Influence of tillage systems and organic amendments on weed dynamics in an organic potato system.

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Period: From March to July 2014

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Preface

This minor thesis was part of my MSc Organic Agriculture program. It took place in Wageningen at the end of the first year of my study program as part of the double degree program with ISARA-Lyon in France. I conducted this research at the Droevendaal farm, the certified organic research facility of Wageningen University between March and July of 2014. Above all, this research is in line with my future ambitions and personal interest while the influence of tillage system is also very pertinent to organic agriculture.

On a more personal point of view, the research contributed to my academic developmental since I was part of an international team of students who had different research topics related to mine, and as we shared results and cooperated for field work on a daily basis.

I want to thank first my supervisors Johannes Scholberg and Egbert Lantinga who accepted me in this project and who guided me during four months. I also want to thank the students working with me, Ioannis Koufakis, Konstantinos Litsos and Carlos Salamanca Fresno, all the members of Unifarm and last but not least student friends and specifically Elisabeth Simon who was a great support to me.

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Summary

One of the ongoing research studies conducted by the chair group Farming System Ecology focuses on the effects of tillage systems on organic potato production. During my minor thesis I assessed the influence of tillage systems and organic amendments on weed dynamics in this system as part of an integrated study that addressed the interactive effects of tillage (reduced vs conventionl) and organic soil amendments (cow manure, luzerne pellets, and grass clover sillage) on soil quality and crop performance. One key question was if the use of plant-based vs animal-based fertilizer affected weed biomass.

My research was structured in four components. The first one determined the influence tillage and soil amendments on weed diversity by comparing the weed species in different treatments. The second one assessed the effects on weed density while the third focused on biomass as related to crop growth and plant interaction (El Titi, 2002). The last aspect was to examine the influence of the canopy of the potato plant on the growth of the weed and alternatively the effects of weeds on the growth of potato. In order to assess the influence of tillage and amendment on weed communities, several measures were conducted at different time intervals such as the identification of weed species, the total weed density and corresponding weed biomass for selected treatment combinations.

The shift in composition of the weed fauna due to different tillage regimes is in agreement with findings in the literature. It was observed that the incidence of Chenopodium album and Capsella bursa-pastoris was higher in reduced tillage compared to the other species. Regarding diversity and biomass, the treatments related to tillage and amendments numerically were differed but were statistically similar. In general it appears that the total density of weed species was higher in standard tillage than reduced tillage.

Identification of the weed species was difficult during initial growth due to lack of distinct differentiating features including flowers of very small plants. At the end of the cycle just before the harvest, some weeds reached the reproductive stage, and the identification was facilitated by the presence of flowers.

The incidence of *Phytophthora infestans* (early blight) disease was noticed half way through the research in half of the field plots. The rapid development of the fungi that decimated the potato canopy was due to the combination alternating warm and wet climatic conditions during the end of May and the beginning of June. The rapid decline in the crop canopy favored weed development in those plots that were impacted most by early blight (see figure 1).

Figure 1: Phytophthora

It is concluded that there is no main effect of tillage and amendments on weed diversity and weed biomass in this experiment. But there is an effect of these factors on the weed diversity since the density of Chenopodium album and Capsella bursa-pastoris are higher in reduced tillage compared to the other species.

1.0 Introduction

1.1 Research context

The Droevendaal farm is the certified organic research facility of Wageningen University. One of the research studies conducted by the chair group Farming System Ecology deals with the effects of tillage systems on organic potato production. Organic agriculture has to comply with proposed production standards as defined by the International Federation of Organic Agricultural Movement. According to the principle of health, use of chemical fertilizer and pesticides are prohibited in organic agriculture (IFOAM). Hence, weed control is one of the major challenges that organic farmer are facing. The composition and incidence of weed in farmers' fields depend strongly on farm management, field history and environmental conditions (El Titi A.,2003).

This research will mostly focus on the impact of strategic decisions, which are characterized by long-term choices prior to planting a crop including tillage regime , choice of soil amendment, and crop rotation (El Titi A.,2003) on weed dynamics in organic potato production. Tactical decisions that occur during the growing season including operational decisions are typically taken on a weekly or a daily basis and these also affect weed population and these will be taken in to consideration in terms of defining sampling dates.

1.2 Potato production

In 2013, 155000 hectares in the Netherlands were planted with potato while the total fresh market production amounted to 3.8 million tons (CBS, 2014). In 2014, the organic potato production represented 1556 ha which translates to less than 1% of the total production. Typically the yield of organic potato is around 25-30 tons per hectares, which represent 50 to 60% of conventional yields. There is a year-to-year variation in yield due to late blight damages (Lammerts van Bueren, 2008). Another challenge for the organic potato production in the Netherlands is the nutrient availability since the manure used as fertilizer is provide only by organic farms (Möller , 2000 cited in Lammerts van Bueren, 2008).

1.3 System diagram

The history and the characterization of the experiment site can have an impact on the research (see diagram 1). Firstly regarding the management of the field, tillage and fertilization impact the crop growth. The tillage regime applied has mostly been standard tillage (Andries Siepel, personal communication). The tillage regime has long-term effects and consequences. It is desirable that studies need to be continued over a period of at least three years to measure the long-term effect of reduced or non-tillage on weeds, soil biota and properties (Marion Casagrande, personal communication). Regardless, short-term experiments can still provide an assessment of initial changes and potential challenges that farmers may face when reverting to reduced tillage practices. Secondly, the physical and chemical soil properties are also impacting the research results. In this case, the soil type is sandy. Some initial measures such as the density of earthworms, soil bulk density and nitrogen content may be warranted to provide a baseline assessment of overall soil quality. Such values obtained at the beginning of the crop cycle, before any intervention on the field, then can be compared with the following results and used to establish an evolution of the measures amongst the cycle (Johannes Scholberg, personal communication).

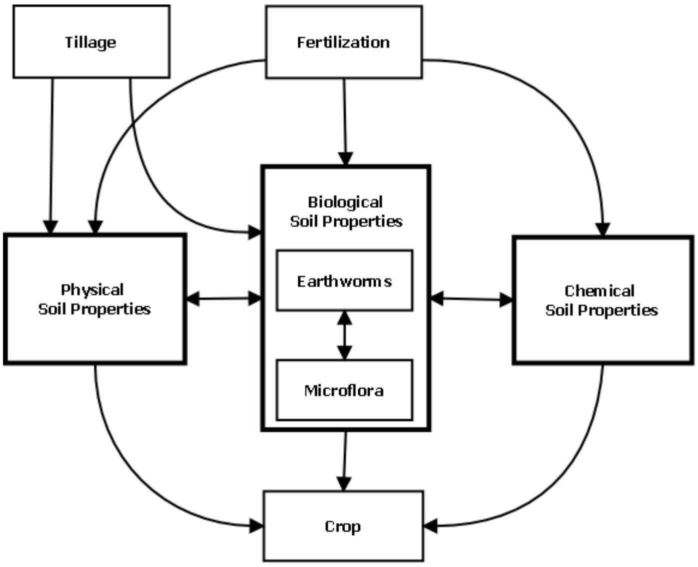

Diagram 1: system diagram showing the interactions between the components. Please make your own diagram and focus on weeds instead of earthworms and/or microflora

1.4 WEED DYNAMICS and MANAGEMENT

1.4.1 EFFECT OF TILLAGE ON WEED DYNAMICS

Since organic farmers don't have recourse to herbicides, mechanical weed control including frequent tillage is commonly used in organic farm to suppress weeds. Organic farmers also prefer the use of plough-based conventional tillage while non-inversion conservation tillage is only practiced by few farmers (Gruber & Claupein, 2009). On one hand, standard tillage is defined by cultivating and inverting the top 20-30 cm of the soil profile. Thereby it facilitates the incorporation of crop residues and soil amendments, provides effective weed control, and results in a uniform seed bed prior to sowing. On the other hand, reduced tillage is non inverted tillage and is defined as tillage types that ensure a 30% soil cover by residues (El Titi, 2003). No tillage system leaves the soil undisturbed during the growth cycle, except for the supply of chemical fertilizers or herbicides when needed in conventional systems. In potato crop, ridge-tillage is commonly used as ridges are formed before planting which are being rebuilt during the growth cycle.

According to El Titi (2003), soil cultivation has an indirect impact on emergence, germination and dormancy of seeds. In Figure 2 the influence of soil cultivation on soil inversion is shown. Others consequences are presented on the right side that are not directly related to the incorporation of seed into deeper soil layers.

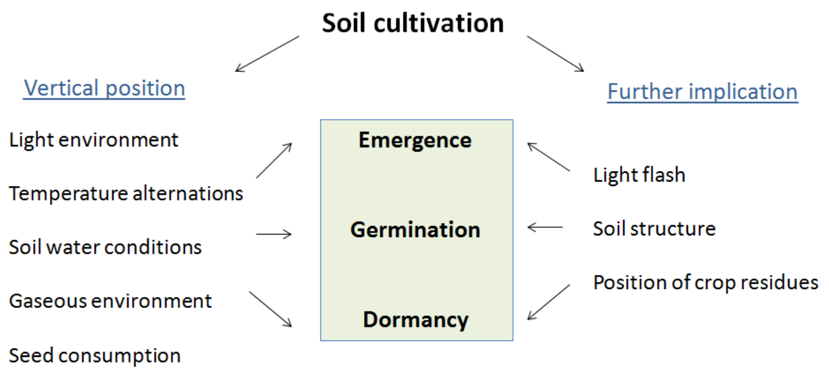

Figure 2: Implications of soil tillage for weed seeds (El Titi, 2003)

One of the consequences of the soil inversion is the incorporation and transfer of weed seeds, from the top to deeper layers and vice versa (see figure 3) which is changing the vertical distribution of weed seeds in the soil (Peigné et al., 2007). Seed stratification influences the emergence; germination and dormancy of the seeds though change of abiotic factors in the soil presented at the right side of the figure 2. Due to these modifications, it is assumed that the density of weed is usually lower in standard tillage than in reduced tillage (Ghersa & Martinez-Ghersa, 2000).

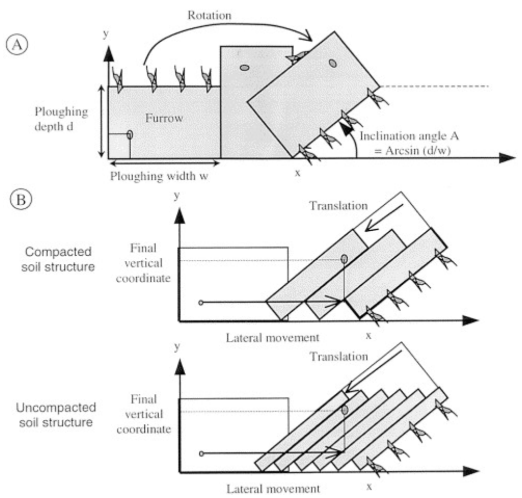

Figure 3: overturning of the tillage (Colbach et al., 2000)

However, regarding the **emergence of weed seeds**, intrinsic features of the weed seeds have an impact on this as well. For example, a study conducted by Leblanc et al. (1998) stated that the maximum depth of emergence difference across species. For example, this depth is 4.9 cm for Polygonum persicaria and 2.7 cm for Chenopodium album. In addition, the distribution of the seeds also depends on tillage systems, and thereby influence subsequent emergence. Conventional tillage randomly disperses the seeds across the different layers. Thereby the emerging weed represents only a small fraction of the total seed bank. On the contrary, a high fraction of the total seed bank is located in the top layers with conservation tillage: "weed seeds are more uniformly distributed in the topsoil with conventional tillage, but are mainly located in the first few centimeters of soil under conservation tillage" (Peigné et al., 2007). Some models have been proposed to assess the emergence of the seed in difference tillage systems by taking into account parameters such as seed distribution across different soil layers and the environmental conditions such as light, moisture and temperature which all have an influence on the weed seed germination (see figure 2). It was shown that most models have "a better predictive capability in zero-tillage systems" (Ghersa & Martinez-Ghersa, 2000). In terms of seed predation of weeds this will increase when the seeds are close to the soil surface, especially for the weed species with larger seed (Ghersa & Martinez-Ghersa, 2000). Regardless, with conservation tillage a higher emergence rate is not off-set by seed predation losses and overall weed pressure tends to be higher, especially during initial transition or for poorly managed systems.

It has been observed that weed **germination** is linked to soil temperature as affected by tillage systems while optimal germination temperature is species-specific. For example, for Chenopodium album this value ranges between 20 and 25°C, and for Polygonum convolvulus, germination is very slow at around 2-5°C while maximum rates occurring at a temperature of 30°C (Leblanc et al. 1998).

Dormancy is also modified by tillage systems. For example, when weed seeds with a high longevity rate are removed from upper to deeper layers, they will survive due to seed dormancy (Gruber & Claupein, 2009). On the contrary, for seeds with low longevity rate, germination will not occur particularly because of the lack of light and oxygen availability in the deeper layers (see figure 2). That is also explaining why the weed density in standard tillage is usually lower than in conservative tillage.

Seed exposure to light, soil structure and the position of the crop residues, which are not linked with the vertical distribution of the seeds still are affected by tillage an influence weed seeds environment and germination (see right part of the figure 2). First, light has an effect on the germination rate and the longer the seeds are exposed to sunlight, the higher the germination rate (El Titi, 2003). The placement of crop residues also affects the emergence of the seed (El Titi, 2003). In no-tillage system, the crop residues remain on the surface and impact the emergence since they constitute an obstacle for the seeds to emerge. Soil structure also is influencing weed germination since it determines seed-soil contact, soil aeration, soil moisture and soil warming thereby governing seed growth environment seed (Bàrberi & Lo Cascio, 2001).

As mentioned earlier, tillage has an influence on the **distribution of weed seeds** across different soil layers (stratification), and thus also affects the diversity of different weed species. Characteristics of the seed such as its size and longevity are the main parameter influencing weed emergence and thus weed density. Small seeds can only emerge if they are located near the soil surface while "big seeds are able to germinate even from 20 cm depth" (Gruber & Claupein, 2009). Longevity, which is also called the persistence or the viability of the weed seed to sustain its germination vigour may be assessed using a "Bekkers" score with value ranging between zero and one (Ghersa & Martinez-Ghersa, 2000). A previous study (Flores, 2013), showed that in potatoes grown at the Droevendaal farm, Chenopodium album was the most dominant weed species (Flores, 2013). The two other prevailing weed species were Polygonium convolvulus and Lolium perenne. Chenopodium album has a persistence of 0,45.

Last but not least, **seed reproductive rate** is also an intrinsic factor governing weed pressure. Annual weed are usually characterized by a r-strategy (El Titi, 2002), which implies that a large numbers of seed coupled with a high level of dispersion is being used as reproduction strategy. The opposite is the K-strategy, used by large seeded weeds and perennial weeds that are centered around greater persistence (Zimdahl, 2013).

Additionally differences in weed density as affected by tillage practices may also be related to a modification of species an/or diversity of species. In order to assess the effect of tillage on weed diversity, a study was conducted during three years in Spain (Dorado & Lopez-Fando, 2006). It was shown that conventional tillage system, had a lower Shannon's H′ diversity index with values being lower or equal to one, whereas in the minimum tillage plots values were on average 0.5 higher. Moreover, "several authors have reported an increase in annual grasses, perennial weeds and wind-dispersed species with reduced tillage" (Dorado & Lopez-Fando, 2006). The presence of biennial and perennial weeds is expected to increase under conservation tillage such as reduced tillage because the perturbation of root systems is diminished in no tillage system and re-growth during the next year is thus enhanced (Swanton et al., 1993). On the contrary, use of conventional tillage tends to favour more persistent seed types within the overall weed seed bank (Ghersa & Martinez-Ghersa, 2000). , This since it results in seeds being buried in deeper soil layers, therefore only those species that have high longevity will survive. However, another study by Derksen et al. (1993) tried to determine the association of weed species under different tillage systems, using a canonical discriminant analysis and no clear differentiation effect could be demonstrated.

1.4.2 Effect of SOIL amendments on weed DYNAMICS

The second key factor governing weeds may be the use of different organic soil amendments and their effect on weed population. This may be related to presence of seeds in manure or crop residues along with the effects of nutrient release patterns and/or soil biological processes on subsequent weed germination and growth (Miyazawa et al,. 2004). The main focus in most research studies is the potential competition for N uptake between weed and the potato crop. It was shown that "organic fertilization alters the weed community through a changing soil nutrient regime that influences weed seed germination, growth and competitiveness" (Miyazawa et al,. 2004).

Different soil amendments, either animal or plant based fertilizer, may have different C/N ratio's. The C/N ratio of straw, which may be used a mulch in no-till treatments, is close to 100. The higher the C/N ratio, the slower the decomposition of the residue which delays the net release of nutrients. Different mineralization rates and corresponding N release patterns will influence the availability of nitrogen for the crop and the synchronization of the net mineralization with actual crop vs prevailing weed species. The resulting competition between the potato and the weed may thus be differentially affected depending whether nutrient release patterns, in terms of synchronization more closely match those of the crop or the weed specie. On the other hand, the use of manure was shown to result in an increase of weed density, because it may contain undigested weed seeds (Miyazawa et al,. 2004).

1.5 Research questions and hypothesis

The main research questions included the following:

1) In what manner do tillage systems influence weed density, biomass and diversity?
2) How do organic amendment affect weed density?

The corresponding research hypotheses were:

- Weed abundance will be higher in reduced tillage than in standard tillage (weed pressure will be highest, intermediate and lowest for non-tilled, reduced tillage standard tillage plots, respectively (Miyazawa et al,. 2004).
- Tillage systems will result in a shift in weed species with increased prevalence of perennial weed species.
- Use of solid cattle manure will increase weed density, due to the introduction of weed seed via the manure.
- The weed diversity in the mulch treatments will be lower than the other treatments.

2.0 Materials and Methods

2.1 EXPERIMENTAL CONDITIONS AND CROP MANAGEMENT

The experiment was conducted in an experimental field plot located in the Droevendaal farm which is the certified organic research facility of Wageningen University, the Netherlands (51°58'N, 5°39'E). The previous crops included field beans (2011)), wheat (2012), and rye (2013). The soil is a well drained sandy soil with an initial organic matter content of 27,2 g kg^{-1} (in April 2014).

The weather station De Veenkampen located in the west part of Wageningen was used to provide information on daily precipitation and the temperatures. Based on an 80-year dataset (1928–2008) for Wageningen compiled by Jacobs and al (2010), the mean annual rainfall amount at the site would be on the order of 765 ± 130 mm.

An outline of agronomic practices along with corresponding dates is provided in Table 1.

Table 1: Outline of key agronomic practices during the growing season of the potato crop

	APRIL	MAY	JUNE	JULY
Tillage	11^{th} of April			
Fertilization	10^{th} – WAP 0			
Planting	??			
Ridging	17^{th} – WAP ?	WAP 3 and 6		
Weed sampling		WAP 3 and 6	WAP 8 and 10	WAP 11

2.2 EXPERIMENTAL TREATMENTS AND DESIGN

Experimental treatments consisted of three tillage systems and three soil amendments. The three tillage systems included: a) Standard tillage, moldboard ploughing up to a depth of is 30cm (ST); b) Reduced tillage, roto-tilling the soil up to a depth of 15 cm deep (RT) and zero tillage at all (NT). Ridging occurred 4 times at approximately three week interval (Table 1). For the Grass Clover Silage Half (GCSH) treatment, the last two ridging were omitted and at 6 weeks after planting (WAP) potato ridges were covered with half of the grass clover silage material that served both as a fertilier and as a mulch layer. This second application of material was applied manually 6 weeks after planting (WAP). With Grass Clover Silage Mulch (GCSM), potatoes were planted by hand in planting holes, there was no ridging and the soil was covered with a mulch right after planting. At 8 WAP a layer of 5 cm mulch layer of chopped wheat straw (36.6 t ha^{-1}) was added as well as a means to provide weed control.

In terms of soil amendments there were two plant-based soil amendments including luzern pellet (LP) and grass clover silage (GCS). Soil amendments were either fully incorporated in the soil (GCS), 50% incorporated (GCSH) with the rest applied as a mulch six weeks after planting or 100 % surface applied as a mulch (GCSM). GCS-based amendments are representative of the so called "cut-and-carry" fertilizers an on-farm produced soil fertility source. In terms of animal-based soil amendment only solid cattle manure (SCM) was tested. In terms of application rates these were either 0, 57, 117 and 170 kg N ha^{-1}. The non-amended (zero treatment) was included as a control to assess soil N mineralization. In summary, the experiment included 16 treatments with four replications (see Figure 4 and Appendix 1).

1	C	0	ST
2	SCM	57	ST
3	SCM	113	ST
4	SCM	170	ST
5	LP	57	ST
6	LP	113	ST
7	LP	170	ST
8	GCS	57	ST
9	GCS	113	ST
10	GCS	170	ST
11	C	0	RT
12	SCM	170	RT
13	LP	170	RT
14	GCS	170	RT
15	GCSH	170	RT
16	GCSM	170	NT

Figure 4: Outline of experimental Treatments

2.3 MEASUREMENTS

In order to assess the interactive effects of tillage/mulching techniques on weed dynamics, only the treatments with the highest application rates and the control treatments were selected for monitoring weed dynamics. As a result, 40 plots out of the 72 were part of the weed monitoring campaign (see Figure 5). Due to Phytophthora, twelve plots were burned the 20th of June (a) and other part of the field was burned the 20th of July (b).

			Date of burning
Block 1 - ST	1	LP 170	a
	3	SCM 170	a
	5	GCS 170	a
	8	CONTROL	a
Block 2 - RT	13	GCSM 170	b
	14	GCSHM 170	a
	15	GCS 170	a
	16	SCM 170	a
	17	LP 170	a
	18	CONTROL	b
Block 3 - RT	19	GCSM 170	b
	20	GCSHM 170	a
	21	GCS 170	a
	22	LP 170	a
	23	SCM 170	a
	24	CONTROL	b
Block 4 - ST	27	LP 170	b
	33	SCM 170	b
	34	CONTROL	b
	36	GCS 170	b

			Date of burning
Block5- ST	38	SCM 170	b
	40	CONTROL	b
	42	GCS 170	b
	45	LP 170	b
Block 6 - RT	49	GCS 170	b
	50	CONTROL	b
	51	SCM 170	b
	52	LP 170	b
	53	GCSHM 170	b
	54	GCSM 170	b
Block 7 - RT	55	GCS 170	b
	56	LP 170	b
	57	SCM 170	b
	58	CONTROL	b
	59	GCSHM 170	b
	60	GCSM 170	b
Block 8 - ST	61	SCM 170	b
	62	CONTROL	b
	63	GCS 170	b
	64	LP 170	b

Figure 5: Outline of harvesting date of potato plots ("a" refers to premature burning of the canopy on June 20th to control the spread of early bight where as plots labeled "b" the crop canopy was maintained until July 20th)

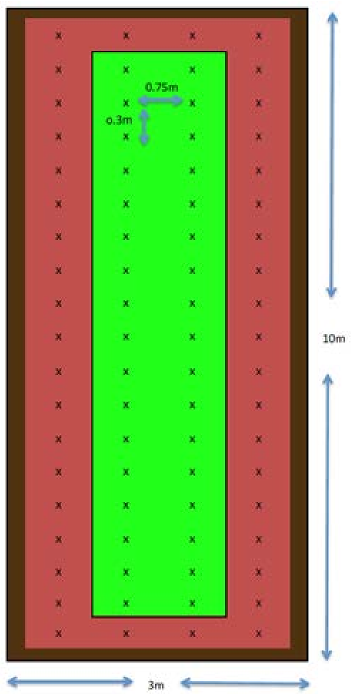

Figure 6: Schematic diagram of field plot with each "x" representing a potato plant , the green marked area the net sampling plot and the brown coloured area the border rows/plants. Total plot size was 3 x 10 m and each plot consisted of 4 rows spaced 75 cm apart of 30 ? potato plants each.

Weed density was measured at 3, 6, 8, 10 and 11 WAP. **Weed diversity** was not measured at week 3 because the determination was impossible due to the early stage of the weed (only cotyledons were visible). The identification was made by comparing observations of leaves, stems and flowers at a later stage with an online weed key (http://www.int-koop.de/unkraut/mod_liz_unkraut_bestimmung/partner/bs/lang/en/index.html).Weed density and weed diversity were assessed just before the rebuilding of the ridges. The area to be sampled included the two middle rows of the plot, excluding the two outer rows because of possible border effect (the green shaded region shown in Figure 6). Four representative samples per plot were measured; two at the top of the ridges and two others between the rows. A metal sampling frame with a dimension of 30 x 30cm ($0.09m^2$) was used for these measurements.

The weed biomass was determined at 6, 8, 10 and 11 WAP. The above-ground parts of the weeds were cut at the soil surface using metal scissors. Samples from two sampling location (both the top and bottom of the ridge) were mixed into composite sample and put into a plastic bag in order to obtain one representative sample per plot. To obtain the weed dry matter yield in grams, the fresh biomass was transferred to aluminium boxes and oven-dried at 70°C during 24 hours. The above-ground weed biomass was converted to gram dry weight per square meter.

The **canopy** of the potato crop was measured at 6, 8 and 10 WAP. The canopy has an influence on the weed growth and thus on weed biomass. The formula used is provided below, where D is the mean of the two diameters and H the height:

$$Canopy = \pi * (D/2)^2 * H$$

The final harvest of the potatoes occurred the 29th of July by hand. Both tuber number and weight for different size classes (25- 40 mm and > 40mm) were determined and tubers affected by soft rot were graded as being non-marketable.

2.4 Statistical analysis

For the statistical analysis, there were several experimental factors. The first one was *tillage* with 2 levels only out of the three: standard tillage (ST) and reduced tillage (RT). The second being f*ertilizatio*n with 6 levels: luzerne pellet (LP), solid cattle manure (SCM), Grass clover silage (GCS), a non-amended check (control), grass clover silage half mulch (GCSH) and grass clover silage full mulch (GCSLM). The last two treatments were only implemented for the reduced tillage trial. The third factors is sampling *location*, and refers to the place where the measurements where taken either at the top of the ridge or between the rows. The fourth factor was sampling time which had 4 or 5 levels depending on the test, week after planting 3, 6, 8, 10 and 11. The response (dependent) variables included *density, biomass* and *diversity* of the weeds, the *canopy* size of the potato plant.

Several tests were done, starting with a general linear model including all the interactions to a more specific one with only the independent variable and interactions influencing the dependent variable. Here, we want to test for differences between groups created by the use of several independent variables. The experiment is hence known as a factorial design. In order to test if there was a difference between the treatments we conducted a factorial ANOVA. The procedure follows the several steps: model presentation, assumptions, F test, F-ratios and conclusion. The **model** is the following one:

$$y = \beta0 \ + \ \beta1x1 + \beta2x2 + \ \beta3x3 + \beta ixi + \varepsilon$$

Where y is the dependent variable and x1, x2 and x3 are the independent variables, with i the number of independent variable. xi can be either one variable or a two way interaction or three way interaction. With the example of the density, y is the density, the independent variables are tillage, fertilization, sampling location and/or time.

The outcomes of the **F test** are indicative of the overall model and specific model components being significant. The null hypothesis states that the model is not significant (β1=β2=β3=…=βi=0) and the alternative hypothesis is that at least one of these β's is not equal to zero. If the p-value is higher than 0.05, there is a significant effect of the model. Then, the **F-ratio** of each effect shows if it has or not an influence on the dependent variable, either as a main effect, or several two way interactions effects or finally for the only three way interaction.

Due to Phytophthora, some measures are missing. To deal with the missing values, the code 999 was chosen in the SPSS software (include version, company, location company).

Morover, several **assumptions** were checked before doing the ANOVA. These include a normal distribution of the residuals and the homogeneity of variances.

3 Results and discussion

3.1 Weather conditions

The weather conditions favored the development of early blight (*Phytophthora infestans* see Fig. 1). The development of the disease started at the beginning of June, and the first signs were noticed on the 9th of June. According to the farm manager Andries Siepel, the infestation happened 10 days before the observation of dark spots surrounded by a white area on leaves. Based on the weather data of the station Deelen from KNMI, the Royal Netherlands Meteorological institute we can see that during the last 10 days of May, the mean temperature was 15.2°C and a total rainfall amounted to around 10mm during three days between the 26th and 28th which are ideal conditions for propagation of phythopthora spores Half of the field was burnt by the 20th of June; due to rapid spreading of the disease, the entire field was burnt by the 20th of July.

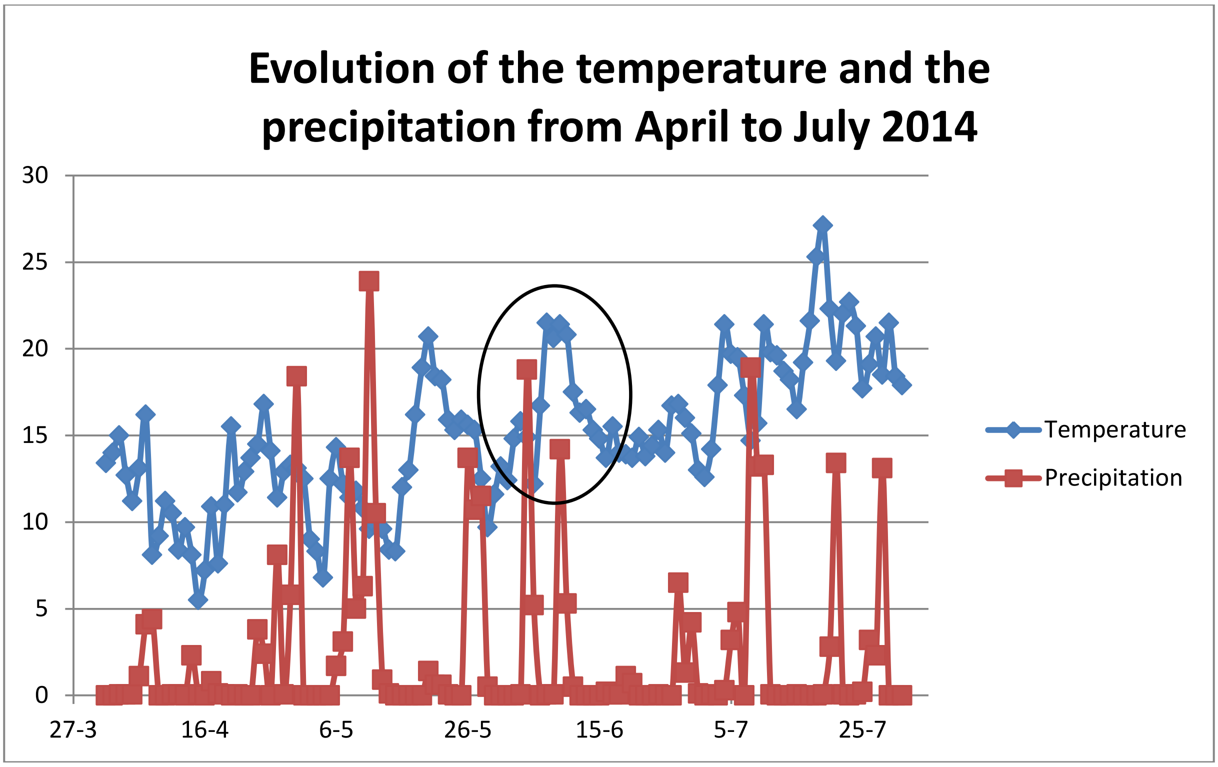

Figure 7: Average daily temperatures and daily precipitation (from the station Deelen (KNMI)

3.2 PREVAILING WEED SPECIES

The observed weed species and their features are presented in the Table 1. From this table it can be seen that annual species were more numerous and that the most common perennial species are typical pasture plants.

Table 2: Overview of most commonly observed weed species in the potato field during the spring and early summer of 2014

Latin names	English names	Features	Flowering
Capsella bursa-pastoris (L.)	Shepherd's purse	Annual plant	From mars to December
Chenopodium album	Common lambsquarter	Annual plant	July to October
Lolium perenne	Perennial ryegrass	Perennial plant	May to September
Matricaria chamomilla L.	Wild chamomile		From April to October
Polygonum persicaria L.	Redshank	Annual plant	From July to September
Polygonium convolvulus L.	Black bindweed	Annual plant Germination spring	July to October
Veronica persicas	Birdeye speedwell	Annual plant Germination throughout the year	March to October
Viola arvensis	Wild pansy or field violet	Annual or perennial plant	April to October
Taraxacum officinale	Dandelion	Biannual	April to June
Trifolium repense	White Clover	Perennial	Mid flowering

Stellaria media	Chickweed	Annual plant

From the book Mauvaises herbes des grandes cultures Bailly R., Mamarot J., Psarski P. (1981)

3.3 WEED DENSITY

Weed density as affected by tillage and soil amendment treatments for the different sampling positions and times is presented in Table 3. On top of the ridge use of standard tillage increased weed density at 3, 8 10 and 11 WAP while at the bottom of the ridge values were higher at 8 and 10 WAP. In terms of the soil amendments there were no differences between the materials as such but in terms of the management practices of grass clover silage the fully mulched treatment had no weeds at 6 WAP (Table 3). Weed density in the ridge for the half-mulched treatment was significantly higher at 6 WAP compared to other treatments while at 8 WAP the reverse was true. Since some interaction effects were significant, results are also shown for specific treatments for reduced tillage in Table 4. In the mulch treatment, the density is much lower, and sometimes zero. Indeed, according to the literature, straw mulch is a barrier of the development of the weed by limiting the emergence and growth. Others benefits have been pinpointed such as the reduction of erosion and increase of the biological activity of soil (Teasdale and Mohler 2000, Grassbaugh et al. 2004, Ramakrishna et al. 2006 cited in Kosterna 2014).

Overall averages accross the season and treatments are presented in Table 5 show that for all the different amendments, the density average is 35% higher in standard tillage than in reduced tillage. This finding is disagreement with reports in the literature where increased weed abundance was observed in reduced tillage than in standard tillage and therefore the first hypothesis is not verified. For the plant based fertilizers, the density in standard tillage is 78% higher for the grass clover and 59% higher for the Luzern pellet treatments than in the reduced tillage. For the control and the solid cattle manure, the increase is respectively 16% and 11%. The second hypothesis is that the plots where solid cattle manure was applied have the highest weed density, due to the introduction of weed seed through the manure (Miyazawa et al,. 2004). When we look at the average mean for the solid cattle manure, it's 27% higher than the one obtain in grass clover treatment, but the difference with Luzern pellet is minimal. Moreover, the highest weed density is obtained for the non-amended control-treatment in standard tillage plots. Consequently, the first two hypotheses are both rejected **although differences are not always statistically different for each and every sampling date and position. .**

Table 5: Overall seasonal averaged weed density in weed number per m²

	SCM	LP	GCS	Control	**Average**
ST	203	230	195	224	213
RT	183	144	109	193	157
Average	193	187	152	209	

Moreover, we noticed in Table 4, that for the ridge treatment, there is a decrease of the density over time. A two-way Anova was conducted in order to analyze the density at the top of the ridge (see Appendix 1, Table A1). There is a significant effect of the model ($p < 0.001$) and an effect of sampling time (p-value < 0.001). Even if the measurement were realized just before rebuilding of the ridges, meaning that the weed had 3 weeks of growth every time, the canopy of the potato plant may have an effect on the weed development since throughout the cycle, the plant are getting bigger. To check this hypothesis, the canopy was separated into four groups according to the quartiles values (see Table A2). A one way ANOVA test was conducted to confirm if the canopy has a real influence on the amount of weed. The result shows a significant effect of the canopy group on the weed density ($p<0.001$). From this it is concluded that the higher the potato canopy, the lower the weed density and that factors that enhance potaot growth thus seem to reduce weed incidence.

3.4 WEED BIOMASS

The main effect of tillage and soil amendments on weed biomass are outlined in Table 6. From this table it can be concluded that non of these factors affected weed biomass at any of the sampling positions or sampling times. In terms of overall calculated numeric values the average mean of the biomass in standard tillage is higher than in reduced tillage, respectively 2,65 and 1,55 g/m². Regarding the difference of the biomass between the tillage systems, the tendency is that it is higher in standard tillage than in reduced one (70% in WAP8, 40% in WAP10 and 120% in WAP11) with the exception during WAP6, where it is nearly the same.

According to the post hoc test, it appeared that there is one group composed of WAP3 and the second group is WAP11. When we look at the means, the difference are most pronounced at WAP 10 and 11 (see Table 6). Between week 10th and 11th there was no re-ridging. In order to understand the influence of the WAP on the biomass, the link with the canopy was tested. Indeed, the shadow created by the potato plant is higher at the end of the cycle than at the beginning. But due to phytophthora, the leaves and the stem of the plants were damaged and consequently, light availability to weeds during the second part of the season would be improved again and weed growth thus later on may be favored again. However, when looking at the effect of canopy on the biomass, there was no statistical effect ($p=0.201$).

3.5 WEED DIVERSITY

A two-way anova was conducted with weed diversity as independent variable including three factors: tillage, fertilization and species. The results show that there main effects of the tillage system, species and sampling time were highly significant ($p< 0.001$). There is no fertilization effect (see Table 13). If we run the factorial ANOVA again, without the time effect to simplify the analysis; we obtain results presented in Table A3. There is a main effect of the tillage ($p=0.033$), the species ($p<0.001$) and the two way interaction Tillage-species ($p<0.001$). The Post hoc test divided the data into four groups (see Table A4). One group includes Chenopodium album and Capsella bursa-pastoris which are the weed species with the highest overall density. The other groups are overlapping due to the interaction effect, one is made of trifolium repense, Matricaria chamomilia, Polygonium convolvulus and the category named others.

From Fig. 8 it can be observed that the density of both these two weed species tends to be higher in standard tillage (green line). We can also see that there is an interaction between tillage regimes and species, because the relative densities of Chenopodium album and Capsella bursa-pastoris are disproportionally higher in reduced tillage compared to the other species.

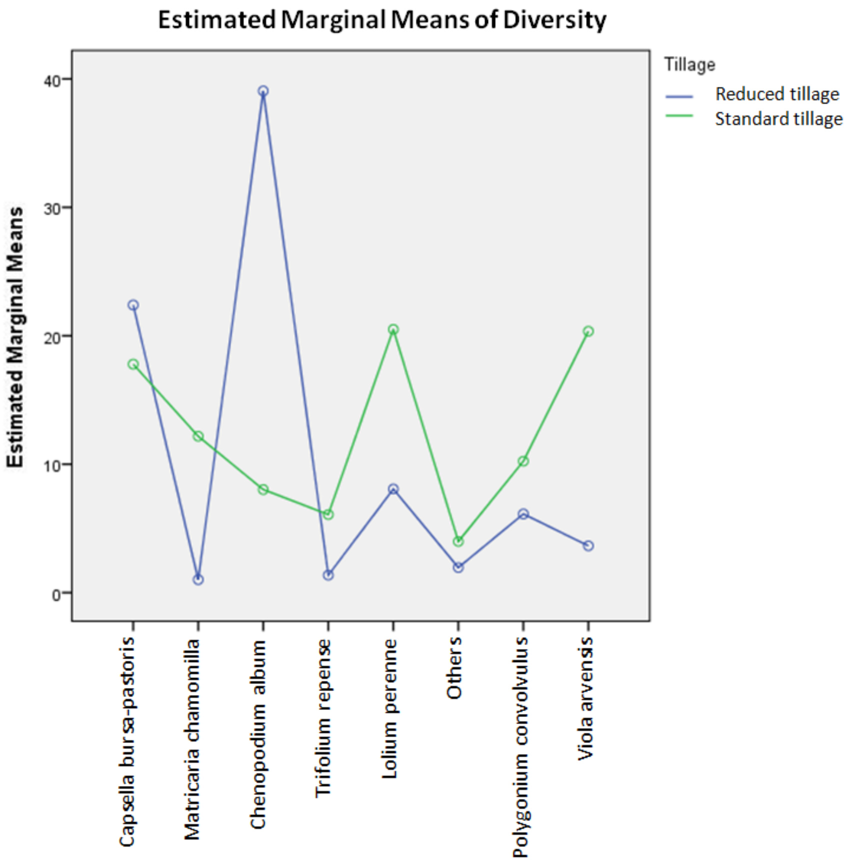

Figure 8: Difference in occurance of selected weed species in standard vs reduced tillage plots. t

SHANNON INDEX

The weed diversity was also assessed using the diversity (H') Shannon index where "N is the total weed population density per square meter and n is the population of each weed species found in this area" (Dorado & Lopez-Fando, 2006).

$$H' = (N \log N - \sum n \log n \,)\, N^{-1}$$

The overall average values accross treatments are shown in Table 5. The maximum value is ln(S) where S is the maximum number of species. Here we have 7 major species plus a "*Other*" category, with a maximum amount of 3 species. The highest value for the Shannon index is 2.30 (ln10). When the index is high, the community is diverse and the amount of species high and inversely. In the following table, the underlined cells indicate a value of the Shannon index lower than the first quartile of all the number (0.84). All the lower scores occur in the reduced tillage treatments. Moreover, almost all the treatments in reduced tillage are lower than the median (1.09). Therefore it is concluded that reduced tillage lowers weed species diversity compared to standard tillage.

Table 3: Shannon index

Tillage	Location	C	SCM	LP	GCS	GCSH	GCSM

ST	Ridge	1.42	1.28	1.27	1.37		
	Between	1.69	1.70	1.56	1.36		
RT	Ridge	0.80	0.76	1.01	0.56	1.29	0.85
	Between	1.11	0.85	0.83	1.00	1.09	0.73

If we have a look at Chenopodium album, we can see that it's occurrence is higher in reduced tillage than in standard, almost 4 times higher for the control treatment, 5 times higher for LP and 6 times higher for SCM and GCS (see table 14). On the contrary, if we have a look at the total average, there are more Polygonium in standard tillage, than in reduced tillage (67%, see table 15).

4. Conclusions and Synthesis

On one hand, conventional tillage is changing seed position in the soil layers, thus, the micro environment is altering. The depth of conventional tillage on average is 35 cm, whereas in reduced tillage which is a non-inversion tillage, the depth was 10-15 cm (Peigné et al., 2007). According to the review *Is conservation tillage suitable for organic farming* (2007), researchers state some advantages of conservation tillage, including reduced tillage, which conserves soil moisture and last but not least increases the macro-porosity in the soil surface linked with the tendency of higher earthworms population. One of the disadvantages is the weed pressure which tends to be higher in conservation tillage systems. According to literature tillage can affect weed communities by affecting seed dormancy, emergence and germination (El Titi, 2002).

The first result of the current research is that the evolution of weed density is statistically linked to crop canopy, whereas weed biomass is not. Indeed, it appears that the taller the canopy, the lower the weed density. We also have to take into account the link between weed density and the biomass obtained per plot in order to compare the competition caused by the weed on the potato plant. For example, several small Chenopodium at the 2 leaf stage and one big Chenopodium can have the same biomass, but the competition is truly different in term of water and nutrient uptake since taller plants will be more competitive as they also explore deeper soil layers.

One consequence is a shift in weed composition due to the innate features of each weed specie. “Several authors have reported an increase in annual grasses, perennial weeds and wind-dispersed species with reduced tillage” (Dorado & Lopez-Fando, 2006; El Titi, 2002; Peigné et al., 2007). This can be explained because grass species, also called monocots, are more competitive than dicots at the emergence stage and thus, more difficult to control (El Titi, 2002; Armengot et al., 2014). Results of the current study are not confirming this statement. Annual and perennial species could have been compared using the contrasts methods. Table A7 shows that Lolium perenne and Viola tricolor, which are the two perennial species encountered in the study in both tillage systems, have a higher density in standard tillage. Moreover, according to the literature, dicot annuals such as Polygonum convolvulus and Chenopodium album are dominant in conventional tillage (El Titi, 2002). This result is only confirmed in the current study for Polygonum convolvulus. However, other studies showed that this trend is not “always constant over time, and it is usually crop specific” (Légère et al. 2013; Sans et al. 2011; Vakali et al. 2011 cited in Armengot et al., 2014). Armengot et al. also pointed out that nowadays, studies in organic systems dealing with the influence of reduced tillage on weed diversity are rare, compared to the numerious research studies done for conventional systems. Moreover, most studies have been conducted a few years after the conversion from a conventional system to an organic one, meaning the change from conventional tillage (moldboard plowing) to reduced tillage. However, the impact of reduced tillage is to be measured a long period of time meaning that long term studies in organic systems about the weed flora dynamics under reduced tillage are necessary to assess the evolution (Armengot et al., 2014).

Tillage is a mechanical way to reduce the weed population, while other weed management practices can be used by farmers as well. First, it appears that ridging every three weeks is an efficient mechanical technique to destroy the weed every in order to avoid the reproductive stage of the weed plant. Moreover, the use of mulch could prevent the development of weed in crop field. But here, the results are more difficult to explain. The density of weed in the mulch treatment is the lowest, because of the thick layers of straw. But the weed biomass was astonishingly higher in these treatments. The growth of Chenopodium album and Polygonum convolvulus was high, the plants could sometimes be 30cm high.

5. Recommendations for future research

It is to be recommended to include incubation tests on manure during subsequent years to assess if the amount of seed from the manure enhances the total amount of weed encountered in the plot with manure as fertilizer. Some manure has to be mixed with soil and put in containers which have to be outside, in order to generate the same condition as in the field.

Moreover, according to Lammert Bastiaan, in order to determine the influence of tillage on weed population and the consequence for the potato crop, an area should be delimited for hand weeding. Indeed, the effect of tillage on the yield is two-fold: it includes a direct biophysical and biological effect as soil processes are being affected that govern plant growth. The second one is an indirect effect since it affects weed which in turn compete with plants for resources. So if possible it would be good to differentiate between those effects and tillage effects in the absence of weed impact should be assessed as well. A comparison between the yield of the potato crop when the weed impact is taken into account (path 2) and when it is not (path 1) is also relevant (see Fig. 9). It is a way to understand the competition between the weed and the crop better.

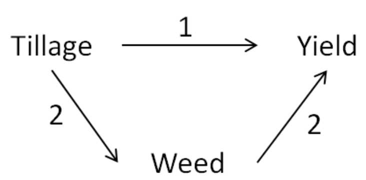

Figure 9: Hand weeding impact

Another aspect is the influence of the ridges. In the experiment, the no-ridge treatment is used for the mulch treatment. It is impossible to compare the results with the ones obtained with other fertilization. The practice of ridging every three weeks is seen as a mechanical weed control. Indeed, the seed phase is not reached since the flowering of the weed is not occurring. The ridges are made in a way that weeds cannot achieve the reproductive stage and since there is no dispersal of the seeds by the wind, less seeds at the top layers of the soil are germinate. Thus, the seed bank is diminishing. The seed phase is related to the production of seeds from a plant, in opposition with the plant phase associated to the development of a mature plant from the seed.

It is there for concluded that additional studies are needed in order to estimate the seed bank. But this would be relevant only if the experiment was continued in the same field over a prolonged period of time.

Appendix 1 Additional tables and figures

Table 3 Effects of tillage, soil organic amendments main and interaction effects on weed density (number of weeds m^{-2}).

	Sampling time									
	WAP=3		WAP=6		WAP=8		WAP=10		WAP=11	
Treatment	Ridge	Bottom	Ridge	Bottom	Ridge	Bottom	Ridge	Bottom	Ridge	Bottom
Tillage (T)										
Standard tillage	777	473	253	30	98	99	76	67	62	81
Reduced tillage	445	287	195	61	64	51	48	43	35	64
One way ANOVA p-value	0.017	0.073	0.135	0.206	0.005	<0.001	0.023	0.021	0.021	0.111
Significance [1]	*	ns	ns	ns	**	***	*	*	*	ns
Soil amendments (SA) [2]										
Control	745	536	235 a	30 b	104 a	71 a	77 a	62	65	81
LP	594	412	245 a	32 b	78 a	91 a	67 a	54	47	81
SCM	723	368	207 a	31 b	79 a	81 a	74 a	50	61	64
GCS	543	250	267 a	29 b	76 a	66 ab	63 a	58	45	68
GCSH	247	358	274 a	244 a	15 b	7 b	0 b	39	9	62
GCSM	324	127	0 b	0 b	86 a	83 a	69 a	55	30	69
One way ANOVA p-value	0.343	0.358	0.001	<0.001	0.006	0.009	0.001	0.870	0.062	0.834
Significance	ns	ns	***	***	**	**	***	ns	ns	ns
T x SA										
One way ANOVA p-value	0.378	0.390	0.011	< 0.001	0.01	<0.001	0.01	0.207	0.087	0.822
Significance	ns	ns	*	***	**	***	**	ns	ns	ns

[1] **, **, and *** refer to P values < 0.05, < 0.01, and < 0.001, respectively; ns = not significant.*

[2] *Different letters indicate significant differences according to the Tukey-test (P < 0.05).*

Table 4 Effects of specific tillage and organic amendments treatment combinations on weed density (number of weeds m^{-2}).

	Sampling time									
	WAP=3		WAP=6		WAP=8		WAP=10		WAP=11	
Treatments	Ridge	Bottom	Ridge	Bottom	Ridge	Bottom	Ridge	Bottom	Ridge	Bottom
1) LP_ST	775	561	293 a	37 b	85 ab	123 a	74	55	48	83
2) LP_RT	413	264	198 ab	26 b	72 ab	58 bc	58	53	47	77
3) SCM_ST	819	408	194 ab	18 b	96 b	104 ab	75	46	59	68
4) SCM_RT	627	327	221 ab	44 b	62 ab	58 bc	72	56	63	58
5)GCS_ST	780	419	261 a	26 b	90 ab	89 ab	68	78	61	75
6) GCS_RT	305	80	273 a	33 b	62 ab	43 bc	55	19	14	55
7) GCSH_RT	247	358	274 a	244 a	15 a	7 a	0	39	9	6
8)GCSM_RT	324	127	0 b	0 b	86 ab	83 ab	69	55	30	69
9) C_ST	736	505	263 a	40 b	120 b	82 ab	91	87	79	100
10) C_RT	755	566	206 ab	21 b	87 ab	61 abc	66	44	55	66
p-value	0.378	0.39	0.011	<0.001	0.01	<0.001	0.01	0.207	0.087	0.822
Significance [1]	ns	ns	*	***	**	***	**	ns	ns	ns

[1] **, **, and *** refer to P values < 0.05, < 0.01, and < 0.001, respectively; ns = not significant.*

Table 6 Effects of tillage and organic amendments on weed biomass (g m^{-2} ?)

	WAP=6		WAP=8		WAP=10		WAP=11	
Treatment	Ridge	Bottom	Ridge	Bottom	Ridge	Bottom	Ridge	Bottom
Tillage (T)								
Standard tillage	1,5292	No data	1,5401	2,1226	1,5946	3,7112	3,7901	4,9650
Reduced tillage	1,6299		,9933	1,1533	1,5504	2,2159	2,4906	1,4044
P-value	0,750		0,155	0,080	0,948	0,390	0,190	0,080
Significance [1]	ns		ns	ns	ns	ns	ns	ns
Soil amendments (SA)								
Control	1,6287	No data	0,6575	2,149	1,5871	3,5473	2,686357	3,330
SCM	1,2117		1,1284	1,5894	2,3351	2,2333	2,686357	2,023
LP	1,3153		1,5065	1,4736	1,3082	2,6018	4,02824	2,427
GCS	2,1624		1,7743	1,3396	1,1511	3,5663	3,734267	5,504
p-value	0,119		0,1840	0,763	0,643	0,9350	0,674	0,658
Significance	ns		ns	ns	ns	ns	ns	ns

[1] **, **, and *** refer to P values < 0.05, < 0.01, and < 0.001, respectively; ns = not significant.*

Table 7 Effects of specific treatment combinations of tillage and organic amendments on weed biomass

	WAP=6		WAP=8		WAP=10		WAP=11	
Treatments	Ridge	Bottom	Ridge	Bottom	Ridge	Bottom	Ridge	Bottom
1) LP_ST	1,5178	No data	2,1725	0,9697	1,5411 ab	3,059633	4,7063	2,729233
2) LP_RT	1,1128		0,8406	1,9775	0,9589 ab	1,915	3,0111	1,97445
3) SCM_ST	1,007		1,3174	2,6244	0,9966 ab	2,1978	1,4889	2,79225
4) SCM_RT	1,5161		1,0551	0,6403	4,5883 b	2,1978	3,2911	1,16665
5)GCS_ST	1,916		1,7918	1,8366	1,4333 ab	5,18956	4,3367	6,976
6) GCS_RT	2,0817		1,5225	0,9536	0,1228 a	0,2717	1,9939	0,1711
7) C_ST	1,4486		0,76	3,2564	2,3155 ab	2,907767	3,4971	5,2974
8) C_RT	1,8089		0,555	1,0417	1,0408 ab	4,026925	2,0783	1,855
P-value	0,713		0,383	0,216	0,094	0,889	0,714	0,659
Significance [1]	ns		ns	ns	*	ns	ns	ns

[1] **, **, and *** refer to P values < 0.05, < 0.01, and < 0.001, respectively; ns = not significant.*

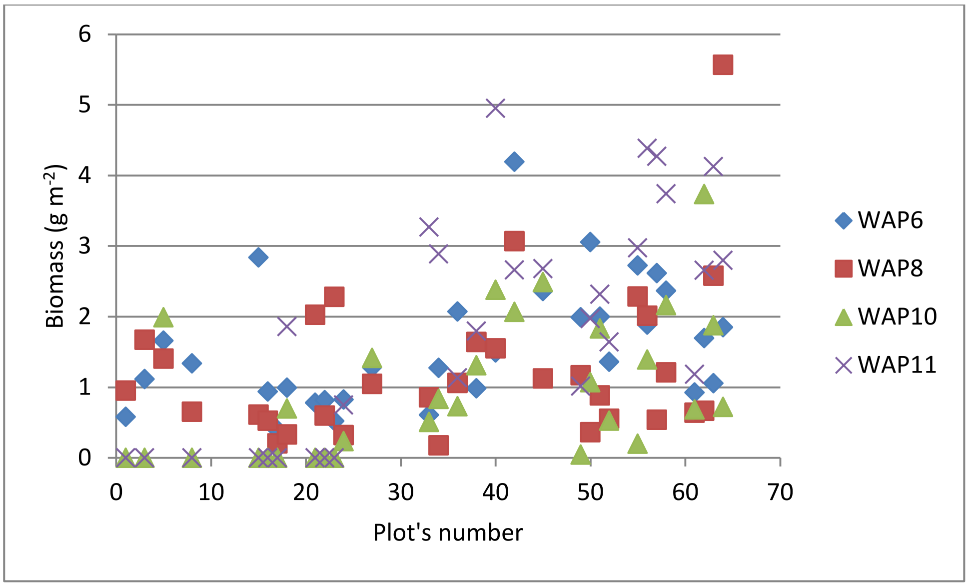

Figure 9: Obtained weed biomass per plot
*Biomass of GCSM and GCSH are not taking into account in the chart for clarity reasons

Table A1: ANOVA with weed density as a dependent variable

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected model	9417233,051[a]	48	196192,355	4,025	,000
Intercept	5953616,301	1	5953616,301	122,138	,000
Fertilization	113131,754	5	22626,351	,464	,802
Tillage	152112,593	1	152112,593	3,121	,080
WAP	6876717,402	4	1719179,351	35,269	,000
Fertilization * Tillage	45880,846	3	15293,615	,314	,815
Fertilization * WAP	447442,749	19	23549,618	,483	,965
Tillage * WAP	325257,615	4	81314,404	1,668	,162
Fertilization * Tillage * WAP	242104,261	12	20175,355	,414	,956
Error	5946886,686	122	48744,973		
Total	23877593,568	171			
Corrected total	15364119,737	170			

Table A2: Post hoc test with weed density as dependent variable

Tukey test

Canopy_gp	N	Subsets with alpha = 0.05		
		1	2	3
>129130	27	73,07826		
[99672;129130]	26	84,88035		
[68354;99672]	22		150,25255	
<68354	25			241,92440
Sig.		,953	1,000	1,000

Table A4: Post hoc test with weed diversity as dependent variable

Tukey test[a,b,c]

Species	N	Subset for alpha = .05			
		1	2	3	4
Others	262	2,85			
Clover	262	3,45			
Chamomilia	262	5,95	5,95		
Polygonium	264	7,96	7,96		
Viola_tricolor	262		11,04	11,04	
Lolium_perenne	262			13,57	
Capsella	262				20,36
Chenopodium	262				25,32
Sig.		,091	,093	,860	,112

Means for groups in homogeneous subsets are displays

Table A3: AVOVA with weed diversity as dependent variable

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	222179,893[a]	15	14811,993	34,464	<0001
Intercept	270209,365	1	270209,365	628,720	<0.001
Tillage	1947,592	1	1947,592	4,532	0.033
Species	102249,026	7	14607,004	33,987	<0.001
Tillage * Species	100566,395	7	14366,628	33,428	<0.001
Error	894796,285	2082	429,777		
Total	1385368,235	2098			
Corrected Total	1116976,178	2097			

a. R^2 = 0.199 (R^2 adjusted = 0.193)

Table A5: Occurrence of Chenopodium album as affected by tillage and soil amendments

Tillage	Fertilization	Location	Mean
RT	Control	Between	45.94
		Ridge	30.56
		Total	38.25
	GCS	Between	49.25
		Ridge	22.75
		Total	36
	LP	Between	52.5
		Ridge	28.17
		Total	40.33
	SCM	Between	52.75
		Ridge	36.92
		Total	44.83
	GCSH	Between	10.5
		Ridge	20.38
		Total	15.44
	GCSM	Between	40.15
		Ridge	61.69
		Total	50.92
	Total	Between	43.77
		Ridge	34.36
		Total	39.06

Tillage	Fertilization	Location	Location
ST	Control	Between	10.86
		Ridge	7.36
		Total	9.11
	GCS	Between	6
		Ridge	7.76
		Total	6.88
	LP	Between	10.47
		Ridge	7.29
		Total	8.88
	SCM	Between	6.43
		Ridge	8.4
		Total	7.41
	Total	Between	8.35
		Ridge	7.7
		Total	8.03

Table A6: : Occurrence of Polygonum convolvulus as affected by tillage and soil amendments

Tillage	Fertilization	Location	Mean
RT	Control	Between	8.25
		Ridge	4.25
		Total	6.25
	GCS	Between	7.58
		Ridge	2.46
		Total	5.02
	LP	Between	8.00
		Ridge	4.33
		Total	6.17
	SCM	Between	6.67
		Ridge	2.42
		Total	4.54
	GCSH	Between	6.25
		Ridge	9.13
		Total	7.69
	GCSM	Between	7.00
		Ridge	7.91
		Total	7.45
	Total	Between	7.40

Tillage	Fertilization	Location	Location
ST	Control	Between	17.43
		Ridge	12.36
		Total	14.89
	GCS	Between	9.81
		Ridge	5.38
		Total	7.59
	LP	Between	12.73
		Ridge	6.87
		Total	9.80
	SCM	Between	13.57
		Ridge	4.57
		Total	9.07
	Total	Between	13.25
		Ridge	7.22
		Total	10.24

	Ridge	4.85
	Total	6.13

Table A7: The three predominant weed species observed in each treatments with actual densities per m2 presented in parentheses

	ST	RT
Control	Lolium (26) – Viola (20) – Capsella (16)	Chenopodium (38) – Capsella (18) – Lolium (8)
SCM	Lolium (18) – Viola (15) – Capsella (12)	Chenopodium (44) – Capsella (22) – Lolium (5)
LP	Viola (26) – Capsella (21) – Lolium (18)	Chenopodium (40) – Capsella (20) – Polygonium (6)
GCS	Capsella (20) – Viola (19) –Lolium (18)	Chenopodium (36) – Capsella (30) – Polygonium (5)
GCSH		Capsella (28) - Chenopodium (15) – Lolium (10)
GCSM		Chenopodium (50) – Capsella (18) – Lolium (14)
Mean	Lolium (20) – Viola (20) – Capsella (17)	Chenopodium (39) – Capsella (22) – Lolium (8)

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Appendices

Appendix 1: Experimental design

Block 1 ST		Block 2 RT	BLOCK 3 RT	Block 4 ST	
1. LP 170	7. SCM 57	13. GSCM 170	19. GSCM 170	25. 0	31. GCS 113
2. SCM 113	8. 0	14. GCSH 170	20. GCSH 170	26. LP 113	32. GCS 57
3.SCM 170	9. LP 57	15. GCS170	21. GCS 170	27. LP 170	33. SCM 170
4. 0	10. GCS 57	16. SCM 170	22. LP 170	28. LP 57	34. 0
5. GCS 170	11. 0	17. LP 170	23. SCM 170	29. 0	35. SCM 113
6.GSC 113	12. LP 113	18. 0	24. 0	30. SCM 57	36. GCS 170

Block 5 ST		Block 6 RT	Block 7 RT	Block 8 ST	
37. SCM 113	43. 0	49. GCS 170	55. GCS 170	61. SCM 170	67. 0
38. SCM 170	44. GCS 113	50. 0	56. LP 170	62. 0	68. SCM 57
39. LP 57	45. LP 170	51. SCM 170	57. SCM 170	63. GCS 170	69. GCS 57
40. 0	46. SCM 57	52. LP 170	58. 0	64. LP 170	70. GCS 113
41. 0	47. GCS 57	53. GSCH 170	59. GSCH 170	65. 0	71. SCM 113
42. GCS 170	48. LP 113	54. GCSM 170	60. GCSM 170	66. LP 113	72. LP 57

Appendix 2: Biomass g/m²

				BIOMASS							
				WAP 6		WAP 8		WAP 10		WAP 11	
Block	**Plot**	**Fertilization**	**Tillage**	**Ridge**	**Between**	**Ridge**	**Between**	**Ridge**	**Between**	**Ridge**	**Between**
1	1	LP	ST	0,5767	-	0,9522	0,9556	-	-	-	-
1	3	SCM	ST	1,1156	-	1,6722	4,5144	-	-	-	-
1	5	GCS	ST	1,6556	-	1,4022	0,9422	1,9900	3,0667	10,5044	13,1633
1	8	C	ST	1,3378	-	0,6533	5,6522	-	-	-	-
2	13	GCSM	RT	29,2056	-	-	-	28,6711	0,0000	116,6733	0,0000
2	14	GCSH	RT	-	-	0,2778	0,8311	-	-	-	-
2	15	GCS	RT	2,8367	-	0,6100	0,9278	-	-	-	-
2	16	SCM	RT	0,9367	-	0,5256	0,0889	-	-	-	-
2	17	LP	RT	0,3944	-	0,2033	0,4011	-	-	-	-
2	18	C	RT	0,9933	-	0,3289	0,1022	0,6956	0,2611	1,8578	1,1222
3	19	GCSM	RT	25,9644	-	-	-	93,6978	0,0000	128,5956	0,0000
3	20	GCSH	RT	-	-	0,2956	0,5567	-	-	-	-
3	21	GCS	RT	0,7778	-	2,0267	2,5111	-	-	-	-
3	22	LP	RT	0,8144	-	0,5956	1,1678	-	-	-	-
3	23	SCM	RT	0,5200	-	2,2778	0,8244	-	-	-	-
3	24	C	RT	0,8256	-	0,3200	0,9656	0,2356	0,5144	0,7444	1,6867
4	27	LP	ST	1,2822	-	1,0467	1,1989	1,4144	0,9178	8,6456	5,4222
4	33	SCM	ST	0,6078	-	0,8544	2,2811	0,5056	5,0933	3,2656	2,1989
4	34	C	ST	1,2733	-	0,1744	1,6833	0,8322	1,9144	2,8867	1,5067
4	36	GCS	ST	2,0689	-	1,0600	1,0022	0,7278	0,3656	1,1300	0,2522
5	38	SCM	ST	0,9811	-	1,6400	1,4900	1,3100	3,3300	1,7956	1,6267
5	40	C	ST	1,4911	-	1,5478	4,6278	2,3800	6,1689	4,9478	12,4844
5	42	GCS	ST	4,1933	-	3,0667	4,0933	2,0678	16,6133	2,6578	18,9300
5	45	LP	ST	2,3622	-	1,1244	0,6400	2,4889	4,1000	2,6778	1,8644
6	49	GCS	RT	1,9878	-	1,1689	0,2244	0,0456	0,0867	1,0156	0,1622
6	50	C	RT	3,0522	-	0,3633	0,7356	1,0700	2,9644	1,9711	0,7089
6	51	SCM	RT	1,9956	-	0,8804	0,4889	1,8289	1,0422	2,3133	0,3633
6	52	LP	RT	1,3589	-	0,5511	5,5978	0,5267	1,8200	1,6400	3,0033
6	53	GCSH	RT	-	-	0,8789	0,8756	0,8078	1,8344	14,7411	12,3267
6	54	GCSM	RT	79,2844	-	-	-	95,5733	0,0000	99,5344	0,0000
7	55	GCS	RT	2,7244	-	2,2844	0,1511	0,2000	0,4567	2,9722	0,1800
7	56	LP	RT	1,8833	-	2,0122	0,7433	1,3911	2,0100	4,3822	0,9456
7	57	SCM	RT	2,6122	-	0,5367	1,1589	7,3478	0,6356	4,2689	1,9700
7	58	C	RT	2,3644	-	1,2078	2,3633	2,1622	12,3678	3,7400	3,9022
7	59	GCSH	RT	0,0000	-	0,3533	0,7389	11,9289	6,5389	2,2644	0,5967
7	60	GCSM	RT	25,0556	-	-	-	0,0000	0,0000	51,4333	0,0000
8	61	SCM	ST	0,9244	-	0,6400	1,8689	0,6833	1,0656	1,1822	3,9578
8	62	C	ST	1,6922	-	0,6644	1,0622	3,7344	0,6400	2,6567	1,9011
8	63	GCS	ST	1,0544	-	2,5756	0,8644	1,8756	0,8089	4,1256	0,3356
8	64	LP	ST	1,8500	-	5,5667	1,0844	0,7200	4,1611	2,7956	0,9011

Appendix 3: Density per m² after the average of the samples per plot.

				DENSITY									
				WAP 3		WAP 6		WAP 8		WAP 10		WAP 11	
Block	Plot	Fertilization	Tillage	Ridge	Between	Ridge	Between	Ridge	Between	Ridge	Between	Ridge	Between
1	1	LP	ST	1544	322	122	72	67	94	-	-	-	-
1	3	SCM	ST	1156	433	172	11	67	78	-	-	-	-
1	5	GCS	ST	833	133	133	17	44	106	44	61	89	61
1	8	C	ST	1156	567	194	44	133	56	-	-	-	-
2	13	GCSM	RT	144	233	211	250	-	-	0	22	6	61
2	14	GCSH	RT	244	133	-	-	89	56	-	-	-	-
2	15	GCS	RT	189	22	289	17	56	39	-	-	-	-
2	16	SCM	RT	322	44	156	33	28	22	-	-	-	-
2	17	LP	RT	111	33	161	17	17	39	-	-	-	-
2	18	C	RT	456	144	133	6	33	44	28	11	39	44
3	19	GCSM	RT	256	356	183	178	61	28	0	56	22	67
3	20	GCSH	RT	244	44	-	-	67	89	-	-	-	-
3	21	GCS	RT	222	56	178	17	61	33	-	-	-	-
3	22	LP	RT	211	67	156	22	72	61	-	-	-	-
3	23	SCM	RT	289	178	150	11	67	67	-	-	-	-
3	24	C	RT	422	122	144	6	89	50	61	22	50	50
4	27	LP	ST	400	611	228	22	67	156	61	44	50	39
4	33	SCM	ST	378	322	222	22	139	167	111	39	50	83
4	34	C	ST	222	256	194	28	100	50	78	44	39	61
4	36	GCS	ST	400	556	261	11	89	111	56	67	17	61
5	38	SCM	ST	1456	722	206	17	72	89	72	61	61	78
5	40	C	ST	1300	767	383	39	144	122	128	117	122	128
5	42	GCS	ST	778	667	394	33	100	67	111	128	111	106
5	45	LP	ST	767	922	283	17	78	89	83	56	61	78
6	49	GCS	RT	322	44	278	17	72	28	33	6	11	22
6	50	C	RT	1744	1644	306	39	72	67	72	67	61	67
6	51	SCM	RT	900	567	339	83	78	78	67	56	33	44
6	52	LP	RT	233	100	217	28	106	67	50	56	44	72
6	53	GCSH	RT	411	144	-	-	122	111	67	44	50	50
6	54	GCSM	RT	433	578	494	400	-	-	0	67	0	89
7	55	GCS	RT	489	200	350	83	61	72	78	33	17	89
7	56	LP	RT	1100	856	261	39	94	67	67	50	50	83
7	57	SCM	RT	1000	522	239	50	78	67	78	56	94	72
7	58	C	RT	400	356	244	33	156	83	106	78	72	106
7	59	GCSH	RT	400	189	-	-	67	78	72	67	11	89
7	60	GCSM	RT	156	267	211	150	-	-	0	11	11	33
8	61	SCM	ST	289	156	178	22	106	83	44	39	67	44
8	62	C	ST	267	433	283	50	106	100	67	100	78	111
8	63	GCS	ST	1111	322	256	44	128	72	61	56	28	72
8	64	LP	ST	389	389	539	39	128	156	78	67	33	133

Appendix 4: Diversity block 1 and 2

						DIVERSITY							
Block	Plot	Fertilization	Tillage	Time	Location	Chenopodium album	Polygonium convolvulus	Viola tricolor	Clover	Capsella	Chamomilia	Lolium perenne	other
1	1	LP	ST	6	Ridge	11	0	22	0	0	11	28	0
1	1	LP	ST	6	Between	6	6	39	0	33	22	11	6
1	1	LP	ST	8	Ridge	6	0	44	6	6	0	33	0
1	1	LP	ST	8	Between	0	6	22	0	6	6	22	6
1	1	LP	ST	10	Ridge	-	0	-	-	-	-	-	-
1	1	LP	ST	10	Between	-	0	-	-	-	-	-	-
1	1	LP	ST	11	Ridge	-	-	-	-	-	-	-	-
1	1	LP	ST	11	Between	-	-	-	-	-	-	-	-
1	3	SCM	ST	6	Ridge	6	0	0	0	0	6	0	0
1	3	SCM	ST	6	Between	11	6	6	11	28	28	61	22
1	3	SCM	ST	8	Ridge	6	6	28	11	6	0	22	0
1	3	SCM	ST	8	Between	0	0	17	22	11	11	6	0
1	3	SCM	ST	10	Ridge	-	-	-	-	-	-	-	-
1	3	SCM	ST	10	Between	-	-	-	-	-	-	-	-
1	3	SCM	ST	11	Ridge	-	-	-	-	-	-	-	-
1	3	SCM	ST	11	Between	-	-	-	-	-	-	-	-
1	5	GCS	ST	6	Ridge	0	0	11	6	0	0	0	0
1	5	GCS	ST	6	Between	17	0	50	17	33	6	11	0
1	5	GCS	ST	8	Ridge	11	0	17	11	33	6	22	6
1	5	GCS	ST	8	Between	0	0	11	11	17	0	6	0
1	5	GCS	ST	10	Ridge	17	0	17	0	6	0	11	11
1	5	GCS	ST	10	Between	0	6	0	11	6	6	17	0
1	5	GCS	ST	11	Ridge	22	6	22	6	0	0	0	6
1	5	GCS	ST	11	Between	11	6	0	6	11	17	28	11
1	8	C	ST	6	Ridge	17	0	22	0	0	0	6	0
1	8	C	ST	6	Between	22	0	17	11	39	67	22	17
1	8	C	ST	8	Ridge	11	0	6	0	11	11	17	0
1	8	C	ST	8	Between	17	17	17	11	6	28	33	6
1	8	C	ST	10	Ridge	-	-	-	-	-	-	-	-
1	8	C	ST	10	Between	-	-	-	-	-	-	-	-
1	8	C	ST	11	Ridge	-	-	-	-	-	-	-	-
1	8	C	ST	11	Between	-	-	-	-	-	-	-	-
2	13	GCSM	RT	6	Ridge	139	6	28	0	17	0	44	17
2	13	GCSM	RT	6	Between	39	17	0	0	39	17	89	11
2	13	GCSM	RT	8	Ridge	-	-	-	-	-	-	-	-
2	13	GCSM	RT	8	Between	-	-	-	-	-	-	-	-
2	13	GCSM	RT	10	Ridge	6	0	0	0	17	0	0	0
2	13	GCSM	RT	10	Between	0	0	0	0	0	0	0	0
2	13	GCSM	RT	11	Ridge	28	17	0	0	11	0	6	0
2	13	GCSM	RT	11	Between	0	0	0	0	0	0	6	0
2	14	GCSH	RT	6	Ridge	-	-	-	-	-	-	-	-
2	14	GCSH	RT	6	Between	-	-	-	-	-	-	-	-
2	14	GCSH	RT	8	Ridge	6	6	0	0	28	0	17	0
2	14	GCSH	RT	8	Between	6	0	11	0	56	0	11	6
2	14	GCSH	RT	10	Ridge	-	-	-	-	-	-	-	-
2	14	GCSH	RT	10	Between	-	-	-	-	-	-	-	-
2	14	GCSH	RT	11	Ridge	-	-	-	-	-	-	-	-
2	14	GCSH	RT	11	Between	-	-	-	-	-	-	-	-
2	15	GCS	RT	6	Ridge	11	6	0	0	0	0	0	0
2	15	GCS	RT	6	Between	17	11	0	0	222	0	39	0
2	15	GCS	RT	8	Ridge	22	6	6	0	0	0	0	6
2	15	GCS	RT	8	Between	11	28	6	0	11	0	0	0
2	15	GCS	RT	10	Ridge	-	-	-	-	-	-	-	-
2	15	GCS	RT	10	Between	-	-	-	-	-	-	-	-
2	15	GCS	RT	11	Ridge	-	-	-	-	-	-	-	-
2	15	GCS	RT	11	Between	-	-	-	-	-	-	-	-
2	16	SCM	RT	6	Ridge	22	0	0	0	11	0	0	0
2	16	SCM	RT	6	Between	39	6	0	0	61	11	39	0
2	16	SCM	RT	8	Ridge	6	0	0	0	17	0	0	0
2	16	SCM	RT	8	Between	17	6	0	0	6	0	0	0
2	16	SCM	RT	10	Ridge	-	-	-	-	-	-	-	-
2	16	SCM	RT	10	Between	-	-	-	-	-	-	-	-
2	16	SCM	RT	11	Ridge	-	-	-	-	-	-	-	-
2	16	SCM	RT	11	Between	-	-	-	-	-	-	-	-
2	17	LP	RT	6	Ridge	11	0	6	0	0	0	0	0
2	17	LP	RT	6	Between	56	11	6	0	67	0	22	0
2	17	LP	RT	8	Ridge	6	0	11	6	6	0	6	6
2	17	LP	RT	8	Between	6	0	6	0	6	0	0	0
2	17	LP	RT	10	Ridge	-	-	-	-	-	-	-	-
2	17	LP	RT	10	Between	-	-	-	-	-	-	-	-
2	17	LP	RT	11	Ridge	-	-	-	-	-	-	-	-
2	17	LP	RT	11	Between	-	-	-	-	-	-	-	-
2	18	C	RT	6	Ridge	6	0	0	0	0	0	0	0
2	18	C	RT	6	Between	39	17	0	17	39	0	22	0
2	18	C	RT	8	Ridge	22	11	6	0	0	0	6	0
2	18	C	RT	8	Between	17	6	6	0	0	0	0	6
2	18	C	RT	10	Ridge	6	0	0	0	0	0	6	0
2	18	C	RT	10	Between	11	11	0	0	0	0	6	0
2	18	C	RT	11	Ridge	22	6	6	6	6	0	0	0
2	18	C	RT	11	Between	17	0	6	6	0	0	11	0

Appendix 5: Diversity block 3 and 4

						DIVERSITY							
Block	Plot	Fertilization	Tillage	Time	Location	Chenopodium album	Polygonium convolvulus	Viola tricolor	Clover	Capsella	Chamomilia	Lolium perenne	other
3	19	GCSM	RT	6	Ridge	61	0	11	6	28	11	50	11
3	19	GCSM	RT	6	Between	44	6	0	11	56	11	39	17
3	19	GCSM	RT	8	Ridge	0	0	0	0	28	0	0	0
3	19	GCSM	RT	8	Between	0	0	0	6	44	0	11	0
3	19	GCSM	RT	10	Ridge	28	17	0	0	6	0	6	0
3	19	GCSM	RT	10	Between	0	0	0	0	0	0	0	0
3	19	GCSM	RT	11	Ridge	44	0	0	0	22	0	0	0
3	19	GCSM	RT	11	Between	0	6	0	6	0	0	11	0
3	20	GCSH	RT	6	Ridge	-	-	-	-	-	-	-	-
3	20	GCSH	RT	6	Between	-	-	-	-	-	-	-	-
3	20	GCSH	RT	8	Ridge	11	0	0	11	56	0	11	0
3	20	GCSH	RT	8	Between	0	0	0	0	67	0	0	0
3	20	GCSH	RT	10	Ridge	-	-	-	-	-	-	-	-
3	20	GCSH	RT	10	Between	-	-	-	-	-	-	-	-
3	20	GCSH	RT	11	Ridge	-	-	-	-	-	-	-	-
3	20	GCSH	RT	11	Between	-	-	-	-	-	-	-	-
3	21	GCS	RT	6	Ridge	6	6	0	0	6	0	0	0
3	21	GCS	RT	6	Between	28	6	11	6	94	6	22	6
3	21	GCS	RT	8	Ridge	11	0	0	0	0	0	22	0
3	21	GCS	RT	8	Between	11	17	0	0	33	0	0	0
3	21	GCS	RT	10	Ridge	-	-	-	-	-	-	-	-
3	21	GCS	RT	10	Between	-	-	-	-	-	-	-	-
3	21	GCS	RT	11	Ridge	-	-	-	-	-	-	-	-
3	21	GCS	RT	11	Between	-	-	-	-	-	-	-	-
3	22	LP	RT	6	Ridge	11	0	0	6	0	6	0	0
3	23	LP	RT	6	Between	61	17	0	0	44	6	28	0
3	24	LP	RT	8	Ridge	28	0	6	11	11	0	0	6
3	25	LP	RT	8	Between	17	0	0	0	56	0	0	0
3	26	LP	RT	10	Ridge	-	-	-	-	-	-	-	-
3	27	LP	RT	10	Between	-	-	-	-	-	-	-	-
3	28	LP	RT	11	Ridge	-	-	-	-	-	-	-	-
3	29	LP	RT	11	Between	-	-	-	-	-	-	-	-
3	23	SCM	RT	6	Ridge	11	0	0	0	0	0	0	0
3	24	SCM	RT	6	Between	44	6	0	17	61	0	22	0
3	25	SCM	RT	8	Ridge	22	11	0	6	17	0	11	0
3	26	SCM	RT	8	Between	17	0	0	0	50	0	0	0
3	27	SCM	RT	10	Ridge	-	-	-	-	-	-	-	-
3	28	SCM	RT	10	Between	-	-	-	-	-	-	-	-
3	29	SCM	RT	11	Ridge	-	-	-	-	-	-	-	-
3	30	SCM	RT	11	Between	-	-	-	-	-	-	-	-
3	24	C	RT	6	Ridge	6	0	0	0	0	0	0	0
3	25	C	RT	6	Between	61	6	0	0	56	0	22	0
3	26	C	RT	8	Ridge	22	6	0	0	11	0	11	0
3	27	C	RT	8	Between	28	11	0	0	28	0	17	6
3	28	C	RT	10	Ridge	17	0	0	6	0	0	0	0
3	29	C	RT	10	Between	17	0	0	11	17	0	17	0
3	30	C	RT	11	Ridge	39	0	6	0	0	0	6	0
3	31	C	RT	11	Between	6	22	0	6	6	0	11	0
4	27	LP	ST	6	Ridge	0	6	0	6	6	6	0	0
4	27	LP	ST	6	Between	17	11	6	11	72	50	61	0
4	27	LP	ST	8	Ridge	0	6	72	22	17	6	28	6
4	27	LP	ST	8	Between	0	6	0	22	0	17	17	6
4	27	LP	ST	10	Ridge	0	0	22	6	0	11	6	0
4	27	LP	ST	10	Between	0	0	0	0	17	11	28	6
4	27	LP	ST	11	Ridge	0	6	17	6	0	6	6	0
4	27	LP	ST	11	Between	17	11	0	6	6	11	0	0
4	33	SCM	ST	6	Ridge	0	0	0	0	0	11	11	0
4	33	SCM	ST	6	Between	6	6	22	28	39	72	39	0
4	33	SCM	ST	8	Ridge	22	6	22	22	28	17	44	6
4	33	SCM	ST	8	Between	0	0	11	11	28	33	39	17
4	33	SCM	ST	10	Ridge	0	6	11	11	0	6	6	0
4	33	SCM	ST	10	Between	6	11	6	6	22	17	33	11
4	33	SCM	ST	11	Ridge	0	6	11	6	11	11	39	0
4	33	SCM	ST	11	Between	6	0	0	11	11	11	0	11
4	34	C	ST	6	Ridge	6	0	11	0	0	6	6	0
4	34	C	ST	6	Between	11	11	56	11	39	33	33	0
4	34	C	ST	8	Ridge	6	0	6	6	11	0	17	6
4	34	C	ST	8	Between	6	6	11	0	6	17	44	11
4	34	C	ST	10	Ridge	0	0	22	17	0	6	0	0
4	34	C	ST	10	Between	6	17	17	11	0	22	6	0
4	34	C	ST	11	Ridge	0	11	11	6	6	6	17	6
4	34	C	ST	11	Between	6	0	0	17	0	11	6	0
4	36	GCS	ST	6	Ridge	6	0	0	0	0	6	0	0
4	36	GCS	ST	6	Between	17	0	39	28	83	67	28	0
4	36	GCS	ST	8	Ridge	6	6	44	28	6	6	11	6
4	36	GCS	ST	8	Between	0	0	22	11	11	11	22	11
4	36	GCS	ST	10	Ridge	0	11	22	6	0	11	17	0
4	36	GCS	ST	10	Between	17	0	0	0	6	22	6	6
4	36	GCS	ST	11	Ridge	0	17	28	0	11	6	0	0
4	36	GCS	ST	11	Between	6	6	6	0	0	0	0	0

Appendix 6: Diversity block 5 and 6

						DIVERSITY							
Block	Plot	Fertilization	Tillage	Time	Location	Chenopodium album	Polygonium convolvulus	Viola tricolor	Clover	Capsella	Chamomilia	Lolium perenne	other
5	38	SCM	ST	6	Ridge	0	0	11	0	0	6	0	0
5	38	SCM	ST	6	Between	33	22	28	0	67	22	22	11
5	38	SCM	ST	8	Ridge	28	0	28	11	6	11	6	0
5	38	SCM	ST	8	Between	11	6	6	0	11	0	33	6
5	38	SCM	ST	10	Ridge	22	6	11	0	0	0	17	6
5	38	SCM	ST	10	Between	11	22	6	11	0	0	17	6
5	38	SCM	ST	11	Ridge	17	17	17	6	11	0	0	11
5	38	SCM	ST	11	Between	0	28	6	0	0	0	22	6
5	40	C	ST	6	Ridge	6	0	28	0	0	6	0	0
5	40	C	ST	6	Between	17	61	33	6	144	44	78	0
5	40	C	ST	8	Ridge	6	28	44	0	11	6	28	0
5	40	C	ST	8	Between	0	22	22	0	11	11	44	33
5	40	C	ST	10	Ridge	11	22	33	6	0	0	39	6
5	40	C	ST	10	Between	11	33	17	6	0	11	39	11
5	40	C	ST	11	Ridge	6	67	17	6	0	6	22	6
5	40	C	ST	11	Between	0	22	11	11	0	6	61	11
5	42	GCS	ST	6	Ridge	6	0	11	0	0	17	0	0
5	42	GCS	ST	6	Between	0	33	67	11	156	56	61	11
5	42	GCS	ST	8	Ridge	0	6	6	0	22	6	22	6
5	42	GCS	ST	8	Between	0	6	17	0	28	33	39	0
5	42	GCS	ST	10	Ridge	11	11	44	6	11	6	39	0
5	42	GCS	ST	10	Between	11	17	0	6	17	22	33	6
5	42	GCS	ST	11	Ridge	6	1	17	0	17	17	33	0
5	42	GCS	ST	11	Between	0	22	17	6	0	22	44	0
5	45	LP	ST	6	Ridge	0	0	6	0	0	11	0	0
5	45	LP	ST	6	Between	6	28	100	11	67	44	22	6
5	45	LP	ST	8	Ridge	44	6	17	0	0	6	17	0
5	45	LP	ST	8	Between	28	11	17	0	0	6	17	0
5	45	LP	ST	10	Ridge	6	6	28	0	6	11	0	0
5	45	LP	ST	10	Between	11	28	6	11	6	17	6	0
5	45	LP	ST	11	Ridge	6	11	39	0	6	6	0	11
5	45	LP	ST	11	Between	22	6	0	11	0	6	6	11
6	49	GCS	RT	6	Ridge	17	0	0	0	0	0	0	0
6	49	GCS	RT	6	Between	178	17	0	0	72	0	11	0
6	49	GCS	RT	8	Ridge	11	0	0	0	11	0	6	0
6	49	GCS	RT	8	Between	56	6	0	0	6	0	6	0
6	49	GCS	RT	10	Ridge	6	0	0	0	0	0	0	0
6	49	GCS	RT	10	Between	28	0	0	0	6	0	0	0
6	49	GCS	RT	11	Ridge	17	6	0	0	0	0	0	0
6	49	GCS	RT	11	Between	6	0	0	0	6	0	0	0
6	50	C	RT	6	Ridge	33	0	0	0	0	6	0	0
6	50	C	RT	6	Between	244	6	6	6	44	0	0	0
6	50	C	RT	8	Ridge	50	0	6	0	11	0	0	0
6	50	C	RT	8	Between	56	6	6	0	0	6	0	0
6	50	C	RT	10	Ridge	39	11	0	0	17	0	0	0
6	50	C	RT	10	Between	33	6	6	0	17	0	6	6
6	50	C	RT	11	Ridge	100	22	0	0	6	0	6	0
6	50	C	RT	11	Between	50	6	0	0	0	0	6	0
6	51	SCM	RT	6	Ridge	83	0	0	0	0	0	0	0
6	51	SCM	RT	6	Between	228	6	11	6	56	22	11	0
6	51	SCM	RT	8	Ridge	56	0	6	0	17	0	0	0
6	51	SCM	RT	8	Between	44	11	11	0	0	0	6	6
6	51	SCM	RT	10	Ridge	44	0	0	0	0	0	11	0
6	51	SCM	RT	10	Between	39	11	0	6	11	0	0	0
6	51	SCM	RT	11	Ridge	33	0	6	0	0	0	0	6
6	51	SCM	RT	11	Between	11	6	6	0	11	0	0	0
6	52	LP	RT	6	Ridge	22	0	0	0	6	0	0	0
6	52	LP	RT	6	Between	106	6	22	6	67	6	6	0
6	52	LP	RT	8	Ridge	33	17	17	0	0	0	0	0
6	52	LP	RT	8	Between	50	6	17	0	17	0	11	6
6	52	LP	RT	10	Ridge	28	11	6	0	6	0	6	0
6	52	LP	RT	10	Between	11	11	6	0	6	0	6	11
6	52	LP	RT	11	Ridge	39	6	6	0	22	0	0	0
6	52	LP	RT	11	Between	33	6	6	0	0	0	0	0
6	53	GCSH	RT	6	Ridge	-	-	-	-	-	-	-	-
6	53	GCSH	RT	6	Between	-	-	-	-	-	-	-	-
6	53	GCSH	RT	8	Ridge	56	11	11	0	22	0	6	6
6	53	GCSH	RT	8	Between	44	28	6	0	39	0	6	0
6	53	GCSH	RT	10	Ridge	6	22	6	0	6	0	6	0
6	53	GCSH	RT	10	Between	11	11	11	0	17	0	11	6
6	53	GCSH	RT	11	Ridge	6	11	17	0	11	0	0	6
6	53	GCSH	RT	11	Between	17	0	0	0	11	0	17	6
6	54	GCSM	RT	6	Ridge	317	17	6	0	44	0	17	0
6	54	GCSM	RT	6	Between	361	28	17	0	50	0	39	0
6	54	GCSM	RT	8	Ridge	-	-	-	-	-	-	-	-
6	54	GCSM	RT	8	Between	-	-	-	-	-	-	-	-
6	54	GCSM	RT	10	Ridge	39	6	0	0	17	0	6	0
6	54	GCSM	RT	10	Between	0	0	0	0	0	0	0	0
6	54	GCSM	RT	11	Ridge	61	6	0	0	22	0	0	0
6	54	GCSM	RT	11	Between	0	0	0	0	0	0	0	0

Appendix 7: Diversity block 7 and 8

						DIVERSITY							
Block	Plot	Fertilization	Tillage	Time	Location	Chenopodium album	Polygonium convolvulus	Viola tricolor	Clover	Capsella	Chamomilia	Lolium perenne	other
7	55	GCS	RT	6	Ridge	78	0	0	0	6	0	0	0
7	55	GCS	RT	6	Between	194	6	17	0	117	0	17	0
7	55	GCS	RT	8	Ridge	44	0	0	0	22	0	6	0
7	55	GCS	RT	8	Between	39	0	6	0	11	0	6	0
7	55	GCS	RT	10	Ridge	28	0	0	0	6	0	0	0
7	55	GCS	RT	10	Between	17	0	0	6	39	0	11	6
7	55	GCS	RT	11	Ridge	22	6	0	0	61	0	0	0
7	55	GCS	RT	11	Between	6	0	0	0	6	0	6	0
7	56	LP	RT	6	Ridge	39	0	0	0	0	0	0	0
7	56	LP	RT	6	Between	156	11	11	0	83	0	0	0
7	56	LP	RT	8	Ridge	44	6	6	0	11	0	0	0
7	56	LP	RT	8	Between	56	17	0	0	17	0	6	0
7	56	LP	RT	10	Ridge	33	6	0	0	11	0	0	0
7	56	LP	RT	10	Between	50	0	0	0	17	0	0	0
7	56	LP	RT	11	Ridge	44	6	6	0	17	0	6	6
7	56	LP	RT	11	Between	28	11	0	0	11	0	0	0
7	57	SCM	RT	6	Ridge	44	0	0	0	6	0	0	0
7	57	SCM	RT	6	Between	122	11	0	0	89	6	11	0
7	57	SCM	RT	8	Ridge	50	6	0	0	11	0	0	0
7	57	SCM	RT	8	Between	17	0	6	0	28	0	11	17
7	57	SCM	RT	10	Ridge	28	6	0	0	6	0	0	17
7	57	SCM	RT	10	Between	33	6	17	0	17	0	0	6
7	57	SCM	RT	11	Ridge	44	6	0	0	11	0	6	6
7	57	SCM	RT	11	Between	22	11	0	0	56	0	0	6
7	58	C	RT	6	Ridge	11	0	0	0	1	0	11	0
7	58	C	RT	6	Between	50	17	6	0	161	0	11	0
7	58	C	RT	8	Ridge	33	6	11	0	22	0	6	6
7	58	C	RT	8	Between	39	6	11	6	61	0	22	11
7	58	C	RT	10	Ridge	39	6	6	0	22	0	6	0
7	58	C	RT	10	Between	28	6	11	6	17	0	33	6
7	58	C	RT	11	Ridge	44	0	6	0	44	0	11	0
7	58	C	RT	11	Between	39	6	6	0	6	6	11	0
7	59	GCSH	RT	6	Ridge	-	-	-	-	-	-	-	-
7	59	GCSH	RT	6	Between	-	-	-	-	-	-	-	-
7	59	GCSH	RT	8	Ridge	22	6	11	0	17	0	17	6
7	59	GCSH	RT	8	Between	6	0	11	0	17	0	28	6
7	59	GCSH	RT	10	Ridge	17	11	0	0	22	0	17	0
7	59	GCSH	RT	10	Between	0	11	6	0	39	0	11	6
7	59	GCSH	RT	11	Ridge	39	6	0	0	33	0	11	0
7	59	GCSH	RT	11	Between	0	0	0	0	11	0	0	0
7	60	GCSM	RT	6	Ridge	56	28	6	0	17	17	22	6
7	60	GCSM	RT	6	Between	78	28	11	6	39	11	22	17
7	60	GCSM	RT	8	Ridge	-	-	-	-	-	-	-	-
7	60	GCSM	RT	8	Between	-	-	-	-	-	-	-	-
7	60	GCSM	RT	10	Ridge	6	0	6	0	0	0	0	0
7	60	GCSM	RT	10	Between	0	0	0	0	0	0	0	0
7	60	GCSM	RT	11	Ridge	17	6	0	0	11	0	0	0
7	60	GCSM	RT	11	Between	0	6	0	6	0	0	0	0
8	61	SCM	ST	6	Ridge	6	0	11	0	0	6	0	0
8	61	SCM	ST	6	Between	6	50	50	6	33	17	17	0
8	61	SCM	ST	8	Ridge	0	0	44	11	6	6	6	11
8	61	SCM	ST	8	Between	0	28	28	6	6	6	28	6
8	61	SCM	ST	10	Ridge	0	0	11	11	0	0	11	6
8	61	SCM	ST	10	Between	0	0	0	0	11	11	22	0
8	61	SCM	ST	11	Ridge	11	17	11	0	6	0	0	0
8	61	SCM	ST	11	Between	0	11	17	11	0	6	6	17
8	62	C	ST	6	Ridge	6	0	6	0	6	11	22	0
8	62	C	ST	6	Between	17	22	33	11	111	22	67	0
8	62	C	ST	8	Ridge	11	22	22	0	17	6	22	0
8	62	C	ST	8	Between	11	11	28	11	11	6	22	6
8	62	C	ST	10	Ridge	6	6	44	0	17	0	17	11
8	62	C	ST	10	Between	17	11	6	6	6	6	11	6
8	62	C	ST	11	Ridge	11	17	44	0	0	11	33	0
8	62	C	ST	11	Between	11	11	0	6	11	6	28	0
8	63	GCS	ST	6	Ridge	11	0	17	0	6	6	6	0
8	63	GCS	ST	6	Between	11	33	22	6	106	28	50	0
8	63	GCS	ST	8	Ridge	0	17	22	11	6	6	11	0
8	63	GCS	ST	8	Between	0	11	28	6	28	11	39	6
8	63	GCS	ST	10	Ridge	17	0	22	0	11	0	6	0
8	63	GCS	ST	10	Between	6	17	6	0	6	6	22	0
8	63	GCS	ST	11	Ridge	11	11	33	0	0	6	11	0
8	63	GCS	ST	11	Between	0	0	0	0	17	6	6	0
8	64	LP	ST	6	Ridge	0	6	22	0	0	6	6	0
8	64	LP	ST	6	Between	11	28	78	0	317	28	72	6
8	64	LP	ST	8	Ridge	17	28	61	6	11	0	33	0
8	64	LP	ST	8	Between	17	33	33	0	11	0	33	0
8	64	LP	ST	10	Ridge	6	6	44	0	0	0	11	0
8	64	LP	ST	10	Between	6	17	0	11	6	17	17	6
8	64	LP	ST	11	Ridge	6	22	39	0	6	6	44	11
8	64	LP	ST	11	Between	6	0	6	6	6	0	6	6