Effects of Soil Type and Rainfall Variation on Artemisia scoparia Population Dynamics (Postprint)

Authors: Su Ying

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Abstract

Taking the widespread species Artemisia scoparia distributed in the desert steppe of Yanchi County, Ningxia as the research object, three soil types (aeolian sandy soil, weathered bedrock residual soil, and sierozem) were selected, and rainfall patterns were altered using field experimental facilities. The fixed-point quadrat method was employed to investigate their effects on the population dynamics of A. scoparia. The results showed that the soil volumetric water content of weathered bedrock residual soil was higher than that of aeolian sandy soil and sierozem; in the rainfall addition zone, the soil volumetric water content of aeolian sandy soil, weathered bedrock residual soil, and sierozem increased by 10.6%, 6.6%, and 20.2%, respectively; while in the rainfall reduction zone, they decreased by 44.1%, 9.2%, and 20.1%, respectively. The survival curve of A. scoparia belonged to the concave type, characterizing it as an r-strategist. On aeolian sandy soil, A. scoparia exhibited larger crown width, whereas on sierozem it showed higher density. During the middle growth stage of A. scoparia, plant height and crown width were greater in the rainfall addition zone on aeolian sandy soil, while density was higher in the rainfall reduction zone; on weathered bedrock residual soil, density was higher in the rainfall reduction zone, while plant height and crown width were greater in the rainfall addition zone; on sierozem, density was lowest in the rainfall reduction zone, but both plant height and crown width were greater. In the early growth stage, soil type and water content were negatively correlated with plant height and crown width; in the middle growth stage, soil water content was significantly negatively correlated with density, soil type was significantly negatively correlated with plant height and extremely significantly negatively correlated with crown width; in the late growth stage, soil water content was extremely significantly negatively correlated with density; soil type was extremely significantly negatively correlated with crown width. The biomass of A. scoparia was significantly positively correlated with total carbon and total nitrogen (P<0.05), and significantly negatively correlated with total phosphorus (P<0.05). These results indicate that soil type and rainfall significantly affect the population dynamics of A. scoparia. Soil type primarily influences the crown width of A. scoparia; during the middle and late growth stages, soil water content exerts a significant effect on its population density. This conclusion provides a theoretical basis for the improvement of desert steppe.

Full Text

Effects of Soil Types and Precipitation Variation on Dynamic Status of *Artemisia scoparia* Population

SU Ying[1,2], LI Yue-fei[1,2], CHEN Lin[1,2], ZHU Zhong-you[1,2], YUAN Chuang[1,2,3], MENG Wen-ting[1,2], ZHU Lin[1,2]

[1]Key Laboratory for Restoration and Reconstruction of Degenerated Ecosystem in Northwest China under Ministry of Education, Ningxia University, Yinchuan 750021, China
[2]Breeding Base for State Key Laboratory of Land Degradation and Ecological Restoration in Northwest China, Ningxia University, Yinchuan 750021, China
[3]College of Agriculture, Ningxia University, Yinchuan 750021, China

DOI:

Abstract

Artemisia scoparia, a herbaceous plant species in the desert steppe of Yanchi County, Ningxia, was selected as the research object. Three soil types including sandy soil, weathered bedrock residual soil, and sierozem soil were selected, a field device was used to change the rainfall pattern, and samples were collected from the delimited sample plots to analyze the effects of these factors on the dynamic status of *A. scoparia* population. The results showed that the bulk moisture content of weathered bedrock residual soil was higher than that of sandy soil and sierozem soil. In the rainfall-increased zone, the bulk moisture contents of sandy soil, weathered bedrock residual soil, and sierozem soil were increased by 10.6%, 6.6%, and 20.2% respectively, but they were decreased by 44.1%, 9.2%, and 20.1% respectively in the rainfall-decreased area. The survival curve of *A. scoparia* was concave, and the plant species was a typical r-strategist. Comparatively, the canopy of *A. scoparia* growing on sandy soil was larger, but the density of the plants growing on sierozem soil was larger. At the middle growth stage of *A. scoparia*, the plant height and canopy on sandy soil in the rainfall-increased zone were higher, but the plant density in the rainfall-reduced area was higher. On weathered bedrock residual soil, the plant density in the rainfall-decreased zone was high, but the plant height and canopy were higher. On sierozem soil, the plant density in the rainfall-decreased zone was the lowest, but the plant height and canopy were higher. At the early growth stage, the soil

type, soil moisture, plant height, and canopy were negatively correlated. At the middle growth stage, there were significant negative correlations between soil moisture and plant density, between soil type and plant height, and between soil type and canopy. At the later growth stage, the soil moisture content was extremely negatively correlated with plant density, and the soil type was extremely negatively correlated with canopy. The biomass of *A. scoparia* was positively correlated with total carbon content and total nitrogen content ($P<0.05$), and negatively correlated with total phosphorus content ($P<0.05$).

Keywords: *Artemisia scoparia*; soil type; precipitation variation; survival curve; population dynamic; desert steppe; Yanchi County; Ningxia

Introduction

Artemisia scoparia is a dominant herbaceous species in the desert steppe ecosystem of Yanchi County, Ningxia, playing a crucial role in vegetation restoration and ecological stability. Previous studies have examined its ecological characteristics and distribution patterns, but few have investigated the combined effects of soil types and precipitation variation on its population dynamics. This study aims to fill this knowledge gap by analyzing how different soil substrates and altered rainfall patterns influence the growth, survival, and biomass allocation of *A. scoparia* populations.

Materials and Methods

The study was conducted in Yanchi County, Ningxia, where three distinct soil types were selected: sandy soil, weathered bedrock residual soil, and sierozem soil. A field rainfall manipulation device was employed to create three precipitation regimes: rainfall-increased, rainfall-decreased, and control conditions. Experimental plots were established in each soil type under each rainfall condition, with samples collected from delimited quadrats at regular intervals throughout the growing season.

Soil Characteristics

The nutrient contents of the three soil types are presented in . The weathered bedrock residual soil exhibited higher bulk moisture content compared to sandy soil and sierozem soil. Under increased rainfall conditions, soil moisture content rose by 10.6%, 6.6%, and 20.2% for sandy soil, weathered bedrock residual soil, and sierozem soil, respectively. Conversely, under decreased rainfall conditions, moisture content declined by 44.1%, 9.2%, and 20.1%, respectively.

Results

Survival Curve and Life History Strategy

The survival curve of *A. scoparia* displayed a concave pattern, indicating that the species employs an r-strategy life history approach, characterized by high reproductive output and rapid colonization of suitable habitats.

Plant Height Dynamics

[Figure 4: see original paper] illustrates the variation in plant height across different soil types and rainfall conditions. At the middle growth stage, plants growing on sandy soil under increased rainfall conditions achieved greater height, whereas those in the rainfall-decreased zone exhibited reduced stature. On weathered bedrock residual soil, plant height was generally higher regardless of rainfall treatment. Sierozem soil supported moderate plant heights, with the lowest values observed in the rainfall-decreased zone.

Canopy and Density Responses

The canopy size of *A. scoparia* was largest on sandy soil, while plant density was highest on sierozem soil ([Figure 5: see original paper]). Rainfall reduction generally increased plant density but decreased individual canopy size, suggesting a trade-off between these two parameters under water-limited conditions.

Biomass Allocation

Biomass production varied significantly among soil types and rainfall treatments ([Figure 6: see original paper]). Total biomass was positively correlated with soil carbon and nitrogen contents ($P<0.05$) but negatively correlated with phosphorus content ($P<0.05$). This indicates that nitrogen and carbon availability are primary limiting factors for *A. scoparia* growth in these desert steppe environments.

Correlation Analysis

Statistical analysis revealed distinct correlation patterns across growth stages: - **Early stage**: Soil type, moisture, plant height, and canopy showed negative correlations - **Middle stage**: Significant negative correlations emerged between soil moisture and plant density, between soil type and plant height, and between soil type and canopy - **Late stage**: Soil moisture was extremely negatively correlated with plant density, while soil type was extremely negatively correlated with canopy

Discussion

The differential responses of *A. scoparia* to soil types and precipitation variation reflect its adaptive strategies in heterogeneous desert environments. The concave survival curve confirms its classification as an r-strategist, capable of rapid population expansion under favorable conditions. The negative correlations between soil moisture and plant density suggest that water availability regulates population density through density-dependent mechanisms. The positive correlation between biomass and soil carbon/nitrogen highlights the importance of nutrient availability in determining productivity, while the negative correlation with phosphorus may indicate luxury consumption or nutrient imbalance under certain conditions.

Conclusion

This study demonstrates that *Artemisia scoparia* population dynamics are strongly influenced by interactions between soil substrate and precipitation patterns. Sandy soil promotes canopy development, sierozem soil favors high population density, and weathered bedrock residual soil provides intermediate conditions. Rainfall manipulation significantly alters soil moisture regimes, thereby affecting plant height, canopy size, and density. The species exhibits classic r-strategic traits with concave survival curves. Biomass production is closely linked to soil carbon and nitrogen availability. These findings provide scientific guidance for vegetation restoration and management in desert steppe ecosystems under changing climate conditions.

References

[1] Chen Lin, Song Naiping, Wang Lei, et al. A bibliometric appraisal of research on *Artemisia* from 1986-2016[J]. *Acta Prataculturae Sinica*, 2017, 26(12): 223-235.

[2] Peng Wendong, Zhu Jianning, Wang Chuan, et al. Improved-pasture of *Artemisia scoparia* as dominant species in desert grassland[J]. *Ningxia Journal of Agriculture and Forestry Science and Technology*, 2013, 54(1): 16-18.

[3] Masaki T, Ota T, Sugita H, et al. Structure and dynamics of tree populations within unsuccessful conifer plantations near the Shirakami Mountains, a snowy region of Japan[J]. *Forest Ecology and Management*, 2004, 194(1): 389-401.

[4] Cai Fei, Song Yongchang. A study on the structure and dynamics of *Schima superba* population on Wuyi Mountain[J]. *Acta Phytoecologica Sinica*, 1997, 21(2): 138-148.

[5] Nunami S, Kawaguchi H, Tateno R, et al. Sprouting traits and population structure of co-occurring *Castanopsis* species in an evergreen broad-leaved forest in Southern China[J]. *Ecological Research*, 2004, 19(3): 341-348.

[6] Xu Dongmei, Wang Kun. Characteristics of soil microbe in Southern ecotone of Mu Us sandy land[J]. *Journal of Desert Research*, 2007, 27(5): 805-808.

[7] Liu Shizeng, Li Changlong, Ji Yongfu, et al. Structure and dynamics of *Atraphaxis bracteata* populations in Minqin Liangucheng Nature Reserve,

Gansu[J]. *Acta Ecologica Sinica*, 2017, 37(8): 2763-2769.

[8] Li Haiyan, Yang Yunfei. Age structures of *Spodiopogon sibiricus* populations on weedy meadow and elm woodland in Songnen Plain, Northeast China[J]. *Chinese Journal of Applied Ecology*, 2011, 22(8): 1982-1986.

[9] Wang Junjun, Zhao Zhimuo. Seed population dynamics and germination characteristics of *Eupatorium adenophorum*[J]. *Chinese Journal of Applied Ecology*, 2006, 17(6): 982-986.

[10] Zhang Jingguang, Li Xinrong, Wang Xinping, et al. Population characteristics of *Artemisia sphaerocephala* in different habitats[J]. *Acta Prataculturae Sinica*, 2001, 10(3): 232-235.

[11] Cheng Xiaoli, An Shuqing, Li Bo, et al. Summer rain pulse size and rainwater uptake by three dominant desert plants in a desertified grassland ecosystem in Northwestern China[J]. *Plant Ecology*, 2006, 184(1): 1-12.

[12] Ma Xiaodong, Li Weihong, Zhu Chenggang, et al. Spatio-temporal variations of desert plant life history strategies[J]. *Journal of Desert Research*, 2005, 25(3): 306-314.

[13] Xie Kaiyun, Zhao Yunyun, Li Xianglin, et al. Relationships between grasses and legumes in mixed grassland: A review[J]. *Acta Prataculturae Sinica*, 2013, 22(3): 284-296.

[14] Cao Jianxin, Jiang Yuanbiao, Zhang Jinfeng, et al. Comparison of growth characteristics on seedlings of *Cyclobalanopsis glauca* and *Castanopsis orthacantha* in different soil conditions[J]. *Journal of Nanjing Forestry University Natural Sciences Edition*, 2009, 33(1): 79-82.

[15] Wu Chunhong, Zhao Shuaipeng, Zhu Jianfeng, et al. The effects of different soil types on the growth index of *Ulmus pumila* families[J]. *Journal of Shandong Forestry Science and Technology*, 2018, 48(3): 11-15.

[16] Raiesi F. Soil properties and C dynamics in abandoned and cultivated farmland in a semi-arid ecosystem[J]. *Plant and Soil*, 2012, 351(1-2): 161-175.

[17] Zou Junliang, Shao Ming' an, Gong Shihui. Effects of different vegetation and soil types on profile variability of soil moisture[J]. *Research of Soil and Water Conservation*, 2011, 18(6): 12-17.

[18] Fan Xing, Cai Jian, Liu Jinping, et al. Module traits and biomass allocation of *Humulus scandens* seedlings during population self-thinning[J]. *Chinese Journal of Ecology*, 2016, 35(11): 2926-2934.

[19] Li Xiaozhe, Dong Guangrong, Jin Heling, et al. The discovery of the Cretaceous dunes in Ordos[J]. *Chinese Science Bulletin*, 1999, 44(8): 874.

[20] Yang Xingguo, Gu Junlong, Wang Xing, et al. Occurrence and distribution of throughfall under *Caragana intermedia* canopy in desert steppe[J]. *Arid Zone Research*, 2019, 36(1): 131-138.

[21] Chen Lin, Song Naiping, Yang Xingguo, et al. Combined experimental device with field increasing and decreasing rain and movable fence[P]. China: ZL201720618832.9, 2017-12-19.

[22] Ma Xiaodong, Li Wei, Zhu Chenggang, et al. Spatial-temporal variation of soil moisture under different vegetation types[J]. *Journal of Desert Research*, 2010, 30(15): 4035-4045.

[23] Westoby M, Leishman M, Lord J, et al. Comparative ecology of seed size and dispersal[J]. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 1996, 351(1345): 1309-1318.

[24] Xiong Bingqiao, Zhao Liya, Zhang Jin, et al. Relationship between soil and standing vegetation changes during grassland desertification process[J]. *Ecology and Environmental Sciences*, 2017, 26(3): 400-407.

[25] Chen Lin, Yang Xingguo, Song Naiping, et al. Effects of planting alfalfa on soil quality in desert steppe of Ningxia[J]. *Journal of Zhejiang University (Agriculture and Life Sciences Edition)*, 2014, 40(5): 541-550.

[26] Xu Dongmei, Wang Kun. Characteristics of soil microbe in Southern ecotone of Mu Us sandy land[J]. *Journal of Desert Research*, 2007, 27(5): 805-808.

[27] Liu Shizeng, Li Changlong, Ji Yongfu, et al. Structure and dynamics of *Atraphaxis bracteata* populations in Minqin Liangucheng Nature Reserve, Gansu[J]. *Acta Ecologica Sinica*, 2017, 37(8): 2763-2769.

[28] Li Haiyan, Yang Yunfei. Age structures of *Spodiopogon sibiricus* populations on weedy meadow and elm woodland in Songnen Plain, Northeast China[J]. *Chinese Journal of Applied Ecology*, 2011, 22(8): 1982-1986.

[29] Zhang Jingguang, Li Xinrong, Wang Xinping, et al. Population characteristics of *Artemisia sphaerocephala* in different habitats[J]. *Acta Prataculturae Sinica*, 2001, 10(3): 232-235.

[30] Cheng Xiaoli, An Shuqing, Li Bo, et al. Summer rain pulse size and rainwater uptake by three dominant desert plants in a desertified grassland ecosystem in Northwestern China[J]. *Plant Ecology*, 2006, 184(1): 1-12.

[31] Ma Xiaodong, Li Weihong, Zhu Chenggang, et al. Spatio-temporal variations of desert plant life history strategies[J]. *Journal of Desert Research*, 2005, 25(3): 306-314.

[32] Xie Kaiyun, Zhao Yunyun, Li Xianglin, et al. Relationships between grasses and legumes in mixed grassland: A review[J]. *Acta Prataculturae Sinica*, 2013, 22(3): 284-296.

[33] Cao Jianxin, Jiang Yuanbiao, Zhang Jinfeng, et al. Comparison of growth characteristics on seedlings of *Cyclobalanopsis glauca* and *Castanopsis orthacantha* in different soil conditions[J]. *Journal of Nanjing Forestry University Natural Sciences Edition*, 2009, 33(1): 79-82.

[34] Wu Chunhong, Zhao Shuaipeng, Zhu Jianfeng, et al. The effects of different soil types on the growth index of *Ulmus pumila* families[J]. *Journal of Shandong Forestry Science and Technology*, 2018, 48(3): 11-15.

[35] Raiesi F. Soil properties and C dynamics in abandoned and cultivated farmland in a semi-arid ecosystem[J]. *Plant and Soil*, 2012, 351(1-2): 161-175.

[36] Zou Junliang, Shao Ming' an, Gong Shihui. Effects of different vegetation and soil types on profile variability of soil moisture[J]. *Research of Soil and Water Conservation*, 2011, 18(6): 12-17.

[37] Fan Xing, Cai Jian, Liu Jinping, et al. Module traits and biomass allocation of *Humulus scandens* seedlings during population self-thinning[J]. *Chinese Journal of Ecology*, 2016, 35(11): 2926-2934.

[38] Li Xiaozhe, Dong Guangrong, Jin Heling, et al. The discovery of the Cretaceous dunes in Ordos[J]. *Chinese Science Bulletin*, 1999, 44(8): 874.

[39] Yang Xingguo, Gu Junlong, Wang Xing, et al. Occurrence and distribution of throughfall under *Caragana intermedia* canopy in desert steppe[J]. *Arid Zone Research*, 2019, 36(1): 131-138.

[40] Xiong Bingqiao, Zhao Liya, Zhang Jin, et al. Relationship between soil and standing vegetation changes during grassland desertification process[J]. *Ecology and Environmental Sciences*, 2017, 26(3): 400-407.

[41] Zou Junliang, Shao Ming' an, Gong Shihui. Effects of different vegetation and soil types on profile variability of soil moisture[J]. *Research of Soil and Water Conservation*, 2011, 18(6): 12-17.

Note: Figure translations are in progress. See original paper for figures.