Effects of an invasive plant Palmer Amaranth (*Amaranthus palmeri*) on herb communities

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Abstract. Based on the investigation of vegetation samples in the university town of Xiqing District, Tianjin, this paper summarized the status of biological invasion of *Amaranthus palmeri* in Tianjin, and searched for the methods to suppress the biological invasion of *Amaranthus palmeri*, which laid a foundation for the study on the solution measures for plant invasion of *Amaranthus palmeri* in China.

1. Introduction

1.1. Research object

*Amaranthus palmeri* is an annual dioecious herb belonging to the family Amaranthus and Amaranthus genus. It is native to the southwest of the United States to northern Mexico, and has become an invasive species worldwide due to its strong adaptability, strong reproductive ability, strong survival ability, and difficulty in eradication [1]. In just 30 years, the biological invasion effect of *Amaranthus palmeri* has caused great impact on the society and has attracted wide attention, which is called "super weed".

1.2. Research status

Foreign studies on *Amaranthus palmeri* mostly focus on physiological and ecological characteristics [2], diffusion and distribution, etc., and the development and use of herbicides are increasing day by day [3], especially studies on glyphosate-resistant [4].

At present, the domestic data on *Amaranthus palmeri* are mainly reported by the inspection and quarantine departments of coastal ports and news reports, and there are few scientific research literature or reports. Since 1985, when *Amaranthus palmeri* was first discovered in Beijing, China [5-6], it was only described by Li Zhenyu in the form of a research briefing in 2003. Later, Che Jin-dian from Beijing Plant Protection Station briefly introduced the morphological characteristics, biological characteristics, distribution, harm and control of *Amaranthus palmeri*. In recent years, there have been reports of *Amaranthus palmeri* detection all over the country (such as Tianjin, Beijing, Hebei, Zhejiang, Fujian, Anhui and Guangxi, etc.). Until 2014, Lv Yu-feng et al studied the distribution and ecological risk of 6 *Amaranthus* species including *Amaranthus palmeri* in Beijing [7].

1.3. Overview of the study area

After many considerations, the sample area selected for this project is located in the open space in the university town of Xiqing District, Tianjin, which is connected with the University of Science and
Technology. After comprehensive species removal, the plots have been in the natural growth mode since then, and there was no human intervention in the ecological environment. It is a typical sample for the natural growth of *Amaranthus palmeri* in Tianjin. Moreover, Tianjin is located in the North China Plain and belongs to the typical semi-humid monsoon climate of warm temperate zone, which is the microcosm of the vegetation growth environment in the eastern coastal areas. The study in this area is conducive to the exploration of the proposed growth situation of *Amaranthus palmeri* in Tianjin and even in the eastern coastal areas, and to pave the way for the research on the status of biological invasion of *Amaranthus palmeri* in China.

1.4. Indicators to measure

On June 30, 2019, August 30, 2019, and October 30, 2019, the team members selected 6 1m×1m square typical herb community quadrats in the university town of Xiqing District of Tianjin for three times, and used the Handheld GPS to conduct GPS positioning and work records. The herbaceous plants in the sample square were counted in terms of plant name, number, phenology, average height, coverage, etc., and the diversity index was calculated by referring to the research methods of Liu Zhong-gnan, Liu Hai, Qin Tian-jian, etc., so as to further understand the basic characteristics of the community and the invasion status of *Amaranthus palmeri* [8-10]. The formula is as follows:

**Shannon-Wiener diversity index (E):**

\[ H = - \sum_{i=1}^{S} p_i \times \ln p_i \]  
(1)

**Pielow evenness index (E):**

\[ E = H / \ln S \]  
(2)

**Relative dominance index of *Amaranthus palmeri* (RID):**

\[ RDI = N1 / S \]  
(3)

Where: \( p_i \) is the ratio of the total number of plant individuals in the same square; \( S \) is the total number of species in the quadra; \( N1 \) is the total number of *Amaranthus palmeri*.

2 Overview of surface vegetation growth

2.1. Community characteristics

As can be seen from Table 1 of the vegetation quadrate survey, there are 16 species of herbaceous plants in the plant community quadrate, including 8 families and 15 genera, among which there are 6 species of Gramineae at most, 3 species of Conconiferous family, 2 species of Chenopodiaceae, and 1 species of the rest. The total number of individuals of *Amaranthus palmeri* was much larger than that of other species, which was an absolute advantage, and there was a trend of biological invasion to the sample site.

| Species name               | Family name      | Genus name    | Life type     |
|----------------------------|------------------|---------------|---------------|
| Kochia scoparia            | Chenopodiaceae   | Kochia        | Annual herb   |
| Chenopodium album          | Chenopodiaceae   | Chenopodium   | Annual herb   |
| Amaranthus palmeri         | Amaranthaceae    | Amaranthus    | Annual herb   |
| Portulaca oleracea         | Portulacaceae    | Portulaca     | Annual herb   |
| Bidens pilosa              | Compositae       | Bidens        | Annual herb   |
| Digitaria sanguinalis      | Gramineae        | Digitaria     | Annual herb   |
| Chloris virginata          | Gramineae        | Chloris       | Annual herb   |
| Setaria viridis            | Gramineae        | Setaria       | Annual herb   |
| Echinochloa crusgalli      | Gramineae        | Echinochloa   | Annual herb   |
| Eleusine indica            | Gramineae        | Eleusine      | Annual herb   |
| Phragmites australis       | Gramineae        | Phragmites    | Perennial herb|
| Lagopsis supina            | Labiatae         | Lagopsis      | Perennial herb|
| Calystegia hederacea       | Convolvulaceae   | Pharbitis     | Annual twining herb|
| Ipomoea hederacea          | Convolvulaceae   | Pharbitis     | Annual twining herb|
| Ipomoea purpurea           | Convolvulaceae   | Pharbitis     | Annual twining herb|

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2.2. Community diversity
From the perspective of time series analysis, from June to October, the biodiversity index of *Amaranthus palmeri* was in a declining trend. The Shannon-Wiener diversity index increased at first and then decreased, with a maximum of 1.65 and a minimum of 0, indicating that a single dominant species community was gradually formed. The Pielow evenness index, a symbol of species richness, ranged from 0 to 0.9, and most of them were at the 0 scale. The overall trend of decline indicated that with the maturity of *Amaranthus palmeri*, the effect of biological invasion was increasing, the dominance of single species was enhanced, and the species richness decreased gradually, which seriously damaged the biodiversity in this area. The relative dominance index of *Amaranthus palmeri* showed a steady rising trend, indicating that there was no species that could inhibit the survival and expansion of *Amaranthus palmeri* in the natural conditions.

![Fig. 1 Change trend of community diversity](image)

2.3. *Amaranthus palmeri* grows in density
According to the survey of vegetation quadrats, the individual number of *Amaranthus palmeri* in the same quadrats decreased rapidly over time, but the coverage and average height of the community increased rapidly. When *Amaranthus palmeri* was fully mature in October, there were only less than 50 plants on average in the 1m² plot, but the average height was up to 1.5m, indicating that from the germination stage to the fruit stage, the growth density of *Amaranthus palmeri* in a fixed area will continue to decrease, but the influence of individual plant on the population will continue to increase, and the invasion ability will be stronger. The survival competition of *Amaranthus palmeri* in the community is not only interspecific competition but also intraspecies competition.
Fig. 2 Change trend diagram of *Amaranthus palmeri*

3. Conclusion
In this study, we found that the relationship between relative dominance of *Amaranthus palmeri* and herbaceous species diversity in invasive sites was as follows: Shannon-Wiener diversity index and evenness index were positively correlated, increasing and decreasing with each other. The greater the relative dominance of *Amaranthus palmeri*, the lower the diversity index and evenness were, showing a negative correlation. Therefore, the invasion of *Amaranthus palmeri* brought loss to the species diversity of the community, and destroyed the surface vegetation coverage during its growth. The evolution from multi-species and multi-coverage to single-plant growth of *Amaranthus palmeri* seriously broke the balance of the ecosystem.

4. Suggestion
*Amaranthus palmeri* has strong drug resistance, so it is necessary to strengthen the research and development of herbicides and intensify the search for a radical cure for *Amaranthus palmeri* invasion in North China.

The soil seed bank of *Amaranthus palmeri* has dormant period and latent period. Therefore, according to the growth cycle of *Amaranthus palmeri*, it should be pulled out before the fruitage period to avoid causing invisible damage to the local seed bank.

At the same time, we should increase the publicity of the harmful effects of *Amaranthus palmeri* and the status of biological invasion, attracting the attention of relevant government departments.

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