שיפור הייצור החקלאי על ידי ממשק קרקע בר-קיימא

תכנית מס. 301-0750-13

Improving agriculture productivity through sustainable soil management

דוח סופי המוגש

למדען הראשי של משרד החקלאות

צוות היגוי- איטליה ישראל 7182 – 02

ע"י

אשר בר-טל	*מינהל המחקר החקלאי, המכון למדעי הקרקע, המים והסביבה, מרכז וולקני.* abartal@volcani.agri.gov.il
יעל לאור	*מינהל המחקר החקלאי, המכון למדעי הקרקע, המים והסביבה, נווה יער.*
גיא לוי	*מינהל המחקר החקלאי, המכון למדעי הקרקע, המים והסביבה, מרכז וולקני.*
מיכאל רביב	*מינהל המחקר החקלאי, המכון למדעי הצמח, נווה יער*
אלן גרבר	*מינהל המחקר החקלאי, המכון למדעי הקרקע, המים והסביבה, מרכז וולקני.*
בני לב	*מינהל המחקר החקלאי, המכון להנדסה חקלאית, , מרכז וולקני.*
פביו טיטארלי	*מוסדות מחקר איטליה*

י"א שרי תשע"ו **24 ספטמבר 2015**

הממצאים בדוח זה הינם תוצאות ניסויים ואינם **מהווים המלצות לחקלאים**

אשר ברטל

חתימת החוקר

תקציר

הגדרת הבעיה: חקלאות בת קיימה תלויה בפוריות הקרקע. החקלאות האינטנסיבית באזור הים התיכון מתאפיינת בפגיעה בפוריות הקרקע ובעמידות למחלות קרקע כתוצאה מדלדול החומר האורגני בקרקע. לכן החקלאים מגבירים את השימוש בתשומות כגון מים, דשנים וחומרי הדברה ובכך גורמים להגדלת הסיכון לזיהום סביבתי ולפחיתה ביעילות השימוש במים.

מטרת המחקר: לשפר לטווח ארוך את פוריות הקרקע ע"י ממשק משמר קרקע מבוסס על יישום קומפוסט בשילוב עם ביוצ'אר או גידולי כיסוי.

ההיפותיזה: לשילוב של 1. קומפוסט עם גידול כיסוי, ו-2. קומפוסט עם ביוצ'אר תהייה השפעה סינרגיסטית בשיפור פוריות הקרקע, העלאת תכולת הפחמן בה והגברת העמידות למחלות קרקע.

מתודולוגיות המחקר: תוכנית המחקר מבוססת בעיקר על ניסויי שדה בשתי המדינות. בישראל אנו חוקרים את השפעות מנות הקומפוסט והביוצ'אר על תכונות כימיות ופיזקליות של הקרקע, על היבול ועל עמידות למחלות שמקורן בקרקע. באיטליה בוחנים את השפעת מנת הקומפוסט על אותם מדדים עם וללא גידול כיסוי. בשני ניסויי השדה אנו מקיימים מחזורי גדולים אופיינים לאזור. בנוסף בישראל מתבצעים שני ניסויי מעבדה. הראשון – בחינת דיכוי מחלות קרקע ע"י הטיפולים השונים בקרקעות השונות. השני – השפעת תוספת ביוצ'אר על שטיפת יונים ומומסים שונים מקומפוסט על גבי עמודות קרקע והשפעת ביוצ'אר על טרנספורמציות החנקן בקרקע בניסוי אינקובציה. באיטליה משתמשים במודל Roth להערכת הצטברות הפחמן בקרקע בשני הניסויים בממשקים שנבחנו בניסוי זה ובממשקים שונים נוספים.

תוצאות: איטליה – סכום תוצאות ניסוי השדה מצביע על כך שמנת הקומפוסט הבינונית (15 טון\הקטאר חומר יבש) במשולב עם גדול שעורה כצמח כיסוי היה הטיפול הטוב ביותר העונה על הדרישה לחקלאות ברת קיימא לפי המדדים הבאים: הגדלת תכולת הפחמן האורגני בקרקע, מניעת התפתחות של עשבים רעים, הקטנת הסיכון של שטיפת חנקה והקטנת המגבלה של ירידה בזמינות החנקן. ישראל –לא התקבלה השפעה מובהקת של טיפולי הקומפוסט על היבול של תירס, חמניות, בקיה וחיטה, אך התקבלו השפעות מובהקות על קליטת אשלגן על ידי החיטה ועל מדדי קרקע הבאים: עליה בריכוזי הפחמן והחנקן האורגנים, האשלגן המסיס והספוח והזרחן הזמין לצמחים בשכבות הקרקע העליונות עם הגדלת מנת הקומפוסט. מאזן היסודות חנקן, זרחן ואשלגן בטיפולים השונים בשדה מצביע על דלדול בטיפול הקונבנציונאלי לעומת עליה בהצטברות שלהם בקרקע ככל שמנת הקומפוסט גבוהה יותר. התקבלה התאמה טובה בין ההפרש במנת החנקן המצטברת בטיפול הקומפוסט הגבוה לטיפול הקונבנציונאלי להפרש בכמות החנקן האורגני המדוד בקרקע בטיפולים אלו. מנת הקומפוסט הגבוהה הגבירה את יציבות התלכידים לעומת הביקורת. יישום ביו-פחם גרם לירידה ביבול הבקיה אך הגדיל את יבול החיטה והשפיע על מדדי הקרקע הבאים: הקטין את צפיפות הקרקע ותכולת המים הנפחית ברוויה ובנקודת הכמישה בשכבה העליונה, אך לא הייתה השפעה ברורה ומובהקת על יציבות התלכידים. בשני האתרים הטיפולים לא השפיעו על כושר הדיכוי של מחלות צמחים. סימולציה של הפחמן האורגני בקרקע – הסימולציה של נתוני הקרקע והטיפולים באיטליה הראתה התאמה טובה של המודל לתוצאות מדודות מהעבר והצביע על כך שצפויה השפעה ניכרת של הטיפולים על מצב הפחמן האורגני בקרקע בשנים הבאות. נמצאה גם התאמה טובה של תוצאות הסימולציה לשינויים בריכוזי הפחמן האורגני בקרקע בישראל בטיפולי הביקורת ורמת הקומפוסט הגבוהה ביותר.

CRA
CONSIGLIO PER LA RICERCA
E LA SPERIMENTAZIONE
IN AGRICOLTURA

Italy-Israel Joint Project

Improving agriculture productivity through sustainable soil management

Project 301-0750-13

Final report 2015

Submitted: 9.9.2015

Participants

Position in Proposal	**Name**	**Institution affiliation**
1) Coordinator	Asher Bar-Tal	ARO
2) Co-coordinator	Fabio Tittarelli	CRA-RPS
3) Participant	Michael Raviv	ARO
4) Participant	Stefano Canali	CRA-RPS
5) Participant	Guy Levy	ARO
6) Participant	Gabriele Campanelli	CRA-ORA
7) Participant	Yael Laor	ARO
8) Participant	Roberta Farina	CRA-RPS
9) Participant	Ellen Graber	ARO
10) Participant	Rosario Napoli	CRA-RPS
11) Participant	Benny Lew	ARO

Abstract

Definition of the research problem: Sustainability of agricultural production systems is highly dependent on maintaining soil productivity. Depletion of soil organic matter (SOM) is a common phenomenon in soils in both countries. Compost application is becoming popular as a means of counteracting these effects. However, very high doses of composts are required to meet the nitrogen consumption requirements of crops, which results in surface water and groundwater contamination from compost-borne nutrients, as well as excess accumulation of some nutrients in the rhizosphere. Objectives: The goal of the research is to find sustainable ways to reverse the process of SOM depletion and soil degradation by combining compost application with cover crop rotation, and by combining compost with biochar. **Hypotheses**: Combining compost with (i) cover crops and (ii) Biochar is expected to have a synergetic effect on soil fertility and productivity due to its ability to increase SOM stores and soil disease suppressiveness (SDS). **methodology**: The research program is based mainly on field studies. In Israel we investigate the effects of compost dose (0, 10, 20 and 30 t ha^{-1}) in combination with biochar (20 t ha^{-1}) on biomass production, nutrients uptake, soil physical and chemical properties. In Italy two factors are investigated: compost dose (0, 15 and 30 t ha^{-1}), and cover crop. In both countries the treatments are applied to rotational crops (Israel: maize, sunflower, vetch, winter wheat; Italy: vegetables). In addition in Israel the following laboratory experiments are conducted to investigate the effects of combined application of compost and biochar on: (i) leaching of various ions in columns and (ii) transformations of nitrogen in an incubation experiment. The RothC model is used by the Italian group to predict long run SOC changes for various managements based on the field collected data. Finally, the impact of the investigated treatments in Israel and Italy on SDS is measured in laboratory trials in Israel. **Results:** Italy: The overall results obtained indicated that the application of the intermediate dose of compost (i.e. 15 t ha^{-1} as compost dry matter) and the simultaneous introduction of a properly managed cover crop represents an effective trade-off among advantages (i.e. increment of soil organic carbon stock, weed control, NO_3^--N leaching risk reduction) and constrains (N availability reduction), increasing the sustainability of cropping systems. Israel: No significant effects of compost application on biomass production but the yield of K and P in wheat increased with compost dose. Also the following parameters in top soil layers were significantly

elevated with compost dose: soil organic C and N, soluble and exchangeable K, available P, soluble salts and aggregates stability. Biochar application led to reduced vetch biomass but increased wheat biomass and it decreased soil density, the volumetric water content at saturation and wilting point in the top soil layer (0-10 cm). However, no consistent effect on aggregates stability was obtained. No effects of the studied treatments in Italy and Israel on SDS have been obtained. The calibrated SOC model predicted considerable effects of compost application on future organic carbon content in soil in both countries.

I. Statement of the research problem and its general background

Research problem

Depletion of SOM is a common phenomenon in soils in both Israel and Italy, leading to soils with reduced productivity due to a low nutrient cycling rate, degraded physical stability, non-adequate hydraulic properties, and high incidence of soil-borne diseases. Compost application is becoming popular as a means of counteracting these effects. In order to avoid slow plant growth, low crop quality and yield reduction, nutrients must be available in the soil at amounts that meet the minimum requirements for the whole plant and in synchronization with the plant's consumption curve as a function of time. In conventional farming splitting of N fertilizer applications is a suitable approach to better match N need and supply (Vos and Mac Kerron 2000; Goffart *et al.* 2008). In the case of compost application it is difficult to achieve good synchronization between nutrient supply and crop nutrient demand (van Noordwijk and Cadisch, 2002). An additional problem in the Mediterranean region is that the increase in SOM by compost application is very slow due to the high rate of decomposition of the applied organic matter. Consequently, very high doses of composts are required to meet the nitrogen consumption requirements of crops. This can result in surface water and groundwater contamination from compost-borne nutrients, as well as excess accumulation of some nutrients in the soil at the root zone. Several management tools to overcome these problems arising from composts' use have been developed; two of them will be tested in the proposed research: (i) introducing cover crops into the crop rotation with compost application to the soil and (ii) application of composts together with biochar.

Introducing cover crops into a crop rotation is a well-known method for enhancing soil fertility (Danga et al. 2010), reducing weeds and soil-borne diseases, and improving soil structure. As far as cover crops are concerned, their contribution to soil fertility management is usually measured in terms of the amount of nutrients applied to soil when the cover crop is utilized as green manure. Sikora and Enkiri (2000) reported that the combination of cover crop residues with composts resulted with maximum crop yields due to enhanced N supply, but no experimental studies under Mediterranean conditions have been reported.

Biochar (charcoal) is a relatively new amendment in field soils in modern agriculture, and its use still in the research and development stage. Charcoal retains the nutrients provided by organic wastes, and prevents their leaching out of the soil. Biochar has been seen to enhance soil physical properties, including soil water retention and aggregation, both of which may improve water availability to crops, as well as decrease erosion (Verheijen et al., 2009). Charcoal has also been reported to form complexes with minerals as a result of interactions between oxidized carboxylic acid groups at the surface of the charcoal particles and mineral grains (Verheijen et al., 2009), suggesting that charcoal amendments may improve in this way soil aggregate stability. There is also mounting evidence that when used along with organic and inorganic fertilizers, biochar can significantly improve soil tilth (Glaser et al. 2002; Chan et al. 2008), crop productivity (Steiner et al. 2008; Graber et al. 2010), nutrient availability to plants (Lehmann et al. 2003; Silber et al. 2010), and protection against plant diseases (Elad et al. 2010; Kolton et al. 2011; Meller Harel et al. 2012). Application of biochar alone or in combination with organic fertilisers/compost has, therefore, been suggested as a strategy to increase soil carbon sequestration and generate more stable soil carbon pools (Glaser et al. 2001; 2002; 2009; Glaser 2007; Lehmann et al. 2009; Verheijen et al. 2009). Most of the published studies on the application of biochar in modern agriculture have been conducted in laboratory or pots grown plants. There is only limited information from long term field experiments involving biochar mixed with compost and manures (Steiner et al., 2007; 2008), and none from a Mediterranean climate.

Through the use of a simulation model such as RothC (Coleman and Jenkinson, 1996; Coleman et al. 1997), we hope to be able to determine the best agricultural options for enhancing soil C storage and extending the results to similar agro-ecosystems. Eventually, such estimations are crucial to driving policies related to sustainable agricultural managements.

There is increasing evidence that soil applications of composts made from a range of waste materials (e.g. animal manure, domestic and communal green waste, bark) result in (a) soil disease suppressiveness (SDS) against root/vascular diseases and pests from soil-borne inocula (Darby et al., 2006; Giotis et al., 2009; Markakis et al., 2008; Yogev et al., 2006; Bonanomi, 2010) and/or (b) induced crop resistance against root/vascular and/or foliar diseases (Yogev et al., 2010). Also, there is evidence that changes in nutrient supply patterns (especially of nitrogen) associated with a switch from mineral to organic fertilisers increases the production of secondary metabolites linked to pest and disease resistance mechanisms (Cooper et al., 2006; Ghorbani et al., 2008).

Positive effects of biochar amendment on plant resistance to various plant diseases have been shown. In Japan mixes of composts with charcoal have been shown to suppress root diseases and inhibit the growth of some soilborne pathogens such as *Pythium*, *Rhizoctonia*, *Phytophtora*, and *Fusarium* (Ogawa and Okimori, 2010). Furthermore, pioneering work from one of our group (Graber) has shown that biochar can induce a systemic response in tomato and pepper plants (Elad et al, 2010) and strawberry (Meller-Harel et al., 2012.) protecting the plant from necrotrophic and biotrophic foliar fungal diseases.

Much less is known about the effect (positive or negative) of cover crops. In some cases cover crops may serve as carrier of plant pathogen, which may survive for relatively long periods (Kluth et al., 2010). In a few other cases a suppressive effect was occasionally recorded (Larkin et al., 2011), but no consistent and reliable knowledge enables a prediction of such an effect. To the best of our knowledge, information regarding the interactive effect of both compost and cover crops on soil-borne diseases does not exist, and therefore one of the main aims of this project is to study this subject.

II. Research objectives

The main objective of this project is to improve the long term productivity of agriculture by introducing sustainable soil management practices based on application of composts with biochar or cover crops. To this end four specific key research objectives are set:

- Quantify the synergistic effects of applied compost with biochar, and compost with cover crop on soil chemical and biochemical properties such as soil organic matter (SOM) content, Organic N content, available nitrogen and other nutrients.
- Predicting SOM content in soil as affected by composts application and cover crops management in Mediterranean region using the RothC model.

- Quantify the effects of applied compost with biochar or cover crop on soil physical properties such as bulk density, aggregate stability, infiltration rate, water retention curve, saturated hydraulic conductivity.
- Investigating the effect of biochar application and cover crop on minimizing possible environmental risks involved with applied composts due to pollutant (mainly nitrate) percolation below the root zone of treated soils and increased soil salinity.
- Characterise the beneficial effects of combined compost and biochar in terms of suppressing soil-borne fungal pathogens (*Fusarium oxysporum* f. sp. melonis (FOM), the causal agent of Fusarium wilt of melon and *Verticillium dahliae*, the causal agent of Verticillium wilt of several important crops, including olives, tomatoes, eggplants etc.).

III. Hypotheses and their rationale

We hypothesize that:

(i) Combining compost with cover crops is expected to improve availability of soil nutrients, especially nitrogen due to nutrient accumulation in the cover crops, and to improve soil structure and microbial activity, as a result of root associated processes.

(ii) Biochar added together with c**o**mpost is expected to have a synergetic effect on soil fertility and productivity due to its ability to retain nutrients and increase SOM stores.

IV. Research Methodology and means

Israel

Laboratory

Biochar Characterization - Many standard methods used for characterizing soils were found to be unsuitable for biochar because of various physical and chemical characteristics. In particular, we concentrated on developing a method for determining acidic group functionality of biochar surfaces. This is because acidic functional groups are the main sites of cation adsorption, and hence are very important in understanding biochar impacts on nutrients and metals. Ultimately, we developed and published a modified Boehm titration (Tsechansky and Graber, 2014). The Boehm titration is frequently employed to characterize acidic groups at biochar surfaces. However, biochars contain inorganic basic components (carbonates, oxides, hydroxides), inorganic acidic species (silica, alumina) and organic acids (carboxylic acids, phenols, humic-like substances) that can be differentially solubilized in the Boehm bases, rendering invalid results. Prior to titrations (Boehm or continuous), biochar should be pretreated with NaOH to remove solubilizable acidic species, and then with HCl to remove solublizable basic components and protonate carbon acid sites. Pretreatment is successful when direct and indirect titrations yield identical results and no precipitate is observed.

Many biochars have a complex carbon lattice structure with aromatic and aliphatic domains, acidic and basic groups, vacancies, metallic and non-metallic elements, and free radicals. Biochars also have separate mineral oxide, silicate and salt phases, and small and large organic molecules. In the rhizosphere, such constituents can be involved in chemical and biological processes along soil-microbe-plant continuum, including nutrient cycling, metal chelation and stabilization, redox reactions, and free radical scavenging. We hypothesized that the greater the amount of these nanoparticles and dissolved components, the greater the plant and microbial responses. We published (Josef et al., 2013) suggestions for developing low-dose, high efficiency biochar nanoparticle-composites, as well as initial field trial results and detailed characterization of such a biochar-fertilizer composite to highlight the potential of such composite biochars.

Ash content of the biochar used in the field trial, which was produced from citrus wood and denoted NYBC, was found to be 49.3% by loss on ignition. Judging by this result and the fact that wood biochars generally have no more than about 15% ash, the conclusion is that the purchased biochar was contaminated with soil/sand.

Incubation experiment - An incubation experiment was established to investigate whether biochar impacts N transformations. Six treatments were prepared: (i) soil + 1% sand; (ii) soil + 3% sand; (iii) soil + 1% biochar; (iv) soil + 3% biochar; (v) soil + 1% perlite; and (vi) soil + 3% perlite. The soil was collected from the Newe Yaar field site, dried, ground, and sieved to pass 2 mm sieve. The biochar was the same biochar as used in the field trial. The sand treatments were intended as non-porous inert control, and the perlite treatments as porous inert control. Perlite particles were lightly crushed to be the same particle size as the biochar particles, determined by sieving. Eleven time points and four replicates per time point were prepared using 40 g soil in 250 mL plastic jars and the appropriate weight of the additive to give the desired additive weight %. Pot capacity was determined for all the treatments in advance, and the treatments were wet to 70% of the determined pot capacity, initially with $(NH_4)_2SO_4$ solution (2.9 g/L) to give a concentration of 100 mg N/kg soil. The jars were lightly covered and incubated at 30^{o}C in the dark. Analytes include: N-NH_4, N-NO_3, N-NO_2, N_2O, CO_2 and CH_4. $NH_{4,}$ NO_3 and NO were extracted into 1M KCl in 2 consecutive extractions and analyzed by autoanalyzer. For gas analyses, the plastic jars were placed for 24 hours into hermetically sealed glass jars with rubber septa. After 24 hours, the airspace in the glass jar was sampled by syringe and injected into sealed autosampler vials. The gas samples were stored for analysis of N_2O, CO_2 and CH_4 by gas chromatograph dedicated to greenhouse gas measurements.

Column experiment, ARO - Saturated column experiments testing the uptake and release of NH_4^+ on the same biochar used in the field trial, NYBC, were conducted. The biochar was lightly crushed, soaked in 0.1 M HCl, rinsed clean of HCl residues, dried 48 hrs at 40^{o}C, and then sieved. Particles between 0.8 to 1 mm in size were used. A 10 cm long, 2.4 cm inside diameter, stainless steel high pressure liquid chromatograph (HPLC) preparative column was filled with biochar particles (17.68 g). The filled column was then connected to an HPLC pump. The column was slowly saturated at 0.5 mL/min with a background buffer solution (10 mM sodium phosphate buffer pH 7; prepared by weighing 3.27 g $Na_2HPO_4{\cdot}7H_2O$ + 1.08 g $NaH_2PO_4{\cdot}4H_2O$ and bringing the volume to 2 L, with pH adjustment to pH 7 if needed). The volume of solution passed through the column until initial breakthrough was recorded as the pore volume, determined to be 22 mL. Sodium saturation and steady state were achieved by passing 100s of pore volumes of background buffer through the column. The buffer was then replaced with a 10 mM NH_4Cl solution, and the column effluent was collected by automatic fraction collector in 6 or 12 mL fractions. pH, NH_4, Na, and Cl concentrations were monitored in the fractions. pH remained nearly constant at about 7. After complete breakthrough of NH_4, the NH_4Cl solution was replaced by the background buffer solution, and the same analytes were monitored in the column effluent. Na was determined by flame photometer, pH by potentiometric probe, Cl by chloridometer, and NH_4 by colorimetric microplate analysis. This experiment was repeated multiple times using NH_4Cl, NH_4NO_3 and urea, to examine the breakthrough and sorption of these different N-forms on biochar. Following the multiple uptake and release experiments, the biochar in the column was rinsed at 0.5 mL/min with 10 L of acetic acid-Na-acetate buffer at pH 3.7, representing 400 pore volumes. The idea was to simulate long-term abiotic weathering of biochar in the root zone, and to see how this weathering would affect uptake and release of NH_4. After leaching with 400 pore volumes, the column was washed with the original background buffer at pH 7 until steady state was achieved, and the NH_4 uptake and release experiment was repeated.

Soils from the experimental Newe Yaar plots were sampled in order to make disturbed column experiments that would test the impact of soil +/- biochar +/- compost on the leaching of nitrate under saturated conditions. The treatments sampled included compost 0 m^3ha^{-1} +/- 10 ton biochar ha^{-1}, and compost 60 m^3ha^{-1} +/- biochar 1 10 ton biochar ha^{-1}, that is to say, 4 treatments altogether. Soil was sampled from 0-20 cm depth from 5 points per plot and well mixed to make one composite sample per plot. Five replicate plots for each treatment were sampled. Soils were air-dried, crushed, and sieved (2 mm). The soils were mixed with cleaned coarse sand (~ 1mm grain size) at a ratio of 1:1 to avoid excessive swelling in the soil columns. The same column apparatus as described above was used. The leaching solution was comprised of 20 meq $CaCl_2$. Before leaching began, half the columns had 1.67 mL of 100 mg/L of NH_4NO_3 applied (total 4 mg N-NH_4 and 4 mg N-NO_3 per column) to the top layer of soil, and the other half had 1.67 mL of water applied in the same fashion. After application, the columns were allowed to rest 24 hr, following which time, rinsing with the CaCl2 leaching solution was begun. The column was inverted and leaching begun from below at a rate of 0.1 mL/min for wetting of one pore volume, and then the rate was increased to 2 mL/min for a maximum of 240 min. Fractions of leachate were collected by automatic fraction collector in units of 5 mL for the first 14 test tubes, following which volume per tube was increased to 25 mL each in 66 tubes (total of 80 tubes). Total leaching time was 14 hours. Fractions were stored for subsequent analysis of NO_3 and NH_4, as described above. Three replicate columns for each treatment were run, each replicate column was constructed from soil sampled from a different plot.

Field experiment – Newe Ya’ar, ARO

Starting from September 2009, a group of scientists from the ARO are conducting a long-term (9 year) project aimed at understanding the changes occurring over time in the soils of organically-farmed plots in two locations (Newe Ya’ar and Gilat) in Israel (Fig. 1, AppendixII). Over the years we expect those changes to be expressed as improved soil fertility and resilience to biotic and abiotic stresses. Within the context of this project, we devoted part of the Newe Ya'ar field to test several effects of biochar on soil characteristics and crop yield.

Newe Ya'ar Research Center is located in the Jezre'el Valley, Northern Israel (Fig. 1). The soil is a Chromic Haploxerert (fine-clayey, montmorillonitic, thermic), some properties of the soil are presented in Table 1 (Appendix I). The climate is typical of the Mediterranean region: cool winter (average minimum of 8-9°C) and warm dry summer (average maximum of 28-29°C). The average annual precipitation is about 560 mm, concentrated mostly between November and March.

The biochar field experiment began on 6 November 2012 and it lasted two years over two consecutive crops, vetch and wheat. The following crop rotation is maintained: **(i)** Sunflower in Spring and summer, **(ii)** vetch as a green manure in winter, **(iii)** wheat in winter followed by corn in the summer of the same year. This rotational sequence is typical for arable crop rotation in the Mediterranean region. Unfortunately, the corn plants had to be terminated just 4 weeks after planting because of agro technic difficulties and this crop is not included in the report.

The study is focused on assessing the effects of different fertilization regimes (cattle manure compost at three different levels *vs.* standard mineral fertilization) ± biochar on:

- yield and quality of crops,
- soil biological, chemical and physical parameters,
- downward leaching of pollutants, mainly nitrate and salts,

A 2-factorial split plot experiment is conducted with 4 fertilizer input treatments at 5 replicates/blocks, with a total of 20 plots. The size of the main plots is 18 x 25 m. Biochar has been applied in subplots of 8 x 6 m in size (Figure 2, Appendix I), one subplot in each main plot.

The organic fertilizer input used is compost produced by a certified producer, known for its high quality compost (Sde Eliyahu). Each year, the compost was tested for all total and soluble macro and micro nutrients, ash content, pH and EC (Electrical Conductivity).

The composition and quality of the compost varied between years. The range of organic matter and N contents in the compost were 40.0-47.5% and 1.68-1.98% of the dry matter, respectively (Table 2, Appendix I). The C/N values were in the range of 12.9-15.6, indicating mature and stable composts. Note the typical high P and K contents in compost relative to N and also the high concentration of P-PO_4^{-3} and K^+ in the water extract of the compost. Note also the high salts content of the compost as measured by the EC of the compost water extract.

The mineral fertilizer control follows fertilization regimes recommended for these crops grown in conventional systems in Israel. The applied compost levels are 20, 40 and 60 m^3 ha^{-1}. The control is fertilized using commercial chemical fertilizers, based on soil analyses, in relation to the needs of each specific crop. In April 2012, before sunflower sowing, urea was applied to the control at a rate of 92 kg N ha^{-1}. The biochar was produced of citrus tree cuttings using traditional pit techniques. The main chemical characteristics of the biochar were determined (Table Appendix I). The biochar was applied one time only at 1.75 ton (DW) ha^{-1}. A photo of the field site immediately following biochar application and before its incorporation to 10 cm depth on Nov. 6, 2012 is given in Picture 1 (Appendix I).

Soil samples were taken from each plot from the following depth layers: 0-5, 5-15, 15-30, 30-60 cm, twice during the growing season: before seeding and after harvest. The samples were analysed for total soil organic carbon and nitrogen, concentrations of major ions in soil solution (K, Na, Ca, Mg, Cl, SO_4) and plant available concentrations of N and P. The effect of the treatments on top soil (0-15 cm) biological activity (dehydrogenase, respiration) and physical parameters (bulk density, aggregate stability, water retention curve and saturated hydraulic conductivity) were determined at April 2013. The topsoil layer (field moist) has been analysed for mineralization activity (CO_2 emission and inorganic N accumulation during 1 week incubation), dehydrogenase activity and hydrolytic activity of Fluorescein Diacetate (FDA) (Schnurer and Rosswall, 1982; Stuberfield and Shaw, 1990). These biochemical measures will indicate the extent and duration of enhanced biological activity induced by the compost and or biochar.

Plants were sampled at the end of each season. The crop was harvested and biomass (total and grain) determined. Chemical leaf analyses were conducted at the time of biomass assessment using standard procedures to measure actual concentrations of N, P and K. Rainfall events and irrigation events and amounts have been monitored.

Sunflower, the first crop in the rotation was sown in April 2012, and it was harvested on 19th September 2012, before the application of Biochar, therefore only the effect of compost dose at this time could be tested. Yield and biomass of each plot was determined by harvesting a subunit of 1 m^{-2}, then plants were divided to stems, heads and seeds. A subsample of two plants was used for determination of dry matter content and analysis of nutrient content.

Vetch (*Vicia faba* cv. Sadot) was sown (70 Kg. per hectare) on 22.11.2012. It served as green manure and it was cultivated by the end of March 2013. Wheat was sown on December 30th 2013, and it was harvested in April 2014. After harvesting the soil profile was sampled, then compost was applied to the organic plots, while mineral fertilizers of N, P and K was applied according to soil tests and the requirements of the next crop. Several agro technic problems led to termination of the corn crop just 4 weeks after seeding, therefore no results from this crop are presented.

Biochar preparation for the field tests

Seven biochars produced from different biomass sources (olive, citric and lemon trees) and by different methods (traditional and Egyptian method) were tested in pot tests for wheat germination to determine the best char for the field tests. In the traditional method, the pile of biomass is cover with straw and soil (to maintain the anaerobic conditions) and only a small hole is left on the top part of the pile. From this hole, a small amount of hot biochar is introduced. Due to the anaerobic conditions inside the pile, the biomass is transformed into biochar in a slow process that can take up to three weeks. The biochar is produced at low temperatures (around 400 ^{O}C).

In the Egyptian method, the biomass pile is burned in an open space (aerobic conditions at the top of the pile, anaerobic inside the pile). When the conversion process is finished, the fire is extinguished with water. The process is faster, however, the biochar is produced at higher temperatures, around 700 ^{O}C.

The wheat germination pot tests in a greenhouse were conducted with sand mixed with 3% biochar (and control without biochar) in pots with ten wheat seeds per pot. Water and fertilizer were provided for germination. After one week, the amount of germinated seeds and height of seedlings were evaluated. Based on the results, biochar produced from citrus trees by the traditional method gave the highest germination result and were used for the field experiments. The main chemical properties of the applied biochar are presented in Table 3, Appendix I.

Two tons of biochar were produced for the field experiments, crushed into particle size less than 1 cm, and divided in 50 kg bags. To prevent dust problems with the biochar application in the field, the bags of biochar were wetted before spreading. On the 6.11.12

biochar was spread in the experimental field, according to Fig. 2 (Appendix I). On each plot of 48 m^3, 190 liters of biochar were manually spread, weighing 105.3 Kg FW and 78.8 Kg DW. Immediately after application the whole field was cultivated to a depth of 10-15 cm. General photo of the field before cultivation is presented (photo 1, Appendix I).

Field experiment - Monsampolo del Tronto Italy

The Italian experimental site is located at Vegetable Research Unit of the Research Council for Agriculture (CRA-ORA) in Monsampolo del Tronto (AP), (latitude 42° 53' N, longitude 13° 48' E), in the coastal area of the Marche Region, Central Italy.

Soil type determination was performed by an early survey conducted in the experimental trial site one year before the starting trial time, during March 2011.

The soil was classified as Fluventic Haploxerept, fine silty, mesic (Soil Taxonomy USDA) or Fluvic Cambisol (Calcaric) (World Reference Base), developed on a footslope colluvial deposits partially reworked and terraced by fluvial dynamic, on plio-pleistocene silty and fine sand deposits with gravel levels. The soil hydric regime is Xeric, and Soil Thermic regime is Mesic (Picture 1 and 2, Appendix II).

During the last 12 years, a 4-year crop rotation based on 6 main crops has been established. The rotation was: tomato (*Lycopersicon esculentum* Mill.), melon (*Cucumis melo* L.), fennel (*Foeniculum vulgare* M. var. azoricum), lettuce (*Lactuca sativa* L.), cauliflower (*Brassica oleracea* L. var. botrytis) and bean (*Phaseolus vulgaris* L.). In this system, three different green manures were included in the rotation: hairy vetch (*Vicia villosa* R.), cropped before the tomato, barley (*Hordeum vulgare* L.), cropped before the melon and radish (*Raphanus sativus* L.), cropped before the lettuce (Picture 3 and 4, Appendix II).

Experimental design

The IT experimental design was set up in order to test the research hypothesis of the project in the framework of the constraints given by the available field area. On the basis of recent research activities carried out in the experimental site of Monsampolo del Tronto, cover crop (barley) management has demonstrated to have a great potential in providing relevant ecosystem services (i.e. nutrients supply, weed control, soil temperature control, energy and water saving). Cover crop treatments were combined with different doses of compost.

The experimental design was a strip-plot with three replicates of two factors, testing the cover crop management and compost amendment. The strips were used to test the cover crop management factor and the following three different treatments were compared: (i) control (no cover crop), (ii) green manure (barley) and (iii) roller crimper (flattened barley mulch obtained by roller crimper technique). Within the strips, the plots were used to compare three different doses of compost (0, 15 and 30 t/d.m.) (Fig.1, AppendixI). In order to establish a more complex experiment respect to what reported in the project (with the introduction of a third level in the cover crop management factor), the original design was modified.

Cover crop cultivation

First year

Barley was sown on the 3rd of November 2011. Compost amendment at the doses of 15 and 30 tons d.m.ha^{-1} was applied and superficially incorporated to soil at tillering, by rotary spade (on the 21st of February). Before compost distribution in the field, a compost sample was randomly collected from the compost pile (10 boreholes), dried and stored for subsequent analysis (TC, TN and TP).

Barley was terminated on the 2nd of May 2012. Samples of barley above soil biomass were collected in each plot either in the green manure and in the roller crimper treatments. Above ground biomass was measured and a representative fraction was dried and stored for the subsequent analysis (TC, TN and TP). Similarly, the remained barley above ground biomass in the roller crimper treatment was collected at melon harvest, dried and stored for the subsequent analysis.

Second year

Barley was sown on the 7th of November 2012. Compost amendments at the doses of 15 and 30 tons d.m.ha^{-1} were applied and superficially incorporated to soil at tillering, by rotary spade (on the 21st of February 2013). Before compost distribution in the field, a compost sample was randomly collected from the compost pile (10 boreholes), dried and stored for subsequent analysis (TC, TN and TP).

Barley was terminated and green manured on the 16th of April 2013. Total fresh biomass was 48.4 t ha^{-1}. In the roller crimper treatments, barley was flattened on the 26th of April and the biomass produced was 55.2 t ha^{-1}. Samples of barley above soil biomass were collected in each plot either in the green manure and in the roller crimper treatments. A representative fraction was dried and stored for the subsequent analysis (TC, TN and TP). Similarly, the remained barley above ground biomass in the roller crimper treatment was collected at melon harvest, dried and stored for the subsequent analysis.

Melon crop cultivation

First year

The melon crop (*Cucumis melo* L var. reticulatus HF1 Anish) was manually transplanted on the 7th of May 2012. Harvest started on 13th of July and ended on the 7th of August, the whole cropping cycle lasting 88 days. The melon crop was irrigated with 430 m^3 ha^{-1} of water. The crop was fertilized, at transplanting, with organic off-farm fertilisers based on animal manure (3% N at the dose of 1.2 t ha^{-1}) and by fertigation during the cropping cycle. Melon yield was measured within 24 hours after the harvest, made in accordance to fruit ripening, collecting fruits 3 times per week along the harvest period. Total yield was then calculated as the sum of the different harvests. Marketable yield was evaluated according to the local market standards. All the quality parameters (i.e. fruit weight, diameter and length) and the number of fruit per plant were measured on a sample of the produce obtained from at least 3 plants/plot.

At the end of the harvest period, melon crop residues, flattened barley biomass and weeds above soil biomass were measured. Samples of fruits, crop residues and weeds were dried for 48 h at 70 °C to determine their dry weight and stored for subsequent analysis (TC, TN and TP, still in progress).

Second year

The same cultivar of melon crop utilized in 2012 was cultivated in 2013 (*Cucumis melo* L var. reticulatus HF1 Anish). It was manually transplanted on the 14th of May 2013. Harvest started on 23rd of July and ended on the 14th of August, the whole cropping cycle lasting 90 days. The melon crop was irrigated with 345 m^3 ha^{-1} of water (including fertigation).

The crop was fertilized, at transplanting, with organic off-farm fertilisers based on animal manure (3% N at the dose of 1.2 t ha^{-1}) and by fertigation during the cropping cycle.

Melon yield was measured within 24 hours after the harvest, made in accordance to fruit ripening, collecting fruits 3 times per week along the harvest period. Total yield was then calculated as the sum of the different harvests. Marketable yield was evaluated according to the local market standards. All the quality parameters (i.e. fruit weight, diameter and length) and the number of fruit per plant were measured on a sample of the produce obtained from at least 3 plants/plot.

At the end of the harvest period, melon crop residues, flattened barley biomass and weeds above soil biomass were measured. Samples of fruits, crop residues and weeds were dried for 48 h at 70 °C to determine their dry weight and stored for subsequent analysis (TC, TN and TP).

Soil physical, hydrological and chemical parameters

Soil temperature and water content were measured in continuous by specific probes installed in the field (Delta Ohm, Padova, Italy and Sentek Pty, Stepney SA, Australia for soil temperature and soil water content, respectively) and information stored in outdoor data loggers.

In the experimental trial, it was established to collect samples for aggregate stability determination, bulk density, and undisturbed soil cores for determination of the water retention curve two times per year, whereas the saturated hydraulic conductivity by infiltration rate has to be measured once a year.

The Aggregate stability was performed on a sample about 500 g of natural surface aggregates in the first 0-5 cm of each plot, including in the diameter of 5-10 mm. Subsequently, the aggregates were taken to the laboratory and dried in an oven at 50 ° C, and subjected to manual crushing, to reduce them to smaller sizes suitable to the test of structural stability. The test was performed with the wet sieving, with sieves of 2,1,0.5 and 0.25 mm mesh, to determinate both the Mean Weight Diameter and the Geometric Mean Diameter, using the procedure described by Kemper and Rosenau (1986). The Mean Weight Diameter was calculated by the equation:

$$\mathbf{MWD} = \sum_{i=1}^{n} \bar{x}_i \, w_i$$

where Xi is the arithmetic mean diameter of the i-1 and i sieve openings (mm), Wi is the proportion of the total sample weight occurring in the fraction (dimensionless) and n is the number of size fractions (in this case 4).

The Geometric Mean Diameter suggested by Mazurak (1950), is another stability index, that Gardner (1956) supported , finding that aggregate size distribution for most soils is approximately log-normal rather than normal. The GMD was calculated by equation:

$$\mathbf{GMD} = \exp\left[\Sigma_{i=1}^{n} \, w_i \log \bar{x}_i / \Sigma_{i=1}^{n} \, w_i\right]$$

Where wi is the weight of aggregates in a size class with average diameter xi, and ∑ni=1wi is the total weight of the sample.

In Israel aggregate stability was determined using a laser particle size analyzer. Aggregates (0-2 mm) were subjected to 5 min of stirring followed by additional 5 min of stirring+ultrasonication.

Soil Bulk Density was sampled by using a steel cylinder in three replicates for each plot, in the range of 20-30 cm of depth, with undisturbed soil core method (MAFS, 1997). The soil cores were dried at 105 C° and weighted. The soil dry bulk density, as ratio of the mass of dry soil to the total volume of soil expressed in grams per cubic centimeter, was determined.

The water retention curve was measured according to the Italian standard official method (MiPAAF, 1997b). Soil undisturbed samples were collected from the field plots in three rrplicates at 10-20 cm of depth; in the laboratory they were previously saturated with de-mineralized water on ceramic plates and plastic membranes, and were used for analyses of gravimetric water content (gg^{-1}) at seven different pF values (0, 10, 20. 30, 100, 500 and 1500 Kpa) with a set of pressure extractors (Richard apparatus, Soilmoisture Equipment Co., USA). Samples were weighted, then drained to soil matric potential (h) of 0, -100, -200, -300, -1000, -5000 and -15000 cm. After applying the desired cell gas pressure, samples were allowed to come to equilibrium and weighted; when the equilibrium at the maximum pressure was reached, samples were re-weighed and the water contents were determined gravimetrically by drying the samples at 105°C for 24 h. The water content at each pressure head θ (h) is expressed as a percentage of the oven dry weight of the soil with the formula: θ (h) = [(Ww-Wd)/Wd] x 100, with Ww = wet weight at pressure head h, and Wd = dry weight. Finally the gravimetric content was transformed in volumetric by multiply for the soil dry bulk density.

Available water capacity (AWC) was calculated by difference between the Field Capacity (at 30 Kpa) and Wilting Point (at 1500 kpa) water content, and expressed in mm of water column.

Saturated hydraulic conductivity was determinate by measures of Infiltration rate on field. The equipment used was:

a) for the first year (June 2012) measures were taken by the Tension disc infiltrometer (Soilmeasurement Co. USA). The applied method refers to the Ankeny (Soil Sci. Soc. Am. J., 55:467-470, 1991) approach, based on the equilibrium among two different tension levels (see also Comegna et al., 1996, Riv. Ing. Agr., 4:230-236). The Measures of Saturated hydraulic conductivity by Tension Disc Infiltrometer were used to apply the analytical solution of Wooding(1968) that describe tridimensional flux under the porous disk with the equation:

$Q(h0)=(\pi r20+4r0/\alpha)K(h0)$

Where Q = stationary flux; $r0$ = disk radius; α = relative rate between capillarity and gravity water forces at unsaturated conditions. Trials were conducted with multiple Hydraulic head (12-9-6-3 cm) and equal radius, and time of measure of about 2 hours for each test.

b) for the second year (august 2013) the Aardvark Permeameter (Soilmoisture Equipment Co., USA) was utilized.

Description of the method:

The Aardvark is a constant-head permeameter. It means that the depth of water in borehole (h) does not change during the measurement period. As a result, the measurement conditions remain constant during the measurement period. The rate of water supplied corresponds to soil infiltration rate from the bottom and side surfaces of the testing borehole.

The Aardvark Permeameter estimates soil hydraulic conductivity using the amount of supplied water measured at equal time intervals. This is equivalent to the amount of water that was infiltrated by soil. Soil-water infiltration rate is the amount of percolated water over time which is equivalent to the reservoir flow rate, according to the equation:

reservoir flow rate = reservoir water change / time

The measurement ends when the reservoir flow rate (soil-water infiltration rate) does not change over several consecutive readings. Soil hydraulic conductivity (Ksat) then can be calculated using this steady flow rate (Q), based on USBR 7300-89 procedure (Earth Manual Part 2, Third Edition, and P. 1234-5. Denver, Colorado 1990).

In our case, the setting parameters used were: a) “Elapsed Time Interval” for each reading was set for 1 minute; b) Steady Flow Rate (Q) was established when “Water Consumption Rate” (flow rate) did not change more than 5 ml over three consecutive readings.

Soil samples, in triplicates, were collected from each elementary plot during the melon cropping cycle at (i) transplanting, (ii) fast growing, (iii) initial flowering and (iv) harvest. Each sample was obtained with 2 boreholes and combined just after the collection. Soil samples were fresh analyzed for mineral N content and then air-dried, crushed, passed through a 2-mm sieve (USDA-NRCS, 1996) and stored for subsequent analyses (TOC, Total N and Olsen P). Total soil organic carbon (TOC) and mineral N (NO_3^--N + NH_4^+-N) were determined according to the procedure reported in the box 1. All the soil laboratory tests were carried out in three replicates in order to control intra-laboratory variability. Soil total N and Olsen P analysis is in progress at the time of this report.

RothC simulation model

RothC model simulates SOC turnover in non-waterlogged soils, as influenced by soil type, temperature, soil moisture and plant cover. Briefly, SOC is split into five pools, four active pools and one inert pool (IOM). The four active pools are Decomposable Plant Material (DPM), Resistant Plant Material (RPM), Microbial Biomass (BIO) and Humified Organic Matter (HUM). Each of the active pools decomposes by first order kinetics into CO_2, BIO and HUM. Decomposition of each pool is influenced by three rate modifying factors: soil moisture, air temperature and plant cover. RothC has been successfully used in many ecosystems throughout the world.

The model does not contain a submodel for plant production: so inputs to soil from plants must be estimated or obtained by the iterative use of the model. The calibration of the model is the process that possibly modifies the internal parameters of the model in order to adapt it to the site. For Roth10N, already modified for Mediterranean dry areas, the only parameter adjusted was the RPM/DPM ratio of the compost, that was set at 0.29, i.e. 75% of the compost applied in Monsampolo was considered degradable and 25% resistant to decomposition. Carbon input from plants (cover crops, plant residues, roots, etc.) and compost were derived from the experimental data. The croplands soils were considered in the model as “covered” when having some portion of a plant canopy over the soil during the growing seasons, including cover crops. RothC was initialized on the SOC data from the beginning of the experiment, using a fixed distribution over the pools, with values derived from previous studies in the experimental field. The distribution of pools for the cover crops residues and the composts were derived from residues with similar properties and calibrated with the results from the relevant plots.

Firstly, we validated the model in order to verify its ability to simulate a set of data provided by a previous study of Campanelli & Canali (2012)[1], concerning soil characteristics (including TOC) and crops yields and management, that were obtained in the same site. The

---

[1] . “Crop production and environmental effects in conventional and organic vegetable farming systems: the case of a long–term experiment in Mediterranean conditions (Central Italy)”. Journal of Sustainable Agriculture, 36: 599-619)

model was first run in inverse mode to equilibrium to generate the input required to match the initial stock of soil organic carbon. Thereafter we used the input of C based on values estimated with the formulas in Table 1 (Apendix I).

Suppressiveness Studies

Italian soil samples - Each soil samples was mixed with Perlite #4 (HaBonim, Israel) 1:1, V:V. Half liter pots were filled with each mixture. Irrigation started 6 days before planting, in order to allow regeneration of full microbial activity.

Melon seeds ("Ofir", Zeraim Gedera, Israel, a cultivar highly susceptible to Fusarium) were sown in sand. 7 days later, on 5/6/13, the roots were washed and soaked for 2 minutes in *Fusarium Oxysporum* f. sp. *melonis* Race 0 spores (microconidia) suspension, containing 300,000 spores/ml. Five plantlets were planted in each pot. The whole experiment was conducted in a growth chamber. Temperature was 26^{o}C. The disease symptoms in plants were monitored for 27 days.

Israel Soil - Soil samples were taken in spring of 2013 following vetch incorporation to the ground and in spring of 2014. Half liter pots filled with soil, planted and infected like the Italy soil.

Israel Results

Laboratory Incubation and Column experiments

Results of the incubation experiment are shown in Figure 3, Appendix I. It can be seen that transformations of $(NH_4)_2SO_4$ in all six treatments were identical. Ammonium transformation to nitrate was complete by Day 15, with nitrite, an intermediary, disappearing between Day 5 and 10. Thus, no apparent influence of biochar on N transformations was detected in this experimental setup, in contrast to reports in the literature.

The break curve of NH_4^+ through HCl treated biochar column indicates that the adsorption/uptake of NH_4^+ by the HCl treated biochar was greater than release of Na^+ (Fig. 4. Appendix I). Subsequent release of NH_4^+ (green) was the same as the exchange with Na^+, suggesting that NH_4^+ and Na^+ have different selectivities on biochar. Further studies are underway to examine cation selectivity on biochar. Total NH_4^+ taken up was 158 mmol/kg, which is the same as the CEC measured using a batch technique for with ammonium acetate at pH 7 in a separate experiment (mean ± σ: 152 ± 9 mmol/kg). Total release of Na^+ was 101 mmol/kg.

The break curve of NH_4^+ through a biochar column after long-term treatment with acetic acid buffer indicates that the adsorption/uptake of NH_4^+ by the treated biochar was greater than release of Na^+ (Fig. 5 Appendix I). However, cumulative uptake and release of both cations was greater. Total NH_4^+ uptake was 225 mmol/kg, compared with 158 mmol/kg before long-term treatment, and total release of Na^+ was 168 mmol/kg, compared with 101 mmol/kg before treatment. This suggests that the long-term column rinsing oxidized sites at the biochar surfaces and increased cation exchange sites. This may be one means by which oxidized acidic functionalities of biochar increase with residence in soil. A similar rinsing experiment with buffered dilute $HClO_4$ is planned, with the idea being to simulate oxidation by microbial activity.

Relative breakthrough curves of nitrate (NO_3^-), Chloride (Cl^-), Phosphate (PO_4^-) and urea through biochar columns are presented in Fig. 6, Appendix I. Chloride is the typical non-interacting tracer. The results show that none of the anionic species have any interactions with biochar. On the other hand, urea does exhibit limited adsorption by the biochar, although its retardation factor is not very high (R=1.33; R is the retardation factor defined as the ratio of the relative volume (V/V_o) at a relative concentration (C/C_o) of 0.5 to the same measure for the inert tracer. R of a non-adsorbing compound is unity).

Leaching of nitrate and ammonium through field soils - There were no significant differences in the net leaching of nitrate from any of the four treatments (3 replicate columns for each treatment) (Fig. 7, Appendix I). This figure takes into account leaching of nitrate from columns to which no NH_4NO_3 was added, as well as those which were dosed with NH_4NO_3. Twelve leaching curves for NH_4 are shown in Fig. 7, Appendix I. It can be seen that there are no significant differences in NH_4 leaching from any of the treatments, once variability between replicate columns is taken into account.

Israel Field experiment

Crop production

Sunflower biomass of above ground organs and seeds production (harvested in 19th September 2012) were not significantly affected by compost dose and no difference was obtained between conventional and organic treatments (Table 4, Appendix I). The N and P concentrations in the stem, heads and seeds were not significantly affected by the treatments, although a trend of increased N and P concentration in the stem and heads was obtained with elevating the compost dose from 20 to 40 m^3 ha^{-1} (Table 5, Appendix I). The stem K concentration was significantly lower in the conventional than the organic treatments. The highest stem N concentration and the lowest heads P concentration were obtained in the conventional treatment. The total N, P and K taken up by the above ground organs of sunflower were not affected by compost dose (Table 5, Appendix I). The P and K uptake in the conventional treatment were lower than in the organic treatment.

No significant effects of the compost dose on vetch biomass and N, P and K uptake by the above ground organs were observed (Table 6, Appendix I). Note that compost wasn't applied after sunflower harvest, therefore just the residual effect of compost applied before sunflower seeding could be examined. Vetch was the first crop that was sown after the biochar application. The biomass of the vetch was significantly reduced by the biochar application from 11.6 to 9.0 ton ha^{-1} and the N, P and K uptake were also reduced in the same proportion. No interactions of the biochar treatment with the compost dose treatments were obtained.

No significant effect of the compost dose on wheat aboveground biomass, N and P concentrations and uptake by the aboveground organs was obtained, whereas K concentration in the highest compost dose treatment was significantly higher than in the conventional treatment (Table 7, Appendix I). Wheat was the second crop that was sown after the biochar application. The biomass of wheat increased significantly by the biochar, opposite to the effect of the biochar on vetch. No effect of biochar on N, P and K concentrations were observed, consequently the total uptake of these elements by wheat significantly increased by the biochar application. No interactions of the biochar treatment with the compost dose treatments were obtained. The reasons for the positive and negative effects of biochar application on vetch and wheat yields are not clear.

Main Soil measurements

Soil Chemical properties

The contents of organic C and N in top soil layers (0-5 cm, 5-15 cm and 15-30 cm) of the two extreme composts treatments, 0 and 60 m^3 ha^{-1} were determined 4 times, from June 2010 to May 2013. The organic C content in the 0-5 cm top layer of the highest compost dose increased from 1.4% to 2.4% at the last sampling date whereas in the control a slight increase to 1.6% was observed (Fig. 8, Appendix I). Similar differences between the control and the highest compost treatment were observed in the 5-15 cm layer, whereas smaller differences between these treatments were determined in the 15-30 cm layer. The effects of the highest compost dose on organic soil N content in comparison to the control is very similar to the effect on organic C described above, just the values of organic C are 10 times higher than that of organic N. The total difference in soil organic C and N contents in the 0-30 cm top layer between the highest compost dose and the control treatment are 17.90 and 1.64 ton ha^{-1}, respectively.

The effects of biochar without and with 60 m^3 ha^{-1} on the extractable (1N KCl) nitrate and ammonium concentrations in the soil profile is shown in Fig. 9 (Appendix I). In all treatments ammonium concentrations decreased with depth from 16-24 to 4-10 mg kg^{-1}, with small and inconsistent differences between treatments. Nitrate in the top layers (0-30 cm) was significantly higher in the biochar treatment, whereas no significant effect of the compost amendment was obtained. The soluble K and the available P (Olsen extract) were significantly higher in the 60 m^3 ha^{-1} compost treatment than control, whereas biochar amendment had no effect in May 2013, whereas it reduced the P availability in November 2013 in the 60 m^3 ha^{-1} compost treatment (Fig. 9, Appendix I).

The effects of compost dose on the change in the content of soluble K and available P (Olsen extract) in 0-30 cm depth as function of time from the beginning of the treatments to May 2014 is shown in Fig. 10 (Appendix I). No consistent change of the available P with time was observed from June 2010 to May 2014, however a clear increase of the available P with compost dose was observed in all sampling dates from April 2012 to May 2014. The soluble K was significantly higher in compost treatments than the conventional treatment without K fertilization, whereas the differences between compost levels weren't significant in all sampling dates from April 2012 to May 2013. In the last sampling date on May 2014, the available P in the 20 and 60 m^3 ha^{-1} were significantly higher than the conventional treatment without compost, however no difference was obtained between the 40 m^3 ha^{-1} and conventional treatment.

The soluble Na, Cl and EC in 0-30 cm depth as function of time from the beginning of the treatments to May 2014 are shown in Fig. 11, Appendix I. Changes in EC and Na as a function of time were similar and were related to compost application and season. Both variables showed significantly higher values as the compost dose increased from the control to the highest compost dose while the two median doses were intermediate, not different from each other. Cl concentrations were no affected by treatments, except Dec 2012, probably because the main source of salinity in the compost isn't salts of Cl.

The exchangeable K expressed as EPP decreased with depth for all compost treatments (Fig. 12, Appendix I). The maximum difference between compost treatments was observed at the top 0-5 cm and it decreased with depth until no difference was obtained at 60 cm depth. The total difference in exchangeable K content in the 0-60 cm top layer between the 20, 40 and 60 m^3 ha^{-1} and the control treatment are 714, 701 and 1102 kg ha^{-1}, respectively.

Physical properties of undisturbed soil samples

The bulk density of the soil wasn't affected by compost dose with and without Biochar, whereas biochar application significantly reduced the bulk density from 1.09 to 1.03 g cm^3, and no interaction between the two factors was obtained (Table 8, Appendix I). The reduction in soil density by biochar application was expected to increase soil porosity and the water holding capacity at saturation (0 Kpa). However the volumetric water content at saturation (θ_{sat}) was reduced by biochar application from 53.7 to 49.1 ($p<0.01$), whereas it was not influenced by the application of compost, and a significant interaction of the two factors was obtained. At field capacity (33 Kpa), no significant effects of biochar and compost applications on the volumetric water content (θ_{fc}) were observed. At wilting point (1500 Kpa) the volumetric water content (θ_{sat}) was not influenced by the application of compost, whereas biochar application reduced θ_{sat} from 29.0 to 26.3 ($p<0.01$), and no significant interaction of the two factors. Biochar application increased the available water (the difference between field capacity to wilting point) than it by 2.7 cm^3 cm^{-3}, whereas the difference between saturation to wilting point decreased from 24.7 to 22.8 cm^3 cm^{-3}.

The results of aggregate stability measurements of soil samples taken on May 2014 from the 0-15 top layer indicate that there was no difference in treatments when the aggregates were subjected to stirring + ultra-sonication, probably because the level of energy applied was excessive (Fig. 13, Appendix I). However, during the stirring alone differences among the treatments were noted. Results of a single factor ANOVA tests revealed that: 1. Aggregates in the 6 m^{-3} compost treatment exhibited a significantly higher stability than those from the control with and without biochar treatments. 2. Aggregates from the 6 m^{-3} compost treatments with and without biochar had a comparable stability. 3. Aggregates from the 6 m^{-3} compost with biochar exhibited a significantly higher stability than those from the control treatment without biochar, but not from the aggregates of the control with biochar treatment. 4. Aggregates from the control with and without biochar treatments had a comparable stability.

Simulation of Soil Organic C by RothC model

Previous modeling with RothC of data from semiarid sites, that included those with a fallow in the rotation, required an unrealistically high carbon input to the soil. Thus, modification were made because in semiarid regions soil water content can decrease below wilting point due to the very high evaporation rate, which is enhanced by the formation of desiccation cracks, particularly in vertisols. For this reason, in this site we used the model RothC10_N, a version of the model RothC modified for the simulations in dry arid and semiarid regions (Farina et al., 2013).

As in the Monsampolo site, the first step to run the model is the preparation of all input files: weather, land management (yearly), setup file. The model was first run iteratively to equilibrium to generate the input required to match the initial stock of soil organic carbon. Then, it was run including crops and soil management. The information on the Israeli site before 2009, when the cultivation of vetch started, wasn't available, at the moment of the simulation. However, the site, as it is common in these areas, was probably fallow, with sparse vegetation. From 2009, the cropping sequence was: vetch (as cover crop), winter wheat, maize, sunflower. For all the crops, the C input to soil was calculated using the formulas in Table 1, Appendix II. The initial carbon content measured in 2009 was used to initialize the simulation.

Initially simulations were made without considering the addition of compost, in order to detect the potential mineralization/sequestration of the soil. The emissions of C as CO_2, under standard conditions (average site weather and climate) is 2.18 t ha^{-1} yr^{-1}. This means that to increase the soil OC we need to input more than this quantity of C.

After having assessed the potential capacity of soil to store C, we tested the effect of compost addition. The ratio between decomposable and resistant plant material (DPM/RPM) was set at 0.21 for compost (is 1.44 for herbaceous residues and 0.45 for farm yard manure) and we considered a 3% C content. The simulations showed a remarkable effect of compost addition on the increase of C content, while the incorporation of the cover crop had a smaller effect (Fig. 14, Appendix II).

Soil suppressivity tests

In the spring of 2013 compost application had no any beneficial effect on soil resilience to the pathogen in comparison to the control, whereas increasing the dose of compost from 20 to 60 m3/ha enhanced suppressivity (Fig. 15, Appendix I). In the spring of 2014 no significant effect of the biochar and the compost treatments on the suppressiveness of the soil was found. These results contradict our hypothesis based on our own previous experience and other publication (Yogev et al., 2011). More work should be done to elucidate possible factors that lead to these results.

Discussion Israel experiments

Nitrogen, phosphorus and potassium balances for the period May 2010 to May 2014 was calculated based on the following data: Input - compost application to organic treatments on 25.5.2010 (all treatments 60 m^3 ha^{-1}), and three rates (20, 40 and 60 m^3 ha^{-1}) on 13.6.2011 and 2.4.2012; fertilizer applications to the conventional treatment on 11.11.2010, 13.6.2011 and 25.3.2012; Soil content (0-60 cm) of inorganic available N, available P (Olsen extract) and soluble K (1:5 soil:water extract) on 8.6.2010. Output – above ground content at harvesting of Wheat, Corn, Sunflower and Wheat on 4.5.2011, 2.10.2011, 19.9.2012, and 9.4.2014, respectively; Soil content (0-60 cm) of inorganic available N, available P (Olsen extract) and soluble K (1:5 soil:water extract) on 1.5.2014. We assumed that the soil data of the conventional treatment (without compost) on 8.6.2010 represents the initial content of the nutrients in all treatments.

The calculation of N balance showed a negative balance (103 kg ha^{-1}) in the conventional treatment, whereas compost application led to positive balance that increased from 721 to 1577 kg ha^{-1} as the compost dose increased from 20 to 60 m^3 ha^{-1} (Table 9, Appendix I). The unbalanced N is indication to N depletion in the conventional treatment and enrichment of organic soil N in the organic treatments. Other processes that can contribute to the positive N balance in the organic treatments are N loss by leaching, runoff and emissions of N gases. The calculated difference in soil organic N content between the highest compost dose treatment and the conventional treatments on May 2013 was 1640 kg ha^{-1}, whereas the difference in the N mass balance between these treatments was 1680 kg ha^{-1}, very close values indicating soil enrichment in the organic treatments and soil depletion in the conventional treatment as the main mechanism for the difference between the treatments. The relative small depletion of N in the conventional treatment indicates that the N dose by fertilizer was very close to the crops demands.

The calculation of P balance showed a small negative balance (25 kg ha^{-1}) in the conventional treatment whereas compost application led to positive balance that increased from 697 to 1330 kg ha^{-1} as the compost dose increased from 20 to 60 m^{3} ha^{-1} (Table 10, Appendix I). The unbalanced P indicates P depletion in the conventional treatment and enrichment of unavailable soil P in the organic treatments. Other processes that can contribute to the positive P balance in the organic treatments are P loss by leaching and runoff. However, the low mobility of P in soil indicates that the main mechanisms are inorganic mineral P transformations to lower solubility forms and fixation by microorganisms to less available organic forms. Note that the consumption of N by plants is higher than 5 times that of P, whereas the enrichment of the soil by P is in the same order of magnitude as N enrichment. The overdose of P by organic residues application to soil is well known. Adjustment of compost dose to P demand should be considered to eliminate nutritional problems due to excess P.

The calculation of K balance showed negative balance (404 kg ha^{-1}) in the conventional treatment, whereas compost application led to positive balance that increased from 1076 to 2483 kg ha^{-1} as the compost dose increased from 20 to 60 m^{3} ha^{-1} (Table 11, Appendix I). The unbalanced K indicates K depletion in the conventional treatment and enrichment of exchangeable soil K in the organic treatments. Other processes that can contribute to the positive K balance in the organic treatments are K loss by leaching, runoff and fixation by clay minerals. The depletion of soil K in the conventional treatment indicates that K fertilization should be considered for sustainable soil management and the overdose of K in the organic treatments should also be considered.

As expected, compost application at the tested level leads to improvement in aggregate stability measurements in 2014; whereas no effect on bulk density and water holding capacity was obtained in measurements done a year earlier. Biochar application had mixed effects on the physical properties of the soil: I. it did not contribute to aggregate stability, II. it reduced bulk density and III. It increased water holding capacity.

We expected interactive effects of compost and biochar on soil physical properties, however none has been obtained. Further research should focus on the combined effects of wider range of biochar and compost types for longer time.

The results of the incubation and columns studies demonstrate that the addition of the biochar in this soil did not have any impact on N transformations and transport behaviour of either nitrate or ammonium. These results stand in contrast to recent reports that biochar additions can have substantial effects on N transformations and NO_3 behaviour in soils. Consequently, it is necessary to examine what is different about the studied systems in contrast to previous works.

The suppressivity test of the Israeli soil didn't approve our assumption that organic management improve soil suppressiveness of soil born plant pathogens. It indicates that the suppressiveness effect of compost is dependent of environmental conditions and it is not general for all conditions and pathogens.

The simulation by RothC model was found as a powerful tool for prediction of compost application and cover crop on soil organic C. We will further validate it by comparing prediction with additional soil samples from May 2014, including intermediate compost doses, which are being conducted. We will also use the model for predicting long run effects of the studied and hypothetical scenarios.

Italy Results

Field Experiment Italy

The main phenological and productive data of melon are reported in Table 2, Appendix II. Both cover crop management and compost dose had significant effect on melon yield, but the compost had no significant effect on the marketable yield. Moreover, the yield per plant for both total and marketable production showed a significant interaction of both factors.

The analysis of the data regarding the cover crop management factor showed that green manure treatment had the best performance and roller crimper the worst. In particular, the yield and the number of fruits per plant in the roller crimper treatment were less than 50% of the yield of green manure. All parameters measured for the evaluation of the fruit quality (weight, size, thickness of the skin, thickness of the pulp, size of the internal cavity etc.) (data not reported) confirmed the lower performances of roller crimper. Less evident was the effect of compost dose, being the yield differences significant only in comparison with the control (zero compost), whereas no significant differences were observed comparing the two doses (15 and 30 t d.m. ha^{-}

^{1}). More in depth analysis on the interactions between the two factors of our experiment on crop yield is in progress.

Soil temperature trends during melon cropping cycle are reported in Fig. 2, Appendix II. They clearly showed that the dead mulch, obtained by the roller crimper, preserved soil by direct solar radiation determining an average temperature which is of 4-5°C below the other two treatments.

The above ground biomass at barley termination resulted 11.2 and 15.1 t ha^{-1} for the green manure and roller crimper treatments, respectively. At harvest, the remained barley above ground biomass in the roller crimper treatment was 5.5 t ha^{-1} and was not affected by the compost doses.

The weed above soil biomass measured at melon initial flowering was reported in Table 3, Appendix II. Cover crop management strongly influenced the weed growth while no significant differences among the compost treatments were observed.

Total soil carbon field average value (measured at the beginning of the experiment in the no barley plots, before compost application) was 11.819 ± 1.287 g kg^{-1} and the values measured at the end of the experiments are reported in Table 3. Cover crop strongly enhanced SOC and the highest impact was of green manure. As expected, SOC value increased with the dose of compost applied.

The mineral N of the no barley, green manure barley and roller crimper barley treatments (average value among all the compost doses and all the sampling times) were 36, 27 and 22 mg kg^{-1}, respectively with statistically significant differences. Compost application had significant effect on the soil mineral N (average value among all the cover crop management treatments and all the sampling times) but the order of the obtained SOC didn't follow the order of compost dose, 28, 32 and 25 mg kg^{-1} for the 0, 15 and 30 t ha^{-1}, respectively.

Since for this parameter we found a significant cover crop management x compost interaction ($p \leq 0.05$), the results were divided by cover crop management. In Figure 3 (Appendix II) the compost effect for each single cover crop management treatment along the melon cropping is shown. For the compost dose treatments, mineral N increased along the cropping cycle in the no barley and in the green manure barley and in the first part of the cropping cycle in the roller crimper barley treatment. Moreover, in the no barley management, mineral N showed lower values in the compost 30 and intermediate and lower values in the compost 15 and compost 0 treatments, respectively. Differently, in the green manure and roller crimper barley managements, the highest mineral N values was shown by the compost 15 treatment and lower, similar values were obtained for the compost 0 and compost 30.

As far as the physical and hydrological parameters are concerned, the analysis of the results was performed by grouping the two cover crop treatments (green manured and roller crimper barley) under the only “barley” treatment, because, at the time of sampling (March-May 2012), the crop was in the growing season, and didn’t show any difference for different types of management treated by the experimental design.

The results obtained with the Mean Weight Diameter (for the determination of the Surface Aggregate Stability) for the different experimental conditions (Fig.4, Appendix II) showed a general effect of increase in aggregate stability which was significant for the treatment of 15 t ha^{-1} of compost, but not for the 30 t ha^{-1} one. No difference appears between the two cover crop treatments.

The analysis with the GMD index (Fig.5, Appendix II) showed the same trends and the same significant effects only for the compost 15 t ha^{-1} treatment.

The results of measurements of the soil dry bulk density are shown in Fig. 6 (Appendix II). No significant differences were shown neither for the compost and cover crop treatments. We expect to observe significant differences in a period of time longer than a few months, as a consequence of more intimate organic matter incorporation in the mineral matrix.

The trends of water retention curves measured at negative pressure (water potential expressed as tension) for seven steps (0, 10, 20, 30, 100, 500 and 1500 kpa) were measured only for the different treatments of compost. The results are reported for three main pF benchmark points, corresponding to Saturation (SAT, 0kpa), Field Capacity (FC, 30kpa) and Witling Point (WP, 1500kpa) (Fig. 7, Appendix II).The results showed a significant difference only for the 30 t ha^{-1} of compost at the saturation point, but not for the other pF points. This is, as expected, the early effect of organic matter addition, but not yet incorporated in the soil structure. No effect of compost dose was observed at higher soil water tension.

As consequence, the Available Water Capacity, that is the water content available in the Field Capacity – Wilting Point range, calculated for the whole depth of the first soil horizon Ap$_1$, doesn’t show any significant difference for the compost treatments, as shown in Table 4 (Appendix II).

Infiltration rate measurements were performed to estimate initial surface infiltration rate at field soil moisture conditions, until the achievement of the equilibrium with constant water flux, to measure the saturated hydraulic conductivity (K_{sat}). The results are reported in Fig. 8 (Appendix II.), that shows the K_{sat} vaules for all the cover crops and compost rates. The values of K_{sat} show a significantly decrease for both the 15 and 30 t ha^{-1} compost addition rates. No remarkable and significant effects were observed for the cover crop treatments. As previously observed also in this case the 15 t ha^{-1} rate seems to have stronger impact, in terms to better reduce the surface rate of infiltration.

Roth model - Calibration and Simulation

a) *Calibration of the model*

The ability of the model to perform a good simulation can be evaluated through the use of several statistics. two types of statistics were selected: 1) the relative root mean square error (RMSE) based on the differences among measured and simulated value, and 2) the Pearson's correlation coefficient based on correlation between measured and simulated data. The formulas, the range of values and significance of the tests used to evaluate model performance are presented in Table 5 (Appendix II).

Figure 9 (Appendix II) shows clearly how the simulated and measured data have very similar trends. This is confirmed also by the values of RMSE that is 2%. Since there is not a threshold standard value for RMSE allowing for an objective evaluation of the goodness of the index, we assumed that RMSE expressed as a percentage of the average of the observed values, should be under an error of 5% total difference. The correlation between measured and simulated values is very high (r=0.87), denoting that there is a strong correlation between modeled and simulated data (Fig. 10, Appendix II).

b) *Simulation of the effect of composting on soil C level*

After calibration and validation of the model, it was possible to use it to predict how soil and crop management could affect soil C storage in soil. The effect of two levels of compost addition, i.e. 15 and 30 t ha^{-1} , every 4 years, at 3% C, compared with the business as usual (BAU) scenario are shown in Fig. 11 (Appendix II). Apparently in the BAU conditions the C content of soil will increase in average by about 0.5 t $ha^{-1}y^{-1}$, while the addition of compost every 4 year would allow for increase of 0.77 and 0.82 t $ha^{-1}y^{-1}$ for 15 and 30 t ha^{-1}, respectively.

Suppressivity tests

Italian soil samples - No significant effect of the cover crops or of the compost on the suppressiveness of the soil was found (Tukey-Kramer HSD, $P<0.05$. Cover crop served as blocks) (Fig. 13).

Discussion

During the first year of the research (in field 1), lower soil temperature of roller crimper treatment was observed. These results were observed also during the second year of the research (field 2). The lower temperature in RC is considered the main responsible of the slower fruit development observed during the whole melon cycle, either in field 1 and 2, respect to the other two treatments. Melon is sensitive to soil temperature, taking advantage of high soil temperature. For this reason, black plastic mulch is a common practice for melon in Italy.

As expected, the barley strongly contributed to control weeds during the melon cropping cycle and, in particular, the roller crimper technique used to terminate the cover crop was highly effective, completely preventing the weeds germination and growth. The RC treatments at all doses of compost, significantly reduced the amount of weeds in terms of biomass and the nutrient competition with the cash crop determined by their growth (significantly lower amount of N uptaken respect to the other cover crop management). The lack of the cover crop in the fallow treatment was the main reason of the N deficit of the system at compost 0 dose.

Both the factors studied influenced the total C input, enhancing soil C storage. In any case, soil C content was significantly higher compared to other treatments just in RC and GM at higher compost dose (compost 30).

The barley cultivated in autumn-winter always reduced the available mineral N for the next melon crop probably because the cover crop uptakes the element during its cropping cycle. However, the green manured barley, the biomass of which was completely incorporated into the soil at the beginning of the melon cropping cycle, returned - by mineralization - a larger share of the previously uptaken N to the melon soil – plant system respect to the roller crimper barley (which was left on the soil surface).

Respect to the previous year, no lower values of mineral N were observed for compost 30 treatment and so no evidences of N immobilization process can be hypothesized. Nitrogen deficit was observed only for FA at compost 0. In this case, the absence of cover crop and compost do not allow the system to compensate the amount of N uptaken by the weeds.

RothC10N showed to be able to simulate the organic cropping system, even though at high level of compost model's predictions are somehow less precise that other situations. Probably this is due to the fact that interactions and synergic effects are not considered in the model code, where degradation processes are simulated using first order kinetic.

As far as the physical and hydrological parameters are concerned, we have observed also in the second year of the project that the treatment with 15 t ha^{-1} of compost seems more efficient to induce an increase of aggregate stability, respect to other compost doses. On the other side, from the analysis carried out on field 1 to verify the residual effect of treatments on soil physical and hydrological parameters, it was observed that the compost effect was not persistent.

Conclusions

The overall results obtained indicated that the application of the intermediate dose of compost (i.e. 15 t ha^{-1} as compost dry matter) and the simultaneous introduction of a properly managed cover crop represents an effective trade-off among advantages (i.e. increment of soil organic carbon stock, weed control, NO_3^--N leaching risk reduction) and constrains (N availability reduction), increasing the sustainability of cropping systems.

Publications

As decided during the meeting held in Israel, some of the results obtained in the first year of the project were utilized for writing a scientific paper published in the Proceedings of the 4th ISOFAR Scientific Conference 'Building Organic Bridges', at the Organic World Congress 2014, 13-15 Oct., Istanbul, Turkey (see references). Another paper, on the simulation of soil C trends in organically managed vegetable cropping systems in Mediterranean areas, is in progress.

Description of cooperation

In the Italy –Israel project, the Italian group of research carried out, as joint activity, a simulation, by RothC model, for the prediction of soil C content and dynamic in the Israeli experimental site. The Italian team also conducted measurements of physical properties (bulk density and water holding capacity at several tension points) in undisturbed soil samples from the top soil in Israel. The Israeli team conducted suppressivity tests to soil samples from the

Italian experiment. Mutual discussions on the findings from both countries were carried out during the meeting in Israel and through frequent mail correspondence.

Meetings held in Israel and Italy

A two-day meeting was held in Israel, on the 18th and 19th of March 2013. The first day in the Volcani Center, Bet-Dagan and the second day in Newe Ya'ar research station. The main aims of this meeting were to give the Italian scientists the opportunity of visiting the Israeli research centers and the experimental field, sharing information regarding the project in both countries and enhancing the cooperation between the participants from both countries. Each project participant were asked to present background, objectives and the results of the first year of the project.

Last 17th of January 2014 a one-day meeting was held in Rome, with the participation of the components of Italian Group of Research. The main aim of the meeting was to share and discuss the results obtained during the second year of the project and regarding either the residual effect of treatments implemented in 2012 and the effects of treatments applied in 2013.

The last joint meeting of the Israelian and Italian Group was held on the 7th of October 2014, at CRA-RPS Headquarter in Rome.

סיכום עם שאלות מנחות

מטרות המחקר תוך התייחסות לתוכנית העבודה.

מטרת העבודה הכללית היא לשפר את פוריות הקרקע לטווח ארוך ע"י ממשק משמר קרקע מבוסס על יישום קומפוסט בשילוב עם ביו-פחם או גידולי כיסוי.

עיקרי הניסויים והתוצאות: המדידות והניסויים התבצעו כמתוכנן. באיטליה נמצא שהשילוב בין רמת הקומפוסט הבינונית (15 טון\הקטאר) במשולב עם גדול שעורה כצמח כיסוי היה הטיפול הטוב ביותר העונה על הדרישה לחקלאות ברת קיימא לפי המדדים הבאים: הגדלת תכולת הפחמן האורגני בקרקע, מניעת התפתחות של עשבים רעים, הקטנת הסיכון של שטיפת חנקה והקטנת המגבלה של ירידה בזמינות החנקן. ישראל –לא התקבלה השפעה מובהקת של טיפולי הקומפוסט על היבול של תירס, חמניות, בקיה וחיטה, אך התקבלו השפעות מובהקות על קליטת אשלגן על ידי החיטה ועל מדדי קרקע הבאים: עליה בריכוזי הפחמן והחנקן האורגנים, האשלגן המסיס והספוח והזרחן הזמין לצמחים בשכבות הקרקע העליונות עם הגדלת מנת הקומפוסט. מאזן היסודות חנקן, זרחן ואשלגן בטיפולים השונים בשדה מצביע על דלדול בטיפול הקונבנציונאלי לעומת עליה בהצטברות שלהם בקרקע ככל שמנת הקומפוסט גבוהה יותר. התקבלה התאמה טובה בין ההפרש במנת החנקן המצטברת בטיפול הקומפוסט הגבוה לטיפול הקונבנציונאלי להפרש בכמות החנקן האורגני המדוד בקרקע בטיפולים אלו. מנת הקומפוסט הגבוהה הגבירה את יציבות התלכידים לעומת הביקורת. יישום ביו-פחם גרם לירידה ביבול הבקיה אך הגדיל את יבול החיטה והשפיע על מדדי הקרקע הבאים: הקטין את צפיפות הקרקע ותכולת המים הנפחית ברוויה ובנקודת הכמישה בשכבה העליונה, אך לא הייתה השפעה ברורה ומובהקת על יציבות התלכידים. בשני האתרים הטיפולים לא השפיעו על כושר הדיכוי של מחלות צמחים. סימולציה של הפחמן האורגני בקרקע – הסימולציה של נתוני הקרקע והטיפולים באיטליה הראתה התאמה טובה של המודל לתוצאות מדודות מהעבר והצביע על כך שצפויה השפעה ניכרת של הטיפולים על מצב הפחמן האורגני בקרקע בשנים הבאות. נמצאה גם התאמה טובה של תוצאות הסימולציה לשינויים בריכוזי הפחמן האורגני בקרקע בישראל בטיפולי הביקורת ורמת הקומפוסט הגבוהה ביותר.

מסקנות מדעיות וההשלכות לגבי יישום המחקר והמשכו. האם הושגו מטרות המחקר לתקופת הדוח?

המסקנות העיקריות מהמחקר באיטליה הן ששילוב של מנת קומפוסט בינונית (15 טון\הקטאר) עם גדול שעורה כצמח כיסוי הוא הטיפול הטוב ביותר העונה על הדרישה לחקלאות ברת קיימא. המחקר בישראל הראה שככל שמנת הקומפוסט גבוהה יותר (עד הרמה המירבית של 30 טון\הקטאר) עולה תכולת הפחמן והחנקן האורגנים בקרקע לעומת דלדול הקרקע בטיפול הקונבנציונלי, עולה זמינות האשלגן בקרקע וקליטתו על ידי הצמחים וחל שפור במבנה הקרקע. לעומת זאת לא נמצאו השפעות ברורות ומובהקות של טיפול יישום ביו-פחם על הקרקע ואילו השפעתו על היבולים היו מנוגדות בצמחים שונים. מטרות המחקר בנושא השפעת הגומלין של קומפוסט עם ביו-פחם לא הושגו בטווח הזמן של שנתיים ויש צורך בהמשך המחקר בתחום זה. השימוש במודל RothC הצביע על ההשפעה החיובית לטווח ארוך של המשך יישום קומפוסט ושל שילוב קומפוסט עם גידול כיסוי על הפחמן האורגני בקרקע. בשיטת המבחן שבה השתמשנו לבחינת השפעת הטיפולים על עמידות הצמחים למחלות לא

מצאנו השפעה חיובית של טיפולי הקומפוסט וגדולי הכיסוי ושל יישום ביו-פחם על דיכוי מחלות צמחים.

בעיות שנותרו לפתרון ו/או שינויים (טכנולוגיים, שיווקיים ואחרים) שחלו במהלך העבודה; התייחסות המשך המחקר לגביהן, האם יושגו מטרות המחקר בתקופה שנותרה לביצוע תוכנית המחקר?

יש להמשיך במחקר שדה לטווח ארוך לבחינת ההשפעות הגומלין של קומפוסט עם ביו-פחם על הקרקע ועל היבול. בנוסף יש לחקור את הקשר בין תכונות הביו-פחם והשפעתו על הקרקע ועל הצמחים בניסויי מעבדה ושדה. נושא השפעת הקומפוסט, גידולי כיסוי וביו-פחם על דיכוי מחלות קרקע דורש פיתוח מבחנים נוספים ומתאימים יותר.

הפצת הידע שנוצר בתקופת הדו"ח: **פרסומים בכתב** - ציטוט ביבליוגרפי כמקובל בפרסום מאמר מדעי; **פטנטים** - יש לציין שם ומס' פטנט; **הרצאות וימי עיון** - יש לפרט מקום, תאריך, ציטוט ביבליוגרפי של התקציר כמקובל בפרסום מאמר מדעי.

התוצאות הוצגו בכנס בינלאומי לחקלאות אורגנית באינסטנבול באוקטובר 2014. תוצאות המחקר בישראל הוצגו בישראל בכנסים מקומיים: הרצאה בכנס האגודה הישראלית למדעי הקרקע בדצמבר 2013, שתי הרצאות ביום עיון של המכון למדעי הקרקע מים והסביבה על הקרקע כמשאב בדצמבר 2013. במשך השנה הקרובה נכין את תוצאות ניסוי השדה בישראל לפרסום בעיתונות בינלאומית מבוקרת.

פרסום הדוח: אני ממליץ לפרסם את הדוח: (סמן אחת מהאופציות)

➢רק בספריות

➢**ללא הגבלה (בספריות ובאינטרנט)**

➢חסוי – לא לפרסם.

האם בכוונתך להגיש תוכנית המשך בתום תקופת המחקר הנוכחי? אנו נבחן את האפשרות לבקש הארכת התוכנית ל 3 שנים נוספות, אם ייצא קול קורא מתאים.

Relevant Bibliography

Bonanomi, G., Antignani, V., Capodilupo, M. and Scala, F. 2010. Identifying the characteristics of organic soil amendments that suppress soilborne plant diseases. Soil Biology & Biochemistry 42 (2): 136-144.

Chan, K.Y., Van Zwieten, L., Meszaros, I., Downie, A., Joseph, S. (2008) Using poultry litter biochars as soil amendments. Australian Journal of Soil Research 46:437-444

Coleman, K., D. S. Jenkinson. 1996. RothC-26.3 – A model for the turnover of carbon in soil. In: Powlson, D.S., Smith, P., Smith, J.U. (Eds.), Evaluation of soil organic matter models using existing, long-term datasets. NATO ASI Series I, vol. 38. Springer, Berlin, pp. 237-246.

Coleman, K., D. S. Jenkinson, G. J. Crocker, P. R. Grace, J. Klír, M. Körschens, P. R. Poulton, D. D. Richter. 1997. Simulating trends in soil organic carbon in long-term experiments using RothC-26.3 Geoderma 81:29-44

Cooper, J.M., Schmidt, C.S., Wilkinson, A., Lueck, L., Hall, C.M., Shotton, P.N. and Leifert, C. (2006) Effect of organic, 'low-input' and conventional production systems on disease incidence and severity in winter wheat. *Aspects of Applied Biology* 80, 121-126.

Danga, B. O., Ouma, J. P., Wakindiki, I. C., and Bar-Tal, A. 2010. Chickpea - Wheat Rotation for higher production in a humid tropical region. *Agron. J.* 102:363-371

Darby, H.M., Stone, A.G. and Dick, R.P (2006) Compost and manure mediated impacts on soilborne pathogens and soil quality. *Soil Science Society American Journal* 70, 347-358.

Farina, R., K. Coleman, A.P. Whitmore. 2013. Modification of the ROTHC model for simulations of organic C dynamics in dryland regions. *Geoderma* 200-201, 18-30.

Ghorbani, R., Wilcockson, S., Koocheki, A. and Leifert, C**.** (2008) Soil management for sustainable crop disease control: a review. *Environmental Chemistry Letters* 6**,** 149–162.

Giotis, C., Markelou, E., Theodoropoulou, A., Toufexi, E.. Hodson, R.. Shotton, P., Shiel, R., Cooper, J. and Leifert, C. 2009. Effect of soil amendments and biological control agents (BCAs) on soil-borne root diseases caused by *Pyrenochaeta lycopersici* and *Verticillium albo-atrum* in organic greenhouse tomato production systems. European Jour. of Plant Pathology 123 (4): 387-400.

Glaser, B., Lehmann, J. and Zech, W. (2002). Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal - a review. *Biology and Fertility of Soils* 35, 219-230.

Graber, E.R., Meller Harel, Y., Kolton, M., Cytryn, E., Silber, A., Rav David, D., Tsechansky, L., Borenshtein, M. and Elad, Y. (2010) Biochar impact on development and productivity of pepper and tomato grown in fertigated soilless media. *Plant and Soil* 337, 481-496.

Gilmour, J.T., M.D. Clark, and G.C. Sigua. 1985. Estimating net nitrogen mineralization from carbon dioxide evolution. *Soil Sci. Soc. Am. J.* 49:1398-1402.

Heller, H., Bar-Tal, A., Tamir, G., Venterea, R.T., Chen, D., Zhang, Y., Clapp, E.C., Bloom, P. and Fine. P. 2010. Manure and Cultivation Effects on CO_2 and N_2O Emissions from a Corn Field. *J. Envir. Qual.* 39:437-448.

Joseph, S., Graber, E.R., Chia, C., Munroe, P., Donne, S., Thomas, T., Nielsen, S., Marjo, C., Rutlidge, H., Pan, GX., Li, L., Taylor, P., Rawal, A., Hook, J. (2013). Shifting Paradigms on Biochar: Micro/Nano-structures and Soluble Components are Responsible for its Plant-Growth Promoting Ability. *Carbon Management* 4:323-343.

Kluth, C., C. Buhre and M. Varrelmann (2010) Susceptibility of intercrops to infection with *Rhizoctonia solani* AG 2-2 IIIB and influence on subsequently cultivated sugar beet. Plant Pathology 59:683-692

Larkin, R. P., Honeycutt, C. W., Griffin, T. S., Olanya, O. M., Halloran, J. M. and He, Z. Q. 2011. Effects of different potato cropping system approaches and water management on soilborne diseases and soil microbial communities. *Phytopathology* 101 (1): 58-67.

Lehmann, J., and Joseph, S., eds. (2009) "Biochar for Environmental Management, Science and Technology." Earthscan, UK.

Markakis E.A., Tjamos, S.E., Chatzipavlidis I., Antoniou, P.P. and Paplomatas E.J. (2008) Evaluation of compost amendments for control of vascular wilt diseases. *Journal of Phytopathology* 156, 622-627.

Raviv, M., Oka, Y., Katan, J., Hadar, Y., Yogev, A., Medina, Sh., Krasnovsky, A. and H. Ziadna (2005). High-nitrogen compost as a medium for organic container-grown crops. *Bioresource Technology* 96: 419-427.

Silber, A., Levkovitch, I. and Graber, E.R. (2010) pH-Dependent Mineral Release and Surface Properties of Cornstraw Biochar: Agronomic Implications.Environmental Science & Technology, 44:9318-9323.

Steiner C, Glaser B, Teixeira W G, Lehmann J, Blum W E H and Zech W 2008 Nitrogen retention and plant uptake on a highly weathered central Amazonian Ferralsol amended with compost and charcoal. J. Plant Nutr. Soil Sci. 171, 893-899.

Steiner C, Teixeira W G, Lehmann J, Nehls T, de Macedo J L V, Blum W E H and Zech W 2007 Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. Plant Soil 291, 275-290.

Tsechansky, L. and Graber E.R. (2014). Methodological limitations to determining acidic groups at biochar surfaces via the Boehm titration. Carbon, 66: 730-733.

Verheijen, F.G.A., Jeffery, S., Bastos, A.C., van der Velde, M. and Diafas, I. (2009) Biochar Application to Soils - A Critical Scientific Review of Effects on Soil Properties, Processes and Functions, Luxembourg.

Yogev, A., Raviv, M., Hadar, Y., Cohen, R. and Katan, J. (2006) Plant waste-based composts suppressive to diseases caused by pathogenic *Fusarium oxysporum*. *European Journal of Plant Pathology* 116, 267-278.

Yogev, A., Raviv, M., Hadar, Y., Cohen, R., Wolf, S., Gil, L. and J. Katan (2010) Induced resistance as a putative component of compost suppressiveness. *Biological Control*. 54, 46-51.

Appendix I

Newe Ya’ar, Israel

Table 1. Initial soil properties of the top soil layer (0-15 cm), NeweYa'ar (May 2009).

Property	**Units**	**Newe Ya'ar**
Clay	g/ kg	587
Silt	g/ kg	332
Sand	g/ kg	81
CaCO3	g/ kg	15
Organic C	g/ kg	12.6
Organic N	g/ kg	1.35
C/N		9.3
CEC	meq/ 100g	61

Table 2. Properties of the composts applied in spring (2010 - 2014), Newe Ya'ar

Property	**units**	**2010**	**2011**	**2012**	**2014**
Bulk density	**g cm^{-3}**	0.715	0.780	0.774	0.542
Dry Matter	**%**	68.0	72.1	67.1	77.6
Organic matter	**% w/w**	47.5	46.0	40.0	45.9
Organic carbon	**% w/w**	27.9	27.1	23.5	25.5
Organic nitrogen	**% w/w**	1.94	1.74	1.68	1.98
C/N		14.4	15.6	14.0	12.9
Total P	**% w/w**	1.24	0.89	1.21	1.40
Total K	**% w/w**	3.38	3.28	2.43	2.32
Water Extracted 1/10					
pH		8.7	8.2	7.5	7.2
EC	dS m^{-1}	10.06	9.80	9.20	9.72
$N\text{-}NO_3^-$	mg l^{-1}	2310.0	848.4	196	3.4
$N\text{-}NH_4^+$	mg l^{-1}	322.0	778.4	392	16.8
Ratio $N\text{-}NO_3^-$ / $N\text{-}NH_4^+$		7.18	1.09	0.50	4.94
K^+	$mmol_c$ l^{-1}	48.7	58.6	37.6	45.0
$P\text{-}PO_4^{-3}$	mg l^{-1}	40.0	51.1	65.4	68.3
Respiration rate	CO_2 mg/g DW/day	0.93	nd	0.90	2.18
Heat release rate	Joule g^{-1} DM/12 h	9.42	nd	10.3	

Table 3. Properties of the biochar applied in the field experiment, Newe Ya'ar 6.11.2012.

Property	**Units**	
Pyrolysis Temperature	^{O}C	600-800
Ash Content[a]	%	54.6±0.5
CEC (pH=7)	Meq/100g	28.8
pH		9.2
EC	dS m^{-1}	0.32
Elements Composition		
N	%	0.8±0.01
C	%	37.8±0.12
H	%	1.46±0.03
S	%	0
O	%	6.03±0.09

Table 4: The effect of compost dose on the number of flowers, dry biomass and seeds yield of sunflowers, Newe Ya'ar, 19.9.2012.

Treatment	Compost dose	flowers	stem	heads	Seeds	Ave. seed dry weight	total
	m^3 ha^{-1}	ha^{-1}	ton ha^{-1}	ton ha^{-1}	ton ha^{-1}	g	ton ha^{-1}
conventional	0	28200a	2.41a	1.65a	3.72a	131.9 a	6.99a
organic1	20	30800a*	2.67a	1.66a	3.69a	119.7 a	6.98a
organic 2	40	29200a	2.97a	1.68a	3.88a	133.0 a	7.60a
organic 3	60	27600a	3.67a	1.61a	3.52a	127.5 a	8.12a

* Figures followed by the same letter are not significantly different at $p<0.05$ according to Tukey-Kramer Honestly Significant Difference Test.

Table 5: The effect of compost dose on N, P and K content in sunflowers organs, Newe Ya'ar, 19.9.2012.

		Stem			Heads			Seeds			Uptake		
Treatment	Compost	N	P	K	N	P	K	N	P	K	N	P	K
	m^3 ha^{-1}	mg g^{-1}			mg g^{-1}			mg g^{-1}			kg ha^{-1}		
conventional	0	6.9	1.13	26.9b	13.2	2.2	42.9	20.9	3.8	10.7	116.2	20.3	175.5
organic1	20	3.8	0.84	38.0a	11.4	3.4	43.3	19.0	4.4	11.1	99.3	24.2	214.4
organic 2	40	4.8	1.12	33.5a	14.0	3.5	42.6	19.9	4.2	11.2	114.9	25.5	214.7
organic 3	60	4.5	1.22	45.2a	13.3	3.9	43.3	19.6	4.0	11.2	107.0	24.9	274.8

* Figures followed by the same letter are not significantly different at $p<0.05$ according to Tukey-Kramer Honestly Significant Difference Test.

Table 6. The effect of compost dose on the above-ground biomass production and major elements taken up by vetch, Newe Ya'ar, 15.5.2013.

Treatment	Compost	Biochar	Biomass	Nitrogen	Phosphate	Potassium
	m^3 ha^{-1}	ton ha^{-1}	ton ha^{-1}	kg ha^{-1}		
Conventional	0	0	10.8	261	40	288
organic1	20	0	12.0	294	44	305
organic 2	40	0	11.2	235	44	323
organic 3	60	0	12.1	316	44	332
Conventional	0	20	8.6	202	30	234
organic1	20	20	8.3	188	38	243
organic 2	40	20	8.8	204	40	253
organic 3	60	20	10.2	247	39	288
mean		0	11.6a	276a	43a	312a
mean		20	9.0b	210b	37b	255b

* Different letters indicate statistical significance ($P \leq 0.05$)

Table 7. The effect of compost dose and biochar on the above-ground biomass production of wheat and the concentrations of major elements, Newe Ya'ar, 9.4.2014.

Treatment	Compost	Biochar	Biomass	N	P	K	N	P	K
	m^3 ha^{-1}	ton ha^{-1}	ton ha^{-1}		mg g^{-1}			kg ha^{-1}	
Conventional	0	0	5.4	19.6	2.40	22.1	105.9	12.98	119.3
organic1	20	0	5.5	19.5	2.46	24.2	107.1	13.56	133.1
organic 2	40	0	5.3	22.2	2.75	25.0	117.6	14.57	132.6
organic 3	60	0	5.3	21.0	2.61	27.0	111.3	13.83	142.9
Conventional	0	20	8.3	19.6	2.36	23.0	162.5	19.58	191.3
organic1	20	20	7.1	20.6	2.47	26.7	146.3	17.55	189.3
organic 2	40	20	5.4	21.3	2.66	25.0	115.1	14.38	134.8
organic 3	60	20	7.4	21.2	2.67	26.7	156.5	19.74	197.9
mean	0		5.3	19.6	2.38	22.6 b	134.2	16.3	155.3
mean	20		6.3	20.0	2.47	25.4ab	126.7	15.6	161.2
mean	40		5.3	21.7	2.71	25.0ab	116.3	14.5	133.7
mean	60		6.3	21.1	2.64	26.9 a	133.9	16.8	170.4
mean		0	5.4a	20.6	2.60	24.6	110.5a	13.7a	132.0a
mean		20	7.1b	20.7	2.58	25.4	145.1b	17.8b	178.3b

* Different letters indicate statistical significance ($P \leq 0.05$)

Table 8. The effects of compost dose and biochar amendment on the Bulk Density (BD) and water holding of the upper soil layer (0-10 cm) at saturation, field capacity and wilting point (0, 33 and 1500 Kpa, respectively), NeweYa'ar, March 19th 2013.

Compost	**Biochar**	**B.D.**[*]	**θ saturation**	**θ Field capacity**	**θ Wilting point**
m^3 ha^{-1}	**ton ha^{-1}**	**g cm^3**	**cm^3 cm^{-3}**	**cm^3 cm^{-3}**	**cm^3 cm^{-3}**
0	0	1.15(±0.08)	55.4 *(±6.1)*	35.6 *(±2.8)*	29.9 *(±1.7)*
20	0	1.11(±0.07)	48.3 *(±3.3)*	31.8 *(±1.9)*	30.3 *(±5.4)*
40	0	1.02(±0.04)	52.7 *(±5.7)*	30.1 *(±3.3)*	26.5 *(±2.2)*
60	0	1.09(±0.03)	58.3 *(±4.5)*	34.1 *(±3.3)*	29.1 *(±1.1)*
0	20	1.02(±0.07)	50.4 *(±5.3)*	32.8 *(±4.1)*	25.6 *(±1.0)*
20	20	1.05(±0.07)	51.8 *(±4.9)*	35.8 *(±3.8)*	26.9 *(±0.8)*
40	20	1.04(±0.07)	48.0 *(±1.5)*	32.2 *(±2.3)*	26.3 *(±3.8)*
60	20	1.02(±0.07)	46.3 *(±4.1)*	32.6 *(±4.0)*	26.3 *(±1.5)*
mean	0	1.09*(±0.07)	53.7 (±6.0)	32.9 (±3.4)	29.0 (±3.2)
mean	20	1.03*(±0.07)	49.1 *(±4.5)*	33.3 *(±3.6)*	26.3 *(±2.0)*
Probability of F					
	Biochar	*	**	n.s.	**
	Compost	n.s.	n.s.	n.s.	n.s.

Significance level: * - $p<0.05$, ** - $p<0.01$

Table 9: The effect of compost dose on the mass balance of Nitrogen in Newe Ya'ar, from 22/04/2010 to 1.5.2014.

	Date	Conventional Kg ha^{-1}	Organic 2	Organic 4	Organic 6
Input					
Compost	25/05/2010	0	792	792	792
Soil	08/06/2010	163	163	163	163
Fertilizer	11/11/2010	92	0	0	0
Fertilizer	13/06/2011	92	0	0	0
Compost	13/06/2011	0	233	466	699
Fertilizer	25/03/2012	92	0	0	0
Compost	02/04/2012	0	195	390	585
Sum		439	1383	1811	2239
output					
Wheat	04/05/2011	101	154	121	145
Corn	02/10/2011	99	125	103	121
Sunflower	19/09/2012	99	115	107	116
Wheat	09/04/2014	106	107	118	111
Soil N	1/5/2014	137	161	179	169
Sum		542	662	628	662
Balance		-103	721	1183	1577

Table 10: The effect of compost dose on the mass balance of Phosphorus in Newe Ya'ar, from 22/04/2010 to 01.05.2014.

	Date	Conventional Kg ha^{-1}	Organic 2	Organic 4	Organic 6
Input					
Compost	25/05/2010	0	438	438	438
Soil	08/06/2010	55	55	55	55
Fertilizer	11/11/2010	0	0	0	0
Fertilizer	13/06/2011	0	0	0	0
Compost	13/06/2011	0	166	332	498
Fertilizer	25/03/2012	0	0	0	0
Compost	02/04/2012	0	140	281	421
Fertilizer	5/01/2014	11	0	0	0
Sum		66	855	1170	1512
output					
Wheat	04/05/2011	16	31	20	26
Corn	02/10/2011	16.5	23.9	19.4	24.1
Sunflower	19/09/2012	20	24	26	25
Wheat	09/04/2014	13.0	13.6	14.6	13.8
Soil P	01/05/2014	26.3	65.0	64.1	92.7
Sum		92	158	143	182
Balance		-25	697	1027	1330

Table 11: The effect of compost dose on the mass balance of potassium in Newe Ya'ar, from 22/04/2010 to 01.05.2014.

	Date	Conventional Kg ha^{-1}	Organic 2	Organic 4	Organic 6
Input					
Compost	25/05/2010	0	1102	1102	1102
Soil	08/06/2010	47	47	47	47
Fertilizer	11/11/2010	0	0	0	0
Fertilizer	13/06/2011	0	0	0	0
Compost	13/06/2011	0	439	878	1318
Fertilizer	25/03/2012	0	0	0	0
Compost	02/04/2012	0	282	564	846
Fertilizer	05/01/2014	150	0	0	0
Sum		197	1909	2646	3390
output					
Wheat	04/05/2011	101	154	121	145
Corn	02/10/2011	95	135	135	142
Sunflower	19/09/2012	176	214	215	275
Wheat	09/04/2014	119	133	133	143
Soil K	01/05/2014	110	196	131	202
Sum		601	832	734	906
Balance		-404	1076	1912	2483

Fig 1. Map showing Newe Ya’ar site (red dot in the north of Israel) and Gilat site (red dot in the south of Israel).

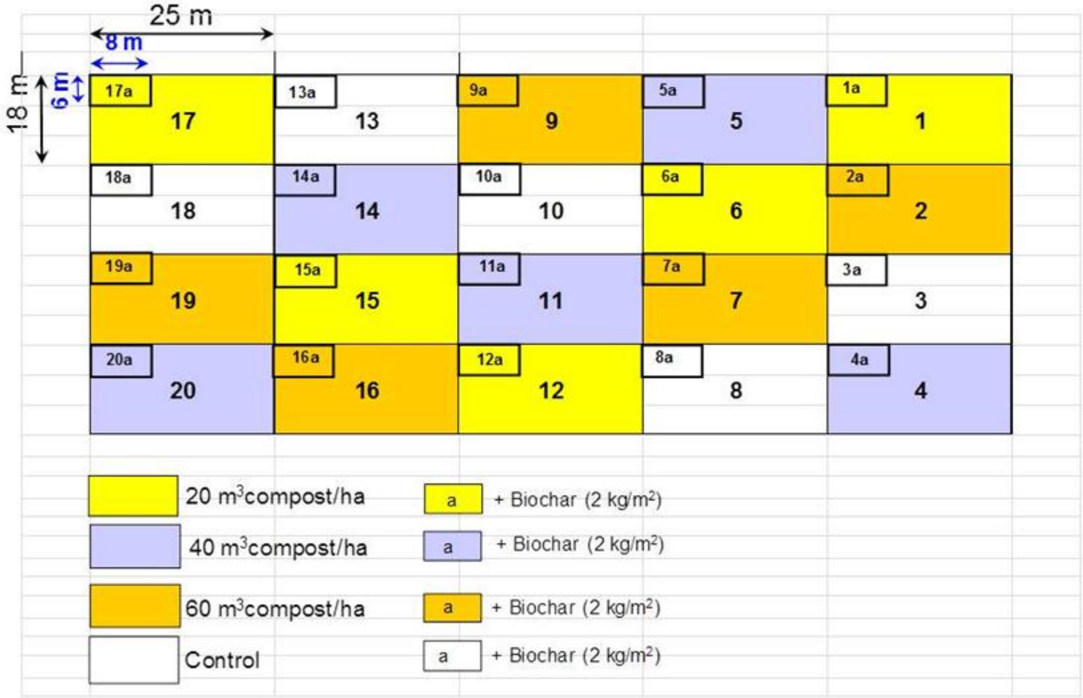


Fig. 2. Plots map of the Newe Ya'ar field experiment.

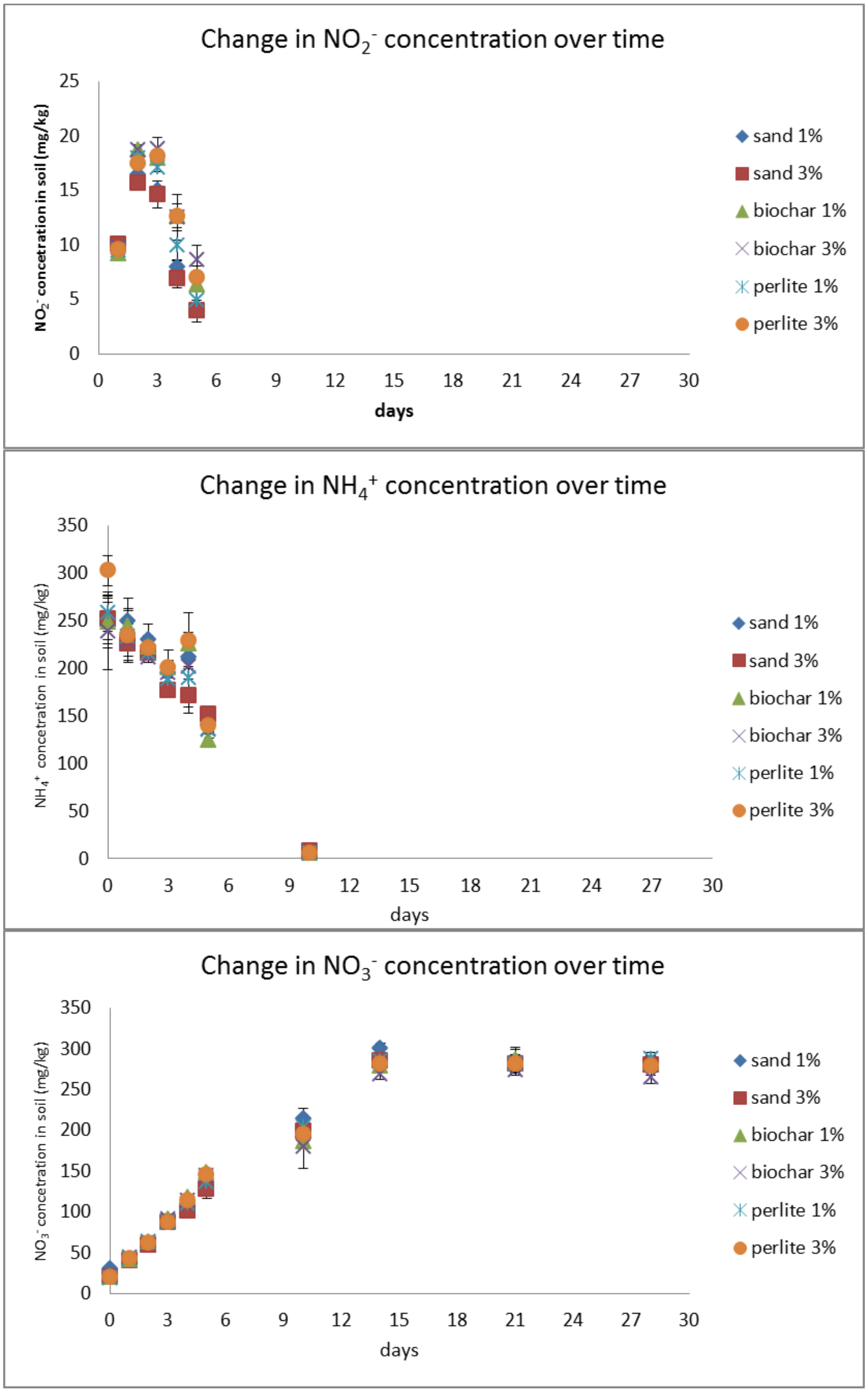


Fig. 3. An incubation experiment of nitrification in Newe Yaar soil with and without amendments (sand, perlite and biochar) a. Nitrate concentration in soil over time, b. Nitrite concentration in soil over time and c. Ammonium concentration in soil over time.

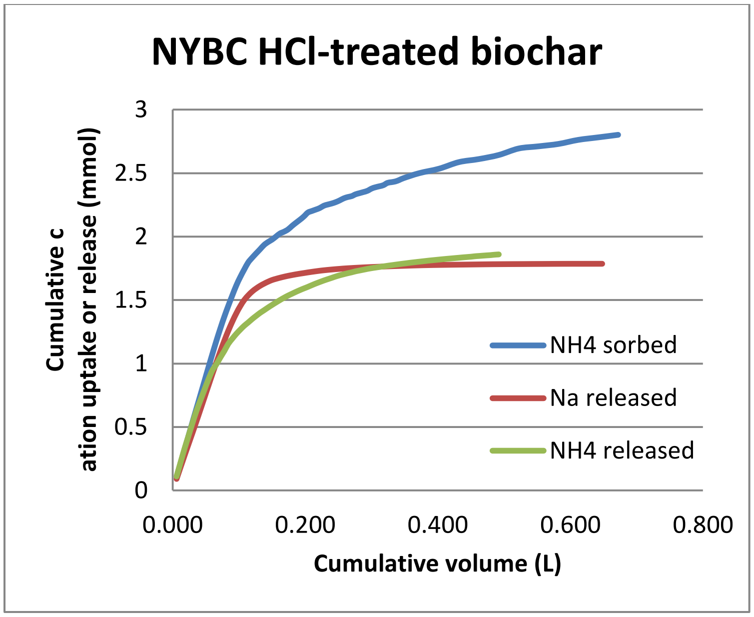


Fig. 4. Simultaneous uptake of NH_4^+ (blue) and release of Na^+ (red) during NH_4Cl leaching through HCl treated biochar experiment.

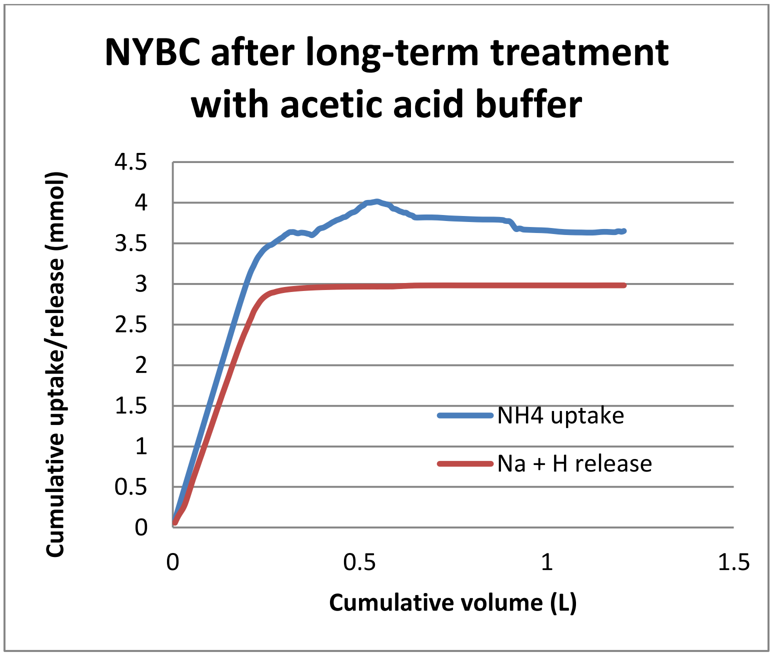


Fig. 5. Simultaneous uptake of NH_4^+ (blue) and release of Na^+ (red) during NH_4Cl leaching through long-term treated biochar with acetic acid buffer.

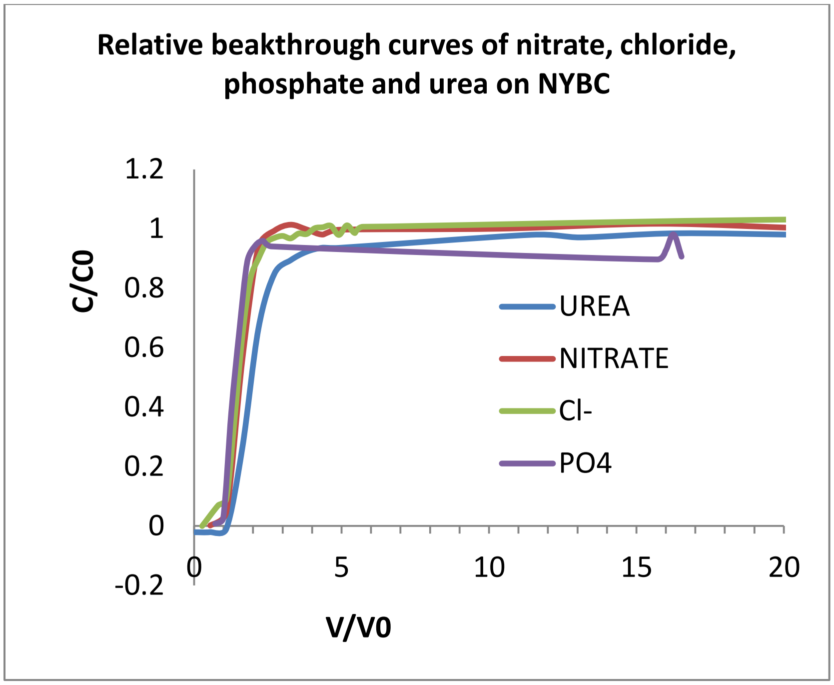


Fig. 6. Relative breakthrough in terms of relative concentration (C/C_o) and relative volume (V/V_o) of nitrate (NO_3^-), Chloride (Cl^-), Phosphate (PO_4^-) and urea.

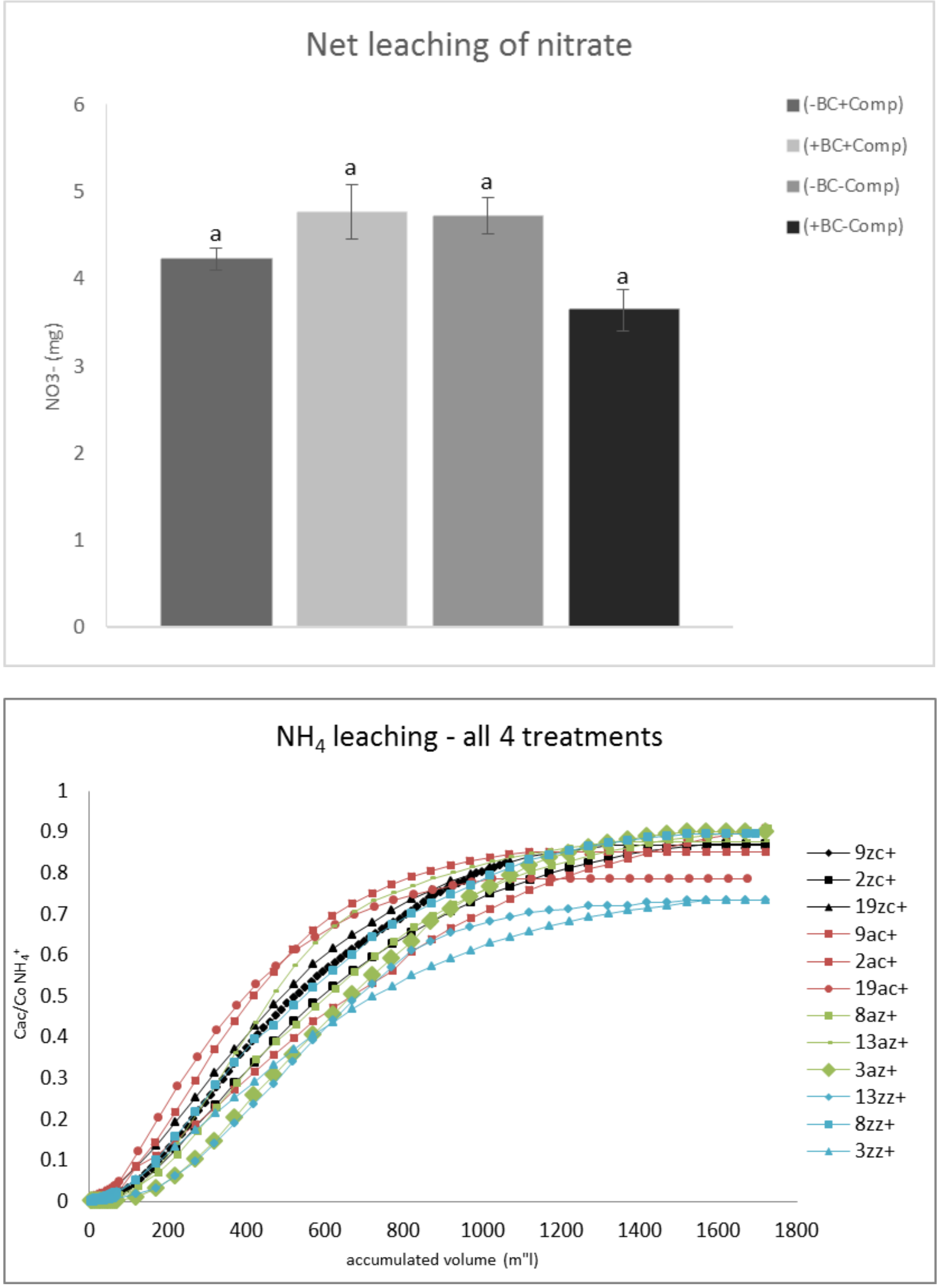


Fig. 7. Nitrate and ammonium leaching from soils of the Newe Ya’ar experimental plots.

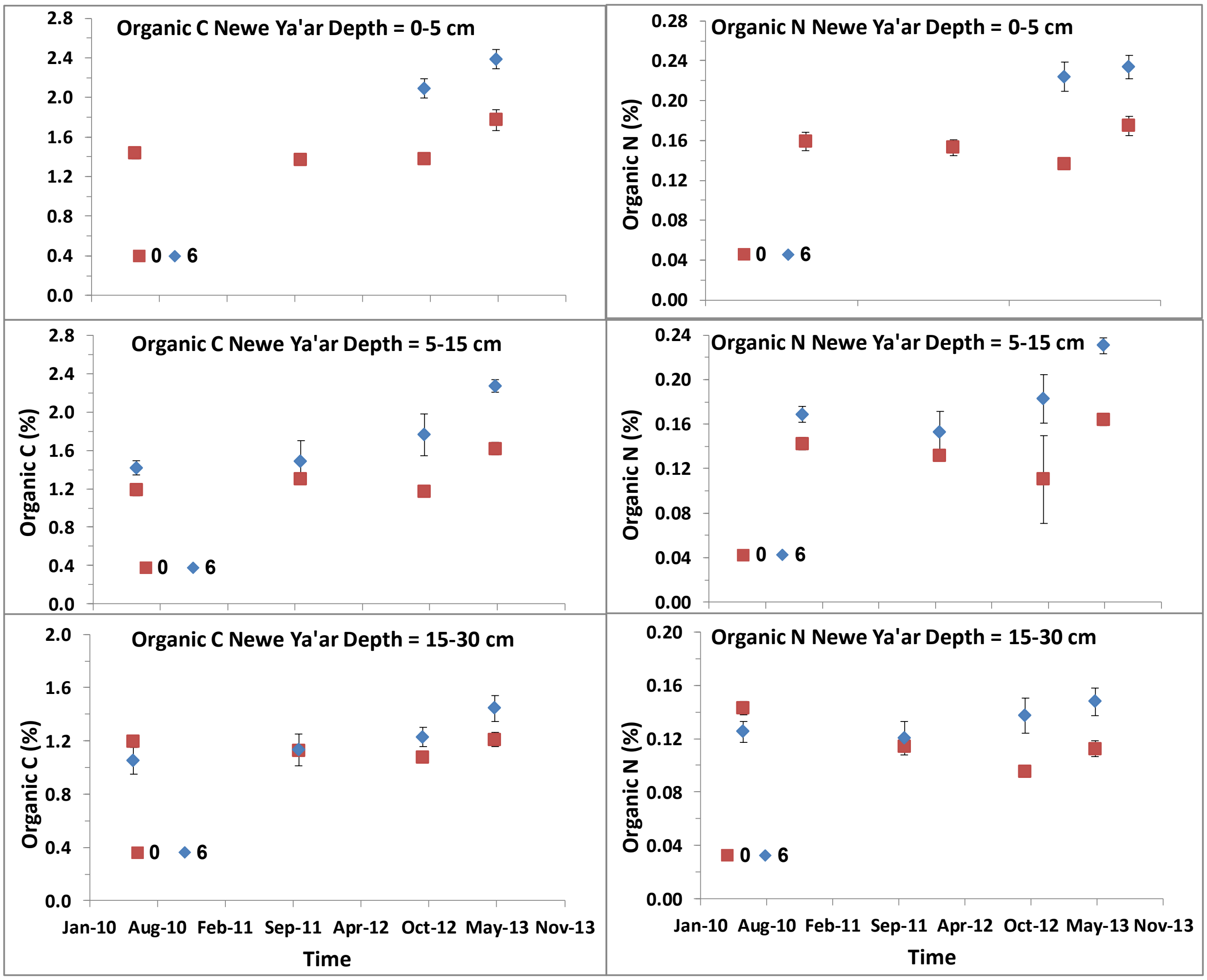
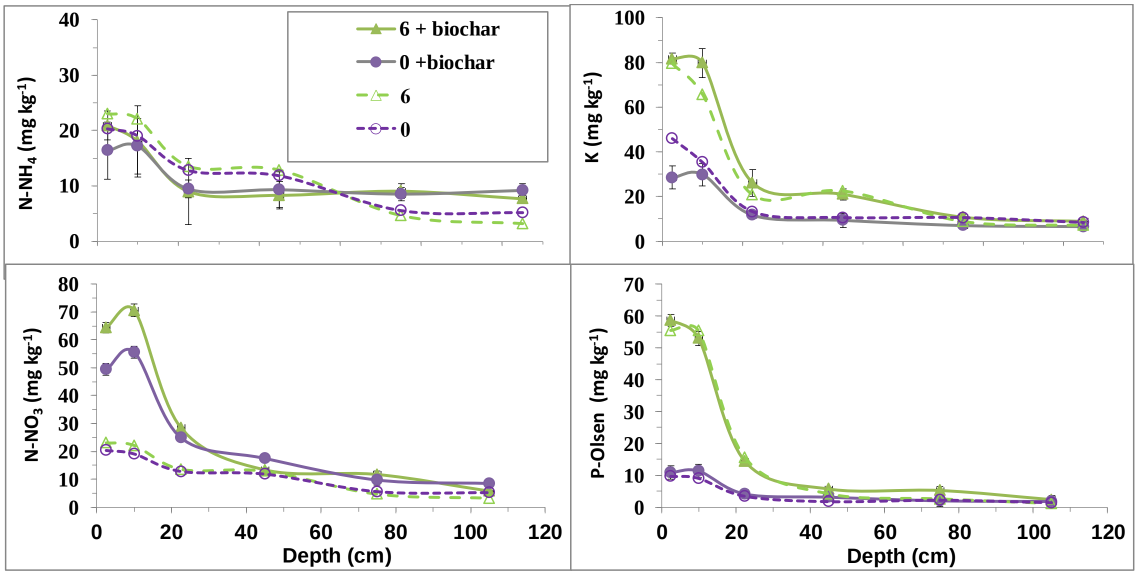


Fig. 8. The effect of the highest compost dose (60 m^3 ha^{-1}) vs. the conventional fertilization on soil organic C and N contents in the top soil layers (0-5, 5-15 and 15-30 cm) as a function of time, Newe Ya'ar, 2009-2013.

May 2013



November 2013

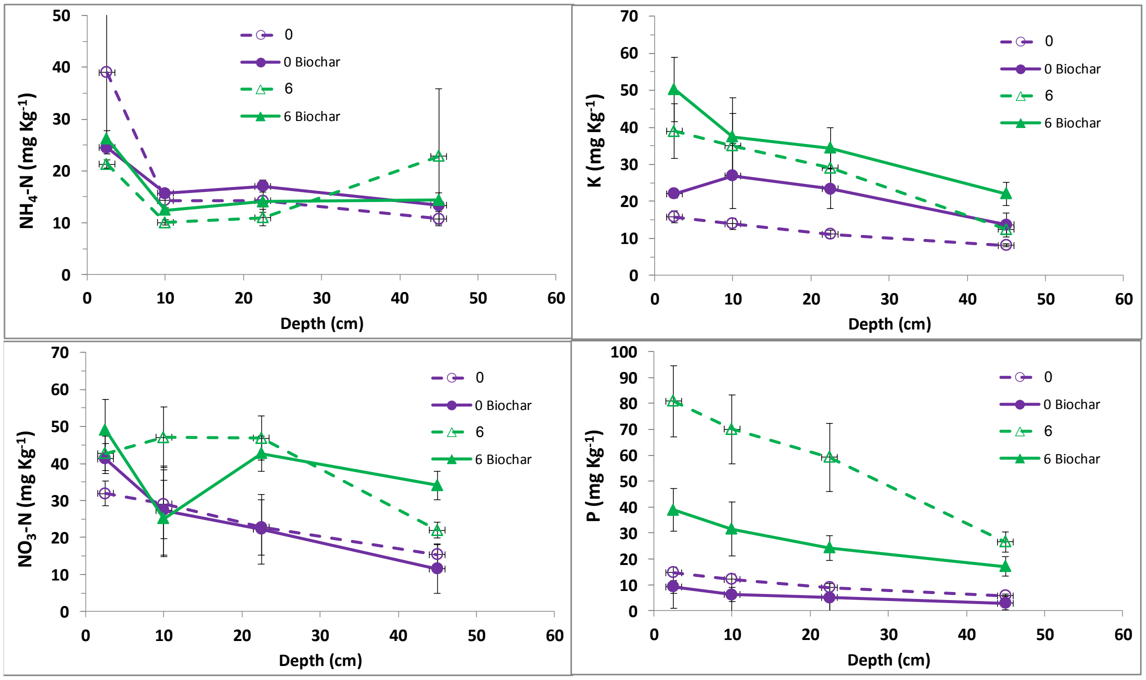


Fig. 9. The effect of the highest compost application vs. conventional fertilization with and without biochar on the distribution in the soil profile of NH_4^+ and NO_3^- extracted by 1MKCl solution and P extracted by Olsen solution, Newe Ya'ar, May 2013.

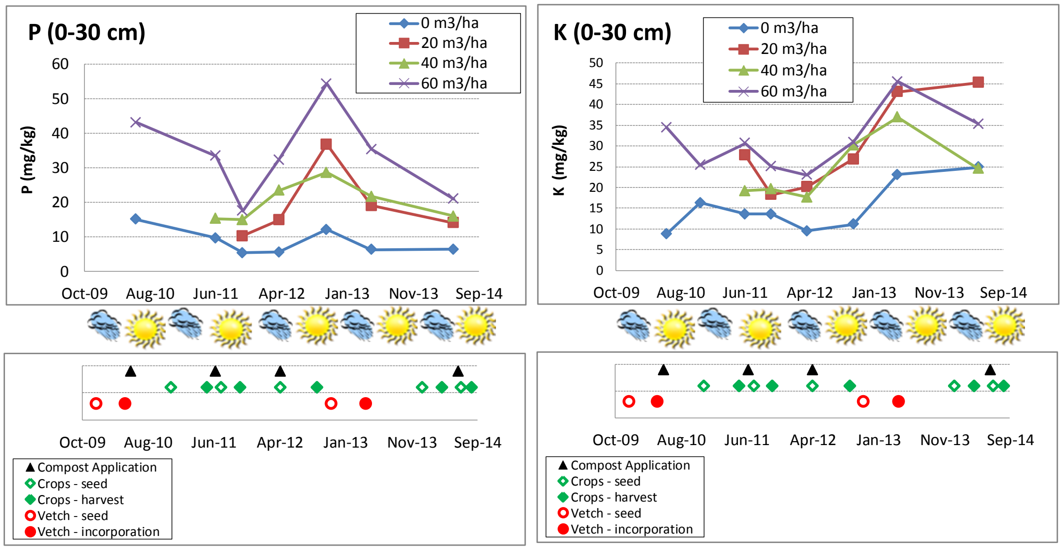


Fig. 10. The effect of compost dose on available P (Olsen extraction) and soluble K (1:5 soil:water extraction) as a function of time, Newe Ya'ar, May 2010- May 2014.

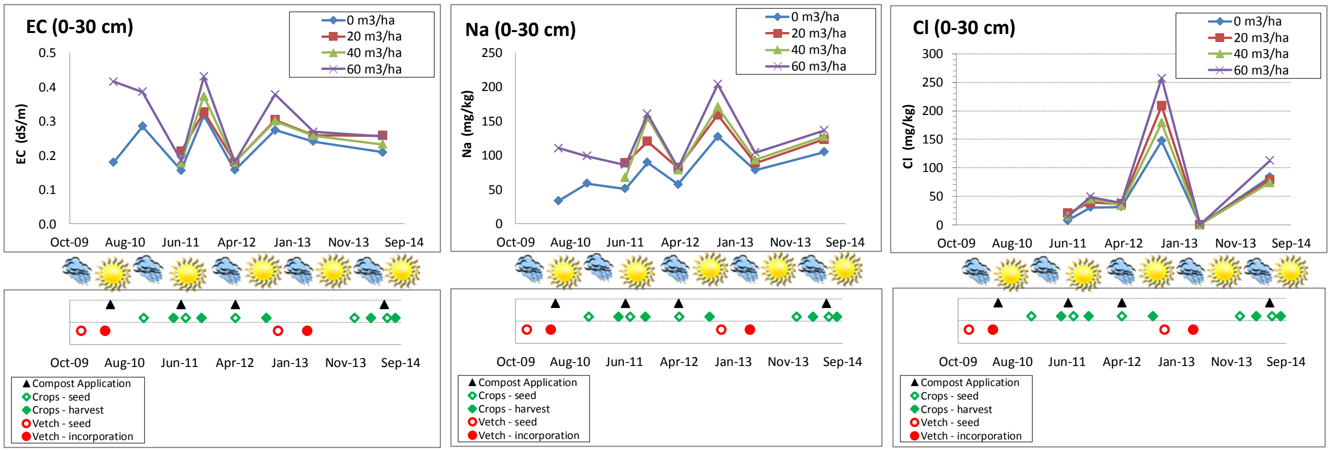


Fig. 11. The effect of compost dose on the soil solution (1:5 soil:water extraction) salinity electrical conductivity (EC), Na and Cl concentrations in the top soil layers (0-30 cm) as a function of time, Newe Ya'ar, May 2010- May 2014.

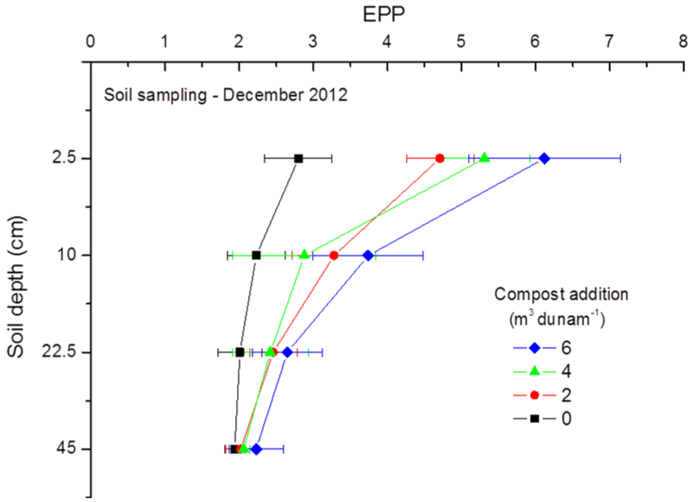


Fig. 12. The effect of compost dose on the exchangeable potassium (EPP) as a function of soil depth, Newe Ya'ar December 2012.

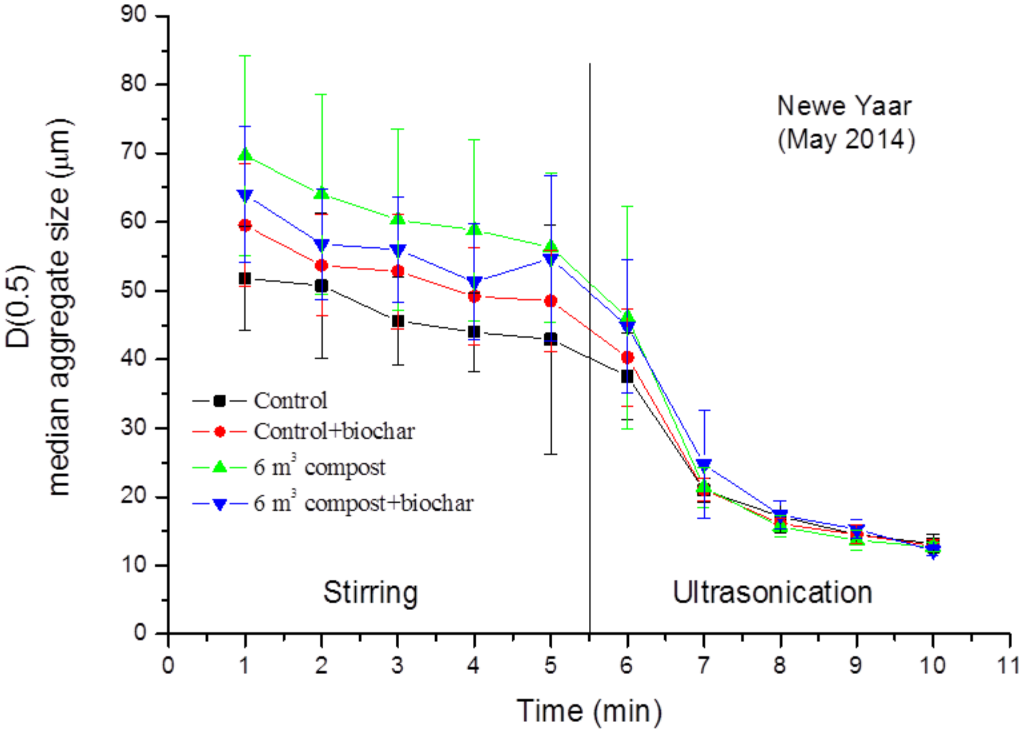


Fig. 13. Effect of compost addition (6 m-3) and biochar on soil aggregate stability (from soil depth 0-15 cm) expressed by the size of the median aggregate (D(0.5)).

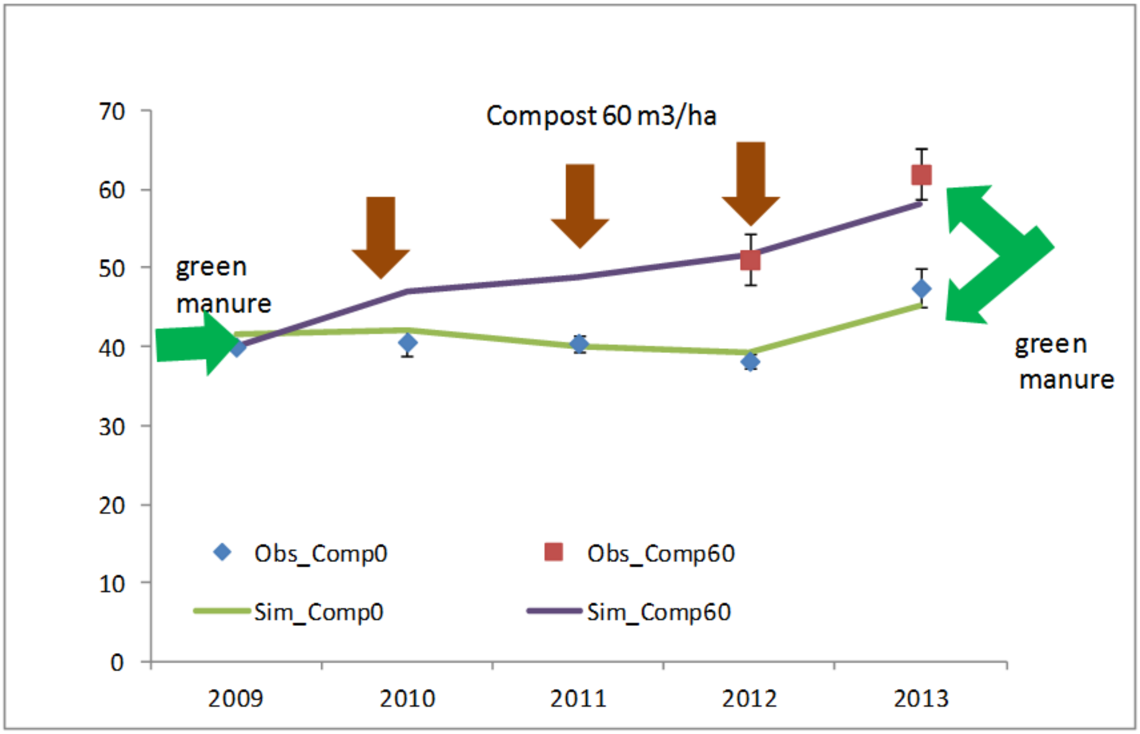
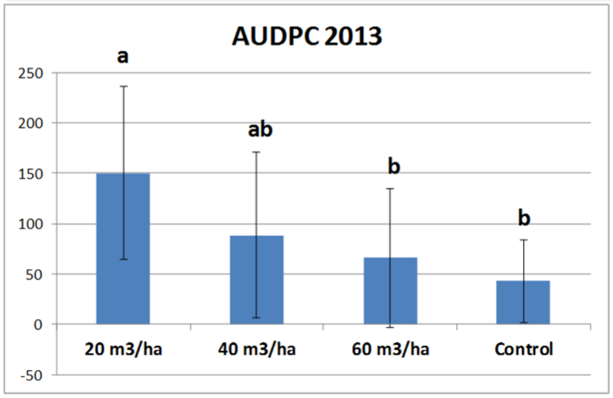
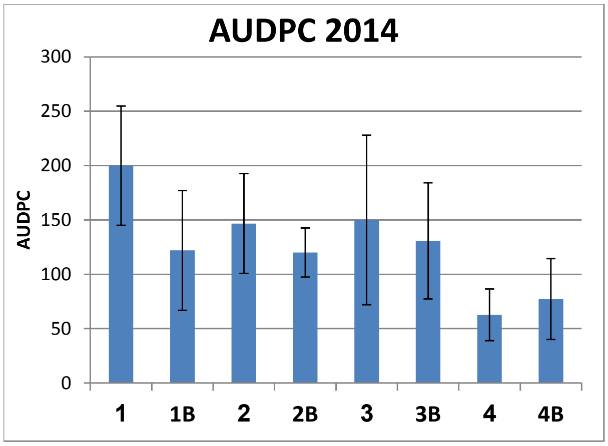


Fig. 14. The effect of organic (the highest compost dose treatment = 60 m^3 ha^{-1}) versus conventional farming on the organic C content (ton ha^{-1}) in the top soil layers (0-30 cm), Newe Ya'ar 2009 to October 2013. Symbols – measured data, Lines – Simulated data Roth model.





Trt. No.	Treatment
1	20 m^3/ha
1B	20 m^3/ha + biochar
2	40 m^3/ha
2B	40 m^3/ha + biochar
3	60 m^3/ha
3B	60 m^3/ha + biochar
4	Control
4B	Control + biochar

Fig. 15. Israel soil: area under the disease-progress curve (AUDPC) of melon seedlings contaminated with *Fusarium Oxysporum*. Bars represent the SE.

Picture 1. Newe Ya'ar field experiment after manual application of biochar and before soil cultivation, December 2012.

Appendix II

Italy

Table 1 Formulas used to calculate C input (t ha^{-1}) for simulations

Crop	Source of C	Formula
Wheat, Barley and Chickpea[*]	C from roots (Cr)	Cr = (Y / (HI * S:R)) * 0.45
	C from stubble and shuffle (Cs)	Cs = 0.1 * (Y / HI) * 0.45
	C from root exudates (Ce)	Ce = 0.09 * (Y / HI) * 0.45
	C from roots and residues of weeds (Cw)	Cw = 0.07 * (Y / HI) * 0.45
	Total C input	Ctot=Cr+Cs+Ce+Cw
Tomato[**] **and other horticultural crops**	Total C input	C tot=(0.001(fresh wt. yield t $ha^{-1})^2$) * 0.05(fresh wt. yield t ha^{-1}) *0.3*0.45

Where Y is the yield (t ha^{-1}), HI is the harvest index, and S:R is the shoot to root ratio.

[*] modified from Skjemstad et al. (2004) and Kuzyakov and Domanski (2000)

[**] from Kong et al. (2005)

Table 2. Phenological and productive parameters of melon

	Phenological Parameters			**Total Production**		**Marketable Production**		**Not Marketable Production**	
	****Development of fruits – DAT (days after transplant)**	**** Beginning of Harvest (DAT)**	**** End of Harvest (DAT)**	*** kg/plant**	*** fruits/plant (n)**	*** kg/plant**	*** fruits/ plant (n)**	*** kg/plant**	*** fruits/ plant (n)**
Management									
Green Manure barley	33,67 b	71,44 b	92,00	3,95 a	3,38 A	3,67 A	2,78 A	0,28	0,60
No Barley	33,22 b	70,00 b	89,56	3,09 b	2,96 A	2,99 A	2,67 A	0,11	0,29
Roller Crimper Barley	36,67 a	76,33 a	90,67	1,68 c	1,82 B	1,63 B	1,60 B	0,05	0,22
Compost									
30	34,22	71,44	90,89	3,20	2,98	3,08	2,62	0,12	0,36
15	34,33	72,89	90,11	2,76	2,47	2,62	2,18	0,14	0,29
0	35,00	73,44	91,22	2,76	2,71	2,59	2,24	0,18	0,47
Management x Compost									
Significance				ns	ns	ns	ns	ns	ns

Different letters in column correspond to values significantly different according to:

* Test di Tukey for A= p≤ 0,01 ; a= p≤ 0,05 ; *= p≤ 0,05 ; **= p≤ 0,01 ; ns= non significant

** Test di Wilcoxon for A= p≤ 0,01 ; a= p≤ 0,05 ; *= p≤ 0,05 ; **= p≤ 0,01 ; ns= non significant

Table 3. Barley - Melon C input (t ha^{-1})

Barley - melon C INPUT (t ha^{-1})

	1	2	3	4	5	6	7	8	9
Date DABY	Fallow (no barley)			Roller crimped barley			green manured barley		
	0	15	30	0	15	30	0	15	30
compost		5,24	10,48		5,24	10,48		5,24	10,48
barley				3,28 b	2,08 b	3,28 b	7,32 a	5,41 ab	5,43 ab
organic fertilizers	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37	0,37
weeds	1,25 b	1,40 b	1,53 b	0,38 c	0,18 c	0,00 c	1,07 b	1,19 b	2,11 a
RC barley residues (late incorporation)				2,88	3,69	2,22			
crop residues	0,84 abc	0,86 ab	1,20 abc	0,36 c	0,64 bc	0,62 bc			
total	**2,46 f**	**7,87 e**	**13,58 bc**	**7,27 de**	**12,20 b**	**16,97 a**	**10,32 de**	**13,29 bc**	**19,26 a**

The mean values in each column followed by a different letter are significantly different according to LSD and DMRT (two and more than two comparisons, respectively) at the reported probability level. n.s., not significant; ***, $P < 0.001$; **, $P < 0.01$; *, $P < 0.05$.

Table 4. Soil organic C (mg kg^{-1}) at melon harvest

Soil organic C (mg kg-1) at melon harvest: II year

			FA			RC			GM		
	Date	DABY	0	15	30	0	15	30	0	15	30
Soil organic C	05-ago-13		10825 c	11650 bc	11753 bc	11235 c	10401 c	14527 a	10122 c	12026 bc	13605 ab

Table 5. N simplified budget for melon (kg ha^{-1})

			Fallow (No Barley)			Roller Crimped Barley			Green Manured Barley		
		Source	0	15	30	0	15	30	0	15	30
Input	In farm	Min Avail N	130 ab	129 ab	142 a	59 cd	36 d	65 cd	96 bc	81 c	87 c
		Barley	0	0	0	102	71	73	174	158	181
	Off farm	Organic fertilizers	46	46	46	46	46	46	46	46	46
		Compost	0	339	678	0	339	678	0	339	678
		Total	**176 f**	**514 d**	**866 b**	**207 f**	**492 d**	**862 b**	**316 e**	**624 c**	**992 a**
Output		Yield	30 bc	32 b	26 bcd	17 cde	10 d	14 de	35 ab	37 ab	47 a
		Crop residues	15 bcd	19 abc	14 bcd	5 d	8 cd	7 d	28 a	20 ab	13 bcd
		Min Avail N	152	138	146	136	120	185	154	148	197
		Weeds	74 ab	72 ab	59 abc	31 cd	8 d	0 d	63 abc	46 bc	96 a
		Total	**271 b**	**261 bc**	**245 bc**	**189 cd**	**147 d**	**207 bcd**	**281 b**	**252 bc**	**353 a**
Difference (Input - output)			**-95 e**	**254 c**	**621 a**	**18 d**	**345 bc**	**655 a**	**35 d**	**372 b**	**639** a

The mean values in each column followed by a different letter are significantly different according to LSD and DMRT (two and more than two comparisons, respectively) at the reported probability level. n.s., not significant; ***, $P < 0.001$; **, $P < 0.01$; *, $P < 0.05$.

Fig. 1: Experimental design

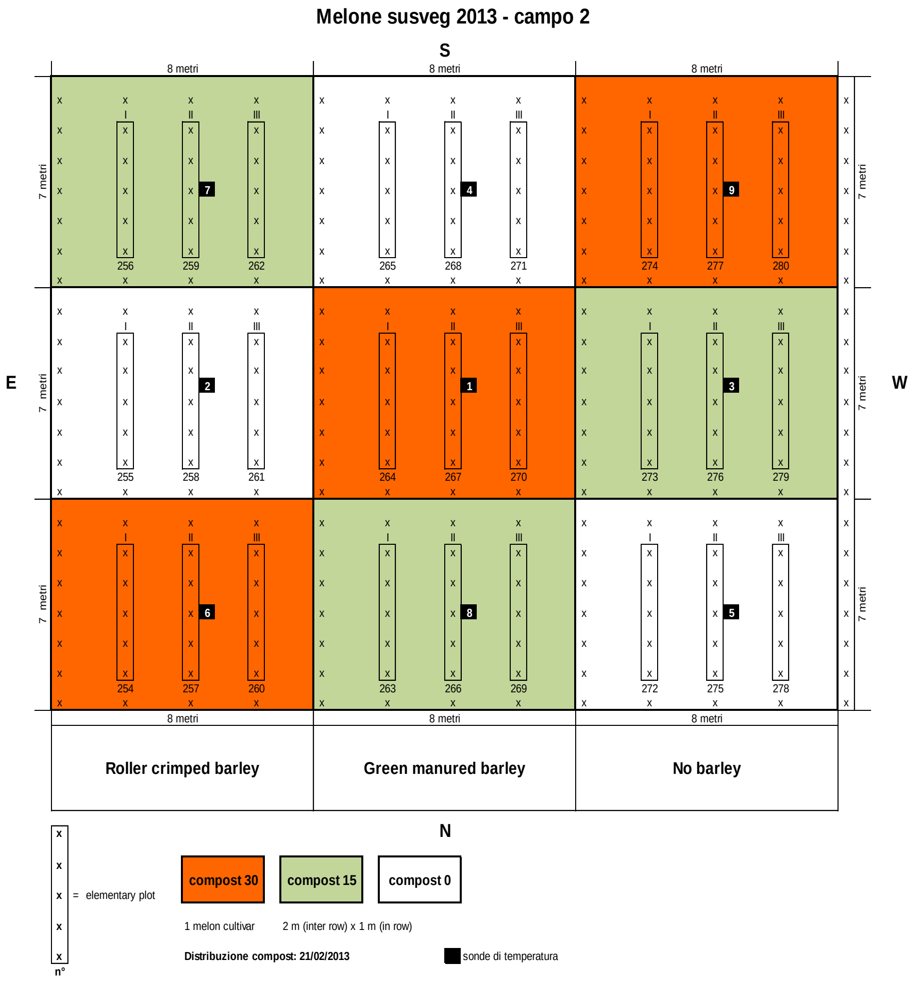


Fig. 2 Soil temperature, during melon cultivation, under different cover crop managements

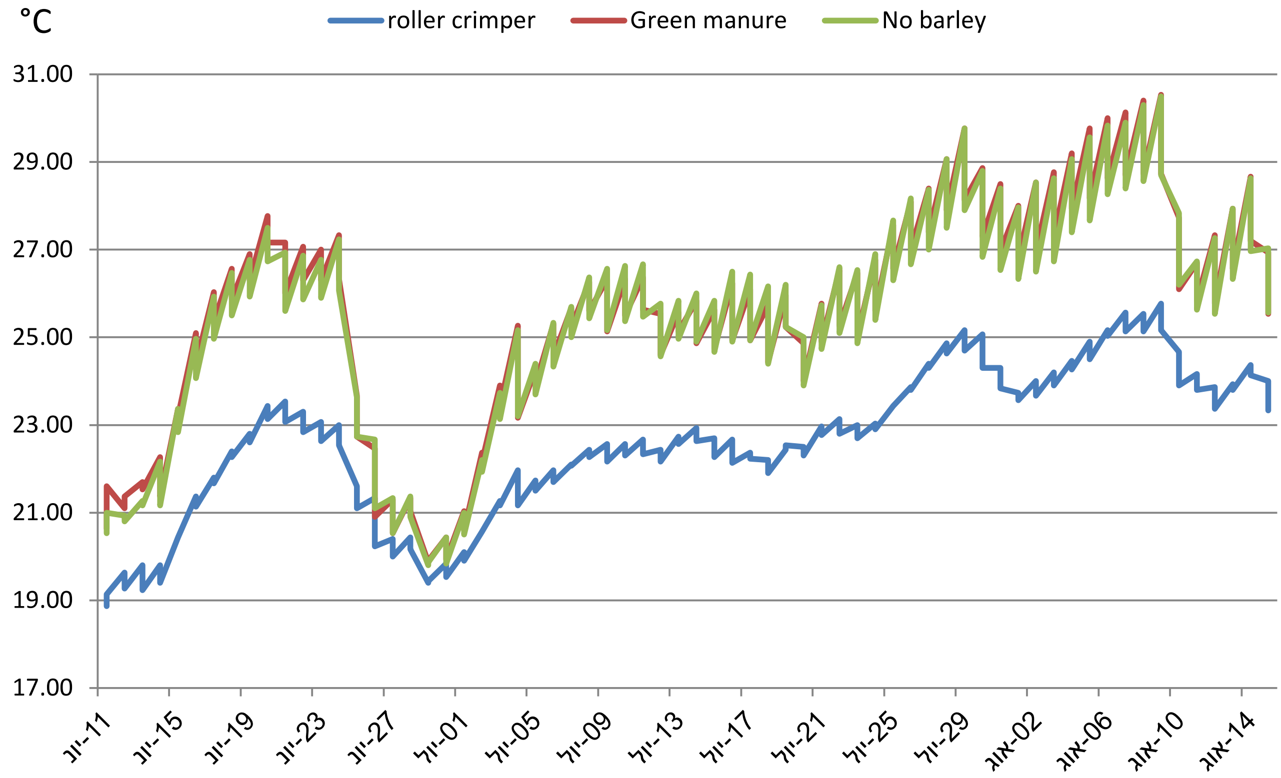
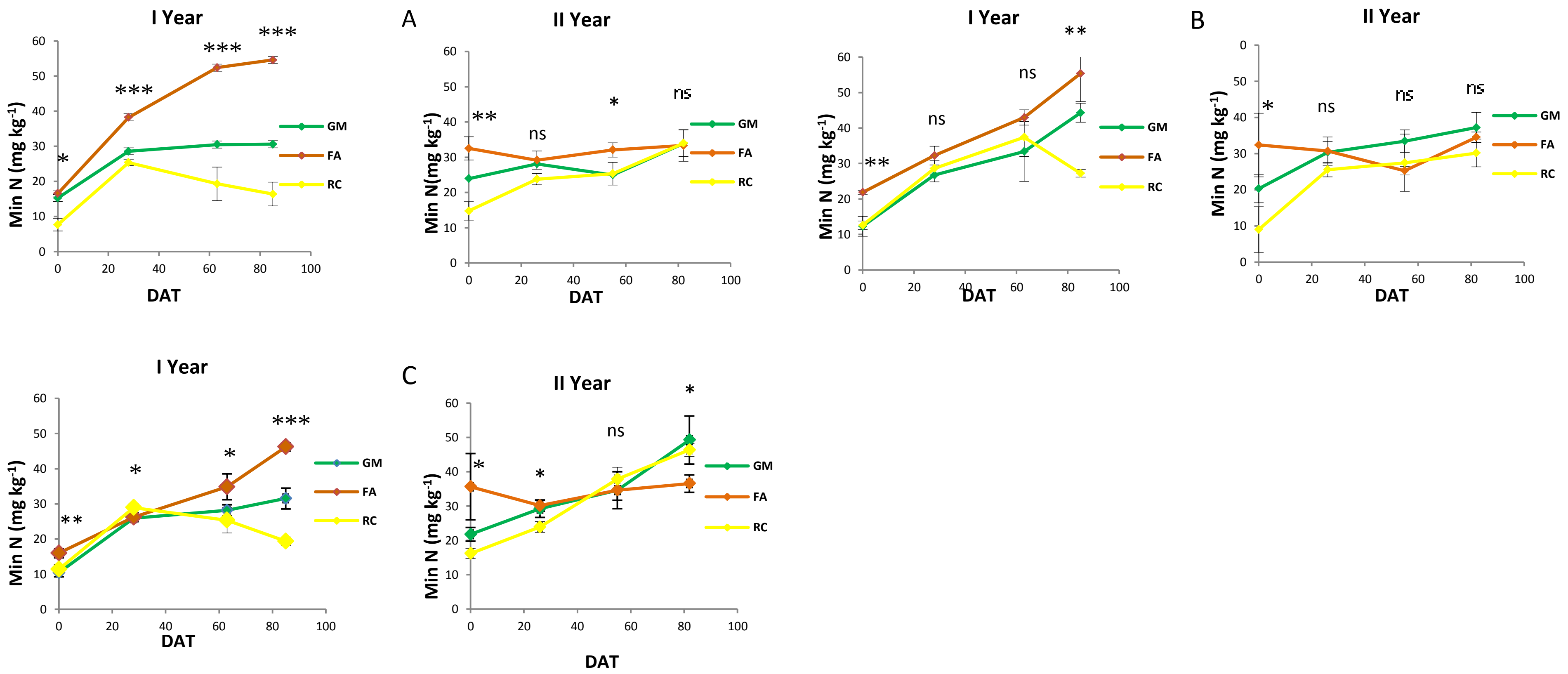
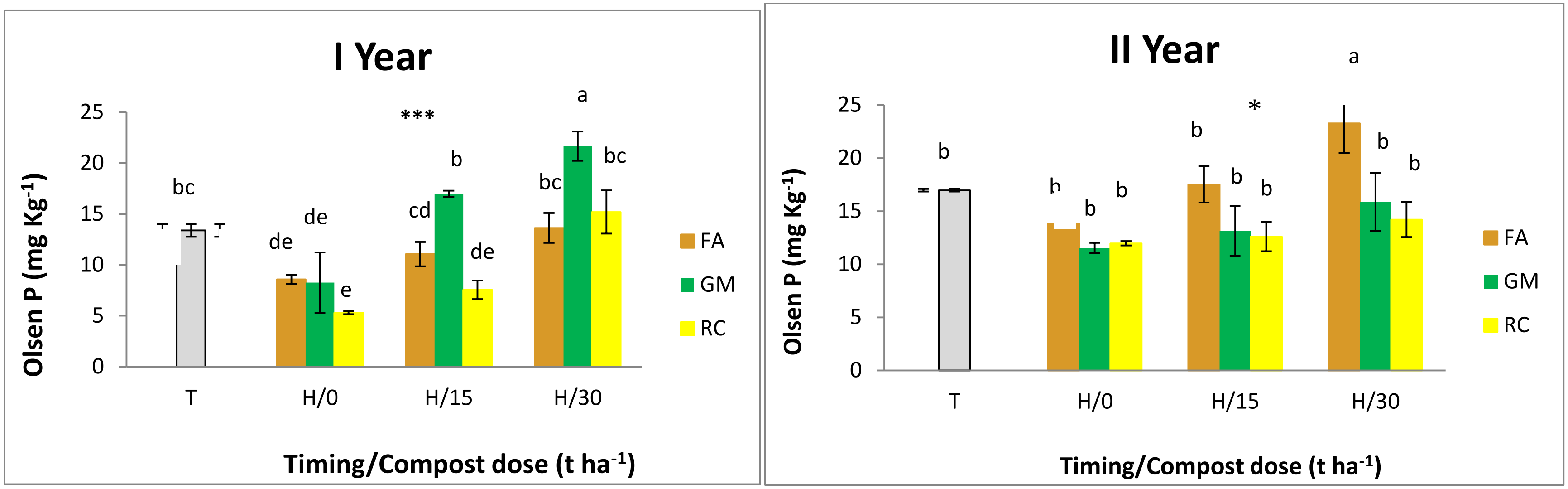


Fig. 3. Effect of cover crop management on soil mineral N content in the compost 0 (A), compost 15 (B) and compost 30 (C) doses for Year I and Year II)



Note: DAT=days after transplanting; ns= not significant; * P≤0.05; ** P≤0.01); *** P≤0.001.

Fig. 4. Effect of compost dose and cover crop management on soil available P content for Year I and Year II



Note: T=transplanting; H=harvest.

Different letters mean significantly different values according to DMRT at the reported probability level ** $P \leq 0.01$. *** $P \leq 0.001$.

Fig. 5 Comparison among measured and simulated values for the No Barley No compost treatment in cycle 1 during 6 years.

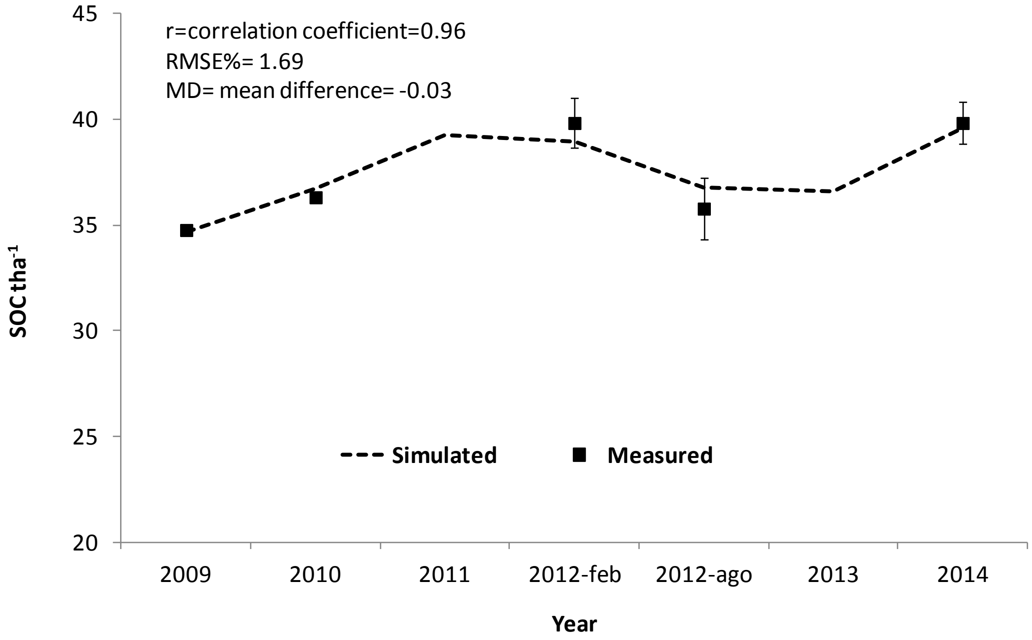


Fig. 6 Relationship between the measured and simulated values grouped for compost dose treatment (for measured, error bars represents standard errors)

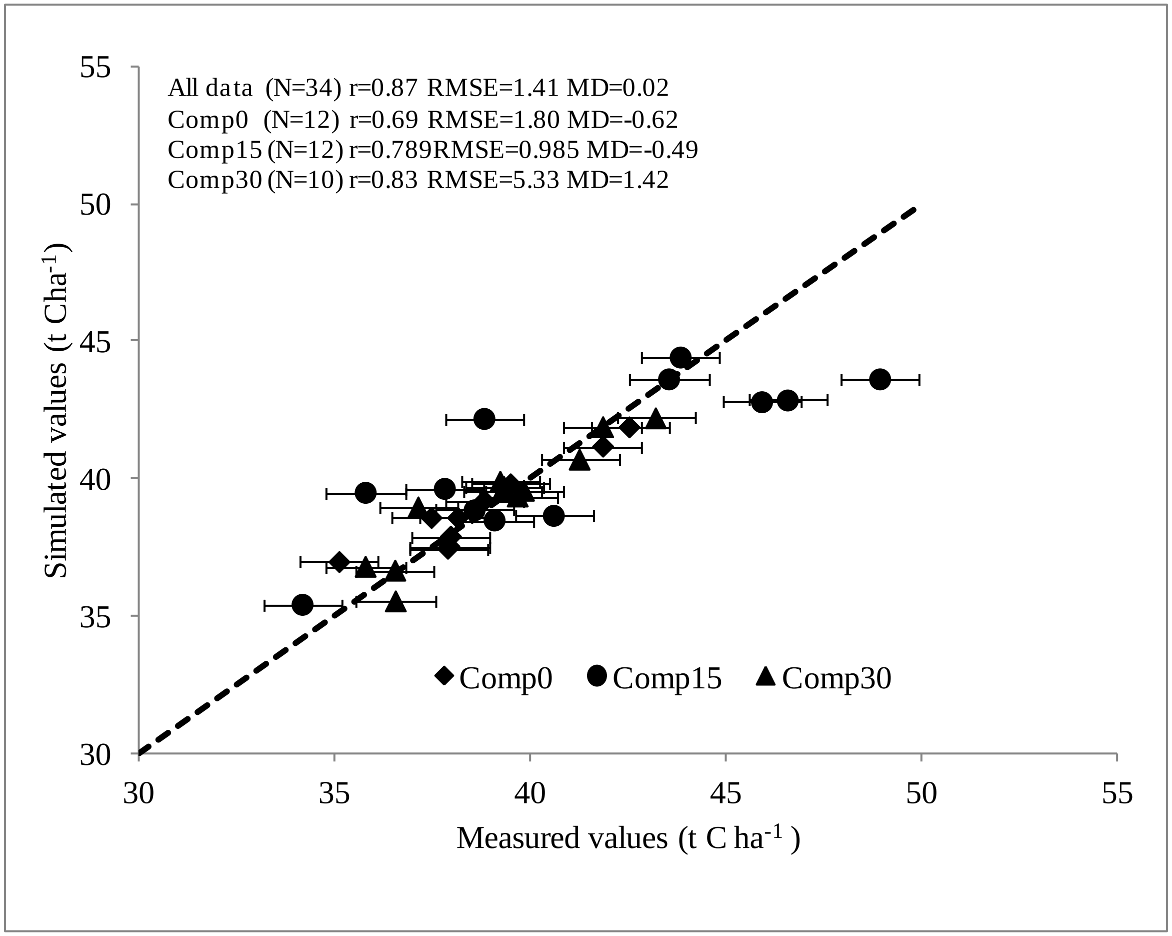


Fig. 7 Relationship between the measured and simulated values grouped for cover crop treatment (for measured data , error bars represents standard errors). The dotted line is the one to one

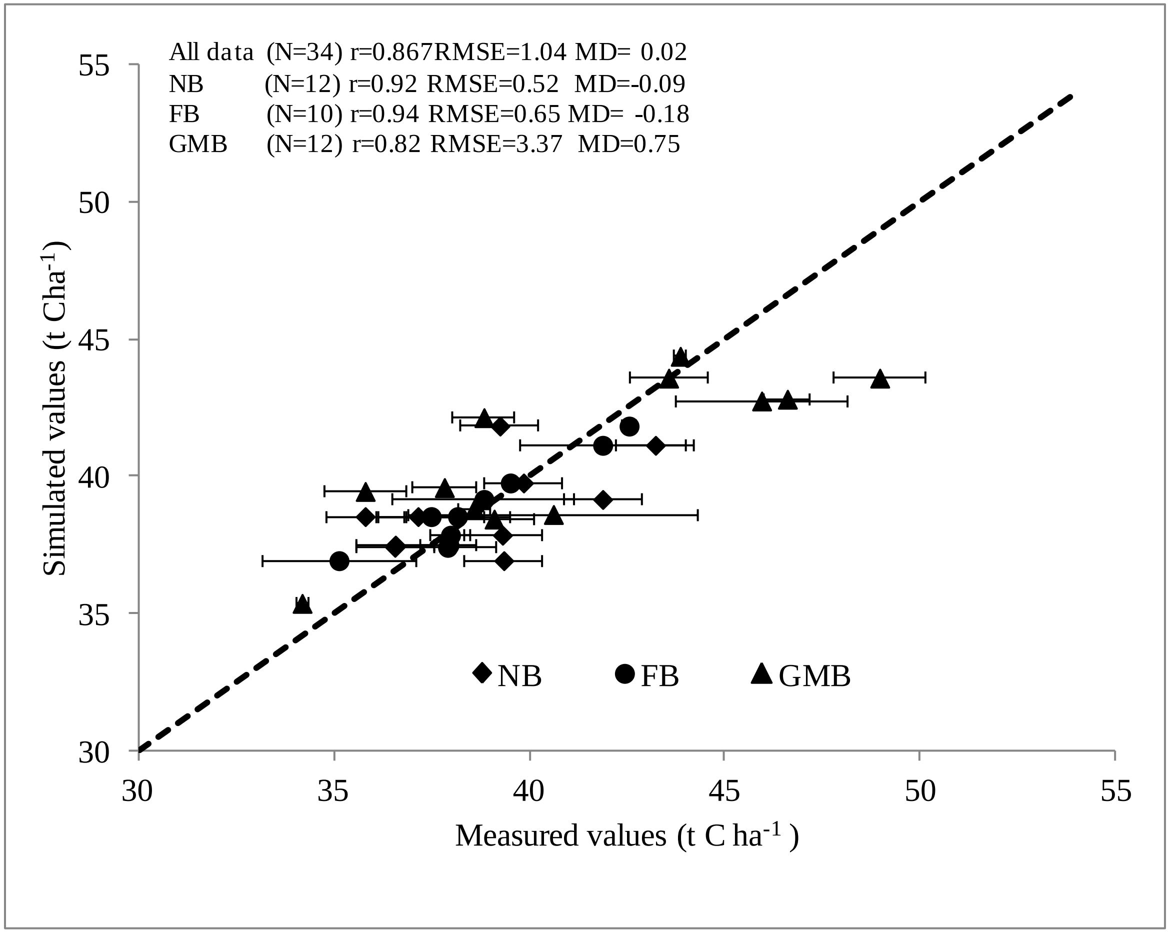


Fig. 8 Geometric Mean Diameter (GMD) cumulative values showing the aggregate stability trend in the different trial fields and sampling dates. T0 (may 2012) represent the start values after first tillage for compost incorporation and crop plantation.

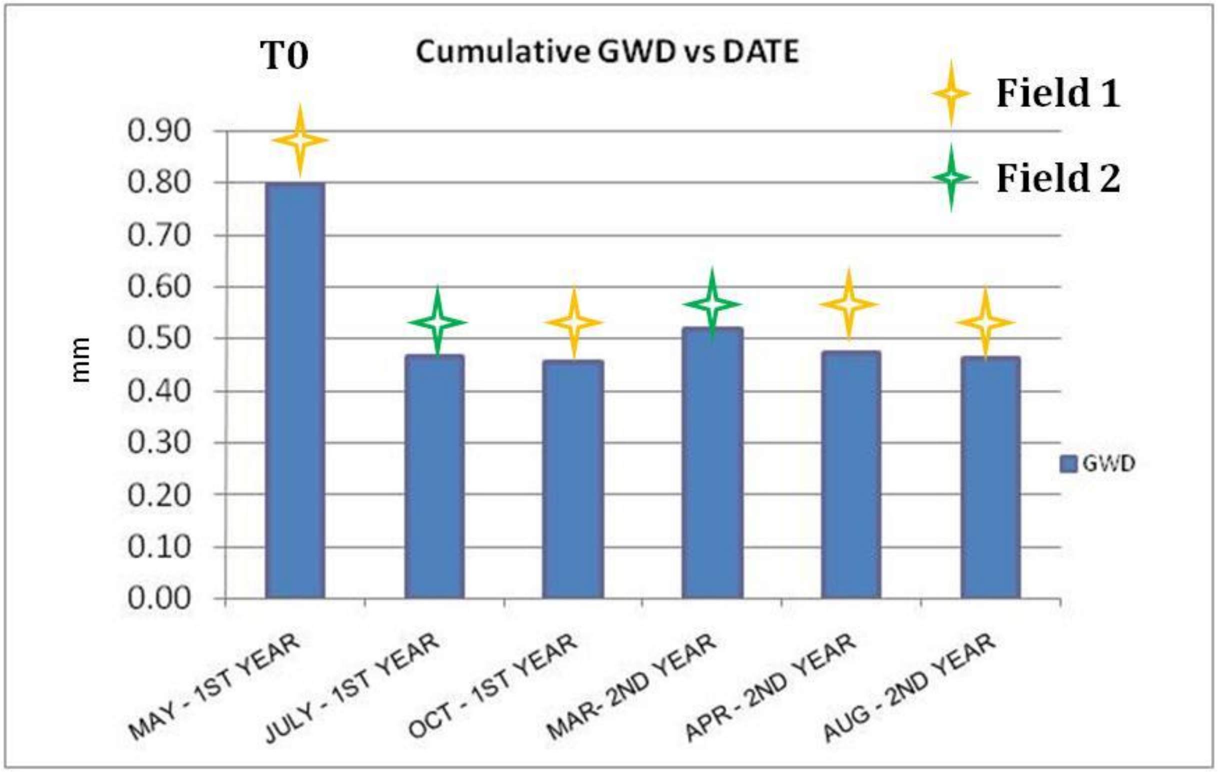


Fig. 9 Geometric Mean Diameter (GMD) trend for the Cover crops (a) and compost (b) thesis.

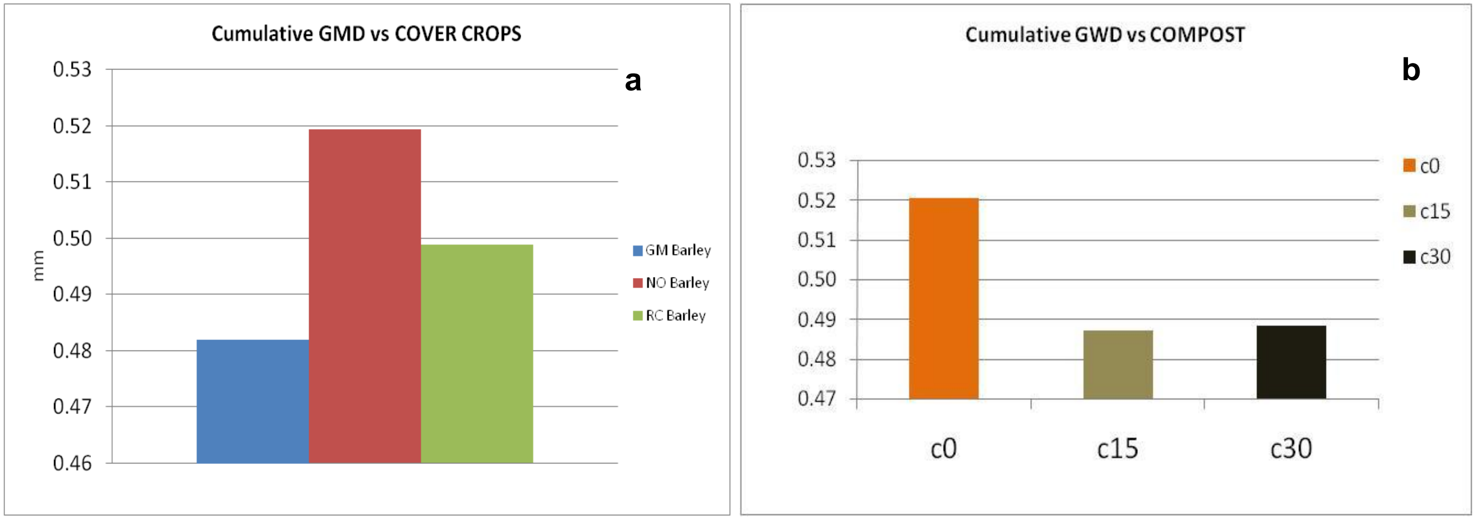


Fig. 10 Soil bulk density at field capacity values for the different trial fields as cumulative values in the two fields for different cover crops (a) and the same splitting for sampling times (b).

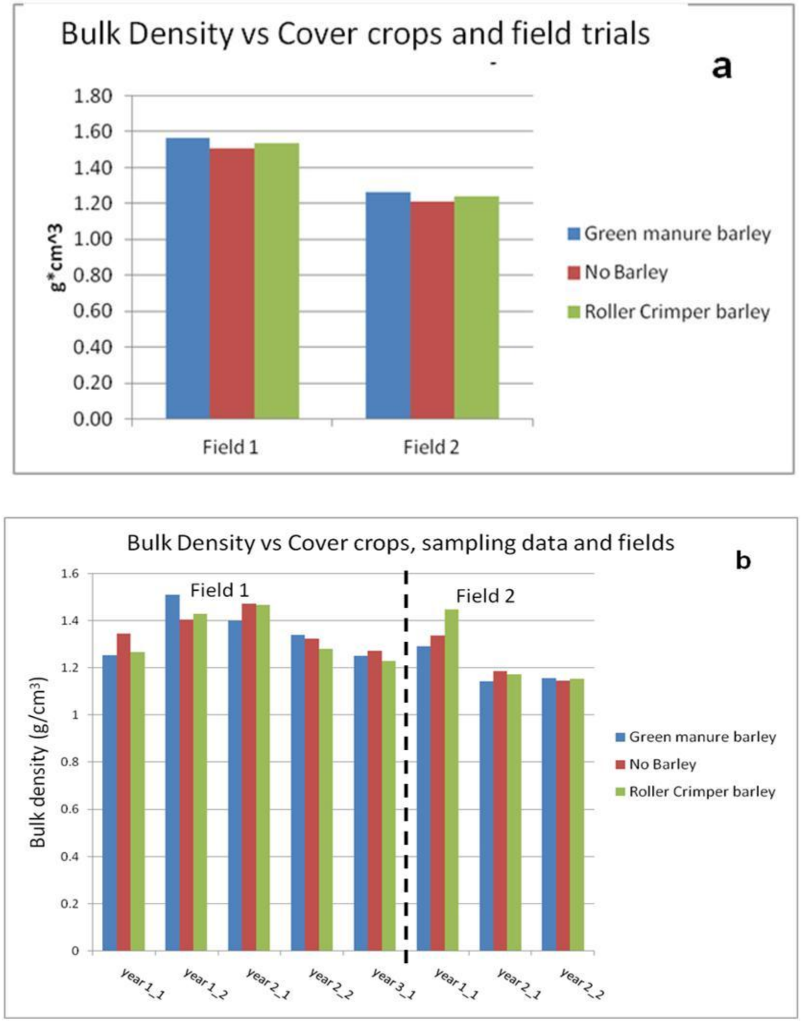


Fig. 11 . Saturated hydraulic conductivity (Ks, as cm*h-1) calculated by infiltration rates for the cover crop thesis vs measurements dates (a) for the first (a) and second (b)field trial. In the graphs are reported the variations for the field measurements times, the mean values and trend dotted lines. Significant differences according to T test: (*) = P<0.1.

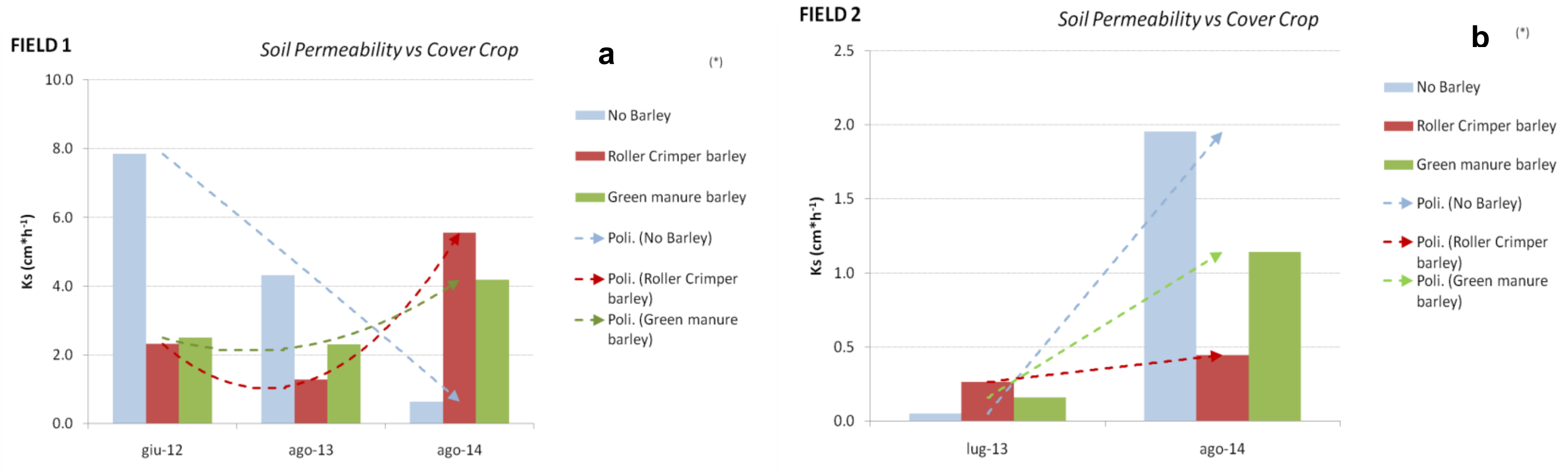


Fig. 12. Cumulative Saturated hydraulic conductivity (Ks, as cm*h^{-1}) as mean values for three years of measurements.

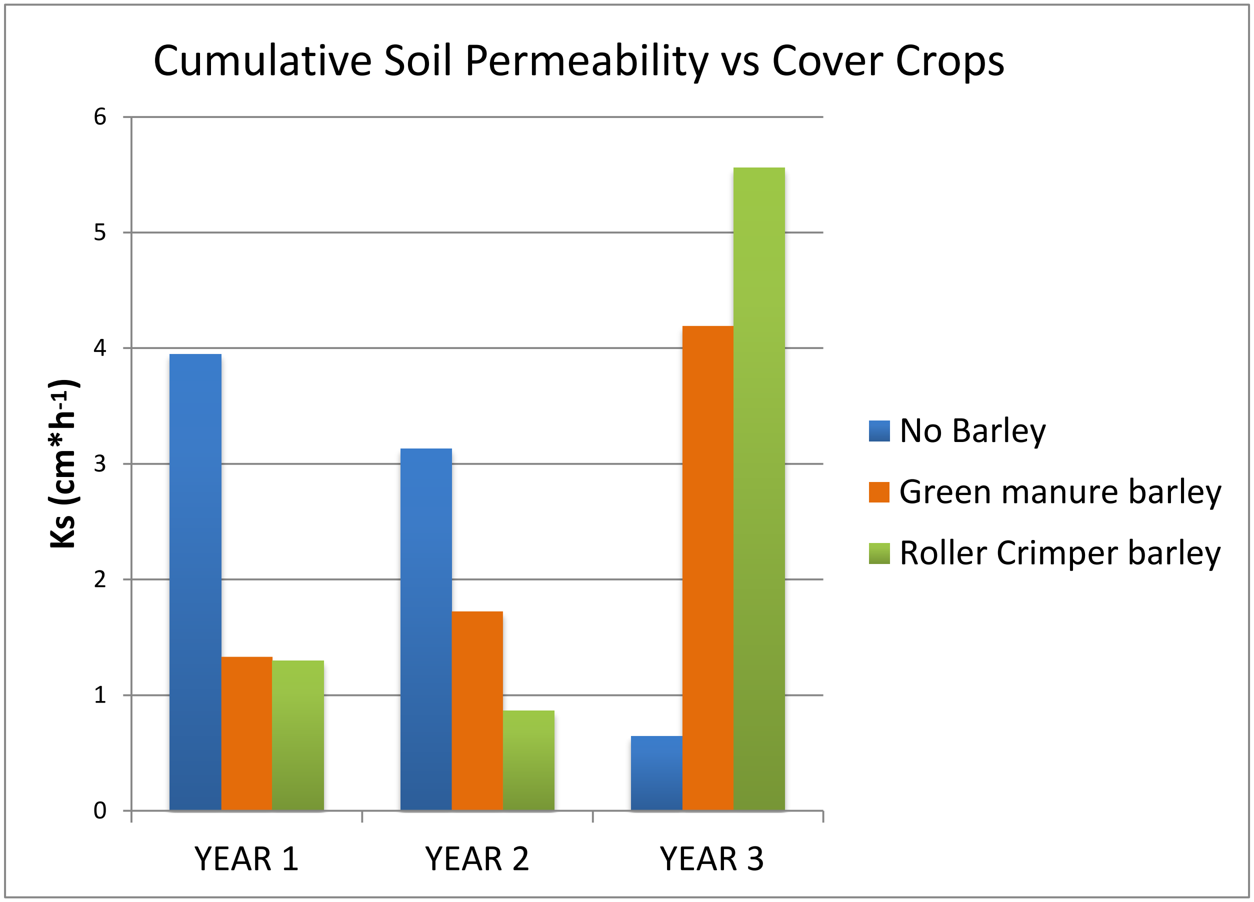


Fig. 13 Soil water retention content at the benchmark saturation point (0Kpa) for the Cover crop (A) and Compost (B) treatments.

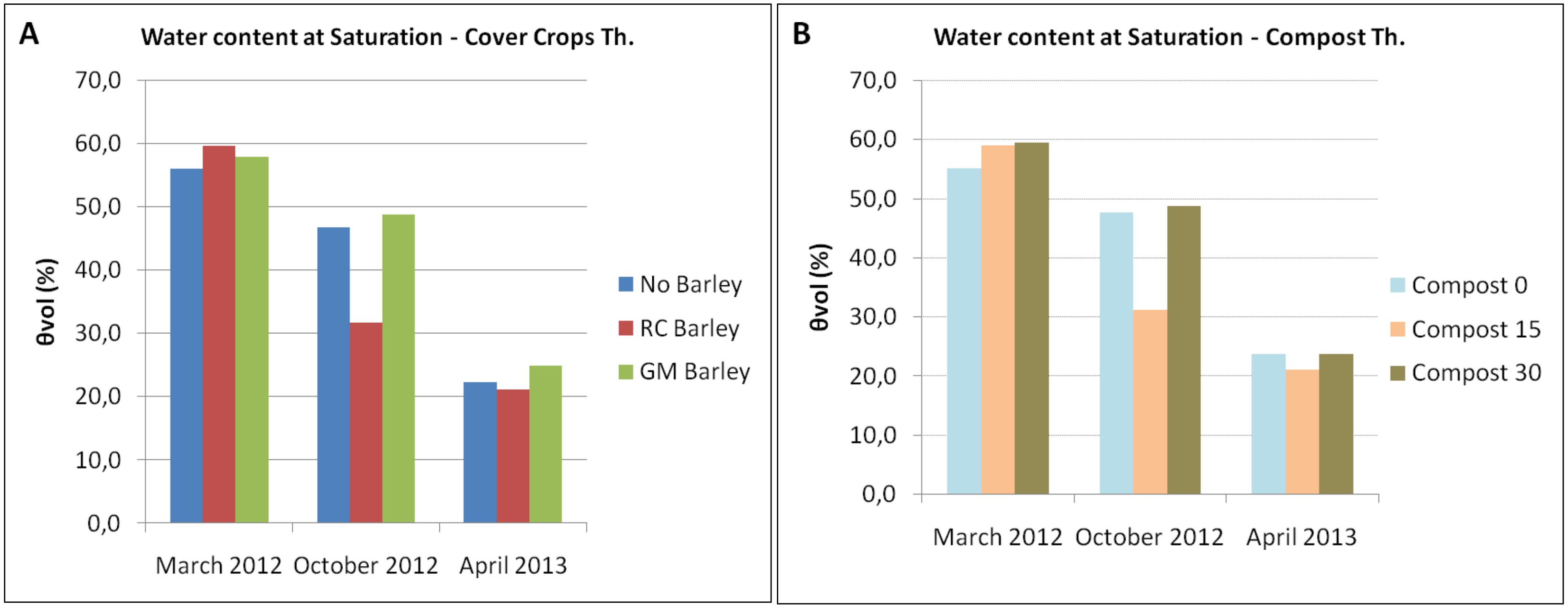


Fig. 14 Soil water retention content at the benchmark Field Capacity point (33Kpa) for the Cover crop (A) and Compost (B) treatments. With the letters (a), (b) and (c) the significant differences according to T test (P<0.05).

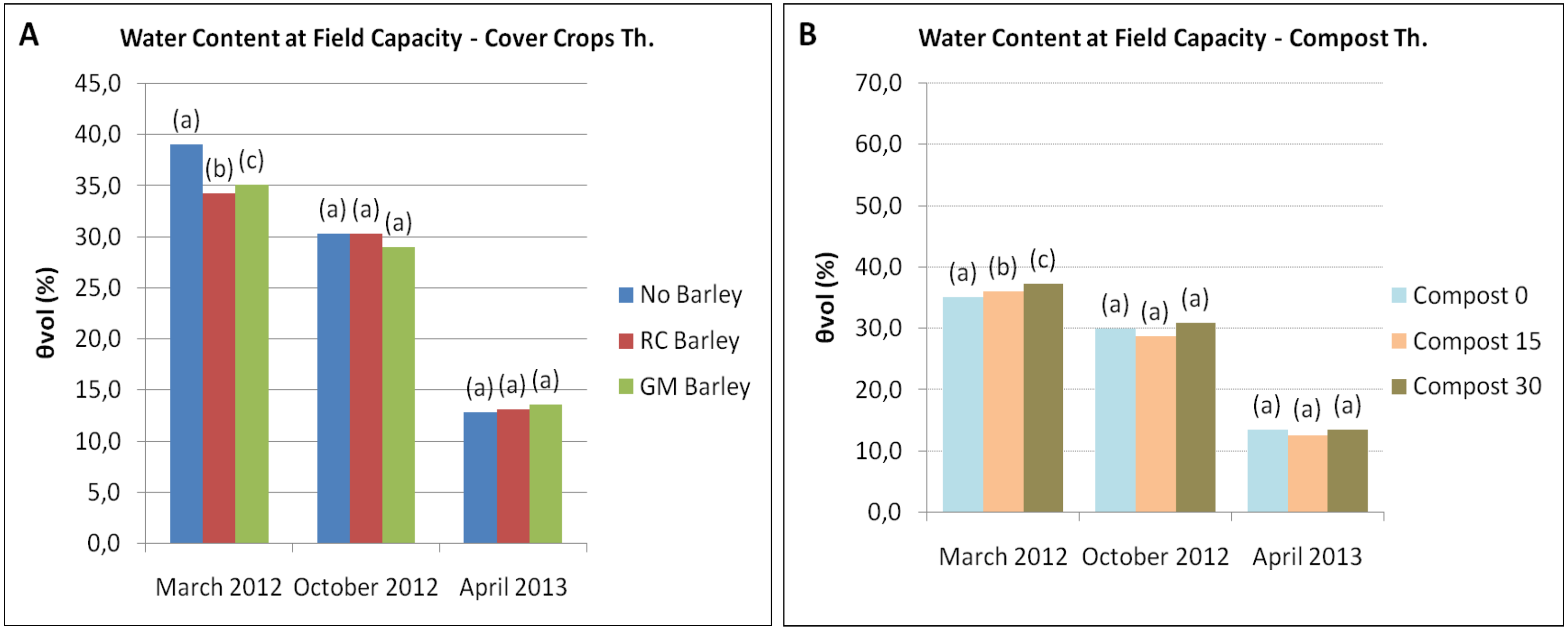


Fig.15 Soil water retention content at the benchmark Wilting Point (1500Kpa) for the Cover crop (A) and Compost (B) treatments. With the letters (a), (b) and (c) the significant differences according to T test (P<0.05).