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Original paper

Growth and biomass of Siberian elm seedlings (*Ulmus pumila L.*) grown in tree nursery

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Abstract

In this paper, we studied growth and biomass of 1-2 years old Siberian elm seedlings grown in the tree nursery, near Ulaanbaatar, Mongolia. *Ulmus pumila* L. has a wide natural distribution throughout the country. Due to climate change and other factors, environmental degradation has become inevitable in the country and efforts to restore degraded land are made in different regions. Due to its drought and cold resistance, Siberian elm is considered to be one of the most suitable species of tree to be used for restoration and windbreaks. We measured height, diameter and biomass of 1-2 year-old seedlings, and composed allometric equation to estimate aboveground and belowground biomass. Equations have high prediction power (R^2=0.80-0.96), however, they are more suitable to seedlings and saplings due to difference in the allometric relationship of trees at different ages. We also explored relationship between diameter (at root collar) and height, which was fairly good (R^2=0.73).
In order to be able to use the equation to indirectly estimate belowground biomass of seedlings, we estimated Root/shoot ratio of seedlings. Root/shoot ratio was 0.85 for 1-2-year-old seedlings. Belowground biomass estimation can be useful in determining how well the tree can fix soil around it, and draw water and nutrients from the soil. The result of the study can be used for further work concerning the viability of Siberian elm for restoration and windbreaks.

Keywords: Diameter, height, biomass equation, regression, root/shoot ratio

1 Introduction

Climate change in the recent decades has accelerated environmental degradation in countries like Mongolia, where the majority of the land lies in the arid and semi-arid zone. The country has extreme continental climate, cold, long winter and dry, short summer. It is reported that the climate warming in Mongolia has been over 2℃ from 1940 to 2015 [1]. Researchers reported the change in summer precipitation pattern [2], causing further degradation, including soil erosion, and runoff. Therefore, it is very important to widen activities to restore degraded land. Major factors contributing to land degradation in Mongolia apart from climate change are mining, road development in the rural areas, grazing, agriculture development with poor management, and deforestation. Experiences to use tree and shrub species in environmental restoration has been widely used outside of the natural forest area. These include windbreaks along roads, around farm sites, and near settlements. One of the major tree species planted for windbreaks and environmental restoration is Siberian elm (*Ulmus pumila* L.).

Siberian elm has wide natural distribution throughout the Central [3] and Northeast Asia [4]. In this country, it is found in the 15 out of 16 vegetation-geographic districts [5], and is considered as one of the sturdiest tree species. It can grow up to 5-10 meters tall in height, and depending on the region its growth season lasts from early May to late September. Under favorable conditions it can grow fast, and it favors locations with abundant sunlight. Also, it is drought and cold resistant [4], which makes it superior to other tree species when grown under harsh climate. These qualities make this species one of the most suited tree species to be used in environmental restoration and windbreaks. One of the priorities in planting trees in poor soil condition is to develop sufficient belowground biomass to support the tree growth. Further, it has become important issue to understand the biomass allocation pattern in the Siberian elm seedlings and saplings, and the findings can be used in the estimation of carbon storage in Siberian elms and organic matter accumulation in their soil. Hence it is highly significant to estimate the growth parameters of seedlings, their root/shoot ratio, and develop biomass equations using easily measurable parameters as independent variables of the equations.

In this study, we aimed to explore the relationship between growth parameters, and develop biomass equations for the Siberian elm seedlings /1-2 year-old/ grown in the tree nursery. The following objectives were defined. These are:

1. Define relationship between height and root collar diameter of 1-year-old seedlings
2. Develop allometric equations to estimate above ground and belowground biomass for 1-2-year-old seedlings
3. Determine root/shoot ratio of 1-2 year-old seedlings

2 Materials and Methods

The study was conducted in the tree nursery located in the Dambadarjaa area, Ulaanbaatar, and field measurements were collected in September, 2016. Before planting Siberian elm seeds raised beds were prepared using soil mixture 50:30:20 percent (soil:sand:manure). The size of the nursery was 6 m x 30 m, and width of the raised bed was 1 m. Seeds were planted in rows according to MNS 6253-2: 2011 standard (General requirement: Planting seeds of trees). Weight of 1000 seeds was 3.7±0.28 gram, and approximately 1 gram of seeds were planted per 1 meter. Spaces between rows were 20 cm, and width of the row was 5 cm. Depth of planting seeds were 5-7 cm and covered with 3 cm thick saw dust and 2 cm thick sand layer. Watering of the seeds were done during early morning (6-9 am), and evening (5-8 pm), with 5-10 liters of water per square meters of area. Once the seedlings developed sufficient roots, weeding and soil aeration has been carried out once in every 3 weeks. At the end of the growing season in September, some 300 seedlings (survival rate 83%) were randomly selected and measured for height (cm), and diameter at root collar (mm) using electronic caliper. Further, a total of 13 seedlings (10 one-year-old, 3 two-year-old) were randomly selected for destructive sampling. Destructive sampling involves harvesting whole seedlings for their biomass measurements. Hence the relatively small size of sampling is commonly used for developing allometric equations [6], and in some studies as few as 5 trees can be harvested for equation development. The 1-2 year-old seedlings were sampled to produce single equation, rather than separate equations for different ages. These 13 seedlings were measured for their height and diameter at root collar, then separated as aboveground and belowground section at root collar. These samples were dried in the oven at 70℃ for 48 hours, and then weighed for oven dry biomass. Regression analysis was used to explore the relationship between height and diameter, and develops equations for biomass estimation using height and/or diameter as independent variables. The predictive power of the equations is evaluated by their R^2 values. Root/shoot ratio of the seedlings were estimated by the ratio between dry biomass of roots by shoot (stem, twigs and leaves). Spreadsheet of data was created using EXCEL, and statistical analysis and graphs were done using SigmaPlot.

3 Results

Relationship between diameter at root collar and height of seedlings

Height and diameter at root collars of 300 seedlings were measured and mean values were calculated (table 1). The relationship between diameter at root collar and height of the seedlings were explored using these measurements (
Fig.).

Table 1. Root/shoot ratio of Siberian elm (*Ulmus pumila* L.) seedlings

Seedling age	Maximum	Minimum	Mean± Standard deviation
1-2 year-old	1.58	0.59	0.85±0.25

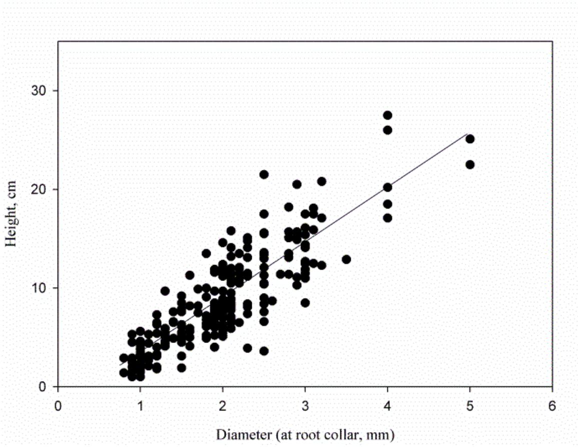

Fig. 1. Relationship between height and root collar diameter of 1-year-old Siberian elm seedlings (Height=-2.4263+5.6682*Diameter, R^2=0.73)

Height and diameter at root collar of seedlings have linear relationship with fairly good prediction power (R^2=0.73). Range of measured values shows the different growth rate amongst seedlings.

Biomass equations for seedlings

Oven dried biomass was measured for total biomass, aboveground biomass and belowground biomass, using 13 destructively sampled seedlings (1-2-year-old). Diameter and height both had very good predictive power for the total biomass using power equations (Fig 2).

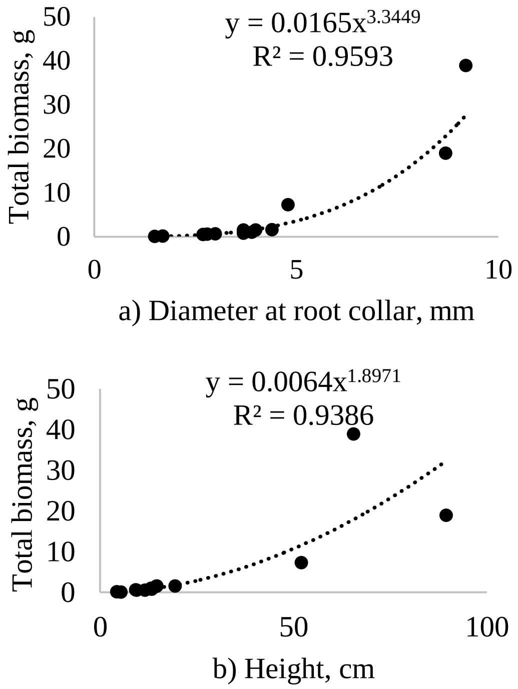

Fig. 2. Total biomass versus diameter (a) at root collar, and height (b) for 1-2-year-old Siberian seedlings

However, when the both parameters combined, predictive power became much less, and therefore we omitted height from further analysis to develop equations for aboveground and belowground biomass estimation. We developed separate equations for aboveground and belowground biomass estimation using the diameter at root collar as an independent variable (Table 2).

Table 2. Biomass equations for Siberian elm seedlings (1-2-year-old)

Biomass part	Equation form	Equation	R^2 values
Aboveground biomass (stem, twigs, leaves)	Exponential	$B = 0.0299*e^{0.755*D}$	0.91
	Linear	B = 2.7081*D - 7.8385	0.80
	Power	$B = 0.008*D^{3.4417}$	0.96
Belowground biomass	Exponential	$B = 0.0307*e^{0.6977*D}$	0.88
	Linear	B = 1.6124*D - 4.5022	0.81
	Power	$B = 0.0086*D^{3.2223}$	0.95

Note: B-Biomass, g; D-Diameter at root collar, cm

Amongst the equations power form has the highest prediction for both above and belowground biomass (R^2=0.96 and 0.95, respectively).

Root/shoot ratio of seedlings

We estimated root/shoot ratio based on the belowground and aboveground dry biomass of both 1 and 2-year-old seedlings (table 3).

The estimated ratio shows that the aboveground biomass is higher than the belowground biomass, which could be explained by the watering treatment of the seedlings in the nursery.

Table 3. Root/shoot ratio of Siberian elm (*Ulmus pumila* L.) seedlings

Seedling age	Maximum	Minimum	Mean± Standard deviation
1-2 year-old	1.58	0.59	0.85±0.25

4 Discussion

Experiments to planting Siberian elm in Mongolia has started as early as 1956 in Umnugovi aimag, and later in 1973-76 in Selenge aimag [7]. Since 1996, Center for combating desertification (Institute of Geography and Geoecology, Mongolian Academy of Sciences) has planted Siberian elm for windbreaks to prevent sand accumulation near Zamiin-Uud area. This study shows that the height and diameter at root collar of seedlings have fairly good linear relationship (R^2=0.73), and similar relationship (R^2=0.76-0.78) is reported for other species of elms by researchers [8]. Adding height as independent variable didn’t increase the predictive power of our equations, and therefore we omitted height from the equations. Biomass equations developed for elms commonly used diameter as only independent variable [9, 10], however, some studies used height and diameter both as independent variables [6]. According to researchers [4] Siberian elm seedlings are capable of growing over wide range of climate condition with different precipitation patterns, and their study indicated that indigenous Siberian elm trees in arid areas have substantially altered their morphological and physiological characteristics to avoid heat stress and increase water conservation in comparison to mesic areas. Cho *et al.* [11] studied drought adaptation of *Ulmus pumila* L. in Lun soum of Tuv aimag, Mongolia, and concluded that Siberian elm has much higher water use efficiency compared to poplars. Similar study showed [12] that the root/shoot ratio in *Ulmus americana* can be altered by nitrogen availability in the soil, resulting in higher shoot proportion. Some studies on *Ulmus americana* [13] and *Ulmus glabra* [14] stated that the use of ectomycorrhizal and arbuscular mycorrhizawill increase water absorption and increased biomass accumulation. Growth of plants under drought stress reduces, however root is less affected than the growth of the shoot. This is related to the capillary roots of the plants and these roots are capable of finding water even under very dry condition, hence the change in root/shoot ratio is reported due to environmental condition. Root/shoot ratio in our study was 0.85, which could be due to nursery condition with high water availability. This ratio is further expected to change once the seedlings are transplanted to field conditions. The findings of this study could be used in further studies to estimate biomass of potential saplings to be planted for environmental restoration and windbreaks in arid areas. Growing superior seedlings will result in the effective field adjustment after transplantation, as well as higher carbon accumulation in biomass.

5 Conclusions

1. Height and diameter at root collar of seedlings have a linear relationship with fairly good prediction power (R^2=0.73). This shows that the growth rate of seedlings is homogenous. Also the equation of this relationship can be used for estimating the height of the seedlings using the diameter at root collar.
2. Aboveground and belowground biomass equations showed high predictive power (R^2=0.80-0.96) using the diameter at the root collar as independent variable. Amongst these equations the most powerful form was power equations (R^2=0.95-0.96). These equations can be used for biomass estimation of seedlings. However, the equations were developed for 1-2-year-old seedlings in Ulaanbaatar area, and therefore using these equations outside of the area and for older trees will require calibration.
3. Mean value of root/shoot ratio of Siberian elm was 0.85 for 1-2-year-old seedlings, which shows higher shoot proportion compared to root biomass. This ratio can change later once the environmental condition changes and trees grow older.
4. Biomass equations for Siberian elm has practical significance to estimate seedling biomass without damaging them, using only diameter at the root collar as an independent variable.

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