First year's crop and soil response to different tillage methods under organic management

Name student: Xiangqian Gu (Tony)

Period: 2014.3-2014.8

Farming Systems Ecology Group

Droevendaalsesteeg 1 – 6708 PB Wageningen - The Netherlands

First year's crop and soil response to different tillage methods under organic management

Name student: Xiangqian Gu

Registration number student:

Credits: 36

Code number: FSE-80436

Name course:MSc thesis farming systems ecology

Period: 2014.3-2014.8

Supervisors: Dr.ir Egbert lantinga

Examiner: Dr.ir. Jeroen Groot

Abstract

It is well established that the distribution of nitrogen with in a soil profile and crop performance are significantly by long-term conversion of soil from conventional tillage practice to conservation tillage, but little is known about the short-term changes during transition between different tillage systems. This study was carried out in spring 2014 in a short-term (5 month) field experiment with the objectives of assessing the effects of conservation tillage and conventional tillage on soil chemical, biological properties and crop (wheat) performance during transition. Three different tillage methods (mouldboard plough, eco plough and non-inversion tillage) and two types of manure (solid cattle manure and liquid cattle manure) were included. Soil mineral nitrogen content, crop emergence, LAI, SPAD values, plant height, above ground plant dry matter yield and final grain yield were measured during growing season. Number of earthworms was counted before sowing and after harvesting. The amount of soil mineral nitrogen was affected by different tillage practices. Conventional tillage generated more soil mineral nitrogen during the growing season, mainly because of the richness of mineral nitrogen in 20-30cm soil layer. Non-inversion tillage accumulated more soil mineral nitrogen at the top 10cm soil layer which contributed to a better plant growth at early growth stage. But at the later growth stages, the advantages at early stage were gradually diminished due to a better plants growth under eco ploughing and conventional tillage. Although plant height under conventional tillage was relatively lower than which under non-inversion tillage and eco ploughing, a higher grain yield was recorded from conventional tillage than non-inversion tillage and eco ploughing due to more productive ears and better nitrogen supply. The interaction between different types of manure and tillage methods had affects on plants growth but not on the final yield. The effects on final yield from different types of manure applications were highly identical. The first year application of eco ploughing and non-inversion tillage had no influence on root growth: root distribution under the three tillage methods was identical. Furthermore, increased earthworm populations were detected in the non-inversion tilled plots.

Contents

1. Introduction

1.1 Historical view of tillage method

The beginning of civilization depended on agricultural food production, so does civilization's future. Tillage originated 10-13 millennia ago (Lal et al., 2007) and has always been an important part of technological development in the evolution of agriculture. Our ancestors who developed simple tools to place and cover seed in soil 10 millennia ago set the rudiment of 'plough'. Since then, with the development of civilization, a wide variety of tillage tools were originally designed, ranging from a simple digging stick to a paddle shaped spade that could be mounted on animals. In Europe, the 'roman plough' with the iron share was widely used around fifth century AD and it evolved into a soil inverting plough during the 8th to 10th century AD (Lerche, 1994). Later, wheels were attached to this type of plough. Only in the 18th and 19th century did ploughs become more and more sophisticated. German, Dutch people and British developed an almost perfect shaped mouldboard in the 18th century which turned the soil by 135^{o} and it avoided the famine and death in Europe since it was the only effective tool of weed control at that time (Derpsch, 1998). Because the plough saved Europe from famine, this tillage method became a "conventional tillage" method and also became in Europe and an important tool somewhat later in agriculture worldwide as the colonial power took the plough into Africa, Asia and America.

1.2 Why conventional tillage?

Eurostat (2010) defined the conventional tillage (Con) as 'a soil cultivation method that involves soil inversion, normally with a mouldboard or a disc plough as the primary tillage operation, followed by secondary tillage with a disc harrow'. Conventional mouldboard ploughing is still used as the preferred tillage method worldwide. In Europe and the USA where around 70% of the arable land is still under conventional tillage method (Derpsch, 2004; Eurostat, 2010). .

The popularity of conventional tillage is due to it offers several advantages including 1) providing better soil drainage, 2) weed suppression, 3) excellent incorporation of organic residuals, 4) decompacting dense soil layers, 5) wide availability of machinery. Conventional tillage can increase soil porosity and loosen soil with inversion deeper (30cm) layers up, allowing good air exchange (Hoffmann, 2008) and root growth (Glinski and Lipiec, 1990). Especially for clay and sandy soils with poor structure, conventional tillage is an ideal choice for solving internal drainage problems (El Titi, 2010). The utilization of mouldboard plough controls the regeneration of weed by burying weed seeds to deeper layer. So the seeds cannot germinate unless they return to a suitable depth (Norman, 1949). Mouldboard plough operations that bury nearly all previous crop residue and organic fertilizers (e.g. manure) that maximize the contact between soil and residues, therefore hasten the decomposition of residues. It is an easy way for seedbed preparation without extra investment because of its wide availability.

1.3 The conventional becomes less conventional

However, the intensive use of conventional tillage brought mixed blessings. Environmental problems were caused by the repercussions of applying conventional tillage (Crosson, 1981). The soil degradation and erosion are major issues triggered by conventional tillage (Holland, 2004). As the tilled and loosened soil, buried residues and a relative bare surface, the potential of accelerating soil loss by wind and water increases (Triplett and Warren, 2008). Eroded soil was once the biggest source of pollutants in the United States (Crosson, 1981). Part of the chemical fertilizers and pesticides from famers' fields are drifted and carried by eroded soil, which have negative impacts on the quality of people's life. On the other hand, not only farmers need to re-invest into the fields to compensate the input losses but also governments spend substantial amounts of money as off-site costs (Holland ,2004). Despite the losses of soil, continuous conventional tillage practices with soil inversion lead to soil degradation which generates many changes on soil (degraded soil structure, decreased soil organic matter and reduced soil organisms) (Bruce et al., 1995; Holland, 2004). All of these problems, in turn, affect agricultural field and crop production. In Europe, about 15 percent of total European land was suffering from serious erosion and 17 percent of land was degraded (Oldeman, 1994). And these numbers are still increasing (EEA, 1995; Montanarella, 2007).

The crisis of 'dust bowl' caused by intensive tillage and drought during 1930s in the United States created a controversy about the necessity of using mouldboard plough for seedbed preparation. Soon, the soil conservation movement elevated to a national level. President Frankin D. Roosevelt elaborated in his letter to state governors that 'a nation that destroys its soils destroys itself', he prompted soil conservation through establishing soil conservation districts to against soil erosion (Roosevelt, 1937). In 1935, a new soil conservational federal agency service was established which is now called Natural Resources Conservation Service (NRCS) of USDA. Since 1950s, a trend of transition from conventional tillage to conservation tillage became more and more conspicuous worldwide (Owens, 2001).

1.4 What is conservation tillage?

In general, conservation tillage includes several kinds of tillage practices that preserve soil moisture and reduce soil erosion by maintaining more than one-third of soil surface covered by crop residues (Peigné et al., 2007). In conservation tillage systems, the soil is disturbed as little as possible by mulching tillage, reduced tillage, strip tillage or direct seeding (Unger, 1984). The growth of conservation tillage application coincided with the development of modern technologies. For example, the commercial use of synthesized herbicide and improved seeding and harvesting equipments are effective for weed control and lead to the prevalent use of no-till systems in the United states (Triplett and Warren, 2008). However only little agricultural land in Europe is under no-till systems compared with the USA. This is because of the humid and cold weather conditions during crop growth limit the suitability of no-tillage practices in Europe (Mäder, 2012). So the European researchers are more focused on reduced tillage through the reduction of plough depth or the application of non-inversion tillage (Mäder, 2012)

The term non-inversion (Non) tillage is defined as any tillage practice without substantially inverting the soil like the disc plough or chisel plough. Non-inversion tillage was mostly preferred by organic farmers because it was considered as less harmful to soil biota (Munkholm et al., 2001). The use of rotator and tine cultivate soil without soil inversion (Christian, 1994). Non-inversion tillage systems usually work at shallower depth (5-10cm) than mouldboard plough, mixing part of residues into top soil and part on the soil surface (Carter et al., 2003). The deeper non inversion tillage is applied in some Europe countries. For example, in the UK, it reaches into the soil more than 20cm to remove soil compaction (Batey, 2009).

Eco ploughing (Eco) as a soil conservation strategy was developed by a Dutch company. It was designed to meet the requirements of shallower tillage and featured with good soil inversion but shallower depth compared with traditional mouldboard plough. Despite the depth, it could be mounted on the side of the beam to make the construction of plough lighter. It was preferred by organic farmers since it offers good weed control, good land quality (aeration, soil moisture content) and good incorporation of organic inputs (Van Kouwenhoven et al., 2002).

Both non-inversion tillage and eco ploughing as conservation tillage strategies are encouraged by European agricultural policy and IFOAM, aiming at minimized environmental problems (e.g. CO_2, CH_4, NO_2 emissions), conserved and improved soil quality and reduced energy requirement (Basch et al.,2012; IFOAM, 2009) . Different tillage methods can significantly influence the soil by altering soil chemical, physical and biological properties and eventually affect the crop production (Mathew et al., 2012).

1.5 Effects of conventional tillage and conservation tillage on soil chemical properties

Soil is a chemical entity. Soil is consisted of liquid, solid and gas, soluble and insoluble, organic and inorganic substances. Soil organic matter is the most important component in soil, which plays many important roles in terms of physical, chemical and biological functions (Osman, 2012a). For example, soil organic matter improves soil structure and porosity, thus provides better water holding capacity and better water infiltration. It enhances the ion exchanges within soil and provides food for soil organisms. Soil organic matter includes plant and animal residues at several phases of decomposition. In soil-plant system, soil organic matter is crucial due to its organic constituents of nutrients for plant growth (Schnitzer, 1975). Nitrogen is the most needed element after C, H and O for plants. Nitrogen gives plants green colour and consists the chlorophyll molecules which allow plants convert solar energy into chemical energy through photosynthesis. It also plays an important role in all metabolic process. So the adequate nitrogen supply is the key to successful plant production (Osman, 2012b). Plants can only take up nitrogen in inorganic form (NH_4^+ and NO_3^-) from soil. While soil organic matter can only provide these inorganic nitrogen by mineralization. During the process of mineralization, organic nitrogen which bounded with soil organic matter (e.g. amino acid, protein) is converted into inorganic nitrogen and available to the plants. Mineralization is determined by the environmental factors and the C:N ratio of organic input. Temperature and soil moisture directly affect the microbial activities which lead to the changes on mineralization. Organic matter with lower C:N ratio has a faster nitrogen mineralization compared with the material with higher C:N ratio. Inorganic nitrogen with a higher C:N ratio from organic input was consumed by microorganisms in the soil and converted into organic nitrogen during the process of immobilization, an opposite process to mineralization.

Soil organic matter is redistributed with tillage practices. Balesdent et al (2000) found in a long-term research that soil organic matter was evenly spread in the ploughed layer (30cm) under conventional tillage. While under conservation tillage, more than 50% of soil organic matter is accumulated in the top 10cm and only 20 percent of soil organic matter appears above 20cm. In terms of quantity, soil organic matter in the soil varies because of different soil type and crop management such as tillage. Andeade et al (2003) demonstrated in his paper that there was more soil organic matter in the tilled layer under conservation tillage management than conventional (For eco ploughing, the tilled layer is the layer between 0-15cm depth and for non-inversion tillage, the tilled layer is between 0-10cm). Furthermore, Kay and Vandenbygaart (2002) proved their hypothesis that there was no significant difference in organic matter content between conventional tillage and conservation tillage at untilled soil layer (For eco ploughing, the untilled layer is the layer below 15cm depth and for non-inversion tillage, the untilled layer is below 10cm). The amount of mineral nitrogen is affected by tillage as well. Tillage practices play a crucial role in organic nitrogen turnover where nutrients are made available to plants by microbial decomposition of added or in situ organic matter. Young and Ritz (2002) concluded in their research that there was more mineralized nitrogen in the tilled layer under conservation tillage practices than conventional tillage practice and similarly amount of mineralized nitrogen at untilled layer between conservation tillage and conventional tillage. In another 10 years study carried out by Ahl (1998), more mineralized nitrogen was observed from tilled layer after 10 years conservation tillage practices than conventional tillage. But there was less mineralized nitrogen in the whole top soil (0-30cm) in conservation tillage system than conventional. Different opinions were purposed by Andrade (2003), he found more mineralized nitrogen in the whole top soil under conservation tillage from a long-term study, while in a short term, less mineralized nitrogen was found in the whole top soil with conservation tillage.

1.6 Effects of conventional tillage and conservation tillage on crop performance

Crop performance is determined by crop development, growth and yield. All these processes are dynamic and influenced by environmental factors. Those environmental factors including aerial conditions and soil conditions. Aerial conditions such as precipitation and radiation together with soil conditions such as soil moisture and availability of nutrients impact crop development and growth. In the end, regulate the yield (Ritchie et al., 1998; Haferkamp, 1988).

Tillage affects crop performance by modifying the soil environment. Soil physical, chemical and biological properties are affected by tillage, including soil moisture content and water movement, soil structure and porosity, soil nutrients status and microbial population (Blevins et al., 1983). Plants response differently to different soil conditions (Passioura, 2002). Plants under conservation tillage treatment tend to grow higher and have a larger leaf area than plants under conventional tillage treatment during a study in Spain. The author reckoned that this may result from the higher replenishment of soil water storage in the conservation tillage than in the conventional tillage (Moreno et al, 1997). Conservation tillage results in decreased top soil temperature which would hamper crop emergence (Guerif, 1994). This problem entwined with short-term soil compaction caused by conservation tillage during the initial years of transition will have a negative effect on final yield because of rooting problem (Whalley et al., 1995). While Njos and Ekeberg (1980) considered conventional tillage gives plants a better roots development in a long term. Tillage also affects plants nitrogen status by influencing soil nitrogen status. Chlorophyll as an extremely important compound in plants indicates plants nitrogen status and responsible for photosynthesis which strongly correlated with yield (Reeves et al., 1993). Throughout a study by Liu (2012), no significant differences of the amount of chlorophyll were found between conservation tillage management and conventional tillage management during a three years study.

Regarding of yield, Similar yield were found between conservation tillage and conventional tillage based on López andArrúe (1997) 's long term study. In another study (Husnjak et al., 2002), conventional tillage application led to a higher yield than conservation tillage at the beginning of the study, but after 3 years conservation tillage practices, higher yield were achieved in the field that treated with conservation tillage.

Although intensive studies have been done on the effects of tillage on yield, the effects of tillage on yield is variable. It does not only depend on the soil type and climate but also depend on the agronomic skills of the farmers (El Titi, 2010; LampurlanCs et al., 2002) .

1.7 Effects of conventional tillage and conservation tillage on soil biological properties

Earthworms, as the most important indicator of soil biological properties, potentially provide ecosystem services that benefits the farming system. Generally, the benefit effects of earthworms are 1) improved soil structure and 2) nutrient cycling. Earthworms improve soil structure by their movements in the soil such as casting. Thus earthworms have important effects on soil infiltration and aeration. Earthworms can also influence soil nutrient cycling by selective activation of organic matter mineralization (Lavelle, 1988).

For different tillage methods, there were more earthworms were found under conservation tillage practices than conventional tillage (Birkas et al., 2004). Because earthworms habitats are disrupted by deep ploughing. They are exposed to an unsuited environment that leads to the decrease of population. Since there are more earthworms in reduced tillage system, so the problem of subsoil compaction could be improved by the help of earthworms activities (Rasmussen, 1999). Besides, the lack of nitrogen supply in conservation tillage systems could be alleviated by the activities of earthworms since the existence of earthworms promotes the microbial activity (Vakali et al., 2002). There are abundant of papers about how tillage affects earthworms population and in the light of their roles in ecosystem. An excellent review summarized by Chan (2001) provides a whole image of the relation between tillage and earthworms.

1.8 Research objectives

Although a great number of studies have been done studying various aspects of tillage effects in different tillage systems, most of them are focusing on long-term effect. This paper aims to investigate the effects of three different tillage methods (conventional tillage, eco ploughing tillage and non-inversion tillage) and two types of manure (solid cattle manure and liquid cattle manure) on crop performance , soil chemical and biological properties in the first year of transition under organic management.

Tillage effects: To investigate the effects of 3 different tillage methods (conventional tillage, eco ploughing and non-inversion tillage) on crop performance , soil chemical and biological properties in an organic wheat production system.

Manure effects: To explore the effects of 2 different type manure (solid and liquid) on crop performance , soil chemical and biological properties in an organic wheat production system.

Interactions: To know the interaction of three different tillage practices (conventional tillage, eco ploughing and non-inversion tillage) and two types of manure (solid and liquid manure) on soil properties and crop performance in an organic wheat production system.

1.9 Hypotheses

1.9.1 Soil mineral nitrogen content

Eco ploughing and non-inversion tillage lead to less mineral nitrogen in the whole topsoil (0-30cm) compared with conventional tillage (Andrade et al., 2003). Regarding the different types of manure, more mineral nitrogen will be achieved in the field with liquid manure treatment. Not only because the high-fraction of mineral nitrogen of liquid manure itself but also the higher mineral nitrogen materials could facilitate organic nitrogen mineralization (Peigné et al., 2007). As a consequence, More mineral nitrogen will be achieved at the field with conventional tillage and liquid manure treatment.

1.9.2 Soil biological property

More earthworms will be found under non-inversion tillage because less soil disturbance (Birkas et al., 2004).

1.9.3 Crop performance

Plants under conventional tillage and liquid manure treatment will have a better growth because of sufficient available nitrogen supply. Consequently , higher yield will be obtained with conventional tillage with liquid manure fertilization.

2. Materials and Methods

2.1 Site description

The experiment was conducted at the organic experimental farm (51°59'31.2"N 5°39'48.7"E) of farming systems ecology group of Wageningen University, The Netherlands in 2014 between April and September. The location of the area is marked in Figure 1. The mean annual air temperature for this location is 11^{o}C and the mean annual precipitation is 829mm. The soil classified as sandy loam and had a soil organic matter content of 4.9% in the top 10cm, 4.9% in the 10-20cm depth, 4.5% in the 20-30cm layer and 2.9% in the 30-60cm soil layer. The site was under a long-term organic management with conventional tillage before this experiment.

Figure 1.Experimental site (Area in blue) (51°59'31.2"N 5°39'48.7"E)

2.2 Experimental design and treatments

There are two experimental factors involved in this experiment, tillage and manure. Three kinds of tillage methods: Conventional (Con), Eco ploughing (Eco) and Non-inversion (Non) and two fertilization treatments: Solid Manure (SM) and Liquid Manure (LM) were combined and implemented in a random design with three replicates (Details show in Table 1).

Table 1.Experimental factors and treatments

Factors and treatments		Tillage		
		Con: mouldboard plough to a depth of 30cm.	**Eco**: Eco plough to a depth of 15cm.	**Non**: Rotary tiller to an depth of 10cm without soil inversion.
Fertilization (Appendix 1)	**LM** Application rate: 20m^3/ha. Mineralnitrogen content: 70kg/ha.	Con+LM1, Con+LM2, Con+LM3	Eco+LM1, Eco+LM2, Eco+LM3	Non+LM1, Non+LM2, Non+LM3
	SM Application rate: 20ton/ha. Mineralnitrogencontent: 150kg/ha.	Con+SM1, Con+SM2, Con+SM3	Eco+SM1, Eco+SM2, Eco+SM3	Non+SM1, Non+SM2, Non+SM3

The conventional tillage was applied with the use of a mouldboard plough to a depth of 30 cm. Eco ploughing was accomplished with a seven or eight bottom revisable plough developed by Rumptstad industries BV, it featured with a 2.1m working width and plough to a depth of 15cm (Kouwenhoven et al., 2002). The non-inversion tillage was implemented with the use of a rotary tiller to a depth of 10cm without soil inversion.

Spring wheat was seeded followed with tillage at the rate of 190kg/ha.The plot size was 20m* 3m, which permitted 24 rows of wheat to be planted in a 12.5cm row width. Tillage practices were incorporated with manure application according to the constructions of experiment (Figure 2). The application rates of liquid manure and solid manure were 20m^3/ha and 20 ton/ha respectively (Table 1, Appendix1).

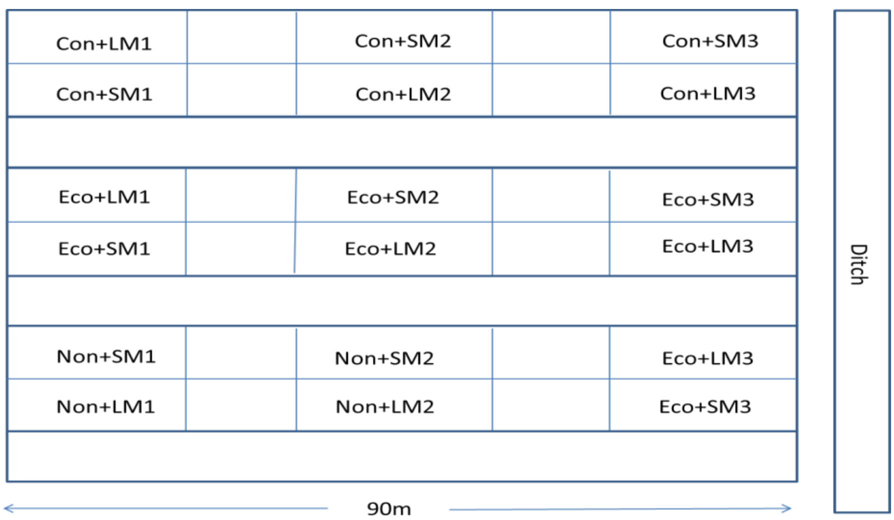


Figure 2. Constructions of experimental field

2.3 Sampling and data collection

2.3.1 Data collection principle

Sampling positions were randomly selected within each plot, leaving a distance of 0.5m from the nearby plots in order to minimise edge effects (Austin and Blackwell, 1980). The sampling time schedulewas presented in Appendix 2.

2.3.2 Earthworm abundance

In April 2014, monolith samples of 40 x 40 x 30 cm were taken to determine earthworms density in the large fields before field activities. 8 samples were taken within the field. In August 2014, Two monolith samples were taken within each plot. Earthworms in the soil samples were carefully removed by hand and were subsequently counted for each plot.

2.3.3 Soil mineral nitrogen content

Soil mineral nitrogen content was assessed 3 times during growing season (Tillering stage, booting stage andend of milking stage) at the depth of 0-10cm, 10-20cm, 20-30cm and 30-60cm. To measure soil mineral nitrogen, the ammonium-N and Nitrate-N were extracted from the fresh soil as-received (immediately submitted to the laboratory or refrigerated to less than $4^{o}C$). Otherwise, microbial activity and mineralization of organic matter would continue in the soil samples until it is analyzed (HGCA,2006). Fresh soil samples were extracted in $CaCl_2$ (30ml, 0.01mol) after 2 hours shaking and analyzed using a segmented-flow system (Auto-analyzer II, Technicon). The final results of mineral nitrogen are expressed in Kg/ha in this paper.

2.3.4 Plants emergence

Plants emergence was counted twice in a fixed area after planting. 3 replications per plot were taken by hand counting the number of plants in a 1m length in rows.

2.3.5 Plants height and plant dry weight

Plants height was measured for each plot 4 times (tillering stage, booting stage, heading stage and milking stage). Plants height was measured in centimetre from the soil surface to the tip of the plants (top of spike, excluding awns). Plants height were measured at 8 representative plants per plot. Plants dry weight was measured through oven at $70^{o}c$ till the weight is constant. Plants dry weight was measured 3 times (tillering stage, booting stage and milking stage).

2.3.6 Root distribution

Root distribution was measured at the end of the milking stage through making a soil profile.

2.3.7 Leaf area index (LAI)

LAI was assessed directly by using destructive sampling 2 times (tillering stage, booting stage). By collecting all the wheat leaves from a 40*40cm area, the leaf area was determined by scanning planimeter in laboratory. The results were converted from 40*40cm area to the scale of 1*1m.

2.3.8 Chlorophyll content

Chlorophyll content was measured 3 times (booting stage, heading stage and milking stage) by using SPAD meter: at the first fully expanded leaf from the top of the plant; about halfway between the tip and the base of the flag leaf (Murdock et al., 2004). 8 plants were measured and 4 readings per leaflet were taken and an average value was calculated.

2.3.9 Final yield

Final yield was measured by hand harvesting a 1*1m area for each plot. Then the yield components were measured (number of ears per m^2, weight per ear, thousand kernel weight).

2.4 Data analysis

All the data from plants was putted into SPSS for analysis. T-test and two-way ANOVA were used for compare the significant differences and to declare effects and interactions at 95% confidence interval. Levene's test was conducted for checking the homogeneity of variance. In some circumstances, liner regression was used to check the coefficient of determination (R square).

3. Results

3.1 Soil mineral nitrogen

Line charts were established based on the soil mineral dataset (Appendix 4) to see the trends of soil mineral contents within a growing season.

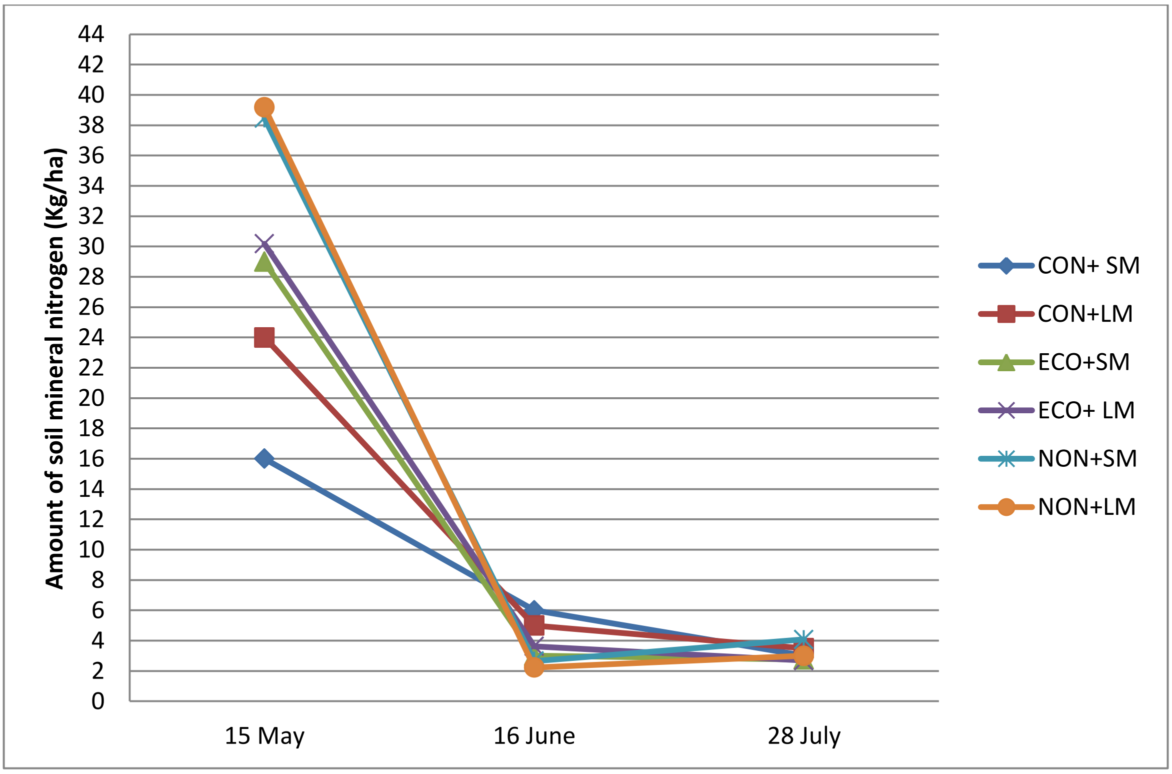


Figure 3. Soil mineral content (Kg/ha) in the 0-10cm layer at 3 different date

In top soil (0-10cm layer), the mineral nitrogen status shows in Figure 3. Non-inversion tillage showed the highest soil mineral nitrogen content at tillering stage (15 May) compared with other two tillage methods. Top soil under eco ploughing had an intermediate amount of mineral nitrogen, higher than conventional ploughed soil and lower than soil with non-inversion tillage. Furthermore, the amount of mineral nitrogen in the top 10cm layer showed kind of uniformity under different tillage practices. Liquid manure application led to higher amount of mineral nitrogen than solid manure treatment in each specific tillage method. The soil mineral nitrogen content at booting stage (16 June) decreased dramatically compared with tillering stage. Soil mineral nitrogen content extremely declined at non-inversion tillage, together with eco ploughing had a relatively lower amount of soil mineral nitrogen compared with conventional tillage. Although conventional tillage resulted in the lowest soil mineral nitrogen content at tillering stage, while at booting stage, higher mineral nitrogen was found under conventional tillage. The differences of mineral nitrogen content between different treatments were not that much as tillering and booting stage at milking stage (28 July). Almost all treatments showed a decreasing trend of soil mineral nitrogen comparing with booting stage despite non inversion tillage. The soil mineral nitrogen contentat milking stage under non-inversion tillage bounced up from booting stage.

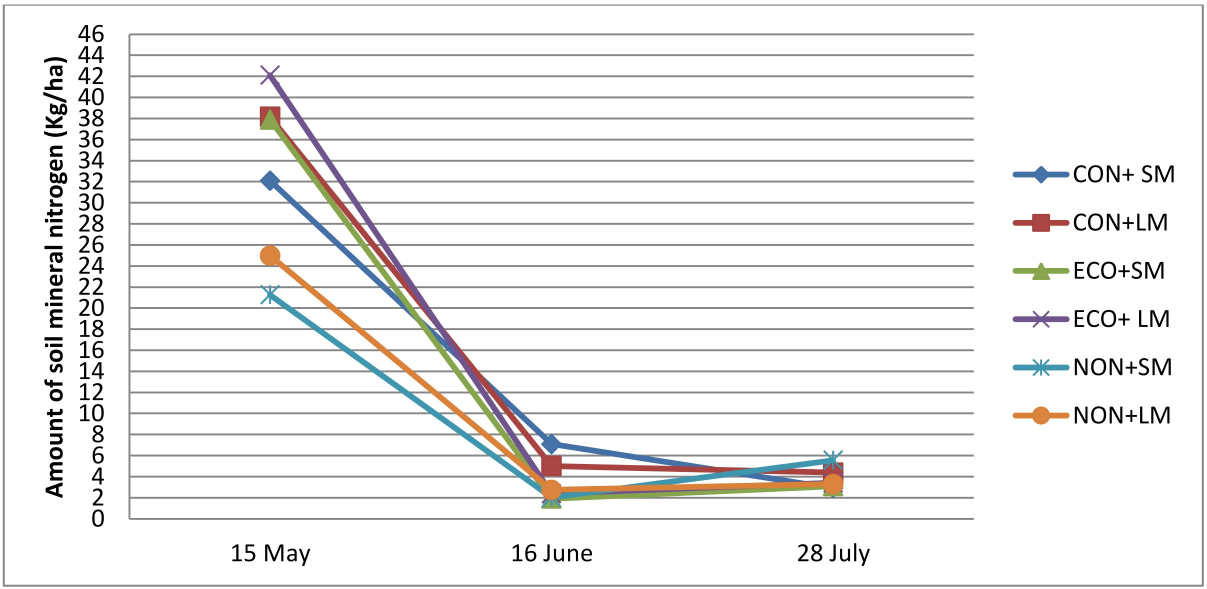


Figure 4. Soil mineral nitrogen content (Kg/ha) in the 10-20cm layer at 3 different date

Figure 4 illustrates the soil nitrogen content of different treatments at 10-20cm layer. Eco ploughing led to higher soil mineral nitrogen content at tillering stage (15 May) followed by conventional tillage and non-inversion tillage. At the same time, within each tillage methods, liquid manure application led to more soil mineral nitrogen than solid manure treatment. The amount of mineral nitrogen at booting stage (16 June) presented some differentiation at booting stage. Eco ploughing and non-inversion tillage clustered together at a lower level compared with conventional tillage. Conventional tillage showed a highest amount of mineral nitrogen with solid manure treatment with liquid manure treatment stayed behind.

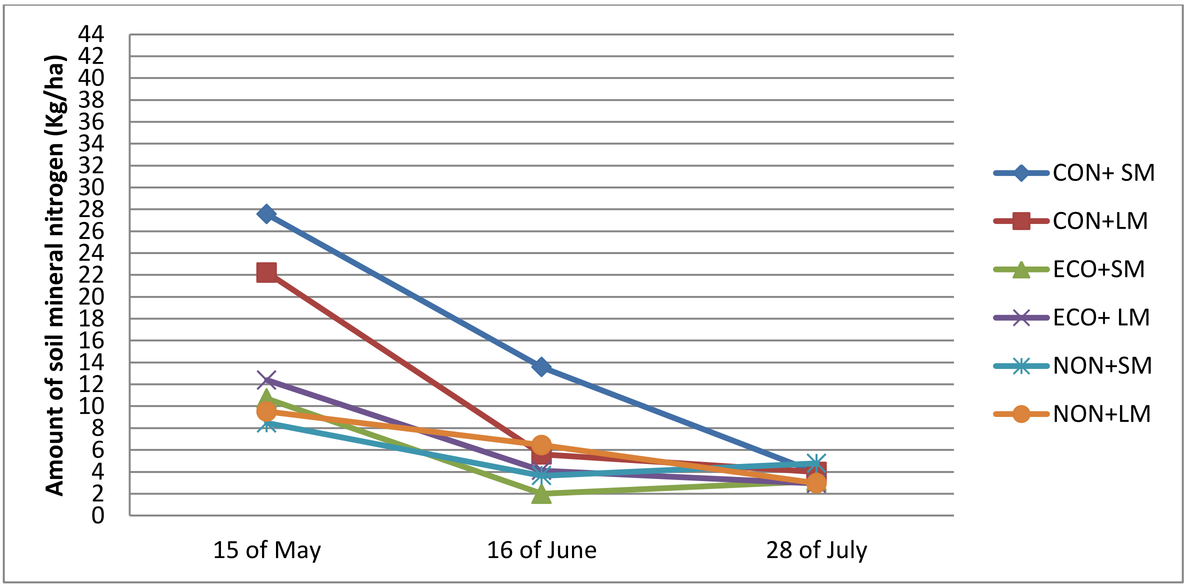


Figure 5. Soil mineral nitrogen content (Kg/ha) in the 20-30cm layer at 3 different date

At deep layer (20-30cm), the soil mineral nitrogen status demonstrated by Figure 5. Conventional tillage presented a higher amount of mineral nitrogen than other tillage methods at tillering stage (15 May). Especially for conventional tillage incorporated with solid manure, the highest amount of mineral nitrogen was recorded at tillering stage and booting stage (16 June). While the higher concentrate of mineral nitrogen of conventional tillage disappeared at milking stage (28 July), dropped to the same level of eco ploughing and non-inversion tillage.

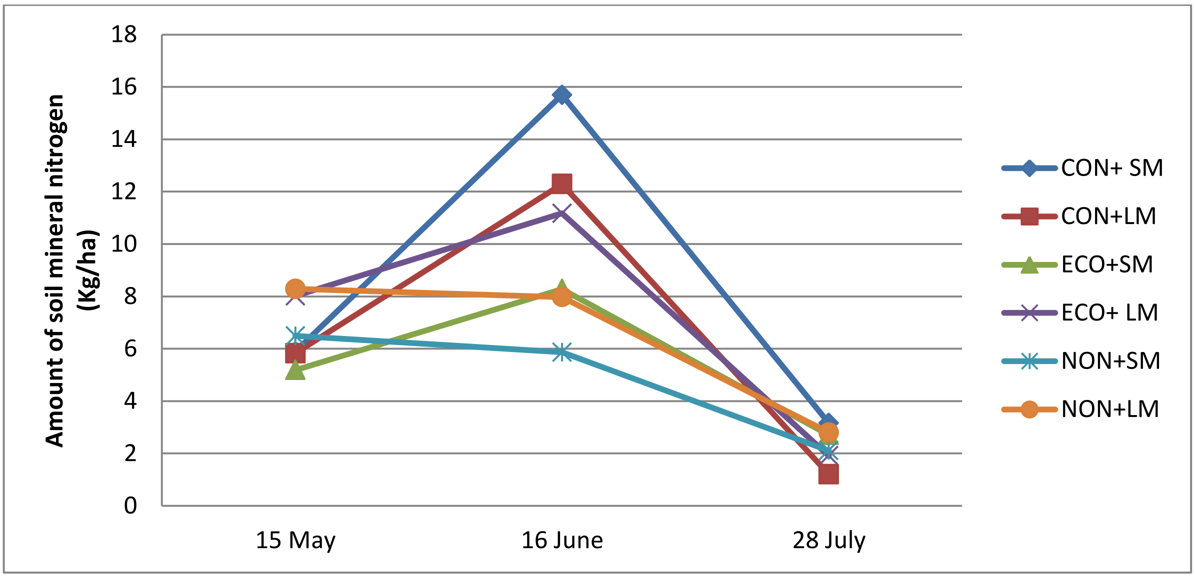


Figure 6. Soil mineral nitrogen content (Kg/ha) in the 30-60cm depth at 3 different date

At the 30-60cm layer, the dramatic changes happened during the interval between first (15 May) and second measurement (16 June) as well as second and third (28 July) measurement. Conventional tillage and eco ploughing greatly increased at first and then dropped to a lower level while non-inversion tillage stood still at first and then slightly decreased to a lower level.

Bar charts were established based on the soil mineral dataset (Appendix 4) to see the amount of soil mineral nitrogen of each layer at a specific time.

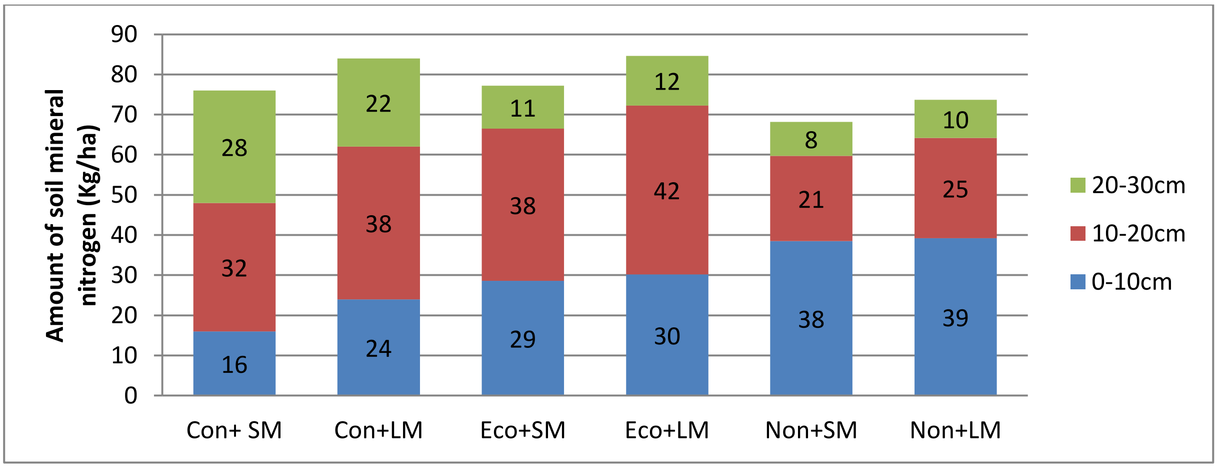


Figure 7. Soil mineral content (Kg/ha) in 3 different layers (0-10, 10-20, 20-30cm) at 15th of May

It could be seen from Figure 7 that there were more soil mineral nitrogen at 0-10cm layer at tillering stage (15 May) under non inversion tillage than eco ploughing and conventional tillage. While eco ploughing and conventional tillage led to more soil mineral nitrogen than non-inversion tillage at 10-20 and 20-30cm layers.

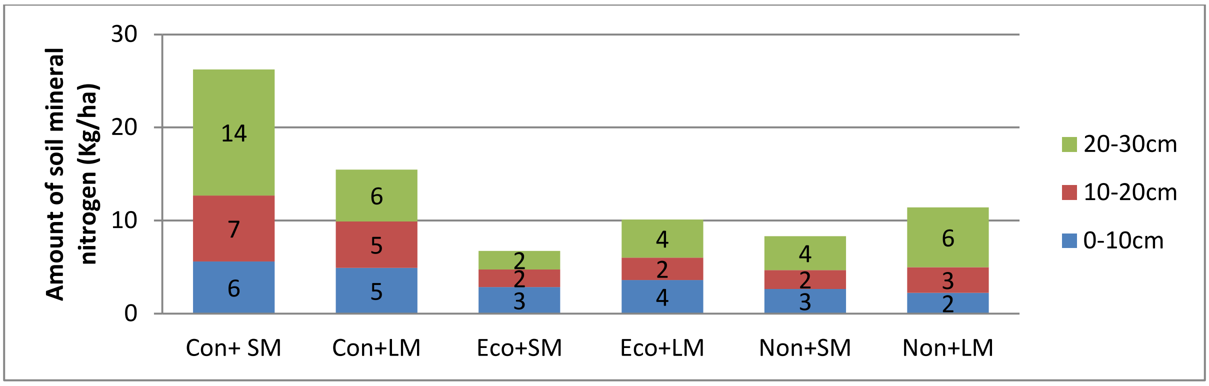


Figure 8. Soil mineral content (Kg/ha) in 3 different layers (0-10, 10-20, 20-30cm) at 16th of June

At booting stage (16th of June), Conventional tillage resulted in more soil mineral nitrogen than eco ploughing and non-inversion tillage at 0-30cm layer. Specifically, more mineral nitrogen was located at 0-10cm and 10-20cm layers compared with eco ploughed and non-inversion tilled soil.

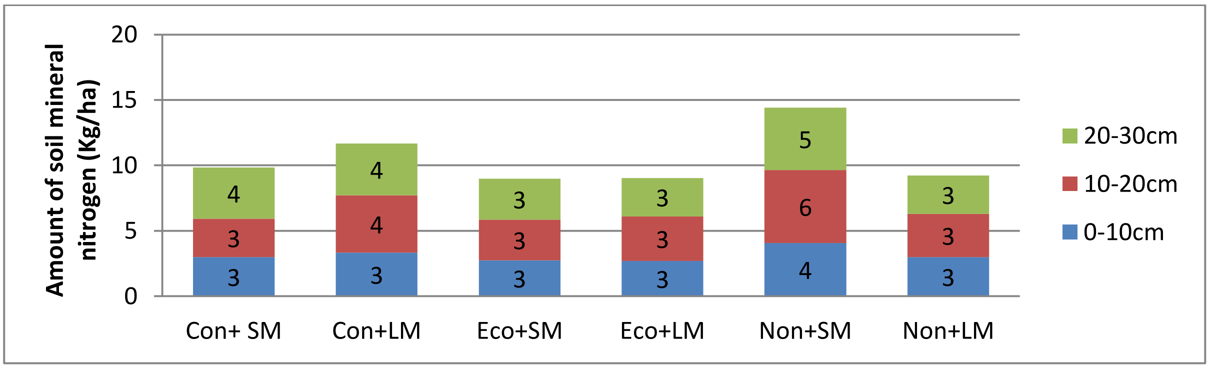


Figure 9. Soil mineral content (Kg/ha) in 3 different layers (0-10, 10-20, 20-30cm) at 28th of July

The soil mineral nitrogen status at milking stage (28 July) between each treatments were relatively similar despite the non-inversion tillage with solid manure treatment, which was greatly higher than other treatments.

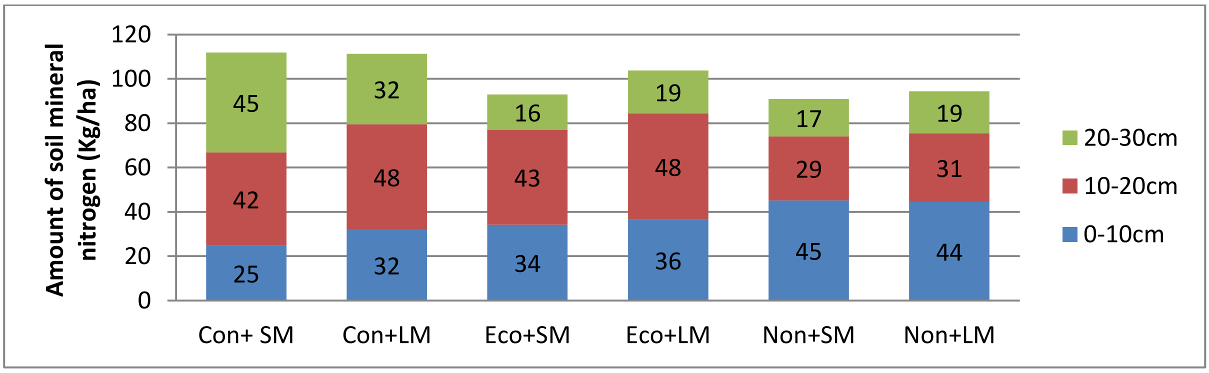


Figure 10. Overall soil mineral content (Kg/ha) of 3 times measurement in 3 different layers (0-10, 10-20, 20-30cm)

Overall, Conventional tillage led to more mineral nitrogen at 0-30cm than eco ploughing and non-inversion tillage, especially in the 20-30cm layer. Non-inversion tillage resulted in more soil mineral nitrogen than conventional tillage and eco ploughing at 0-10cm layer.

3.2 Crop emergence

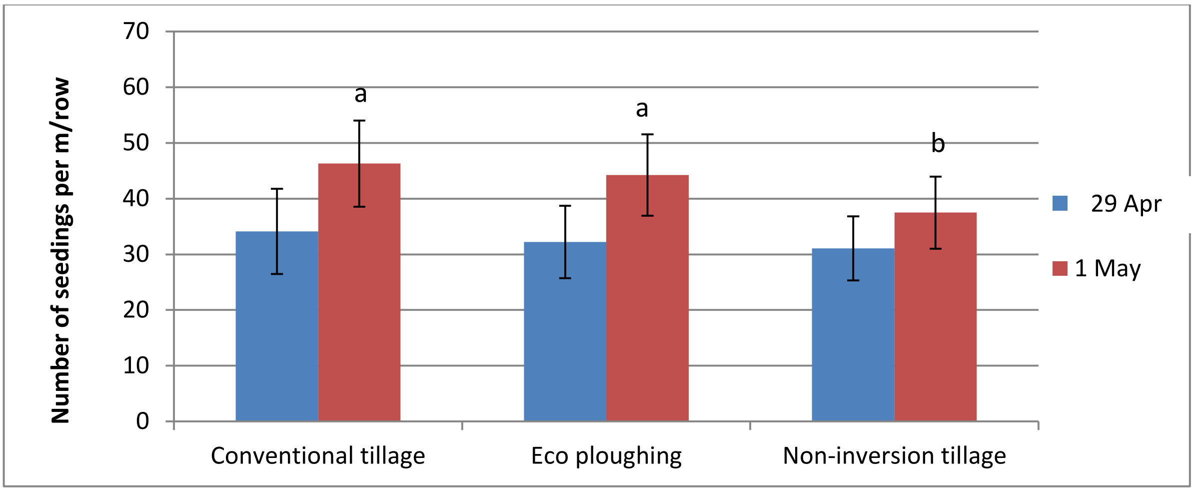


Figure 11. Number of seedlings under different tillage methods at 2 different times during seedling stage

Wheat seedlings were counted twice (29th of April and 1st of May) during seedling stage in 3 days. Based on the data from April, tillage (p=0.4), type of manure (p=0.826) had no impact on the number of seedlings and there was no interaction between tillage and manure type (p=0.475). The seedling emergence was homogeneous among three tillage methods.

But during the second observation of emergence (1 May), it was found that the tillage had influences on emergence at a significant level (p=0.002) while types of manure did not have significant effects on emergence (p=0.792). There was no interaction between manure and tillage (p=0.249). Number of seedlings under conventional tillage and eco ploughing maintained at the same level without statistical differences (p=0.396). Non-inversion tillage led to the lower number of seedling between three tillage methods with a 0.001 p-value comparing with conventional tillage and a p-value 0.007 with eco ploughing.

3.3 Leaf area index

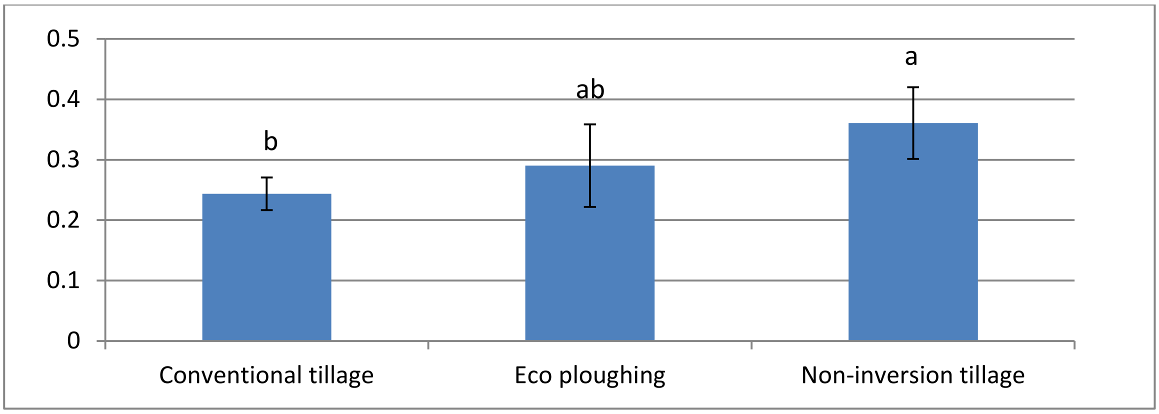


Figure 12. Average values of LAI under different tillage methods at tillering stage (19 May)

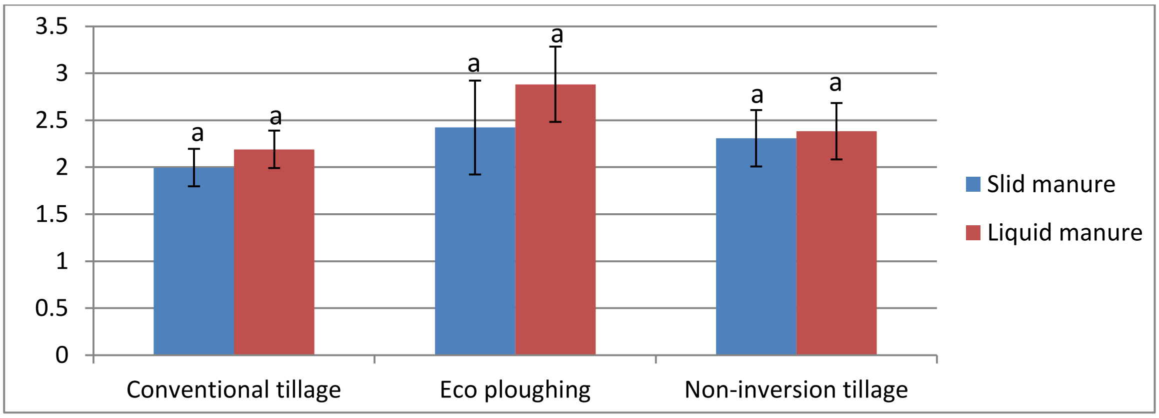


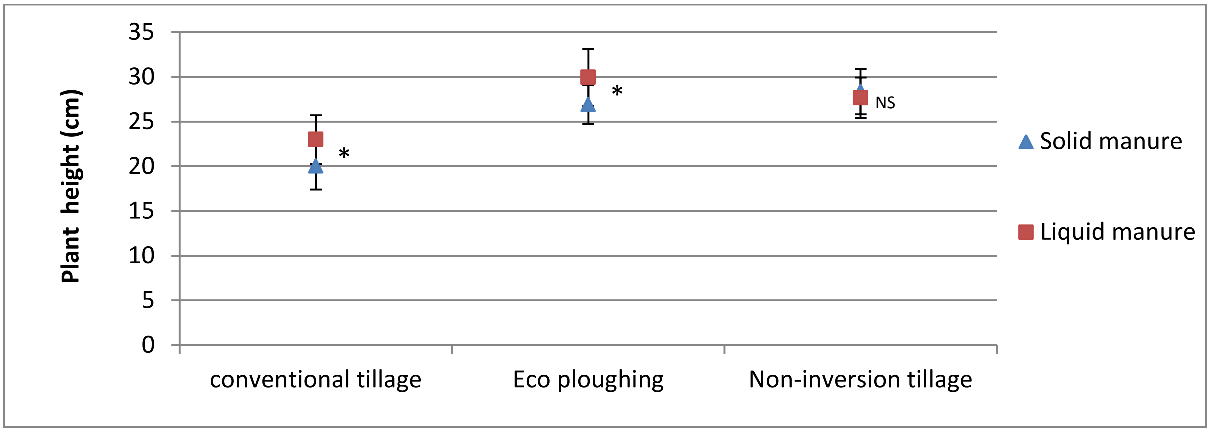
Figure 13. Average values of LAI under different tillage practices and fertilization at booting stage (20 June)

The chart above (Figure 12) shows the values of leaf area index with different methods of tillage at tillering stage (19 May). The manure type had no influences on LAI at this stage with a p-value 0.451. The interaction between tillage methods and manure type was not significant with 0.695 p-value. The values of LAI were only affected by different tillage practices (p=0.012). Non-inversion tillage practice led to the highest value of LAI than conventional tillage and eco ploughing. The LAI under non-inversion tillage had the highest value (0.36 on average) followed by Eco ploughing (0.29 on average) and conventional tillage (0.24 on average). But the difference between non-inversion tillage and eco ploughing was not statistical significant with a p-value 0.57. The difference between non-inversion tillage and conventional tillage was significant with a p-value 0.004. Although eco ploughing had a higher LAI value than conventional tillage on average, however, this difference was not statistical significant (P=0.188).

Figure 13 illustrates the values of LAI under different tillage managements and manure treatments during booting stage (20 June). Tillage, types of manure had no significant impacts on LAI with the p-value 0.101, 0.234 respectively. The interaction between tillage and type of manure was weak with p-value 0.716 . In general, LAI under each treatment showed statistical homogeneous at booting stage (20 June).

3.4 Plant height

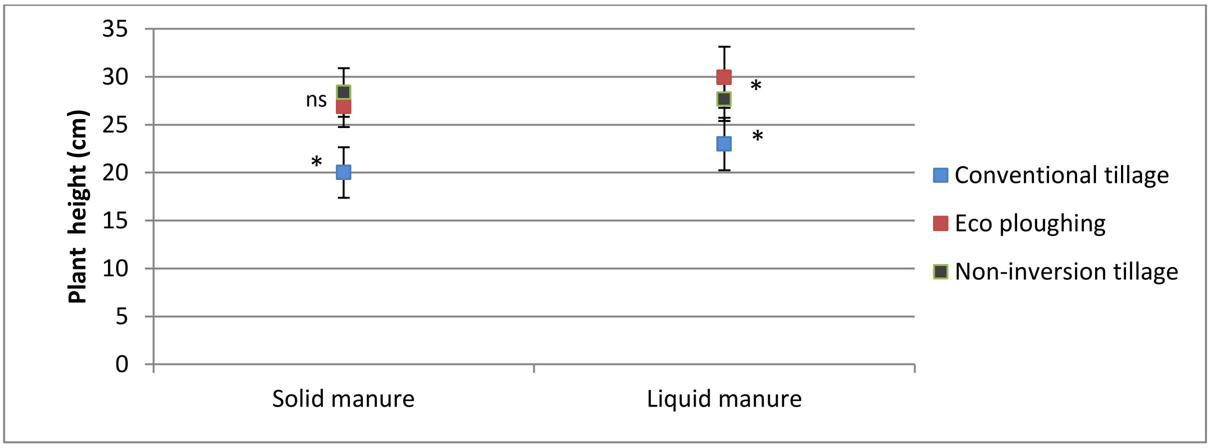
By using two-Away ANOVA analysis to compare the differences of plant height, it was proved that tillage and types of manure have interaction during tillering stage(20 May; p=0.009).



***: significant difference at 95% confidence interval NS: no significant at 95% level**

Figure 14. Average Plant height (cm) of each treatments at wheat tillering stage (20 May)

Plants had different responses to different combination of tillage method and type of manure (Figure 14). Under conventional tillage method, Plant grew higher with liquid manure treatments than treated with solid manure. This difference was statistical significant (p=0.005). Plant under eco ploughing also showed significant higher plant height when fertilized with liquid manure than solid manure (p=0.005). While no differences were found between different type of manure under non-inversion tillage management (p=0.789).



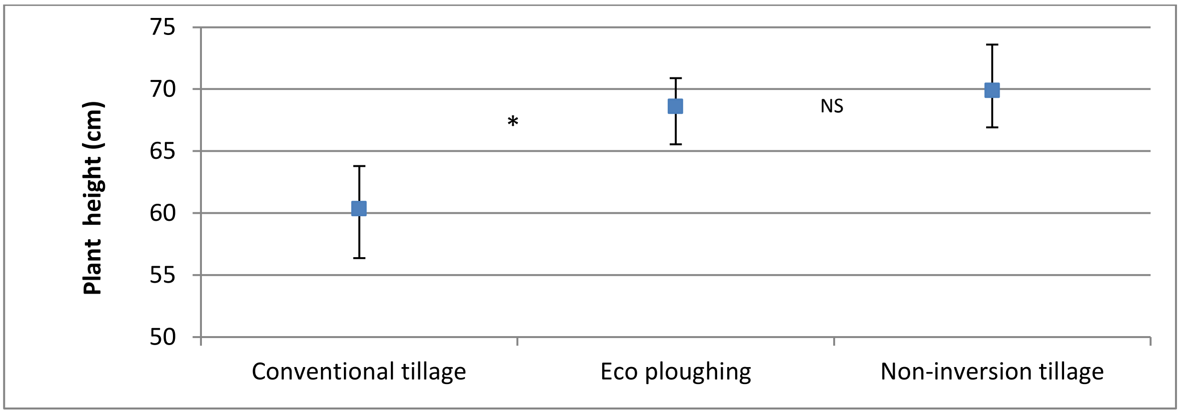
***: significant difference at 95% confidence interval NS: no significant at 95% level**

Figure 15. Average Plant height (cm) of each treatments at tillering stage (20 May)

From the chart above (Figure 15), conventional tillage performed the poorest on plant height under solid manure, resulting the lowest plants height among three tillage methods. Eco ploughing and non-inversion tillage led to higher plant height compared with conventional tillage (p=0.00). While the differences between eco ploughing and non-inversion tillage were not significant (p=0.116).

Conventional also led to the lowest plant height comparing with eco ploughing and non-inversion tillage under liquid manure treatment. Plant with non-inversion tillage method were significant lower than plants with eco ploughing (p=0.029) and significant higher than plants with conventional tillage (p=0.00).

During booting stage (20 June), the interaction between tillage and manure type was not found (p=0.096). Only tillage method effected plant height during this stage.



***: significant difference at 95% confidence interval NS: no significant at 95% level**

Figure 16. Average plant height under different tillage methods at booting stage (20 June)

Conventional tillage, among the 3 kinds of tillage methods, resulted the lowest plant height compared with eco ploughing and non-inversion tillage (p=0.00 compared with non-inversion tillage and eco ploughing). The difference of plant height between eco ploughing and non-inversion could be ignored as it was not significant (p=0.115).

During heading stage (2 July), there was no interaction between tillage method and type of manure (p=0.922). Tillage methods solely determined plant height at significant level (p=0.00).

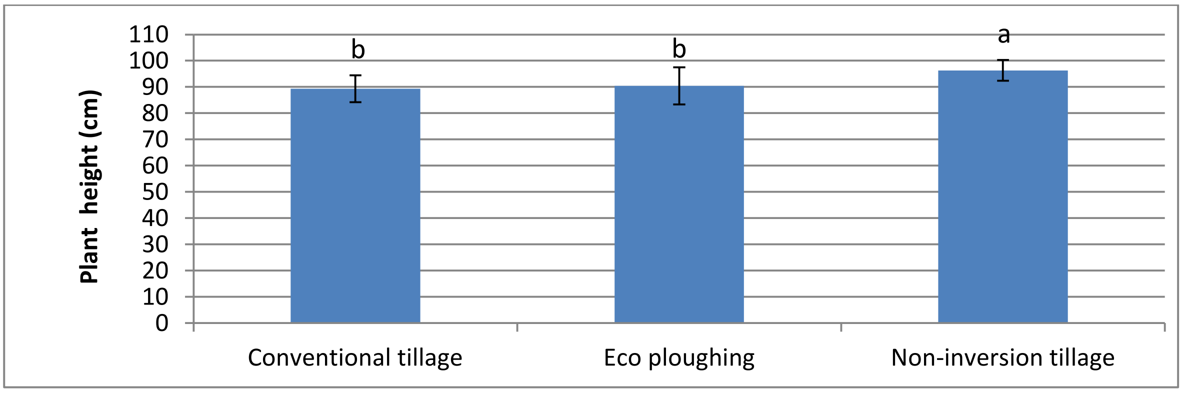


Figure 17. Average plant height (cm) at heading stage (2 July) under three tillage practices

Higher plants were found under non-inversion tillage practice, approximate 6.5 cm higher than plants with conventional tillage on average and 5.83 cm higher than plants in eco ploughed fields. These differences on plant height were significant with both P-value 0.00. While no difference of plant height was observed between conventional tillage treatment and eco ploughing treatment (p=0.644).

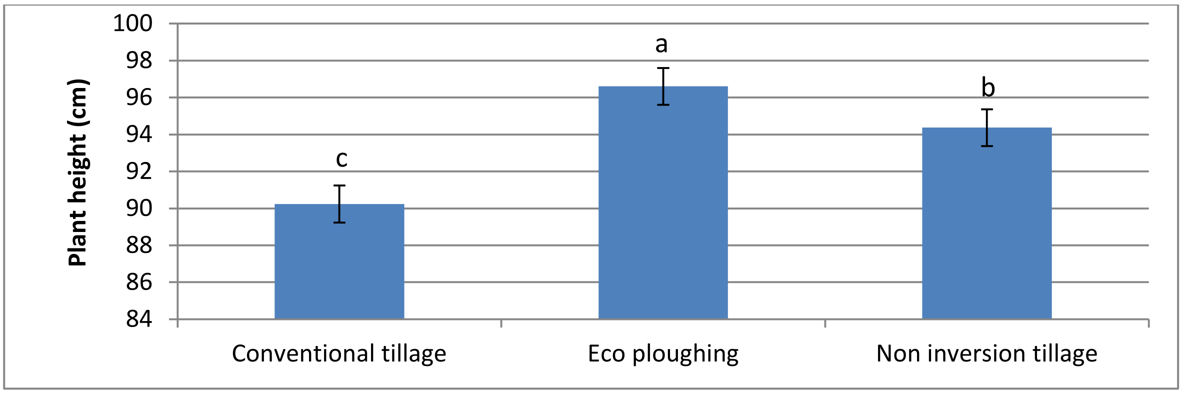


Figure 18. Plant height at milking period (22 of July) under three tillage practices

The effects of tillage on plant height existed at milking stage at a significant level (p=0.00) and led to some obvious variations. Manure types had no effects on plants height (p=0.169) and no interactions were found between tillage methods and types of manure (p=0.31). Fields were prepared with eco plough resulted highest plant among 3 tillage methods with a p-value 0.00 compared with conventional tillage and a p-value 0.038 compared with non-inversion tillage. Non-inversion tillage stood in the middle, while the application of conventional tillage generated the lowest plants amongst 3 tillage methods (p=0.00 compared with eco ploughing; p=0.00 compared with non-inversion tillage).

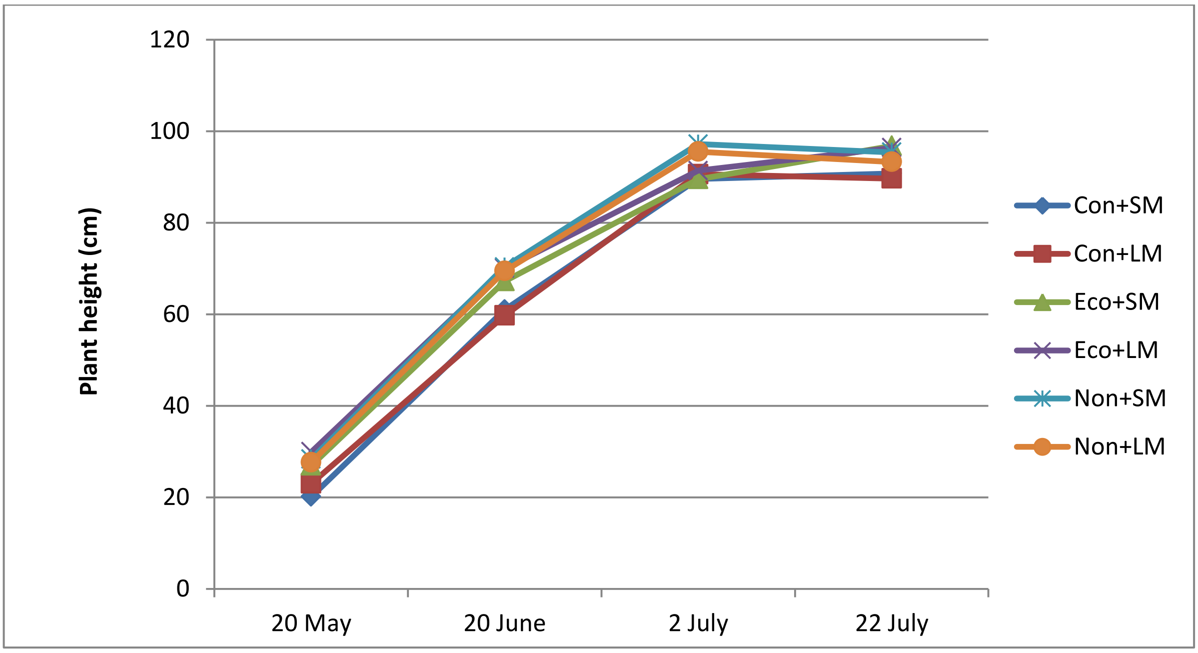


Figure 19. Trends of Plant height (cm) under different treatments during 4 times measurements

Overall, plants under conventional tillage tended to grow lower than plants under non-inversion tillage and eco ploughing practices.

3.5 SPAD

The contents of chlorophyll were measured 3 times by SPAD meter, the first group of data was collected during booting stage (20 June), followed by the second group of data at heading stage (2 July). The last data collection was received from the milking stage (22 July).

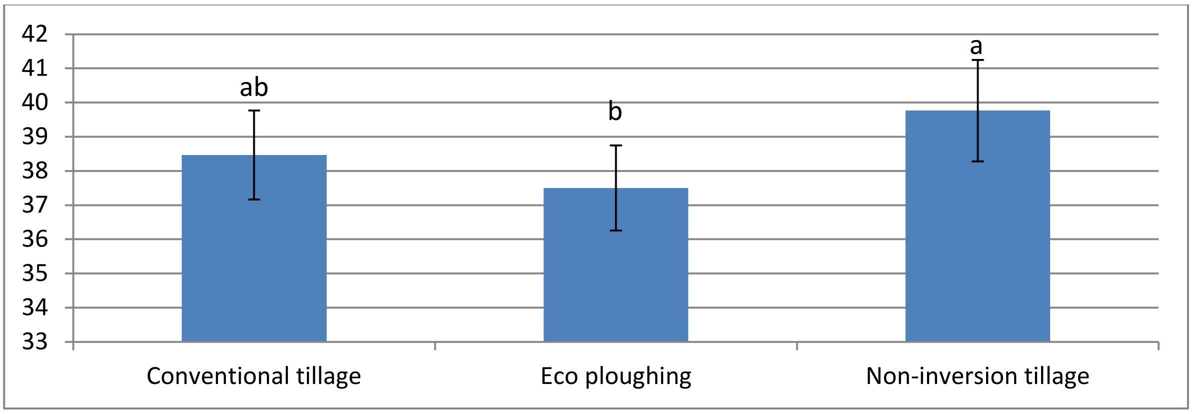


Figure 20. SPAD values at booting stage (20 June) under different tillage practices

Based on the data from booting stage (20 June), through two-way ANOVA analysis, the SPAD values were not affected by type of manure (p=0.511) and no interactions were found between tillage method and manure type (p=0.471). The differences of SPAD readings were significant between non-inversion tillage and eco ploughing (p=0.016) and this difference was resulted from tillage methods (p=0.047). SPAD values measured from non-inversion tillage practiced fields were significant higher than values from eco ploughed fields. Conventional tillage showed no significant differences compared with the rest two tillage methods.

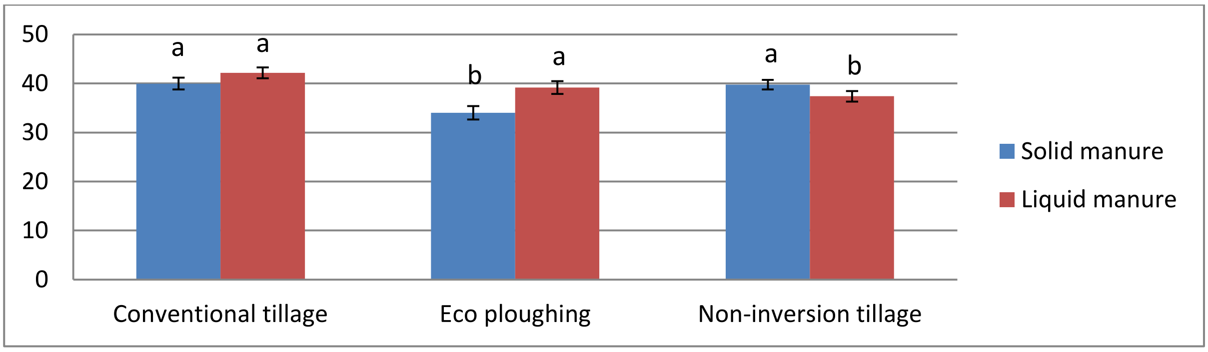


Figure 21. SPAD values at heading stage (2 July) under different treatments

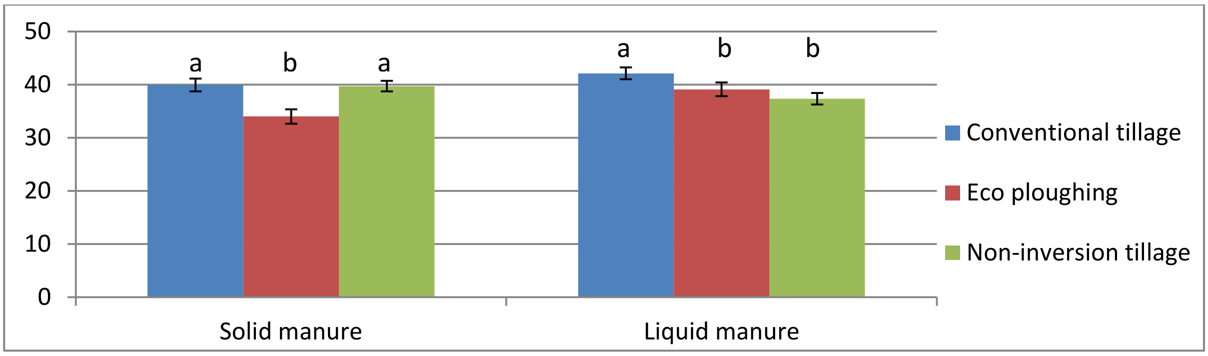


Figure 22. SPAD values at heading stage (2 July) under different treatments

During heading stage (2 July), SPAD values were influenced by the interaction between tillage methods and type of manure (p=0.001).

Types of manure did not significantly affect SPAD value under conventional tillage (p=0.081), while the type of manure influenced SPAD value significantly under eco ploughing (p=0.01), leading to higher SPAD value with liquid manure treatment than solid manure. The difference of SPAD value under non-inversion tillage management attributed by manure type significantly (p=0.048). Plants fertilized with solid manure had higher SPAD value than plants treated with Liquid manure.

From another point of view (Figure 22), conventional tillage and non-inversion tillage led to higher SPAD values compared with eco ploughing under solid manure treatment. The differences was statistical significant (p=0.001 compared with conventional tillage, P=0.001 compared with non-inversion tillage). No differences were found between conventional tillage and non-inversion tillage under solid manure treatment (p=0.819). While under liquid manure, SPAD values were affected by tillage in a different way. Conventional tillage resulted in higher SPAD value compared with eco ploughing and non-inversion tillage with the p-value 0.02 and 0.003 respectively. The difference between eco ploughing and non-inversion tillage was not significant (p=0.115).

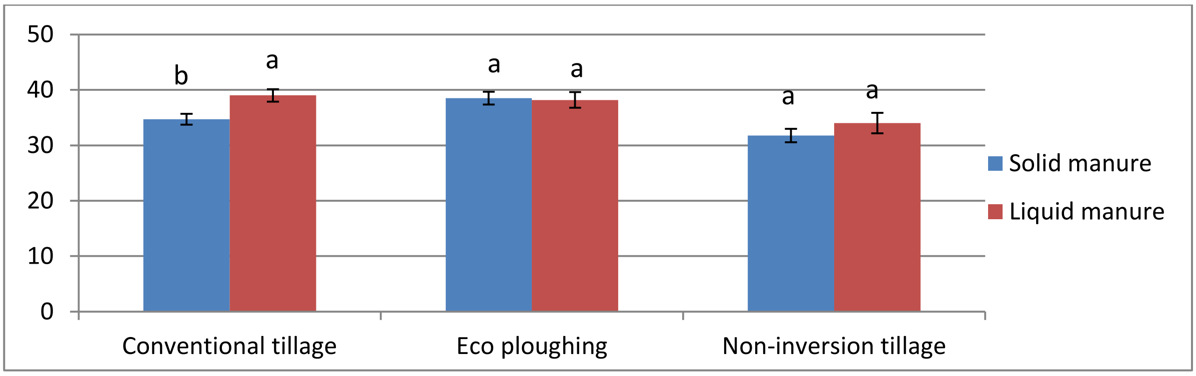


Figure 23. SPAD values at milking stage (22 July) under different treatments

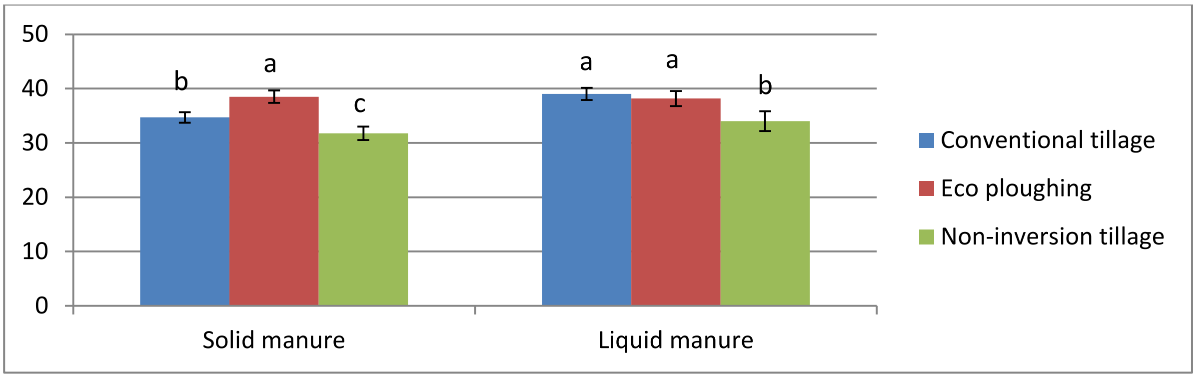


Figure 24. SPAD values at milking stage (22 July) under different treatments

During milking stage (22 July), the interaction between tillage methods and manure type affected SPAD value differently the interaction between tillage methods and type of manure were significant (p=0.031).

When analysed through the view of different type of manure. Liquid manure application led to significant higher SPAD value than solid manure under conventional tillage (p=0.008). While the significant differences between types of manure did not appear under eco ploughing and non-inversion tillage (P values are 0.768 and 0.153 respectively).

Regarding the differences between tillage methods (Figure 24), eco ploughing led to a higher SPAD value significantly, compared with conventional tillage (p=0.006) and non-inversion tillage (p=0.00) under solid manure treatment. Although conventional tillage resulted in a lower SPAD value than eco ploughing, it was still significant higher than non-inversion tillage (p=0.018). When comparisons were made based on liquid manure, conventional tillage and eco ploughing maintained the SPAD value at significant higher value than non-inversion tillage (p=0.006 and p=0.016 respectively). While the difference between conventional tillage and eco ploughing was not significant at all (p=0.516).

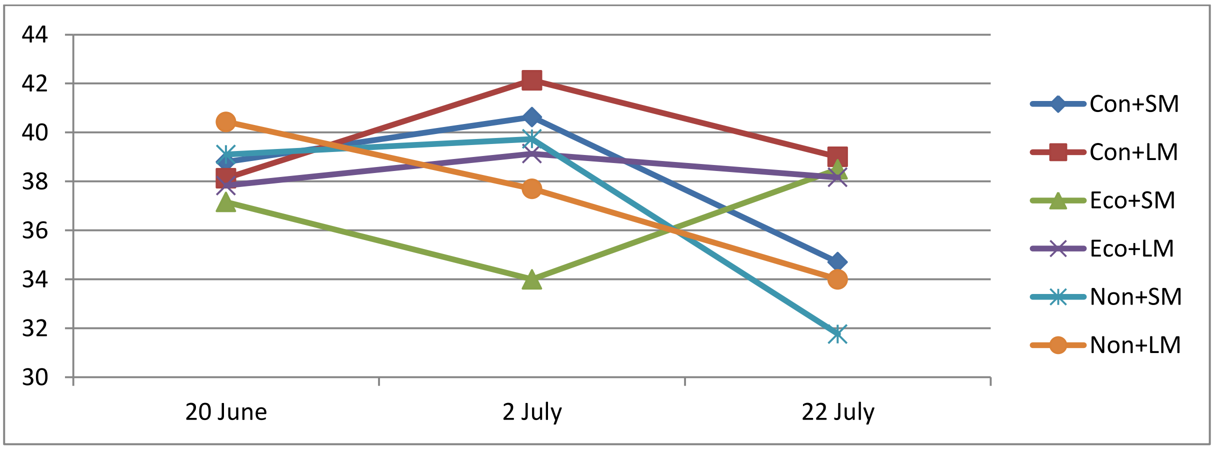


Figure 25. Trends of SPAD values under different treatments during 3 times measurements

Overall, Non-inversion tillage led to higher SPAD value than other two tillage methods at early growth stage, and then, the SPAD values started decreasing. Although conventional tillage resulted in lower SPAD value at early stage, however, an increasing trend at later stage contributed to the higher SPAD value than non-inversion tillage at milking stage.

3.6 Above ground plant dry matter yield

Above ground plant dry matter yield was measured 3 times during growing season. Interactions between tillage methods and type of manure were found during the second (19 June) and third measurements (22 July). The tillage effects on above ground plant dry matter yield were only existed at first measurement (19 May) at tillering stage (p=0.047).

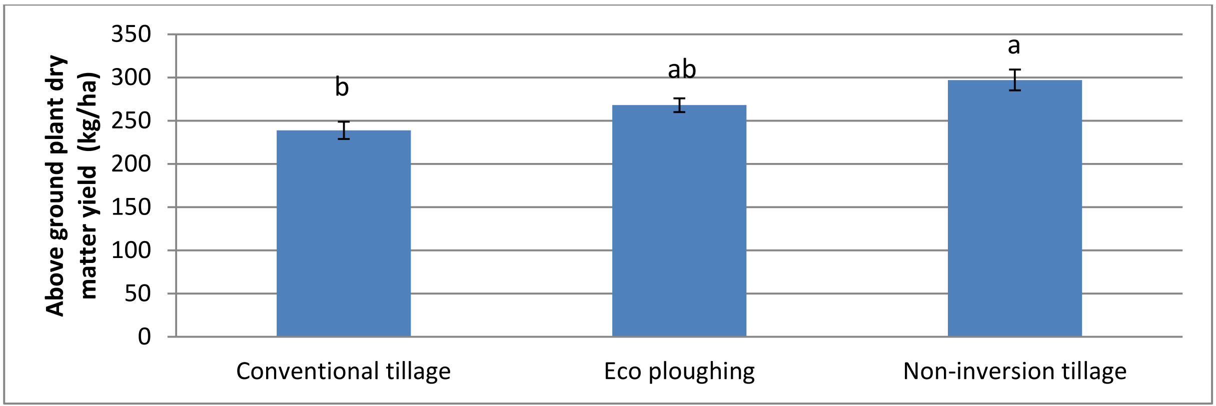


Figure 26. Above ground plant dry matter yield (kg/ha) under different tillage methods at tillering stage (19 May)

At tillering stage (19 May), the plants under non-inversion tillage had a higher above ground plant dry matter yield than conventional tillage (p=0.015). Eco ploughing showed no significant differences compared with non-inversion tillage and conventional tillage.

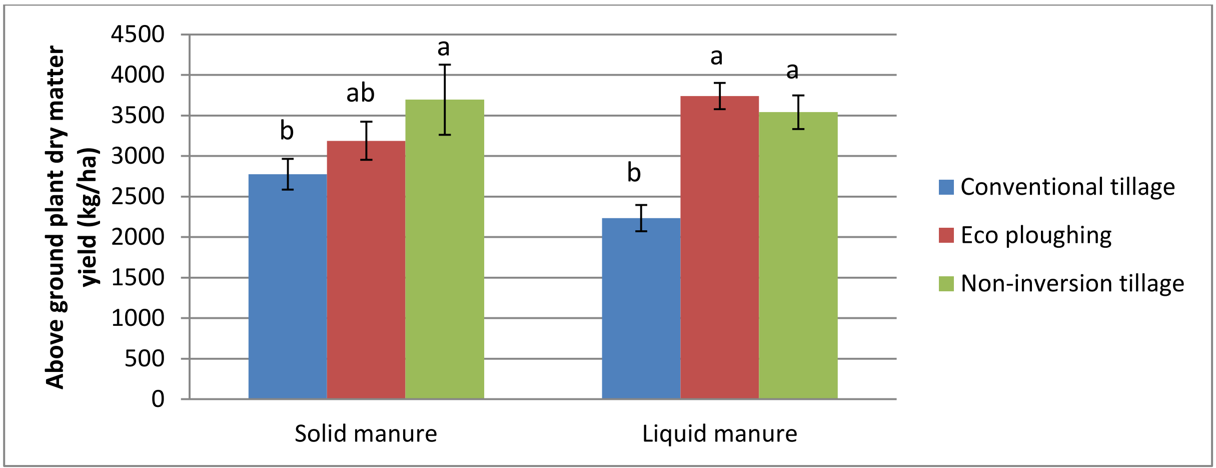


Figure 27. Above ground plant dry matter yield (kg/ha) measured at booting stage (19 June) under different treatments

At booting stage (19 June), the interaction between tillage methods and manure type appeared. In terms of different tillage methods with same manure (Figure 27), non-inversion tillage led to significant higher dry matter yield than plants under conventional tillage (0.010 p-value), when fertilized with solid manure. While in the fields where fertilized with liquid manure, eco ploughing and non-inversion tillage resulted in higher plant dry matter yield compared with conventional tillage (p=0.00).

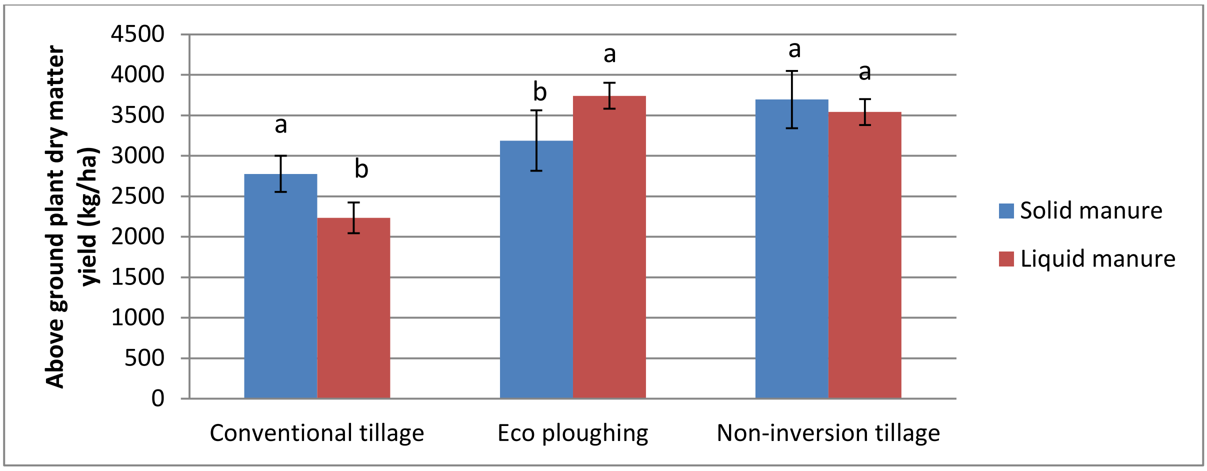


Figure 28. Above ground plant dry matter yield (kg/ha) measured at booting stage (19 June) under different treatments

When comparing plant dry matter yield with same tillage method and different types of manure (Figure 28), conventional tillage led to higher dry matter yield under solid manure treatment than liquid manure treatment (p=0.020). A reverse result happened when measured plants with eco ploughing, plants with liquid manure application gained more dry matter yield than plants with solid manure (p=0.028). No significant differences were found under non-inversion tillage with different types of manure (p=0.606).

At milking stage (22 July), although both tillage methods and types of manure affected plant dry matter yield significantly (p=0.00 for tillage and p=0.002 for manure type), while the interactions between them were strong (p=0.004).

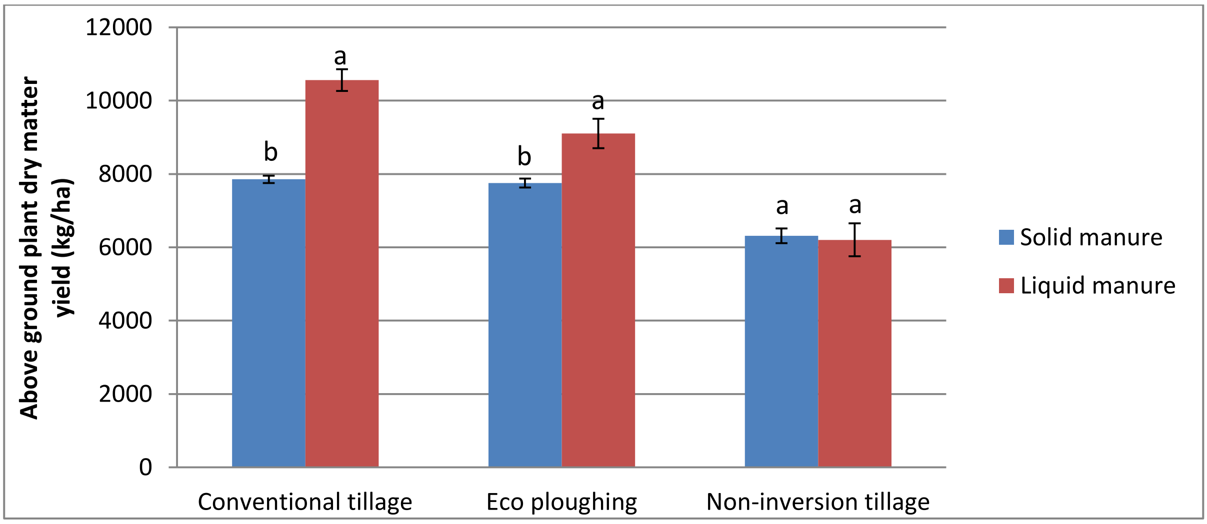


Figure 29. Above ground plant dry matter yield (kg/ha) measured at milking stage (22 July) under different treatments

Manure type influenced plants dry weight when fields were practiced with conventional tillage or eco plough. Liquid manure led to more dry matter yield under these two tillage methods compared with solid manure (p=0.001 for conventional tillage and p=0.033 for eco ploughing). However, under non-inversion tillage practices, the effects of manure type on dry matter yield vanished, no significant differences were found between solid manure and liquid manure treatment (p=0.567).

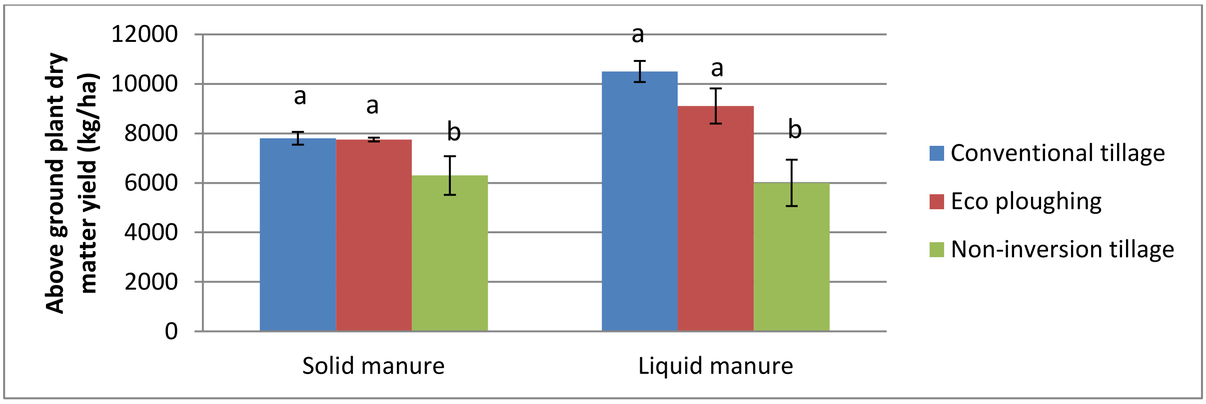


Figure 30. Above ground plant dry matter yield (kg/ha) measured at milking stage (22 July) under different treatments

From the perspective of different tillage methods (Figure 30), both conventional tillage and eco ploughing showed a result that more plants dry matter yield was accumulated from these two tillage than non-inversion tillage under solid manure treatment (p=0.019 when compared with conventional tillage and p=0.016 compared with eco ploughing). As to liquid manure, although the gap between eco ploughing and conventional tillage was significant visually, the difference was not statistical significant (p=0.102). Conventional tillage and eco ploughing resulted in higher dry matter yield than non-inversion tillage (p=0.00 for conventional and p=0.002 for eco ploughing).

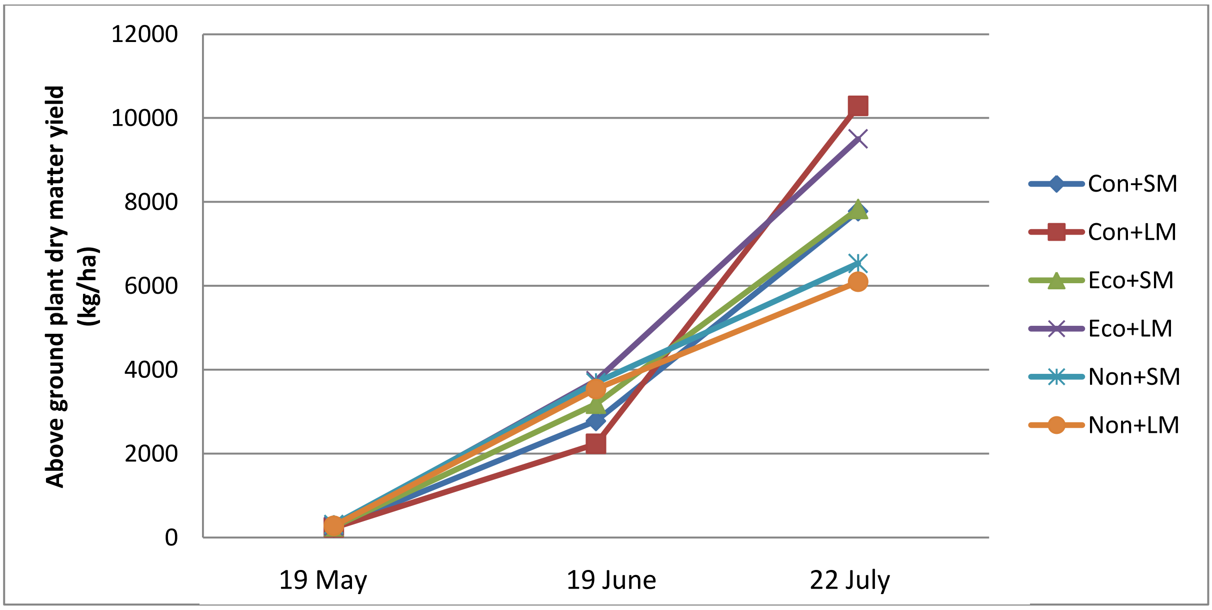


Figure 31. Above ground plant dry matter yield (kg/ha) under different treatments during 3 times measurements

Figure 31 illustrates the plants dry weight of each treatments at 3 different stages. Generally , plants under non-inversion tillage practiced soil generated higher above ground plants dry matter yield than plants practiced with eco ploughed and conventional tillage tilled soil at tillering stage (19 May) and booting stage (19 June). While conventional tillage and eco ploughing resulted in more dry matter accumulation at latter stage (between 19 June and 22 July), overpassed the plants dry matter yield under non-inversion tillage at milking stage (22 July).

3.7 Earthworm abundance

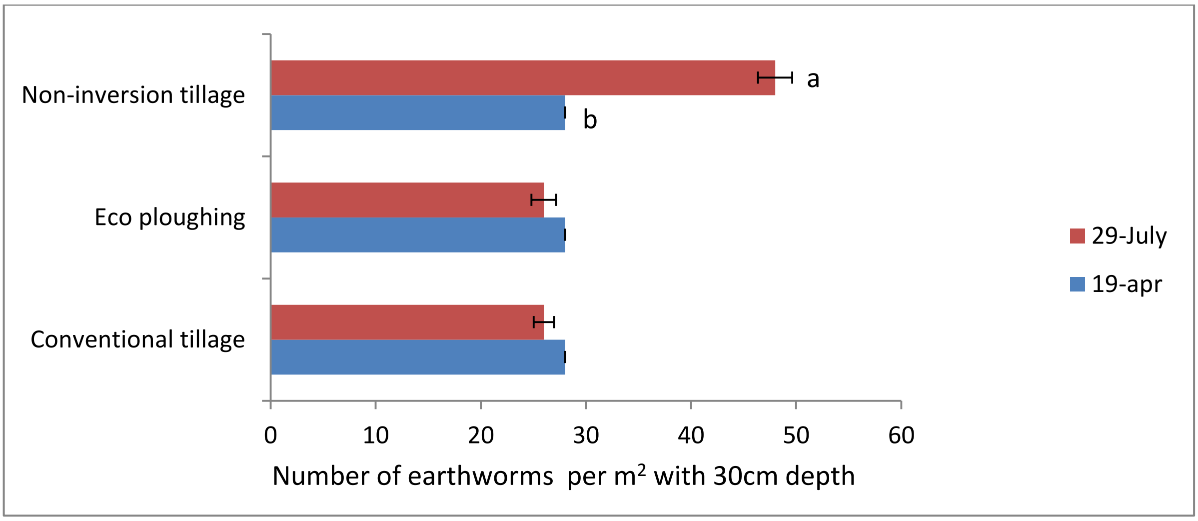


Figure 32. Average number of earthworms in different tillage systems before (19 April) and after ploughing (29 July)

Only tillage methods significantly affected the number of earthworms during the growing season (p=0.001). Type of manure did not significantly affect the number of earthworms (p=0.512). The interactions between tillage methods and types of manure was weak (p=0.821).

Through the wheat growing season, the number of earthworms was prompted by non-inversion tillage compared with conventional tillage and eco ploughing (p=0.001 compared with conventional tillage and p=0.001 compared with eco ploughing). Even when comparison was made based on the data before growing season, non-inversion tillage still had prior feature of increasing the number of earthworms at a significant level (p=0.002). Unchanged trend of earthworms number was showed before and after tillage practices when fields were implemented with conventional tillage (p=0.215) and eco ploughing (p=0.353).

3.8 Root distribution

Figure 33. Root distribution under different tillage systems (left: conventional mid: eco ploughing right: Non-inversion)

Soil profiles were made for observing the different root distribution for each tillage methods. No strong differences were found from the soil profile. Roots in three tillage systems were evenly distributed in 0-30cm soil layer.

3.9 Final yield

Average number of wheat ears per square meter was measured for each treatments before harvesting.

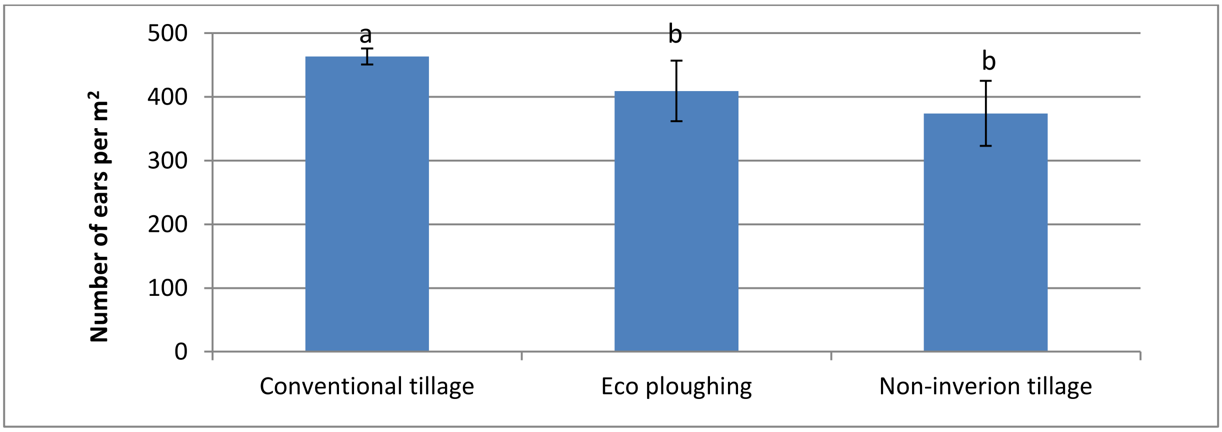


Figure 34. The average number of wheat ears per square meter under different tillage practices.

Tillage significantly affected the number of wheat ears (p=0.007) while the types of manure hardly had any effect on numbers of ear (p=0.156) and there was no interaction between tillage method and types of manure (p=0.447). Conventional tillage practice generated more wheat ear per m^2 than eco ploughing and non-inversion tillage (p=0.035 compared with eco ploughing and p=0.002

compared with non-inversion tillage). The difference of wheat ears per m^2 between eco ploughing and non-inversion tillage was not significant (p=0.150).

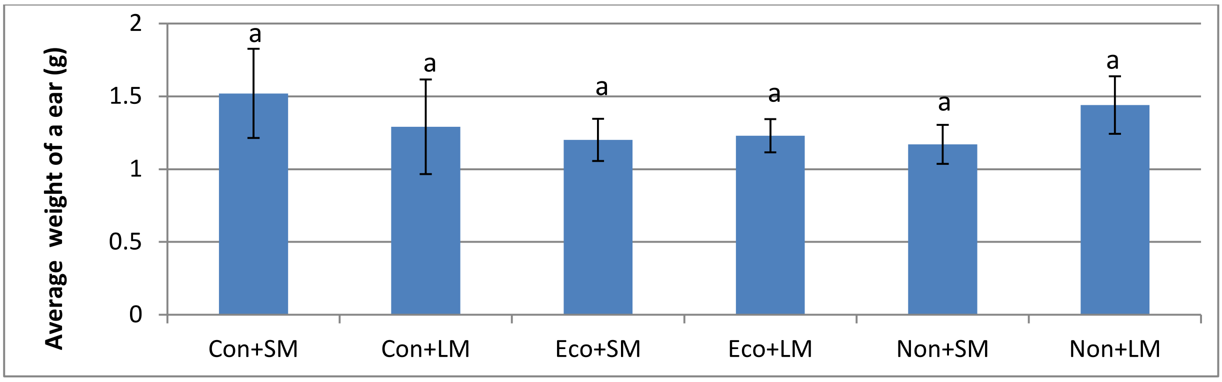


Figure 35. Average weight (g) per wheat ear of each treatment.

The average weights per wheat ear under each treatment were showed in Figure 35. Tillage method and types of manure had no effect on ear's weight (p=0.366 for tillage, p=0.878 for types of manure) and no significant differences of ear weight were found between treatments.

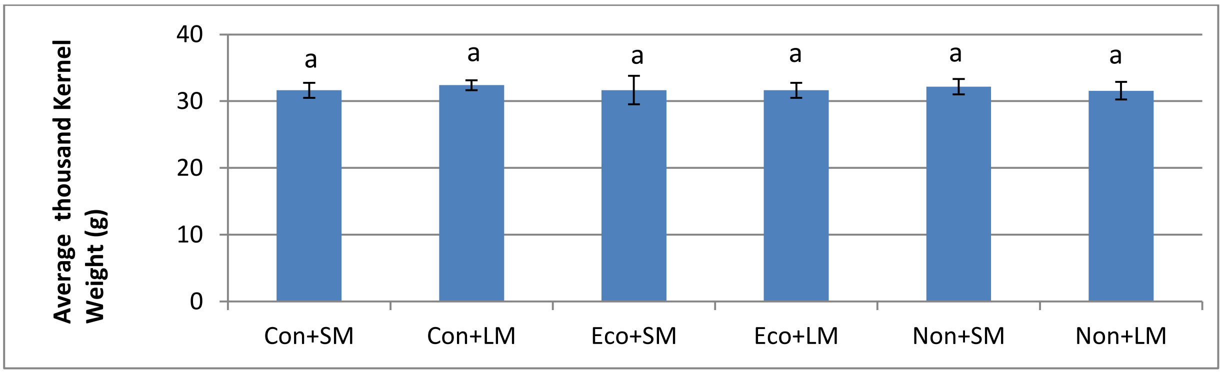


Figure 36. Average thousand Kernel Weight (g) under different treatments

The average thousand kernel weight showed no differences between different treatments, all around 31g per thousand kernel. Tillage methods and different manure applications had no influences on the weight (p=0.892 for tillage and p=0.945 for types of manure).

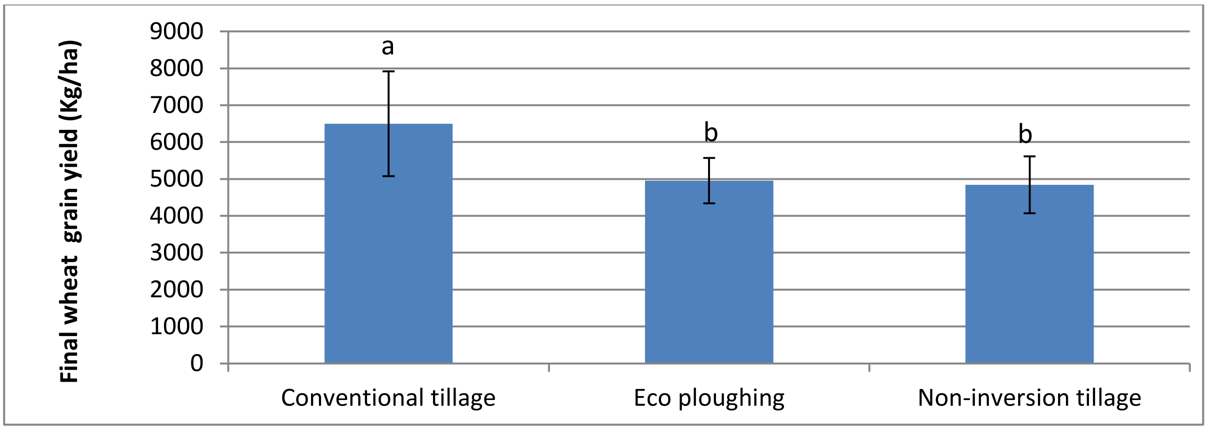


Figure 37. Final wheat grain yields(15% moisture) of different tillage treatments (Kg/ha).

Different tillage practices finally resulted in the significant differences of wheat yield (p=0.027). However, there was no significant relationship between different manure applications and the final grain yield (p=0.477). Fields under conventional tillage practice harvested around 6500kg wheat grain per hectare, this production was significant higher than the productions under eco ploughing (4952kg/ha) and non-inversion tillage (4843kg/ha). The disparities in productivity between eco ploughing and non-inversion tillage were not significant (p=0.856).

4. Discussion

4.1 Short–term effects of tillage on soil properties

The soil fertility is entwined with soil organic matter through nitrogen mineralization. Particularly for organic farming where nitrogen is the main limiting factor of yield. Adjusting nitrogen status is possible by tillage practices and large amount of organic input (Williams et al., 2006). Non-inversion tillage led to a larger amount of mineral nitrogen at the tilled layer (0-10cm) than soil under eco ploughing and conventional tillage practices during the growing season. It could be explained with little doubt due to the working depth of non-inversion tillage, all the fresh manure was applied in 0-10cm soil layer and the mineralization rate is stimulated by the large amount of high nitrogen content input (Peigné et al., 2007). Although Pekrun et al (2003) concluded in his study that the nitrogen immobilization would happen with slower soil organic matter turnover rate during transition years from conventional tillage to conservation tillage. While an overwhelming effect of large amount of fresh organic input replenished the nitrogen deficiency at the top layer was found in this study. Regarding to 10-20cm layer, both eco ploughing and conventional tillage work at this depth and provide similar soil condition, thus the amount of mineral nitrogen between conventional tillage and eco ploughing was relative the same. Conventional tillage provided a relative homogeneous loose soil condition till 30cm depth. As consequence, the mineralization rate at 20-30cm was still maintained at the same level compared with upper layers which resulted in more mineral nitrogen at 20-30cm layer contrasted with eco ploughing and non-inversion tillage because the mineralization of non-inversion tillage and eco ploughing were impeded. Comparing with long–term effects of conservation tillage on soil mineral nitrogen (Ahl et al, 1998), less mineral nitrogen was found in the deeper layer under eco ploughing and non-inversion tillage in this study. The significant decrease in soil mineral nitrogen content between the first (15 May) and second measurement (16 June) might be due to denitrification, NH_3 volatilization or leaching. Denitrification was a possible reason for the observed decrease in soil mineral nitrogen concentrations because increased C supply with manure application may increase denitrification rates (Paul and Beauchamp 1989). But more significant decline should be attribute to the leaching because the changes of soil mineral nitrogen at 30-60 layer. The 30-60cm layer was more about leaching than provide nutrients for wheat especially at the early stage of wheat growth. The frequent rainfall between May and June provided a good chance to investigate the nitrogen leaching problem with the influences of different tillage methods in a short-time scale. Excessive rainfall led to the dramatic decline of soil mineral nitrogen content at 0-30cm layer under conventional tillage practice. Accordingly, the soil mineral nitrogen content at 30-60cm was increased a lot. Although the soil mineral nitrogen under eco ploughing and non-inversion tillage was also leached by rainfall, the significant decrease of mineral nitrogen only occurred at 0-20cm layer. In addition, at the same time, the amount of mineral nitrogen between 20-30cm and 30-60cm layer remained relatively stable. This might be explained when correlated with the lower soil mineral nitrogen content at 20-30cm soil layer under eco ploughing and non-inversion tillage. When the mineral nitrogen from upper layer was passing through 20-30cm layer, the mineral nitrogen was immobilized and became organic nitrogen. Through this way, the mineral nitrogen transformed to organic nitrogen and stayed at 20-30cm layer and cannot be detected as mineral nitrogen. Ball et al (1998) had a similar result and concluded in his paper that less nitrogen is like to be lost under conservation tillage systems than conventional tillage system. While he considered that the nitrogen losses are mainly by denitrification particularly in wet condition.

It is noteworthy that conventional tillage provided more soil mineral nitrogen than eco ploughing and non-inversion tillage during growing season, and the differences were mostly came from the 20-30cm layer, the overall soil mineral nitrogen at 20-30cm layer almost doubled under conventional tillage practice than eco ploughing and non-inversion tillage. The overall amount of mineral nitrogen in 0-30cm layer between eco ploughing and non-inversion tillage was similar, although the distribution was different: Non-inversion tillage accumulated more soil mineral nitrogen at 0-10cm layer and most of soil mineral nitrogen was concentrated at 10-20cm under eco ploughing. The overall amount of soil mineral nitrogen at 20-30cm layer was similar between eco ploughing and non-inversion tillage.

Numbers of reports pointed out that higher earthworm population was found under conservation tillage system compared to conventional tillage system (Chan,2001). While in this study, eco ploughing as a conservation tillage strategy did not demonstrate the significant differences of earthworms abundance compared with conventional tillage, at least not significant in a short term. In contrast, non-inversion tillage was doing better in terms of maintaining higher earthworm populations. Gerard and Hay (1979) found similar results from a long-term experiment. The authors attributed the results to reduced mechanical damage during ploughing. Although effects of earthworms on soil structure and nutrient cycling are well documented (Chan,2001) , the effects have not be quantified in this study.

4.2 Short–term effects of tillage on plant performance

Tillage practice affects plant growth by direct manipulating soil chemical, physical and biological properties (Lal, 1983). In this short-term study, tillage affects plants growth during the whole growing season (Appendix 3) and finally impacts the final yield. The effect of tillage on plants growth started from seedling stage. Soil inverted tillage methods (conventional tillage and eco ploughing) led to more wheat seedling than non-inversion tillage, which may attribute to the decreased top soil temperature under non-inversion tillage (Guerif, 1994). However, soil temperature data is not available in this study. The plant growth at tillering stage showed correspondences with the amount of mineral nitrogen in the top 10cm layer in terms of plants height (R square=0.69), LAI (R square=0.82) and dry weight (R square=0.84). The more mineral nitrogen in the top 10cm soil, the higher plants, larger LAI and more dry matter yield. Since non-inversion led to more mineral nitrogen than conventional tillage in the top 10 cm layer, thus plants were growing better at tillering stage under non-inversion tillage. After tillering stage, the eliminated correlations between the amount of soil mineral nitrogen and plants growth indicators made the effects of tillage on plants growth hard to explain (Appendix 3). It is difficult to have an exact idea about how different tillage methods affected plants through altering the soil mineral nitrogen status during growing season since the soil nitrogen dynamic is influenced by many factors (E.g. weed problems, precipitations). It is still possible to observe the differentiation of plants performance under different tillage methods and fertilizations from the overall trends. Plants under non-inversion tillage tended to have a better initial growth than conventional tillage and eco ploughing because of sufficient nitrogen supply in the 0-10cm layer. But its advantages at early stage were soon overpassed by conventional tillage and eco ploughing at later stage, resulted lower plants dry matter yields of non-inversion tillage at milking stage. The root distributions under different tillage methods are similar, which means the potential effect of conventional tillage practices in previous year still affected root growth in the first year of transition.

A notable feature of this study was the higher grain yield response to conventional tillage compared with conservation tillage in the first transition year. The yield differences between conventional tillage and other two tillage methods were mainly due to the different population of productive ears caused by tillage because the differences of ear weight and kernel weight were not significant. Kouwenhoven et al (2002) also found a similar result based on his long term study. Jones (2006) concluded on his paper that the higher yield under conventional tillage might attribute to less weed problems compared with non-inversion tillage. A strong liner correlation was found between the overall mineral nitrogen content at 0-30cm layer and the final grain yield with a R^2: 0.84. This means the increased yield of conventional tillage attributed to the increased amount of soil mineral nitrogen at 0-30cm layer compared with non-inversion tillage and eco ploughing.

5. Conclusions

Conventional tillage strategies exerted its ability of maintaining higher final yield than conservation tillage in the first year transition due to more soil mineral nitrogen supply. The stratification of soil mineral nitrogen depends on the ploughing depth of different tillage methods. Conventional tillage provided more soil mineral nitrogen than eco ploughing and non-inversion tillage during growing season, and the differences were mostly came from the 20-30cm layer. The overall amount of mineral nitrogen between eco ploughing and non-inversion tillage was similar, although the distribution is different: Non-inversion tillage accumulated more soil mineral nitrogen at 0-10cm layer and most of soil mineral nitrogen was concentrated at 10-20cm layer under eco ploughing. The shortage of soil mineral nitrogen in the 20-30cm layer under non-inversion tillage and eco ploughing may limit the final populations of productive ear as well as contribute pronounced controlling of leaching. One growing season's practice of non-inversion tillage significantly increased earthworm populations. While eco ploughing and conventional tillage have no effect on earthworm populations. The fluctuations of soil mineral nitrogen status during growing season contribute to different plant growth with date. In general, plants under non-inversion tillage performed better with large LAI, higher plant height, higher SPAD value and higher above ground plant dry matter yield at early stage. But in the later stages, soil inverted cultivation (conventional tillage and eco ploughing) leads to a better growth and higher above ground plant dry matter yield. In the end, conventional tillage attained a higher yield, which is significant higher than non-inversion tillage and eco ploughing due to more productive ears and better mineral nitrogen supply. The different types of manure applications did not show effect on the final grain yield.

6. Acknowledgements

Foremost, I would like to express my sincere gratitude to my supervisor Dr.ir Egbert lantinga for the continuous support of my research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis.

Besides my advisor, I would like to thank Shuyao Wang, for his devotion to inspired me during my study. Without his untiring assistance, encouragement, this research would not have succeeded well.

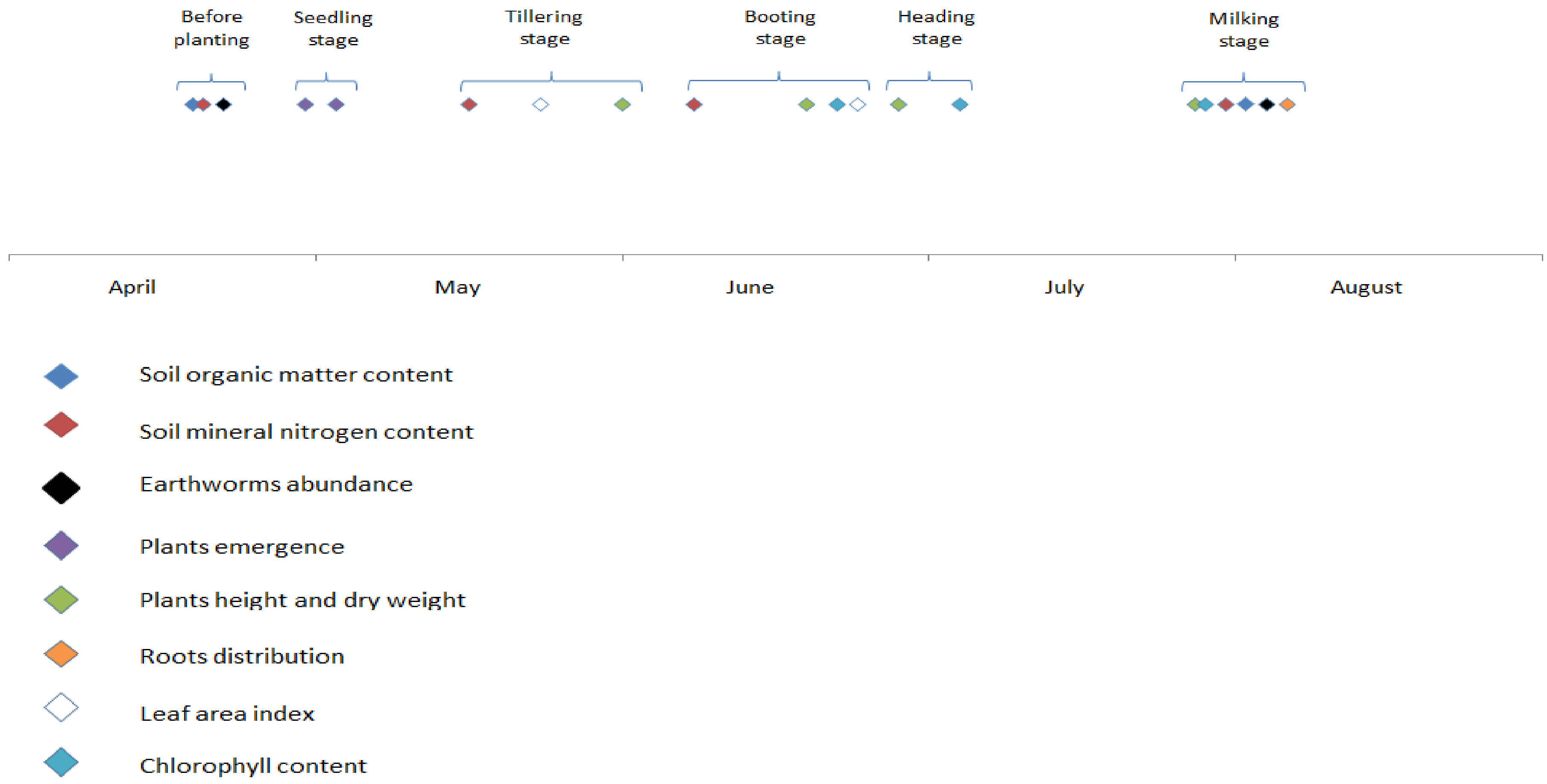
My sincere thanks also goes to my family ,my friends their kindness, advice, patience, and time to teach me to be a more confident person that I am was before. Thank Wageningen university for allowing me to experience the amazing world and meet wonderful people.

7. Appendixes

Appendix 1. Application rates of manure

Manure type	Application rate	mineral nitrogen content	Total mineral nitrogen
Solid manure	20ton/ha	0.75kg/ton	150kg/ha
Liquid manure	$20m^3$/ha	$3.5kg/m^3$	70kg/ha

Appendix 2. Sampling time table



Appendix 3. Factors (tillage, manure, interactions) affected plants growth indicators at different stages

	Seedling stage	Tillering stage	Booting stage	Heading stage	Milking stage	Ripening stage
Emergence	Tillage: Con=Eco>Nit	NA	NA	NA	NA	NA
Plants height	NA	Interactions: Con:LM>SM Eco:LM>SM Nit:LM=SM	Tillage: Nit=Eco>Con	Tillage: Nit>Eco=Con	Tillage: Eco>Nit>con	NA
SPAD	NA	NA	Tillage: Nit>Eco	Interactions: Con:SM=LM Eco:LM>SM Nit:SM>LM	Interactions: Con:LM>SM Eco:SM=LM Nit:SM=LM	NA
LAI	NA	Tillage: Nit>Con	No effects: Con=Eco=Nit	NA	NA	NA
Dry weight	NA	Tillage: Nit>Con	Interactions: Con: SM>LM Eco: LM>SM Nit: SM=LM	NA	Interactions: Con:LM>SM Eco:LM>SM Nit:SM=LM	NA

Appendix 4: Soil mineral nitrogen (Kg/ha) contents at different soil layers and sampling datesof each treatments.

Treatments	Depths	Sampling dates			Overall of every 10cm	Overall of 0-30cm
		5.15	6.16	7.28		
Con+SM	0-10cm	16	6	3	24.72	111.84
	10-20cm	32	7	3	42.1	
	20-30cm	28	14	4	45.02	
	30-60cm	6	16	3	24.74	
Con+LM	0-10cm	24	5	3	31.98	111.27
	10-20cm	38	5	4	47.54	
	20-30cm	22	6	4	31.75	
	30-60cm	6	12	1	19.31	
Eco+SM	0-10cm	29	3	3	34.18	92.89
	10-20cm	38	2	3	42.89	
	20-30cm	11	2	3	15.82	
	30-60cm	5	8	3	16.16	
Eco+LM	0-10cm	30	4	3	36.48	103.8
	10-20cm	42	2	3	47.9	
	20-30cm	12	4	3	19.42	
	30-60cm	8	11	2	21.09	
Non+SM	0-10cm	38	3	4	45.2	90.88
	10-20cm	21	2	6	28.83	
	20-30cm	8	4	5	16.85	
	30-60cm	6	6	2	14.46	
Non+LM	0-10cm	39	2	3	44.41	94.31
	10-20cm	25	3	3	31.01	
	20-30cm	10	6	3	18.89	
	30-60cm	8	8	3	13.05	

8. References

Ahl, C., Joergensen, R.G., Kandeler, E., Meyer, B. &Woehler, V. 1998. Microbial biomass and activity in silt and sand loams afterlong-term shallow tillage in central Germany. Soil & Tillage Research, 49, 93–104.

Andrade, D.S., Colozzi-Filho, A. &Giller, K.E. 2003. The soil microbial community and soil tillage. In: Soil tillage in agroecosystems (ed. A. El Titi), pp. 51–81. CRC Press, Boca Raton, FL.

Austin, R.B. and Blackwell, R.D., 1980. Edge and neighbour effects in cereal yield trials. J. Agric. Sci., 94:731 734.

Balesdent, J., Chenu, C., &Balabane, M. 2000.Relationship of soil organic matter dynamics to physical protection and tillage.Soil and tillage research, 53(3), 215-230.

Ball, B.C., Tebru¨ gge, F., Sartori, L., Gira´ ldez, J.V. &Gonza´ lez, P.1998.Influence of no-tillage on physical, chemical and biologicalsoil properties. In: Experiences with the applicability of no-tillagecrop production in the west-European countries, review papers, summariesand conclusions of the concerted action (eds F. Tebru¨ gge&A. Bo¨ hrnsen), pp. 7–27. Justus-Liebig University, Giessen, Germany.

Basch, G., Kassam, A., González-Sánchez, E., &Streit, S. 2012. Making Sustainable Agriculture real in CAP 2020: the role of conservation agriculture.

Batey, T., 2009.Soil compaction and soil management—a review.Soil useand Management 25, 335–345.

Blevins, R. L., Smith, M. S., Thomas, G. W., & Frye, W. W. 1983. Influence of conservation tillage on soil properties.Journal of soil and water conservation, 38(3), 301-305.

Bruce, R. R., Langdale, G. W., West, L. T., & Miller, W. P. 1995. Surface soil degradation and soil productivity restoration and maintenance. Soil Science Society of America Journal, 59(3), 654-660.

Carter, A., Jordan, V., Stride, C., 2003. A Guide to Managing Crop Establishment.Soil Management Initiative, Chester.

Chan, K. Y. 2001. An overview of some tillage impacts on earthworm population abundance and diversity—implications for functioning in soils. Soil and Tillage Research, 57(4), 179-191.

Christian, D.G., 1994. Experience with Direct Drilling and Reduced Cultivation in England. In: Tebrugge, F. (Ed.), EC Workshop: Experience with the Applicability of No-tillage Crop Production in the West-European Countries, Giessen, Langgons: WissenschaftlicherFachverlag, June 27–28, pp. 25–31.

Crosson, P. 1981. Conservation tillage and conventional tillage: a comparative assessment. Ankeny, Iowa: Soil Conservation Society of America.

Derpsch, R. 1998.Historical review of no-tillage cultivation of crops.In FAO International Workshop, Conservation Tillage for Sustainable Agriculture (pp. 205-218).

Derpsch, R. 2004. “History of Crop Production, With and Without Tillage.” *Journal ofNo-Till Agriculture*. 3(1):150-154.

Edwards, J.H., C.W. Wood, D.L. Thurlow, and M.E. Ruf. 1992.Tillage and crop rotation effects on fertility status of a Hapludult soil. Soil Sci. Soc.Am. J. 56:1577-1582.

EEA 1995 Soil. In: Europe's Environment: the Dobris Assessment. Office for Official Publications of the European Communities, Luxembourg.

El Titi, A. (Ed.). 2010. Soil tillage in agroecosystems. Chapter 3,pp 97-100 CRC press.

Eurostat. 2010.Tilled arable area by tillage practice, EU-27, IS, NO, CH, ME and HR.

FAO. 2006.The importance of soil organic matter: Key to drought-resistant soil and sustained food and production. ISSN 0253-2050.

Gerard, B.M., Hay, R.K.M., 1979. The effect on earthwormsof ploughing, tined cultivation, direct drilling and nitrogenin a barley monoculture system. J. Agric. Sci., UK 93, 147±155

Glinski, J., Lipiec, J., 1990. Soil Physical Conditions and Plant Roots. CRS Press, Boca Raton, USA.

Guerif, J. 1994. Influence de la simplification du travail du sol surl'e´ tat structural des horizons de surface: conse´quencessurleursproprie´te´s physiques etleurscomportementsme´caniques. In: Simplification du travail du sol (eds. G. Monnier, G. Thevenet&B. Lesaffre INRA), pp. 13–33. INRA Edition, Paris.

Haferkamp, M. R. 1988.Environmental factors affecting plant productivity. In Achieving efficient use of rangeland resources. Fort Keogh Research symposium, Miles City (pp. 27-36).

Hoffmann, Nancy. 2008. "Conventional Tillage: How Conventional Is It?" EnviroStats2.3 : 12-15

Holland, J. M. 2004. The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. Agriculture, Ecosystems & Environment, 103(1), 1-25.

Husnjak, S., Filipovic, D., &Kosutic, S. (2002). Influence of different tillage systems on soil physical properties and crop yield. RostlinnaVyroba-UZPI (Czech Republic).

IFOAM, 2009. Growing Organic: Developing Sustainable Organic Sectors. Soil Conservation in Organic Agriculture.

Jones, C.A., Basch, G., Baylis, A.D., Bazzoni, D., Bigs, J., Bradbury, R.B., Chaney, K., Deeks, L.K., Field, R., Gomez, J.A., Jones, R.J.A., Jordan, V., Lane, M.C.G., Leake, A., Livermore, M., Owens, P.N., Ritz, K., Sturny, W.G., Thomas, F., 2006. Conservation Agriculture in Europe: An Approach to Sustainable Crop Production by Protect- ing Soil and Water? SOWAP, Jealott's Hill, Bracknell, UK.

Kay, B.D. &VandenBygaart, A.J. 2002. Conservation tillage and depth stratification of porosity and soil organic matter.Soil&Tillage Research, 66, 107–118.

Kouwenhoven, J. K., Perdok, U. D., Boer, J., & Oomen, G. J. M. 2002. Soil management by shallow mouldboard ploughing in The Netherlands. Soil and Tillage research, 65(2), 125-139.

Lal, R. 1983. No-till farming: Soil and water conservation and management in the humid and sub-humid tropics. IITA Monograph No. 2, Ibadan, Nigeria.

Lal, R., Reicosky, D. C., & Hanson, J. D. 2007.Evolution of the plow over 10,000 years and the rationale for no-till farming.Soil and Tillage Research, 93(1), 1-12.

Lampurlanks, J., Angbs, P. and Cantero-Martinez, C. 2002. Tillage effects on water storage during fallow, and on barley root growth and yield in two contrasting soils of the semi-arid Segarra region in Spain. Soil Tillage Research. 65: 207-220

Lavelle, P., 1988.Earthworm activities and the soil system. Biol. Fert. Soils 6, 237±251.

Lerche, G., 1994. Ploughing Implements and Tillage Practices in Denmark from the Viking Period to About 1800: Experimentally Substantiated. Commission for Research on the History of Agricultural Implements and Field Structures, vol. 8. Royal Danish Academy of Sciences and Letters: PoulKristensen, Herning.

Liu, K., &Wiatrak, P. 2012. Corn production response to tillage and nitrogen application in dry-land environment. Soil and tillage research, 124, 138-143.

López, M. V., &Arrúe, J. L. 1997. Growth, yield and water use efficiency of winter barley in response to conservation tillage in a semi-arid region of Spain. Soil and tillage research, 44(1), 35-54.

Mäder, P., &Berner, A. 2012. Development of reduced tillage systems in organic farming in Europe. Renewable Agriculture and Food Systems, 27(01), 7-11.

Mathew, R. P., Feng, Y., Githinji, L., Ankumah, R., &Balkcom, K. S. 2012.Impact of no-tillage and conventional tillage systems on soil microbial communities.Applied and Environmental Soil Science, 2012.

Montanarella, L. 2007. Trends in land degradation in Europe. In Climate and land degradation (pp. 83-104). Springer Berlin Heidelberg.

Moreno, F., Pelegrín, F., Fernández, J. E., & Murillo, J. M. 1997. Soil physical properties, water depletion and crop development under traditional and conservation tillage in southern Spain. Soil and Tillage Research, 41(1), 25-42.

Munkholm, L. J., Schjønning, P., & Rasmussen, K. J. 2001. Non-inversion tillage effects on soil mechanical properties of a humid sandy loam. Soil and Tillage Research, 62(1), 1-14.

Murdock, L., Call, D., & James, J. 2004.Comparison and Use of Chlorophyll Meters on Wheat (Reflectance vs. Transmittance/Absorbance).

Ndayegamiye, A., & Cote, D. 1989. Effect of long-term pig slurry and solid cattle manure application on soil chemical and biological properties.Canadian Journal of Soil Science, 69(1), 39-47.

Nelson, D.W., L. E. Sommers, 1996. Total carbon, organic carbon, and organic matter, In: Sparks, D.L. (Ed.), Methods of soil analysis. Part 3-chemical methods. Soil Science Society of America, Madison, pp. 961-1010.

Njøs, A. &Ekeberg, E. 1980. Forsøk med pløyingtil to dybderhøstogvårpåmorenejordiStangeiårene 1969-1975.Forsk. Fors. Landbr. 31, 221-242. (In Norwegian with English summary.)

Norman, Arthur Geoffrey.1949. "Weed Control." Advances in Agronomy. Vol. 1. New York, NY: Academic, 289-90.

Oldeman, L. R. 1994.The global extent of soil degradation. Soil resilience and sustainable land use, 99-118.

Osman, K. T. 2012a. Soils: principles, properties and management. Chapter 7, pp.89-95,Springer.

Osman, K. T. 2012b.Soils: principles, properties and management. Chapter 10, pp.128-130, Springer.

Owens, H., 2001. Tillage. From Plow to Chisel and No-tillage, 1930–1999.Midwest Plan Service, Ames, IA.

Passioura, J. B. 2002. Soil conditions and plant growth. Plant, cell & environment, 25(2), 311-318.

Paul, J. W. and Beauchamp, E. G. 1989. Effect of carbon constituents in manure on denitrification in soil. Can. J. Soil Sci. 69:49-61.

Peigné, J., Ball, B. C., Roger ‐ Estrade, J., & David, C.2007. Is conservation tillage suitable for organic farming? A review. Soil Use and Management, 23(2), 129-144.Pekrun, C., Kaul, H.P. &Claupein, W. 2003.Soil tillage for sustainable nutrient management. In: Soil tillage in agroecosystems (ed. A. El Titi), pp. 83–113. CRC Press, Boca Raton, FL.

Pekrun, C., Kaul, H.P. &Claupein, W. 2003.Soil tillage for sustainable nutrient management. In: Soil tillage in agroecosystems (ed. A. El Titi), pp. 83–113. CRC Press, Boca Raton, FL.

Reeves, D. W., Mask, P. L., Wood, C. W., & Delaney, D. P. 1993. Determination of wheat nitrogen status with a hand ‐ held chlorophyll meter: Influence of management practices 1. Journal of Plant Nutrition, 16(5), 781-796.

Ritchie, J. T., Singh, U., Godwin, D. C., & Bowen, W. T. 1998.Cereal growth, development and yield.In Understanding options for agricultural production (pp. 79-98). Springer Netherlands.

Roosevelt, Franklin, D., 1937. Letter from President to Governors.White House, Washington, DC.

S. M. Knight, 2006 ,Soil Mineral Nitrogen Testing:practice and Interpretation." Rev. of HGCA, Research Review Mar. 2006: 15-17. HGCA.

Schnitzer, M., & Khan, S. U. (Eds.). 1975. Soil organic matter (Vol. 8).chapter3,pp 94-97, Elsevier.

Triplett, G.B., Warren, A.D., 2008. No-tillage crop production: a revolution in agriculture! Agron. J. 100, S-153–S-165.

Trump, A. RESEARCH TOPIC REVIEW: Non-Inversion Organic Arable Cropping.

Unger, P.W., 1984. Tillage Systems for Soil and Water Conservation.FAO Soils Bull. #54. FAO, Rome, Italy, 278 pp.

Whalley, W.R., Dumitru, E. & Dexter, A.R. 1995. Biological effects of soil compaction. Soil & Tillage Research, 35, 53–68.

Williams, A.G., Audsley, E. &Sandars, D.L. 2006.Energy and environmental burdens of organic and non-organic agriculture andhorticulture. ’What will organic farming deliver?’ COR 2006.Aspects of Applied Biology, 79, 19–23.

Young, I.M. & Ritz, K. 2000. Tillage, habitat space and function of soil microbes.Soil&Tillage Research, 53, 201–213.