Divergency of compost extract and organic manure effects on lucerne plant and soil (#18551)

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Divergency of compost extract and organic manure effects on lucerne plant and soil

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Aim: Application of organic materials into agricultural systems enhances plant growth, yields, and improves soil fertility and structure. This study was undertaken to examine the effects of “compost extract (CE)”, a soil conditioner, and organic manure (OM) on the growth of lucerne (*Medicago sativa*), and compare the efficiency between OM, which included numbers of microorganisms and CE, which included no added microorganisms. Method: A greenhouse experiment was conducted with four soil amendment treatments (control, OM, CE and CE + OM) , and was arranged in a completely randomized design with 10 replicates. Plant biomass, nutritive value and rhizobia efficacy as well as soil characteristics were examined. Result: CE rather than OM application showed a positive effect on plant growth and soil properties when compared with the control. Lucerne nodulation responded equally between CE adding and rhizobium inoculating. CE alone and in combination with OM significantly increased plant growth and soil microbial activities and improved soil structure in the study location. The synergistic effects of CE and OM indicate that applying CE and OM together could increase their efficiency, leading to higher economic returns and improved soil health. However, CE alone is more effective for legume growth since nodulation was suppressed by external nitrogen from OM. CE had a higher efficiency than OM for enriching the indigenous microorganisms in the soil instead of adding additional microorganisms and plant nodulating.

Divergency of compost extract and organic manure effects on lucerne plant and soil

Running title: Compost extract improve lucerne nodulation process

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Abstract

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Keywords: compost extract, organic manure, soil amendment, indigenous microorganism, nodulation

Introduction

Preserving and restoring native grasslands and agricultural production systems by improving soil quality have been common goals worldwide (Henwood 2010). However, long-term inappropriate management and large inputs of chemical fertilizers and pesticides into soils have led to severe soil problems ~~and thus emerged types of soil conditioners~~. ~~These c~~ommercial soil conditioners or manures are used in agricultural production systems for amend~~ment of~~ nutrient-deficient soils by providing multiple nutrients (Soumare et al. 2003, Hu and Qi 2013), including but not limit~~ing~~ to organic manure (OM), effective microorganisms (EM), and compost ~~tea~~. However, farmers are sometimes reluctant to use organic fertilizers because the effects of organic nutrients on plant growth are not as quickly seen as inorganic fertilizers. Thus, new materials and new techniques for increasing the efficiency of organic materials are needed.

Introducing exogenous microorganisms into environments has been applied to accelerate bioremediation and improve agricultural productivity (Paluch et al. 2013). Although less is known about the practical effectiveness and mechanisms of these products, assessment of their impacts ha~~ve~~ focused on their potential to increase ~~the~~ soil organic matter ~~level~~, promote nutrient availability to crops (Khan et al. 2007), enhance the proliferation of beneficial bacteria (Priyadi et al. 2005, Javaid 2010), and prevent infection by pathogens (Compant et al. 2005). However, ~~the~~ additional microorganisms from commercial products have to be incubated and propagated in the lab and further applied. Their survival rate and their influences on plant and soil have been viewed skeptically (Watanabe et al. 2000, Chen et al. 2015).

In contrast, indigenous microorganisms may be optimally suited for survival and multiplication in significant amounts (Paluch et al. 2013). However, there is less information available on the ways to activate naturally occurring microorganism populations in soils. The use of CE produced by using plant extraction technology may be one method to activate indigenous soil microbial populations. CE derived from endophytes extracted from different plant species such as soybean (*Glycine max (L.) Merr.*), lucerne (*Medicago sativa L.*), the brown algae (ascophyllum nodosum) (Bestfarming systems Co.), and has been widely used recently. A new bio-molecular method for determining the presence of *nifH*, the gene harboured in entophytic bacterium for nitrogenase reductase from plant species has been developed (www.amazingcarbon.com) (Gao et al. 2015, Le et al. 2015). This study demonstrates that if CE activate indigenous microorganisms in the soil, particularly N-fixing bacteria or archaea that are not able to be cultured in the laboratory. Besides, increasing evidence suggests that isoflavonoids and flavonoids exuded from the root of many leguminous plants can activate rhizobium genes, which helps in the nodulation process (Peters et al. 1986, Brunetti et al. 2013). Combing microbial remediation with legume plant remediation is expected to be an economically and environmentally appropriate approach for soil amendment.

This study was undertaken to determine: (1) the significant effects of adding CE on the plant and microbial biomass, activity of the microorganism community, plant and soil nutrient; (2) combining CE and OM achieve the highest impacts on soil nutrient and lucerne growth; (3) CE stimulate the nodulation of legume as effectively as inoculating rhizobium bacteria. The results are expected to reveal the interactive effects of CE and OM application on plant species growth and soil properties, and aid in the selection of optimal fertilization approaches for soil quality

amendment. In addition, the experiments will enable explore the stimulative effect of CE on activating and enriching the abundance of indigenous microorganisms from the plant rhizosphere.

Materials and methods

Experimental design

A greenhouse experiment was conducted in the lab of prataculture science, Nanjing Agriculture University, Jiangsu province, China, from June 2015 to September 2015 as preliminary trial, and the visual evaluation was observed. To determine the actual effects of the treatments, the experiment was completely repeated from October 2015 to January 2016, and the second time data was recorded. The experiment was set up with 4 soil amendment treatments and 10 replications. The 4 treatments included: organic manure (OM), compost extract (CE), organic manure + compost extract (CEOM) and the control.

We collected the seed of lucerne from barren land in Xilinhot (43°38' N, 116°42' E), Inner Mongolia, China. The seed were sterilized firstly and germinated on 1.5% water-agar plates and transplanted into pots (height 15 cm, diameter 15 cm). Each pot filled with 1 kg of soil (dry weight equivalent) and 200 g double-washed quartz sand. Soil without containing any heavy metal was collected from the same study area and the soil had 1-year history for planting legume. The soil was taken from 15 cm depths with 5 cm diameter soil cores and evenly mixed, then applied to each pot. The characteristics of the soil were listed in table 1. Prior to seedling transplantation, OM was collected and mixed into the top layer of the potting applied at a rate of 5 g per pot. It was made of pig dung compost and amino acid fertilizer, the pig dung compost contained 30.1% organic matter, 3.0% N, 2.7% P_2O_5, 0.9% K_2O; And the amino acid fertilizer

contained 40.2% organic matter, 11.1% ~~of~~ amino acids, 3.4% N, 1.7%P_2O_5, 1.1% K_2O. Four of ten strongest seedlings were finally left per pot. ~~The~~ CE consisted of alfalfa meal 15.9% (weight/weight), barley grain 10.2%, barley straw 6.4%, wheat straw 4.3%, liquidized ~~F~~ish 8.7%, kelp 39.5%, sulphur 0.3%, calcium carbonate 10.2%, and molasse~~s~~ 4.5%. The mixture ~~of CE~~ was fermen~~at~~ted at < 50°C for 14 days in ~~the~~ incubator, then extracted, filtered, freezed, dried. The final composition~~s~~ (minimum guaranteed analysis) contained 16.9% ~~of~~ amino acids, 0.5% soluble potash (weight/weight), 0.06% calcium, 1.5% sulphur, 1.2% nitrogen, 0.3%phosphorus. 20 ml of CE (Best farming Systems Co.) (2 ml/pot for each application) diluted with 5 L of water wa~~s~~ sprayed onto the soil ~~(the total application rate in the pot experiment were~~ comparable to agricultural practice with 750 ml /hectare~~)~~. Four weeks later, ~~the~~ CE was applied for second time (practical dosage at ~~the~~ manufacturers' recommendation) and no more ~~was applied~~ after that.

A ~~corresponding~~ supplementary experiment on nodulation effects was conducted when ~~the~~ seedlings were transplanted into additional pots (~~the~~ same size as above). The seedlings in the pots were inoculated with 6 ml liquid per pot with rhizobium strains (~~Rhizobium meliloti~~ ~~d~~angeard- CX 107) cultured from nodules ~~of the legume lucerne~~ (provided by ~~the~~ Key Laboratory of Agro-Microbial Resource and Application, ~~Ministry of Agriculture,~~ China Agriculture University). Bacterial suspensions were diluted to ~~have~~ an optical density of 0.70 (λ= 600 nm), which was equivalent to a concentration of 3.10^8 bacteria/ml, as measured by ~~the~~ Bradford method (Bradford 1976) on a yeast-mannitol culture medium (Vincent and Humphrey 1970).

Starting from 10. June 2015, ~~the~~ seedlings were grown under glasshouse conditions at 50-

70% relative humidity and a temperature regime of 20-25°C during ~~the~~ day and night. Pots were watered to maintain soil water content between 20~~%~~ and 25%. Eighty days later, seedlings of both experiments were destructively harvested, and separated into leaves, shoots and roots, ~~measured~~ their biomass, and examined for nodulation by counting and weighing ~~the~~ root nodules (roots were washed to remove ~~the~~ soil before checking).

Chemical analyses

Plant samples

Samples of ~~the~~ stem and leaves were milled to <0.2 mm and analyzed for total C and N. Plant total P content was determined using a UV/visible spectrophotometer (Beckman Coulter DU 800, USA). Plant total K content was measured using H_2SO_4-salicylic acid -H_2O_2-Se digestion (Zheng et al. 2012).

~~Samples of plant~~ were ground to pass a 1 mm sieve and scanned twice using ~~the~~ Near-Infrared-Spectroscopy (NIRS) technique for forage nutritive value determination (Ren et al. 2016). Nutritional value was tested by evaluating crude protein (CP; nitrogen concentration×6.25), neutral detergent fibre (NDF), cellulose digestible organic matter (CDOM) and metabolisable energy (ME) (MJ/kg DM) (Schonbach et al. 2009). NDF was analyzed sequentially using the method described by ~~(~~Vansoest et al. 1991), which used semiautomatic ANKOM 220 technology and was expressed with residual ash. CDOM value as a percentage of organic matter and ME value were calculated using crude ash (CA) and non-soluble enzymatic substance (EULOS). Detailed calculations are given in equations 1 and 2 below (Schonbach et al. 2009):

$$CDOM = 100\ (940 - CA - 0.62\ EULOS - 0.000221\ EULOS^2) / (1000 - CA); \quad (1)$$

130 $ME = 13.98 - 0.0147\ CA - 0.0102\ EULOS - 0.00000254\ EULOS^2 + 0.00234\ CP;$ (2)

131 Soil samples

132 Soil samples were separated in two portions, one portion was weighed to determine soil
133 bulk density by using foil sampler (volume =100cm^3) and dried at 105℃ for 24h to calculate
134 water holding capacity (%), another portion was stored at -22℃ for microbial abundance
135 analysis by real-time PCR (Gupta et al. 2017). Subsamples were sieved ~~through~~ 0.15mm and
136 analyzed for soil organic matter (OM), alkaline hydrolysable nitrogen (N), available
137 phosphorus (P), available potassium (K), and total C, N, P and K content. Soil OM content was
138 determined through the potassium dichromate external heating method (Blakemore et al. 1972).
139 The alkaline-hydrolysable diffusion method was applied to determine alkaline- hydrolysable N
140 content (Bremner et al. 1996). Available P was measured ~~using~~ the Olsen method (Blakemore
141 et al. 1972). Available K was measured ~~with~~ the flame photometry method (Blakemore et al.
142 1972). Total C was analyzed using ~~the~~ Kurmies determination (Blakemore et al. 1972). Soil
143 total N was analyzed ~~using~~ a Kjeltec analyzer (Kjeltec Analyzer Unit 2300, FOSS, Hillerød,
144 Sweden). Soil total P and K was measured the same way as plant total P. Soil pH was measured
145 in a 1:2.5 (soil: water) suspension.

146 Microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) as well as
147 microbial respiration (MR) were measured to ~~compare~~ differences in microbial colonization
148 and activity. MBC and MBN were estimated using the chloroform fumigation extraction
149 method (Frostegard et al. 2011). MR was measured in pre-incubated (24h at 28℃) samples by
150 determining CO_2 evolution over a period of 72 h (FAL, 1996). The abundance of viable bacteria
151 and fungi w~~ere~~ ~~analyzed~~ according to ~~the~~ real-time quantitative PCR-DGGE (denaturing

gradient gel electrophoresis) of 16S rDNA ~~method~~, which was performed using the ABI 7300real-time PCR system (Applied Biosystems, Foster, California, USA) with fluorescence TaqMan@ probe detection (Le et al. 2015, Gupta et al. 2017).

Statistical analysis

~~For the complete randomized experiment design,~~ one-way ANOVA (analysis of variance) was used to determine differences among treatment for lucerne species growth ~~or~~ soil properties. The LSD-test procedure was used for testing mean differences among control, OM and CE treatments. The level of significance was $P < 0.05$. All the variables were statistically tested for homogeneity of variance. All statistical analyses were carried out using SAS, Version 9.2 (SAS Institute Inc., Cary, NC, USA).

Results

3.1. Biomass and nutritional value of lucerne

~~The~~ shoot, root and total biomass of inoculated lucerne significantly increased ($P < 0.05$) under CE application ~~for~~ 73.3%, 38.3% and 63.8%, respectively (Fig. 1). Compared with the control, the three biomass of lucerne did not change under CE + OM treatment, ~~but~~ ~~significantly~~ decreased ~~from~~ 17.5% to 26.6 % when OM was added. For non-inoculated lucerne, all three biomass showed highest value with CE addi~~ng~~ alone by increase~~d around~~ 46.0% to 85.3%, then were second with CE + OM treatment. OM addi~~ng~~ did not affect the biomass of non-inoculated lucerne. The ~~interactive~~ effect ~~between soil~~ amendment treatments ~~and~~ plant nutritional values were further analyzed ~~using the~~ ANOVA ~~test~~ (Table S1). CE and OM ~~(Table 2)~~ significantly affected the nutritional values. The CP concentration of lucerne was significantly higher ~~for the~~ OM ~~treatment~~ and CE treatment than the control. CDOM and ME showed the same trend in

response to treatments. The effect of CE and OM on NDF of lucerne significantly decreased from 66.18 to 52.45 g kg^{-1} DM and CE alone decrease NDF for 36.3%.

3.2. N, P, K contents in stems, leaves and soil

The N content of stems, leaves and soil decreased significantly in the order of CE + OM > OM > CE > control (Table 3, Table S1). The N contents of stem, leaves and soil in the CE + OM treatment were 40.4%, 35.0% and 91.4% higher than in the control treatment, respectively. The P content of stems was significantly higher in the three soil amendment treatments than in the control treatment. The P content of leaves and soils increased in the order: CE + OM > CE > OM > control. The K content of stems and soil was significantly higher in the CE + OM treatment than in the other treatments, and both the CE and OM treatments had a higher K content in stems than the control treatment. The soil amendment treatments significantly enhanced K content in leaves than in the control treatment. The K content of soil was decreased significantly in order of CE + OM > CE > OM > control treatment.

3.3. Biological and abiotic characteristics of soils

MBC and MBN showed a significant increase with treatments (Table 4, Table S1). In CE + OM treatment, MBC and MBN were 37% and 30% significantly higher than in the control, respectively. MBC was not significantly different between CE and OM treatments. Microbial respiration rates and metabolic quotients significantly increased in the order of CE + OM > OM = CE > control, at highest microbial respiration rate by about 82% and metabolic quotient by 28%. The numbers of soil bacteria and fungi showed an increase in treatments with CE, OM and CE + OM application, but were significantly higher with CE alone than OM. The application of CE and OM together strongly increased the amounts of bacteria in the

196 rhizosphere soil of lucerne.

197 Of the three soil amendments, only CE + OM significantly increased soil ~~P~~H and water
198 holding capacity (Table 5, Table S1). The three ~~soil~~ amendment treatments significantly reduced
199 bulk density and increased organic matter, soil alkaline-hydrolysable N, available P content and
200 available K. ~~Soil bulk density decreased significantly only between CE + OM treatment and~~
201 ~~control.~~

202 3.4. Comparison between rhizobium nodulation among soil amendment treatments

203 The highest number of nodules and total nodule weight occurred in inoculated lucerne with
204 CE treatment (Fig. 2, Table S1 and S2). The number of nodules and total nodule weight of the
205 inoculated lucerne ~~in the control treatment~~ showed no significant difference ~~to the~~ non-
206 inoculated lucerne ~~with~~ CE application.~~With~~ OM application, nodulation of lucerne decreased
207 significantly. Table S3 showed the effects of treatments on plant N and soil N of inoculated
208 lucerne.

209 **Discussion**

210 The shoot, root and total biomass and nutritional value of inoculated and non-inoculated
211 lucerne were significantly increased ~~due to~~ the application of CE alone and CE with OM
212 together. It indicates that CE acts better than OM for improving legume ~~plant~~ growth, because
213 nitrogen-fixation ~~plant~~ can be suppressed by external nitrogen ~~adding~~. However, it does not
214 imply that OM can substitute for CE, because highly synergistic effects on plant nutrient and
215 soil properties were observed. Both soil biotic (MBC, MBN, MR) and abiotic (soil water
216 holding capacity, organic matter, alkaline N, available P and K) factors were improved, and thus
217 ~~the~~ plant growth was enhanced.

When CE was applied, 163.8% higher plant biomass occurred in the present study, which could be mainly attributed to the stimulation of the beneficial microorganisms (increased in numbers of bacteria and fungi, Table 4) by accelerating the decomposition of organic materials and increasing the release of nutrients (Javaid and Bajwa 2011). In contrast, the OM provided additional microorganisms and external nutrient into the soil (Higa 2001). These inoculated microorganisms have to compete with naturally occurring bacteria (Sherr et al. 1992). The interactions of different microorganisms may complement each other and further influence plant growth due to microbial diversity (van der Heijden et al. 2008). By stimulating the proliferation of beneficial bacteria and restraining harmful microorganisms through CE addition, some essential substances such as nucleic acids, amino acids and bioactive substances (e.g. hormones and enzymes) are synthesized. They can accelerate decomposition of lignin materials in the soil and mineralization of organic material as well as control soil diseases, resulting in the change in soil microbial parameters and physical and chemical characteristics as seen in this study (Kim et al. 2004, Javaid and Bajwa 2011). Besides, lucerne has been reported to produce the root-derived antimicrobials indole, terpenoid, benzoxazinone, flavonoid and isoflavonoid, which used for inhibiting soil-borne pathogenic bacteria (Dixon 2001) and thus enhance the symbiosis between plant and beneficial microorganisms. In soil organic amendment systems, the beneficial microbes activated by CE and added by OM accelerate the mineralization of the soil organic matter (Javaid 2011), which releases more nutrients for plant uptake (Flores et al. 1999).

Higher uptake of N, P and K by plant and higher soil content of N, P and K (Table 2) indicating that soil amendment treatments increased the availability of nutrients in the soil. In

this study, the soil had a low ~~P~~H value indicating acidic conditions, which resulted in low nutrient availability and low inorganic fertilization efficiency (Chen et al. 2015). The observed increase in soil ~~P~~H with applying CE and OM together demonstrated that combination of soil conditioner and OM could amend ~~the~~ acidic soil by accelerating the rate of microbial processes and thus releasing ~~the~~ nutrients ~~in the acid soil~~ quickly, as shown by other studies (Hati et al. 2006, Lee et al. 2009). Separately, they had no significant effects. ~~Although both OM and CE contain nutrient content, it is not necessary to be the major reason for nutrient increasing of plant and soil.~~ ~~Because~~ CE includes ~~very~~ less nutrient element but has greater effects on soil and plant nutrient in comparing with OM. ~~If the contribution of OM to soil and plant attribute to additional nutrient adding, then CE need to have access to active soil nutrient availability by using very less nutrient content.~~

The identical numbers of nodules as well as nodule weight ~~of~~ inoculated lucerne ~~as non-inoculated lucerne~~ added with CE indicates the abilities of CE for activating indigenous rhizobia (Le et al. 2015). ~~The m~~echanisms for the maintenance of root-soil contact have been attributed to root exudation (Le et al. 2015). The plant-soil feedback driven by root exudates could initiate and manipulate signal ~~traffic~~ between roots and soil organisms (Keymer and Lankau 2017). CE may stimulate root exudates, which could initiate one-way signals ~~contacting the~~ chemical and physical soil properties ~~to the roots~~, and regulate the symbiotic and protective interactions with microbes (Jones et al. 2003, Johnson et al. 2015). They accumulate mainly inducible antimicrobial compounds gathered in the roots (Flores et al. 1999, Dixon 2001). Many indigenous microorganisms in the soil are not able to interact synergistically with plant species; therefore, a number of antimicrobial root exudates are secreted. Le et al. (2015) confirmed that

some endophytic actinobacteria had the potential to enhance the growth of lucerne and its interactions in rhizobial symbiosis. The mechanism ~~of how~~ CE produces a stimulat~~ive~~ effect on properties soil and plant growth need to be further explored.

Conclusions

This study demonstrated that CE application alone and in combination with OM enhanced lucerne biomass and nutritional value by improving nodulation and soil biotic and abiotic ~~factors~~. The similar effects of CE and OM on plants and soils does not necessary mean that they can be treated as substitutes for one another. Rather, their combination provides a mode of soil amendment ~~to~~ improve soil quality ~~effectively~~. CE synthesizes some kinds of active substrates that stimulate the activity of indigenous rhizobia in the soil rather than adding extra microorganisms into the soil as OM. Root exudation may help in regulating soil properties and root-microbe-soil interactions. However, the nature of their reactions in the soil need to be further explored.

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Table 1 Soil properties in the study area

Soil property	pH	Bulk density (g/cm^3)	WHC (%)	OM (g/kg)	organic C (%)	total N (%)	total P (%)	C: N ratio (%)
value	5.88	1.61	25.73	13.25	12.12	0.83	0.16	14.60

~~The a~~bbreviations are: OM (organic matter), WHC (water holding capacity).

Table 2 Effect of compost extract (CE), organic manure (OM) and CE + OM (CEOM) application on ~~the~~ shoot nutrient value of lucerne

Treatment	CP (g DM/kg)	NDF (g DM/kg)	CDOM (g DM/kg)	ME (MJ DM/kg)
Control	17.7c	66.18a	68.61b	9.84b
CE	23.3a	58.24c	77.77a	10.87ab
OM	21.4b	61.48ab	72.42b	10.09b
CEOM	24.6a	52.45bc	79.99a	11.01a

~~The a~~bbreviations are: DM - dry matter; CP - crude protein; NDF - neutral detergent fibre; CDOM - cellulose digestible organic matter; ME - metabolisable energy; and MJ – joule per mole

Different letters within a column indicate significant differences ($P < 0.05$) between treatments. LSD multiple comparison w~~as~~ used.

Table 3 Effect of compost extract (CE), organic manure (OM) and CE + OM (CEOM) application on N, P, K content of lucerne stems, leaves and soil

Treatment	Stem (g/kg)			Leaf (g/kg)			Soil (g/kg)		
	N	P	K	N	P	K	N	P	K
Control	2.30c	0.72b	11.90c	3.77c	1.30c	7.51b	0.81c	0.18c	1.31c
CE	2.73b	1.17a	24.66b	4.89b	2.13b	13.39a	1.29b	0.26b	2.46b
OM	2.98b	1.17a	24.28b	4.19b	2.02b	13.36a	1.20b	0.24b	2.00b
CEOM	3.23a	1.22a	30.35a	5.09a	2.37a	13.17a	1.55a	0.35a	3.54a

Different letters within a column indicate significant differences ($P < 0.05$) between treatments. LSD multiple comparison was used.

Table 4 Effect of compost extract (CE), organic manure (OM) and CE + OM (CEOM) application on MBC, MBN, MR, QCO_2 and numbers of bacteria and fungi in rhizosphere soil of lucerne

Treatment	MBC (mg/kg)	MBN (mg/kg)	MR (mg/kg/d)	QCO_2 (mg C/kg)	Bacteria ($\times 10^6$copies/ml)	Fungi ($\times 10^6$copies/ml)
Control	303.21c	63.86c	49.01c	13.49c	22.5d	3.20c
CE	384.44b	70.60b	57.33b	14.92b	34.7b	4.33a
OM	340.73b	62.80c	59.81b	14.36bc	30.0c	4.01b
CEOM	414.50a	83.03a	89.00a	17.25a	38.5a	4.35a

The abbreviations are: MBC (microbial biomass Carbon), MBN (microbial biomass N), MR (microbial respiration rate), QCO_2 (metabolic quotient), N= 20.

Different letters within a column indicate significant differences ($P < 0.05$) between

treatments. LSD multiple comparison was used.

Table 5 Effect of compost extract (CE), organic manure (OM) and CE + OM (CEOM) application on soil characteristics

Treatment	pH	Bulk density (g/cm^3)	WHC (%)	OM (g/kg)	Alkaline N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
Control	5.90b	1.63a	25.38bc	14.22b	67.60c	4.02c	79.88c
CE	6.05ab	1.47b	28.48b	23.03a	102.46b	35.85b	159.79b
OM	5.95b	1.46b	25.87c	22.53a	110.63b	50.08a	204.70a
CEOM	6.33a	1.32b	35.17a	25.37a	128.20a	52.83a	214.37a

The abbreviations are: OM (organic matter), WHC (water holding capacity)

Different letters within a column indicate significant differences ($P < 0.05$) between treatments. LSD multiple comparison was used.

Fig. 1 Shoot biomass, root biomass and total biomass of inoculated (a) and non-inoculated (b) lucerne under different soil amendment treatments: control, compost extract (CE), organic manure (OM) and compost extract + organic manure (CEOM).Bars represent the standard errors, n= 20

Fig. 2 Effect of soil amendment treatments: control, compost extract (CE), organic manure (OM) and compost extract + organic manure (CEOM) on inoculated and non-inoculated nodulation of lucerne plants. Left: number of nodules; Right: total nodule weight. Straight line showed the same level between inoculated control and non-inoculated CE adding treatment. Bars represent standard errors, n = 20

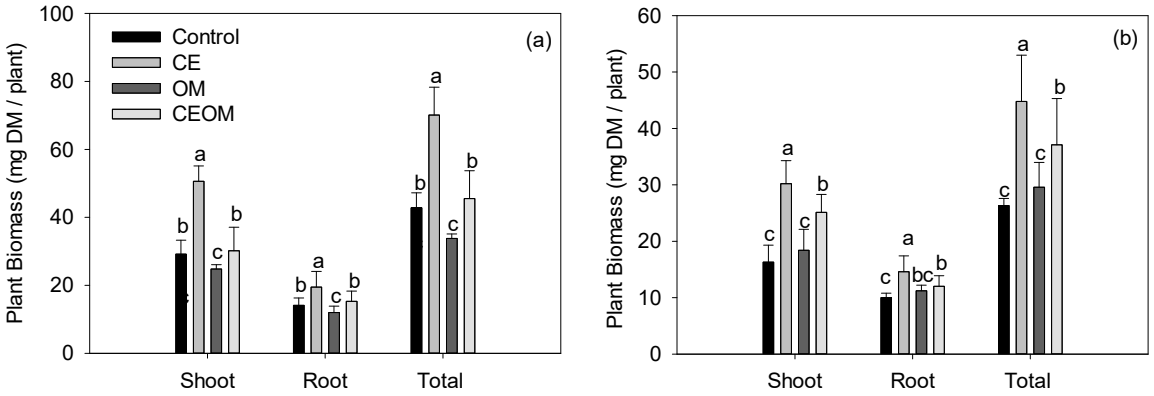

Fig. 1

Fig. 2