Field Crops Research 164 (2014) 22–29

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

A simplified pruning method for profitable cotton production in the Yellow River valley of China

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ARTICLE INFO

Article history:
Received 21 April 2014
Received in revised form 16 May 2014
Accepted 16 May 2014
Available online 2 June 2014

Keywords:
Cotton
Plant pruning
Yield
Labor input

ABSTRACT

Intensive plant pruning involving removal of vegetative branches, topping, and continuously excising old leaves, growth tips of fruiting branches, excessive buds and empty fruit branches, has been widely adopted in the field management of cotton (*Gossypium hirsutum* L.) in China, but this practice is facing a serious of challenges because it is labor-intensive and time-consuming. In the present study, an extensive (simplified) pruning system was designed by concurrent removal of vegetative branches and the main-stem leaves below the first fruiting branch at squaring, topping by mid-July when there are 10–12 fruiting branches per plant, and omitting other pruning measures. The objective was to determine if the extensive pruning is better than intensive pruning and non-pruning (plant topping only) in yield and economic benefits. To achieve this goal, two field experiments were conducted at one site from 2011 to 2012 and at five sites in 2013 in the Yellow River delta of China. A split-plot design was used in both experiments with the main plots assigned to cotton cultivars and the subplots assigned to plant pruning (non-pruning, intensive pruning and extensive pruning). The effects of plant pruning, cultivar and their interactions on seed cotton yield were evaluated in both experiments, and on plant growth, harvest index, earliness, yield components and labor input in the first experiment. Both the intensive and extensive plant pruning were beneficial to plant height, harvest index, boll weight and seed cotton yield regardless of cotton cultivar. The extensive pruning was comparable to the intensive pruning system in cotton yield in the first experiment, but produced 4.3% and 4.8% more seed cotton than non-pruning in 2011 and 2012. Greater increases in cotton yield under extensive pruning were obtained in the multi-site experiment in 2013, with an average seed cotton yield increase of 7.7% compared with non-pruning. Both intensive and extensive pruning consumed more labor days than non-pruning, but the labor input under extensive pruning was 76–81% less than that under intensive pruning. Compared with non-pruning, extensive pruning increased the net revenue by 7.9% as a result of improved cotton yield, but intensive pruning decreased net revenue by 3.5% due to increased labor input. The overall results showed that extensive plant pruning is more simplified and beneficial than the traditional intensive pruning and should be a promising alternative in the Yellow River valley of China and other regions with similar ecological conditions.

1. Introduction

Cotton is intensively cultivated currently in China. The intensive farming technologies mainly include seedling transplanting, double cropping, plastic mulching and plant pruning measures, which have played crucial roles in supporting China to become the largest cotton producer in the world (Dai and Dong, 2014). Of the intensive farming technologies, plant pruning has been widely adopted in China for more than 60 years since 1950s. It is believed that intensive plant pruning better coordinates the vegetative and reproductive growth by adjusting the distribution of nutrients in cotton plant tissues and reducing the nutrient consumption in surplus organs (CRI, 2013). Traditionally intensive plant pruning mainly consists of removal of vegetative branches (VB), plant topping, and continuously excising old leaves, excess buds, growth tips of fruiting branches (FB) and empty fruit branches (Dai and

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http://dx.doi.org/10.1016/j.fcr.2014.05.010
0378-4290/

Dong, 2014). Removal of vegetative branches at squaring can significantly enhance the growth of main-stem and fruiting branches, increase dry mass of fruiting parts per leaf area, and reduce boll shedding rate (CRI, 2013; Dong et al., 2008a). Plant topping by mid-July can improve squaring and boll setting through inhibiting excess growth of main stem, and finally increase lint yield (Li et al., 2006; Hosny et al., 1995). Removing the apical points of fruit branches can effectively arrest earlier canopy closure by limiting horizontal growth of branches, increasing earliness, and reducing the number of boll abscission and boll rot (CRI, 2013; Obasi and Msaakpa, 2005; Dong et al., 2003; Bennett et al., 1965; Li et al., 2007). Removal of early fruiting forms can reduce the *Verticillium* wilt disease incidence and early senescence (Zhu et al., 2008; Gu et al., 1990), and is thus performed on early-squaring cotton to mitigate premature senescence (Dong et al., 2008b, 2009a; Sadras, 1995; Pettigrew, 1994).

Although Chinese cotton yield has been continuously increased with the help of intensive farming practices like plant pruning, it is currently facing great challenges, especially the labor shortage due to fast urbanization. It is known that intensive cotton farming requires a great deal of labor, especially for plant pruning and harvesting processes (Dai and Dong, 2014). The quantity and quality of rural labor, however, have been greatly reduced with the rapid urbanization and transfer of labor from rural areas to cities and towns to work in secondary and tertiary industries in China (Mao, 2010). Therefore, it is necessary to reform and simplify the traditional intensive technologies to deal with the challenges of the current labor shortage in cotton production in China.

Simplifying cotton cultivation needs a transition from current intensive farming to relatively extensive farming without reduction in cotton yield and quality (CRI, 2013). Studies in China have indicated without exception that leaving the growth tips of the main stem intact usually leads to yield reduction relative to plant topping. Plant topping must thus be performed if yield is to be maintained without reduction. However, many previous studies also indicated that some of the traditional plant pruning processes can be simplified or even omitted (CRI, 2013). It was reported that retaining vegetative branches at lower plant densities (1.5–3.0 plants m^{-2}) had no negative effect on cotton yield owing to the contribution of vegetative branches to yield (Dong et al., 2012). However, vegetative branches grow vigorously and excessively consume nutrients and aggravate the competition between vegetative and reproductive growth at a medium plant population density of 4.5–7.5 plants m^{-2}, leading to yield reduction from increased abscission of squares and bolls (CRI, 2013). Since 4.5–7.5 plants m^{-2} is a widely-used plant density in the Yellow River valley, it is necessary to determine how to simplify plant pruning at such a medium plant density without compromising yield.

There are generally three to four vegetative branches on the main stem of a cotton plant. It is labor-intensive and time-consuming to identify and then manually remove all VB without damaging the main stem leaves. After VB removal, traditional plant pruning also requires to continuously excise old leaves, excess buds, growth tips of fruiting branches and empty FB. To simplify pruning and save labor input, we have designed a simplified pruning system termed as extensive plant pruning (Dong, 2013). In the extensive plant pruning system, vegetative branches and main-stem leaves below the first fruiting branch are simultaneously removed by hand at squaring. Other traditional plant pruning practices except plant topping are omitted in this system. Our previous study indicated that extensive plant pruning can be more easily performed with less labor input than intensive plant pruning (Dong, 2013). However, the effects of extensive pruning on plant growth, yield and economic benefits are not clearly understood.

The objectives of the present study were to determine (i) the effects of cultivar type, modes of plant pruning, and their interactions on biological yield, harvest index, earliness, seed cotton yield, yield components and labor requirement; (ii) whether extensive plant pruning provides more benefits than the non-pruning or intensive pruning; and (iii) if the performance of extensive plant pruning is affected by cultivars and sites. We hypothesized that extensive pruning would provide more economic benefits than the conventional pruning measures.

2. Materials and methods

2.1. Experimental sites and cultivars

Two field experiments (one in 2011 and 2012; another in 2013) were conducted in the north or northwest of Shandong province, in the Yellow River delta of China. The first experiment was carried out at the Experimental Station of Shandong Cotton Research Center, Linqing (115°42′E, 36°61′N) (S1), from 2011 to 2012. The second experiment was conducted simultaneously in Chiping (116°15′E, 36°34′N) (S2), Huimin (117°5′E, 37°48′N) (S3), Wudi (117°6′E, 37°73′N) (S4), Dongying district (118°40′E, 37°26′N) (S5), and S1. The climate of the 5 sites is temperate and monsoonal. The rainfall is variable with greater distribution in July and August. The background data including soil type, soil salinity and fertility (0–0.20 m) are summarized in Table 1.

High-yielding commercial Bt (*Bacillus thuringiensis*) transgenic cotton (*Gossypium hirsutum* L.) cultivars, SCRC21, SCRC28, SCRC36, SCRC37 and SCRC41 were used in the first experiment, and SCRC28, SCRC41 and K836 in the second experiment. These cultivars were developed by Shandong Cotton Research Center, and officially registered and released by the Chinese Crop Cultivar Registration Committees or the Shandong Provincial Crop Cultivar Registration Committees. Their growth and developmental period from emergence to initial boll-opening around the planting areas was 125–133 days. Acid-delinted seeds (percentage germination = 80%) of each cultivar were treated with imidacloprid (Gaucho FS600, Bayer CropScience, Monheim, Germany) by the Luyi Cottonseed Company Ltd., Jinan, Shandong. Cotton is usually planted in mid-April and harvested by hand at the end of October, with a period of nearly 6 months for cotton growth and development.

2.2. Experimental design

The first experiment was conducted in both 2011 and 2012 to study the effects of pruning modes (intensive, extensive and non-pruning) on plant height, biomass, earliness, seed cotton yield and labor days using 5 cotton cultivars (SCRC21, SCRC28, SCRC36,

Table 1
Soil fertility of the five experimental sites studied.

Experimental site	Soil type	pH	ECe ($ds\,m^{-1}$)	Organic matter ($g\,kg^{-1}$)	Available N ($mg\,kg^{-1}$)	Available P ($mg\,kg^{-1}$)	Available K ($mg\,kg^{-1}$)
Linqing (S1)	Alluvial soil	7.71	1.56	1.33	58.9	31.5	181.3
Chiping (S2)	Alluvial soil	7.62	1.42	1.45	49.7	29.8	167.9
Huimin (S3)	Saline soil	8.13	4.55	1.64	36.2	27.1	181.0
Wudi (S4)	Coastal saline soil	8.27	6.23	1.21	33.8	20.4	194.6
Dongying (S5)	Coastal saline soil	8.24	6.13	1.12	42.7	20.6	202.3

Data were collected from 0 to 0.2 m soil samples in early spring of 2011 for S1 and 2013 for other sites.