Pak. J. Agri. Sci., Vol. 51(4), 807-815; 2014
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
http://www.pakjas.com.pk

EFFECT OF FRUITING BRANCH/SQUARE REMOVAL ON BT COTTON UNDER DIFFERENT NITROGEN RATES

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Removal of early fruiting branches with optimum nitrogen dose caused more source and no sink at early growth stages leading to delay in onset and progression of senescence in Bt cotton (*Gossypium hirsutum* L.). Field trials were conducted at Students' Farm, University of Agriculture, Faisalabad, during 2011 and 2012. Experiments were laid out in a randomized complete block design (RCBD) with factorial arrangement using three replications. Study comprised of manual alteration of plant architecture i.e. F_1: no fruiting branch removal, F_2: removal of first fruiting branch, F_3: removal of first and second fruiting branch, F_4: removal of all squares (floral bud) from first fruiting branch, F_5: removal of all squares from first and second fruiting branch; and nitrogen rates i.e. N_1: 175, N_2: 225 and N_3: 275 kg ha^{-1}. More monopodial and sympodial branches per plant were recorded in F_5 and F_3 with higher and medium level of nitrogen application while minimum was recorded in F_1 at all levels of nitrogen. Increasing nitrogen application increased total bolls per plant and cotton yield to highest level in F_3 and F_5 against lowest in control at all levels of nitrogen. Potassium concentration in leaf increased with increasing nitrogen application in F_3 and F_5 treatment while in F_1, F_2 and F_3 medium and higher nitrogen application was at par with each other. Ginning out turn, fiber length, seed oil and seed protein content were influenced by fruiting branch or square removal but difference was less. Increasing nitrogen improved seed oil and protein content and fiber quality (length, strength, fineness, elongation etc.)

Keywords: Branches, bolls, fiber quality, potash in leaf, seed oil, seed protein

INTRODUCTION

Cotton is the leading fibre crop worldwide and is grown commercially in more than 50 countries (Smith, 1999). Cotton crop is primarily grown for fiber and oil purpose (Oosterhuis, 2001). Pakistan is one of the largest cotton producing and consuming countries in the world and one of the ancient homes of cotton cultivation. Cotton has played major role in agriculture, financial stability, employment, economic viability and industrial development ever since the country attained the independence. Bt (*Bacillus thuringiensis*) cotton is rapidly dominating world cotton production due to tolerance to the insects (Pray *et al*., 2002). In 2011-12, cotton was grown on an area of 2835 thousand hectares with production of 13.6 million bales which was higher by 18.6% over the last year production. This increase in production was attributed to the cultivation of Bt cotton with average production of 815 kg ha^{-1}. Cotton shared 6.7% of value added in agriculture and 1.4% to GDP (Govt. of Pakistan, 2014).

Biological characteristics of Bt cotton varieties vary from conventional cotton varieties. Bt transgenic cotton varieties have a drawback of slow emergences but first true leaf appearance is early than conventional cotton varieties (Zhao *et al*., 2002). Bt gene and expression of insecticidal proteins caused change in metabolic processes both in reproductive and vegetative growth in Bt cotton (Chen *et al*., 2002). Early season floral buds and fruiting branches removal increased root growth (Dumka *et al*., 2004) and leaf as well as canopy photosynthesis rate (Wells, 2001; Dumka *et al*., 2003) and enhanced the Cry1Ac expression in Bt cotton (Dongmei *et al*., 2009). Among all nutrients nitrogen is required in larger amount consistently for cotton production (Hou *et al*., 2007). Optimum N rates and N use efficiency are affected by numerous factors like field management, soil fertility and yield potential, however, nitrogen can be used in moderately lower rate with more efficiently manner than traditional way (Clawson *et al*., 2008; Kumbhar *et al*., 2008). Seed protein content increased with nitrogen application (Patil *et al*., 1997).

Result of two years field trial on Bt cotton cultivar SCRC-showed that two basal fruiting branches removal at squaring significantly increased leaf area, plant biomass, the plant height, lint yield, boll size, number of fruiting nodes, Cry1Ac protein in the fully expanded young leaves and Cry1Ac expression in term of more insects pest resistance and improved the fiber strength and micronaire compared with their control treatment (Dong *et al*., 2008). Plant height, number of nodes per plant, sympodial branches per plant, first sympodial position, number of opened bolls, seed index, lint percentage and seed cotton yield were increased by increasing nitrogen supply (Emara and Gammaal, 2012). Lint percentage was not affected with increasing nitrogen level from 45 to 134 kg ha^{-1} (Phipps *et al*., 1996). Fiber length, strength and micronaire were significantly increased by the use of the higher N rate, but the effects were too small to be economically important while there was no effect on fiber uniformity (Sawan *et al*., 2006). Nitrogen levels did not exhibit significant effects on fiber quality traits except the lint percentage (Saleem *et al*., 2010). The highest seed cotton yield was recorded in 240 kg N ha^{-1} + 100 kg K ha^{-1} treatment with an increase of 14% over the control (no N and K); while the highest K uptake efficiency of 42% was recorded in 240 kg N ha^{-1} + 0 kg K ha^{-1} treatment. It was concluded that application of nitrogen increased potassium uptake when cotton crop was grown on moderate fertile land (Khalifa *et al*., 2012). The present study was therefore, conducted to check the effect of removal of squares and/or fruiting branches under different N levels on growth, yield and quality of Bt cotton.

MATERIALS AND METHODS

The experiment was conducted at students' Farm, University of Agriculture, Faisalabad, for two consecutive years (2011 and 2012). Soil samples were taken before sowing of crop to a depth of 15 cm and 30 cm for physio-chemical analysis (Table 1) prior to sowing while weather data for experiments' season were collected from meteorological observatory of department of crop physiology, University of Agriculture Faisalabad (Fig. 1). Experiment was conducted in randomized complete block design (RCBD) in factorial arrangement with three replications. There were five rows per plot with 0.75 m and 0.30 m of row to row and plant to plant spacing, respectively. Each experimental plot size was 6 m ✕ 3.75 m. Delinted seed of Bt cotton cv. IR-3701 was obtained from office of Punjab Seed Corporation in Ayub Agricultural Research Institute Faisalabad, Pakistan and planted on ridges with the help of dibbler. The experiment comprised of five treatments regarding manual alteration in growth viz. no fruiting branch removal (F_1), removal of first fruiting branch (F_2), removal of first and second fruiting branch (F_3), removal of all squares from first fruiting branch (F_4), removal of all squares from first and second fruiting branch (F_5) and three levels of nitrogen viz. 175 kg ha^{-1} (N_1), 225 kg ha^{-1} (N_2) and 275 kg ha^{-1} (N_3) as low, medium and higher rates, respectively. Whole of phosphorus (in the form of SSP) @ 87 kg ha^{-1} and potassium (in the form of K_2SO_4) @ 100 kg ha^{-1} was applied at sowing and variable rates of nitrogen (in the form of urea) for different treatments were calculated based on the gross plot area and applied in three equal splits viz. at planting, at squaring stage and at peak flowering stage. On the whole nine irrigations were applied and weeds were controlled by a pre-emergence herbicide (Dual gold (S-metola cholor) @ 1.50 L ha^{-1}) and a post emergence herbicide (Roundup (Glyphosate) @ 2.7 L ha^{-1}) with help of protective shield at 50 days after planting. Insecticides (Polo 500 SC (Diafenthioran) @ 620 ml ha^{-1} and Confidor 200 SL (Imidacloprid) @ 620 ml ha^{-1}) were applied to control the sucking insects (Aphid, Jassid, Whitefly and Thrips) while Proclaim 019 EC (Emamectin benzoate) @ 500 ml ha^{-1} and Karate 2.5 EC (Lambda-cyhalothrin) @ 1 L ha^{-1}) were sprayed for control of pink bollworm, spotted bollworm and army worm immediately after their appearance in the field. The entire agronomic practices were kept uniform and normal for all the treatments. Data on following observations were recorded using standard procedures during the course of studies.

Table 1. Physico-chemical analysis of soil

Characteristics	Value			
	2011		2012	
Depth of sample (cm)	1-15	15-30	1-15	15-30
Sand (%)	50	48	50	49
Silt (%)	22	23	21	22
Clay (%)	28	29	29	29
Textural class				
Saturation (%)	32	34	38	35
EC (dS/m)	2.02	1.79	1.90	1.76
pH	7.8	7.7	7.7	7.7
Organic matter (%)	1.14	1.03	1.03	0.93
Total nitrogen (%)	0.057	0.040	0.046	0.038
Available P (ppm)	18.1	17.5	16.1	17.5
Available K (ppm)	150	150	180	150

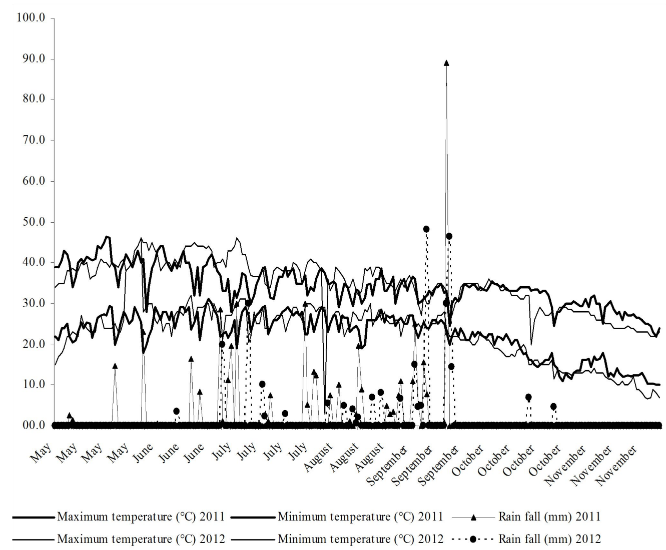


Figure 1. Weather conditions during cotton crop growth period.

Observations: Five guarded plants were selected at random from each plot at initial stage for collection of data.

Monopodial branches of five randomly selected plants from each plot were counted and average number of monopodial branches for each plant was calculated. Sympodial branches of five selected plants from each plot were counted and average number of sympodial branches per plant was calculated. Seed cotton picked from five selected plants during all the pickings was weighed in grams using electric balance. Later the yield of seed cotton per plant was calculated. Seed cotton yield (kg) per hectare was computed from seed cotton yield per plot. Total number of bolls per plant was calculated by counting opened bolls, insects' damaged bolls, rotten bolls and unopened bolls per plant of five randomly selected plants and average was calculated. Potassium concentration (mg g^{-1}) in cotton leaf was determined by collection of subtended leaf from cotton plant at physiologically cutout stage. Leaf samples were washed with distilled water and sundried. After drying ground the samples into powered form, weighed 0.5 g of this sample and digested it in diacid (HNO_3-$HCLO_4$) mixture in 2:1 ratio. Heated the sample at 60°C for 15 min until reaction completed. Then increased heat to 120°C and digested for 75 min or until sample cleared. Remove tubes from digester block, cooled and added distilled water to bring the solution up to 100 mL. Then standard was prepared from stock solution of 1000 ppm (AppliChem 1000 ppm) of 0, 25, 50, 100 ppm concentration and calibrated flame photometer (Sherwood Flame photometer 410) to make curve. Then multiplied the concentration of samples with dilution factor and divided by 1000 to convert ppm to mg g^{-1} (Gupta, 1999).
After roller ginning approximately 100 g samples of the harvested seed cotton, GOT (%) was computed by using the following formula (Singh, 2004).
GOT (%) = (Weight of lint in sample / Weight of seed cotton in that sample) × 100
After ginning, 15 g lint samples were used for determination of fiber length (mm), strength (g/tex), fineness (micronaire), uniformity (%) and elongation (%) with the help of high volume instruments (HVI) at the laboratories of Fiber Technology Department in University of Agriculture, Faisalabad.
Nitrogen content of cotton seed sample collected from each plot was determined by using micro-Kjeldhal methods (Anonymous, 1990) and then crude protein content was calculated by following formula.

Crude protein = Nitrogen × 6.25

Seed oil contents (%) were measured using AOAC method no. 920.85 (AOAC, 1990).
***Statistical analysis*:** Data on all mentioned measurements were statistically analyzed using Fisher's Analysis of Variance Technique with the help of Statistix 10 program and means were compared using least significant difference (LSD) test at P>5 (Steel *et al*., 1997). Figures were drawn by using Excel program.

RESULTS

Year mean effect on number of monopodial and sympodial branches per plant was significant showing more values in 2012 than 2011. Treatments' means and interaction showed significant effect on number of monopodial branches and number of sympodial branches per plant. Maximum number of monopodial branches per plant (2.86 and 3.33 in 2011 and 2012, respectively) was recorded with F_5 (removal of all squares from first and second fruiting branch) at higher nitrogen application (275 kg ha^{-1}) that was at par with medium dose (225 kg N ha^{-1}) of nitrogen application and less number of monopodial branches per plant (1.53 and 2.00 in 2011 and 2012, respectively) was recorded with low (175 kg N ha^{-1}) nitrogen application. Same trend was observed in F_3 (removal of first and second fruiting branch) and F_4 (removal of all squares from first fruiting branch) with higher, medium and low nitrogen rate; while in removal of first fruiting branch (F_2) higher dose of N produced significantly more branches than other two levels of nitrogen. In control (no fruiting branch removal) less number of monopodial branches pre plant (1.13 and 1.53) was recorded with lower nitrogen application (175 kg ha^{-1}) than medium and higher level which performed equal (Table 2).

Table 2. Interactive effect of N levels and removal of square and/or fruiting branch on number of branches in cotton

		Monopodial branches per plant		Sympodial branches per plant	
		2011	2012	2011	2012
F_1	N_1	1.13i	1.53h	17.86d	19.13d
	N_2	1.46ghi	1.86gh	18.06d	19.26d
	N_3	1.73efg	2.13efg	18.20d	19.46d
F_2	N_1	1.33hi	1.80gh	17.60d	18.86d
	N_2	1.53fgh	2.00fg	18.20d	19.40d
	N_3	1.93de	2.40de	20.00c	21.26c
F_3	N_1	1.86ef	2.33ef	17.46d	18.73d
	N_2	2.26cd	2.73cd	20.13c	21.40c
	N_3	2.40bc	2.86bc	21.40ab	22.66ab
F_4	N_1	1.46ghi	1.93g	17.60d	18.86d
	N_2	1.93de	2.40de	18.40d	19.66d
	N_3	2.26cd	2.73cd	20.60abc	21.86abc
F_5	N_1	1.53fgh	2.00fg	18.33d	19.53d
	N_2	2.73ab	3.20ab	20.20bc	21.46bc
	N_3	2.86a	3.33a	21.60a	22.86a
LSD 5 %		0.384	0.378	1.253	1.238
Year mean		1.89b	2.35a	19.04b	20.29a
LSD 5 %		0.230		0.654	

Means not sharing a letter in common differ significantly at 5% probability level; NS= Non-significant.
F_1: No fruiting branch removal; F_2: Removal of first fruiting branch; F_3: Removal of first and second fruiting branch; F_4: Removal of all squares from first fruiting branch; F_5: Removal of all squares from first and second fruiting branch; N_1: 175 kg ha^{-1}, N_2: 225 kg ha^{-1}, N_3: 275 kg ha^{-1}.

For number of sympodial branches all treatments of square or branch removal performed best at higher nitrogen dose than at medium or lower levels however, in control (no square/branch removal) all three nitrogen levels were at par (P=0.05) with each other. Same trend was followed during both study years (Table 2).

Year mean effect on seed cotton yield (per plant and per hectare) was significant. It was more in 2012 than 2011. Data pertaining to seed cotton yield as influenced by treatments' means as well as interaction (F × N) showed significant effect (Table 3).

Table 3. Interactive effect of N levels and removal of square and/or fruiting branch on seed cotton yield in cotton

		Seed cotton yield per plant (g)		Seed cotton yield (kg ha^{-1})	
		2011	2012	2011	2012
F_1	N_1	63.45de	82.53cd	2621.0g	2996.7g
	N_2	61.22de	82.05d	2629.0g	3006.7g
	N_3	61.60de	83.49cd	2721.0fg	3107.7fg
F_2	N_1	57.59e	83.45cd	2593.0g	2964.0g
	N_2	68.82cd	85.74cd	2890.3efg	3303.3efg
	N_3	76.44bc	94.61b	3229.7cde	3694.7cde
F_3	N_1	64.42de	82.82cd	2862.7efg	3272.3efg
	N_2	80.72b	95.18b	3587.7bc	4100.3bc
	N_3	82.09ab	100.89a	3648.3bc	4174.0bc
F_4	N_1	60.60de	83.41cd	2693.7fg	3080.0fg
	N_2	69.52cd	87.04c	3090.0def	3531.7def
	N_3	83.23ab	97.49ab	3699.0ab	4224.3ab
F_5	N_1	60.66de	86.57cd	2696.7fg	3082.7fg
	N_2	75.52bc	95.55b	3371.0bcd	3850.3bcd
	N_3	92.15a	102.07a	4096.3a	4683.0a
LSD 5 %		10.747	4.758	444.94	506.40
Year mean		70.56b	89.52a	3095.3b	3538.1a
LSD 5 %		4.428		235.40	

Means not sharing a letter in common differ significantly at 5% probability level; NS= Non-significant.

F_1: No fruiting branch removal; F_2: Removal of first fruiting branch; F_3: Removal of first and second fruiting branch; F_4: Removal of all squares from first fruiting branch; F_5: Removal of all squares from first and second fruiting branch; N_1: 175 kg ha^{-1}, N_2: 225 kg ha^{-1}, N_3: 275 kg ha^{-1}.

Maximum seed cotton yield was recorded in plots where all squares were removed from first and second fruiting branches and cotton plants were supplied with higher N dose (275 kg N ha^{-1}) during both years of study. Application of F_3 (removal of first and second fruiting branch) and F_4 (removal of all squares from fruiting branch) treatments also performed equally well at higher N dose with respect to seed cotton yield. Trend was also similar in F_2 (removal of first fruiting branch) but its performance was poor than other treatments of branch or square removal. While in control (no fruiting branch removal) all the three nitrogen rates were statistically (P=0.05) same for the parameter under discussion. The trend was same during both study years. Coefficient of determination (R^2) for monopodial and sympodial branches per plant vs. seed cotton yield per plant (g) was strong and positive as shown in Fig. 2.

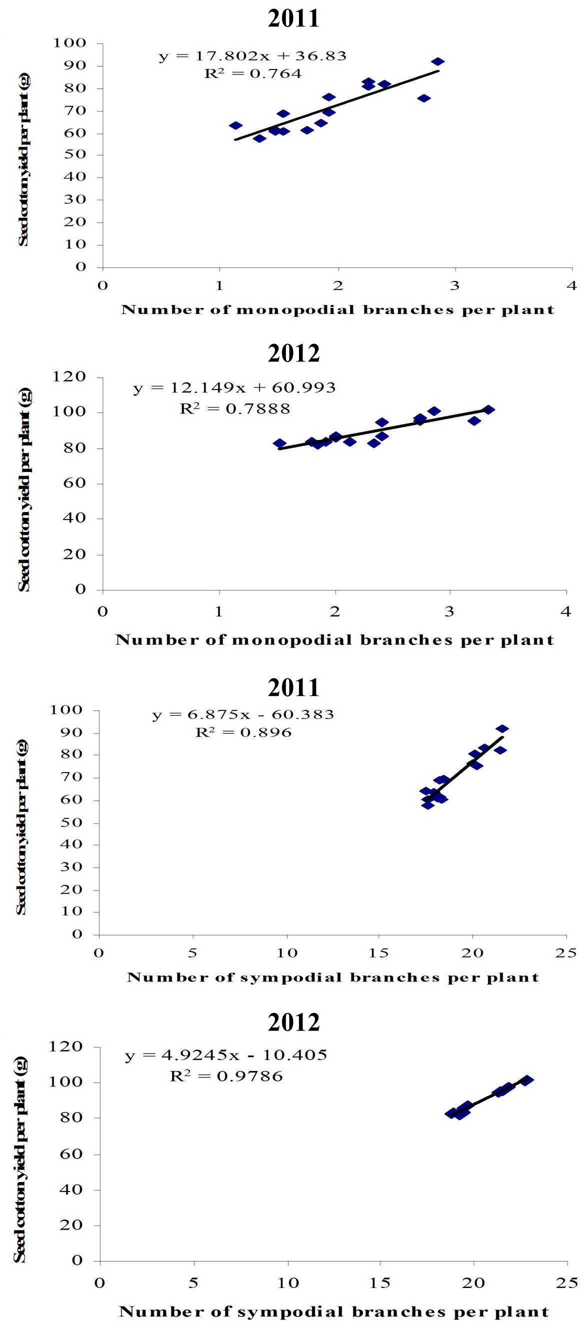


Figure 2. Relationship of number of monopodial and sympodial branches per plant with seed cotton yield per plant (g).

Data in Table 4 indicated that year mean effect on total number of bolls per plant was statistically non-significant but it was significant on potassium concentration (mg g^{-1}) with more values recorded in 2011 than during 2012. Interactive effect showed that in case of first and second fruiting branch removal (F_3) or removal of all squares from these branches (F_5) boll production was maximum when crop was supplied with 275 kg N ha^{-1} closely followed by the medium nitrogen dose (225 kg N ha^{-1}) but differing significantly from low nitrogen dose. In case of F_4 (removal of all squares from first fruiting branch) again higher nitrogen dose produced maximum bolls but other two levels remained significantly low in this regard. Performance of F_2 (removal of first fruiting branch) was poor than F_3, F_4 and F_5 however, higher nitrogen dose produced significantly more bolls than medium or low nitrogen dose.

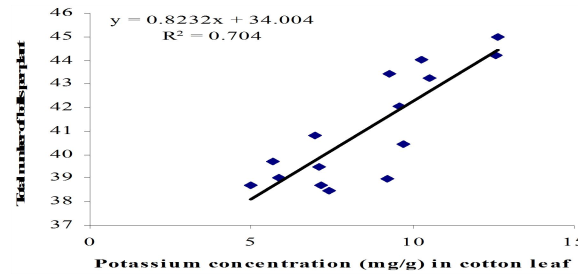
Table 4. Interactive effect of N levels and removal of square and/or fruiting branch on total number of bolls per plant and K concentration (mg g^{-1}) in cotton leaf

		Total bolls per plant		K concentration (mg g^{-1}) in cotton leaf	
		2011	2012	2011	2012
F_1	N_1	38.68de	37.56e	5.00e	5.47d
	N_2	38.69de	36.96e	7.17c	7.70c
	N_3	38.47e	37.32e	7.41c	8.17c
F_2	N_1	39.04de	38.21de	5.88de	7.17cd
	N_2	38.98de	38.17de	9.24b	10.42b
	N_3	42.06bc	41.10bc	9.59b	10.72b
F_3	N_1	39.46de	38.43de	7.11cd	7.82c
	N_2	43.26ab	42.30abc	10.53b	12.07b
	N_3	44.20ab	43.26ab	12.60a	14.31a
F_4	N_1	39.73de	38.23de	5.64e	6.82cd
	N_2	40.46cde	38.63de	9.71b	11.24b
	N_3	44.02ab	42.53ab	10.24b	11.30b
F_5	N_1	40.81cd	40.02cd	6.94cd	8.41c
	N_2	43.43ab	42.49ab	9.30b	11.01b
	N_3	44.98a	44.40a	12.66a	14.60a
LSD 5 %		2.298	2.256	1.294	1.707
Year mean		41.08	39.97	9.81a	8.60 b
LSD 5 %		NS		1.089	

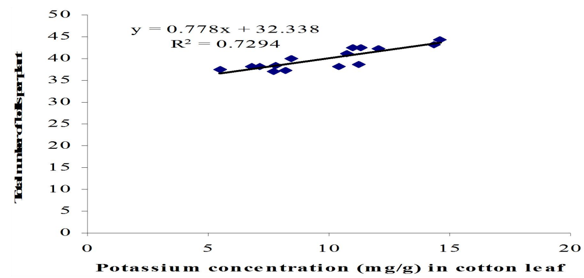
Means not sharing a letter in common differ significantly at 5% probability level; NS= Non-significant.

F_1: No fruiting branch removal; F_2: Removal of first fruiting branch; F_3: Removal of first and second fruiting branch; F_4: Removal of all squares from first fruiting branch; F_5: Removal of all squares from first and second fruiting branch; N_1: 175 kg ha^{-1}, N_2: 225 kg ha^{-1}, N_3: 275 kg ha^{-1}.

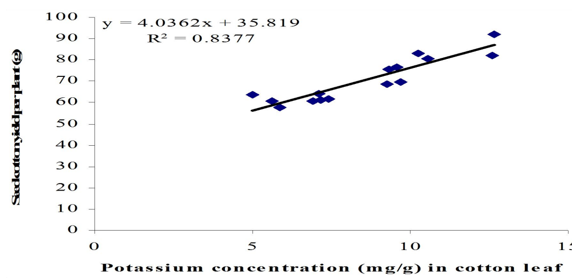
Performance of control (no fruiting branch removal) remained poor at all nitrogen levels in producing bolls per plant. Trend was similar during both study years. Maximum increase in potassium concentration (mg g^{-1}) in cotton leaf was observed in removal of all squares from first and second fruiting branch (F_5) and removal of first and second fruiting branch (F_4) with increased N application rate. It was followed by F_4 (removal of all squares from first fruiting branch), F_2 (removal of first fruiting branch) and then F_1 (no fruiting branch removal) where again more potassium concentration (mg g^{-1}) in cotton leaf was recorded with N_3 (275 kg N ha^{-1}) but it was at par with N_2 (225 kg N ha^{-1}) against the significantly less potassium concentration (mg g^{-1}) with N_1 (175 kg N ha^{-1}). Overall, control (no fruiting branch removal) remained at the bottom in accumulating potash in cotton leaf. Trend was same both years of study (Table 4). Linear regression coefficient (R^2) for potassium concentration (mg g^{-1}) in cotton leaf vs. total number of bolls per plant and seed cotton yield per plant (g) was strong and positive as shown in Figure 3.



2012



2011



2012

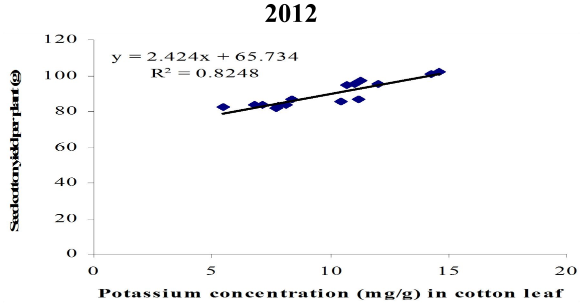


Figure 3. Relationship between potassium concentration (mg/g) in cotton leaf vs. total number of bolls per plant and seed cotton yield per plant (g).

Table 5a. Effect of N level and removal of square and/or fruiting branch on quality traits of cotton.

Square/branch removal (F)	Ginning out turn (%)		Fiber length (mm)		Fiber strength (g tex^{-1})		Fiber fineness (Micronaire)	
	2011	2012	2011	2012	2011	2012	2011	2012
F_1	37.17b	38.15b	24.67b	25.46b	22.2	23.38	5.34	5.36
F_2	37.56b	38.81b	26.21a	26.96a	22.8	23.96	5.08	5.30
F_3	39.43a	40.53a	25.51a	26.67a	22.6	23.91	5.45	5.52
F_4	37.96b	39.08b	25.62a	26.56a	22.8	24.11	5.35	5.34
F_5	39.54a	40.66a	25.78a	26.85a	22.5	23.70	5.48	5.37
LSD (5%)	1.37	1.43	0.77	0.92	NS	NS	NS	NS
Nitrogen level (N)								
N_1	37.74b	38.71b	25.12b	25.66c	21.62c	22.84b	5.58a	5.60a
N_2	38.16ab	39.10b	25.46b	26.49b	22.64b	23.86a	5.26ab	5.26b
N_3	39.09a	40.53a	26.10a	27.36a	23.62a	24.74a	5.18b	5.28b
LSD (5%)	1.06	1.11	0.59	0.72	0.89	0.89	0.323	0.274
Interaction (F×N)	NS	NS	NS	NS	NS	NS	NS	NS
Year mean	38.33b	39.45a	25.56b	26.50a	22.63b	23.81a	5.34	5.41
LSD (5%)	0.735		0.463		0.599		0.190	

Means not sharing a letter in common differ significantly at 5% probability level; NS= Non-significant.
F_1: No fruiting branch removal; F_2: Removal of first fruiting branch; F_3: Removal of first and second fruiting branch; F_4: Removal of all squares from first fruiting branch; F_5: Removal of all squares from first and second fruiting branch; N_1: 175 kg ha^{-1}, N_2: 225 kg ha^{-1}, N_3: 275 kg ha^{-1}.

Table 5b. Effect of N level and removal of square and/or fruiting branch on quality traits of cotton.

Square/branch removal (F)	Fiber uniformity (%)		Fiber elongation (%)		Seed protein content %)		Seed oil content (%)	
	2011	2012	2011	2012	2011	2012	2011	2012
F_1	48.9	50.12	12.0	12.56	13.12d	11.42c	15.27b	16.66c
F_2	49.1	50.37	11.4	12.52	14.82cd	13.36b	17.11ab	18.50b
F_3	46.8	48.04	11.2	12.73	17.01ab	15.06ab	18.72a	20.00a
F_4	47.6	49.28	11.5	12.20	15.55bc	14.09b	17.05ab	18.44b
F_5	49.2	50.64	11.1	12.67	17.49a	16.03a	18.72a	20.00a
LSD (5%)	NS	NS	NS	NS	1.71	1.73	2.00	1.45
Nitrogen level (N)								
N_1	47.00b	48.08b	10.82b	11.66b	13.85c	12.39c	14.76c	16.13c
N_2	50.10a	51.34a	11.78a	12.85a	15.60b	13.85b	17.43b	18.76b
N_3	47.97b	49.65ab	11.89a	13.10a	17.35a	15.74a	19.93a	21.26a
LSD (5%)	2.03	1.76	0.51	0.42	1.32	1.34	1.55	1.12
Interaction (F×N)	NS	NS	NS	NS	NS	NS	NS	NS
Year mean	48.35b	49.69a	11.50b	12.54a	15.60a	13.99b	17.37b	18.72a
LSD (5%)	1.141		0.360		1.108		1.227	

Means not sharing a letter in common differ significantly at 5% probability level; NS= Non-significant.
F_1: No fruiting branch removal; F_2: Removal of first fruiting branch; F_3: Removal of first and second fruiting branch; F_4: Removal of all squares from first fruiting branch; F_5: Removal of all squares from first and second fruiting branch; N_1: 175 kg ha^{-1}, N_2: 225 kg ha^{-1}, N_3: 275 kg ha^{-1}.

Year mean effect was significant on ginning out turn (%), fiber length (mm), fiber strength (g tex^{-1}), fiber fineness (micronaire), fiber uniformity (%), fiber elongation (%), seed protein content (%) and seed oil content (%) with more values recorded in 2012 than 2011 except seed protein content (%) which showed opposite trend (Table 5a & b).

Fruiting branch and/or square removal (F) showed non-significant effect on fiber strength, fineness, uniformity and elongation, however ginning out turn, fiber length, seed protein content and seed oil content were significantly affected by fruiting branch and/or square removal. Effect of nitrogen rates (N) was significant while interactive effect (F × N) was non-significant on all above mentioned quality traits (Table 5a & b). Comparison of treatments' means (Table 5a) showed that more ginning out turn (GOT) was recorded in F_5 (removal of all squares from first and second fruiting branch) and F_3 (removal of first and second fruiting branch) being at par with each other but significantly better than F_1 (no fruiting branch removal), F_2 (removal of first fruiting branch) and F_4 (removal of all squares from first fruiting branch); the later three were also statistically similar. Minimum fiber length was recorded in F_1 (no fruiting branch removal) while all other treatments of square/branch removal were equally good in this regard. Among nitrogen rates; these was observed an increasing trend in GOT and fiber length with increasing N rate (Table 5a). Statistically maximum values for fiber length (26.10 and 27.36 mm) and fiber strength (23.62 and 24.74 g/tex) were exhibited by high N application (275 kg N ha^{-1}), whereas minimum fiber length (25.12 and 25.66 mm) and fiber strength (21.62 and 22.84 g/tex) were recorded with low N rate (175 kg N ha^{-1}). While maximum fiber fineness was obtained with lower N application and minimum fiber fineness was obtained with higher N application trend was same both year of study. Linear regression coefficient (R^2) for ginning out turn (%) and fiber length (mm) vs. seed cotton yield per plant (g) was good and positive (Fig. 4).

The data given in Table 5b show that more fiber uniformity was obtained with medium N application while higher and lower levels reduced fiber uniformity. Maximum fiber elongation (11.89 and 13.10%) was obtained with N_3 (275 kg N ha^{-1}) that was at par with N_2 (225 kg N ha^{-1} and minimum fiber elongation (10.82 and 11.66%) was recorded in N_1 (175 kg N ha^{-1}). Removal of all squares from first and second fruiting branch (F_5) and removal of first and second fruiting branch (F_3) increased seed protein content to a significant level than all other treatments during both years. Seed oil contents were also higher in F_5 and F_3 but the differences were less marked from other treatments of square/branch removal. Among nitrogen levels increase in seed protein content and seed oil content was recorded with increasing N application from low to high (Table 5b). A similar trend was observed during both years of study.

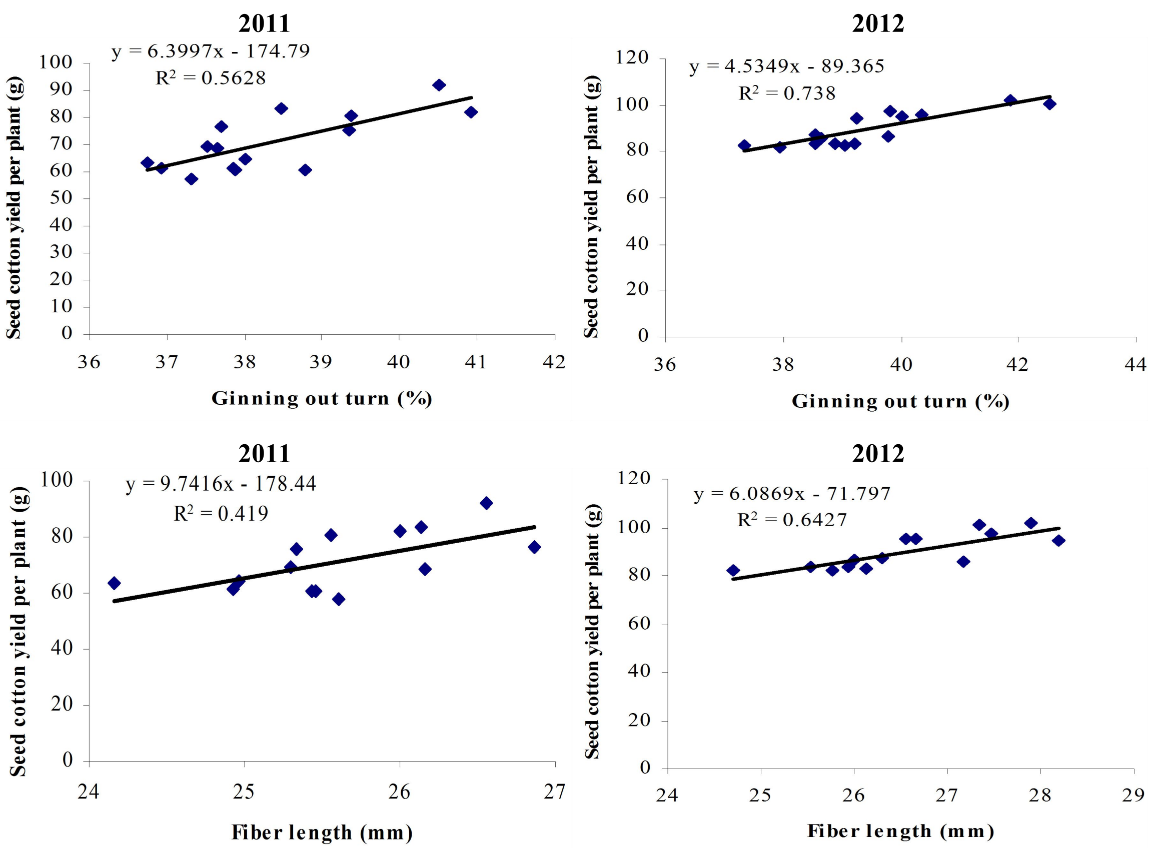


Figure 4. Relationship of ginning out turn (%) and fiber length (mm) with seed cotton yield per plant (g).

DISCUSSION

Numbers of monopodial and sympodial branches are important yield determining traits in cotton. Increase in number of monopodial and sympodial branches with removal of squares from first and second fruiting branch or with removal of first and second fruiting branch was due to increase in main stem nodes by increasing plant height; when flower appears on cotton plant, several hormonal changes occur leading to increased concentration of abscisic acid up to 100 folds (Dong *et al*., 2009). As abscisic acid has role in desiccation tolerance in seed, this higher concentration of abscisic acid in flower indirectly increases concentration of ethylene and forms abscission zone on peduncle and flowers start to drop. Manual removal of early squares increased the concentration of cytokinins and decreased concentration of abscisic acid in cotton and its effect remained effective till 45 days after the removal (Dong *et al*., 2009). Square and/or branch removal interacts with nitrogen and increases more vegetative growth at initial stage that leads toward more number of main stem nodes that may be responsible for more number of monopodial and sympodial branches per plant. Earlier findings showed that two basal fruiting branches removal at squaring increased plant height, leaf area and plant biomass as compared to control (Dong *et al*., 2008). We assumed that square and/or fruiting branches removal at early stage decreased sink/source ratio; less sink at early stage improved more vegetative growth (increased more source) that may be helpful at later stages for boll filling. Previous results showed that flower-bud removal can also increase single-leaf as well as canopy photosynthesis rate (Dumka *et al*., 2003), subtended leaf have 60% role in boll filling that led to increased seed cotton yield per plant (g) and seed cotton yield per hectare in our study. Less seed cotton yield during 2011 may be due to more rainfall at initial stages of crop growth that led to shedding of more flowers at initial stages causing less bolls to contribute in seed cotton yield (Fig. 1). Increase in total number of bolls per plant may be due to more number of sympodial and monopodial branches per plant.

Previous findings showed that two early basal fruiting branches removal had non-significant effect on K concentration (Dong *et al*., 2008) but their study was on two basal fruiting branches removal vs control (no branch removal), in our study nitrogen application might have enhanced K concentration in cotton leaf; According to Khalifa *et al*. (2012) the highest K uptake efficiency of 42% was recorded when cotton crop was supplied with 240 kg N ha^{-1} + 0 kg K ha^{-1}. Another reason behind increased concentration of K in cotton leaf may be that when urea fertilizer is applied in soil it reduces soil pH where fixed potassium becomes exchangeable form and exchangeable potassium goes in solution form so cotton crop take up more potassium.

Overall objective of cotton is lint production; increased lint yield indirectly enhanced ginning out turn (GOT). According to an estimate three percent increase in seed cotton yield could be expected with one percent increase in ginning out turn (Saleem *et al*., 2010). Our experimental results also depicted positive relationship (R^2= 0.56 and 0.73) between ginning out turn and seed cotton yield per plant (g) as shown in Figure 4. Effect of fruiting branch/square removal on fiber length was less markable as compared to no fruiting branch removal. While increase in nitrogen application increased fiber length; Bauer and Roof (2004) concluded that nitrogen application significantly improved fiber length compared to control. Yarn spinning ability depends on fiber strength, cotton with low strength or weak fiber is difficult to handle in manufacturing process. Usman *et al*. (2013) reported that fiber strength, length and fineness increased with application of nitrogen from 150 to 200 kg ha^{-1}. But in our study fiber fineness at medium and higher level of nitrogen application was at par with each other so it can be concluded that fiber fineness did not significantly differed with increase in nitrogen application up to certain limit. Same trend was observed in fiber uniformity and fiber elongation. Earlier findings showed that nitrogen rate had no effect on fiber uniformity (Hussain *et al*., 2000).

***Conclusion*:** Branches or squares' removal improved growth and yield of Bt cotton. Removal of first and second fruiting branch and/or removal of all squares from first and second fruiting branch with higher nitrogen application (275 kg ha^{-1}) proved to be the best combination for obtaining more monopodial branches, sympodial branches, total bolls, seed cotton yield and potassium concentration in cotton leaf. Ginning out turn and other fiber/seed quality traits like fiber length, seed protein content, seed oil content were influenced by square and fruiting branches' removal but differences were less marked. However, increase in nitrogen application improved fiber quality traits, seed protein as well as oil contents.

***Acknowledgements*:** This research was supported by Higher Education Commission of Pakistan and Analytical Lab., Department of Agronomy, University of Agriculture, Faisalabad, Pakistan.

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