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Accumulation and concentration of nitrogen, phosphorus and potassium in Jerusalem artichoke in a semi-arid region

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Abstract

Jerusalem artichoke (*Helianthus tuberosus* L.) has been recognized as being a biomass crop for energy and livestock forage production. In this study, 26 Jerusalem artichoke clones previously collected from 24 provinces of China were grown under semiarid conditions in 2008 and 2011. At harvest, nitrogen (N), phosphorus (P) and potassium (K) concentrations and accumulations were measured for all clones and levels of both were higher overall for 2008 than 2011, with statistically reasonable results for both years. Notably, N and K concentrations in aboveground parts were higher than in tubers for most clones, yet the tuber P concentration was consistently higher than in aboveground parts. Comparing with other forage and energy plants, it demonstrates that under optimal conditions, diverse Jerusalem artichoke clones could meet the requirements of either energy production or livestock forage feed. Based on N, P and K accumulation and concentration profiles, the 26 Jerusalem artichoke clones clustered into six groups. Three clones of one cluster, CQ-1, GZ-1 and HUN-3, are recommended for use as biomass energy materials due to the lower N concentration level in aboveground parts and higher N concentration level in tubers, while 16 clones are recommended for use as forage due to the higher N concentration level in aboveground parts. The phenotypic traits described in this work should facilitate quantitative trait locus mapping and the subsequent use of clone germplasms for development of improved varieties suited to specific growth conditions and applications.

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Introduction

The Jerusalem artichoke (*Helianthus tuberosus* L.) has garnered much attention for its high potential value as a feedstock source for biomass energy production and livestock forage. High levels of inulin and fructose account for 75% of its total dry tuber weight (Baldini *et al*., 2004; Kays and Nottingham, 2008); thus, this crop may serve as a promising raw material for the industrial production of biodiesel (Cheng *et al*., 2009), ethanol (Baldini *et al*., 2004), methane (Lehtomaki, 2005) and biomass briquettes or pellets (Kowalczyk-Jusko *et al*., 2012). Importantly, use of phenotypically diverse crops may allow biomass content control, as previous studies of energy biomass materials have suggested that such control should help to avoid negative environmental influences. For example, during combustion of briquettes or pellets (Jenkins *et al*., 1998), excess nitrogen (N) in raw materials would directly lead to higher emission of nitrides and hydrogen cyanide during combustion. Hence, development of Jerusalem artichoke varieties with lower N content would enhance this crop's value as a raw material in the biomass briquette industry. However, for other applications, higher nitrogen levels might be a desirable trait because the residues from anaerobic digestion of plant biomass for energy production contain mineralised nitrogen, a readily available N source for growing plants. Thus, higher N levels contribute to higher by-product quality after anaerobic digestion. Because Jerusalem artichoke tubers contain high N levels, tubers would thus be better suited for use in ethanol production than for production of biomass briquettes. The N-rich residues produced by anaerobic digestion could thus be returned to the cultivation soil to serve as a fertiliser and soil-improvement medium (Demuynck, 1984; Hons *et al*., 1993; Karpenstain-Machan, 2001).

Comparing with corn silage, tuber of Jeruslaem artichoke showed to have a higher digestible protein content (Kays and Nottingham, 2008). While tubers show potential value, aboveground parts of the Jerusalem artichoke have already long been used as an ideal raw livestock forage for ruminants in cool, wet areas of Europe (Kosaric *et al*., 1984; Hay and Offer, 1992; Youngen, 1992; Cosgrove *et al*., 2000) and in North America (Crawford *et al*., 1969; Seiler, 1993). For this reason, previous studies have focused on evaluation of *in vitro* digestible dry matter from aboveground parts of the plant (Tilley and Terry, 1963; Seilier, 1993). Other studies of perennial silage/forage crops have additionally demonstrated that mineral element composition and quantity should also be assessed (Buxton, 1996) because multiple inorganic elements, including calcium, phosphorus (P), sodium, chlorine, potassium (K), magnesium and sulfur, are essential for normal livestock growth and reproduction (National Academy of Sciences, 2001).

Aside from the applications outlined above, the Jerusalem artichoke holds promise for use in desertification control (Ma *et al*., 2011), due to its high tolerance of drought and saline-alkali conditions (Zhao *et al*., 2010a). However, the utilisation of the plant's underground tubers could cause environmental problems, as the harvest of tubers would cause soil erosion. Therefore, harvest of only aboveground parts is recommended in some environmentally stressed areas. For such applications, the assessment of the quantity and concentration of macroelements in the aboveground parts of the Jerusalem artichoke would be a valuable indicator to inform germplasm selection of pasture varieties for use in ecologically sensitive regions.

Regardless of application, the uptake and utilisation of mineral nutrients, which are closely related to plant growth and yield, are mainly dependent on environmental water (Pilnik and Vervelde, 1976; Mezencev, 1985; Conde *et al*., 1988; Ben Chekroun *et al*., 1996) and soil conditions (Kosaric *et al*., 1984). Although Jerusalem artichokes could be grown in poor soils without high fertiliser input, the resulting tuber sizes tend to be smaller and are accompanied by low aboveground biomass yields (Huxley, 1992). Therefore, an appropriate fertilisation management strategy is needed for optimising biomass accumulation of both Jerusalem artichoke tubers and aboveground aerial parts depending on their intended applications. In our previous study, we evaluated phenological development, morphological traits, shoot biomass and tuber yields of 26 Jerusalem artichoke clones grown in the semi-arid region of the Loess Plateau of China (Liu *et al*., 2012). The objectives of this study were (i) to investigate changes in concentrations and uptake of N, P and K over a growth period of 180 days for 26 Jerusalem artichoke clones and (ii) to group the clones into different clusters according to the nutrient properties.

Materials and methods

Study site

All field experiments were carried out in 2008 and 2011 in a semiarid region of the Loess Plateau Experimental Station of Lanzhou University (35°37´N, 107°48´E, 1298 m above sea level). The multi-year mean annual solar radiation duration, temperature and precipitation from July to September were 2490 h, 556.1 mm and 9.6°C, respectively. The soil at the site was Heilu with a clay texture, pH 7.7, and organic matter of 13.10 g kg^{-1} in the 0-20 cm layer. Total rainfall were 335 mm and 297 mm during the growth periods in 2008 and 2011, respectively, with 78.3% and 83.8% falling between July and September. Soil water potential at the 0-20 cm layer fluctuated from –25 to –80 kPa during the 180 d of the Jerusalem artichoke clone growth. More detailed seasonal weather data, soil texture and moisture data at the study site in 2008 and 2011 have been described in our previous report (Liu *et al*., 2012).

Experimental design

A total of 26 Jerusalem artichoke clones were assessed in this study. The experimental design was a completely randomized block with triplicate plots in 2008 and in quadruplicate plots in 2011. Each plot was 1.6×2.8 m in size and allocated into 4 rows with a row spacing of 0.7 m and hill spacing of 0.4 m. 50 g of tubers for propagation collected from different clones were individually planted in each plot on April 1st after the field was well ploughed and harrowed in the early spring. Guard rows were also set up to surround areas containing each single clone to prevent potential crop identification errors. Basal fertiliser consisted of 150 N kg ha^{-1} as urea, 75 kg P_2O_5 ha^{-1} as superphosphate and 120 kg K_2O ha^{-1} as potassium sulphate, which were applied one day before planting. Surface irrigation was applied with an amount of 50 m^3 ha^{-1} water for each plot on March 31st. Weed was removed manually in all plots at the seedling stage. No additional irrigation and weed control was applied prior to the harvest dates on October 1st of each year.

Sampling and measurements

The aboveground biomass in each plot was collected on each harvest date by cutting the plants at ground level and weighing the fresh aboveground biomass. From the leaf, and stem parts were separated, cut into pieces of 2-3 cm in length, then oven-dried to constant weight at 105°C to determine moisture content. Dry biomass weights of aboveground stem and leaf in each plot were calculated by multiplying fresh biomass weight by its dry matter content (100%-moisture content). Fresh tubers in each plot were harvested manually and further washed, counted and weighed to determine tuber size, fresh weight and numbers of tubers per plant. A subset of tubers was cut into 1.5 cm-thick slices and oven-dried to constant weight at 105°C. Thereafter, dried tuber slices were crushed and passed through a 0.5 mm mesh screen for subsequent chemical analyses. The total dry biomass yield of Jerusalem artichokes was calculated by adding the aboveground biomass yield from leaf and stem parts to the tuber biomass yield.

Chemical analysis

Samples of tubers and aboveground parts (leaf and stem) were first digested with H_2SO_4-H_2O_2 following a Kjeldahl digestion protocol (Wolf, 1982). N, P and K concentrations were determined using the semimicro-Kjeldahl digestion and distillation method (Nelson and Sommers, 1980), vanadomolybdate yellow method (Jackson, 1958) and flame spectroanalysis, respectively. The determinations of N, P and K concentrations for each plot were derived from the averaged values of 3 replicate plots in 2008 and 4 replicate plots in 2011.

Calculation and statistical analysis

The nutrient accumulations in aboveground parts and tubers were computed as the product of the concentration multiplied by the dry biomass weight for each replicate. Means and standard errors were calculated from replicate data for each treatment.

The nutrient data of the 26 Jerusalem artichoke clones were analysed by determining the maximum and minimum values and calculating the standard error. A correlation between concentration and accumulation for each of the three elements was conducted. Two-way ANOVA was conducted for the purpose of examining the effects of year and clone factors on nutrient concentrations using SPSS software package. The significance of the differences between means was determined using the least significant difference at the $P<0.05$ level. The two-year mean concentration and accumulation values for each clone were used for hierarchical cluster analysis using Ward's method. Cluster and principal components analysis were performed using the SPSS Statistics 20 software package (SPSS, IBM Corp., 2011).

Results

Cluster analysis

The 26 Jerusalem artichoke clones were sorted into 6 clusters on the basis of N, P and K accumulation and concentration in 2008 and 2012 (Figure 1). Mean values and standard errors of accumulation and concentration for each cluster are presented in Figure 2. Cluster K_1 with 3 clones was characterised by relatively high levels concentration and accumulation of N and K in aboveground parts, low levels of N concentration and accumulation in tubers. Cluster K_2 including 6 clones exhibited relatively high concentration and accumulation levels of P and K in tubers and low accumulation of P and K in aboveground parts. Cluster K_3 including 2 clone shown the lowest P and K concentration levels in tubers, and highest N, and K concentration levels in aboveground part. Cluster K_4 with 3 clones characterised the highest concentration and accumulation levels of N and P in tubers. Cluster K_5 including 2 clones exhibited relatively low concentration and accumulation levels of both N, P, and K in tubers. Cluster K_6 was the largest group with 10 clones and characterised by relatively low N concentration level in tubers and high N accumulation in aboveground parts.

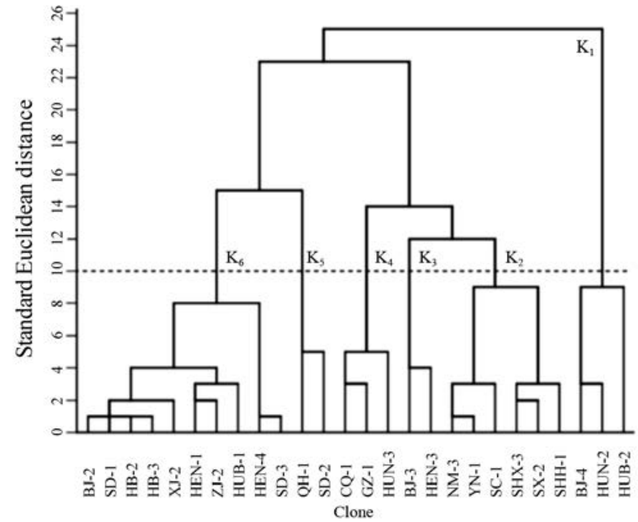

Figure 1. Dendrogram obtained by cluster analysis of concentrations and biomass accumulation of nitrogen (N), phosphorus (P) and potassium (K) in 26 Jerusalem artichoke clones following Ward's method.

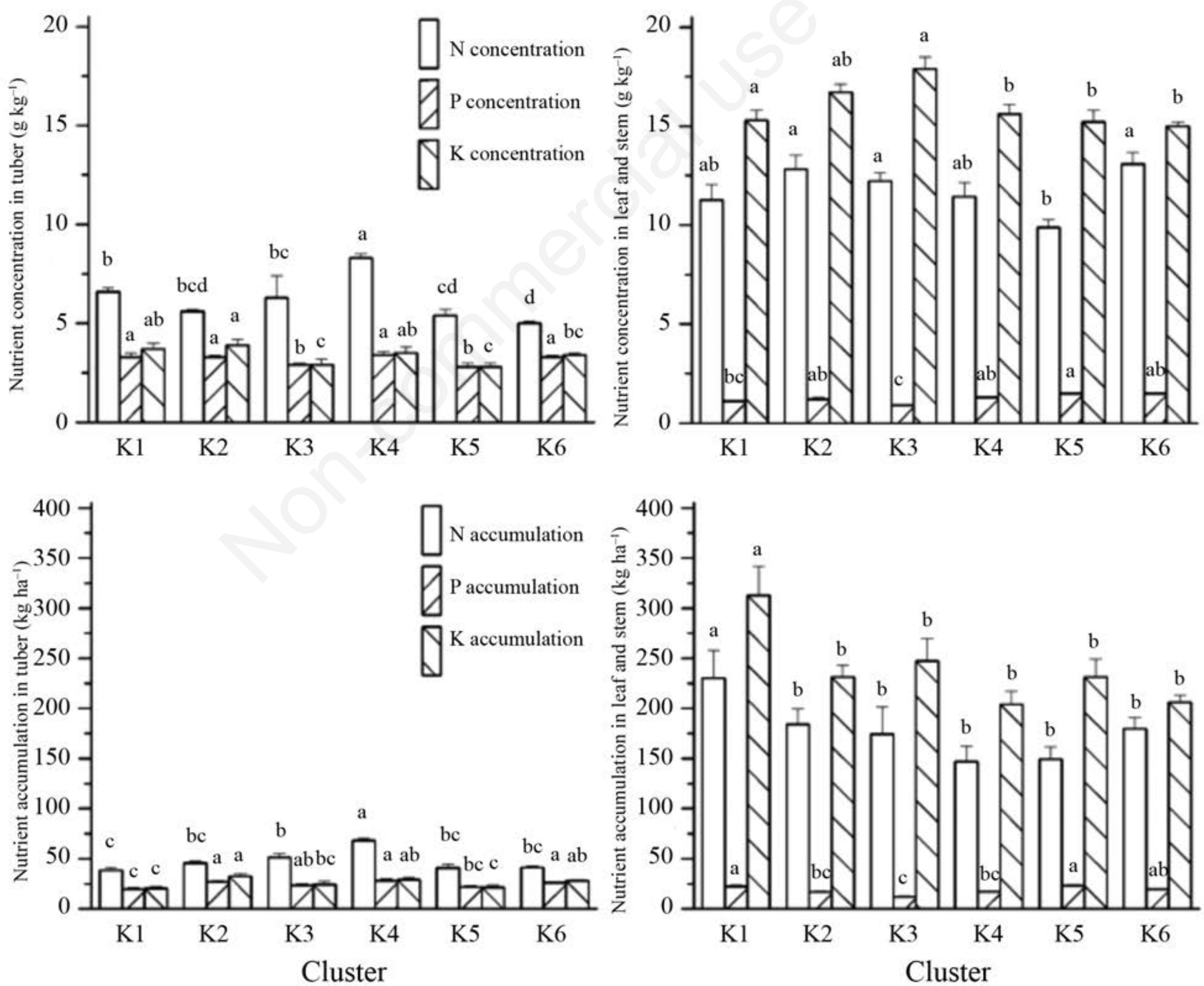

Figure 2. Averaged concentrations and accumulations of nitrogen (N), phosphorus (P) and potassium (K) in tubers, and aboveground parts at harvest date for the six clusters of Jerusalem artichoke grown in 2008 and 2011. Vertical error bars represent standard deviations. Different lower letters within the same parameter represent statistical significance between clusters at P<0.05 level.

N, P and K concentrations in aboveground parts

Relative to tubers, sample from all Jerusalem artichoke clone aboveground parts exhibited lower K concentration levels than either N or P concentration levels for both years (Figure 3). The 26 Jerusalem artichoke clones exhibited N concentrations ranging between 9.33-22.66 g N kg^{-1}, P concentrations between 0.81-1.65 g P kg^{-1} and K concentrations between 14.53-20.38 g K kg^{-1} for both years. The average N and K concentrations in the aboveground parts of all 26 clones were both lower, by 78.9% and 19.1%, respectively, in 2011 than in 2008, whereas the average P concentration did not vary significantly ($P<0.05$). Two-way ANOVA demonstrating the effects of factors of planting year,

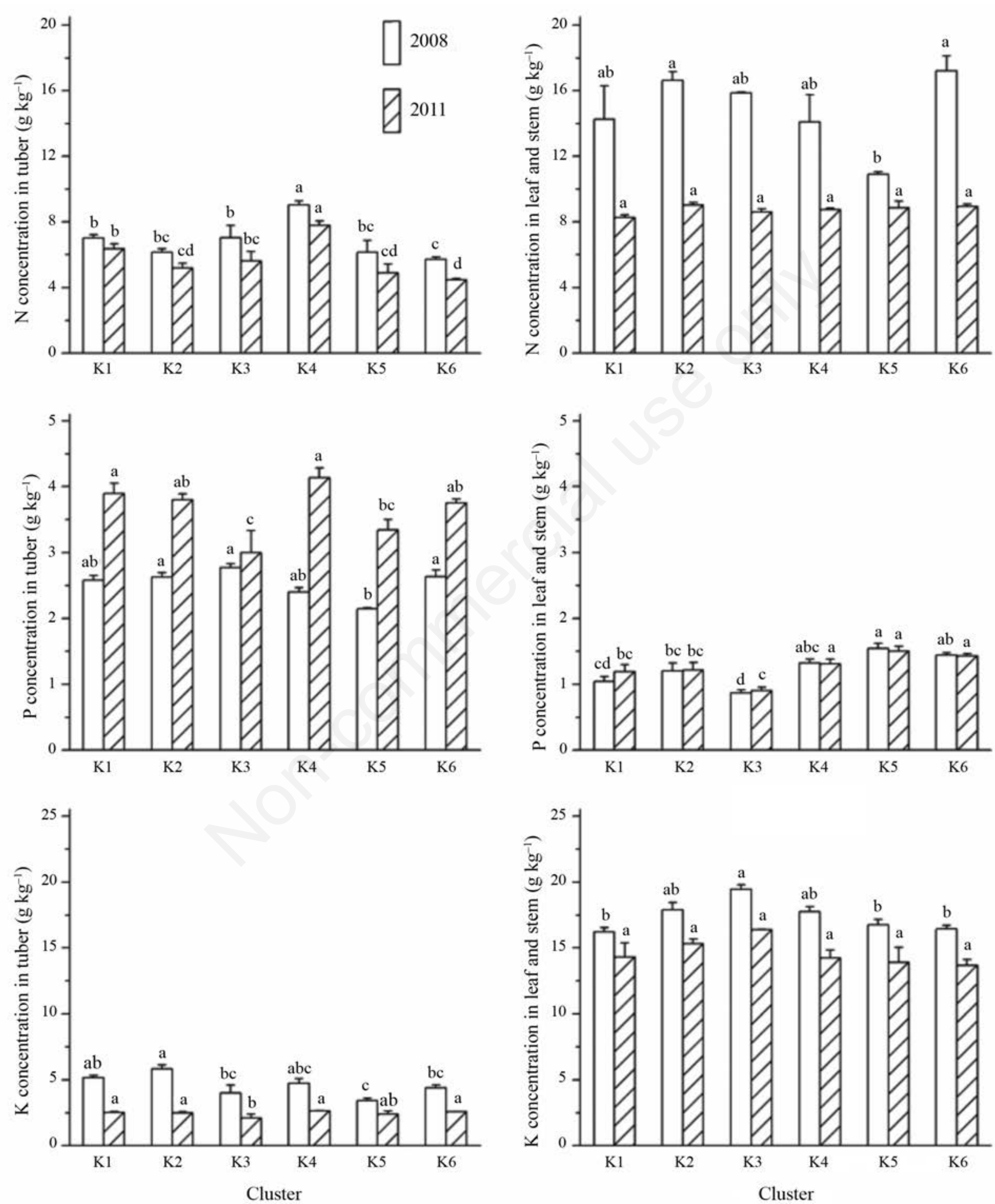

Figure 3. Concentrations of nitrogen (N), phosphorus (P) and potassium (K) in tubers and aboveground parts at harvest date for six clusters of Jerusalem artichoke grown in 2008 and 2011. Vertical error bars represent standard deviations. Different lower letters within the same parameter represent statistical significance between clusters at P<0.05 level.

clone and their interaction factor on the concentrations of the three elements in aboveground parts demonstrated that most variances in the independent and interaction factors were significant at the $P<0.001$ level, however the variance for year × clone effects on N concentration was not significant.

N, P and K concentrations in tubers

Cluster average concentrations of N, P and K in tubers in 2008 and 2011 are shown in Figure 3. Generally, the 26 clones tended to have a higher N concentration in aboveground parts than in tubers in both years. In contrast, P and K concentrations were higher in tubers than in aboveground parts. Average N concentrations of the six clusters were 6.85 g N kg^{-1} and 5.72 g N kg^{-1}, average P concentrations were 2.53 g P kg^{-1} and 3.65 g P kg^{-1}, and average K concentrations were 4.59 g K kg^{-1} and 2.45 g K kg^{-1} in 2008 and 2012, respectively. Average N, P and K concentration in the tubers of the clones planted in 2008 were higher by 21.2% and 89.5%, respectively; whereas average P concentration in tubers in 2008 was lower by 31.1% in comparison with those in 2011. Two-way ANOVA demonstrating effects of factors of year and clone and their interaction factor on tuber N, P and K concentrations generated results that were similar to aboveground part results. However, in tubers the independent and interaction factors were all significantly affected by N, P and K concentrations at the $P<0.01$ level.

N, P and K accumulations

The N accumulation in aboveground parts was higher than in tubers, due to the higher N concentration and biomass in aboveground parts (Figure 2). Moreover, even though the concentrations of P and K in tubers were both generally higher than in aboveground parts, the accumulation of P and K in aboveground parts of most clones were still higher than for tubers overall, due to the overwhelming higher biomass present in aboveground parts.

N accumulation exhibited a significantly much higher level in the aboveground parts (129.98-416.87 kg N ha^{-1}) than that in tubers (27.78-81.67 kg N ha^{-1}) across the six clusters ($P<0.01$) in both years (Figure 2). K accumulation, ranging between 20.48-55.41 kg K ha^{-1} in tubers and 181.84-522.62 kg K ha^{-1} in aboveground part, followed the same pattern as N accumulation. However, the difference in P accumulation between aboveground parts (12.63-31.29 kg P ha^{-1}) and tubers (9.17-27.18 kg P ha^{-1}) was not significant for each of all the clusters with the exception of cluster K_6 ($P<0.05$). The variance of the nutrient accumulations between the two years was the same as for nutrient concentrations. The accumulations of the three elements were generally lower in 2011 than in 2008, except for P accumulation in tubers. The mean values of tuber N, P and K accumulations were lower by 22.2%, –34.6% and 50%, respectively. The average N, P and K accumulations in aboveground parts were lower by 60.4%, 28.0% and 41.1%, respectively (Figure 4). Two-way ANOVA showed that the N, P and K accumulations in both aboveground and tuber parts were all significantly affected by the year, clone and the interaction of year × clone factors at the $P<0.001$ level.

Statistical analysis

Correlations between N, P and K accumulations and concentrations were calculated using the mean values for the 26 clones for both years (Table 1). In agreement with previously established plant nutrition concepts, a significant and positive correlation between N, P and K accumulations and their corresponding concentrations in both aboveground parts and tubers was demonstrated ($P<0.01$).

Discussion

Correlation of N, P and K concentrations with biomass yield

According to a previous report (Liu *et al*., 2011) based on the same field experiment of this study, the 26 Jerusalem artichoke clones exhibited biomass yield ranging from 9.7 ton ha^{-1} to 31.3 ton ha^{-1} for aboveground parts and from 3.7 ton ha^{-1} to 10.6 ton ha^{-1} for tubers in both year 2008 and 2011. The total biomass of above ground parts and tubers ranged from 16.1 ton ha^{-1} to 35.0 ton ha^{-1}. The yield data and our finding were used to analyze the correlation of N, P and K concentrations with biomass yield and found that none of the three nutrient concentrations was significantly correlated with biomass yield of aboveground parts and tubers ($P<0.05$).

N, P and K concentrations in tubers and aboveground parts

All clones in this study exhibited tuber N concentrations ranging between 3.98-9.50 g N kg^{-1} averaged over both years. This level was about a half of the N concentration values (7.0-21.8 g N kg^{-1}) in tubers reported by Kays and Nottingham (2008), who did a field experiment with 140 Jerusalem artichoke clones. The main reasons accounting for lower N, P and K concentrations observed in this work were likely due to the lower N fertilisation rate and earlier harvest date used here. Although the required N fertiliser rate for this crop was reported to range from 60-120 kg N ha^{-1} (Barloy, 1988; Fernandez *et al*., 1988; Honermeier *et al*., 1996), the practical N requirement varied between clones. The sufficient N fertiliser for numerous clones has been reported to range from 150-225 N kg ha^{-1} by many researchers studying Jerusalem artichoke agronomy practices in China (Niu, 2005; Zhao *et al*., 2010b; Zhu *et al*., 2014). Therefore, the fertilisation rate of 150 kg N ha^{-1} applied in our study was a relatively medium or low-level application rate. Considering the proper cropping season for Jerusalem artichoke in China is from March-May to middle October (Niu, 2005), our slightly earlier harvest date might cause our results for the N partition from leaf to tuber to differ from that observed by other researchers who used longer growth season duration. In our study, the N concentration of harvested aboveground parts over both years ranged from 7.87-22.66 kg N ha^{-1}, almost two times higher than the tuber N concentration range of 3.98-9.50 kg N ha^{-1}.

N, P and K uptake and responses to environmental influences

The Jerusalem artichoke has long been reported to be an extremely efficient crop for nutrient uptake of its tubers and above-

Table 1. Coefficients of correlation between concentration and accumulation of nitrogen (N), phosphorus (P), and potassium (K) in tubers and aboveground parts of 26 Jerusalem artichoke clones.

Nutrient	Coefficient	
	Tuber	Aboveground part
N	0.773**	0.878**
P	0.622**	0.457**
K	0.831**	0.587**

**Significant effect at P<0.01 level.

ground parts (Kays and Nottingham, 2008). The clones cultivated in this experiment showed a relatively higher N and K uptake levels than sweet sorghum, miscanthus, and switchgrass, which were reported by Han *et al*. (2011), Beale and Long (1997) and Wilson *et al*. (2013), respectively. However Jerusalem artichoke exhibited a lower P uptake level than sweet sorghum (Han *et al*. 2011). The most possible reason for this could be N and K concentrations in Jerusalem artichoke in this study were higher than those plants in the previous reports, and P concentration with the reverse.

A plant is as well responsive to supplemental fertiliser application (Lim and Lee, 1983). Therefore, proper fertilisation management is recommended to ensure sustainable cultivation. Notably,

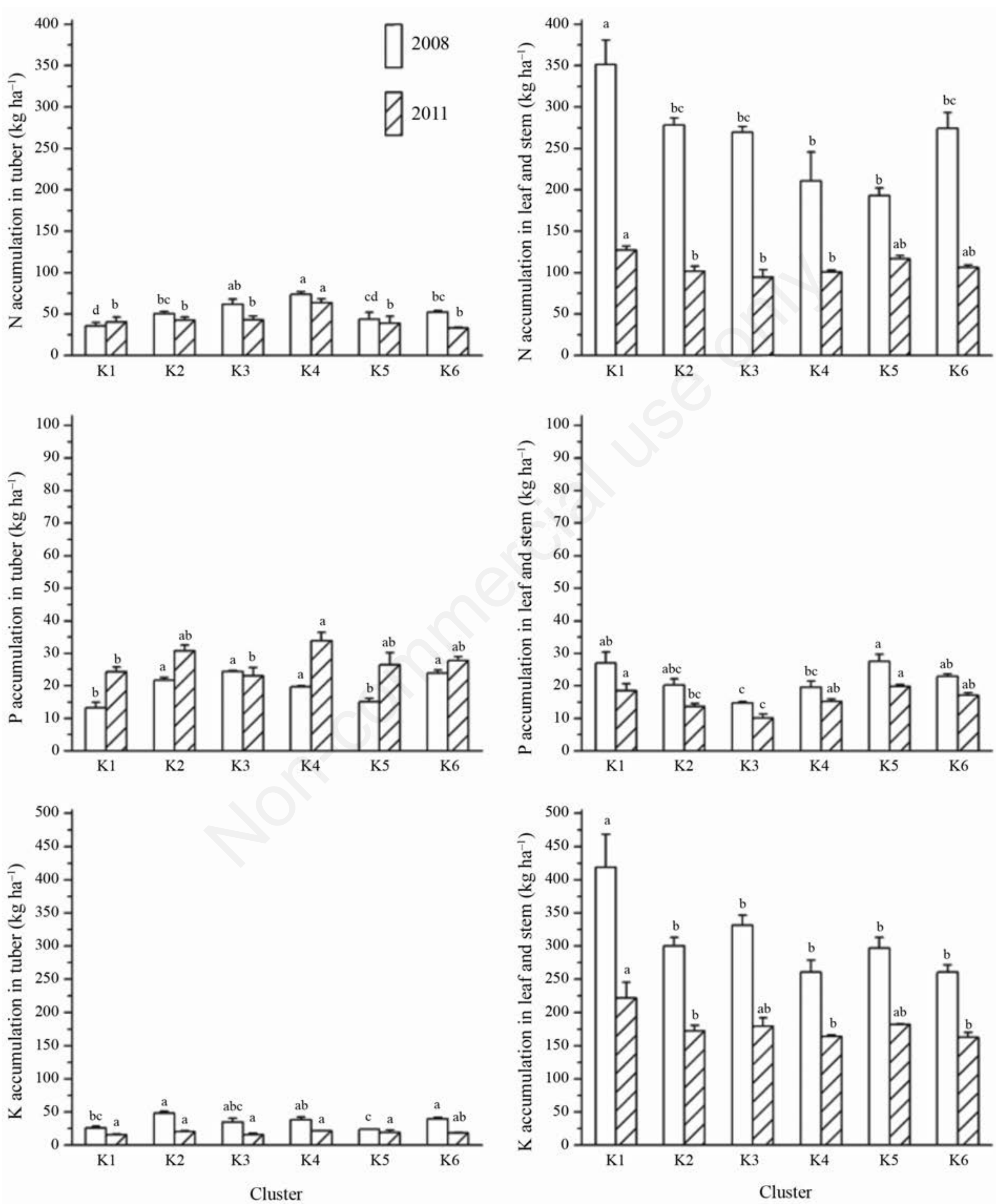

Figure 4. Accumulations of nitrogen (N), phosphorus (P) and potassium (K) in tubers and aboveground parts at harvest date for six clusters of Jerusalem artichoke grown in 2008 and 2011. Vertical error bars represent standard deviations. Different lower letters within the same parameter represent statistical significance between clusters at P<0.05 level.

on the basis of our experiments, the amount of N, P and K removed from the field were larger than the fertiliser amount applied at the beginning of the experiments. As a consequence of insufficient fertilisation, the tuber yield and N, P and K accumulations in 2011 were generally lower than, or consistent with, those in 2008. Thus, higher fertilisation application rates should be used to ensure continuous Jerusalem artichoke cultivation.

Although the Jerusalem artichoke has been considered to be drought tolerant, the level of phloem-mobile elements (*e.g*. nitrogen, phosphorus, potassium), which would be allocated to the tuber, would also be affected by drought stress late in the season (Nemeth and Izsaki, 2006). Although few studies on the Jerusalem artichoke have reported results of nutrient status analysis, Seiler and Campbell (2006) compared the within-population variation for several minerals. The within-population variations were high for N, Ca and K and low for P and Mg. Monti *et al*. (2005) reported leaf N concentrations ranging from 30-36 g N kg^{-1} for the cv. '*Violet de Rennes'* grown in Bologna, Italy, under irrigated and rain-fed conditions. According to our previous study (Liu *et al*., 2012), the clones planted in 2011 suffered a longer period of environmental water deficit than clones planted in 2008. The severe soil moisture deficit period, which is defined as a period of soil moisture potential greater than 50 kPa, lasted for 124 days and 147 days in 2008 and 2011, respectively. The N, P and K concentrations and accumulations in 2008 were therefore greater than those in 2011 and were accounted for by the reasons outlined above.

Potential uses of the clones

In comparisons with other main energy crops, N concentration level (3.98-9.50 g N kg^{-1}) in the tuber of Jerusalem artichoke was lower than that in sweet sorghum (9-10 g N kg^{-1}) reported by Han *et al*. (2011). The tuber also exhibited the similar N concentration level with miscanthus shoot (Beale and Long, 1997) and switch grass shoot (Wilson *et al*., 2013).

Jerusalem artichoke aboveground parts showed relatively higher N (7.87-22.66 g N kg^{-1}) and K concentration levels (14.53-20.38 g K kg^{-1}) in this study in comparison with some main forage crops. Sudangrass shoot N concentration was found to be 2.39 g N kg^{-1} (Li and Lu, 2006). Annual brome (Haferkamp and Heitschmidt, 1996) exhibited K concentration level ranging from 1.7 to 14.8 g K kg^{-1}. However, P concentration in above ground parts, with the reverse, was lower in Jerusalem artichoke (0.83-1.65 g P kg^{-1}). It was reported in the range between 1.8-2.0 g P kg^{-1} for red clover (Davies *et al*., 1966) and between 2.4-2.6 g P kg^{-1} for white clover (Wang, 1982), and between 1.6-2.9 g P kg^{-1} for annual brome (Haferkamp and Heitschmidt, 1996). P concentration in alfalfa shoot (4.7 g P kg^{-1}) was found to be even higher (Xiao and Zhao, 2006).

Cluster K_4, which includes CQ-1, GZ-1 and HUN-3 clones, includes the most appropriate clones for energy production, as these clones contain a high N concentration in tubers (mean 8.42 g N kg^{-1}) and low N concentration in aboveground parts (mean 11.43 g N kg^{-1}). The pellet and briquette industry requires a lower concentration of N in raw materials because the combustion of biomass pellets and briquette would directly release the N in the raw materials into the environment in the form of toxic pollutants (Jenkins *et al*., 1998). Therefore, aboveground parts derived from these clones would be appropriate for pellet and briquette production. While the high N content of tubers precludes their use for pellet and briquette production, anaerobic digestion of tubers for ethanol production would benefit from their high N concentration; higher N concentrations confer value to post-digestion residues to enhance their use as crop fertiliser (Demuynck, 1984; Hons *et al*., 1993; Karpenstain-Machan, 2001). Therefore, these three clones could efficiently furnish ideal raw materials for both pellet/briquette and ethanol energy-production processes, with additional benefits. Clusters K_6 and K_2, including 16 clones in total, would be most suitable to be used as forage, as these clones contain higher mean N concentrations in aboveground parts. The mean aboveground N concentrations of K_6 and K_2 were 13.09 and 12.83 g N kg^{-1}, respectively. If the total N had been converted into protein (total N × 6.25), the crude protein in aboveground parts would be calculated to range from 5.0%-14.3% and 2.5%-6.3% for K_6 and K_2 clusters, respectively. These crude protein content values are higher than those of maize and wheat used for dairy cow feed and thus could be useful as forage (Zhao *et al*., 2011). Furthermore, Rakhimov *et al*. (2003) found this plant to have a high nutritive value, as it contains almost all essential amino acids needed for livestock feed. Stauffer *et al*. (1981) also agreed that the aboveground part is better suited for use as feed than are tubers, as the leaf is rich in lysine and methionine.

In contrast to the N results above, however, our results demonstrate that the P content of Jerusalem artichoke shoots is insufficient for dairy feed (0.81-1.65 g P kg^{-1}), in agreement with results reported by Kays and Nottingham (2008). Seiler and Campbell (2006), who have reported the influence of heritable variation on mineral content, recommend elevating the N, P and K content using hybrid-breeding methods. However, the P and Mg content would hardly be elevated using this method, since the P content in this plant is already generally lower than in forage feed.

K is an element that is important for its roles in osmotic adjustment and enzyme catalysis. Sufficient supply of K is also important in dairy feed. The 26 clones were demonstrated to possess K concentrations ranging from 11.87 to 20.38 g K kg^{-1} and would thus provide nutritionally adequate amounts of K (5.1-19.0 g K kg^{-1}) to serve as a valuable ruminate feed supplement (National Academy of Sciences, 2001).

Conclusions

The N, P and K concentrations and biomass accumulations in 26 Jerusalem artichoke clones collected from 18 provinces in China showed significant variation, with levels that tend to be lower under drought conditions. If optimal cultivation conditions can be sustained, this crop is a promising source of raw materials for use in the biomass energy industry, as well as for forage feed from the perspective of macroelement concentration. Three clones, CQ-1, GZ-1 and HUN-3, are recommended for use as biomass energy materials and 16 clones are recommended for use as forage feed. The clones' phenotypic nutrition traits described in this work should aid quantitative trait locus (QTL) mapping of their germplasms for future development of improved varieties tailored to diverse applications and growth conditions.

Highlights

The aboveground parts exhibited higher N and K concentration levels and a lower of P concentration level than the tubers at maturity of Jerusalem artichoke.

Each of N, P, and K concentration was not significantly correlated with the plant biomass yield for the above ground parts and tubers respectively.

Jerusalem artichoke showed a relatively higher N and K uptake levels than sweet sorghum, miscanthus, and switchgrass, and P concentration with the reverse.

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