Effects of Forest Windbreaks deployed in Arid Lands, Turpan, Northwest China

2. Effects on prevention of wind erosion and on crop growth

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Abstract

Observations of sand accumulation and crop growth in arid lands were carried out at the Turpan Desert Research Station, Xinjiang located in the northwestern part of China from 1990 to 1992. It was demonstrated that the use of tamarisk forest windbreaks prevented wind erosion and exerted a beneficial effect on crop growth under very dry conditions. When buried in sand, tamarisk trees display elongation characteristics which enable them to emerge above the land. Tamarisk trees are suitable for use as windbreaks in the marginal agricultural region of Northwest China. Forest windbreaks decrease the total amount of water consumption over large areas, even if the trees consume irrigation water, due to the improvement of the microclimate, decrease of evapo-transpiration, etc. Production and quality of crops are improved by windbreaks and sand erosion can be prevented. Forest windbreaks are very effective for the prevention of sand accumulation and for crop growth in arid lands.

Additional key words : tamarisk, wind direction, sand accumulation, plant growth

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Introduction

Arid or dry lands in China cover 1,308,000km^2 or 13.6 % of the total land area. The process of desertification which has been developing in China for a long time, has made rapid progress recently. Wind erosion and sand accumulation associated with strong dry winds are being accelerated due to the lack of water, and agro-meteorological disasters are apt to occur frequently in the marginal agricultural regions of dry lands. Prevention of desertification and greening of the desert may be achieved through the improvement of meteorological conditions brought about by forest windbreaks.

Observations related to the growth of crops, quality of crops, prevention of soil and sand erosion and effect on sand accumulation were carried out at the Turpan Desert Research Station, Xinjiang Institute of Biology, Pedology and Desert Research, China[4,5,6].

Analysis of the effect of windbreaks on the protection from drifting sand and on crop growth in arid lands will be outlined.

Observation Methods

Turpan Desert Research Station is located at 42° 51'N, 89° 11'E, 200 km southeast of Urumqi. The elevation is 80 m below the sea level. Strong WNW wind period lasts from April to June.

Two tamarisk windbreaks were used for observations of sand accumulation. (1) The height of the tamarisk (*Tamarix elongata* L.) shrub covering an area of 1 km (11 m width) was 4.6 m and the density of the windbreak which was expressed by a value corresponding to 100% - porosity was 85%. Another windbreak located at a distance of 570 m from the other windbreaks, consisted of huyang (*Populus euphratica* O.) and shazao (*Elaeagnus angustifolia* L.) trees with a height of 6 to 8 m. (2) The first and second windbreaks set in double rows at 50 m intervals with a windbreak density of 85% were 10 m and 5.5 m high and 20 m and 15 m wide, respectively.

The accumulation of sand was monitored. Sand accumulation by the tamarisk forest windbreak reaching a height of 4.6 m was observed in May and August, 1991, and that by the two rows of tamarisk forest windbreaks reaching a height of 10.0 m and 5.5 m was observed in April, 1992.

Crop fields cultivated by ordinary farmers near the Turpan Desert Research Station were selected for an investigation of the effects of the windbreaks and several crops commonly cultivated in arid lands were used for the observation of height of crops.

The height of cotton, sorghum and corn plants, and the cotton lint number per hill were observed for two rows of huyang and shazao windbreaks and for three forest windbreaks made of shazao, poplar and tamarisk in November, 1991 and October, 1992, respectively.

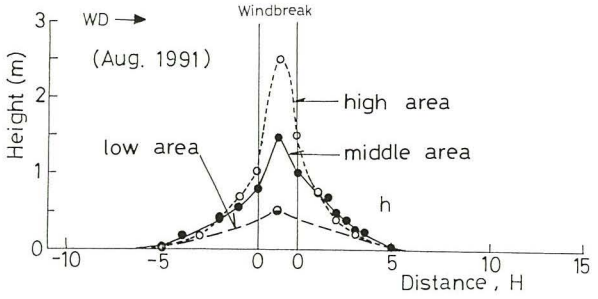
Tamarisk windbreak is usually irrigated once a year in winter, but huyang, shazao and poplar windbreaks are irrigated almost as frequently as crops in summer.

Results

1) Protection from drifting sand by tamarisk windbreaks

(1) Sand accumulation by single row of windbreak

Changes in the amount of sand accumulated by the tamarisk windbreak are shown in Fig. 1. The height of the sand accumulated for a long period of time in the center of the windbreak was 2.5, 1.5 and 0.5 m in the areas with high, medium and low sand accumulation, respectively. Although wind erosion was minimal, sand accumulation was present for values ranging from - 6 H to 6 H (the numerals indicate the distances from the windbreak which are expressed as multiples of the windbreak height; negative sign corresponds to the windward side and positive sign to the leeward side), due to the prevailing strong wind of NW to W or the rather light wind in the opposite direction to the windbreak associated



WD: Wind direction

Fig. 1. Variations in sand accumulation induced by single row of tamarisk windbreak in August, 1991

Plate 1. One of the two rows of tamarisk windbreaks and sand accumulation at Turpan, China

with the change of the wind direction, in particular on the windward and leeward sides from -2 to 2 H. Sand accumulated near the windward and leeward sides due to the decrease of the wind velocity in these areas. Outside of the region from -6 to 6 H, i.e., -10 to -6 H and 6 to 15 H, a mixed zone of sand accumulation and erosion occurred.

(2) Sand accumulation by two rows of windbreaks

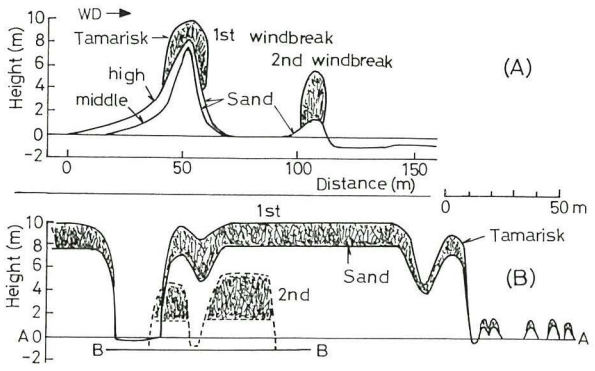
Sand accumulation (Plate 1) is shown in Figs. 2 A and 2 B. The height of the sand accumulated by the first tamarisk windbreak was 8.0 m in higher areas and 7.5 m in areas with average height while in the case of the second windbreak, the height was 1.5 m at the mean point, but 2.5 m above the horizontal level on the leeward side. Consequently, the tree heights and total height of forest windbreaks were 2.5 m and 4.0 m, and 10.0 m and 5.5 m for the first and second windbreaks, respectively.

The windbreak and sand accumulation disappeared in some areas due to the death of the trees. Two oblique open spaces at a lower level below 0 m in Fig. 2 B show the irrigation ditches.

2) Effect of forest windbreaks on crop growth

(1) Effect of forest windbreaks on sorghum and cotton growth in 1991

The effect of windbreaks made of huyang and shazao trees on the height of cotton and sorghum plants and the cotton lint number per hill is shown in Figs. 3 A and 3 B. The first windbreak was 6 m



WD: Wind direction

Fig. 2. Schematic diagram of two rows of tamarisk windbreaks and sand accumulation in April, 1992.
A: transverse section, B: lateral view

high, 11.5 m wide with a density of 70% and an interval of 100 m between the second windbreak, which was 8 m high.

The crop yields are closely related to the height of the crops under dry conditions (lack of water) in arid lands. The crop height (Fig. 3 A) was greater at 3 to 5 H and smaller at 8 to 14 H. The use of the second windbreak made of huyang and shazao trees resulted in the larger height around 16 H from the first windbreak, i.e., -2 to -1 H from the second windbreak. The height of the cotton plants ranged from 50 to 80 cm in the

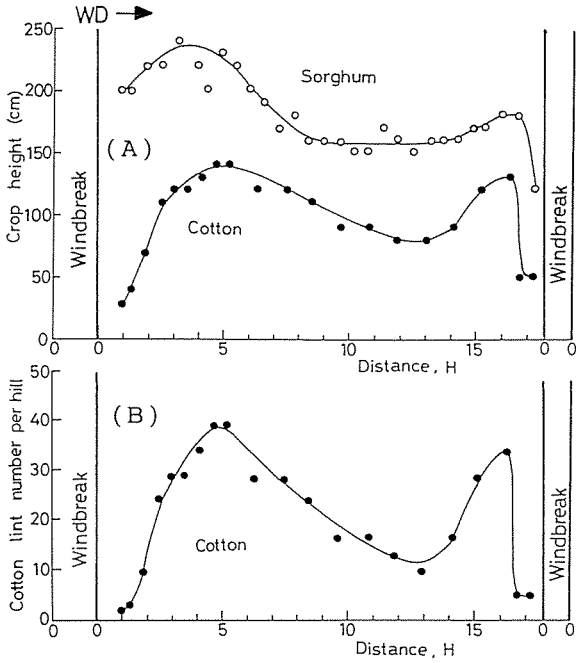


Fig. 3. Changes in (A) height of sorghum and cotton plants and (B) cotton lint number per hill induced by two rows of windbreaks in November, 1991

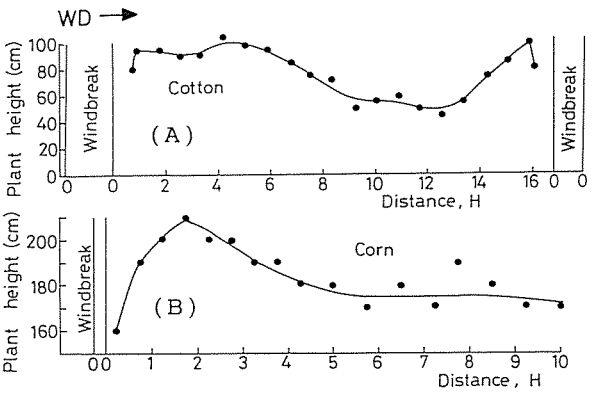


Fig. 4. Changes in height of cotton (A) and corn (B) plants associated with the use of two different windbreaks in October, 1992

control field near the observation field in the absence of forest windbreaks.

The crop heights in the fields except those close to the windbreak on the leeward and windward sides were higher than those of the controls.

The pattern of the changes in the cotton lint number per hill (Fig. 3 B) which is related to cotton production was more signifcant than that of the height of cotton plants. The protected area was not as wide due to the harsh environment in the arid lands.

(2) Effect of tree types in forest windbreaks on cotton and corn growth in 1992

The effect of the tree types in forest windbreaks on the height of cotton and corn plants is shown in Figs. 4 A and 4 B. The height of the cotton plants was the largest around 5 H and lowest around 13 H when the first windbreak consisted of huyang and shazao trees (6 m high, 11.5 m wide and 70% density), and was fairly large around 16 H close to the second windbreak made of shazao, huyang and poplar (*Populus alba* L.) trees.

The effect on the height of corn plants (Fig. 4 B) was most pronounced around 2 H, and less conspicuous or almost similar from 5 to 10 H when young poplars (4 m height, 1 m width and 50% density) were used.

Discussion

There are several studies on sand fixation, prevention of wind erosion, improvement of the climatic conditions of arid lands and prevention of desertification [9,10,11]. However, there are few reports on the effect on crop yield. Based on the research of Xinjiang Agric. Sci. Institute, evaporation decreased by 20% and crop yield increased on the leeward side of the windbreaks[8].

(1) Protection from drifting sand by the use of windbreaks

As tamarisk trees have fine and dense leaves and stems, and the density of the trees is high, the decrease of the wind velocity and control of wind erosion and sand accumulation are substantial. The region of reverse wind direction on the leeward side of the windbreak was smaller than that observed in the experiments under simulation of light wind in a wind tunnel[2]. Filtration efficiency

of sand particles by the windbreak is high because the turbulence intensity is low due to the increase in the formation of small eddies.

Based on observations carried out from 1990 to 1993, tamarisk trees show elongation characteristics which enable them to emerge when buried in sand. The height under sand accumulation reached 10 m following transplanting at Turpan.

(2) Effect of forest windbreaks on crop growth

Green or forest windbreaks in dry lands act as oases when they reach a certain scale. When windbreak forests are established, the climatic conditions over a wide area improve, water consumption decreases, crop production and quality increase, according to many other report[1,2,3]. The example observed at Turpan, suggested that windbreaks fulfill multiple beneficial functions.

It is necessary to use for a windbreak trees which are resistant to strong wind, as well as dry conditions, high and low temperature and salinity in the arid lands of northwestern China. Tamarisk trees are suitable for use as windbreaks to alleviate the adverse effect of the meteorological conditions[3,6] and prevent wind erosion due to their structure characterized by the presence of fine and dense leaves and resistance to harsh environments[6,9,11].

The effective region ranging generally from 2 to 8 H for crops in arid lands was smaller than that in a paddy field in the temperate zone in Japan[2,7] due to the harsh climatic conditions characterized by high temperatures and low humidity.

It is necessary to plant windbreak trees as much as possible in marginal dry lands for agriculture and also to save water. As a result, it may become possible to improve the meteorological conditions over wide areas leading to the increase of the efficiency of water consumption. The establishment of networks of forest windbreaks is effective over wide areas of cultivated fields.

Concluding Remarks

(1) The observations made in the arid lands of Turpan, Northwest China, revealed that windbreaks exert multiple beneficial functions.

(2) The effects on the prevention of wind erosion were appreciable when tamarisk trees with fine and dense leaves and stems were used. On the leeward side of the windbreak, the wind turbulence and the region with the formation of eddies were smaller than that of other windbreak trees and the function of sand filtration was more effective.

(3) Tamarisk trees show elongation characteristics which enable them to emerge when buried in sand. Tamarisks are suitable for use as forest windbreaks in the arid lands of Northwest China, i.e., in marginal agricultural regions.

(4) Forest windbreaks are composed of several kinds of trees, including tamarisk, poplar, shazao, willow and elm in Xinjiang, China. By improving the climatic conditions in arid lands, it is possible to create oases and promote agriculture.

(5) Forest windbreaks exert favorable effects on water consumption by crops, increase of crop production and improvement of crop quality. Consequently, windbreaks are very effective in arid lands.

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中国北西部の乾燥地トルファンにおける防風林の効果

2．風食防止と作物収量への効果

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摘　要

乾燥・半乾燥地は地球上の全陸地の１／３を占めている。中国の乾燥地面積は130.8万km^2で，全国土の13.6%に相当する。中国では砂漠が開発され，緑化されているが，一方では最近，砂漠化が急速に進んでいる。乾燥地では水が少ないために乾燥した強風によって風食と堆砂が増加している。そして，農業気象災害が乾燥農業限界地域で頻繁に発生している。砂漠化の防止と砂漠緑化には防風林による気象改良効果が重要な役割を果たしており，その定量的評価が必要である。

1990～1992年に，中国北西部の新疆生物土壌沙漠研究所吐魯番沙漠研究站で乾燥地における風食や堆砂および作物の生育などの調査を実施した。得られた結果の主なものは次のとおりである。

1）中国北西部の非常に乾燥した地域における防風林の気象観測事例から防風林による種々の効果を明らかにした。

2）細かい密な枝葉を持ったタマリスク防風林は風食防止効果が高く，防風林の風下側では防風林による風の整流作用によって気流の乱流と渦が小さいために砂の濾過作用が大きい。

3）タマリスクは砂に埋まると上に伸長する特性が大きいため，中国北西部の乾燥地，すなわち農業限界地域における防風林として適していることが判かった。

4）中国北西部の新疆の防風林にはタマリスク，ポプラ，沙棗，楊，楡などが利用されている。乾燥地では防風林があって初めて農地が造成でき，オアシスが形成できる。それは防風林による気象改良によって効果を果たすためと考えられる。

5）防風林は微気象の改良や水の消費を減少させる効果が高く，作物の生育を促進させ，生産量を増加させ，品質を向上させる効果がある。従って，乾燥地においては防風林の造成が非常に有効である。

6）防風林は，たとえ樹木の生長に灌漑水を必要とし，水を消費したとしても地域一帯の微気象を改良し，蒸発散量を減少させるため，結果的にはトータルとしての水消費量を減少させる効果がある。

キーワード：タマリスク，風向，堆砂，植物生育

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