Effects of Climatic Factors on Forage Growth and Development in the Northern Horqin Grassland: Postprint

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Abstract

Using observational data of forage grass and meteorology from the Bayartuhushuo Agrometeorological Experimental Station, this study analyzes the influence of climatic factors on the growth and development of forage grass in the northern Horqin grassland. The results show that over the past 27 years, the mean air temperature in the study area has increased by 0.16 ℃·(10a)-1, precipitation has decreased by 23.96 mm·(10a)-1, the aridity index during the forage grass growing season has increased by 0.15·(10a)-1, and grassland aridification has intensified. The green-up period of Leymus chinensis, Agropyron cristatum, and Potentilla chinensis has been delayed, the flowering period has advanced, and the growing season length has shortened; precipitation is the main factor affecting the green-up and withering-yellowing periods of the three species, showing a negative correlation with their green-up periods and a positive correlation with their withering-yellowing periods. Both canopy height and forage yield show extremely significant decreasing trends ($P<0.01$), with annual average reductions of 0.88 cm and 121.43 kg·hm-2, respectively. Canopy height and forage yield are mainly negatively correlated with air temperature and positively correlated with precipitation, indicating that under the background of climate warming, as temperature rises and precipitation decreases, water has become the main limiting factor for forage grass growth, development, and yield formation in the study area. According to integral regression model analysis, during the forage grass regreening-leaf expansion stage, the positive effects of precipitation and sunshine duration in mid-May on forage grass meteorological yield reach their maximum; during the jointing-flowering stage, late May to mid-June is the main period for forage grass water and light demand, while late June to mid-July is the main period for forage grass heat demand; during the grain filling-maturity stage, the effect of August temperature on forage grass meteorological yield shows a negative effect, which reaches its maximum in mid-August.

Full Text

Effects of Climatic Factors on Herbaceous Growth in the North Horqin Grassland

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Abstract

Data on herbaceous growth and its affecting meteorological factors at the Enkhbayar Animal Husbandry Meteorological Experiment Station in Tongliao were used to analyze the climatic factors influencing herbaceous growth in the northern Horqin grassland. Results indicated that the average temperature in the study area over the past 27 years increased by 0.16°C · (10a)^{1}, the average precipitation decreased by 23.96 mm · (10a)^{1}, the dryness index in the herbaceous growing season increased by 0.15 · (10a)^{1}, and drought in the grassland became more serious. Moreover, the seedling establishment period of *Leymus chinensis*, *Agropyron cristatum*, and *Potentilla chinensis* was delayed, the flowering stage of which was advanced, and the growth season of which was shortened. Precipitation was the main factor affecting the seedling establishment period and withering stage of the three plant species; it was negatively correlated with the seedling establishment period but positively correlated with the withering stage of the three plant species. The herbaceous height and yield were significantly decreased ($P<0.01$), and the decreases were 0.88 cm and 121.43 kg · hm^{2} per year, respectively. The herbaceous height and yield were mainly negatively correlated with temperature but positively correlated with precipitation. Under climate warming, water has become more and more important for herbaceous growth in the study area. Analysis with the integral regression model showed that the positive effects of precipitation and sunshine duration in mid-May on herbaceous yield were the highest from the seedling establishment period to the leaf expansion stage. The jointing stage and flowering stage from late May to mid-June were the main stages for herbaceous growth demanding precipitation and sunshine, and the period from late June to mid-July was the main stage for herbaceous growth demanding heat. The effect of air temperature on herbaceous yield was negative in August, especially in mid-August.

Keywords: climatic factor; herbaceous growth; phenological phase; herbaceous yield; Horqin grassland

1.2 Data Sources

The meteorological data from 1990–2016 were obtained from Tongliao National Reference Climatological Station, including daily average temperature, precipitation, sunshine duration, and other meteorological elements. The herbaceous growth data were derived from fixed-point observations at the Enkhbayar Animal Husbandry Meteorological Experiment Station.

1.4.3 Statistical Methods

The integral regression method was used to analyze the effects of meteorological factors on herbaceous yield. The model is expressed as:

$$Y = \int_{t_1}^{t_2} a(t)X(t)dt$$

where Y represents herbaceous yield (kg · hm ²), $X(t)$ represents meteorological factors at time t, and $a(t)$ represents the response coefficient of herbaceous yield to meteorological factors at time t.

2.2 Variation Trends of Temperature, Precipitation, and Dryness Index

[Figure 1: see original paper] shows the variation trends of mean temperature, precipitation, and dryness index in the herbaceous growing season in the study area from 1990 to 2016. The average temperature showed a significant increasing trend (P<0.01), with a rate of 0.16°C · (10a) ¹. Precipitation showed a significant decreasing trend (P<0.01), with a rate of 23.96 mm · (10a) ¹. The dryness index showed a significant increasing trend (P<0.01), with a rate of 0.15 · (10a) ¹, indicating that the drought trend in the study area was significant.

2.4 Effects of Climatic Factors on Herbaceous Height and Yield

2.4.1 Linear Trend Analysis The linear trend analysis showed that herbaceous height and yield were significantly negatively correlated with temperature (P<0.01) and significantly positively correlated with precipitation (P<0.05). For every 1°C increase in temperature, herbaceous height decreased by 0.88 cm. For every 1 mm decrease in precipitation, herbaceous yield decreased by 121.43 kg · hm ².

2.4.2 Integral Regression Analysis The integral regression analysis showed that the response coefficients of herbaceous yield to temperature, precipitation, and sunshine duration varied throughout the growing season. The positive effects of precipitation and sunshine duration in mid-May were the highest from the seedling establishment period to the leaf expansion stage. The jointing stage and flowering stage from late May to mid-June were the main stages for herbaceous growth demanding precipitation and sunshine. The period from late June to mid-July was the main stage for herbaceous growth demanding heat. The effect of air temperature on herbaceous yield was negative in August, especially in mid-August.

3 Discussion

Under the background of global climate change, the IPCC Fifth Assessment Report indicated that the global average temperature increased by 0.85°C from 1880 to 2012, and is projected to continue rising. The study area showed a warming trend consistent with global patterns, with precipitation decreasing and drought intensifying. Precipitation was the main factor affecting herbaceous growth, particularly during the critical periods of seedling establishment and reproductive development. The phenological changes observed in the three dominant species—delayed seedling establishment, advanced flowering, and shortened growth seasons—represent adaptive responses to water stress.

The integral regression model revealed that the response of herbaceous yield to meteorological factors varied significantly across growth stages. The early growing season (mid-May) was most sensitive to precipitation and sunshine, while the mid-season (late May to mid-June) required adequate precipitation for jointing and flowering. The negative temperature effect in August suggests that heat stress during late growth stages may reduce yield. These findings highlight the increasing importance of water resources for grassland productivity under warming conditions.

The results provide a scientific basis for adaptive management of grassland ecosystems in the Horqin region, emphasizing the need for water conservation and sustainable grazing practices to mitigate climate change impacts.

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