Ecological Engineering 83 (2015) 191–198

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Optimizing net greenhouse gas balance of a bioenergy cropping system in southeast China with urease and nitrification inhibitors

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ARTICLE INFO

Article history:
Received 12 November 2014
Received in revised form 12 April 2015
Accepted 23 May 2015
Available online 6 July 2015

Keywords:
Bioenergy crop
Soil heterotrophic respiration
Methane
Greenhouse gas intensity
Nitrous oxide
Urease and nitrification inhibitor

ABSTRACT

Efforts to advance our knowledge on the potential of bioenergy instead of fossil fuels in terms of mitigating climatic impact are in urgent need. No data is currently available on the use of urease and nitrification inhibitors in costal saline bioenergy cropping systems. An overall accounting of net greenhouse gas balance (NGHGB) and greenhouse gas intensity (GHGI) affected by combined effects of urease inhibitor hydroquinone (HQ) and nitrification inhibitor dicyandiamide (DCD) amendment was examined in a coastal saline Jerusalem artichoke bioenergy cropping system. The net ecosystem exchange of CO_2 (NEE) was determined by the difference between soil heterotrophic respiration (R_H) and net primary production (NPP) using static chamber method. Urease and nitrification inhibitors amendment increased the NPP but exerted a suppression effect on soil R_H over the Jerusalem artichoke cropping system. A trade-off relationship was observed by decreasing soil N_2O but stimulating soil CH_4 emissions following HQ+DCD amendment. The plots combined urea with HQ+DCD application increased soil CH_4 by 167% while decreased N_2O by 16% as compared to with urea only in the bioenergy cropping system. On average, the fertilizer N-induced emission factor of N_2O was estimated to be 0.25% across the fertilized plots. Compared with urea, the plots with urea and HQ+DCD resulted in a further decrease by 37% and 15% in estimated NGHGB and GHGI over the Jerusalem artichoke cropping system, respectively. Overall, Jerusalem artichoke production would achieve higher biomass as source of biofuels but lower climatic impacts, particularly when together with urease and nitrification inhibitors amendment in coastal saline soils.

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1. Introduction

Atmospheric carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the most potent long-lived greenhouse gases (GHGs) contributing to global warming. The production of biofuels from bioenergy crop biomass has been proposed as an alternative source of renewable energy instead of fossil fuels to struggle against global warming (Goldemberg, 2007). In comparison with GHGs emission relating to the combustion of fossil fuels, bioenergy crops production is often a source of GHGs but with large uncertainties as a result of site and climate variations. Therefore, field measurements of GHGs emission from typical bioenergy cropping systems are highly needed to fully assess the potential of bioenergy instead of fossil fuels in terms of mitigating climatic impact. While most of the field GHGs flux measurements were taken from traditional bioenergy cropping systems (e.g., sugarcane, sweet sorghum, maize), almost no studies available drew attention on the halophytes bioenergy cropping systems, which quite limits our knowledge on GHGs budget in coastal saline bioenergy cropping systems (Barton et al., 2010; Gauder et al., 2012).

Globally, the development of bioenergy crops is currently advocated to address the increasing energy crisis. Besides traditional bioenergy crops such as sugarcane, maize, sweet sorghum, and potato, halophyte plants with high economic value could be used as a source of biomass material for biofuels (Khan and Qaiser, 2006). Considering the conflicts existed between bioenergy and grain crops for limited farmland arable soils in China, the available non-cultivated coastal saline lands have been extensively exploited for bioenergy crops cultivation (Liu et al., 2012a,b). Jerusalem artichoke (*Helianthus tuberosus* L.) is known as one of the most potential alternatives as source of biofuel, which is widely grown in coastal zones due to its high biomass and growth rate, as well as its strong adaptability towards stress conditions such as soil salinity, drought and low soil nutrients availabilities (Long et al., 2005; Guo et al., 2011).

To our knowledge, there is still lack of information for use of urease and nitrification inhibitors on soil CO_2 emissions from

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http://dx.doi.org/10.1016/j.ecoleng.2015.05.047
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bioenergy cropping soils although a potential direct or indirect interaction between them may exist. However, it is well documented that urease and nitrification inhibitors are effective for decreasing soil N_2O emissions through the mechanisms of slowing down the hydrolysis of applied urea and retarding the nitrification process of NH_4^+, respectively. Some studies reported that urea with DCD significantly reduced soil N_2O emissions in comparison with urea alone (Shoji et al., 2001; Merino et al., 2002; Di et al., 2007). For instance, Ghosh et al. (2003) reported that urea combined application with DCD decreased N_2O emissions by 52.8% in paddy soils, which is confirmed by the results obtained by Malla et al. (2005). In particular, there is evidence that joint application of HQ and DCD is more effective in mitigating N_2O emissions both in upland and flooded soils as compared to the application of HQ or DCD alone (Delgado and Mosier, 1996; Xu et al., 2002; Akiyama et al., 2009).

The effects of urease and nitrification inhibitors on soil CH_4 exchange were inconsistent by increasing CH_4 emissions, promoting CH_4 oxidation or even no effects (e.g., Ghosh et al., 2003; Malla et al., 2005). These inconsistent effects may due to soil type, inhibitor source, application rate and application method of inhibitors (Bharati et al., 2000; Li et al., 2009). Therefore, given the uncertainty and discrepancy with regard to the urease and nitrification inhibitors effect on GHGs emissions across the agricultural soils, an overall accounting of net greenhouse gas balance (NGHGB) and greenhouse gas intensity (GHGI) derived from soil CO_2, CH_4 and N_2O emissions is required when assessing urease and nitrification inhibitors effect on the climatic impact of coastal bioenergy production.

We presented field measurements of soil CO_2, CH_4 and N_2O fluxes as affected by combined use of urease and nitrification inhibitors in a coastal Jerusalem artichoke cropping system on seasonal basis in southeast China. Soil CO_2, CH_4 and N_2O fluxes were simultaneously measured using static chamber-gas chromatograph (GC) method. The net ecosystem exchange rate of CO_2 (NEE) was determined by the difference between soil heterotrophic respiration (R_H) and net primary production (NPP). We proposed that synthetic N fertilizer combined with HQ and DCD application would improve bioenergy crop biomass production and decrease N_2O emissions, whilst yet not clear about its effect on soil R_H and CH_4 emissions and in turn their overall climatic impacts in terms of C-equivalent over the Jerusalem artichoke cropping system. The objectives of this study are to gain an insight into a complete accounting of NGHGB and GHGI from soil CO_2, CH_4 and N_2O emissions as affected by use of urease and nitrification inhibitors in the coastal saline bioenergy cropping system, and thereby to better understanding the potential effects of urease and nitrification inhibitors on mitigating climatic impacts of coastal bioenergy crop production in China.

2. Materials andmethods

2.1. Site description

Field plot experiments were performed in the coastal saline field station of Nanjing Agricultural University located in Dafeng, Jiangsu province, China in 2011 (33° 19′N, 120° 45′E), and it has an altitude of 4 m above sea level. Soil (0–15 cm) of the experimental site was classified as fluvoaquic, consisting of 67% sand, 12% silt and 21% clay. Soil samples were collected one week prior to field plots establishment and at the end of the field experiment for the measurement of soil physicochemical properties as shown in Table 1. Climate information was recorded by the local weather station (Fig. 1). The annual mean minimum and maximum temperatures were 15.2 °C and 16.9 °C in 2011, respectively. Annual rainfall amounted to 1045 mm, of which 540 mm during the Jerusalem artichoke cropping season.

2.2. Field experiments

A split-plot experiment was established in a bioenergy Jerusalem artichoke cropping system. Three field treatments with four replicates consisting of the plots with urea alone (U), the urea plots combined with HQ and DCD application (U+HQ+DCD), and the control plots with no fertilizer or urease and nitrification inhibitors application were setup over the period of April 20 to October 20, 2011. The field plots with no prior cultivation were prepared on April 17, 2011. Identically, each field plot was 5 m × 7 m, the row spacing was 60 cm × 40 cm and thus 50 individual plants were enclosed in each field plot in the Jerusalem artichoke bioenergy cropping system. All field plots were surrounded with pre-established isolation strips, which guaranteed the relative independence for each treatment. The Jerusalem

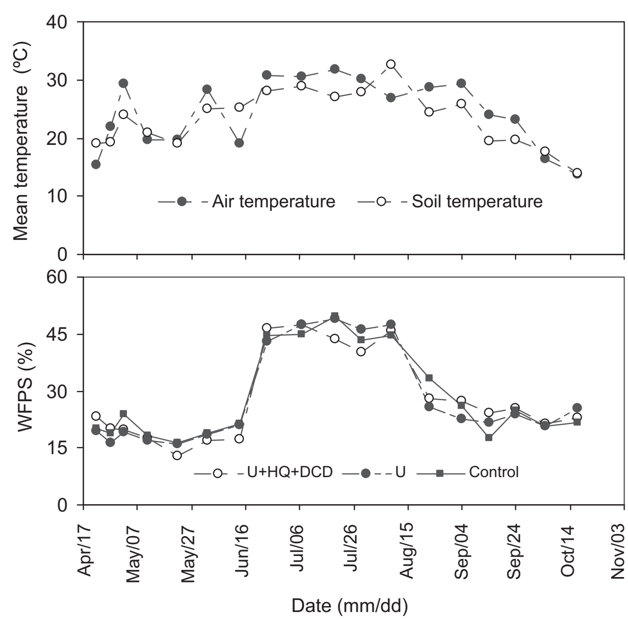

Fig. 1. Mean air/soil temperature across all the treatments and WFPS(%) for all individual treatments at the soil depth of 5–10 cm over the whole Jerusalem artichoke cropping system. Control, the control plots with no N fertilizer and inhibitors application; U, the plots with urea alone; U + HQ + DCD, the urea plots combined with HQ and DCD application.

Table 1
Soil physicochemical properties measured one week prior to field plots establishment and at the end of field experiment in the Jerusalem artichoke cropping system (mean ± SE, $n = 4$).

Measuring time	pH	EC ($\mu S\ cm^{-1}$)	BD ($g\ cm^{-3}$)	TOC ($g\ kg^{-1}$)	TN ($g\ kg^{-1}$)	NH_4^-–N ($mg\ kg^{-1}$)	NO_3^-–N ($mg\ kg^{-1}$)
Before experiment	8.5 ± 0.05	572 ± 24	1.48 ± 0.03	13.42 ± 1.08	0.88 ± 0.14	6.45 ± 0.08	4.28 ± 0.02
After experiment	7.6 ± 0.02	481 ± 16	1.36 ± 0.05	11.73 ± 0.69	0.76 ± 0.16	5.12 ± 0.16	3.89 ± 0.06

EC, soil electrical conductivity; BD, buck density; TOC, soil organic carbon content; TN, total nitrogen content.

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