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Influence of planting spacing on weed suppression and performance of upland cotton

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ABSTRACT

This study evaluated the influence of planting spacing on weed suppression and the performance of three upland cotton varieties (CB-15, CB-hybrid-1, and Rupali-1) during 2018-2019. The experiments involved ten planting spacings (90 cm × 60 cm, 90 cm × 45 cm, 90 cm × 30 cm, 75 cm × 60 cm, 75 cm × 45 cm, 75 cm × 30 cm, 60 cm × 60 cm, 60 cm × 45 cm, 60 cm × 30 cm, and 40 cm × 40 cm). The randomized complete block design (RCBD) with three replications was used. Results revealed that *Digitaria songuilaris* (Retz.) and *Cyperus rotundus* L. were the most dominant weed species. The variety Rupali-1 exhibited the highest weed density and dry matter, while CB-15 had the lowest. Seed cotton yield was significantly influenced by planting spacing, with the highest yield observed in CB-15 at 90 cm × 30 cm spacing, which also led to earlier squaring, flowering, and higher boll production. The variety CB-15 produced 13% and 60% higher yields compared to wider and closer spacings, respectively. These findings highlight the importance of optimized planting spacing for improved cotton yield and weed management.

Introduction

Cotton (*Gossypium* spp.) is a perennial crop that can cover the entire field with its canopy, though the time required to achieve full coverage is influenced by environmental conditions, management practices, plant density, and row spacing (Wright *et al.*, 2000; Papamichail *et al.*, 2002; Bukun, 2004). Research conducted in the USA has demonstrated the effectiveness of narrow row spacing in suppressing weed growth. For example, studies have reported a 35% reduction in weed biomass when cotton was planted in twin rows spaced at 38 cm compared to the standard 102 cm row spacing. Additionally, significant weed suppression was observed with row spacings of 25 cm and 75 cm compared to 102 cm (Gwathmey *et al.*, 2008). These findings suggest that intermediate row spacings, such as 76 cm, can be just as effective for yield and weed management as narrower spacings, as they promote early canopy closure, leading to stunted weed growth.

A survey of agricultural consultants in the USA emphasized the importance of narrow row spacing as a key management practice for weed suppression, particularly during late weed emergence and growth stages (Riar *et al.*, 2013). Ultra-narrow row (UNR) cotton grown in 25-cm rows reduced sicklepod [Senna obtusifolia (L.) H.S. Irwin & Barneby] biomass and seed production by 80% compared to conventional row spacing (91 cm). An inverse hyperbolic relationship was observed between cotton yield and sicklepod seed production, with the highest yields and lowest weed seed production recorded in UNR cotton (Webster, 2017). At maximum cotton density, sicklepod biomass, seed production, and small-flower morning glory seed production were reduced by 70%, 72%, and 82%, respectively, compared to the lowest cotton density. Moreover, increased seeding rates in both conventional and UNR patterns reduced weed seed production.

According to Patel and Raj (2012), high-yielding Bt cotton varieties, combined with appropriate agronomic practices such as proper spacing and effective weed management, can maximize crop yield. Optimal plant spacing facilitates root proliferation and vegetative growth while minimizing competition among plants, ultimately resulting in higher yields. Weeds present a major challenge in cotton production due to their hardy nature and competitiveness for resources like water, nutrients, light, and space, which can significantly reduce crop performance (Sandhu *et al.*, 1997). Weeds can also degrade cotton quality if left uncontrolled.

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Numerous management practices aimed at improving cotton productivity emphasize the importance of sowing methods and planting densities that are adapted to the local ecological conditions and mechanization requirements (Nadeem *et al.,* 2010; Ehsanullah *et al.,* 2017). Khan et al. (2021) reported that both sowing methods and planting densities are critical for managing weed infestations and enhancing cotton morphology and yield-related traits. Higher planting densities not only ensure better weed management but also increase plant population per unit area. However, excessively high densities can negatively impact morphological and yield traits. Conversely, optimized planting densities, such as 75 × 30 cm or 75 × 37.5 cm spacings, can improve crop morphology and yield while enhancing cotton quality.

Weed infestation can lead to cotton yield losses ranging from 10% to 90%, depending on the weed species, cultural practices (e.g., sowing methods, plant spacing, fertilization), and crop varieties (Halemani & Hallikeri, 2002). Weeds compete aggressively with cotton for critical resources like space, nutrients, and light, leading to significant yield reductions (Iftikhar *et al.,* 2010; Bukun, 2004). Planting density plays a crucial role in determining photosynthesis capacity, plant height, fruit production, boll size and number, and overall yield (Kerby *et al.,* 1990; Heitholt *et al.,* 1992). Studies by Hussain and Qasim (2003) and Ehsanullah *et al.* (2017) revealed that fiber quality remains consistent across different planting densities.

Selecting the appropriate planting density not only increases yield but also suppresses weed growth (Gozubenti *et al.,* 2004). While close plant spacing can hinder root and plant development due to increased competition, resulting in yield reductions (Prasad & Prasad, 1993), wider spacings can encourage weed proliferation. Brar *et al.* (2002) found that a spacing of 67.5 × 45 cm significantly improved flower and boll production but resulted in the lowest seed cotton yield. Hussain et al. (2000) reported that 30 cm spacing between plants increased plant height, boll number, and boll weight compared to 10 cm and 20 cm spacings. However, seed cotton yield was higher at 10 cm spacing, and plant spacing did not impact ginning output or fiber quality. Conversely, Muhammad *et al.* (2002) found that boll weight decreased with increasing plant population.

The effects of plant spacing on weed-crop interactions in this study align with previous findings by Rogers et al. (1976) and are influenced by crop density, as in-row cotton seeding rates were similar across different row spacings. In this study, UNR treatments resulted in 3.6 times more plants per hectare than conventional row spacing, enhancing early competition against sicklepod. Higher cotton population densities promote uniform branching, which improves harvest efficiency and reduces bark and trash contamination of lint (Culpepper & York, 2000; Vories & Glover, 2006). However, increasing plant population density significantly raises production costs, particularly for transgenic cotton seeds, which are among the most expensive inputs in cotton cultivation (Shurley & Ziehl, 2007).The objective of the study was to elucidate the role of planting spacing of cotton in suppressing weeds and to identify the optimal planting spacing for better weed suppression and higher yield in upland cotton.

Materials and methods

Experimental site

The experiments were conducted at Cotton Research Station (CRS), Cotton Development Board (CDB), Mahigonj, Rangpur. The experimental site is situated between latitudes 25^o25' N and 25^o44' N and longitudes 89^o16'E and 89^o44'E at about 32.61m above the sea level. The site is situated at the center of the Agro-Ecological Zone ‘Tista Meander Flood Plain (AEZ 3). This tract spreads over the most of greater Rangpur, eastern part of Dinajpur, northern Bogura and part of Jaipurhat, Noagoan and Rajshahi districts of Bangladesh covering an area of about 9464 km^2 (BARC, 2005).

Soil status of the experimental field

The soil of the experimental site, belongs to the Tista Meander Flood Plain, was different from the other tracts of the country due to its undulating topography. It comprises about 35% high land and 55% medium highland which stand above the normal flooding level. The soils are loamy texture at the top and porous silt loams with K-bearing minerals are medium. The soil pH ranges from 4.8 to 6.5, organic matter 1.55 to 1.82%,nitrogen 0.057 to 0.189 %, phosphorus level 4.21 to 92.55 ppm, potash level 0.09 to 0.40 meq /100g soil, sulphur level 0.64 to 68.61ppm, zinc level 1.02 to 3.62

ppm and boron level 0.001 to 1.40 ppm (SRDI, 2019).

The experiment

The experiment was conducted following a randomized complete block design (RCBD) with three replications. Three cotton varieties were selected based on their performances of experiment and planted following ten different planting spacing. The unit plot size was 16.2 m^2, 1.0 m distance between two plots and 2.0 m wide space between two blocks were maintained. Two factors were involved in the experiment. Three varieties viz. CB-15 (V1), CB-hybrid-1 (V2), Rupali-1 (V3) were considered as Factor A and different Planting spacing (S) were considered as Factor B.

Land preparation and fertilizers application

The experimental land was well prepared by deep ploughing and cross ploughing several times with a tractor drawn plough followed by harrowing and laddering to have a good tillage. The experimental land was acidic in nature. So, liming was done 25 days before planting by using Dolochun {$CaMg(CO_3)_2$} at the rate of 1ton ha^{-1}. Urea, triple super phosphate, muriate of potash (MoP), Gypsum, zinc sulphate, magnesium sulphate and borax were applied, respectively as the nutrients source of N, P_2O_5, K_2O, S, Zn, Mg and B. The whole amount of fertilizers except urea and MoP were applied excluding the final land preparation. Urea and MoP were applied in basal and also at 20, 40 and 60 DAS. Well-decomposed cowdung @10ton ha^{-1}were also applied before final land preparation. The amount of manures and fertilizers were used as per Harun-Or-Rashid et al. (2023) used in the experiment as per recommendation by Cotton Development Board (CDB, 2020).

Table 1: Fertilizers and manure applied for the experimental field

Manures and Fertilizers	Dose ha^{-1}	Application			
		Final land preparation	1st installment	2nd installment	Final installment
Cow dung	10 ton	10 ton	--	--	--
Urea	260 kg	50 kg	100 kg	50 kg	60 kg
Triple super phosphate	266 kg	266 kg	--	--	--
Muriate of potash	316 kg	100 kg	100 kg	66 kg	50 kg
Gypsum	100 kg	100 kg	--	--	--
Zinc sulphate	22 kg	22 kg	--	--	--
Magnesium sulphate	22 kg	22 kg	--	--	--
Borax	22 kg	22 kg	--	--	--

Sowing of seeds in the field

The seeds of cotton were defuzzed and treated with Actara @ 5 g kg^{-1} seed and were sown @ 2-3 seeds $hill^{-1}$ on 9 July 2018. Seeds were placed in pit to a depth of 4-5 cm and then covered with loose soil. The seedlings of different varieties emerged between 3-7 DAS of seeds.

Crop management

Different necessary management practices were followed during the crop growing period. Weeding, irrigation and drainage were done. Protections measured were done against insects and diseases (Harun-Or-Rashid et al., 2023).

Crop sampling and data collection procedure

Five plants from each treatment plot were randomly selected and marked with sample card and data were recorded as per the objectives of the experiment.

Harvesting

Harvesting was done from the 10 December 2018 at an interval of 15 days. After full maturation of bolls, seed cotton was collected by hand picking and they were sun dried. Three hand pickings were done at 15 days interval.

Statistical analysis

The collected data were statistically analyzed. Analysis of variance (ANOVA) for each of the parameter was performed with the help of computer packages RStudio software. The mean square at the error and phenotypic variance were estimated as per Johnson et al. (1955). Significant differences among means were adjudged using Fisher's protected Least Significant Difference (LSD) test at P≤0.05.

Results

Growth attributes of cotton

Plant height

Plant spacing significantly affected the plant height of cotton at all observation dates except at 120 DAS. At 30, 60, 90, 150 DAS, the tallest plants (23.39 cm at 90 cm× 30 cm,71.06 cm at 90 cm× 60 cm,71.81 cm at 90 cm× 30 cm and 128.31 cm at 90 cm× 60 cm, respectively) were observed and the shortest one (17.64 cm at 40 cm× 40 cm, 49.87 cm 60 cm× 30 cm, 58.28 cm at 40 cm× 40 cm and 113.67 cm at 90 cm× 30 cm, respectively). However, the tallest plant (128.31 cm) was found in planting spacing of 90 cm× 60 cm at 150 DAS followed by the spacings of 40 cm × 40 cm, 75 cm × 30 cm, 60 cm × 30 cm, 60 cm × 45 cm and 60 cm × 60 cm which were 128.03 cm, 126.94 cm, 126.06 cm, 124.58 cm and 123.53 cm, respectively (Figure 1).

The effect of interaction of variety and planting spacing on plant height was significantly different at 120 DAS and 150 DAS (Table 1). At 120 DAS, the tallest height (113.00 cm) was obtained from the variety CB-15 at 60cm × 30 cm spacing; and the smallest one (83.67 cm) was observed in the variety Rupali-1 at 60 cm × 30 cm spacing. At 150 DAS, the highest plant (138.42 cm) was obtained from the variety Rupali-1 at 40 cm × 40 cm planting spacing followed by CB-hybrid-1 at 90 cm × 60 cm (138.25 cm) while the lowest one (105.33 cm) was found in the variety CB-15 at 90 cm × 30 cm spacing followed by CB-15 (106.58 cm) at 90 cm × 45 cm spacing (Table 1).

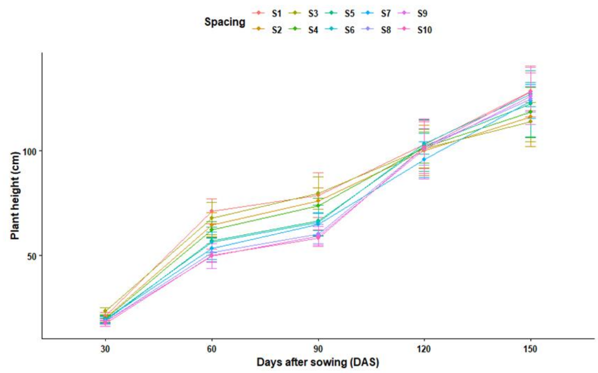

Figure 1: Plant height of cotton as influence by plant spacing at different days after sowing

Table 1: Interaction effect of variety and planting spacing on plant height of cotton at different days after sowing

Variety× spacing	Plant height (cm)				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
$V_1 \times S_1$	20.75	69.25	81.67	111.88 ab	132.17 abc
$V_1 \times S_2$	21.00	64.67	78.67	99.56 a-e	106.58 k
$V_1 \times S_3$	24.08	67.10	80.92	94.00 c-f	105.33 k
$V_1 \times S_4$	20.75	61.50	74.50	101.33 a-e	115.25 f-k
$V_1 \times S_5$	19.58	54.25	64.75	107.50 abc	136.17 ab
$V_1 \times S_6$	20.00	58.17	66.75	101.33 a-e	122.33 c-g
$V_1 \times S_7$	20.67	51.25	61.42	95.00 c-f	131.75 a-d
$V_1 \times S_8$	19.75	51.08	58.92	103.00 a-e	128.00 b-e
$V_1 \times S_9$	19.08	52.92	63.17	113.00 a	137.33 ab
$V_1 \times S_1$	18.75	52.67	60.75	103.67 a-e	121.58 efg
$V_2 \times S_1$	20.50	68.50	69.58	94.83 c-f	114.50 f-k
$V_2 \times S_2$	20.00	60.75	70.75	90.67 ef	107.67 ijk
$V_2 \times S_3$	23.08	71.00	81.17	102.00 a-e	112.92 g-k
$V_2 \times S_4$	19.50	64.17	74.50	94.00 c-f	107.42 jk
$V_2 \times S_5$	18.50	60.33	68.67	94.50 c-f	110.92 h-k
$V_2 \times S_6$	18.58	57.33	67.92	105.00 a-d	129.08 a-e
$V_2 \times S_7$	19.08	55.42	65.92	99.00 b-e	121.75 d-g
$V_2 \times S_8$	17.75	50.67	60.08	93.33 def	117.67 f-i
$V_2 \times S_9$	18.50	43.83	54.42	83.67 f	108.92 ijk
$V_2 \times S_{10}$	16.50	46.42	55.00	90.00 ef	124.08 c-f
$V_3 \times S_1$	21.92	75.42	85.25	102.50 a-e	138.25 a
$V_3 \times S_2$	19.83	68.58	79.17	110.33 ab	134.50 ab

$V_3 \times S_3$	23.00	64.92	77.33	106.83 a-d	122.83 c-g
$V_3 \times S_4$	19.67	61.25	72.58	109.33 ab	132.25 abc
$V_3 \times S_5$	18.50	56.17	66.33	105.17 a-d	120.08 e-h
$V_3 \times S_6$	19.67	53.58	63.42	103.50 a-e	129.42 a-e
$V_3 \times S_7$	18.42	53.00	67.75	93.12 def	117.08 f-j
$V_3 \times S_8$	18.17	52.42	62.17	109.12 ab	128.08 b-e
$V_3 \times S_9$	18.08	52.67	60.75	105.83 a-d	131.92 abc
$V_3 \times S_{10}$	17.67	50.92	59.08	111.17 ab	138.42 a
Level of significance	NS	NS	NS	*	**
CV (%)	7.65	8.45	8.58	8.45	5.06

NS=Non significant, * indicates significant at 5% level of probability, respectively and Within a column, means sharing same alphabets are not significantly different at P=0.05 probability level according to least significant difference test V_1=CB-15, V_2= CB-hybrid-1,V_3= Rupali-1; NFB=Node number of first bearing sympodial branch LSD=Least significance difference; S_1= 90 cm × 60 cm, S_2=90 cm× 45 cm, S_3= 90 cm× 30 cm, S_4= 75 cm× 60 cm, S_5= 75 cm×45 cm, S_6= 75 cm× 30 cm, S_7= 60 cm× 60 cm, S_8= 60 cm× 45 cm, S_9= 60 cm× 30 cm and S_{10}= 40 cm× 40 cm.

Number of leaves plant^{-1}

The number of leaves was significantly affected by planting spacing of different DAS except at 120 DAS and 150 DAS (Table 1). At 30 DAS, the highest number of leaves plant^{-1} (8.11) was produced at 90 cm × 60 cm while the lowest one was recorded with the spacing of 90 cm × 45 cm (6.64). At 60 DAS, the highest number of leaves plant^{-1} (19.64) was found at 90 cm × 60 cm and the lowest one (14.50) at 60 cm × 30 cm spacing. At 90 DAS, the maximum number of leaves plant^{-1} (24.83) was obtained from 90 cm × 60 cm spacing whereas the minimum one (18.69) was obtained from the spacing of 60 cm × 45 cm (Figure 2). The interaction effect of variety and planting spacing on number of leaves plant^{-1} was not significant at different days after sowing (Table 2).

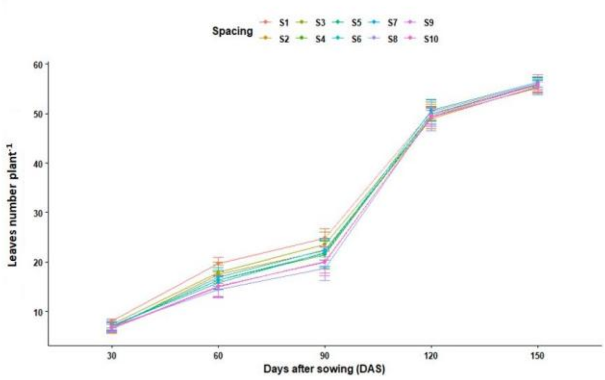

Figure 2: Number of leaves plant^{-1} of cotton as influence by planting spacing at different days after sowing

Table 2: Interaction effect of cotton variety and planting spacing on number of leaves plant^{-1} at different days after sowing

Variety× spacing	Leaves plant^{-1} (no.)				
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
$V_1 \times S_1$	7.94	20.42	26.50	50.42	56.82
$V_1 \times S_2$	7.08	17.50	22.17	49.33	56.58
$V_1 \times S_3$	7.44	18.50	25.08	50.12	55.62
$V_1 \times S_4$	6.83	16.00	20.25	49.33	54.75
$V_1 \times S_5$	7.58	16.58	21.33	49.83	55.31
$V_1 \times S_6$	7.33	17.92	22.58	49.75	55.18
$V_1 \times S_7$	7.00	16.08	24.58	52.08	56.55
$V_1 \times S_8$	7.25	15.58	20.42	51.00	56.88
$V_1 \times S_9$	6.42	14.50	21.25	50.08	55.68
$V_1 \times S_{10}$	6.25	14.08	21.00	48.25	55.15
$V_2 \times S_1$	8.33	18.58	24.58	49.75	55.22
$V_2 \times S_2$	6.67	17.50	21.83	48.83	55.25
$V_2 \times S_3$	7.75	15.92	22.58	50.83	55.41
$V_2 \times S_4$	7.33	15.58	21.42	52.32	56.04
$V_2 \times S_5$	7.25	15.42	22.08	51.08	56.07

$V_2 \times S_6$	6.92	16.58	22.42	49.33	55.11
$V_2 \times S_7$	7.75	16.58	22.75	48.75	55.89
$V_2 \times S_8$	6.75	13.83	17.75	48.15	55.72
$V_2 \times S_9$	7.25	15.00	19.17	49.33	55.32
$V_2 \times S_{10}$	7.50	17.42	20.75	50.92	56.45
$V_3 \times S_1$	8.08	19.92	23.42	50.87	56.28
$V_3 \times S_2$	6.17	17.67	22.92	48.67	54.68
$V_3 \times S_3$	7.17	19.17	22.92	47.33	54.47
$V_3 \times S_4$	6.67	17.42	22.75	48.25	56.93
$V_3 \times S_5$	6.50	17.17	22.00	49.17	56.08
$V_3 \times S_6$	6.75	16.42	22.58	48.67	55.78
$V_3 \times S_7$	6.75	14.92	18.25	51.15	56.72
$V_3 \times S_8$	7.00	14.08	17.92	49.77	55.61
$V_3 \times S_9$	6.17	15.50	20.08	48.33	55.12
$V_3 \times S_{10}$	6.50	13.92	18.25	49.00	56.32 bc
Level of significance	NS	NS	NS	NS	NS
CV (%)	11.82	10.68	11.05	4.19	2.43

Legend: NS = not significant; V_1=CB-15, V_2= CB-hybrid-1, V_3= Rupali-1; NFB=Node number of first bearing sympodial branch LSD=Least significance difference; S_1= 90 cm × 60 cm, S_2=90 cm× 45 cm, S_3= 90 cm× 30 cm, S_4= 75 cm× 60 cm, S_5= 75 cm×45 cm, S_6= 75 cm× 30 cm, S_7= 60 cm× 60 cm, S_8= 60 cm× 45 cm, S_9= 60 cm× 30 cm and S_{10}= 40 cm× 40 cm.

Node number of first bearing sympodial branches plant^{-1} (NFB)

The NFB plant^{-1}was also significantly influenced by the planting spacing (Table 3). The highest node number of first fruiting branches (6.86) was recorded with the planting spacings of 75 cm × 60 cm and 75 cm × 45 cm which was followed by the spacing 40 cm × 40 cm (6.56), 75 cm × 30 cm and 60 cm × 30 cm (6.50), whereas the lowest one was found with the spacing 90 cm × 60 cm (5.92) followed by spacing of 90 cm × 30 cm (5.97) which was statistically identical. The interaction effect of variety and planting spacing on NFB was not significant (Table 3).

Monopodial branches plant^{-1}

Monopodial or vegetative branches plant^{-1} is one of the fruiting branches. Statistical analysis of data revealed that the variety significantly influenced the number of monopodial branches plant^{-1}. The variety CB-15 was recorded with the highest number of monopodial branches plant^{-1} (1.17) whereas the lowest one (0.90) was found in the variety Rupali-1 which was statistically identical with the varieties CB-hybrid-1 (1.03) (Table 3).

The planting spacing also significantly affected the monopodial branches plant^{-1} (Table 3). Results revealed that the highest monopodial branches plant^{-1} (1.42) was recorded with wider planting spacing of 90 cm × 60 cm followed by 60 cm × 60 cm (1.44) and the lowest one (0.67) was found in the spacing of 75 cm × 30 cm (Table 3).

The interaction effect of variety and planting spacing on monopodial branches plant^{-1} was also significant. Results revealed that the highest monopodial branches plant^{-1} (2.18) was obtained from the variety CB-15 at 90 cm × 60 cm and the lowest one (0.42) was found in the variety CB-hybrid-1 at 75 cm × 30 cm (Table 3).

Sympodial branches plant^{-1}

Sympodial branches plant^{-1} is one of the most important yield contributing characters of cotton. Sympodial branches plant^{-1} was significantly influenced by the cotton variety (Table 3). The highest number of sympodial branches plant^{-1} (16.90) was found in the variety CB-15 whereas, the lowest was observed in the variety CB-hybrid-1 (16.51) which was statistically identical with the varieties of Rupali-1 (16.34).

The planting spacing also significantly influenced number of sympodial branches plant^{-1} (Table 3). The highest sympodial branches plant^{-1} (17.94) was recorded with the spacing of 90 cm× 60 cm while the lowest one at 60 cm× 30 cm spacing (15.86) which was statistical identical at 75 cm× 60 cm spacing (15.89) and at 75 cm× 45 cm (16.03) spacing.

The sympodial branches plant^{-1} was also significantly influenced by the interaction of variety and planting spacing (Table 3). The highest sympodial branches plant^{-1} (19.67) was observed in the variety CB-15 at 90 cm× 30 cm spacing and the lowest one (14.08) was recorded with the variety CB-hybrid-1 at 75 cm× 60 cm spacing.

Days to 50% flowering

Day to 50% flowering was significantly influenced by planting spacing (Table 4). Results showed that the highest days for 50% flowering (56.33 days) was recorded with the spacing of 90 cm× 60 cm whereas the lowest days (51.44 days) was required with the spacing of 40 cm× 40 cm which was statistically identical (51.78 days) for 60 cm× 60 cm planting spacing (Table 3).

The interaction effect of variety and planting spacing was also significantly influenced for days to 50% flowering (Table 4). Results revealed that the highest days (58.00 days) required for flowering was recorded with the variety CB-hybrid-1 at 90 cm× 60 cm followed by the variety Rupali-1 with same spacing while the lowest one (50.67 days) was obtained from the variety Rupali-1 at 40 cm× 40 cm spacing (Table 3).

Days to 50% boll split

Days to 50% first boll split was significantly different for planting spacing (Table 4). Results showed that the lowest days required for 50% boll split (122.78 days) was found at 60 cm × 30 cm which was statistically similar at 60 cm × 45 cm (122.89 days) whereas the highest one (140.56 days) was calculated with the spacing at 90 cm × 60 cm (Table 3).

The interaction effect of variety and pant spacing on days to first boll split was also significant (Table 4). Results revealed that the lowest days (121.67 days) required for 50% boll split was recorded with the variety CB-15 at 60 cm × 60 cm spacing followed by (122.33 days) CB-hybrid-1 at 60 cm × 30 cm and Rupali-1 at 60 cm× 45 cm. On the other hand, the highest days required for 50% boll split (141.67 days) was obtained from the variety CB-15 at 90 cm × 60 cm spacing which was statistically similar (140.33 days) for variety CB-hybrid-1 with same planting spacing (Table 4).

Table 3: Effect of variety and planting spacing on number of first fruiting branches plant^{-1} (NFB), monopodial branches plant^{-1}, sympodial branches plant^{-1}, days to 50% flowering and days to 50% boll split of cotton

Variety	NFB plant^{-1}(no.)	Monopodial branches plant^{-1}(no.)	Sympodial branches plant^{-1} (no.)	Days to 50% first flowering	Days to 50% boll split
CB-15	5.39 c	1.17 a	16.90 a	53.53 b	129.47 b
CB-hybrid-1	6.76 b	1.03 b	16.51 b	54.60 a	129.43 b
Rupali-1	7.09 a	0.90 c	16.34 b	53.47 b	130.07 a
LSD $_{(0.05)}$	0.2764**	0.0127**	0.2714**	0.6448**	0.5797*
Planting spacing					
90 cm×60 cm	5.92 c	1.42 a	17.94 a	56.33 a	140.56 a
90 cm×45 cm	6.41 abc	1.08 d	16.06 e	54.00 bcd	136.67 b
90 cm×30 cm	5.97 c	1.36 b	17.31 b	53.56 cd	134.89 c
75 cm×60 cm	6.86 a	1.44 a	16.03 e	54.78 b	131.56d
75 cm×45 cm	6.86 a	1.22 c	15.89 e	54.22 bcd	128.22 e
75 cm×30 cm	6.50 ab	0.67 i	16.72 c	54.56 bc	128.89 e
60 cm×60 cm	6.28 bc	0.92 e	17.25 b	51.78 e	125.78 f
60 cm×45 cm	6.31 bc	0.69 h	16.58 cd	54.67 bc	122.89 h
60 cm×30 cm	6.50 ab	0.72 g	15.86 e	53.33 d	122.78 h
40 cm×40 cm	6.56 ab	0.81 f	16.22 de	51.44 e	124.33 g
Level of significance	**	**	**	**	**
CV (%)	8.34	2.37	3.17	2.32	0.87

Note:*= indicates significant at5% level of probability, respectively

Table 4: Interaction effect of variety and planting spacing on number of first fruiting branches plant^{-1}(NFB), sympodial branches plant^{-1}, days to 50% flowering and days to 50% boll split of cotton

Variety ×spacing	NFB plant^{-1} (no.)	Monopodial branches plant^{-1} (no.)	Sympodial branches plant^{-1} (no.)	Days to 50% first flowering	Days to 50% boll split
$V_1 \times S_1$	5.00	2.18 a	17.08 de	54.00 c-h	141.67 a
$V_1 \times S_2$	5.25	1.50 c	15.50 hij	54.33 c-g	135.67 ef
$V_1 \times S_3$	5.25	1.58 b	19.67 a	52.67 f-k	137.67 cd
$V_1 \times S_4$	5.17	1.50 c	17.25 d	54.33 c-g	125.67 jk
$V_1 \times S_5$	6.42	1.25 e	18.17 bc	53.67 d-i	124.00 k-n
$V_1 \times S_6$	5.25	0.67 l	16.75 d-g	57.00 ab	137.00 de
$V_1 \times S_7$	5.42	0.83 j	17.00 de	52.00 h-k	121.67 o
$V_1 \times S_8$	5.25	0.58 m	17.08 de	52.33 g-k	123.33 l-o
$V_1 \times S_9$	5.50	0.58 m	15.67 hi	53.33 e-j	123.33 l-o
$V_1 \times S_{10}$	5.42	1.00 h	14.83 ijk	51.67 ijk	124.67 jkl
$V_2 \times S_1$	6.08	1.17 f	18.17 bc	58.00 a	140.33 ab
$V_2 \times S_2$	6.58	0.99 h	16.92 de	54.67 c-f	135.00 f
$V_2 \times S_3$	6.42	1.00 h	17.58 cd	55.00 b-e	132.00 h
$V_2 \times S_4$	7.83	1.33 d	14.08 k	56.00 abc	134.00 fg
$V_2 \times S_5$	6.92	1.35 d	14.75 jk	54.00 c-h	128.33 i
$V_2 \times S_6$	7.08	0.42 n	17.08 de	53.67 d-i	125.33 jk
$V_2 \times S_7$	6.42	0.75 k	15.83 h	52.00 h-k	129.67 i
$V_2 \times S_8$	6.67	0.75 k	16.82 def	56.00 abc	123.00 l-o
$V_2 \times S_9$	6.67	0.58 m	15.92 gh	54.67 c-f	122.33 no
$V_2 \times S_{10}$	6.92	0.67 l	16.25 e-h	52.00 h-k	124.33 j-m
$V_3 \times S_1$	6.67	0.92 i	18.57 b	57.00 ab	139.67 b
$V_3 \times S_2$	7.39	0.75 k	15.75 h	53.00 e-j	139.33 bc
$V_3 \times S_3$	6.25	1.50 c	14.67 jk	53.00 e-j	135.00 f
$V_3 \times S_4$	7.58	1.48 c	16.75 d-g	54.00 c-h	135.00 f
$V_3 \times S_5$	7.25	1.08 g	14.75 jk	55.00 b-e	132.33 gh
$V_3 \times S_6$	7.17	0.92 i	16.33 e-h	53.00 e-j	124.33 j-m
$V_3 \times S_7$	7.00	1.17 f	18.92 ab	51.33 jk	126.00 j
$V_3 \times S_8$	7.00	0.75 k	15.83 h	55.67 bcd	122.33 no
$V_3 \times S_9$	7.33	1.00 h	16.00 fgh	52.00 h-k	122.67 mno
$V_3 \times S_{10}$	7.33	0.75 k	17.57 cd	50.67 k	124.00 k-n
Level of significance	NS	**	**	**	**
CV (%)	8.34	2.37	3.17	2.32	0.87

Note:** indicates significant at 5%level of significance, NS = not significant; V_1=CB-15, V_2= CB-hybrid-1,V_3= Rupali-1; NFB=Node number of first bearing sympodial branch LSD=Least significance difference; S_1= 90 cm × 60 cm, S_2=90 cm× 45 cm, S_3= 90 cm× 30 cm, S_4= 75 cm× 60 cm, S_5= 75 cm×45 cm,S_6= 75 cm× 30 cm, S_7= 60 cm× 60 cm, S_8= 60 cm× 45 cm, S_9= 60 cm× 30 cm and S_{10}= 40 cm× 40 cm.

Yield contributing components, yield and biomass of cotton

Aboveground biomass plant^{-1}

Planting spacing significantly affected the aboveground biomass of cotton plant. Result showed that the highest biomass (21.84 g) was obtained from the planting spacing of 90 cm × 30 cm; and the lowest one (14.52 g) was found in spacing of 60 cm × 30 cm (Table 5).

The interaction effect of variety and planting spacing was also significantly affected the aboveground plant biomass (Table 5). Results revealed that the highest biomass (26.37 g) was recorded with the variety CB-15 at 90 cm × 30 cm spacing; and the lowest one (12.60 g plant^{-1}) was found in the variety CB-hybrid-1 at 40 cm× 40 cm spacing followed by CB-hybrid-1 at 60 cm × 45 cm, 60 cm × 60 cm and 60 cm × 30 cm (13.27 g, 13.30 g and 13.43 g plant^{-1}, respectively) which was statistically identical (Table 5).

Number of bolls plant^{-1}

The planting spacing significantly affected the bolls plant^{-1} (Table 5). Results revealed that the highest number of bolls plant^{-1} (29.50) was observed at 90 cm× 30 cm followed by at 90 cm × 60 cm (29.03) while the lowest one (20.33) was recorded with the spacings at 40 cm× 40 cm which was statistically identical at 60 cm × 30 cm and at 75 cm × 30 cm (20.44 and 20.86, respectively) (Table 5).

Number of bolls plant^{-1} was also significantly affected by the interaction of variety and planting spacing. Results revealed that the highest number of bolls plant^{-1} (40.33) was obtained from the variety CB-15 at 90 cm × 30 cm whereas, the lowest one (16.42) was found in the varieties CB-hybrid-1 at 40 cm × 40 cm which was statistically identical Rupali-1 and CB-hybrid-1 at 60 cm × 45 cm and 60 cm × 30 cm spacings (17.67 and 18.58, respectively) (Table 5).

Single boll weight

Boll weight is another important yield contributing character of cotton. Boll weight was not significant affected by the variety (Table 5). Planting spacing differed significantly for single boll weight Wider spacing (90 cm× 60 cm) showed the highest boll weight (6.03 g) which was statistically identical with 5.69 and 5.64 g boll weight at 90 cm × 45 cm and at 90 cm × 30 cm, respectively whereas the lowest one (4.61 g) was recorded in closer spacing of 40 cm× 40 cm and 60 cm × 30 cm followed by 60 cm×45 cm spacing (4.67 g) (Table 5).

Boll weight was also significantly affected by the interaction of variety and planting spacing (Table 5). The highest boll weight (6.17 g) was found in the variety Rupali-1 when planting spacing was 75 cm × 60 cm which was statistically similar with the variety CB-15 with spacing of 90 cm × 60 cm spacing (6.08 g). On the other hand, the lowest boll weight (4.25 g) was found in the variety CB-15 when planted following the spacing of 40 cm × 40 cm followed by $V_2 \times S_8$ (4.42 g), $V_1 \times S_9$ and $V_2 \times S_9$ (4.50 g) and $V_2 \times S_7$ (4.58 g) which was statically similar (Table 5).

Seed cotton yield

A significant difference in seed cotton yield was also observed for planting spacing. The highest seed cotton yield (2.30t ha^{-1}) was recorded with the spacing of 90 cm × 30 cm and the lowest yield (0.94t ha^{-1}) was observed in spacing of 40 cm × 40 cm which was statistically similar at 60 cm × 30 cm (1.00 t ha^{-1}) (Table 5).

The interaction effect of cotton variety and planting spacing was also significantly influenced the seed cotton yield. Results revealed that the variety CB-15 gave the highest seed cotton yield (3.02 t ha^{-1}) at 90 cm × 30 cm spacing followed by same variety CB-15 (2.91 t ha^{-1}) at 90 cm × 45 cm spacing. On the other hand, the lowest yield (0.78 t ha^{-1}) was observed in CB-hybrid-1 at 40 cm × 40 cm spacing which was statistically similar to the varieties CB-hybrid-1 (0.82 t ha^{-1}) and Rupali-1 (0.82 t ha^{-1}) at same spacing (Table 5).

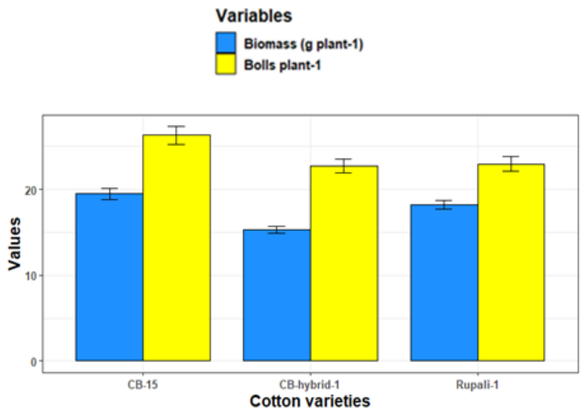

Figure 7: Biomass plant^{-1} and number of bolls plant^{-1}of different cotton varieties

Table 5: Interaction effect of cotton variety and planting spacing on aboveground biomass plant^{-1}, number of bolls plant^{-1}, weight boll^{-1} and seed cotton yield

Variety × spacing	Biomass plant^{-1} (g)	Bolls plant^{-1}(no.)	Weight boll^{-1} (g)	Yield (t ha^{-1})
$V_1 \times S_1$	28.25 cd	28.25 cd	6.08	2.60 b
$V_1 \times S_2$	29.00 c	29.00 c	5.67	2.91 a
$V_1 \times S_3$	40.33 a	40.33 a	5.75	3.02 a
$V_1 \times S_4$	27.67 cd	27.67 cd	4.92	1.80 cd
$V_1 \times S_5$	23.00 efg	23.00 efg	5.42	1.60 de
$V_1 \times S_6$	22.92 e-h	22.92 e-h	5.33	1.47 efg

$V_1\times S_7$	22.58 e-i	22.58 e-i	5.33	1.40 e-i
$V_1\times S_8$	24.17 ef	24.17 ef	4.83	1.35 f-j
$V_1\times S_9$	23.33 ef	23.33 ef	4.50	1.28 g-l
$V_1\times S_{10}$	21.67 f-j	21.67 f-j	4.25	1.20 h-n
$V_2\times S_1$	25.83 cde	25.83 cde	6.00	1.17 i-o
$V_2\times S_2$	28.22 cd	28.22 cd	5.83	1.43 e-h
$V_2\times S_3$	25.50 de	25.50 de	5.67	1.86 C
$V_2\times S_4$	19.67 h-l	19.67 h-l	5.33	1.57 def
$V_2\times S_5$	25.33 de	25.33 de	4.75	1.31 g-k
$V_2\times S_6$	19.67 h-l	19.67 h-l	4.92	1.04 l-r
$V_2\times S_7$	24.25 ef	24.25 ef	4.58	1.03 m-s
$V_2\times S_8$	23.67 ef	23.67 ef	4.42	1.01 n-s
$V_2\times S_9$	18.58 jkl	18.58 jkl	4.50	0.82 rs
$V_2\times S_{10}$	16.42 l	16.42 l	4.92	0.78 s
$V_3\times S_1$	33.00 b	33.00 b	6.00	1.37 e-i
$V_3\times S_2$	21.33 f-j	21.33 f-j	5.58	1.42 e-i
$V_3\times S_3$	22.67 e-i	22.67 e-i	5.50	2.03 c
$V_3\times S_4$	23.25 efg	23.25 efg	6.17	1.27 g-m
$V_3\times S_5$	21.00 f-j	21.00 f-j	5.42	1.40 e-i
$V_3\times S_6$	20.00 g-k	20.00 g-k	4.67	1.10 j-p
$V_3\times S_7$	28.25 cd	28.25 cd	4.58	1.08 k-q
$V_3\times S_8$	17.67 kl	17.67 kl	4.75	0.95 o-s
$V_3\times S_9$	19.42 i-l	19.42 i-l	4.83	0.91 p-s
$V_3\times S_{10}$	22.92 e-h	22.92 e-h	4.67	0.84 qrs
Level of significance	**	**	NS	**
CV (%)	8.49	8.49	8.79	10.59

Note:** indicates significant at 5% level of significance, NS = not significant; V_1=CB-15, V_2= CB-hybrid-1 and V_3= Rupali-1; S_1= 90cm × 60 cm, S_2=90 cm× 45 cm, S_3= 90 cm× 30 cm, S_4= 75 cm× 60 cm, S_5= 75 cm× 45 cm, S_6= 75 cm× 30 cm, S_7= 60 cm× 60 cm, S_8= 60 cm× 45 cm, S_9= 60 cm× 30 cm and S_{10}= 40 cm× 40 cm.

Ginning and lint quality parameters

Ginning out turn (GOT)

Planting spacing significantly influenced GOT%. Planting spacing of 90 cm × 60 cm showed the highest GOT (40.45%); and the lowest one (38.00%) was recorded with the spacing followed by the spacing of 60 cm × 60 cm (38.38%). The ginning out turn was not significantly affected by the interaction of variety and planting spacing (Table 6).

Table 6: Interaction effect of variety and planting spacing on ginning out turn (GOT), seed index and lint index of cotton

Variety×spacing	GOT (%)	Seed index (g)	Lint index
$V_1\times S_1$	40.57	11.33	4.59
$V_1\times S_2$	39.70	10.67	4.25
$V_1\times S_3$	39.92	10.67	4.26
$V_1\times S_4$	38.92	10.67	4.16
$V_1\times S_5$	39.47	10.67	4.22
$V_1\times S_6$	38.86	10.33	4.01
$V_1\times S_7$	38.25	10.33	3.95
$V_1\times S_8$	38.51	10.00	3.85
$V_1\times S_9$	39.04	10.00	3.90
$V_1\times S_{10}$	37.57	10.33	3.88
$V_2\times S_1$	40.15	11.67	4.69
$V_2\times S_2$	40.10	11.00	4.41
$V_2\times S_3$	39.46	10.67	4.22
$V_2\times S_4$	39.33	10.67	4.21
$V_2\times S_5$	38.77	10.33	4.01
$V_2\times S_6$	38.62	10.33	4.00
$V_2\times S_7$	38.38	10.00	3.84
$V_2\times S_8$	38.78	10.00	3.89
$V_2\times S_9$	38.03	10.00	3.80
$V_2\times S_{10}$	38.28	9.33	3.59
$V_3\times S_1$	40.51	11.00	4.44
$V_3\times S_2$	39.36	10.00	3.92
$V_3\times S_3$	39.86	10.67	4.25
$V_3\times S_4$	38.99	10.00	3.89
$V_3\times S_5$	38.95	10.00	3.89
$V_3\times S_6$	38.92	10.00	3.86
$V_3\times S_7$	38.50	10.33	3.97
$V_3\times S_8$	38.53	9.67	3.71
$V_3\times S_9$	38.31	9.67	3.69
$V_3\times S_{10}$	38.15	9.33	3.56
Level of significance	NS	NS	NS
CV (%)	1.65	5.59	5.69

Note: NS = not significant, V_1=CB-15, V_2= CB-hybrid-1,V_3= Rupali-1; S_1= 90cm × 60 cm, S_2=90 cm× 45 cm, S_3= 90 cm× 30 cm, S_4= 75 cm× 60 cm, S_5= 75 cm× 45 cm, S_6= 75 cm× 30 cm, S_7= 60 cm× 60 cm, S_8= 60 cm× 45 cm, S_9= 60 cm× 30 cm and S_{10}= 40 cm× 40 cm.

Seed index

A significant difference in seed index was found due to planting spacing. The highest seed index (11.33 g) was recorded with the spacing of 90 cm × 60 cm and the lowest one (9.67 g) was observed in spacing of 40 cm × 40 cm followed by the spacings of 60 cm × 30 cm and 60 cm × 45 cm (9.89 g) (Table 6).

Seed index was not significantly affected by the interaction of variety and planting spacing of cotton (Table 7).

Lint index

The planting spacing significantly influenced the lint index. Planting spacing of 90 cm × 60 cm showed the highest lint index (4.59) while the lowest one (3.67) was recorded with the spacing of 40 cm × 40 cm followed by the spacings of 60 cm × 30 cm and 60 cm × 45 cm (3.79 and 3.83, respectively) (Figure 10). The lint index was not significantly affected by the interaction of variety and planting spacing (Table 7).

Table 7: Effect of plant spacing on aboveground biomass, Bolls number, single boll weight, seed cotton yield, ginning out tern (GOT), seed index and lint index of cotton

Planting spacing	Biomass plant^{-1} (g)	Bolls plant^{-1} (no.)	Single boll weight (g)	Yield (t ha^{-1})	GOT (%)	Seed index (g)	Lint index
90 cm×60 cm	19.58 b	29.03 a	6.03 a	1.71 c	40.41 a	11.33 a	4.59 a
90 cm×45 cm	20.22 b	26.18 b	5.69 ab	1.92 b	39.72 b	10.56 b	4.19 b
90 cm×30 cm	21.84 a	29.50 a	5.64 ab	2.30 a	39.75 b	10.67 b	4.25 b
75 cm×60 cm	20.04 b	23.53 cd	5.47 bc	1.55 d	39.08 c	10.44 b	4.09 bc
75 cm×45 cm	17.17 c	23.11 cd	5.19 cd	1.44 d	39.06 cd	10.33 bc	4.04 bc
75 cm×30 cm	17.08 c	20.86 e	4.97 de	1.20 e	38.80 cde	10.22 bc	3.96 cd
60 cm×60 cm	15.51 d	25.03 bc	4.83 de	1.17 e	38.38 ef	10.22 bc	3.92 cd
60 cm×45 cm	15.54 d	21.83 de	4.67 e	1.10 ef	38.61 cde	9.89 cd	3.82 de
60 cm×30 cm	14.52 e	20.44 e	4.61 e	1.00 fg	38.46 def	9.89 cd	3.79 de
40 cm×40 cm	15.04 de	20.33 e	4.61 e	0.94 g	38.00 f	9.67 d	3.67 e
Level of significance	**	**	**	**	**	**	**
CV (%)	5.38	8.49	8.79	10.59	1.65	5.59	5.69

Note:** = Significant at 5% level of probability. Within a column, means sharing same alphabets are not significantly different at P=0.05 probability level according to least significant difference test

Table 8: Dominant weed species with relative density (RD), relative dry matter (RDM) and summed dominance ratio (SDR) of the experimental field

No.	Weed name	Scientific name	Family name	Type	RD%	RDM%	SDR
1	Anguli	*Digitaria sangguinalis (*Retz.) koel	Poaceae	Grass	60.79	43.21	50.00
2	Durba	*Cynodondactylon* (L.) Pers	Poaceae	Grass	14.31	20.56	17.44
3	Chapra	*Eleusine Indica*(Limm) Gaertn	Poaceae	Grass	0.62	0.96	0.79
4	Bonchina	*Panicum repens*L.	Poaceae	Grass	0.58	0.91	0.74
5	Carpetgrass	*Axonopus compressus* (Sw.) P. Beauv	Poaceae	Grass	0.25	0.39	0.32
6	Shama	*Echinochloa crus-galli* (L.) Link	Poaceae	Grass	0.18	0.33	0.25
7	Mutha	*Cyperus rotundus* L.	Cyperaceae	Sedge	18.46	25.98	22.22
8	Shaknote	*Amaranthus viridis* L.	Amaranthaceae	Broadleaf	0.51	1.18	0.84
9	Katanote	*Amaranthus spinosus* L.	Amaranthaceae	Broadleaf	0.73	1.22	0.98
10	Foska begun	*Physalis heterophylla* Nees	Solanace	Broadleaf	0.79	1.38	1.08
11	Asthma	*Euphorbia hirta* L.	Euphorbiaceae	Grass	0.93	1.38	1.16
12	Helencha	*Jussiaea repens* Vahi	Onagraceae	Broadleaf	0.42	0.69	0.56
13	Chagolgasa	*Ageratum conozoides*L.	Asteraceae	Broadleaf	0.62	0.96	0.79
14	Kanainala	*Cyanatis axillaris* (L.) D. don ex Sweet	Commeliaceae	Broadleaf	0.52	0.81	0.67
15	Kanaibashi	*Commelina benghalensis* L.	Commeliaceae	Broadleaf	0.22	0.34	0.28

Weed parameters

Weed composition of the experimental field

Fifteen weed species from seven different families were identified in weedy plots comprising six grasses, eight broad-leaved and one sedge. Based on the summed dominance ratio (SDR) values, grass weed *Digitariasonguilaris (Retz.) keol* was the most predominant species (SDR 50.00); *Cyperus rotundus* L. emerged as second dominant sedge weed species (SDR 22.22). Another grass weed species *Cynodon dactylon (L) Pers* ranked third (SDR 17.44). Among the species, *Euphorbia hirta L.* appeared as the fourth dominant broad-leaved weed (SDR 1.16). Broad leaf weed species *Physalis heterophylla Nees*occupied the fifth position (Table 8).

Weed density

Planting spacing significantly influenced the weed density. Results showed that the highest density (410.44 m^{-2}) was observed in the planting spacing of 90 cm × 60 cm followed by 90 cm × 45 cm (308.56). On the other hand, the closest spacing (40 cm× 40 cm) resulted in the lowest one (158.33 m^{-2}) because of completion with plant due to space (Table 9).

The interaction effect of variety and planting spacing on weed density was also significantly different. Results revealed that significantly the highest weed density(435.00 m^{-2}) was recorded with the variety Rupali-1at 90 cm × 60 cm spacing followed by CB-hybrid-1 at 90 cm× 60 cm (413.67 m^{-2}). On the other hand, the lowest density (115.67 m^{-2}) was found in the variety CB-hybrid-1 at 40 cm × 40 cm spacing followed by CB-15 at 60 cm × 30 cm spacing (117.67 m^{-2}) (Table 9).

Weed dry matter

The planting spacing significantly different for the weed dry matter. Results indicated that the highest weed dry matter (360.44 g.m^{-2}) observed in spacing of 90 cm× 60 cm) whereas the closest spacing of 40 cm × 40 cm showed the lowest one of 1858.11 g. m^{-2} (Table 9).

The interaction effect of variety and planting spacing on weed dry matter was significantly different. Results showed that the highest weed dry matter (35.00 g. m^{-2}) was recorded with the variety Rupali-1 at 90 cm × 60 cm. On the other hand, the lowest dry matter (65.67 g. m^{-2}) was found in variety CB-hybrid at 40 cm× 40 cm followed by CB-15 at 60 cm× 30 cm (67.67 g. m^{-2}) (Table 9).

Table 9: Interaction effect of variety and planting spacing on weed density and weed dry matter in cotton

Variety × spacing	Weed density (no. m^{-2})	Weed dry matter (g. m^{-2})
V_1×S_1	382.67 c	332.67 c
V_1×S_2	319.33 f	269.33 f
V_1×S_3	177.67 p	127.67 p
V_1×S_4	211.00 n	161.00 n
V_1×S_5	166.00 q	116.00 q
V_1×S_6	131.00 r	81.00 r
V_1×S_7	207.67 n	157.67 n
V_1×S_8	161.33 q	111.33 q
V_1×S_9	117.67 st	67.67 st
V_1×S_{10}	122.33 s	72.33 s
V_2×S_1	413.67 b	363.67 b
V_2×S_2	378.67 c	328.67 c
V_2×S_3	277.67 i	227.67 i
V_2×S_4	248.33 k	198.33 k
V_2×S_5	260.33 j	210.33 j
V_2×S_6	225.33 m	175.33 m
V_2×S_7	195.00 o	145.00 o
V_2×S_8	301.33 gh	251.33 gh
V_2×S_9	280.33 i	230.33 i
V_2×S_{10}	115.67 t	65.67 t
V_3×S_1	435.00 a	385.00 a
V_3×S_2	227.67 m	177.67 m
V_3×S_3	338.33 e	288.33 e
V_3×S_4	334.33 e	284.33 e
V_3×S_5	204.67 n	154.67 n
V_3×S_6	231.00 lm	181.00 lm
V_3×S_7	300.00 h	250.00 h
V_3×S_8	367.67 d	317.67 d
V_3×S_9	307.33 g	257.33 g
V_3×S_{10}	237.00 l	187.00 l
Level of significance	**	**
CV (%)	1.52	1.89

** indicates significant at 5% level of significance;V_1=CB-15, V_2= CB-hybrid-1,V_3= Rupali-1; S_1= 90cm × 60 cm, S_2=90 cm× 45 cm, S_3= 90 cm× 30 cm, S_4= 75 cm× 60 cm, S_5= 75 cm× 45 cm, S_6= 75 cm× 30 cm, S_7= 60 cm× 60 cm, S_8= 60 cm× 45 cm, S_9= 60 cm× 30 cm and S_{10}= 40 cm× 40 cm.

Discussion

Plant spacing was influenced on weed suppression and yield in different cotton varieties. Increasing plant density is a non-chemical tactic that can be easily integrated with cropping to suppress many dominant weeds (Eslami, 2015; Mahajan *et al.*, 2015). Under high weed pressure situations; there can often be crop yield benefits, better weed control, and reductions in the cost of weed control by adopting dense crop stands (Mahajan *et al*., 2015). Increasing density would lead to the early canopy closure, thus limiting light penetration in space across the rows and eliminating numerous dominant weeds (Eslami, 2015). By integrating this tactic, weeds proliferating in a noncompetitive environment but not performing well in increasing competition effectively be eliminated (Chauhan and Johnson, 2010; Eslami, 2015). *Cyperus* sp. and *Echinochloa* sp. were suppressed in rice by adopting this tactic (Chauhan and Johnson, 2010). In the studied Results showed that closer spacing is dominant to weeds control of the cotton-growing season. Results have been identified (Hake *et al*., 1991;Wright *et al.,* 2000), that cotton planted at a spacing distance of 1 m row, the following planting density is 8-12 plants m^{-2} and 6-9 plants m^{-2}, respectively for irrigated and dry land cotton. Cotton is planted in the traditional system at a row spacing of 1 m and a density of 100,000 to 120,000 plant ha^{-1} is generally followed whereas the plant density can be increased compared with normal row planting in the narrow row (38-76 cm) or ultra-narrowing (19-25 cm) systems (Hake *et al*., 1991; Jost and Cothren, 2000). Jost and Cothren (2000) noted that the 19 cm narrow row configuration of about 40 plant m^{-2} produced 55% and 92% of canopy closures by 49 and 61 days, respectively after planting. For the broad range of 1 m with a seeding density of 10 plants m^{-2}, the corresponding values were 20% and 32% (Jost and Cothren, 2000). Different morphological changes will occur as a competitive reaction and search for more sunshine, while plants will increase in thickness over the thinner stand in the early cultivated phase and help the crop to have a comparative advantage over the weeds at the early phases of crop growth (Hake *et al.,* 1991; Jost and Cothren, 2000).

Planting spacing has great influence on weed growth and cotton yield. Wider plant spacing allowed maximum weed growth, while closest spacing resulted in lowest weed growth because of competition for nutrient and sunlight. The highest seed cotton yield was recorded with 90 cm x 30 cm spacing while, the closet spacing of 40 cm x 40 cm yielded the lowest. Cotton lint yield in the narrow-row spacing was approximately 60% greater than that in the conventional row spacing. It was found great variability in cotton yield in ultra-narrow row(UNR) compared to conventional row spacing (Jost and Cothren, 2000; Boquet, 2005;Vories and Glover, 2006). Rogers *et al.* (1976) determined the critical period of weed control (CPWC) in cotton, the time during which cotton must be kept free of weeds in order to avoid a yield loss, was affected by row spacing. Under high weed densities (100 broadleaf and grass weeds m^{-2}), the CPWC was reduced to a 4 weeks period in cotton with 53 cm rows, while the CPWC was 6 to 12 weeks in cotton rows spaced 106 cm apart (Rogers *et al.,* 1976). The critical period of cotton-weed competition was found as 15-60 DAS (Prabhu, 2010). The cotton field must be reserved weed-free during 6-8 weeks after sowing (Al-Khalidi, 2014). Weed infestation is considered one of the risk factors in cotton production (Nadeem *et al.*, 2013). Since cotton grows very slowly at the early growth stage it is very less competitive with weeds (Oad *et al.*, 2017). Weed infestation reduces the production of seed cotton by 20% to 30% and may exceed 80% in extreme cases (Prabhu *et al.,* 2012). Average reduction in cotton yield due to weed infestation is ranging from 33% to 50% and in some cases weed causes complete crop crash (Makhan and Voecodin, 1984). Weeds are considered a serious threat in cotton production, reducing yield and quality of fiber, harboring insects and disease organisms, harming human health, damaging irrigation systems, and depreciating land values (Douti *et al.,* 1997; Cheema *et al.,* 2008). Weed consistency is also impaired the fiber quality of cotton (Jabran, 2016). Plant height, sympodia and total bolls per plant were reduced in cotton grown in narrow row spacing. In most cases, cotton grown in narrow rows had lint yields equal to or higher than those attained in the 70 cm spacing (Jahedi *et al.,* 2013).

Conclusion

Planting spacing had tremendous influence on upland cotton plant growth, phenology, yield components and yield, and also weed growth. The spacing 90 cm × 30 cm was the optimum one for obtaining highest cotton yield and any spacing closer or wider than that resulted in yield reduction. But, in case of weed growth, the closer spacing the lower the weed density and dry matter.

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