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Effects of Increased UV-B upon the Canopy's Structure of Wheat in China

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This paper is a part of the research into effects of increased UV-B (Ultraviolet-B, 280~320nm) upon the ecosystem of field wheat. Based on a 3-year project with intensified UV-B influencing the crop, observation and calculation were made of such factors and parameters as the morphology of a single wheat plant including its leaf area, leaf base angle and proportion of spacing between joints. The results show that the enhanced UV-B signifantly decreased wheat's SSLA, and the increased percentage of the lower LAI is associated with the change in leaf base angle and proportion of spacing between joints.

Keywords: wheat UV-B canopy's structure effect

INTRODUCTION

As one of the problems regarding global climate change, the intensification of surface UV-B due to stratospheric ozone layer thinning has been receiving ever-increasing concern. In this paper, in the case of UV-B intensification we made observation and calculation of Population's Structure whereupon further analysis was performed.

MATERIALS AND METHODS

The data came partially from other agrometeorological studies and largely from the wheat field experiments made in the Experimental Station of Nanjing Institute of Meteorology, consisting of observations spanning November 1 to May of 1998-1999, 1999-2000 and 2000-2001. The study wheat was the variety Yang-158 at the density of 4500,000 plants per *ha* with soil fertility at slightly-higher-than moderate level and the patch under conventional management. All the experiments started from sowing on Nov. 1 with UV-B illumination immediately from shoots appearing to harvesting.

The supplemental UV-B irradiance was provided in different plots of experimental field through the whole growing season until the harvest with three UV-B treatments (two supplemental UV-B treatments as T1 and T2, and a control as Ck). Artificial UV-B irradiance was supplied by broadband, "Black-light" lamps with the spectral range of 280 – 400 nm. The Koadcel TA 401 0.13-mm-thick polyester plastic films were used to exclude the portion of UV-A (wavelength > 320 nm) and changed weekly to ensure uniformity of UV-B transmission. The lamps were oriented perpendicular to the plant rows and suspended above the plants. Lamps were fitted with 50-mm-wide mini-reflectors and manually adjusted for time and height control. Total daily photosynthetic active radiation (400 – 700 nm) under the lamps was about 90% of that above the lamps. The lamps were suspended from wires stretched between steel poles at the both ends of planted rows. Plants were irradiated daily for 8 hours centered around the solar noon. For the Ck treatment lamps were filtered with 0.13 mm thick polyester (spectrally equivalent to Mylar Type S) plastic films that absorb essentially all radiation below 320 nm. The two supplemental UV-B treatments plants beneath these lamps received supplemental doses in addition to ambient levels of UV-B radiation. The UV-B irradiance was adjusted monthly to allow

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for seasonal changes in ambient UV-B. Different UV-B treatments were obtained by varying the distance between the lamps and the top of the plants. The height of the lamps above the plants was adjusted weekly to maintain constant lamp-to-plant distances as the plants grew. In this experiment the supplemental UV-B treatments UV_1 and UV_2 were equivalent to 4.8% and 9.5% more of the Ck treatment. Biological sampling was regularly performed in 1 m^2 area of each tested plot.

Measurement: 5 plants were taken stochastically, followed by measuring the leaf area, leaf angle and proportion of spacing between joints at a range of altitude above ground.

RESULTS AND DISCUSSION

Increased UV-B Effect on the Population's Structure

SSLA was dependent on the number of leaves and their length/width at the levels above ground (Table 1). The present study clearly shows that UV-B enhancement greatly reduced SSLA because the number of such leaves were one leaf less in T1 and T2 than in CK, and, besides, the second and third leaf numbered upward from ground had the length shortened by roughly 23.4%, although these leaves were somewhat broadened, leading to decreased single-plant leaf area.

Table 1.UV-B effect on the mean length (L, cm), width (W, cm) and area (A, cm^2) of wheat leaves in booting at the first to fourth levels numbered upward.

case	1st leaf		2nd leaf		3rd leaf		4th leaf	
	T	CK	T	CK	T	CK	T	CK
L	18.7	24.8	18.7	24.4	16	21.3		12.7
W	1.6	1.5	1.5	1.4	1.2	1.2		0.82
A	24.9	31	23.4	28.5	16	21.2		8.7

Increased UV-B influence on the vertical distribution of the population's leaves.

The vertical distribution of leaves is also an important index of the population's structure. Our experiments show the vertical distribution was under the close control of strengthened UV-B, indicating a general trend of leaf area change at different levels above ground in such a way that the proportion of upper-level LAI in the total was reduced by 10~15% compared to CK and that of lower-level LAI grew by 10~15%, with practically no change for the middle level (refer to Table 2).

Table 2. Proportion of LAI for the three levels in the total under reinforced UV-B.

	Booting		blooming	
	T	CK	T	CK
upper	0.22	0.37	0.23	0.33
middle	0.42	0.41	0.45	0.44
lower	0.36	0.22	0.32	0.23

We have made further investigation of the relationship between increased UV-B and the LAI change, with its drop in the upper and rise in the lower levels. In our opinion, the increased percentage of the lower LAI may be associated with the change in leaf base angle and proportion of spacing between joints.

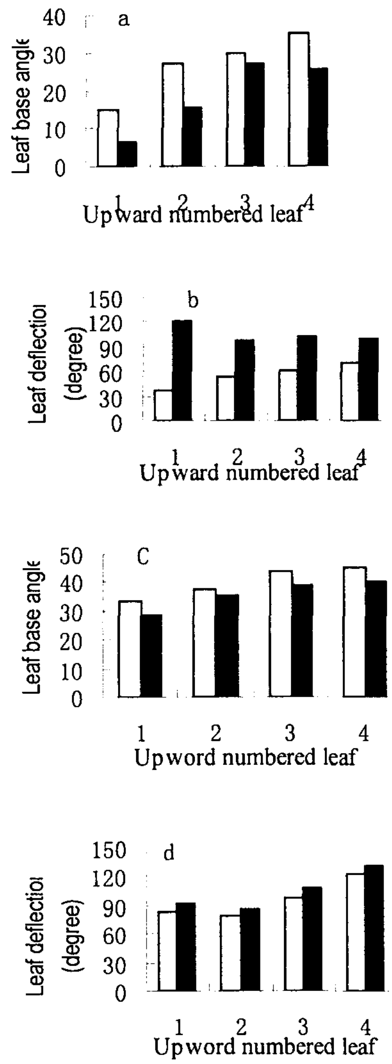

Fig.1. Increased UV-B effect upon leaf base angle and deflection (bending) in the wheat population in the booting (a, b) blossoming stage (c, d) with open squares

denoting T1 and T2 mean T and blackened ones the CK case.

Leaf base angle and deflection (bending angle) are among the factors affecting the vertical distribution of leaves. Reinforced UV-B increased (decreased) the leaf base angle (leaf deflection)of the plants by 37.5% (27.7%), as shown in Fig.1, where we see that the increased angle was related directly to the fact that the LAI displayed its drop in the upper and rise in the lower levels whereas the decline of leaf deflection counteracted partially the effect of enlarged base angles of the crop. Our analysis indicates that increased UV-B related decline of leaf deflection may bear a direct relation to leaf shortening. One variable linear analysis shows that the leaf deflection was positively correlated, to exceedingly great degree, with leaf length at all levels, viz., the longer the length, the more deflecting the leaf blade.

Increased UV-B brought about significant shortening of spacing between joints and the closer to ground, the higher the percentage of shortening, thus leading to an abnormal proportion from one joint to another, with the percentage shortening as 3, 13, 14, 28 and 41% at the 1st, 2nd, 3rd, 4th and 5th interjoint intervals (numbered upward), respectively. Since these joints were the position of leaf growth, the greater shortening at the 2nd and 3rd spacing may be an important cause of the anomaly in the vertical distribution of the population's leaves. Our study demonstrates that under reinforced UV-B the wheat height was lowered not because of the reduced number of interjoint spacings but of their shortening, especially the 2nd and 3rd spacings. From the investigation of causes of change in the 4th and 5th spacings that were shortened more greatly, we discovered that as the 5th spacing began extending in the reviving and jointing stage, natural UV-B was weak and as the other spacings were elongated, it was rather intense. But in both cases, artificial UV-B was kept at the intensity of 1.00 Wm^2 so that the percentage of increased UV-B was higher when the 5th spacing began stretching, thus leading to their differing shortening in percentage. This added to the resistance to lodging, a factor that was instrumental to wheat production.

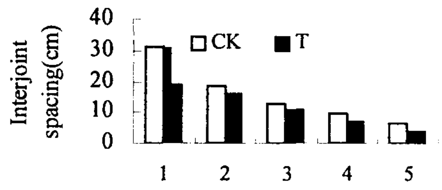

Fig.2.

Increased UV-B effect on interjoint spacing of the wheat, with open (full) squares denoting the results from CK (T).

CONCLUSION AND DISCUSSION

To sum up, increased UV-B illumination decreased wheat's SSLA, which was ascribed to the greatly shortened leaf length and a smaller number of single-stem leaves, and the increased percentage of the lower LAI is associated with the change in leaf base angle and proportion of spacing between joints.

Intensified UV-B related leaf length shortening may be ascribed to the same cause(s) as the dwarfing happened, suggesting that increased UV-B damaged wheat's growth hormone, retarding the growth and simultaneously generated heteroauxin dioxide prevented the growth as well (Tevini et al., 1991). Furthermore, the elongation of leaves were normally at the top and hence they were shortened greatly.

It is generally accepted that strong photosynthesis occurs inside upper-level leaves and weak process in lower-level leaves because of feeble insolation there. As a result, increased UV-B associated drop (rise) in upper (lower-level) does not favor the utilization of light energy by the population. Also, it is widely recognized that increased UV-B is responsible for the decline of dry substance generation and that diminished photosynthetic efficiency per unit area due to increased UV-B is one of the causes of reducing dry matter production (Zheng et al., 1995). In fact, our study demonstrates that enhanced UV-B resulted in the population's leaf area decrease and the unidealized population's structure, which may serve as the causes of the drop in the production of dry matter.

At present, scientists disagree on the relationship between increased UV-B effect and leaf base angle.

Some asserted that the more upright plants are favorable (Cline.M.G, 1966) because they are injured to less extent by strong UV-B; others believed that natural UV-B differs from direct visible light in that it is scattered in the main such that leaf uprightness does not mitigate injuries by UV-B(Caldwell,M.M.1981). However, our experiments demonstrate that increased UV-B affected leaf base angle considerably in such a way it increased the angle, on one hand, and leaf shortening gave rise to the decline of leaf deflection, on the other.

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