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Evaluation of a Production System in China that Uses Reduced Plant Densities and Retention of Vegetation Branches

Hezhong Dong*, Weijiang Li, Zhenhuai Li, Wei Tang, and Dongmei Zhang

ABSTRACT

In China, a cultivation system that uses low plant densities and the retention of vegetative branches is currently referred to as the cost-saving cotton production system, which contrasts with the conventional system that uses moderate plant densities and the removal of vegetative branches. Two experiments were conducted each year in Linqing, Shandong (Yellow River Valley) China, to study the effects of plant density, number of vegetative branches, cultivars, and their interactions on yield, yield components, and production costs in 2002 and 2003. In the first experiment of both years using a hybrid Bt (*Bacillus thuringiensis* Berliner) cotton SCRC15, seed cotton yield and lint percentage averaged across the number of vegetative branches were not significantly different among three plant densities. The interaction between plant density and the number of vegetative branches on lint yield was significant in both years, although no crossover response occurred. Compared with the conventional system (5.25 plants m^{-2} with 0 vegetative branches), the cost-saving system (2.25 plants m^{-2} with 4 vegetative branches) had a 11.4% and 8.5% increase in lint yield in 2002 and 2003, respectively. The cost-saving system had \$110 ha^{-1} decrease in production costs through a reduction in seeding rate and labor costs. Lint yield averaged across population density with 2 vegetative branches and 4 vegetative branches per plant was increased by 6.4% and 14.3% in 2002, and 4.9% and 6.9% in 2003, respectively, compared with plants with all vegetative branches removed. In the second experiment in both years, three hybrid Bt cottons managed with the cost-saving system produced significantly higher yields than with the conventional system, but significant yield reduction was observed in two non-hybrid cottons produced with cost-saving system compared with the conventional system in 2002. These results indicate that hybrid Bt cottons were more adapted to the cost-saving production system than non-hybrid Bt cottons. For Bt hybrid cotton the cost-saving production system that uses a combination of hill-drop planting, plastic mulching, low plant density, and the retention of vegetative branches has the potential to reduce production costs without sacrificing yield.

H. Dong, W. Li, Z. Li, W. Tang, and D. Zhang, Cotton Research Center, Shandong Academy of Agricultural Sciences, Jinan 250100, Shandong, China.
*Corresponding author: donghz@saas.ac.cn

China is the largest producer and consumer of cotton (*Gossypium hirsutum* L.) in the world (Hsu and Gale, 2001). Chinese cotton production is characterized by intensive cultivation due to limited arable land per capita and availability of a large pool of agricultural labor. This situation contrasts with other cotton growing countries where extensive farming is widely adopted to deal with abundant land and costly labor (Dong et al., 2004). Many labor-intensive cultivation techniques, such as seedling transplanting, plastic mulching, and plant pruning, are commonly used in China. Plant pruning mainly refers to manual removal of vegetative branches in late June before flowering and main stem tips (tipping-out) in mid-July at peak flowering. In the Yellow River Valley, the largest cotton growing region in China, the prevailing cotton production system involves using plastic mulch or seedling transplants, planting at moderate plant population densities (4.5-6.0 plants m^{-2}), and plant pruning (Dong et al., 2003a). Research has proven that transplanting and plastic mulching can enhance cotton plant growth by allowing earlier planting and increased soil temperature, respectively (Xue and Qin, 1992). It is also believed that plant pruning alleviates over-shading and excessive vegetative growth of local cotton cultivars under moderate plant population, which enhances lint yield (Dong et al., 2003a).

Cotton producers in China are faced with rising production costs and static yield with the conventional production system. To combat these problems, producers are continually searching for new techniques or systems. Planting modern cotton cultivars with the Bt trait may increase yields and reduce production costs. Because it contains the gene for Cry 1Ac or Cry 1ab, Bt cotton provides a fairly high degree of resistance to lepidopteran pests, and has been widely adopted in both developed and developing countries, including China (Dong et al., 2004; Pray et al., 2002; Tabashnik et al., 2001). Unlike other developing countries where Bt cotton is mostly introduced from the United States, China has developed its own inbred and hybrid Bt genotypes in addition to using Bt cultivars produced in the USA, such as Bollgard 33B. Hybrid cotton developed by crossing a Bt and a local cotton line, usually results in approximately 20% increase in yield compared with non-hybrid cotton (Dong et al., 2004), but hybrid cottonseed production is dependent upon labor-intensive emasculation and hand-pollination, which causes a 5- to 8-fold increase in price than non-hybrid cottonseed (Dong et al., 2003b). Rapid adoption of hybrid Bt cotton has created an interest in reducing seeding rate without sacrificing yields in China and other hybrid cotton growing countries. Decreased plant density reduces seeding rate (Norton et al., 2002; Buehring et al., 2003), and may also result in delayed maturity (Nichols et al., 2004; Jost and Cothren, 2000). Maximum yields were obtained in the Mississippi Delta within a population range of 7.0 to 12.1 plants m^{-2} (Bridge et al., 1973). Studies conducted in Clayton, North Carolina, indicated that plant population did not affect total lint yield, and there was no interaction between cultivar and plant population in terms of lint yield (Jones and Wells, 1998). Bednarz et al. (2000) reported that cotton lint yield was relatively stable across a wide range of population densities, and yield stability was achieved through concomitant changes in boll number per unit area and boll weight.

Another alternative for increasing profits is to simplify field management including leaving vegetative branches intact. Vegetative branches below the fruiting branches, do not directly bear fruit but can give rise to sympodial branches that produce fruit (Davidonis et al., 2004; Boquet and Moser, 2003). Removal of all vegetative branches before flowering is often recommended in China and is used in more than 4 million hectare of cotton each year. This practice accounts for 80% of the total cotton growing area in China (Dong et al., 2003a), but is too labor intensive for other cotton growing countries. Studies have concluded that removal of vegetative branches is not an essential practice for cotton cultivation, because yield of cotton with vegetative branches left intact is either relatively stable or increased in most cases compared with removal of vegetative branches (Dong et al., 2003a). In recent years in Yangtze River Valley in South China, a number of farmers have grown hybrid Bt cotton at plant densities below 3.0 plants m^{-2} and with vegetative branches left intact. This system is termed the cost-saving cotton production system to distinguish it from the conventional production system, which involves high plant density and removal of all vegetative branches from plants. Because scientific references comparing the cost-saving to the conventional system are limited, there are still doubts about its profitability. Moreover, it is still undetermined if the cost-saving system can be adopted for cotton cultivation in the Yellow River Valley where ecological conditions greatly differ from those in Yangtze River Valley (Hsu and Gale, 2001).

The objectives of the present study were, (i) to compare yield and yield components among different treatments of vegetative branch removal across a range of plant densities; (ii) to determine whether the reduced seeding rate and simplified field management of the cost saving system provides more benefits than the conventional production system; and (iii) to determine if the efficacy of the cost-saving system is dependent on cultivar.

MATERIALS AND METHODS

Experimental site and cotton cultivars. Two experiments were conducted at an Experimental Station, Shandong Cotton Research Center, Linqing (115º42′ E, 36º61′ N), Shandong in 2002 and 2003. The soil of the experimental area is a fertile sandy loam that has a pH of 6.1, 1.2% organic matter, 800 mg kg^{-1} total N, 20 mg kg^{-1} available P, and 120 mg kg^{-1} available K. The climate is temperate and monsoonal. Cotton is usually planted in mid-April and harvested at the end of October (6-mo season). From April to October, the rainfall is highly variable and averages 500 mm with the greatest precipitation in July and August. Maximum and minimum temperatures average 29/15°C from summer to early autumn, and 16/10°C during late spring and mid-autumn, respectively.

Hybrid Bt cotton SCRC15 (F_1), developed from a cross between a Bt line with a non-Bt line, was used in the first experiment. Two commercial Bt cotton cultivars, Bollgard33B and SCRC18, and three hybrid Bt cottons, CCRI29 (F_1), SCRC15 (F_1), and SCRC20 (F_1), were used in the second experiment. Acid-delinted seeds (germination percentage ≥90%) treated with imidacloprid (Gaucho FS600; Bayer Cropscience; Monheim, Germany) of each cultivar were provided by the Lumian Cottonseed Company Ltd., Jinan, Shandong.

Experimental design. The first experiment was conducted to compare yield and yield components of SCRC15 grown at three plant populations with different numbers of vegetative branches remaining on plants. In both years, experiments were arranged in a split-plot design with three replications. Main plots were population densities and subplots were numbers of vegetative branches left on each plant. Population densities in the main plots were 2.25, 3.75, and 5.25 plants m^{-2}. The number of vegetative branches were 0 (all the vegetative branches were removed by hand), 2 (2 vegetative branches closest to the first fruiting branch were left and others below were removed), and 4 (untreated plants of this cultivar usually have 4 vegetative branches per plant, and all the vegetative branches were left on each plant). Each main plot was 16.2 m wide and 10 m long, and each subplot was composed of six cotton rows with a row spacing of 90 cm and row length of 10 m.

The second experiment was conducted to compare yield of different cotton cultivars grown using the cost-saving production system (2.25 plants m^{-2} with 4 vegetative branches) and the conventional production system (5.25 plants m^{-2} with 0 vegetative branches). In both years, experiments were arranged in a split-plot design with three replications. Main plots were cultivars and subplots were production systems. Each main plot was 10.8 m wide and 10 m long, and each subplot was composed of six rows with a row spacing of 90 cm and row length of 10 m.

Vegetative branches on the main stem were left intact, or removed by hand at or before flowering to create the required number of vegetative branches per plant.

Field management. For both experiment 1 and 2, cotton was fertilized with 15 t chicken manure and 300 kg of commercial fertilizer containing (by weight) 20% N, 13% P, and 33% K per hectare before planting. Land was plowed, harrowed, and irrigated 15 d before planting. Furrows (3.5 cm deep and 5 cm wide) were prepared by passing an animal-drawn plow every 90 cm. For both experiments, cotton was planted on 12 April 2002 and 15 April 2003. Three seeds per hill were hand planted into the prepared furrow. Within row spacing was 44.4 cm for 2.25 plants m^{-2}, 26.6 cm for 3.75 plants m^{-2} and 19 cm for 5.25 plants m^{-2} in each row. The seeds were covered with moist soil and then mulched with plastic film (6 µm thick and 80 cm wide) along the rows to enhance emergence and plant growth. After emergence, seedlings were freed from the mulch by cutting film above hills. When most seedlings reached the 2-true leaf stage, all plots were thinned to the targeted plant density by leaving one vigorous plant per hill. Plots were side dressed with 90 kg N ha^{-1} at 90 d after planting. Water stress was minimized with timely irrigation. Other management practices in cotton fields were conducted according to local agronomic practices.

Data collection and analysis. In the first experiment, plant stands were recorded after thinning and again at harvest. Yield traits recorded were total number of bolls, boll weight, and lint percentage. Plots were harvested three times by hand from September to October, and lint percentage was determined using a laboratory gin. Production input was calculated based on seed and labor (sowing, vegetative branch removal, and harvest) costs, which were converted from Chinese yuan to U.S. dollar at the official exchange rate (approximately 1 dollar = 8.2 yuan).

In the first experiment of each year, at maturity 20 plants were randomly selected from the two center rows in each plot and uprooted by hand. Vegetative branches were separated from the whole plant, then dried and weighed. Biomass percentage and yield percentage of the vegetative branches were calculated with the following equations: vegetative branch biomass percentage = dry weight of branches (vegetative organs and bolls on vegetative branches)/ dry weight of total plant; vegetative branch yield percentage = dry weight of seed cotton from vegetative branches/dry weight of total seed cotton. In the second experiment of each year, seed cotton in each plot was harvested two times by hand, and lint yield from each plot was recorded after ginning.

All data were subjected to an analysis of variance with SAS (SAS Institute, Inc.; Cary, NC). Means were separated using either Duncan's multiple range test or Fisher's protected least significant difference (LSD) test. All statistical determinations were made at $P = 0.05$. Although the vegetative branch by plant density interaction for yield was significant, interaction was not caused by a crossover response, so brief summaries of both main effects are included in the Results.

RESULTS AND DISCUSSION

Rainfall in 2002 for June, July, August, and September was 147.1, 41.5, 42.0, and 14.3 mm, respectively. Rainfall in 2003 for June, July, August, and September was 54.4, 145.3, 169.5, and 120 mm, respectively. Due to the difference in rainfall distribution between 2002 and 2003, results of yield and yield components in each year were analyzed separately.

Seeding rate and production costs. There are approximately 90,000 delinted seeds per kg for SCRC15 (F_1). Because only three seeds were dropped into each hill, a plant population of 2.25, 3.75, and 5.25 plants m^{-2} required 7.5, 12.5, and 17.5 kg seeds ha^{-1}, respectively. The cost-saving system at 2.25 plants m^{-2} saved 10 kg of seed or \$98 ha^{-1} compared with the conventional system with 5.25 plants m^{-2} (Table 1). Using 2 seeds per hill would reduce this difference to \$61 ha^{-1}.

Rapid emergence and uniform plant stands that provide the targeted plant density are the foundation of a successful production season. Since cold stress, which affects emergence and stand establishment, is frequently encountered in spring, high-quality seed, over-seeding, and/or planting later are considered effective measures for alleviating risks of cold stress (Pettigrew, 2002). In China, raising seedlings in a greenhouse-like hut or mulching the soil with plastic film has been widely adopted to enhance emergence and plant growth in Yangtze and Yellow River Valleys (Xu and Xia, 1999; Xue and Qin, 1992). There were no significant stand losses for each plant density treatment with their corresponding seeding rate in either year of the study, presumably because of the increased temperature and prevention of moisture loss from the soil with the plastic mulch (Xue and Qin, 1992). Averaged across both years of the first experiment, plant densities recorded at 3 d after thinning and at harvest were 99% and 96.5% of the target density, respectively (data not show).

Hill-dropping by hand is labor-intensive, but it reduces the number of seed. Days of labor spent for planting is inversely related to plant density (hills). Reduced density also resulted in decreased labor spent on thinning seedlings and removal of vegetative branches. Although there appeared to be a slight increase in labor days for picking cotton because of increased number of total bolls on non-excised vegetative branches, total labor days for the cost-saving system were reduced relative to the conventional system. With the cost-saving system, the average production costs were reduced by \$110 ha^{-1}. Eighty-eight percent of the reduction was attributed to the decreased seeding rate, and the remaining 12% was attributed to the reduced labor cost (Table 1).

Effects of plant density. Although optimum plant density for maximum lint yield and quality varies with cultivars and environmental conditions (El-Shinnawy and Ghaly, 1985; Fowler and Ray, 1977; Halemani and Hallikeri, 2002), cotton yield is relatively stable across a wide range of population densities (Jones and Wells, 1998). In our experiment, boll weight was significantly influenced by plant density in both years with a trend toward decreased boll weight as plant density increased (Table 2 and Table 3). The number of bolls per unit area among

Table 1. Cost comparison between the conventional production system and the cost-saving production system averaged across 2 yr (Experiment 1)

Production system [w]	Seed cost [x] (\$/ha)	Labor cost (\$/ha) [y]			Total (\$/ha)
		Sowing and thinning	VB removal and tipping out [z]	Cotton picking	
Conventional	170.7	20.3	19.1	56.3	266.4
Cost-saving	73.2	15.2	5.2	62.4	156.0
Difference	97.5	5.1	13.9	-6.1	110.4

[w] The conventional system uses a plant density of 5.75 plants m^{-2} and removal of all vegetative branches. The cost-saving cotton production system uses a plant density of 2.25 plants m^{-2} and no vegetative branches removed.

[x] Hybrid seed cost per kg was 80 Yuan or \$9.75 (\$1=8.2 Yuan).

[y] Cost per labor day was 10 Yuan.

[z] Removal of vegetative branches (VB) and removing the tops of main stems.

Table 2. Effect of plant density, number of vegetative branches (VB), and their interaction on seed cotton yield and yield components of the Bt hybrid SCRC15 in 2002 (Experiment 1)

Plant density (plant m^{-2})	VB remained (no. plant^{-1}) [x]	Yield components [y]					
		Seed cotton yield (kg ha^{-1})	Lint yield (kg ha^{-1})	Bolls (no m^{-2})	Boll weight (g)	Biomass of VB (%)	Yield on VB (%)
2.25	0	3575	1491	63.4	5.65	0	0
2.25	2	3806	1595	69.1	5.51	36.4	39.9
2.25	4	4190	1745	79.4	5.28	40.7	46.9
3.75	0	3600	1500	68.9	5.24	0	0
3.75	2	3770	1571	73.3	5.15	22.6	27.7
3.75	4	4170	1733	81.5	5.12	30.5	36.7
5.25	0	3735	1566	73.1	5.12	0	0
5.25	2	4035	1685	80.5	5.02	18.4	20.2
5.25	4	4110	1720	83.8	4.92	25.2	28.9
LSD (P = 0.05) [z]		93.3	38.9	2.1	0.07	3.5	4.4
				Average			
	0	3637 a	1519 a	68.5 a	5.34 a	0 a	0 a
	2	3870 b	1617 b	74.3 b	5.23 b	25.8 b	29.3 b
	4	4157 c	1733 c	81.6 c	5.11 c	32.1 c	37.5 c
Significance of factors							
Plant density (PD)		2.96	2.85	8.67	7.79	100.41	123.56
No. of branches (NB)		50.81	38.74	12.46	19.47	85.76	83.21
PD × NB		22.52	16.47	10.34	7.34	5.27	11.23

[x] For the number of VB, 0 = all the VB were removed by hand, 2 = 2 VB closest to the first fruiting branch were left and all others were removed, and 4 = all the VB were left on each plant (untreated plants of this cultivar usually have 4 VB per plant).

[y] Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range test.

[z] LSD value applies to comparison of interactions between plant density and branch number.

plant densities was not significantly different in 2003, but number of bolls per unit area was significantly decreased by elevated plant density in 2002. These differences in the affect of plant density on the number of bolls might be attributed to the differences in rainfall between the 2 yr. The heavy and frequent rainfall encountered in 2003 might have resulted in more boll shedding at the higher plant density than at a lower density. Nevertheless, seed cotton and lint yield was not significantly influenced by plant population in either year, which is in agreement with Bednarz et al. (2000) who reported that the stability across population densities was achieved through compensation of boll numbers and weight. The percentage of biomass and yield from vegetative branches decreased as plant population increased, supporting previous reports that the number of vegetative branches per plant is inversely related to plant density (Bednarz et al., 2000; Buxton et al., 1977; Fowler and Ray, 1977).

Effects of the number of vegetative branches. In China, it is traditionally believed that removal of vegetative branches is beneficial to boll retention on fruiting branches and to boll development through reduction of over-shading and excessive vegetative growth (Dong et al., 2003a). Although vegetative branches are left undisturbed in most countries, their removal is considered beneficial to lint yield and quality because assimilates are redirected to the earlier-forming fruit on the fruiting branch (Davidonis et al., 2004; Bednarz et al., 2000). In ultra-narrow row cotton (UNRC), a production system currently used in parts of the United States, the same morphological goal of vegetative branch removal can be achieved by reduced row spacing and increased plant

Table 3. Effect of plant density, number of vegetative branches, and their interaction on seedcotton yield and yield components of the Bt hybrid SCRC15 in 2002 (Experiment 1)

Plant density (plant m^{-2})	VB remained (no. $plant^{-1}$) [x]	Yield components [y]					
		Seed cotton yield (kg ha^{-1})	Lint yield (kg ha^{-1})	Bolls (no m^{-2})	Boll weight (g)	Biomass of VB(%)	Yield on VB (%)
2.25	0	3260	1341	59.4	5.42	0	0
2.25	2	3461	1430	66.6	5.20	33.3	35.9
2.25	4	3665	1510	74.1	4.97	37.5	42.6
3.75	0	3255	1340	60.5	5.38	0	0
3.75	2	3420	1406	66.9	5.13	23.7	23.7
3.75	4	3456	1425	68.3	5.06	29.8	29.8
5.25	0	3375	1392	64.2	5.27	0	0
5.25	2	3450	1420	67.7	5.10	22.4	18.9
5.25	4	3416	1404	70.1	4.93	24.2	23.5
LSD (P = 0.05) [z]		77.7	32.1	1.5	0.317	2.0	2.5
				Average			
	0	3297 a	1358 a	61.4 a	5.37 a	0 a	0 a
	2	3444 ab	1442 ab	67.1 ab	5.14 b	26.5 b	27.3 b
	4	3512 b	1465 b	70.9 b	4.97 c	30.5 c	37.5 c
Significance of factors							
Plant density (PD)		0.21	1.55	0.12	8.34	97.35	97.69
No. of branches (NB)		29.57	25.68	7.22	7.72	92.37	85.46
PD × NB		11.79	10.38	6.99	7.24	5.86	12.45

[x] For the number of VB, 0 = all the VB were removed by hand, 2 = 2 VB closest to the first fruiting branch were left and all others were removed, and 4 = all the VB were left on each plant (untreated plants of this cultivar usually have 4 VB per plant).

[y] Means within a column followed by the same letter are not significantly different (P = 0.05) according to Duncan's multiple range test.

[z] LSD value applies to comparison of interactions between plant density and branch number.

populations (Jost and Cothren, 2001; Bednarz et al., 2000). For the first experiment in both years, lint percentage was not significantly different, but seed cotton yield, boll number, and boll weight were significantly higher in canopies with 4 vegetative branches compared to canopies with no vegetative branches (Table 2 and Table 3). Lint yield averaged across plant densities was increased by 13.8% in 2002, and 6.7% in 2003 for cotton with 4 vegetative branches relative to cotton with all vegetative branches removed. Yield between cotton with 2 and 4 vegetative branches retained was not significantly different in 2003. The number of bolls was positively associated with the number of vegetative branches, and boll weight was inversely related to the number of vegetative branches (Table 2). These results support previous research that indicated the common association between boll number and yield (Dong et al., 2003a). As expected, percentages of biomass and seed cotton from vegetative branches significantly increased with the number of vegetative branches.

Interaction effect between plant density and the number of vegetative branches. Significant interaction between plant density and the number of vegetative branches was observed in both years. A combination of 2.25 plants m^{-2} with 4 vegetative braches provided the highest seed cotton and lint yield in both years, although it did not differ significantly from the two other plant densities with 4 vegetative branches in 2002. Seed cotton and lint yield was increased by 12.2 % and 11.4% in 2002, and 8.6 % and 8.5% in 2003, respectively, with the cost-saving system (2.25 plants m^{-2} with 4 vegetative branches) compared with the conventional system (5.25 plants m^{-2} with 0 vegetative braches) (Tables 2 and 3).

In both years, the interaction between plant density and the number of vegetative branches per plant was significant for boll weight, and percentages of biomass and seed cotton from vegetative branches, but not for lint percentage. The cost-saving system (2.25 plants m^{-2} with 4 vegetative branches) produced 8.6 % and 15.4% more total bolls per unit area than the conventional system (5.25 plants m^{-2} with 0 vegetative branches) in 2002 and 2003, respectively. Average boll weight was significantly increased in the cost-saving system in 2002, but was significantly reduced in 2003. These yield component results show that yield in cost-saving production system is potentially compensated through supplemental boll number, increased boll weight, or both. Increased boll number in the cost-saving system was mainly attributed to the presence of vegetative branches compared with the conventional system, suggesting light interception or fruiting position limited yield in the treatment with no vegetative branches.

Effects of cultivar. In both years, the three hybrid cotton cultivars produced significantly higher yield in the cost-saving system than in the conventional production system (Table 4). Lint yield averaged across three hybrid cultivars was increased by 11.6% in 2002, and 10.8% in 2003 for the cost-saving system relative to the conventional system. Lint yield averaged across non-hybrid cultivars in the cost-saving system was lower than in the conventional system by 5.3% in 2002 (a drought year), but non-hybrid lint yields were unaffected in 2003. Lint yield of non-hybrid cultivars in the cost-saving system appeared to fluctuate more with weather conditions than hybrid cultivars. The cultivar-specific phenomenon suggests that hybrid cottons are more suitable for cost-saving production system than non-hybrid cottons. Therefore, modern hybrid Bt cotton cultivars rather than non-hybrid cultivars should be used in this production system for increasing benefits. The physiological basis for the cultivar-specific phenomenon in cost-saving system should be further investigated.

Table 4. Effect of production system on seed cotton and lint yield among hybrid and non-hybrid Bt cotton cultivars in 2002 and 2003 (Experiment 2)

Production system [y]	Non-hybrid cotton			Hybrid cotton			
	33B	SCRC18	means	CCRI 29	SCRC15	SCRC20	means
2002							
				Seed cotton yield (kg ha^{-1}) [z]			
Conventional	3345 a	3353 a	3349 a	3399 b	3423 b	3558 b	3460 b
Cost-saving	3109 b	3192 b	3151 b	3689 a	3734 a	4082 a	3838 a
				Lint yield (kg ha^{-1}) [z]			
Conventional	1244 a	1271 a	1256 a	1363 b	1313 b	1445 b	1374 b
Cost-saving	1163 b	1216 a	1190 b	1483 a	1512 a	1665 a	1553 a
2003							
				Seed cotton yield (kg ha^{-1}) [z]			
Conventional	3207 a	3292 a	3250 a	3209 b	3368 b	3457 b	3375 b
Cost-saving	3298 a	3263 a	3281 a	3533 a	3691 a	3872 a	3699 a
				Lint yield (kg ha^{-1}) [z]			
Conventional	1199 a	1248 a	1224 a	1287 b	1364 b	1404 b	1352 b
Cost-saving	1227 a	1243 a	1235 a	1420 a	1495 a	1580 a	1498 a

[z] **The conventional system uses a plant density of 5.75 plants m^{-2} and removal of all vegetative branches. The cost-saving cotton production system uses a plant density of 2.25 plants m^{-2} and no vegetative branches removed.**

[z] **Values for each year within a column followed by the same letter are not significantly different (*P* = 0.05) according to Duncan's multiple range test.**

CONCLUSIONS

A production system that includes plastic mulching, seed hill-dropping, low plant density (2.25 plants m^{-2}), and retention of all vegetative branches on the plants is referred to the cost-saving cotton production system. This system differs from the conventional system that uses a higher plant density and removal of all vegetative branches. This research analyzed effects of plant density, the number of vegetative branches, and cotton cultivars on yield and yield components, with emphasis on comparing yield and costs between the two production systems. In comparison with the conventional system, the cost-saving system has several advantages, such as reduced seeding rate and reduced labor spent on planting and vegetative branch removal, which resulted in approximately \$110 ha^{-1} decrease in production costs. Moreover, it also provided approximately 14% increase in lint yield relative to the conventional system. This yield increase in the cost-saving system was mainly attributed to the increased weight per boll at the lower plant density and increased boll number per plant as the number of vegetative branches increased. It should be noted that yields of non-hybrid cultivars were more variable and lower than those of hybrid cultivars when managed with the cost-saving system. Cost reduction through reduced seeding rate for non-hybrid cotton is also less for hybrid cotton, because non-hybrid seed is 5- to 8-fold lower in price than hybrid seed. Given their consistency and price, hybrid rather than non-hybrid cotton cultivars seemed more appropriate for the cost-saving production system. It is recommended that planting moderately earlier with the help of plastic mulching be employed for this system. Additionally, it should be noted that leaving vegetative branches intact on plants make manual tasks in fields relatively more inconvenient than the fields subjected to vegetative branch removal because non-excised vegetative branches may obstruct farm workers during hoeing and harvesting. Despite these disadvantages, cost-saving production system is a potential way to reduce costs or increase yield, and increase profitability.

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DISCLAMER

Mention of a trademark, warranty, proprietary product or vendor does not imply approval or recommendation of the product to the exclusion of others that may be suitable.

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