出國報告(開會)

參加第九屆土壤礦物質與有機質和微生物相互作用國際研討會

服務機關：農業部花蓮區農業改良場

姓名職稱：簡梓丞助理研究員、倪禮豐助理研究員

赴派國家：日本

地區：筑波

出國期間：民國 113 年 10 月 14 日至 10 月 21 日

摘要

第九屆土壤礦物質與有機質和微生物相互作用國際研討會(9th International Symposium of Interactions of Soil Minerals with Organic Components and Microorganisms conference)，10 月 14 日至 21 日於日本筑波舉行，主辦方為 International Union of Soil Sciences(IUSS)。研討會宗旨為提供土壤學、環境學、生態學、生物地球化學等不同領域專家交流平台，討論如何透過土壤延緩全球暖化之解方，提供年輕學生及學者學習機會。會議內容包含土壤保育、土壤碳變化與平衡、土壤微生物對於土壤有機碳形成與團粒之關係、土壤非破壞性監測技術等。其中土壤保育為討論農地栽培、生物炭施用等技術，土壤碳循環部分調查森林、草原、冰原、農地等不同生態系，以及不同礦物對於土壤有機碳之影響。土壤微生物為介紹有機質分解與保護之作用機制，因土壤有機質檢驗成本較高，因此學者們開發非破壞性調查方法，期望未來可以提高檢驗之效率。本場亦發表文旦果園碳匯試驗及有機龍鬚菜土壤微生物相變化張貼海報，與各國專家學者交流共同找出全球暖化之解方。

Abstract

The 9th International Symposium of Interactions of Soil Minerals with Organic Components and Microorganisms, hosted by the International Union of Soil Sciences (IUSS), was held in Tsukuba, Japan, from October 14th to 21st. The symposium aims to provide a platform for experts from soil science, environmental science, ecology, and biogeochemistry to exchange ideas on how to mitigate global warming through soil management. This event offers valuable learning opportunities for young students and researchers. The topics of the conference program contain soil conservation, soil carbon changes and balance, the relationship between soil microorganisms and soil organic carbon formation and aggregation, and non-destructive soil monitoring techniques. Soil conservation will discuss techniques like agricultural cultivation and biochar application. The researchers about soil carbon cycle investigate soil organic carbon in various ecosystems, including forests, grasslands, ice field, and farmland, and the impact of different minerals on accumulating soil organic carbon. The soil microbiology section introduced the mechanisms of organic matter decomposition and protection. As soil organic matter testing is costly, researchers are also developing non-destructive investigation methods to improve testing efficiency. This symposium will also feature poster presentations on carbon sequestration trials in pomelo orchards and changes in soil microbial communities in organic chayote cultivation, providing opportunities for exchange with international experts to find solutions to global warming.

目錄

一、 研習目的

工業革命後，溫室氣體排放量漸增，導致全球暖化及氣候變遷問題日趨嚴重，因此如何透過不同手段減少大氣溫室氣體濃度為重要課題。陸地上土壤為最大土壤碳庫，先前亦有學者提出千分之四倡議，藉由增加土壤有機碳含量以抵銷人為活動所產生之二氧化碳排放，但土壤有機碳形成與流失受到人為操作、土壤微生物、土壤礦物、土壤環境等因素影響，因此需了解各項因子對於土壤碳之影響，以利開發合適之操作農事作法。本次研討會名稱為土壤礦物質與有機質和微生物相互作用國際研討會，因此參加本次會議幾項目的如下

1. 碳匯相關技術交流

   學習有關土壤有機質與微生物相互作用、土壤碳循環、養分循環等最新科學研究相關知識，並將本場近年土壤碳匯與微生物研究成果與其他學者交流分享並獲得專業意見，增加國際觀點，了解土壤知識最新研究及未來可能研究之目的與走向。

2. 開拓與國際學者合作機會

   許多不同領域之專家學者參加本次研討會，可認識與本場研究領域相關之研究室與老師，未來可討論交流相關意見，或至該實驗室觀摩學習是否有適合應用於台灣田區之技術。

3. 增加土壤碳匯國際研究最新資訊

因土壤碳匯為近年較為熱門之議題，許多外國學者包含本場對於該領域熟悉度較低，因此可藉由參加本次研討會學習土壤礦物性質、有機質測定、農耕操作技術等基礎知識。

4. 分享本場研究成果

本場分享調查文旦果園碳匯基礎資料及不同草毯對於土壤有機質含量之影響，以及有機栽培對於龍鬚菜園土壤微生物相變化之影響。發表海報並與各國專家學者意見交流。

二、 行程紀要

<table>
<tr><th>日期</th><th colspan="2">訪視內容</th><th>地點</th></tr>
<tr><td>113.10.14</td><td colspan="2">從花蓮出發至桃園，搭乘飛機前往日本，並於研討會地點 Hotel Grand Shinonome 住宿</td><td>桃園-筑波</td></tr>
<tr><td>113.10.15</td><td rowspan="4">ISMOM 研討會</td><td>介紹 ISMOM 宗旨與現況挑戰</td><td rowspan="4">筑波</td></tr>
<tr><td>113.10.16</td><td>介紹土壤礦物、有機物和微生物之相互作用關係</td></tr>
<tr><td>113.10.17</td><td>土壤微生物循環及土壤碳管理</td></tr>
<tr><td>113.10.18</td><td>土壤管理政策制定對於土壤有機質之影響</td></tr>
<tr><td>113.10.18</td><td rowspan="3">ISMOM 田間參訪</td><td>參觀 Imaichi 火山土壤剖面</td><td rowspan="3">栃木</td></tr>
<tr><td>113.10.19</td><td>參觀盆栽介質工廠</td></tr>
<tr><td>113.10.20</td><td>水稻田參訪</td></tr>
<tr><td>113.10.21</td><td colspan="2">從日本搭機返台，並於當天返回花蓮</td><td>筑波-桃園</td></tr>
</table>

三、 會議議程

October 15 (Tuesday)

7:15 - 8:00 **Reception** (please get name card and registration info)

8:00 - 8:20 **Opening Ceremony**

Session 1. Fundamental aspect of ISMOM: challenges & opportunities

Chairs: Angela Possinger (USA) & Carsten Muller (Germany)

8:20 - 9:00	<Invited-Keynote> **Microbe-Mineral-Organic Matter Interactions at Pore to Hillslope Scales** Jon Chorover, University of Arizona, USA
9:00 - 9:25	**Promotion of carbon storage by weathering of pristine phyllosilicate at the decadal timescale** Delphine Derrien, INRAE, France
9:25 - 9:50	**Influence of plant litter quality on soil carbon accumulation patterns in the converted upland from lowland paddy in Japan using ^{13}C-labeled residues** Le Van Dang, Tokyo University of Agriculture and Technology, Japan
9:50 - 10:15	**Mineral type and land use shape formation, microbial colonization, and stability of mineral associated organic matter** Marion Schrumpf, Max-Planck-Institute for Biogeochemistry, Germany
10:15 - 10:35	***coffee break (20 min)***
10:35 - 11:00	<Invited> **Microscale self-organization of mineral-associated organic carbon for macroscale global predictions** Francisco Matus, Universidad de La Frontera, Chile
11:00 - 11:25	**What are the organo-mineral associations called 'nanoCLICs'?** Isabelle Basile-Doelsch, INRAE, France
11:25 - 11:50	**Chemical properties of soil organic matter resposible for available nitrogen** Syuntaro Hiradate, Kyushu University, Japan
11:50 - 13:30	***lunch break*** *(walk to two restaurants. Check your restaurant at Reception)*
13:30 - 13:55	**A view from inside: Organic matter's influence on iron mineral structures through the lens of Mössbauer Spectropscopy** Aaron Thompson, University of Georgia, USA
13:55 - 14:20	**Scaling organic carbon stocks – from microbes to landscapes** Sam McNally, Manaaki Whenua Landcare Research, New Zealand
14:20 - 14:45	**Integrating grassland species with beneficial root traits to promote soil C stabilization** Chupei Shi, University of Amsterdam, Netherland
14:45 - 15:10	**Mineral-organic associations influence the capacity and vulnerability of soil carbon storage** Katerina Georgiou, Lawrence Livermore National Laboratory, USA
15:10 - 16:00	**Open Discussion (tentative topic: soil C saturation)** <moderators> Caitlin Hicks Pries, Aaron Thompson (USA), and Klaus Kaiser (Germany)
16:00 - 17:30	**Poster Session (Session 1 & Session 2)** ***+ coffee break***

October 16 (Wednesday)

Session 2. Soil structure as physical constraints of the interfacial reactions among minerals, organic matter, and microbes

Chairs: Cheng-Hsien Lin (Taiwan) & Valerie Pot (France)

8:00 - 8:40	<Invited-Keynote> **Microbial geography within the constrains of soil structure – are we there yet?** Alexandra Kravchenko, Michigan State University, USA
8:40 - 9:05	**Mineral and substrate control on MOM formation efficiency, and feedbacks to microbial composition and function** Ye Yuan, Max Planck Institute for Biogeochemistry, Germany
9:05 - 9:30	**Does structure really matter? Exploring implications of microbe-structure interactions to carbon dynamics at the field scale** Sara König, UFZ - Helmholtz Centre for Environmental Research, Germany
9:30 - 10:00	**The effects of spontaneous cover crops on soil aggregation in Mediterranean orchards** Raul Zornoza, Universidad Politecnica de Cartagena, Spain
10:00 - 10:20	***coffee break (20 min)***
10:20 - 10:45	<Invited> **Spatial heterogeneity in soils – Assessing microbial metabolism** Anke Hermann, Swedish University of Agricultural Sciences, Sweden
11:05 - 11:30	**Arbuscular mycorrhizal fungi augment carbon and nitrogen storage in soil microaggregates even under low water availability** Julien Guige, Chair of Soil Science, Technical University of Munich, Germany
11:30 - 11:45	**Distribution of microbial metabolic power in the soil pore network** Naoise Nunan, CNRS, France
11:45 - 12:15	**Open Discussion** <moderators> Sara König (Germany) & Naoise Nunan (France)
12:15 - 13:30	***Group photo & lunch break*** *(lunch box at Hotel Grand Shinonome)*
13:30 - 14:30	**Poster Session (Session 3)** ***+ coffee break***

Session 3. New concepts and approaches: Methodological and conceptual advances
Chairs: Clementine Chirol (France) & Atsushi Nakao (Japan)

14:30 - 15:10	<Invited-Keynote> **The fine-scale spatial organisation of the soil microbiome** Christina Kaiser, University of Vienna, Austria
15:10 - 15:35	**Stability of mineral-associated organic matter in soils depends on mineral type and land use** De Shorn Bramble, Max Planck Institute for Biogeochemistry, Jena, Germany
15:35 - 16:00	**Correlative imaging of the rhizosphere – A multi-method workflow for targeted mapping of chemical gradients** Eva Lippold, Helmholtz Centre for Environmental Research UFZ, Halle (Saale), Germany
16:00 - 16:25	**Micro-scale approach to quantitative analysis of enzymatic activity in soils** Andrey Guber, Michigan State University, USA
16:25 - 16:40	***coffee break (15 min)***
16:40 - 17:05	<Invited> **Fantastic voyage to the Asteroid Ryugu: a world of clays and organics** Motoo Ito, JAMSTEC, Japan
17:05 - 17:30	**Soil warming and rain exclusion promote stable soil mineral-organic associations in dryland soils** Luis Carlos Colocho Hurtate, Diamond Light Source, UK
17:30 - 17:55	**Rechargeable biogenic mineral induced by a sulfate reducing bacterium enhances microbial community activities** Hiroyuki Futamata, Shizuoka Univ., Japan
17:55 - 18:20	**Resolving microbe-mineral-organic matter interactions in soils and sediments using photothermal infrared microscopy** Floriane Jamoteau, University of Lausanne, Switzerland

October 17 (Thursday)

Session 4. ISMOM and biogeochemical cycling across scales
Chairs: Juan Jia (China) & Kazumichi Fujii (Japan)

8:00 - 8:40 <Invited-Keynote> **Nature, time and humans: Why we need a landscape perspective to get soil organic matter cycling right at larger scales**
Sebastian Doetterl, ETZ Zurich, Switzerland

8:40 - 9:05 **Earthworms enhance plant-derived OM stabilization through mineral interactions: effects of species and soil types** Chao Song, (1) IRD, iEES-Paris; (2) Institute of Hydrogeology & Environmental Geology, CAGS

9:05 - 9:30 **The ultimate stabilisation: making the organic mineral. The case for irrigated gypsum-rich soils** Inigo Virto, Universidad Publica de Navarra, Spain

9:30 - 9:55 **The role of basalt particle size on organic and inorganic carbon sequestration: leaching/incubation experiments using rock-plant residue mixtures**
Puu-Tai Yang, NARO, Japan

9:55 - 10:15 ***coffee break (20 min)***

10:15 - 10:40 <Invited> **Behavior of organic carbon governed by soil components interplay** Qiaoyun Huan, Huazhong Agricultural University, China

10:40 - 11:05 **Unraveling the effect of soil aeration on soil organic carbon mineralization in soils with different tillage intensity** Orly Mendoza, University of Lausanne; Swiss Federal Institute of Technology in Lausanne (EPFL)

11:05 - 11:30 **Moisture-driven relationships between soil organic carbon and short-range ordered minerals at the global scale** Sophie von Fromm, Dartmouth College, USA

11:30 - 11:25 **Metal-organic carbon interactions in wetlands: Implications for wetland carbon preservation** Xiaojuan Feng, Institute of Botany, Chinese Academy of Sciences

11:55 - 13:30 ***lunch break*** *(we all walk to a restaurant)*

Session 5. ISMOM as a basis for soil carbon management
Chairs: Jaruwan Jindawong (Thailand) & Mark Farrell (Australia)

13:30 - 13:55 <Invited> **How does fire affect the nature and stability of soil organic C and N? implications for biochar management**
Heike Knicker, Spanish National Research Council, Spain

13:55 - 14:20 **Carbon Dynamics and Sequestration in Semen Euryales Pond Ecosystems: Insights from the Lower Xijiang River Basin** Guodong Yuan, Zhaoquing University, China

14:20 - 14:45 **Climate change induces rapid losses of occluded particulate organic carbon in Alpine grassland soils** Noelia Garcia Franco, Technical University of Munich, Germany

14:45 - 15:00 ***Coffee break (15 min)***

15:00 - 15:25 **Soil aggregate formation, stability, and associated carbon accumulation as influenced by diversified organic amendment-derived dissolved organic matter**
Kiattisak Sonsri, Kasetsart University, Thailand

15:25 - 16:05 <Invited-Keynote> **Management practices and soil organic C: lessons learned, controversies, and knowledge gaps** Denis Anger, Agriculture & Agri-Food Canada

16:05 - 16:35 **Open Discussion:** <moderators> Marion Schrumpf (Germany), Alain Plante (USA)

16:35 - 18:00 **Poster session (Session 4 and Session 5)**

October 18 (Friday)

Session 6. The role of organo-mineral-microbial interactions in soil management and policy making: Implications for climate change and C credit markets

Chairs: Sabina Devkota (Nepal) & Rota Wagai (Japan)

8:00 - 8:40	<Invited-Keynote> **From organo-mineral interactions to soil and carbon policies** Claire Chenu, INRAE, France
8:40 - 9:05	<Invited> **Soil and Climate Change: Evolving Policy Landscapes and Intersections** Asmeret Asefaw Berhe, UC Merced, USA
9:05 - 9:30	<Invited> **From economics of land to economics of soils: implications for public policies and private markets** Alisher Mirzabaev, IRRI, Phillipines
9:30 - 9:50	***coffee break (20 min)***
9:50 - 10:30	**Pannel Discussion (wrap-up session)** <moderators> Katarina Georgiou (USA) & Rota Wagai (Japan)
10:30 - 10:45	OECD-CRP Event Questionaries
10:45 - 11:15	<PM Huang Prize talk> **Resolving the Molecular Complexity and Dynamic Nature of Mineral-Organic Interactions in Soils** Macro Keilweit, University of Lausanne, Switzerland
11:20 - 11:45	**Closing Ceremony**

土壤觀察主題田區參訪行程

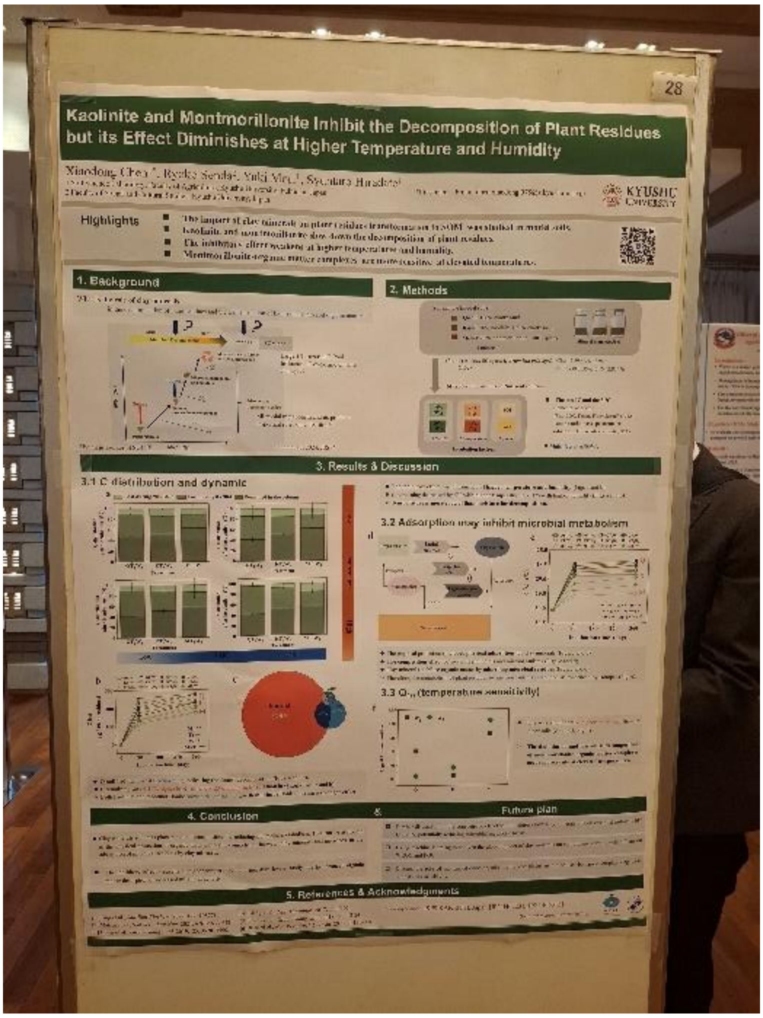
Time	18th Oct	19th Oct	20th Oct
9:00-12:00	ISMOM conference	8:00 Departure (bus) (Watching Senjogahara) to 9:00-10:30 Kegon falls	8:30 Departure (taxi) to 9:00-10:00 Bonsai art museum and a walk to Minuma paddy soil site (depending on weather), back to hotel by taxi or local train (Ohmiya Koen to Ohmiya)
12:00	12:00 Departure (bus, Hotel entrance)	Lunch 11:00-12:00	12:00 Farewell at Omiya station
13:00-18:00	12:00-14:00 Bus & lunch box (Self-introduction)	Nikko toshogu shrine 12:00-14:00	
	Convenience store (toilet)	Bus 14:00-15:00 to get "Oobari" company	
	14:15-16:30 Three color icecream soil profile	15:00-17:00 Volcanic soil profile (Kanuma)	
	Bus to Oku-nikko Hotel (Kamenoi Yumoto)	Bus to Omiya Hotel Super Hotel Premier Saitama Omiya East gate	
18:00-19:00	Dinner	19:00-21:00 Dinner* (Ginnotsuki)	
19:00-21:00	Hot spring (optional) or Table tennis etc.	Hot spring (optional)	

四、 研習內容

本次會議演講及海報內容大致可分為土壤礦物、微生物、農事操作對於土壤有機碳之影響。此外，亦有部分研究與都市土壤改良、土壤檢測、特殊生態系土壤調查等不同主題相關。會議研發成果依照不同主題彙整分敘如下：

(一)土壤礦物及生態系

土壤有機碳的穩定性和持久性受到土壤礦物組成影響，礦物內化學元素決定有機質與礦物質結合能力，不同礦物類型，如黏土礦物、氧化鐵和短程有序礦物，對有機碳的吸附能力和保護能力較佳，其中尤其又以含有氧化鐵之礦物如針鐵礦、火山灰土等有機質累積能力最佳，因富含氧化鐵土壤可藉由凡得瓦力及靜電力等抑制土壤微生物活性，降低有機質分解速度。其中日本學者 Tetsuhiro Watanabe 等人指出於 B 層土壤中鐵、鋁總量與有機質含量相關性達 R^2=0.79-0.86，但 A 層土壤之有機質含量則主要受到氣候因素影響。而 Xiaodong Chen 等學者研究，不同介質孵育艾草殘渣盆栽試驗結果顯示，相較於石英砂，加入蒙脫石及高嶺石可保護有機質增加 4-11% 及 8-23%累積，但仍受到環境影響，而溫度之影響力又大於濕度。



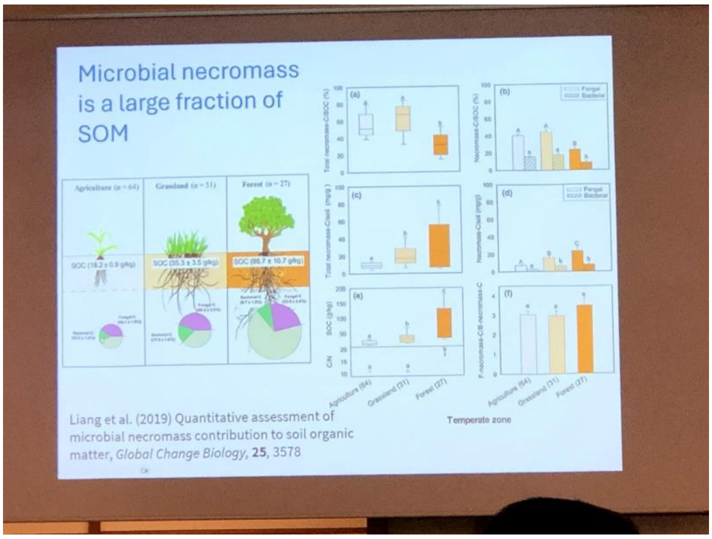
圖、蒙脫石及高嶺石延緩有機質分解之研究

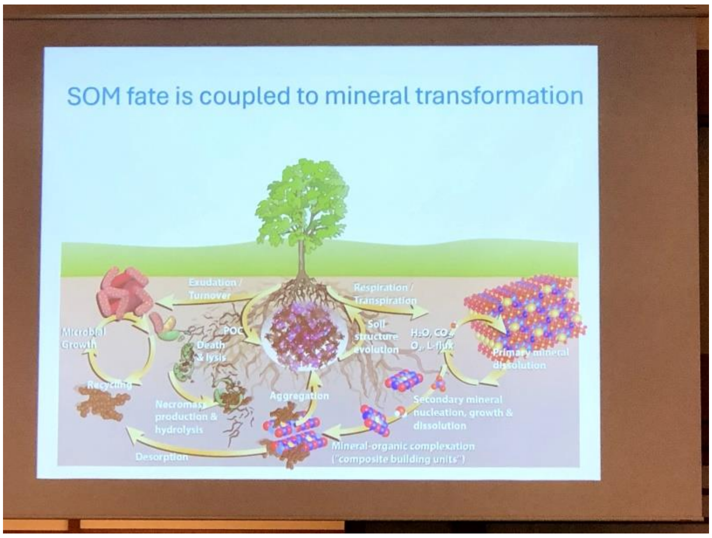
生態系部分，Khalfallah F.等學者調查歐洲不同森林土壤有機質含量，結果顯示森林樹種及土壤性質(質地、鐵鋁含量、鈣鎂含量)分別解釋了 24%及 30%土壤變異性，而樹種之影響力於粗質地土壤有機質較大。

(二)土壤微生物

生物體死亡後回歸土壤，微生物會利用有機殘體或有機質作為能量來源，產生呼吸作用釋放出二氧化碳，而剩下之有機碳則可被礦物固定，土壤微生物的活動會影響土壤的 pH 值、養分有

效性和水分含量等理化性質，進而影響土壤顆粒的膠結和土壤聚集體的穩定，其中礦物結構及微生物扮演重要角色，枯枝落葉等有機質分解後變為 particulate organic matter (POM) ，並藉由微生物進一步分解為 mineral-associated organic matter (MAOM)，MAOM 會被包覆於土壤礦物晶格或是土壤團粒中避免微生物分解，因此可於土壤中維持數百年，但其中部分與生化作用無關之反應可以將複雜的有機分子分解成更簡單、更穩定的化合物如腐植質。因此微生物代謝產物可以與土壤礦物質結合，形成礦物結合有機碳 (MAOM)，碳循環代謝物生物薄膜(EPS)亦可提高碳分子與土壤礦物表面之親和性形成土壤聚集體，而小孔隙內微生物族群歧異度較大孔隙高，但本次研討會仍較少研究直接指出何種微生物對於土壤碳匯有正面效益，多數次世代定序分析結果，仍探討微生物歧異度以及營養循環相關菌種為主。相關田間可執行措施為，於作物接種叢枝菌根菌可促進根部生長，並增加根圈土壤有機質含量。蚯蚓可透過直接利用土壤不同醣類作為養分，並增加土壤 MAOM 之含量。





圖、會議中介紹微生物於土壤中如何影響有機質與礦物交互作用

微生物殘體亦為有機質重要來源之一，真菌及細菌於農業、草地、森林土壤有機質貢獻度分別佔 55%、61%、32.6%，且額外投入不同碳氮比之資材，會影響富營養型(copiotrophic)與貧營養型(oligotrophic)微生物比例，有可能提高微生物活性加速有機質分解，或是營造合適之微生物群落有利於有機質與礦物鍵結，提高穩定性，因此於不同地區應用不同資材會有不同之結果

(priming effect)。

(三)農事操作對土壤有機質種類及調查指標之影響

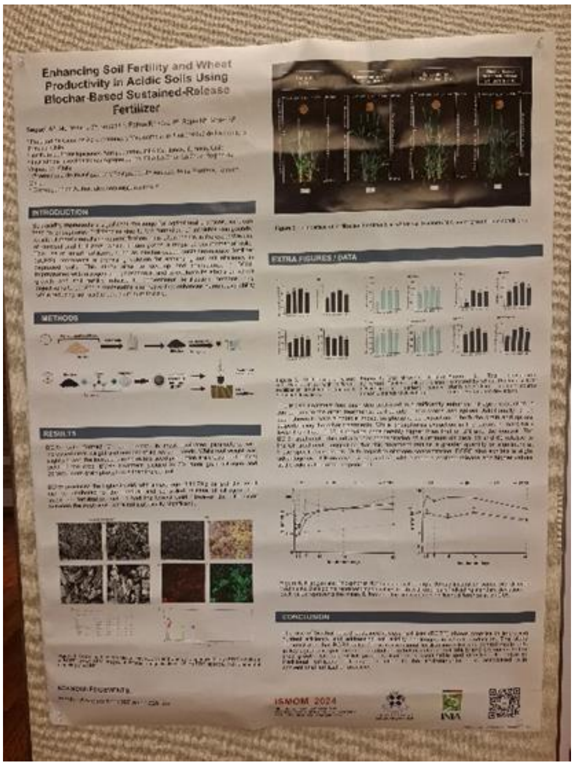
土壤有機碳會直接受到土地利用方式，如農業、林業和草地等不同生態環境下，會影響有機碳的輸入和分解速率，影響土壤有機碳的含量。相較於草原及農田，森林土壤有最高之土壤有機碳含量。

不整地栽培部分，Sophia 等人報告指出於美國農田實施不整地或條耕栽培搭配種植冬季綠肥作物可顯著增加土壤有機質含量；另一研究團隊試驗結果亦顯示少耕犁和覆蓋作物有助於真菌菌絲活動進而增加> 2mm 之土壤團粒形成，統計數據顯示，免耕犁有助於減少碳流失達 37%，尤其於熱帶國家操作有更顯著之效果。

覆蓋作物部分，於地中海橄欖園與果園中種植大麥、小麥、豌豆等覆蓋作物，會增加土壤 POM、團粒穩定度與生物酶活性，尤其大直徑之團粒與有機質相關性為 R^2=0.89，因此於地中海果園中種植覆蓋作物有助於增加土壤碳儲量。台灣麻豆地區文旦果園種植覆蓋作物亦有提高土壤微生物酶活性之結果。

生物炭部分，韓國之研究結果顯示將作物殘體回歸農田可增加作物產量，而施用生物碳有最高增加土壤有機碳能力，以辣椒

田為例，相較於對照組，於田間施用稻殼（-1.93 公噸/公頃）及木頭（-3.81 公噸/公頃）生物炭有最小的 NECB（淨生態系碳平衡），且可增加土壤理化性質（如容重、pH、總碳含量等），但施用辣椒殘渣堆肥則有最高辣椒產量；此外韓國其他研究團隊亦將生物碳施用於都市公園之土壤，因生物碳可以增加土壤保水性、微生物活性、養分有效性等，有助於促進植物根系發育，未來更有可能提高土壤之有機質含量。斯洛伐克農業大學研究團隊結果顯示於農田施用生物炭顯著改善了土壤孔隙度、相對團聚穩定性、可利用水容量、陽離子交換能力及土壤水分含量，其中施用 20 公噸/公頃生物炭有最佳土壤有機質增加能力。而智利研究團隊則開發含氮肥及磷肥之燕麥殼生物炭緩效肥，應用於酸性小麥田土壤，可增加小麥產量及穀粒內 38%氮及 33%磷含量。



圖、生物炭開發為肥料相關研究海報

此外於土壤投入有機質資材亦可增加有機質含量，如前段微生物影響所述，資材之碳氮比會影響分解速度，日本學者盆栽試驗結果顯示玉米殘枝因碳氮比較高相較於大豆可貢獻較多有機質，其中又以葉片之有機質可保留最多。

(四)土壤檢測

碳匯研究中，土壤檢測亦為重要領域，許多研究團隊利用非破壞性儀器或是碳同位素追蹤土壤有機碳，可利用碳 14 先種植作物後，再將植物混入土中觀察不同資材於土壤中有機質之變化。非破壞性檢測儀器方面則使用近紅外光、紅外光、遠紅外光、拉曼光譜等，利用有機質會吸收特定光波長之特性，使用光譜檢測

推定搭配現有不同有機碳分析儀資料訓練模型，目前研究遭遇瓶頸為部分方法檢測之數據資料過多不易分析，以及部分方法之訓練模型樣本數需再增加，未來如成功建立測定流程後可大幅加快並降低有機質測定成本，但該技術需考慮土壤含水量對於測定之干擾。

(五)土壤觀察主題田區參訪

本次田野參訪地點為栃木縣，內容主要為參觀火山灰土土壤剖面、盆栽介質工廠及火山灰土水稻田介紹。本次參觀之剖面為已休眠火山赤城山噴發形成，推估當地先經歷過土石流掩埋形成土層後，於 14800 年前火山噴發直接覆蓋厚度達 1 公尺以上，因此土壤分層相當明確，無明顯化育痕跡。火山灰土壤特性為偏酸、土壤密度低(≤0.9 g cm^{-3})、富含鐵鋁不定型化合物、容易缺水、容易吸附磷肥等特性，早期被歸類為不適合種植之土壤，但現因可補充大量磷肥，缺磷問題已解決，而本次參觀之大宮區水稻田區除具火山灰土壤特性外，早期位於海平面交界處，因此皆為沼澤地，於 500 年前建設運河疏浚後開發為水稻田。當地過去有生產製作清酒之稻米，肥料用量非常低(N<60 公斤/公頃)，但因近年來日本稻米需求下降，且製作清酒之稻米產地逐漸移至日本其他縣市，開始輪作小麥等其他作物。台灣除陽明山地區外，無火山灰

土田地，因此臺灣農田較少有相同之土壤議題。火山噴發後形成之赤玉土與鹿沼土，具有偏酸、孔隙大、排水、通氣度佳等特性，適合用於園藝盆栽之介質，且日本盆栽文化盛行，政府單位給予民間介質廠商開採權，開挖後場域會再建置太陽能板。

五、 研習心得與建議

多數國家有關土壤碳匯相關研究還在起步階段，因此部分實驗有互相牴觸之結果，如於不同國家地區施行不整地栽培對於土壤有機質影響結果不同；大部分學者認為土地不同利用方式會影響土壤有機碳累積，但有報告指出不同放牧強度下之草地土壤於 80 年後，雖不同處理土壤 POM 和 MAOM 比例不同，但最終有機質含量無顯著差異；會議中研究施用生物炭對於作物生長有正面影響，但許多國際文獻卻有不同之結果；如討論至土壤礦物則更為複雜，隨著不同礦物之晶格結構、金屬離子等差異，對於植物、真菌、細菌殘體保護能力不同。以上研究可能因為地區或操作細節導致結果不同，國內相關資料不足，因此亟需於本地調查相關措施效益，評估是否可行。

本次研討會參加者多為學校教授、農業機構學者，討論許多土壤礦物與微生物相互作用之機制，但多數研究如欲實際應用於田間，仍有許多細節成本仍須考量。但仍可提供我們相關土壤作用機制，開發具有增加土壤碳匯潛力之農法、增加評估選項，但目前台灣仍缺乏淨零碳排相關基礎資料，相關建議如下

(1) 土壤碳匯基礎資料：雖台灣已進行全國土壤普查，測定酸鹼度、有機質含量、各項營養元素、陽離子交換能力等資料，但已為 30 年前資料庫，數據較為老舊，且少部分地區有較完整土壤質地、

土壤穩定度等其他相關土壤物理資料，建議可針對農業熱點更新土壤資料庫。但仍可先使用現行之土壤、氣候資料庫、作物種類等，計算開發有較高土壤碳匯潛力地區，避免於已飽和或不適合碳匯場域實行碳匯措施。

(2) 長期試驗：草生栽培、混林農業、農田施用生物炭等長期研究，國外發展已久，於本次及其他相關研討會多種措施之結果至少評估 10 年以上，亦不乏調查百年以上田間土壤資料，如生物炭為不易分解之材料，可長期將碳固定於環境中，為良好碳匯資材，但仍須試驗於不同作物與土壤，觀察長期對作物及環境之影響；混林農業除土壤外樹木亦為良好碳匯標的，但此措施亦須長期評估生態系變化及挑選合適之經營模式。有關土壤碳匯、環境營造等議題須長期經營，台灣極度缺乏相關成果，現行調查多於溫帶國家施行，熱帶環境可能會有不同之結果或合適方法，因此期未來政策可支持長期相關試驗，以評估適合台灣之碳匯經營操作。

(3) 具體措施：本次研討會提供許多科學基礎資料，可借鏡思考可能之田間操作，如植物殘體之碳氮比影響有機質微生物分解效率或是微生物族群種類，可針對欲保留較多 POM 或 MAOM，於田間操作不整地栽培、種植綠肥、覆蓋作物、施用不同碳氮比資材等農業措施，以上措施於台灣仍需考慮許多細節，如合適作物、雜

草管理、作物品質、輪作時機等需再調整。而試驗初期可測定土壤穩定度、微生物群落變化等作為是否可能增加有機質之指標。本場碳匯試驗場域於瑞穗，為酸性土壤，根據本次研討會會議上分享結果，相較於 MAOM 可累積較多 POM，因此選擇高碳資材應用於文旦果園，如種植越橘葉蔓榕草毯，施用以木屑為主要成分之堆肥，觀察有機質長期變化，期未來可建立合適之方法。此外微生物部分，可透過接種叢枝菌根菌、提高微生物族群歧異度、增加土壤生物群落等對於土壤碳匯皆有正面效益，如本場之有機龍鬚菜田因平時無使用農藥且皆施用有機質肥料，可增加土壤微生物豐富度，就為可能增加土壤碳匯之操作。

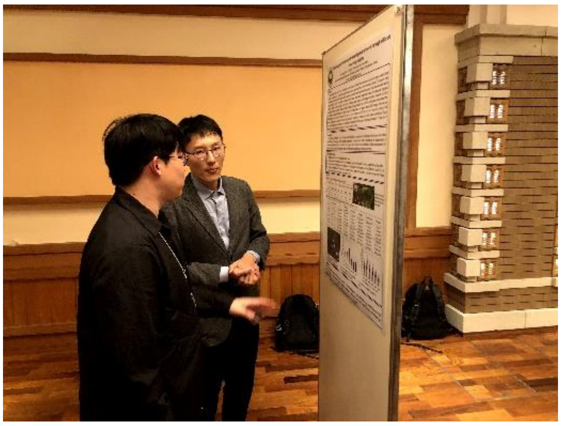
(4) 有機質測定方法：淨零碳排相關成本，除田間操作外，數據收集及測定亦須納入考量。因此可開發不同光譜測定、資料訓練等相關非破壞性調查方法降低檢測成本，未來可減輕農民或政府申請碳權驗證負擔。

淨零碳排為全世界需共同面對之議題，各個國家政策層面還在起步階段，同樣面臨相關操作成本較高、有機質累積量估算不易，且容易分解等問題。美國同樣規劃於 2050 年達成淨零碳排目標，因此現階段已推出不同土壤康管理獎勵補助措施，吸引農民改變田間操作模式。台灣優勢為小農較多可執行較為複雜之措施，但為執行碳匯操作

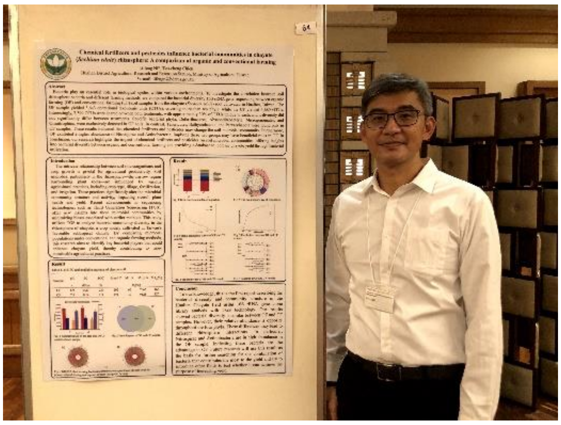
勢必增加操作成本，因此有關成本議題仍為一大挑戰。淨零碳排為長期目標，短期於田間不易有成效，需全面評估相關操作措施細節，未來需結合產官學各方努力，以達成土壤永續經營、淨零、循環、友善環境等目標。

六、　照片分享


圖、各國專家學者與會嘉賓合影




圖、本場分享文旦不同覆蓋作物應用於果園相關碳匯成果及碳匯基礎資料與外國學者分享，左圖為與韓國學者交流，右圖為美國德州大學土壤科學系教授



圖、本場分享有機及慣行龍鬚菜園土壤微生物相變化相關研究成果

圖、本場與台南區農業改良場同仁合影

圖、田間參訪之土壤剖面。左上圖為火山灰土壤剖面(由下而上為最早之本地土壤-土石流沖積土壤-火山爆發累積土壤)，右上圖為赤玉土及鹿沼土開採地區土壤剖面(紅色箭頭交界處推測早期有人為生活痕跡，因此土壤呈現不連續化育層)，下圖為火山灰土壤之水稻休耕田區


圖、開發火山灰土之介質工廠(左上)、赤玉土產品(右上)及當地之盆栽藝術(下，樹齡 150 年之黑松)

七、附件-壁報論文發表內容

ISMOM 2024

9th International Symposium of Interactions of Soil Minerals with Organic Components and Microorganisms

Commission 2.5 Soil Interfacial Reactions, International Union of Soil Science

Enhancing soil carbon sequestration in pomelo orchards through different cover crop adoption

Tzu-cheng Chien *, Li-feng Ni, Gou-en Yan, Hao-cyuan Huang

Hualien District Agricultural Research and Extension Station, Ministry of Agriculture, Taiwan

*Presenter. Email: tzucheng@hdares.gov.tw

Abstract

Implementing cover crops (CC) in the orchards can foster an eco-friendly environment and enrich soil organic matter (SOM) content. Wentan pomelo is an important crop in Taiwan, and some regions still farm with conventional tillage (CT) practice, which was supposed would accelerate SOM depletion. In this study, we assessed the carbon sequestration capacity in the pomelo orchard and the impact of the CC on SOM. We conducted a comparison of the carbon sequestration capabilities among CT, spontaneous vegetation, and four different cover crops, such as white clover (Trifolium repens), fish mint (Houttuynia cordata), vaccinium fig (Ficus vaccinioides Hemsl. ex King) and wild peanut (Arachis duranensis), implemented for one year. Five soil samples were collected from the orchard to measure the SOM and soil bulk density (BD), providing data on soil organic carbon (SOC) change. After one year, SOC of the top soil (0-30 cm) of CT increased by 3 tons ha-1. Cover crops further increased SOC by a range of 4.8 to 12.4 tons ha^{-1}, except for wild peanut. Furthermore, we evaluated the carbon stock by felling five pomelo trees, estimating a 110 kg carbon content for a 35-year-old tree. Combining the carbon fixation data obtained from soil and pomelo tree revealed that the orchard stored approximately 71.3 tons ha^{-1} of organic carbon for CT, and potentially increasing to 78.5 tons ha^{-1} with CC adoption.

Chemical fertilizers and pesticides influence bacterial communities in chayote (*Sechium edule*) rhizosphere: A comparison of organic and conventional farming.

Li-feng Ni *, Tzu-cheng Chien

Hualien District Agricultural Research and Extension Station, Ministry of Agriculture, Taiwan
*Presenter. Email: lifengn@hdares.gov.tw

Abstract
Bacteria play an essential role in biological cycles within various environments. To investigate the significance of bacteria in the rhizosphere those are associated with different farming methods, the 16S rRNA gene sequencing was introduced to compare the bacterial diversity between organic farming (OF) and conventional farming (CF) soil samples from the chayote (*Sechium edule*) root cultivated in Hualien, Taiwan. The OF sample yielded 3,643 operational taxonomic units (OTUs), covering more than ten phyla, while the CF yielded 3,680 OTUs. Interestingly, 2,399 OTUs were shared between both treatments, with approximately 30% of OTUs unique to each, and α-diversity did not significantly differ between treatments. Specific bacterial phyla, Deferribacteres, Absconditabacteria, Microgenomates, and Omnitrophica, were exclusively detected in OF soils. In contrast, Tenericutes, Bathyarchaeota, and Parvarchaeota were found only in CF samples. These results indicated that chemical fertilizers and pesticides may change the soil microbial community. Furthermore, OF exhibited a higher abundance of Nitrospirae and Actinobacteria, implying these two groups may have beneficial roles in OF. In conclusion, our research highlights the impact of chemical fertilizers and pesticides on soil microbial communities, offering insights into bacterial diversity between organic and conventional farming and providing a database to optimize chayote yield through bacterial utilization.

海報

Enhancing soil carbon sequestration in pomelo orchards through different cover crop adoption

Tzu-cheng Chien*, Li-feng Ni, Gou-en Yan, Hao-cyuan Huang
Hualien District Agricultural Research and Extension Station, Ministry of Agriculture, Taiwan
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Abstract

Implementing cover crops (CC) in the orchards can foster an eco-friendly environment and enrich soil organic matter (SOM) content. Wentan pomelo is an important crop in Taiwan, and some regions still farm with conventional tillage (CT) practice, which was supposed to accelerate SOM depletion. In this study, we assessed the carbon sequestration capacity in the pomelo orchard and the impact of the CC on SOM. We conducted a comparison of the carbon sequestration capabilities among CT, spontaneous vegetation, and four different cover crops, such as white clover (Trifolium repens), fish mint (Houttuynia cordata), vaccinium fig (Ficus vaccinioides Hemsl. ex King) and wild peanut (Arachis duranensis), implemented for one year. Five soil samples were collected from the orchard to measure the SOM and soil bulk density (BD), providing data on soil organic carbon (SOC) change. After one year, SOC of the topsoil (0-30 cm) of CT increased by 3 tons ha-1. Cover crops increased SOC by 4.8 to 12.4 tons ha-1, except for wild peanuts. Furthermore, we evaluated the carbon stock by felling five pomelo trees, estimating a 110 kg carbon content for a 35-year-old tree. Combining the soil and pomelo tree carbon fixation data revealed that the orchard stored approximately 71.3 tons ha-1 of organic carbon for CT, potentially increasing to 78.5 tons ha-1 with CC adoption.

Introduction

Soil is the largest carbon sink on land. Soil organic matter is difficult to accumulate in Taiwan due to the hot and rainy climate. Orchards farmed with no tillage can slow down the decomposition of organic matter. Studies indicated that the implementation of cover crops would be helpful in the accumulation of soil organic matter. However, few related data in Taiwan were observed. The purpose of this study is to evaluate the carbon storage ability in pomelo orchards through planting cover crop.

Materials and Methods

1. Orchard location: Ruisui Township, Hualien County, Taiwan.
2. Cover crops: Conventional tillage (no cover crop), spontaneous vegetation, wild peanut, fish mint, vaccinium fig, white clover.
3. Soil carbon analysis: Five samples were collected along the farm to detect the soil organic matter by Elementar. vario MAX cube.
4. Pomelo tree carbon analysis: Five trees were cut down and weighed. Sample of trunks, leaves, roots and branches were collected. Carbon content was determined with Elementar vario EL cube.

Result

Table 1. pH, EC and available nutrients of pomelo orchard soil. (n=5)

pH	EC	SOC	Bray I_P	M1_K	M1_Ca	M1_Mg	0.1N HCl_Fe	0.1N HCl_Mn
-	ds/m	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
4.9	0.11	1.41	211	463	788	280	101.02	13.74

Fig. 1 Pomelo orchard plot with conventional tillage (left) and cover crop (right).

Table 2. The soil organic matter (SOM) and soil organic carbon (SOC) for different implementation. (n=5)

	Year	Depth (cm)	CT	Spontaneous vegetation	White clover	Fish mint	Vaccinium fig	Wild peanut
SOM (%)	2023	0-15	1.51 ± 0.38^{defg}	1.36 ± 0.21^{efgh}	1.71 ± 0.4^{bcde}	1.64 ± 0.14^{cdef}	1.48 ± 0.38^{defg}	2 ± 0.88^{abc}
		15-30	1.21 ± 0.51^{fgh}	0.96 ± 0.22^{h}	1.13 ± 0.21^{gh}	1.38 ± 0.19^{efgh}	1.17 ± 0.24^{gh}	1.33 ± 0.38^{efgh}
	2024	0-15	1.71 ± 0.24^{bcde}	1.93 ± 0.11^{abcd}	2.17 ± 0.38^{ab}	2.24 ± 0.56^{a}	2.32 ± 0.62^{a}	2.11 ± 0.27^{ab}
		15-30	1.43 ± 0.36^{efgh}	1.31 ± 0.11^{efgh}	1.29 ± 0.18^{efgh}	1.52 ± 0.41^{defg}	1.35 ± 0.25^{efgh}	1.39 ± 0.31^{efgh}
SOC (ton ha^{-1})	2023	0-15	17.66 ± 5.91^{defg}	16.28 ± 2.71^{efg}	20.28 ± 6.92^{abcdef}	19.93 ± 1.60^{abcdef}	17.76 ± 4.39^{defg}	24.68 ± 9.69^{ab}
		15-30	17.36 ± 7.64^{efg}	13.12 ± 3^{g}	15.22 ± 3.05^{fg}	18.29 ± 2.33^{cdefg}	15.36 ± 2.93^{fg}	18.37 ± 5.51^{cdefg}
	2024	0-15	19.45 ± 2.97^{bcdef}	21.96 ± 1.32^{abcde}	23.94 ± 4.04^{abc}	23.17 ± 5.18^{abcd}	25.65 ± 5.02^{a}	24.84 ± 3.19^{ab}
		15-30	18.57 ± 4.19^{cdefg}	16.97 ± 0.93^{efg}	17.00 ± 2.69^{efg}	19.84 ± 5.86^{abcdef}	19.84 ± 2.88^{defg}	18.06 ± 3.84^{defg}

Fig. 2 Carbon content of pomelo tree was determined by cutting , weighing and sampling.

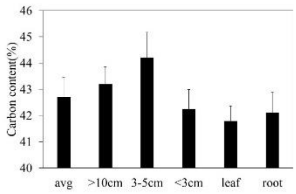

Fig. 3 Carbon content of leaf, root and different diameter pomelo tree branches.(n=3)

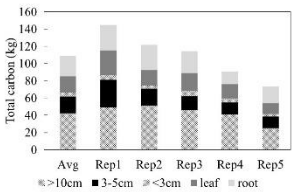

Fig. 4 Total carbon content of pomelo tree. (n=5)

Conclusion

SOM of the pomelo orchard without cover crop (CT) is 1.4%. Farming with different cover crops would increase SOC by 6-21%, with a significant effect (16-44% increase) observed in the topsoil layer (0-15 cm). Planting vaccinium fig is particularly effective in increasing SOC, maybe because of the high lignification.

Chemical fertilizers and pesticides influence bacterial communities in chayote (*Sechium edule*) rhizosphere: A comparison of organic and conventional farming

Li-feng Ni*, Tzu-cheng Chien
Hualien District Agricultural Research and Extension Station, Ministry of Agriculture, Taiwan
*e-mail: lifengn@hdares.gov.tw

Abstract

Bacteria play an essential role in biological cycles within various environments. To investigate the correlation between soil rhizosphere bacteria and different farming methods, we compared the bacterial diversity 16S rRNA gene sequencing between organic farming (OF) and conventional farming (CF) soil samples from the chayote (*Sechium edule*) root cultivated in Hualien, Taiwan. The OF sample yielded 3,643 operational taxonomic units (OTUs), covering more than ten phyla, while the CF yielded 3,680 OTUs. Interestingly, 2,399 OTUs were shared between both treatments, with approximately 30% of OTUs unique to each, and α-diversity did not significantly differ between treatments. Specific bacterial phyla, Deferribacteres, Absconditabacteria, Microgenomates, and Omnitrophica, were exclusively detected in OF soils. In contrast, Tenericutes, Bathyarchaeota, and Parvarchaeota were found only in CF samples. These results indicated that chemical fertilizers and pesticides may change the soil microbial community. Furthermore, OF exhibited a higher abundance of Nitrospirae and Actinobacteria, implying these two groups may have beneficial roles in OF. In conclusion, our research highlights the impact of chemical fertilizers and pesticides on soil microbial communities, offering insights into bacterial diversity between organic and conventional farming and providing a database to increase chayote yield through bacterial utilization.

Introduction

The intricate relationship between soil microorganisms and crop growth is pivotal for agricultural productivity. Soil microbes, particularly in the rhizosphere—the narrow region surrounding plant roots—are influenced by various agricultural practices, including crop type, tillage, fertilization, and irrigation. These practices significantly alter the microbial community structure and activity, impacting overall plant health and yield. Recent advancements in sequencing technologies, such as Third Generation Sequencing (TGS), offer new insights into these microbial communities by minimizing biases associated with earlier methods. This study utilizes TGS to analyze bacterial community diversity in the rhizosphere of chayote, a crop widely cultivated in Taiwan's favorable subtropical climate. By comparing microbial populations under conventional and organic farming methods, this research aims to identify key bacterial players that could enhance chayote yield, thereby contributing to more sustainable agricultural practices.

Result

Table 1. pH, EC and available nutrients of chayote soil.

Sample	pH	EC	SOC	BrayI_P	M1_K	M1_Ca	M1_Mg
	-	dS/m	%	mg/kg			
CF	6.9	0.20	2.8	292	66	2065	168
OF	7.8	0.14	1.3	174	37	9128	125

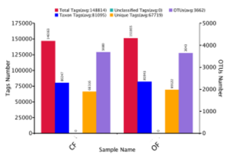

Fig. 1 Summarization of the tags and OTUs number of each sample.

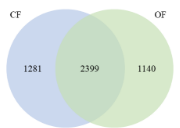

Fig. 2 Venn diagram of OF and CF sample.

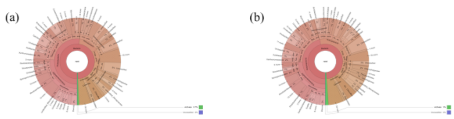

Fig. 3 KRONA chart showing bacterial community composition at phylum level for (a)conventional farming and organic farming (b)organic farming

Result

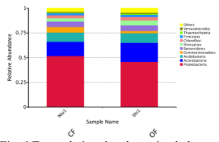

Fig. 4 Taxa relative abundance in phylum.

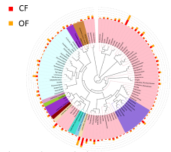

Fig. 5 The evolutionary tree at genus level.

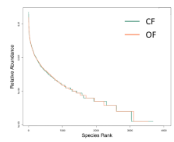

Fig. 6 Rank abundance curves of OF and CF sample.

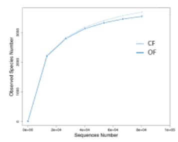

Fig. 7 Rarefaction curves of OF and CF sample.

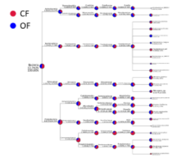

Fig. 8 Taxonomy tree of OF and CF sample..

Fig. 9 Taxatree of OF and CF sample.

Conclusion

To our knowledge, this is the first report describing the bacterial diversity and community structure in the Hualien Chayote field using 16S rRNA gene clone library analysis with TGS technology. Our results showed bacterial diversity is similar between OF and CF samples. However, their relative abundance is opposite throughout the four phyla. These differences may lead to different rhizosphere interactions. In particular, Nitrospirae and Actinobacteria are in high abundance in the OF sample, indicating these bacteria are the advantage in OF. Future research will use this result as the basis for further searching for the combination of bacteria that contributes the most to the yield and try to introduce other fields to test whether it can achieve the purpose of increasing yield.