy season.

Kroeck (2011) stated plowing cover crop can enhance the fertility of the soil. Besides that, some researchers reported legumes are not able to contribute to N saving for long-term, despite the fact that they increase the nitrogen uptake in the soil for the plant grown with or after them. Also, some agronomists stated that beside the nutrient which is the result of decomposing in crop, the decomposition process itself can increase the fertility in the soil (Kroeck & Langer 2011). Cuttle and Goodlass (2004) reported the crop with higher yielding which fixed by more N has relationship with the quantity of N fixed by special kind of legume. They described these relations as a way of estimating N fixation. Any problem in crop, like disease effects performing of crop and will affect the N fixation and subsequently the yield (Hopkins 2004).

There are some other plants which contribute to other nutrients which can be considered for further researches. For instance, Kroeck (2011) illustrated Buckwheat (*Fagopyrum esculentum*) is good phosphorus; whereas timothy (*Phleum pratense*) is a good K gatherer and brassicas are good in collecting sulfur but Mustard revert calcium to the soil.

Weed as one of the major restrictions for organic production can reduce potential yields around 45% to 95% depending on the crop, ecological and climatic condition. In some transplanting crops like tomato which have slow early growth, yield losses can reach up to 32% (Mennan et al. 2009). The risk of weeds is not just because of reducing the quantity of main crop but also decreasing the quality of or crop and weeds increasing their soil seed banks as well, which may cause severe weed invasion in the next growing season. Uchino et al. (2012) reported that weed was significantly suppressed by cover crop (rye and hairy vetch) in soybean and maize farm. This study shows, during the years coefficient of variation between years and the main crop in weed dry matter for areas with cover crop was less than without cover crop. It shows cover crop in a long term can effect weed growth by suppressing that stably. This stability in weed suppression can be very helpful for decreasing the mechanical weed management in organic farming which affects the quality of farm and the main crop. The new studies indicates that effective and stable weed management without harmful yield reduction of main crop is possible by applying cover crop and enough fertilization in organic farming regimes.

Date of sowing as a part of cover crop management should be considered. Understanding about critical period during crop growing life is important for weed control and to improve the weed management strategies (Tursun et al. 2007). Uchino et al. (2009) illustrated that date of sowing can affect weed suppression efficiently. The author reported that in general the yield of maize and soybean as main crops were higher when rye and hairy vetch as cover crop were sown after main crop establishment compared with same date and before establishment of main crop. Farmer's experiences have shown weed invasion is higher when the soil moisture is high and the crop is in the beginning of its growing period. In wet area some farmers prefer to keep cover crops on the field more than normal to decrease the moisture level (Kroeck & Langer 2011).

Some researchers showed fast growing weeds with tallness and huge biomass are most dangerous one for vegetable production, because competing for light is the main factor in weed and vegetable competition, such as *Amaranthus* species (Müller-Schärer 1996). Baumann et al. (2000) illustrated a positive effect of intercropping of leek (*Allium porrum L.*) with celery (*Apium graveolens L.*) on weed growth suppression and also seed production of the weeds. The mentioned research showed canopy light interception and increasing in competition can reduce biomass and reproductive potentials for weeds and although, it have some negative effects on leek quality and total yield. Increasing in light competition in canopy in intercrop systems cause a reduction on weed biomass production and seed production subsequently. Baumann et al. (2001) reported a significant reduction in both biomass and seed production in special late-emerging weed (*Senecio vulgaris* L.) in intercropped leek with celery compared with mono-culture leek system. However, intercropping with celery had negative impact on leek quality by decline on leek diameter because of competition (Baumann et al. 2001, Bertschinger & Anderson 2004).

Changes in consumer's attitudes towards environmentally friendly agriculture, have created an urgent need to change present used production systems. Intercropping has intentioned by many entomologists and pathologists for reducing pest numbers and diseases (Müller-Schärer 1996, p. 1). Intercropping can control pest's numbers and it can reduce yield loss subsequently. There are many factors in intercropping which can affect the pest population. The plant intercropped can be a natural enemy or it can reduce the resource concentration so, reduction of host quality can be considered. Belder et al. (2000) illustrated the hypotheses about natural enemy, host quality and resource concentration which should be considered by justifying reduction in pest population in intercropping systems. Intercrop as an additional resource can diversify the natural enemies for pests and insects (Risch, 1981). Theunissen (1994) showed that direct interaction between plants in intercropped system can change quality of main or host plant in a way that can affect and reduce pest numbers (Belder 2000). Cover crop can play a beneficial role in pest management. As Kroeck (2011) mentioned, Ladybug is attracting to dandelions as a good habitat, and as the weather getting warm, they will move to vegetable crops (Kroeck & Langer 2011). Researches stating that clover has ability to reduce various pests in some vegetable cultures (den Hollander et al. 2007b, p. 1). Belder et al. (2000) reported that Leek undersowned by strawberry clover (*Trifolium fragiferum L.*) have responded to the pest (Thrips tabaci). The author mentioned that the plots with undersown significantly harbored less thrips compared with mono-crop leek. The author also showed that even after cutting undersown the number of pests were one-third of mono-crop leek plots.

Annex 2

Table 18: Analysis of variance (mean square) for Leek Diameter in first and second Harvest:

Source	DF	Diameter in first harvest	P value	Diameter in second harvest	P value
Treatment	5	12.4979 **	0.0001	16.6272 **	0.0016
Error	10	0.4895	---	1.79	---

Mean Square with ** are significant in P≤ 0.01 and "ns" are not significant. (DF: Degree of freedom)

Table 19: Analysis of variance (mean square) for Leek Height in first and second Harvest:

Source	DF	Height in first harvest	P value	Height in second harvest	P value
Treatment	5	1488.68 ns	0.2741	406.38 ns	0.3366
Error	10	994.3	---	311.93	---

Mean Square with "ns" is not significant (p≤ 0.05)

Table 20: Effect of US management on leek height (mm) average in first harvest:

Treatment	Without US		Same day US	Late US
	HW	No HW		
- CUT	335.17 a	361.97 a	374.22 a	318.33 a
+CUT	- - -	- - -	338.67 a	321.33 a

Means with the same letter do not differ significantly (p≤ 0.05, Duncan test)

Table 21: Effect of US management on leek height (mm) average in first harvest:

Treatment	Without US		Same day US	Late US
	HW	No HW		
- CUT	280 a	286.7 a	302.89 a	268.67 a
+CUT	- - -	- - -	283 a	275.67 a

Means with the same letter do not differ significantly (p≤ 0.05, Duncan test)

Table 22: Analysis of variance (mean square) for Leek N uptake in first and second Harvest:

Source	DF	N uptake in first harvest	P value	N uptake in second harvest	P value
Treatment	5	328.71*	0.014	875.9 ns	0.29
Error	12	169.41	---	1493.6	---

Mean Square with * are significant in P≤ 0.05 and "ns" are not significant.

Table 23: Analysis of variance (mean square) for Leek P uptake in first and second Harvest:

Source	DF	P uptake in first harvest	P value	P uptake in second harvest	P value
Treatment	5	5.4995 *	0.015	10.799 ns	0.687
Error	12	2.9432	---	41.771	---

Mean Square with * are significant in P≤ 0.05 and “ns” are not significant.

Table 24: Analysis of variance (mean square) for Leek K uptake in first and second Harvest:

Source	DF	P uptake in first harvest	P value	P uptake in second harvest	P value
Treatment	5	100.375 **	0.004	209.36 ns	0.315
Error	12	36.853	---	376.76	---

Mean Square with ** are significant in P≤ 0.01 and “ns” are not significant

Annex 3

Table of Soil nitrogen content

1st Sampling Date 12.08.2011	treatment	NO3-N (0-30)	NH4/mg (0-30)	kg ha^{-1}
	1121	1.06	0.11	45
	2121	2.30	0.04	97
	1221	2.14	0.52	90
	2221	0.99	0.18	42
	1211	0.80	0.11	34
	2211	0.61	0.13	26
	1210	0.83	0.10	35
	2210	1.76	0.09	74
	1131	0.78	0.10	33
	2131	3.09	0.04	130
	1110-1	1.01	0.04	42
	1110-2	1.05	0.05	44
	1231	0.34	0.11	14
	2231	1.44	0.15	60

2nd Sampling Date 21.03.2012	treatment	NO3-N (0-30)	NH4/mg (0-30)	kg ha^{-1}
	1121	0.90	0.07	38
	2121	0.49	0.04	21
	1221	1.10	0.09	46
	2221	0.42	0.09	18
	1211	0.64	0.07	27
	2211	0.50	0.08	21
	1210	0.88	0.07	37
	2210	0.81	0.06	34
	1131	0.38	0.05	16
	2131	0.46	0.03	19
	1110-1	0.66	0.05	28
	1110-2	0.48	0.04	20
	1231	0.68	0.07	29
	2231	0.51	0.09	21

List of treatments

1210	**with leek** + without US + **without HW**
1211	**with leek** + without US + with HW
1221	**with leek** + **early US** + without cut + with HW
1231	**with leek** + **early US** + **with cut** + with HW
2221	**with leek** + **late US** + without cut + with HW
2231	**with leek** + **late US** + **with cut** + with HW
1121	without leek + **early US** + without cut + with HW
1131	without leek + **early US** + **with cut** + with HW
2121	without leek + **late US** + without cut + with HW
2131	without leek + **late US** + **with cut** + with HW
1110-1	Fallow
1110-2	Fallow