Quantitative Characteristics of *Solanum Rostratum Dunal* Populations in Two Habitats in Jilin Province

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Abstract: To investigate the expansion and adaptation mechanisms of the invasive plant *Solanum rostratum Dunal* in heterogeneous habitats, this study examined populations in two typical habitats—grassland and landfill—in Baicheng City, Jilin Province. Population samples were collected during the maturity period in 2023, and their structural characteristics and biomass distribution patterns were analyzed. Results showed that the proportion of biomass allocated to reproductive organs was significantly higher in the grassland population (53.27% ± 14.12%) compared to the landfill population (46.63% ± 9.97%), while the vegetative allocation showed the opposite trend. The coefficient of variation (CV) for all biomass components was markedly higher in the landfill populations, with the greatest variation observed in fruit mass (CV = 225.68%). These findings reveal that *Solanum rostratum Dunal* displays pronounced phenotypic plasticity and divergent biomass allocation strategies between habitats. The study provides a theoretical basis for predicting potential invasion risks, monitoring dispersal dynamics, and developing ecological control strategies for this invasive weed in Jilin Province.

Keywords: *Solanum Rostratum Dunal*; Population; Quantitative Trait; Phenotypic Plasticity

1. Introduction

Solanum rostratum Dunal, also known as prickly nightshade, Kansas thistle, prickly eggplant, and pointed-beak eggplant, is an annual herbaceous plant belonging to the Solanaceae family and Solanum genus[1]. *Solanum rostratum Dunal*is native to North America and is now widespread throughout the United States except for Florida, and has invaded many countries including Canada, Mexico, Russia, South Korea, Bangladesh, Austria, Bulgaria, the Czech Republic, Slovakia, Germany, Denmark, South Africa, Australia, and New Zealand. In 1981, *Solanum rostratum Dunal* was first discovered to have been introduced into Liaoning Province, China. Over time, the invasive range of *Solanum rostratum Dunal* has gradually expanded, and the harm it causes to the ecological environment has become increasingly severe. It possesses strong dispersal capabilities. Due to its spiny fruits, it can attach itself to humans, animals, and vehicles, making it highly dispersible, especially in regions primarily focused on livestock farming. When mature, the main stem of the plant breaks near the ground, forming a tumbleweed-like structure that rolls seeds over long distances, thereby increasing the likelihood of its introduction into new environments [2]. Wind dispersal and trampling by animals or humans are the primary means of spread [3]. *Solanum rostratum Dunal* is also a globally quarantined weed. If *Solanum rostratum Dunal* is mixed into agricultural products, it can disrupt import and export trade and cause significant losses to the agricultural economy[4].

The stems, leaves, carpels, berries, and roots of *Solanum rostratum Dunal* contain solanine, a highly toxic neurotoxin. This substance has a significant anesthetic effect on the central nervous system, particularly the respiratory center, and can cause severe enteritis and bleeding. Livestock that consume it may suffer from poisoning and even death [5]. *Solanum rostratum Dunal* can also harm crops and severely inhibit their growth, while also inhibiting the growth of important agricultural crops such as forage grasses[6-7].

Solanum rostratum Dunal weakens the dominance of native plant species, leading to an increasingly simplified structure of native plant communities, which in turn facilitates the spread of prickly nightshade [8]. Field surveys of *Solanum rostratum Dunal* have revealed that it possesses strong adaptability and a broad ecological range, capable of growing in both arid and humid environments. Its primary habitats include wastelands, roadside areas, overgrazed grasslands, disturbed regions, areas near villages, abandoned sites, farmlands, and the surroundings of ponds[9].

Based on the above reasons, this study investigates the intrinsic patterns of quantitative traits in *Solanum rostratum Dunal* populations across two typical habitats in Jilin Province. By exploring the expansion and adaptation mechanisms of *Solanum rostratum Dunal* in heterogeneous habitats, this research provides crucial theoretical foundations for scientifically predicting the invasion risks of this weed in Jilin Province, effectively monitoring its dispersal dynamics, promptly interrupting dispersal pathways, and formulating ecological weed control strategies.

2. Materials and Methods

2.1 Study Area Description

The study area is located in Baicheng City, Jilin Province. Baicheng City is situated in the northwestern part of Jilin Province (121°38′-124°22′E,44°13′-46°18′N), in the western part of the Nenjiang Plain and the eastern part of the Keerqin Grassland, with a total area of 25,758.73 km².

The terrain slopes from northwest to southeast, progressing through low mountains, hills, and plains, with a slight elevation in the southwest. The climate is a temperate continental monsoon climate. Except for a brief period during the peak of summer when it is influenced by marine monsoons, the majority of precipitation throughout the year originates from the westerly wind belt. The annual average temperature is 5.2°C, with an annual average precipitation of 399.9 mm. The unique geographical environment has shaped the region's climate characteristics of “abundant sunlight, high precipitation variability, and more droughts than floods” [10].

Under the influence of a temperate continental monsoon climate, the climate transitions from semi-humid to semi-arid from east to west, with corresponding vegetation zones also changing sequentially. East of Baicheng and Tongyu on the loess plateau, the vegetation is of the meadow grassland type, while the vast undulating regions to the west are dominated by dry grassland vegetation. In the vast low-lying areas, salt meadow grassland vegetation is distributed, with soil types primarily consisting of black calcareous soil, light black calcareous soil, chestnut calcareous soil, sandy soil, meadow soil, and saline-alkali soil [11].

2.2 Plot Selection and Setup

The study site was located in Beidagang, Pingtai Town, Taobei District, Baicheng City, Jilin Province (122°50′E, 45°43′N). This study focused on two representative habitats supporting populations of *Solanum rostratum Dunal*: (1) a grassland habitat subject to heavy disturbance near a landfill site in Hongqi Village, Tongkai Town, Tongyu County (123°09′E, 44°47′N), and (2) a natural grassland habitat with minimal human disturbance.

The landfill habitat is severely disturbed by human activities. In each habitat, areas with relatively uniform and consistent growth were selected as study plots, and sampling was conducted during the maturation period of *Solanum rostratum Dunal*. The plant communities in the grassland habitat primarily include *Bidens parviflora* Willd, *Setaria pumila* (Poir.) Roem. & Schult., *Ipomoea* nil (L.) Roth, X*anthium strumarium* L, *Chenopodium album* L., and *Kali collinum* (Pall.) Akhani & Roalson; the landfill habitat has fewer associated plants, primarily *Ambrosia artemisiifolia* L, *Setaria viridis* (L.) P. Beauv., and *Echinochloa phyllopogon* (Stapf) Kossenko.

2.3 Experimental Methods

This study selected *Solanum rostratum Dunal* plants at seed maturity as research materials in 2023. Large-scale random sampling of *Solanum rostra*tum *Dunal* plants was conducted in landfill and grassland habitats. In both habitats, 30 plants were dug up from areas where *Solanum rostratum Dunal* grew uniformly.

During the excavation process, ensure that the aboveground parts of the *Solanum rostratum Dunal* plants, along with their underground root systems, are completely excavated, numbered, placed in woven bags, and brought back to the laboratory. Label the collected plant samples. Use a ruler to measure the plant height and root length of *Solanum rostratum Dunal*; separate the collected *Solanum rostratum Dunal* plants into components such as roots, stems, leaves, flowers, and fruits, wash the soil off the roots, and record the number of leaves and flowers/fruits. Place the separated *Solanum rostratum Dunal* plant components in a 60°C oven to dry until constant weight is achieved. Use a one-ten-thousandth balance to measure the biomass of each component and record the results.

The biomass allocation index is determined by the percentage of each component's biomass relative to the total biomass. The calculation formula is as follows:

Reproductive allocation = Flower and fruit biomass / Total biomass × 100%

Nutrient allocation = (root biomass + stem biomass + leaf biomass) / total biomass × 100%

Above-ground biomass allocation = (root biomass + stem biomass + leaf biomass + flower and fruit biomass) / total biomass × 100%

Below-ground biomass allocation = root biomass / total biomass × 100%

2.4 Data Processing

Correlation analysis was performed using SPSS 17.0 to examine the relationships among total plant height, total biomass, and the number of roots, stems, leaves, and flowers/fruits. One-way ANOVA was used to compare the significant differences in biomass of roots, stems, leaves, and flowers/fruits, total plant height, and total biomass among species. Graphs were created using Excel software.

3. Results

3.1 Population Size Characteristics

The results showed that the grassland population allocated a significantly greater proportion of total biomass to reproductive organs (flowers and fruits; 53.27% ± 14.12%) than the landfill population (46.63% ± 9.97%; $P < 0.05$). In contrast, the vegetative allocation ratio of the landfill population was significantly higher (53.37% ± 9.97%) than that of the grassland population (46.73% ± 14.12%). The coefficients of variation (CV%) for all biomass traits were substantially higher in the landfill habitat, with the highest variation observed in fruit mass (CV = 225.68%), indicating high phenotypic plasticity under disturbed conditions. (Table 1.)

Table 1. Biomass Components and Coefficients of Variation (CV%) Of *Solanum Rostratum Dunal* in Two Habitats

Component	Grassland		Landfill	
	Mean±SD	CV/%	Mean±SD	CV/%
Root biomass/g	1.67±1.07a	64.26a	1.42±1.66a	116.85b
Stem biomass/g	12.84±11.58a	90.19a	11.65±21.37a	183.45b
Leaf biomass/g	2.19±2.46a	112.05a	1.29±1.90a	146.91b
Flower biomass/g	0.32±0.40a	123.29a	0.17±0.27a	159.61b
Fruit biomass/g	23.60±23.06a	97.71a	15.37±34.69a	225.68b
Reproductive biomass/g	23.93±23.33a	97.50a	15.54±34.78a	223.83b
Total biomass/g	40.64±37.34a	91.88a	29.90±59.00a	197.31b
Vegetative biomass/g	16.71±14.60a	87.35a	14.36±24.42a	170.04b
Vegetative allocation/%	46.73±14.12a	30.21a	53.37±9.97b	18.68b
Reproductive allocation/%	53.27±14.12a	26.50a	46.63±9.97b	21.39b
Aboveground/%	94.04±3.38a	3.59a	93.12±3.42a	3.67b
Belowground/%	5.96±3.38a	56.76a	6.88±3.42a	49.69b

Note: Features of the same magnitude are indicated by different lowercase letters to show significant differences, i.e., there is a significant difference between the two species at a significance level of 0.05.

3.2 Relationship between Above-Ground and Below-Ground Biomass and Total Biomass

The analysis results show that in grassland habitats, the relationship between the proportion of underground biomass and the proportion of above-ground biomass and total biomass is moderately strong ($R^2 = 0.38$) and extremely significant ($p < 0.001$). As total biomass increases, plants tend to allocate a relatively larger proportion of biomass to the aboveground portion while reducing the proportion allocated to the belowground portion. In landfill habitats, the relationship between aboveground and belowground biomass and total biomass is weaker ($R^2 = 0.11$) and statistically insignificant ($p > 0.05$). (Figure 1.)

3.3 Relationship Between Root, Stem, and Leaf Biomass and Total Biomass

The results showed that root biomass, stem biomass, and leaf biomass were all significantly positively correlated with total biomass in both habitats ($p < 0.001$).

A comparison of the results from the two sample sites reveals that the correlations between root biomass, stem biomass, and total biomass in the landfill habitat ($R^2 = 0.85$ and 0.99, respectively) are higher than those in the grassland habitat ($R^2 = 0.70$ and 0.97, respectively), while the correlation between leaf biomass and total biomass is similar in both sample sites.

The rates of increase in root biomass and stem biomass with total biomass in the landfill habitat were slightly higher than those in the grassland habitat, while the rate of increase in leaf biomass with total biomass was lower than that in the grassland habitat. (Figure 2.)

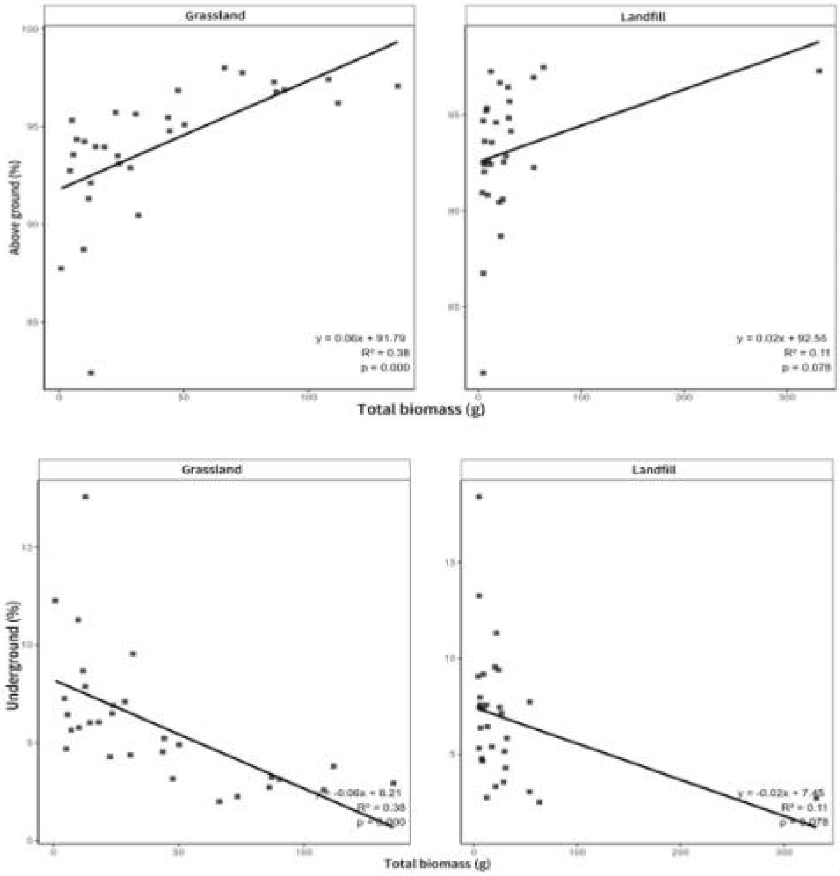

Figure 1. Fitted Curves of Aboveground and Belowground Biomass in Relation to Total Biomass of *Solanum Rostratum Dunal* in Two Habitats

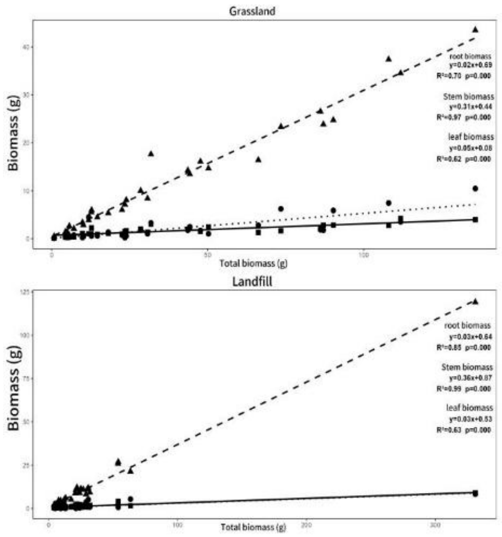

Figure 2. Relationship Between the Biomass of *Solanum Rostratum Dunal* Components and Total Biomass in Two Habitats

3.4 Population Biomass Distribution

Overall, there are significant differences in the biomass distribution patterns between the two study sites. In the grassland habitat, reproductive organs (flowers and fruits) accounted for as much as 53.3% of the total biomass, significantly higher than other components, with the biomass allocation sequence being: flowers and fruits > stems > leaves > roots. In the landfill habitat, the proportion of reproductive biomass decreased to 46.6%, while stem biomass accounted for 41.1%, with the biomass allocation sequence being: stems > flowers and fruits > roots > leaves. (Figure 3.)

4. Discussion and Conclusions

In this study, significant differences were observed in the population characteristics of

Solanum rostratum Dunal across heterogeneous habitats. In grassland habitats, resources were prioritized for reproductive organs (flowers and fruits accounted for 53.3% of biomass). In landfill habitats, which are highly disturbed by human activity and marked by environmental instability, *Solanum rostratum Dunal* m increased the allocation of resources to vegetative organs such as roots, stems, and leaves. The coefficients of variation (CV%) of each biomass component were significantly higher in landfill populations, reflecting the phenotypic plasticity of *Solanum rostratum* in response to heterogeneous environments.

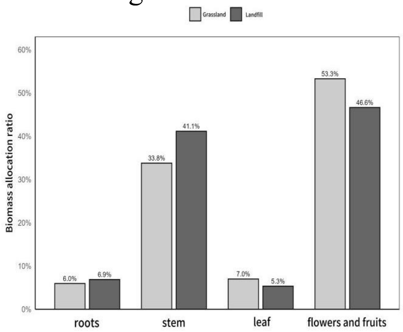

Figure 3. Relationship Between the Biomass Allocation of *Solanum Rostratum Dunal* Population Components in Two Habitats

The relationship between above-ground and below-ground biomass and total biomass in grassland habitats is significant, indicating that the biomass allocation of *Solanum rostratum* in this habitat follows certain patterns, with a clear allocation tendency as biomass increases. In landfill habitats, however, the relationship between the two is not significant, reflecting that in environments with severe disturbance and unstable resources, biomass allocation patterns are more flexible, more influenced by environmental factors, and less likely to form stable patterns.

In both habitats, root, stem, and leaf biomass showed extremely significant positive correlations with total biomass. In the landfill habitat, root and stem biomass exhibited higher correlations with total biomass and grew at faster rates. Leaf biomass, however, grew at a slower rate, indicating that under conditions of limited resources or high disturbance, plants prioritize the growth of roots and stems to maintain basic survival needs.

In conclusion, *Solanum rostratum* demonstrates notable phenotypic plasticity by flexibly altering its allocation of biomass between reproductive and vegetative organs according to habitat disturbance intensity. These results provide new insights into the species' adaptive mechanisms and inform effective management strategies for its invasion in heterogeneous environments.

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