



Applying geostatistics to determine the soil quality improvement by Jerusalem artichoke in coastal saline zone



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ABSTRACT

The plant growth characteristics are spatially variable due to inherent variability in soil properties and other parameters of the landscape. In the study, the plot size in the field was 670 m in length (south–north direction), and 70 m in width. The stem height and diameter were measured in October, and tuber yield was evaluated in December 2012. The salt content of 0–5, 5–10 and 10–20 cm depth of soil was measured. The morphological characteristics and normal distribution test were analyzed by descriptive statistics using Matlab. The collaborative kriging interpolation and the distribution of spatial heterogeneity of related parameters were analyzed using GS+ software. Soil salt content increased with increasing soil depth. At the same soil depth, the salt content was higher in the north than the south part. The root fresh weights, tuber number, stem height and diameter of Jerusalem artichoke were relatively larger in the north than the south. The distributions of tuber fresh weight and tuber number in space were similar. The Pearson correlation coefficient between tuber fresh weight and tuber number was up to 0.70. Jerusalem artichoke's morphological characteristics were directly related to soil salt content. Inherent variability of position and soil properties could strongly influence the morphological characteristics of Jerusalem artichoke.

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1. Introduction

Jerusalem artichoke, which originated in the north-central U.S., is a perennial grown as an annual. Distributed throughout the world, Jerusalem artichoke has showed a wide ecological adaptability. Unlike most crops that store carbon as starch (a polymer of glucose), in the Jerusalem artichoke carbon is stored as inulin (a fructose polymer). Both above- and belowground parts of Jerusalem artichoke are utilizable for various applications, for instance, the tops for biomass and animal feed and the tubers as a feedstock for food and nonfood chemical industry.

Jerusalem artichoke produces large amounts of biomass, is fast growing, needs relatively few inputs in terms of pesticides, fertilizer and water, and can be grown on marginal land. It is therefore a potentially useful crop for the production of biofuel, and in particular bioethanol (Chittendon, 1951; Huxley et al., 1992; Yan et al., 2012; Krivorotova and Sereikaite, 2014). Based on the theory of Maas and Hoffman (Maas and Hoffman, 1977), Jerusalem artichoke is a moderately salt-tolerant crop according to rate of decrease of dry tuber matter and shoot biomass in saline soils in a greenhouse (Newton). Salt tolerance of Jerusalem artichoke cultivars was evaluated by seawater irrigation in north China plain, which proved cultivar difference in salt adaptability (Long et al., 2010).

Geostatistics has been developed for use in mineral exploration in the 1950s. So far, it has been widely used in quantitative description of natural variables of spatial or spatiotemporal domain, including spatial variability and structural analysis, spatial prediction, space simulation and so on. Geostatistical simulation is a helpful tool allowing reproduction of spatial variability of data and providing measures of spatial uncertainty through multiple

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equally probable realizations (Tercan and Sohrabian, 2013). In spatial variability and structural analysis, microbial processes in soil have been investigated for several decades (Parkin, 1993). Some N-cycling processes can be mapped using geostatistical analyses to exhibit spatial patterns (Yanai et al., 2003; Grundmann, 1990; Philippot et al., 2009; Enwall et al., 2010; Guo et al., 2014).

Geostatistical methods create mathematical models of spatial correlation structures (Isaaks and Srivastava, 1989; Goovaerts, 1977) with a variogram as the quantitative measure of spatial correlation. In spatial prediction, geostatistical methods (Zamani et al., 2013; Buczko et al., 2001; Abushammala et al., 2012) were used to investigate the spatial distribution patterns of Cd and Pb in pike (*Esox lucius*) (Raat, 1988; Diana et al., 1977). In space simulation, input statistics such as mean, histogram, variogram and correlation coefficient for the quality variables are reproduced well, and independent component simulation can be used in for multivariate data (Tercan and Sohrabian, 2013).

In order to fully utilize saline soil soils, we hereby propose to grow *Helianthus tuberosus* in saline soil, which could be of particular importance in countries with scarce arable land and fresh water resources, such as China. This study was aimed at evaluating the spatial differences in growth of Jerusalem artichoke in saline soil by using geostatistics. An understanding of the range and spatial variability of Jerusalem artichoke morphological characters in saline soil is a prerequisite for characterizing the plant–saline soil interactions before effective utilization of saline soils in growing Jerusalem artichoke for various biorefinery applications.

2. Materials and methods

2.1. Site description and sample collection

The field experiment was carried out at Dafeng Agricultural Research Station in Jiangsu Province (32.59° N, 120.50° E), 4 km away from the Yellow Sea of China in 2012. Plot size was 670 m in length and 70 m in width. The average salt contents at depths 0–20, 20–40 and 40–60 cm were 1.5, 3.3 and 5.6 g/kg, respectively. The soil was ploughed in winter using a conventional mould board plough and was then tilled twice more prior to sowing tubers. The Jerusalem artichoke (cv Nanyu No. 1) was planted in March. Plant row spacing was inter-row (60 cm) and intra-row distance between plants (50 cm).

The experimental area was divided into 23 m × 23 m grid (Fig. 1) generating 78 sampling points (three replicate samples of plants and soil were taken in each cell) for analyzing spatial heterogeneity of Jerusalem artichoke morphological properties in October when the growth of the aerial part reached maximum. The soil salt content of 0–5, 5–10 and 10–20 cm depth of soil was measured by conventional chemical analysis methods (Lu, 1999). The stem height was measured by a metre ruler, whereas stem diameter was measured by vernier callipers; the tuber numbers were counted. The root biomass of 20 m² (5 m in length and 4 m in width) was washed, air-dried and weighed. The tuber production was evaluated in December (final harvest). Tubers were washed, air-dried and weighed.

2.2. Statistical analysis and graphing

Statistical analyses were conducted using Matlab 7.0. Graphs were plotted using Matlab 7.0 and GS+.

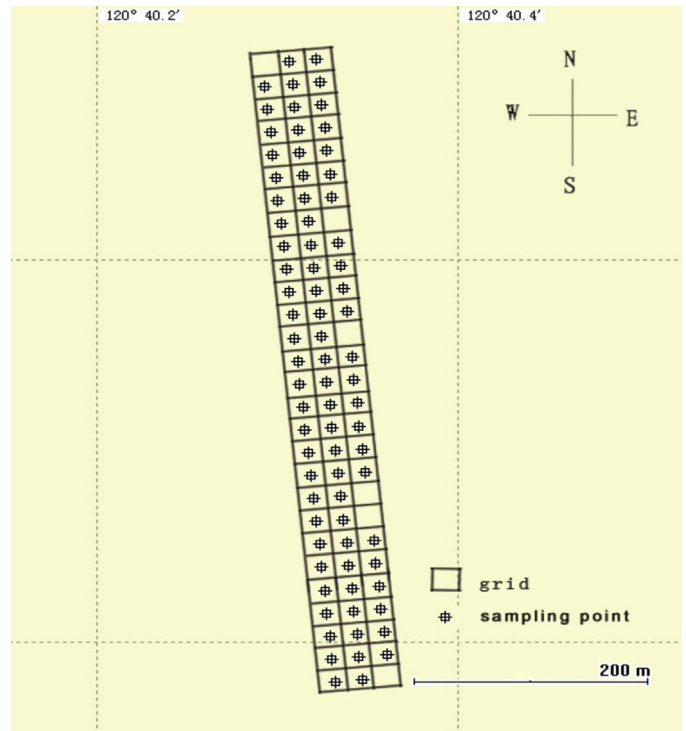


Fig. 1. Spatial heterogeneity-distribution of soil sample.

3. Results

3.1. Jerusalem artichoke morphological characteristics

3.1.1. Descriptive statistical analysis

The descriptive statistics (mean, median, maximum, minimum, standard deviation, variance, range, skewness, kurtosis) of Jerusalem artichoke morphological characters (stem height, stem diameter, tuber fresh weight, tuber number, and root fresh weight) were shown in Table 1. Skewness reflects the symmetry of distribution; the values less than 0 mean the most data are lower than the mean. For a standardized normal distribution, the value of skewness is zero (Antonio et al., 2013; Brovelli et al., 2011). In the present study, the skewness values were near zero (Table 1). Kurtosis describes the distribution shape (Antonio et al., 2013). The value of normal distribution was about 3. In the present study, the kurtosis values were all near 3, indicating normal distribution of the morphological parameters of Jerusalem artichoke (Table 1).

3.1.2. Boxplot and parameter estimation

The boxplot is a simple and flexible graphical tool in exploratory data analysis (Tukey, 1977). Boxplot entails the measurements of maximum, 75th percentile, medium, 25th percentile and minimum (Abuzaid et al., 2012). Its main applications were to identify extreme values and outliers in a univariate data set. The range between 75th and 25th percentile represents a confidence interval (Abuzaid et al., 2012).

Regarding morphological traits of Jerusalem artichoke, there were several outliers (one in graph a – stem height, and two in graph c – root fresh weight). The confidence intervals of the means are presented in Table 2.

Parameter estimation was aimed at using the sample data to deduce population distribution. It could be divided into point estimates and interval estimation. Maximum likelihood method was the most widely used method in parameter estimation (Siddiqui

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