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Review

Review of the technology for high-yielding and efficient cotton cultivation in the northwest inland cotton-growing region of China

Lu Feng[a,1], Jianlong Dai[b,1], Liwen Tian[c], Huijun Zhang[d], Weijiang Li[b], Hezhong Dong[b,*]

[a] Institute of Cotton Research, Chinese Academy of Agricultural Sciences, Anyang 455000, China
[b] Cotton Research Center, Shandong Academy of Agricultural Sciences, Jinan 250100, China
[c] Economic Crop Research Institute, Xinjiang Academy of Agricultural Sciences, Urumqi 830000, China
[d] Cotton Research Institute, Shanxi academy of Agricultural Sciences, Yuncheng 044000, China

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ABSTRACT

The northwest inland is currently the most dominant cotton-growing region in China. In 2015, the region measured 2.3 million hectares with a total output of 4.28 million tons of cotton. The unit yield was 1900 kg hm^{-2}, which was not only 21, 41 and 121% higher than the national averages of China, Brazil and the United States, respectively, but also 2.37 times as much as that of the world's average. Enhanced cotton production, particularly the high unit yield, can largely be attributed to the adoption of a series of key cultivation techniques. These techniques, including earliness-stimulating cultivation for full utilization of accumulated heat, close planting and short plant height for adequate use of light energy, and drip irrigation under plastic mulching for water saving and yield improvement, have been recently established and applied in the northwest inland of China. At the same time, a series of labor and cost-saving technologies or practices have been adopted to increase net production returns. Mechanization and precision seeding has greatly reduced labor inputs, rational high-density planting techniques combined with chemical regulation has simplified plant pruning and harvesting, and the integrated application of water and fertilizer has reduced the inputs and costs in field management. In particular, the integration of these agronomic techniques and material equipment has not only enhanced yields, but is also convenient, cost-effective and simple. These factors have all led to the establishment of the northwest inland as the largest predominantly cotton-growing area in China. However, the region is currently facing major issues including stagnated cotton yields, serious plastic film pollution, continuous degradation in fiber quality, substantial increases in the cost of cotton production and continuously declining profits. These factors necessitate that cotton cultivation strategies in the region need to be further optimized. Yields can be enhanced by exploring heat and water potential, while quality and economic benefits can be improved by exploring light potential, fertigation and integrating agronomic techniques with mechanization. Greater attention should be paid to seed quality and seeding processes to further reduce costs and improve efficiency. Comprehensive steps for improving the cultivation system at all stages of production should also be taken to enhance the quality of the cotton fiber.

1. Introduction

China is one of the world's largest producers and consumers of cotton (Mao, 2013). The northwest inland cotton region is China's major concentrated growing area. Since the mid-1990s, the northwest inland has gradually developed into one of three dominant cotton-growing regions in China, and in recent years it has substantially developed and became the largest cotton-growing region in China in terms of yield, total production and planting acreage (Appiah et al., 2014; Tian et al., 2016). In 2015, the region measured 2.3 million hectares with a total output of 4.28 million tons, accounting for 58% of the entire cotton planting acreage and 69% of the total output of the nation. The yield per unit area was 1900 kg hm^{-2}, which is 21% higher than the national average for the same year. The contribution and status of the area to cotton production and agriculture has rendered it to be the biggest and most successful in the country (Fig. 1). Compared with the world's major cotton-producing countries, cotton yields in this region were 25% and 96% higher than those of Brazil and the United States respectively during the past five years. In addition, cotton yield of this region was 2.37 times as much as that of the world's average

* Corresponding author.
E-mail address: donghz@saas.ac.cn (H. Dong).
[1] These authors contributed equally to this work.

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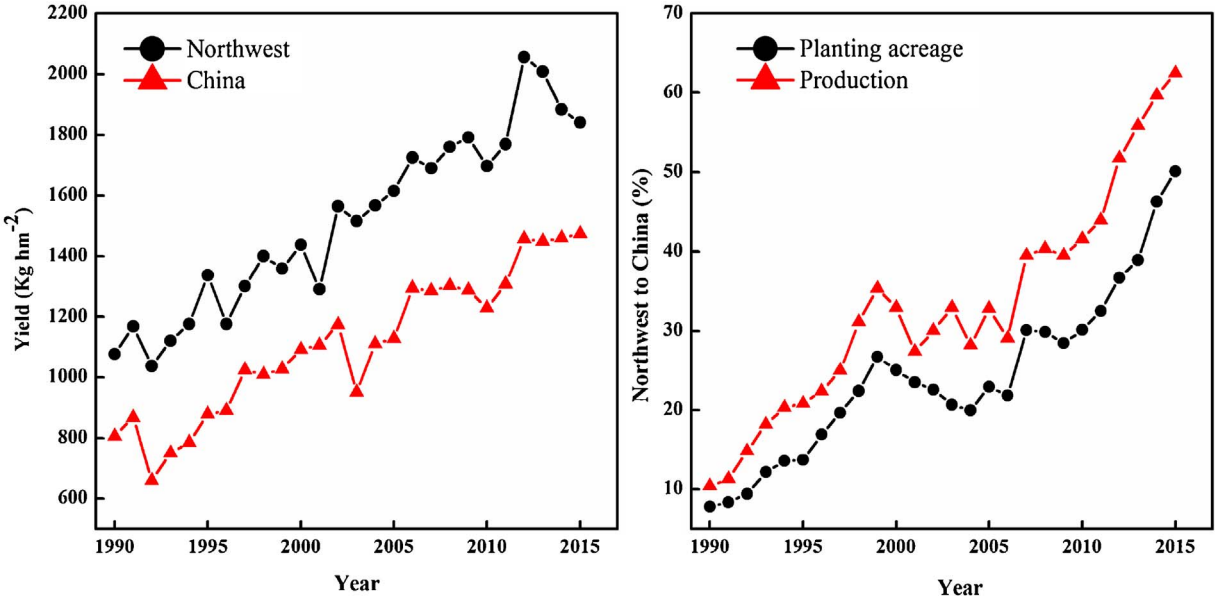

Fig. 1. Variation in the proportion of the northwest inland cotton yield, total production and acreage with respect to the entire country (China).

(Table 1). The cotton yield per unit area was only lower than that of Australia during the same period, but comprises a far larger cotton-growing area than Australia. Furthermore, the main cotton-producing areas of Australia have sufficient light (average light intensity of 5807 MJ m^{-2}), longer growing periods (greater than 300 d) and good irrigation conditions (80–90% of total cotton-growing areas receive good irrigation) (Mao and Li, 2016). In contrast, the natural ecological conditions of the northwestern inland vary, suffering from extreme low light intensities and periods, major seasonal water shortages, low temperatures, frost and frequent natural disasters (Mao, 2013; Shen et al., 2013b). Thus, the cotton production achieved in this region is commendable under the circumstances (Table 2). The majority of researchers in the industry have recently come to believe that cultivation techniques such as close planting (high plant density), dwarfing (reduced plant height) and early maturation stimulating as well as plastic mulching are the main contributors to the high yields and efficiency of the northwest inland cotton region (Mao, 2013; Wang and Zhang, 1995; Tian et al., 2000; Chen et al., 2001b). Furthermore, some scholars consider the enhanced productivity to be the result of a number of introduced strategies, including high density planting, wide plastic film mulching, drip irrigation under mulching, the integration of water and fertilizer application and the integrated use of agricultural mechanization technologies (Yu et al., 2015; Ma and Li, 2006; Li et al., 2015; Xin, 2013). In our opinion, the above-mentioned measures are all factors contributing to the high yield and efficiency of the northwest inland cotton region, but do not fully elucidate the reasons and mechanisms for the sustained high yields and efficiency achieved over the years. We believe that the high cotton yield of the region can be attributed to the full utilization of heat, light and water resources, and the continued high efficiency can be attributed to the high-level integration of agronomic techniques and mechanization. An in-depth analysis of the causes and mechanisms of continued high yields and efficiency of northwest inland cotton will not only provide guidance for the sustainable development of the region's cotton production, but will also act as an important reference for global cotton production.

2. Promotion of early maturation and full utilization of accumulated heat

The northwest inland cotton growing region essentially includes the Xinjiang and Gansu regions, in which poor thermal conditions and insufficient accumulated heat are the main limiting factors for cotton production (Table 2). In the northwest inland, the northern Xinjiang cotton-growing areas suffer from a shortage of heat resources during the seedling and boll-opening stages (Li et al., 2010; Chen et al., 2014a). Crops are prone to chilling injury during the early stages, as well as late fast cooling which renders them vulnerable to frost in autumn. Early frost in southern Xinjiang generally occurs from early October to mid October, while in northern Xinjiang it occurs from the end of September to early October (Pan et al., 2011). In response to the climatic characteristics, particularly the insufficient heat resources, the region has adopted a series of earliness-stimulating measures to accelerate the process of cotton growth and development, such that the majority of cotton fields can meet the requirements for the growth

Table 1
Cotton productivity in the main cotton growing regions and countries.*

Region or country	Planting area ($\times 10^3$ hm^2)			Total output ($\times 10^3$ t)			Lint yield (kg hm^{-2})		
	1991–2000	2001–2010	2011–2015	1991–2000	2001–2010	2011–2015	1991–2000	2001–2010	2011–2015
Northwest§	819	1368	1801	1047	2245	3481	1335	1649	1806
China	5075	5175	4573	4458	6134	6476	899	1183	1420
Australia	360	273	411	544	479	832	1506	1823	2077
Brazil	1147	1000	1080	556	1205	1559	546	1212	1447
USA	5201	4672	3541	3738	4038	3266	721	868	921
World	33107	32920	33589	19181	23884	25597	579	725	761

§Northwest includes Xinjiang and Gansu.
* Data sourced from United States Department of Agriculture and Agricultural Statistics in China.