IMPROVING YIELD AND FIBRE QUALITY OF NEW COTTON VARIETIES THROUGH FERTILIZER MANAGEMENT AND SPACING

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CERTIFICATE

This is to certify that, the thesis entitled " ***Improving yield and fibre quality of new cotton varieties through fertilizer management and spacing"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree* ***DOCTOR OF PHILOSOPHY (Ph. D) IN AGRONOMY****, embodies the results of a piece of bona fide research work carried out by Md. Mominul Islam, Registration number:11-04675 under my supervision and guideline. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of the investigation has duly been acknowledged.

Dated:
Dhaka, Bangladesh

(Prof. Dr. A. K. M. Ruhul Amin)
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DEDICATED

TO

MY LATE ELDER BROTHER

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IMPROVING YIELD AND FIBRE QUALITY OF NEW COTTON VARIETIES THROUGH FERTILIZER MANAGEMENT AND SPACING

ABSTRACT

The research study comprising five experiments were carried out at Cotton Research, Training and Seed Multiplication Farm, Sreepur, Gazipur during the cotton growing season (July – February) of 2015 - 2016, 2016 - 2017 and 2017 – 2018 with a view to investigate the yield and fiber quality improvement of newly released three inbred cotton varieties (CB-13, CB-14,and CB-12} by using different levels of fertilizer and plant spacing. The results revealed that, the variety CB-14 was found superior among the tested three varieties in respect of producing maximum bolls plant^{-1}, single boll weight, seed cotton yield, staple length and staple strength, and lowest micronaire value in all the years. Improving cotton yield and fibre quality through fertilizer management, was observed that yield and fibre quality decreased under excessive higher fertilizer doses in experiment 3. Maximum number of bolls plant^{-1} (22.99), single boll weight (5.45 g), seed cotton yield (2891 kg ha^{-1}) and minimum micronaire value (4.21 µg/inch) were recorded when the crops were grown using 75% higher dose of fertilizer than recommendated dose of fertilizer (RDF) in experiment 5 but in the case of fibre quality, 50 % higher dose than RDF produced maximum staple length (30.98 mm) and uniformity ratio (84.72 %) were recorded in experiment 5. It was also observed that yield contributing characters and fibre quality attributes increased with the wider spacing except the seed cotton yield, where higher seed cotton yield 3414 and 3325 kg ha^{-1}, respectively were observed with intermediate spacings of 60 × 30 cm and 75 × 30 cm found in experiment 4. Higher doses of fertilizer with closer spacing 45 × 30 cm preformed the highest seed cotton yield (3099 kg ha^{-1}) observed in experiment 5. Maximum seed cotton yield, gross margin and benefit cost ratio were recorded with 75% higher than RDF × (45× 30 cm) spacing in all the tested varieties. For economic point of view, it can be concluded that 75% higher dose than RDF and the 45 × 30 cm spacing was found more profitable for all the cotton varieties under study..

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LIST OF ABBREVIATION

Abbreviation	Full name
%	
AEZ	Agro-Ecological Zone
BBS	Bangladesh Bureau of Statistics
BTMA	Bangladesh Textile Mills Association
CDB	Cotton Development Bord
cm	Centimeter
DAP	Date After Planting
et al.	And others
etc.	Etcetera
FAO	Food and Agriculture Organization
ha	Hectare
kg	Kilogram
m	Meter
m^2	Spuare meter
mm	millimeter
MoP	Murate of Potash
No	Number
ºC	Degree Celsius
OP	Open Pollinated
RDF	Recommended Dose of Fertilizer
TSP	Triple Super Phosphate
viz,	Namely
SE	Standard error
Pp	Page number
P	Phosphorous
NS	Non significant
N	Nitrogen
K	Potassium
i.e	That is
ha^{-1}	per hectare
DAS	Days after sowing
cm^{-1}	Centimeter squares
g	Gram
No.	Number
S. No.	Serial Number
ml.	Mile liter
kg ha^{-1}	Kilograms per hectare
µm.	Micro meter
/	Per
@	at the rate of
%	Per cent
GOT	Ginning out turn
NFB	Node number of first fruiting branch
g tex^{-1}	Gram per tex
µg/inch	Microgram per inch
SRDI	Soil Resource Development Institute

Chapter 1
Introduction

CHAPTER 1

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) globally is an important fibre yielding crop. It is also an important industrial crop for supplying raw materials for textile industry. Belonging to the family Malvaceae, it is grown in tropical and subtropical regions of more than 80 countries of the world. Among the countries, China, USA, Russia, India, Brazil, Pakistan, Turkey, Egypt, Mexico and Sudan are accounted for 85-90% of the total cotton production. Cotton refers to those species of the genus *Gossypium* which bear spinnable seed coat fibres.

There are about 42 species of the genus *Gossypium* out of these only four species, viz. *Gossypium arboreum, G. herbaceum, G. hirsutum and G. barbadense are* cultivated and the rest are wild. The first two species are diploid (2n = 2x = 26) and are native of old world. Diploid cultivated species are also known as Desi cottons or Asiatic cottons because they are cultivated in Asian region. The last two of the above mentioned cultivated species are tetraploid (2n = 4x = 52) and are referred to as new world cottons. The *G. hirsutum* is known as American cotton or upland cotton and *G. barbadense i*s also referred to as Sea Island cotton or Egyptian cotton or Tanguish cotton. The *G. hirsutum* is the predominant species, which alone contributes about 90% to the global production.

Cotton is the major textile fibre used by man in the world and it plays a key role in economic and social welfare (Munro, 1994). Although it is grown primarily as a fibre crop, but after the lint, the long twisted unicellular hairs are removed by ginning, the seed can be crushed to extract vegetable oil and protein rich animal food (Mathews, 1989). Cotton seed cake, an industrial byproduct of cotton, is a valuable source of protein for ruminant cattle.

In Bangladesh, cotton is the most important fibre crop which provides raw materials to domestic cotton industry containing 450 spinning mills, 1476 weaving mills, more than 3 laks of handlooms, 802 fabric manufacturing mills:, 446knitting dyeing-printing-finishing mills, 244 and 5000 resistergarment industries (BTMA, 2018). Current domestic requirement of raw-cotton is 11.50 Million bales against production of 128,365 bales which accounts only 1-2 % of the yearly requirement (Anon., 2018). Bangladesh has to import a lot of cotton from abroad, which was 8.00 milion bales in the year 2018 (BTMA, 2018). Therefore, cotton industries of Bangladesh predominantly depend upon import where nearly 99% of the requirement is fulfilled by importing raw cotton from different foreign countries. In this context, it is imperative to increase cotton production in Bangladesh to feed the cotton industry, to save the hard earned foreign currency and to attain self sufficiency in raw cotton. Cotton production in Bangladesh may be increased either by horizontally or vertically or by both the ways. But in fact, it is almost impossible to increase cotton production horizontally because of severe competition to other crops in limited land. Yield enhancement of cotton by alternate may be possible because the productivity of cotton in Bangladesh is only 450 kg lint ha^{-1} against world average yield of 556 kg lint ha^{-1}. Higher yield of cotton may be achieved by developing or selecting appropriate variety especially suited to local ecological condition.

In any cropping system, selection of a cultivar is basic management decision (Nichols *et al.*, 2004) as cultivars perform better for one region may not perform equally at other regions (Freeland, *et al.*, 2010). Some cultivars adopt readily and perform well under changed conditions while the others fail to do so. While selecting a cultivar, different agronomic trait like yield potential, growth period and quality should be considered (Nichols *et al.*, 2004). Kakar *et al.* (2012) observed significant differences in yield, ginning out turn, micronaire and staple length for different cultivars. Muhammad (2001) reported variability among various cotton genotypes for environmental adaptability on the bases of yield, lint percentage and fibre quality. Afzal *et al*. (2002) reported significant differences in yield, boll weight, number of bolls per plant and plant height due to difference in genotypes. Different cotton genotypes behave differently for seed cotton yield and resistance against diseases like cotton leaf curl virus in different ecological conditions (Iqbal and Khan, 2010) due to different genetic makeup (Iqbal *et al.* 2011). Cotton fiber quality is mainly dictated by genetics of the cultivar however, environmental conditions and management practices also influence fiber quality (Subhan *et al.* 2001). Since there is not a single predominate cultivar adapted to all regions of cotton production, genotype-environment interaction is prevalent wherever cotton is produced. Cultivars vary in their structure which determines the optimum spacing required for cost effective yield.

Equally important, desired plant density is a paramount for obtaining high yield in cotton as lower plant density will be a wastage of resources while high plant density limits individual plant growth (Brodrick *et al*. 2013). The potential of any cultivar can only be realized if it is sown with proper spacing at optimum time. Proper plant density depends upon type of cultivar, environment and time of planting (Wang *et al*. 2004). Plant density directly influences the radiation interception, moisture availability, wind movement and humidity (Heitholt *et al*. 1992) that in turn affects the canopy height, branching pattern, fruiting behavior, crop maturity and yield. The field conditions that produce short stature plants can generally tolerate higher plant density without incurring significant yield reduction (Hake *et al*.1991). The number of fruiting structures (blooms, squares and bolls) and their location on the plant can change with plant density (Kerby *et al*.1990). Micinski *et al.*(1990) and Delaney *et al*.(1999) have been reported significant interactions between plant density and planting date. Early sown cotton under high plant density does not perform well for seed cotton production due to high foliage and fruit shedding (Iqbal *et al*. 2007) while, apositive relationship between plant density and plant height was reported by Siebert *et al*. (2006) who also observed inverse relation between plant density and main stem nodes perplant, days after planting to peak bloom, and boll retention. In dense plant population, increased light interception is offset by the ability of the leaves of the low density canopy to more efficiently utilize sunlight resulting in poor radiation use eficiency (Brodrick *et al*., 2013; Pettigrew *et al*. 2013).

Kasap and Killi (2004) evaluated cotton yield at three row spacings (60, 70 and 80 cm) and gained highest seed cotton yield at 60 cm row spacing. Reduced photosynthetic efficiency due to lower leaf nitrogen concentrations as a result of increased LAI in over populated field might be another reason for no added yield advantage for high plant density (Brodrick *et al*. 2013). Adequate plant density facilitates the efficient use of applied fertilizers and irrigation (Abbas, 2000).

Wang *et al.* (2011) suggested that crop growth habits should be considered in deciding target plant populations as lowest density reduced cotton growth and yield significantly in the columnar type cultivar but not in the bush type cultivar because bushy cultivar compensate low plant population better than the columnar type cultivar by increasing growth rate and reducing dry matter partitioning to stems. The recommendation regarding plant density varies with a number of factors such as field location, planting date, soil type and cotton cultivars (Silvertooth, 1999). Mostly, farmers maintain plant spacing and density according to their traditional methods of planting rather than cultivar requirement and hence do not obtain the high crop yield (Nadeem *et al*. 2010).

Besides lint yield, fibre quality such as fibre length, strength, elongation, uniformity index and micronaire are important as it add value to the raw cotton. The extended fruiting period of the cotton plant and the subsequent development cycle forces each boll to develop under different environmental conditions than other bolls on the same plant. Fibers from a single plant, single boll, and even a single seed will vary in length, strength and micronaire value. Plant genetics and environment provide the platform for both higher lint yields and fiber quality.

The primary reasons for the low productivity of cotton in Bangladesh are; cultivation of crops predominantly under rainfed condition, use of less efficient cultivars, predominance of pests on the crop and inadequate supply of nutrients, besides other reasons the important issue that needs to be addressed in crop productions is nutrient usage. Cotton, particularly hybrids being exhaustive, draw plenty of soil nutrients and thus under continuous cropping pattern nutrient management assumes importance.

Nutrient recommendation varies with crop response, soil condition and hence targeted yield. Now a days cotton are being popularized among the cotton growers because of protection from bollworm menace at reduce cost besides being environmental safe. Hybrid cotton is an exhaustive crop and needs heavy fertilization to get higher yield. Further, nutrient recommendation varies with crop response, soil condition, genotype and climatic conditions (Patil *et al.* 2009). Newly release cotton variety (CB-13, CB-14) needs optimization of its fertilizer dose for higher yield.

Different varieties respond differently to varying different doses of fertilizer. In the content of yield potential some improved varieties are comparable to hybrids. The seed cost of hybrids which can not be affordable to marginal farmers. Variety CB-12, CB-13, CB-14 developed by Cotton Research Farm, Jadishpur, Jessere during 2011-14 which has maximum yield potential (2.5-3.0 ton ha^{-1}) and better ginning percentage (40-42). Newly developed variety CB-12 also needs optimization of its fertilizer dose for higher yield.

Nutrient management which advocates need based supply of nutrients ensures application of nutrients at right time in desired quantities by the crop for obtaining target yields. The crop yields under average management and the crop has the potential to produce still higher yield levels under improved management situation. Therefore, the present investigation was planned to study the performance of three inbred cotton varieties as influenced by nutrient management approach under varying plant spacings to realize maximum yield during the growing season of 2015-18 with the following objectives:

1. To optimize the fertilizer doses for the highest yield of cotton varieties under study.
2. To determine the effect of row spacing on growth, yield, earliness and quality traits of cotton.
3. To determine the effect of nutrient management, plant density and their interactive effect on seed cotton yield, its components, early crop maturity and lint quality for the newly developed cotton varieties.

Chapter 2
Review of Literature

CHAPTER-2

REVIEW OF LITERATURE

Five field experiment werecarried out on the performance of 3 newly released cotton inbred varieties under different nutrient levels and plant spacing at the Central Cotton Research Farm,Sreepur, Gazipur during the 2015-16, 2016-17 and 2017-18 in cotton growing season. The relevant informations available in home and abroad on the subject are reviewed in this chapter.

2.1 Variety selection

Variety selection is a key management component in any cropping system. The yield and fiber quality potential of cotton at harvest begin with the selection of genotype. The use of improved cultivars is an important factor to enhance cotton production.

A study was carried out by Dhamayanathi *et al*. (2010) with twenty five *Gossypium barbadense* L. genotypes to obtain information on genetic variability, heritability and genetic advance for seed cotton yield and its yield attributes. Significant differences were observed for characters among genotypes. High genetic differences were recorded for nodes per plant, sympodia, bolls as well as fruiting points per plant, seed cotton yield, lint index indicating ample scope for genetic improvement of these characters through selection. Results also revealed high heritability coupled with high genetic advance for yield and most of the yield components as well as fibre quality traits. Sympodia per plant, fruiting point per plant, number of nodes per plant, number of bolls per plant, and lint index were positively correlated with seed cotton yield per plant and appeared to be interrelated with each other.

Tuteja *et al*. (2006) reported wide differences existed in productivity potential and plant type of cotton. Generally, high yield potential is a predominant consideration but maturity, plant size and fibre properties are also important factors for genotype selection. Less vigorous genotypes are more susceptible to stresses caused by inadequate moisture, cool or high temperature, thrips feeding, seedling diseases, nematodes and other pests.

Singh *et al.* (2006) revealed that biomass accumulation was significantly lower in all *Bt*-hybrids as compared to non–*Bt* cotton hybrids. In fact better retention of early fruiting parts in

Bt hybrids could have led to more efficient translocation of photosynthates into reproductive fruiting bodies and consequently more overall growth attained got reduced in *Bt*as compared to non- *Bt*.

Kudachikar and Janagoudar (2001) reported that high-yielding genotypes were characterized by having low leaf area and high total dry matter content, leaf efficiency, harvest index, and boll number.

Sudha *et al.* (2011) reported that *Bt* cotton genotypes recorded higher total number of bolls per plant compared to non- *Bt* hybrid. Total number of bolls per plant was significantly higher in RCH-708 *Bt* (37.95) compared to all other cotton genotypes.

2.1.1 Variety and agronomic parameters

Pujer *et al*. (2014) evaluated Sixty eight diverse genotypes of American cotton *Gossypium hirsutum* L. for 13 quantitative and fibre quality traits. The variability studies indicated that high PCV and GCV was observed in case of seed cotton yield per plant and number of bolls per plant while moderate PCV and GCV was observed in case of days to first flower, plant height and boll weight. Seed cotton yield per plant, days to first flower, plant height, number of bolls per plant and boll weight showed high heritability with high genetic advance over mean. The correlation study revealed that seed cotton yield was found to be positively and significantly correlated with traits like days to first flower, plant height, number of monopodial branches, number of bolls per plant, seed index, lint index, ginning out turn, and uniformity ratio, where as it had negative association with boll weight, 2.5% span length, fibre fineness, and bundle strength. Path analysis revealed that days to first flower, number of monopodial branches, number of bolls/plant, boll weight, seed index, lint index, ginning out turn and uniformity ratio showed positive direct effect on seed cotton yield. Hence selection for these traits would be quite effective to improve the seed cotton yield in upland cotton.

Vinodhana *et al*. (2013) estimated variability, correlation and path coefficient analysis by using eight lines and seven testers and their 56 F1s made with the parents of *G. hirsutum* and *G. barbadense* genotypes of diverse origin. High heritability coupled with high genetic advance was noticed for the characters seed yield per plant, number of bolls per plant indicating the presence of additive gene action in the expression of these traits. Correlation studies revealed that seed cotton yield had positive significant correlation with number of bolls per plant and fibre length. The value of genotypic correlation coefficient was higher than phenotypic correlation coefficient, which denoted that there was strong association between these two characters genetically, but the phenotypic value was lessened by the significant interaction of environment. Number of bolls per plant had significant positive association with plant height and fibre length. The positive significant correlation was observed for seed index, lint index and micronaire value with boll weight at genotypic and phenotypic level. Thus for increasing seed cotton yield in cotton due emphasis should be given to number of bolls per plant, boll weight (g), seed index, lint index and fibre length (mm) characters.

Nalwade *et al.* (2013) recorded the number of sympodia at harvest time in different hybrids. Akka BG II hybrid showed maximum number of sympodia per plant (27.42) among all hybrids and the hybrid Bramha *Bt* showed minimum sympodia (20.04).

Alse and Jadhav (2011) reported that the sympodia and green bolls per plant were significantly more in Dhroov *Bt* than Dhroov non *Bt*, Kashinath *Bt* and Nathbaba non *Bt.* Apparently better retention of early formed fruiting parts in Dhroov *Bt* has led to more efficient translocation of photosynthates into the reproductive sink component and consequently, the overall growth attainment got reduced in it as compared to other cultivars.

Lekharam and Shastry (2011) found that *Bt* cotton hybrids which possessed higher sympodia, bolls per plant and also the boll weight which contributed more towards seed cotton yield.

Bhongle and Patil (2011) reported that the numbers of sympodia per plant varied from 14.2 to 18.0 in undescriptive *Bt* cotton hybrids. Maximum number of sympodia per plant were recorded by the hybrid NECH- 14 *Bt* (18.9), followed by MRC 6301 *Bt*(18.8), while minimum number was recorded in the hybrid RCH- 138 *Bt* (14.2).

Khan *et al.* (2009) reported that the genetic variability for plant height among different upland cotton cultivars was present and mentioned that plant height was positively correlated with bolls and seed cotton yield if lodging did not occur. Among the yield components bolls per plant is the key independent component and play prime role in managing seed cotton yield. Number of open boll had the highest direct effect on lint yield per plant.

Giri *et al.* (2008) reported *Bt*cotton hybrid NCS-145 to record significantly higher number of sympodia plant^{-1} (20.63) and seed cotton yield per plant (166 gm) as against RCH-2 *Bt* hybrid which recorded lower sympodia per plant (16.7) and seed cotton yield (127 gm).

Khadi *et al.* (2008) reported that increase in lint yield was because of increased boll weight and boll number, which clearly indicated that *Bt*gene offers protection against boll worm damage and which in turn contributes to the development of a number of healthy bolls.

Meena *et al*. (2007) evaluated different upland cotton cultivars for yield and other economic traits and observed significant variations. This genetic analysis suggested that plant height, sympodia per plant, staple length and fibre strength could be improved through individual plant selection, while exploitionofheterosis would be necessary to attain the genetic advancement in monopodia per plant, number of bolls, lint percentage and seed cotton yield.

Mayee *et al.* (2004) reported the difference among *Bt*hybrids for yield contributing characters as well as fiber properties. Maximum yield of 2.13 t ha^{-1} was recorded by MECH 162 (*Bt*) followed by MECH 184 (*Bt*). The yield of MECH 12 (*Bt*) was only 1.77 t ha^{-1} All the three non *Bt* cotton counter parts attributed to higher retention of bolls from the first flush of flowers that resulted to lesser boll damage.

Sankarnarayanan *et al.* (2004) reported *Bt* cotton hybrid MECH-162 as compared to non-*Bt*hybrids to possess higher seed cotton yield, number of sympodial branches per plant and number of bolls per plant.

Nehra *et al*. (2004) observed that the *Bt* cotton hybrid produced significantly higher seed cotton yield in comparison to their respective non-*Bt* hybrids and local check. This increase in seed cotton yield has been attributed to more number of bolls per plant and boll weight per plant.

Ahmad *et al*. (2003) reported that monopodia per plant, number of bolls, lint percentage and seed cotton yield possesses low narrow sense heritability which was due to presence of dominant gene effects.

Channaveeraiah (1983) observed that for selection of high yielding genotypes under rainfed condition, cultivars are more preferred which posses moderate duration, moderate LAI, LAD (80-85 days) and with medium size of monopodial branches.

Worley *et al*.1976) reported that variability in yield and yield attributes among genotypes are common in cotton. Seed cotton yield per unit area is the function of yield of individual plant and population densities. Lint yield of upland cotton is determined by a number of individual components (Yield components such as the plant height, number of sympodia per plant, node of first fruiting branch, days to first flowering, number of bolls per plant, boll weight, days to 50% boll split, and seed index differed significantly in the cotton genotypes).

2.1.2 Variety and earliness parameters

Aziz *et al.* (2011) recorded the number of days required for boll bursting in six cotton genotypes (NAM-77, C-2602, BC-0342, BC-0406, CB-10 and CB-9) with respect of three different population densities viz. 90 × 45 cm (24692 plants ha-1), 75 × 45 cm (29630 plants ha^{-1}) and 60 × 45 cm (37037 plants ha^{-1}). Results indicated interaction of C-2602 recorded minimum of 97.0 days for boll splitting in 60 × 45 cm, where as CB-9 recorded maximum of 129.7 days for boll splitting in 90 ×45 cm spacing.

Ban *et al.* (2015) identified the effect of crop phenology of cotton (*Gossypium hirsutum* L.) genotypes as influenced by different environments. They recorded the number of days required for 50% boll burst in normal sowing (11 July) and late sowing (2 August) in different cotton genotypes under 120 x 45 cm spacing. Non–*Bt* hybrid, LHH-144 reported significantly maximum days (130.5) for 50 % boll bursting, while G. Cot Hy.-8 BG II was reported as earlier, took significantly less days (72.5) for 50 % boll bursting.

Singh *et al.* (2011) evaluated twenty cotton genotypes to study early maturity in cotton- wheat cropping system. Duration of maturity ranged from 130 to 180 days. The genotype AAH-1 reached maturity early (130 days) and Pusa 8-6 genotype reached to maturity late (185 days).

Saleem *et al.* (2009) conducted a field experiment with three cotton cultivars viz., NIAB-111, CIM-496 and FH-901 and three row spacings viz., 60 cm (5.55 plants m^{-2}), 75 cm (4.44 plants m^{-2}) and 90 cm (3.70 plants m^{-2}). Results showed that number of days from planting to first floral bud initiation (squaring) were significantly affected by row spacing while varieties have no significant effect on this character. 35.3 days were recorded in 90 cm row space as against 34.4 days with narrow rows of 60 cm.

Tomar and Singh (1992) crossing 20 genotypes with three well adapted varieties (Lohit, Shyamali, and G-27) as testers (male) in a line x tester mating design. 60 hybrids and their 23 parents were planted in randomized block design with three replications. The number of days recorded in all crosses for flower initiation varied between of 66 – 81 days Shymali recorded 66 days, while RG-8 x Lohit cross breed recorded 81 days.

2.1.3 Variety and quality parameters

Meena *et al*. (2007) mentioned that physiological and morphological differences were observed among cotton cultivars in relation to fibre quality. Growing cotton under non-irrigated conditions resulted in the production of shorted and weaker fibre with reduced micronaire. The fibre properties of cultivars were inconsistently affected by non-irrigated and irrigated conditions indicating variability inherent in cotton fibre.

Iqbal *et al*. (2006) observed the traits ginning out turn percentage (GOT) and staple length had the direct negative effect on seed cotton yield.

Reddy *et al*. (2005) reported that genotypic and phenotypic ratio was high for 2.5% span length and bundle strength, indicating that these traits were not much influenced by the environment. Heritability estimates were high for ginning percentage, span length, bundle strength and seed cotton yield, indicating the amenability of these traits in the selection process. High heritability coupled with high genetic advance for ginning percentage, span length, bundle strength and seed cotton yield indicates the operation of additive gene action in the inheritance of these traits.

Mert *et al*. (2005) reported that, physiological and morphological differences were observed among cotton cultivars in relation to fibre quality. It was found that growing cotton under non-irrigated conditions resulted in the production of shorter and weaker fibre with reduced micronaire. They also mentioned that the fibre properties of cultivars were inconsistently affected by non-irrigated and irrigated conditions indicating variability inherent in cotton fibre.

Mishra *et al*. 2005) reported that fibre elongation and fibre dry weight were closely associated with species and varietal differences. The rate elongation was not uniform over the entire elongation period. The dry weight (secondary thickening) started only after elongation ceased and continued to increase until opened.

Murtaza *et al*. (2004) determined the genetic variation in 8 upland cotton cultivars for fibre strength and staple length. They revealed that the gene action governing fibre strength and staple length in cotton. Additive dominance effects controlled fibre strength, whereas epistatic effects controlled staple length in cotton. In other studied Segarra and Gannaway (1994) established that micronaire and fibre strength are to some extent as a function of cultivar difference.

Green and Culp (1990) reported on the association of lint yield in upland cotton and fibre quality. They reported a negative association between lint yield per unit land area and fibre quality, especially between yield and fibre bundle strength.

Miller (1965) demonstrated strong negative association between total lint yield and fibre quality, while positive association was noted for total lint yield and lint percentage, bolls per plant, micronaire, and fiber elongation. Negative correlations were reported for total lint yield and boll weight, seed index, fiber length and fibre strength.

It may be understood from the above reviews that different environment significantly influences the growth, development and yield of cotton. On the other hand, genotypes itself as an important factor for economical cotton production and different traits played a major role in the improvement of cotton yield.

2.2 Plant spacing

Darawsheh *et al.* (2009) suggested that narrow row spacing system exhibits a dynamic to increase seed-cotton yield and may constitute an alternative method towide row spacing under regular or suitable weather conditions while in rainy season there was no yield difference or even yield was reduced at high plant density.

Wright *et al*. (2008) reported that, advantage of closer row spacing and elevated plant densities is more rapid canopy closure, that in turn reduces the weed competition increases light interception in early season, decreases soil water evaporation and can potentially increase cotton yield.

Zhang *et al*. (2006) reported that, plant population is a production factor which affects canopy structure, canopy photosynthesis and yield formation by exploiting plant photosphere and rhizosphere.

Ogola *et al*. (2006) reported that, in a fertile soil, wide spacing (inter and intra row) can lead to extensive growth of fruiting branches with a good setting of early bolls and highly developed monopodial and sympodial branches and.Contrary, close spacing may enhance competition for nutrients, moisture and even inducepests build up in the canopy thus leading to decrease in seed cotton yield.

Siebert *et al*. (2006) reported that maximizing inputs for cotton production under optimum growing conditions plants in dense plant population often become excessively tall and vegetative as a larger fraction of photo assimilates were directed to vegetative growth rather than reproductive growth and leading to reduced yield.

Khan *et al.* (2005) concluded that plant spacing of 23 cm gave better yield than 30 and 38 cm spacing in cotton

Iqbal *et al*. (2005) concluded that plant height should be kept less than 76 cm to avoid high humidity in very narrow cotton for efficient control of insect pest attack, good retention and to save boll from rottening.

Oad *et al*. (2002) found that dense population stand, the plants are subjected to severe competition from an early stage due to which very few or no vegetative branches formed, fruiting on set delays, and reduced bolls per plant than in widely spaced cotton.

Soomro *et al*. (2000) conducted an experiment on cotton Cultivars CRIS-9, CRIS-19, CRIS-82 and CRIS-134 and found higher yield at 15 cm and 22 cm plant spacing than 30, 37 and 45 cm spacings.

Silvertooth (1999a) reported that, crop canopy can be manipulated by row spacing and population adjustment for improving yields, production efficiencies and profits. Establishment of an acceptable population is significantly influenced by varied regions, agroclimatic conditions, genotype and grower preference.

Silvertooth *et al.*(1999b).observed that, Erect type plants required less space so perform better at high density while plants having bushy growth habits require more space and resultantly produced potential yield atlow plant density. Maximum yield can be obtained by maintaining optimum plant population according to plant morphological characteristics.

Singh. *et al*. (1997) obtained non significant response of row spacing on five cultivars in one year while in second year the highest seed cotton yield was under wider spacing by a medium compact cultivar RAS-1005.

Hake *et al*. (1991) concluded that plant spacing can altered plant architecture, boll distribution and crop maturity by manipulating soil water removal, radiation interception, humidity and wind movement.

2.2.1 Spacing and agronomic parameters

Rao *et al.* (2015) conducted field experiment to study the response of translated *Bt* cotton to different plant geometry. He worked on methods of sowing with varied plant densities. Transplanting at 90 x 45 cm, 90 x 60 cm, 90 x 90 cm, 120 x 45 cm and 120 x 60 cm and dibbling at 90 x 60 cm and 120 x 45 cm spacings. The cotton variety MRC-7351 (Mahyco) BG-II was used.Number of bolls per plant varied from 25.73-50.51. Maximum number of bolls (50.51) per plant was recorded in the treatment of transplanting 90 x 90 cm spacing and minimum number (25.73) was in treatment of dibbling 120 x 45 cm. Seed cotton yield (g) per plant varied from 109.47-211.82. Maximum seed cotton yield (211.82 g) per plant was recorded in the treatment of transplanting 90 x 90 cm spacing and minimum number (109.47 g) was in treatment of dibbling 120 x 45 cm. Seed cotton yield kg ha^{-1} varied from 2095-2828. Maximum seed cotton yield (2828 kg ha^{-1}) was recorded in the treatment of transplanting 90 x 60 cm spacing and minimum seed cotton yield (2095 kg ha^{-1}) was in treatment of dibbling 120 x 45 cm.

Jadhav *et al.* (2015) studied the influence of plant geometry on performance of cotton hybrid Bunny *Bt* (NCS-145 Bt) under irrigated condition. The treatments of plant geometry included S1: 90 x 60 cm, S2: 120 x 45 cm, S3: 150 x 36 cm and S4: 180 x 30 cm. Boll weight and seed cotton yield was significantly influenced by plant geometries. Maximum boll weight (3.48 g) was recorded in wider spacing of 150 x 36 cm followed by (3.28 g) in 120 x 45 cm and the minimum boll weight (3.10 g) was recorded in 180 x 30 cm. Maximum mean seed cotton yield 36.36 q ha^{-1} was recorded in wider spacing of 150 x 36 cm followed by 34.11 q ha-1 in 120 x 45 cm and 31.11 q ha^{-1} in 180 x 30 cm.

Singh *et al.* (2015) studied the effect of agronomic manipulations on growth, yield attributes and seed cotton yield of American cotton under semi-arid conditions. Performance of three hirsutum genotypes (Bihani251, CSH3129 and LH2076) in two plant geometries (67.5 x 60 cm and 67.5 x 75 cm) was evaluated. Findings showed a negative correlation of bolls per plant,boll weight, seed cotton yield and lint yield with plant geometries.Maximum number bolls (44.6) were recorded at closer spacing of 67.5 x 60 cm and minimum number of bolls (40.9) with wider spacing of 67.5 x 75 cm. Maximum boll weight (3.17 g) was recorded at closer spacing of 67.5 x 60 cm and minimum boll weight (3.12 g) with wider spacing of 67.5 x 75 cm. Maximum seed cotton yield (2258.7 kg ha-1) was recorded at closer spacing of 67.5 x 60 cm and minimum seed cotton yield (1958.1 kg ha-1) with wider spacing of 67.5 x 75 cm. Maximum lint yield (777.8 kg ha^{-1}) was recorded at closer spacing of 67.5 x 60 cm and minimum lint yield (684.6 kg ha^{-1}) with wider spacing of 67.5 x 75 cm.

Ahmed *et al.* (2014) conducted a field experiment to compare the seed cotton yield and its components in *Gossypium hirsutum* L. on inter plant densities. Number of bolls per plant is an important yield contributing parameter. Number of bolls per plant increased with increasing plant spacing. Maximum number of bolls per plant (47) was recorded in case of wider plant spacing of 60 cm against the minimum (14) in closer plant spacing of 15 cm of VH-306. Similarly, VH-311 recorded maximum number of bolls per plant (43) in wider plant spacing of 60 cm. Increase in number of bolls per plant with increased plant spacing can be attributed to more availability of space and less intra plant competition.

Kumara *et al.* (2014) reported a positive response on growth and yield of *Bt* cotton hybrids with increased planting density. Treatments consisted of four levels of spacing (120 x 120 cm, 120 x 90 cm, 90 x 60 cm and 90 x 45 cm) with two *Bt* cotton hybrids viz., Rasi-530 *Bt* (H x H) and MRC-6918 *Bt* (H x B). Maximum number of bolls per plant was recorded (83.7) at wider spacing of 120 x 120 cm followed by 120 x 90 cm (76.0) and the minimum bolls (38.6) were recorded with closer spacing of 90 x 45 cm.

Singh *et al.* (2014) reported that the monopodial branches per plant in *Bt* cotton as influenced by different intercropping systems in relation to planting geometries to vary from 1.5 to 3.0. The results showed that maximum plant height (107.7 cm) was recorded in *Bt*cotton + summer mungbean (1:1) in 67.5 x 75 cm, while the minimum plant height (77.8 cm) was recorded in *Bt* cotton + fodder bajra (1:1) in 67.5 x 75 cm spacing. The maximum number of monopodial branches per plant (3.0 plant-1) in *Bt* cotton were recorded in the treatment of *Bt* cotton + long melon (1:1) at 67.5 x 75 cm, minimum number of monopodial branches per plant (1.5 plant^{-1}) in *Bt* cotton were recorded in the treatment of *Bt* cotton + fodder bajra (1:2) at 135 x 37.5 cm spacing,maximum number of sympodial branches per plant (21.4) in *Bt* cotton + long melon intercropping system at 67.5 x 75 cm and minimum number of sympodial branches per plant (12.3) in *Bt* cotton + fodder bajra intercropping system at 135 x 37.5 cm.

Venugopalan *et al.* (2014) reported 25-30% high yield over the recommended spacing on shallow to medium deep soils under rainfed condition using appropriate genotypes like PKV 081, NH-615, SURAJ, KC3, Anjali, F2383 and ADB-39 at high densities viz., 1.5 to 2.5 lakh plants ha-1 at 45 or 60 cm spacing depending upon the soil type.

Deotalu *et al.* (2013) recorded a positive correlation of the plant height, number of sympodial branches per plant with spacing. The variety NDLH 1938 recorded maximum plant height (75.27 cm) followed by AKH 9916 (74.71 cm) and minimum plant height was observed in BS 79 (62.78 cm) under 60 x 30 cm spacing. The number of sympodia per plant was 9.53 in closer spacing of 60 x 30 cm and maximum of 10.79 in wider spacing of 60 x 45 cm.

Ganvir *et al.* (2013) revealed the effect of spacings on plant height,number of monopodial branches per plant and number of sympodial branches per plant with spacing. Maximum plant height of 96.45 cm was observed in 60 x 10 cm, medium plant height of 87.96 cm was observed in 60 x 15 cm spacing and minimum plant height of 79.22 cm was recorded in 60 x 30 cm Maximum monopodial branches per plant were recorded under lower plant densities. Maximum number of monopodial branches per plant (2.08) was recorded in 60 x 30 cm (55,555 plants ha-1) spacing and the minimum number of monopodia per plant (1.37) was recorded in 60 x 10 cm (1,66,666 plants ha^{-1}) spacing. Maximum number of sympodia per plant (11.18) was recorded in wider spacing of 60 x 30 cm, as compared to narrow spacing of 60 x 15 cm (9.09) and in ultra narrow spacing of 60 x 10 cm (8.06).

Nalwade *et al.* (2013) reported the plant height varied from 97.26 to 106.93 cm in undescriptive cultivars. The hybrid Akka *Bt* recorded maximum plant height (106.93) followed by MRC 7301 *Bt* (101.39 cm) and Bramha *Bt* (107 cm). He identified the numbers of monopodial branches per plant in *Bt*cotton cultivars to vary from 2.40 to 3.40. Akka *Bt* recorded maximum number of monopodia per plant (3.40) followed by Super Maruti *Bt* (2.90) and minimum number in Bramha *Bt* (2.40) in 90 x 45 cm spacing.

Singh *et al.* (2012) studied the seed cotton yield, growth and yield contributing characters of new *Bt* cotton hybrids under varied agronomic manipulations. The treatments comprised three *Bt* cotton hybrids (MRC 7361, Bioseed 6488 and RCH 134), two plant geometries (67.5 x 75 cm & 67.5 x 90 cm). Findings showed a positive correlation of number of boll, boll weight, seed cotton yield, lint yield with plant geometries. Maximum number of bolls per plant (55.5), boll weight (4.71 g), seed cotton yield (2387 kg ha^{-1}), lint yield (823.3 kg ha^{-1}) was recorded at wider spacing of 67.5 x 90 cm and minimum seed cotton yield (2218 kg ha^{-1}) with closer spacing of 67.5 x 75 cm.

Pendharkar *et al.* (2010) reported that plant height was positively correlated with the spacing. Maximum plant height of 130 cm was observed in 180 x 30 cm spacing while, minimum of 123 cm was observed in 90 x 60 cm spacing,maximum number of monopodial branches per plant with closer spacing of 90 x 60 cm (1.69) and minimum number of monopodia per plant was reported with wider spacing of 180 x 30 cm (1.42). Maximum number of sympodial branches per plant (19.99) was recorded in closer spacing of 90 x 60 cm and the minimum number of sympodial branches per plant (18.23) with wider spacing of 180 x 30 cm.

Bhalerao and Gaikwad (2010) reported that the plant height differed significantly with different plant spacings. Maximum plant height of 83.5 cm was recorded with narrow spacing of 90 x 60 cm and the minimum plant height of 82.1 cm was recorded with wider spacing of 90 x 90 cm.

Rajakumar and Gurumurthy (2008) reported lowest plant density of 9,259 plants ha^{-1} recorded the maximum number of bolls per plant (32.87) compared to high plant density of 13,888 plants ha^{-1}, which registered 30.78 bolls per plant. Yield was reduced significantly in wider spacing (31.74 m^{-2}) than the closer spacing (43.97 m^{-2}) when compared on unit area basis. Direct seeding recorded a boll setting percentage of 30.29 as against 33.43 per cent under planting through poly bag seedlings.

2.2.2 Spacing and earliness parameters

Vineela *et al.* (2013) reported the number of days for 50 % flowering in American cotton (*Gossypium hirsutum* L.). Average number of days required for 50 % flowering in cotton genotypes was 55.17 days with the spacing of 90 x 60 cm.

Aziz *et al.* (2011) recorded the number of days required for boll bursting in six cotton genotypes (NAM-77, C-2602, BC-0342, BC-0406, CB-10 and CB-9) with respect of three different population densities viz. 90 × 45 cm (24692 plants ha-1), 75 × 45 cm (29630 plants ha^{-1}) and 60 × 45 cm (37037 plants ha^{-1}). Results indicated interaction. C-2602 recorded minimum of 97.0 days for boll splitting in 60 × 45 cm, where as CB-9 recorded maximum of 129.7 days for boll splitting in 90 ×45 cm spacing. . Minimum number of days (55.33) for flowering was reported with the spacing of 60 × 45 cm in the genotype C-2602 and was identical to Namangan-77 and the maximum number of days (65.6) was reported with 60 ×45 cm in CB-9.

Saleem *et al.* (2009) conducted a field experiment to determine the effect of row spacing on earliness in cotton. Three cotton cultivars viz., NIAB-111, CIM-496 and FH-901 were grown with three row spacings of 60, 75 and 90 cm. They recorded the number of days taken from planting to appearance of first flower.Results showed that the varieties and row spacing significantly affected the number of days taken for appearance of ist squaring and first flowering. Maximum of 46.1 days were recorded with 90 cm row spacing and minimum of 43.7 days with 60 cm spacing. Varieties have no significant effect on squaring and flowering. But varieties and row spacing significantly affected the number of days required for appearance of first boll splitting. Maximum of 89.9 days were recorded with 90 cm row spacing and minimum of 86.7 days were reported with 60 cm row spacing. NIAB-III recorded significantly less days (86.5) for the appearance of first boll split than CIM-496 (88.5) and FH-901 (89.8).

Gerik *et al*. (1999).reported that crop maturity is an important consideration when making management decisions.The effect of plant density on earliness may be greater and of more economic importance than yield. The use of narrow-row, high plant-density systems for cotton production was originally conceived as a mean to enhance earliness and to decrease production costs

2.2.3 Spacing and quality parameters

Darawsheh (2010) conducted a field study to addressed the response of fiber quality parameters to the interaction influences of cultivation system and irrigation regime. Three row spacings, conventional (CR), narrow (NR) and ultra narrow (UNR), on eight fiber properties were studied under limited and normal irrigation regimes during two growing seasons. The decrease of row spacing significantly decreased some fiber quality parameters but differed between normal and limited irrigation regimes. The effect of decreased row spacing on most fiber properties was less negative under the limited irrigation regime than the normal one and in this case the significant differences between row spacingswere mainly between CR and UNR. Of the fiber properties investigated, row spacing and irrigation regime influenced most the micronaire readings and less the fiber elongation. The effect of year was significant on six out of eight fiber parameters. Interactions of year × row spacing, year × irrigation and row spacing × irrigation were significant but variable among fiber properties.

Darawsheh *et.al.* (2009) conducted a field study to compared three cropping systems in terms of conventional row (CR; 96 cm 16 plantsm^{-2}), narrow row high plant density (NRHPD; 48 cm, 32 plants m^{-2}) and narrow row low plant density (NRLPD; 16 plants m^{-2}). From the examined lint properties, micronaire and 50% span length were negatively affected ($P \leq 0.05$) by high plant density in narrow row. The other lint quality parameters were not consistently affected by plant density and row spacing.

Ali *et al.* (2014) conducted a field study to investigate the effects of sowing dates, plant spacing and their interactions on seed cotton yield and various fiber quality traits of cotton during 2006-07 at Adaptive Research Station, Rahim Yar Khan, Punjab Pakistan. The cultivar BH-160 was sown on different dates (May 15, June 1, June 15, and June 30), with three plant populations (87822, 58548, 43911 plants ha^{-1}), maintaining the plant spacing of 15, 22.5 and 30 cm respectively in 75 cm apart rows. The results revealed that qualitative traits like ginning out turn, fiber length; fineness and strength were non-significantly affected by different plant spacing treatments and significantly affected by sowing times and their interactions with spacing.

Singh *et al.* (2017) reported in their study that, application of 125% RDF + 25% less than normal spacing + foliar spray of 2% urea and 2% DAP produced significantly highest growth characters *viz.*, plant height at 30, 60, 90 and 150 days after sowing, number of monopopdia and sympodia, fresh and dry weight plant^{-1}, yield attributes viz., number of bolls m^{-2}, number of bolls/plant and boll weight, yield *viz.*,seed cotton, lint, seed and stick, quality characters *viz.*, ginning out tern, span length, micronaire value, uniformity ratio and fiber strength

Clawson *et al*. (2006) found that lint turn out was higher for narrow rows cotton or higher plant density.

Darawsheh *et al*. (2009) reported that lint percentage significantly reduced by increasing plant stands or by narrow rows. Ali *et al*. (2009) reported that GOT was not affected either by inter or intrarow spacing.

Darawsheh *et al*. (2009) found non significant difference for lint percentage under regular or suitable weather conditions but in rainy year lint percentage decreased by increasing plant density independent of row spacing. Generally, plant spacing or density did not affect fibre quality

Darawsheh *et al*. (2009) observed decrease micronaire, fiber fineness and fiber length in response to increased plant population.

Nichols *et al*. (2003) observed increase in fiber length asplant population increased. lint percentage significantly reduced by increasing plant stands or by narrow rows. Nichols *et al*. (2004) reported that negative impact of increased plant density on lint uniformity. Valco *et al*. (2001)found no differences in fibre uniformity due to varied row spacing or plant density.

2.3 Effect of nitrogen

It is widely recognized that nitrogen supply exerts a marked influence on vegetative and reproductive growth. In recent years, there has been tendency among some cotton growers to increase maximum yield potentials by applying higher amount than that recommended nitrogen rates. Soomro *et al.* (1997) found that increasing of nitrogen rate increased plant height and the number of flowers and bolls, but do not increased seed cotton yields because of increased shedding of lower bolls. Moreover, they added that excessive nitrogen fertilization does not improve the yield potential or profitability of cotton production. Cotton requires large amounts of N, particularly under irrigated cropping system.

Munir *et al.* (2015) conducted a field study to evaluate the effect of row spacing and nitrogen on earliness and yield in cotton on a loam soil at Post Graduate Agricultural Research Station, University of Agriculture Faisalabad, during the year 2007 and 2008. Three row spacings of 60, 75 and 90 cm were established as the whole plots and four nitrogen fertilizer rates of 0, 60,120 and 180 kg N ha^{-1} were applied as the split plots. Both the factors significantly influenced plant height, main stem nodes, number of bolls per plant, boll weight and seed cotton yield per hectare. There were no significant differences between row spacings for earliness index but crop maturity hastened with lower N rates. The maximum seed cotton yield (2106 and 1936 kg ha^{-1} in 2007 and 2008, respectively) was recorded from 75 cm row spacing probably due to more number of bolls m-2. Similarly, highest seed cotton yield (2197 and 2032 kg ha^{-1} in 2007 and 2008, respectively) was produced by applying 180 kg N ha^{-1} which was also statistically similar to 120 kg N ha^{-1} during both experimental years. For optimum seed cotton yield, cotton should be sown on 75 cm spaced rows with 120 kg ha^{-1} of nitrogen.

Tekalign Ayissa and Fassil Kebede (2011)conducted a study at Werer Agricultural Research Centre Experimental Site in the 2009 cropping season on aclay loam soil with a pH of 7.73 to investigate the effects of different rates of urea on the growth, yield and fibreproperties of three varieties of cotton *(Gossypiumhirsutum L)*. The treatments included five rates of urea (0, 23, 46,69, and 92 kg N ha^{-1}) and three commercial cotton varieties (Delt pine-90, Acala SG and Arba) arranged in a factorialcombination laid out in a randomized complete block design (RCBD) with three replications. The study revealed that Delta pine variety matured earlier than Acala and Arba varieties while the highest N rate (92 Kg N ha^{-1}) delayedmaturity of cotton varieties as compared to the other urea rates. The variety Arba attained significantly higher plantheight, main stem node and number of first fruiting branch nodes as compared to Delta pine and Acala, while cottonvarietyAcala attained significantly higher height to node ratio as compared to Delta pine and Arba. Averaged over Nfertilizer cotton variety Arba produced higher vegetative dry matter. Delta pine produced significantly higher fruitingdry matter with lower N rate as compared to Acala. It was also revealed that Delta pine variety produced significantlyhigher number of bolls as compared to Acala. Delta pine and Arba varieties produced significantly higher seed cottonyield than Acala. Similarly Delta pine cultivars exhibited significantly higher lint yield than Acala but no significantdifference was observed in lint yield between Delta pine and Arba. Arba showed significantly higher fibre length thanDelta pine variety. Averaged over cotton varieties the highest N rate (92 kg ha^{-1}) recorded significantly higher value forfibre fineness. Correlation result demonstrated a significant and positive association of lint yield with lint percentage($r = 0.9$), seed cotton yield (r = 0.42), total dry matter (r =0.32) and boll number (r = 0.30). While lint yield wassignificantly and negatively correlated with boll weight (r = -0.42). It may therefore be concluded that the Delta pinecotton may be planted for both seed cotton and lint yield with urea application at the rate of 46 Kg N ha^{-1} around MiddleAwash area to ensure optimum cotton yield and high economic return to cotton growers in the area while protectingenvironmental contamination and related problems associated with heavy use of urea.

Ruixiu Sui *et al.* (2017) conducted a studyfor two years to know the effect of nitrogen (N) application rates on lint yield and fiber quality in irrigated and rainfed cotton were. In 2013, cotton was planted in 48 plots. Twenty-four plots were irrigated and the other 24 pots were rainfed. Six N application rates (0, 39, 67, 101, 135, and 168 kg ha^{-1}) with four replicates were randomly assigned to the irrigated and rainfed plots. In 2014, five N treatments (0, 56, 112, 168, and 224 kg ha^{-1}) with four replicates wereassigned to 20 irrigated plots. Effect of N application rates on cotton lint yield was significant in 2014 (p = 0.0196), but not in 2013. Yield showed a quadratic relationship with leaf N content in irrigated cotton in both 2013 (p = 0.0268) and 2014 (p = 0.0099). Correlation between leaf N and yield of rainfed cotton was not significant in 2013. Leaf N of irrigated cotton in had significant correlation with fiber length (p = 0.0037), UQL (p = 0.0001), and UHML ($p < 0.0001$). Yellowness was linearly related with leaf N content.Fiber strength showed a linear relationship with leaf N in 2013 rainfed cotton (p = 0.0495), a quadratic relationship with irrigated cotton in 2013 (p = 0.0231) and 2014 (p = 0.0365). Overuse of nitrogen fertilizer in cotton could result in loss of yield and fiber quality. When the fiber quality from irrigated cotton was compared with rainfed cotton, irrigation increased lint yield by 26% and fiber length by 2%.

Gormus *et al*. (2016) reported that Agronomic practices significantly influence the productivity and quality of cotton plant. a study was undertaken to evaluate the effect of nitrogen and sulfur fertilizer application on the fiber quality of cotton, during the year 2011/2012 and 2012/2013 under Mediterranean environmental conditions. All the treatments were laid in randomized complete block design in factorial arrangement each treatment were replicated thrice. Five rates of nitrogen (0, 60, 120, 180 and 240 kg ha^{-1}) and five rates of sulfur (0, 15, 30, 45 and 60 kg ha^{-1}) were involved in the experiments. Results of study indicated that increases in the rate of sulfur have negative impact on the quality of the cotton fiber and the highest rate of sulfur fertilizer gave the lowest fiber length compared with the other sulfur rates. On the other hand, the lowest uniformity ratio was observed by applications of sulfur at 30, 45 or 60 kg ha^{-1}. It was observed that application of sulfur had ha^{-1} have positive effect on the fiber length and caused 2.7 to 3.4% improvement in fiber lengths in 2012 compared to the treatment without N, while applications of nitrogen at 180 and 240 kg ha^{-1} did not provide an additional increase in fiber lengths. Further, it was reported that application of N significantly improved fiber strength, but these differences were not statistically different from the lowest rate of application and the control treatments in both years and averaged across years. On the other hand, the highest values for uniformity ratio was recorded by using 60 to 180 kg N ha^{-1} in 2011.On the basis of these observations, it can be recommend that the use of 120 to 180 kg ha^{-1} N in terms of fiber length and fiber strength and 30 to 45 kg ha^{-1} S, particularly in terms of fiber length and gin turnout in other areas with similar ecologies. Interestingly, the combination of 60 kg ha^{-1} N and 15 kg ha^{-1} S were the optimal and could be the most beneficial application for achieving the maximum fiber strength in similar ecologies.

Kote *et al.* (2007) carried out a field experiment at Parbhani during *Kharif* seasons of 2001 and 2002, to evaluate the effect of intercrops and fertilizer levels on yield and quality of different cotton genotypes under rainfed conditions. All cotton genotypes (NHH 44, PHH 316 and PH 348) were found equally effective in producing seed cotton yield. Newly released cotton hybrid PHH 316 and variety PH 348 recorded significant effect on quality parameters like ginning percentage and halo length over NHH 44 under intercropped situation during both the years. Cotton intercropped with black gram produced higher seed cotton yield than cotton intercropped with soybean. Intercrops did not produce appreciable effect on quality parameters. Increasing fertilizer level from 50% recommended fertilizer dose of both the crops (RFDB) to 100% RFDB showed positive response in respect of seed cotton yield. Recommended dose of fertilizers of both the crops on area basis (RFDB) enhanced the ginning percentage and halo length significantly than 75% and 50% RFDB. Further, application of 75% RFDB also improved the ginning percentage and halo length than 50% RFDB. Cotton genotypes grown as a sole crop produced significantly higher seed cotton yield than intercropped cotton. Cotton hybrid PHH 316 grown as a sole crop recorded higher ginning percentage and halo length than sole NHH 44 during both the years. Interaction effects indicated that NHH 44 + blackgram, NHH 44 + soybean, PH 348 + blackgram as well as PH 348 + soybean with recommended fertilizer dose of both the crops on area basis produced at par seed cotton yields with application of 75% recommended fertilizer dose of both the crops on area basis of the respective cropping system. However, PHH 316 with either blackgram or soybean intercropping with recommended fertilizer dose of the respective cropping system on area basis produced significantly higher seed cotton yield than lower fertilizer level of the respective intercropping system.

Juan *et al.* (2018)Shading and nitrogen fertilization affect fruit distribution in cotton (*Gossypium hirsutum* L.), but there is no detailed information on earliness of crop maturity according to the phenological development. The aim of this work was to evaluate the effect of shading at early flowering and N-topdressing rates on relative cotton earliness using plant-mapping. Field experiments were conducted in Itapeva (16 days of shading; and 0, 60, 120, and 180 kg N ha^{-1}) and Chapadão do Sul (17 days of shading; 0, 80, and 160 kg N ha^{-1}; and early- and full-season cultivars), Brazil. Seed cotton yield was grouped by phenological position (PP) according to the standard phenological scale, for interpolation calculation at each 10% increment in accumulated harvestable yield (Ac), weighted average phenological position (PPwa) determination, and logistic-regression analysis. Crop maturity earliness was predicted based on the reduction in PPwa, and in PP. Shading increased PP up to 10 and 30% of accumulated yield due to a decrease of 33 and 40% in the number of bolls on early fruiting sites in Itapeva and Chapadão do Sul, respectively, but did not affect PPwa. Increases in PP up to high Ac percentages and inPPwa values were observed at the two higher N rates in both experiments, mainly due to lower and higher boll number at earlier and later fruiting sites, respectively. Short- term shading during early flowering of cotton changes yield distribution by decreasing boll number on early fruiting sites, but does not affect the earliness of crop maturity. Earliness is decreased by high N rates due to higher cumulative seed cotton yield at later fruiting sitsites.

Saleem et al. (2010) reported that seed cotton yield and fiber qualities may be significantly altered by a number of agronomic practices. The present study investigates the effect of nitrogen levels on cotton cultivar's seed cotton yield and fiber quality traits. Three cotton cultivars (NIAB-111, CIM- 496 and FH- 901) were tested against four nitrogen levels (0, 60, 120 and 180 kg ha^{-1}) to check reliability, the highest yielding and good quality fiber traits variety. Varieties differed non significantly with respect to boll weight and seed cotton yield. Similarly nitrogen levels did not exhibit significant effects on fiber quality traits except the lint percentage. Among the three varieties NIAB-111 showed maximum fiber strength, fiber fineness and fiber elongation followed by CIM-496, whereas FH-901 found to have low fiber strength, fiber fineness and fiber elongation and 120 kg N ha^{-1}was proved to be the best nitrogen level for obtaining higher yield and lint percentage.

Madani *et al.* (2015) conducted an experiment to study fiber quality and yield response of cotton to nitrogen supply, during 2008, 2009 and 2010 growing season at Varamin and Gorgan Regions. Four nitrogen supply levels (200, 300, 350 and 400 kg N ha^{-1}) were applied. Results shows that optimum rate of N fertilizer application for maximum yields is less than amount that causes to better fiber characteristics of cotton. Excess amounts of N decreased lint yield. Also, hot weather of Varamin during flowering to maturity caused excessive plant growth, slows fruiting and decreases the earliness index. Earliness index may influence on the possible trade-off between the lint yield and the quality in response to nitrogen supply.

Shukla *et al.* (2014) done a field experiment for study the production potential of lint yield kg ha-1 of cotton hybrids under different plant spacings and NPK levels. Results indicated that the lint yield was negatively correlated with plant spacings but had a positive correlation with NPK levels. Maximum lint yield (345 kg ha^{-1}) was recorded in closer pacing of 60 x 60 cm, but in wider spacing of 90 x 60 cm lint yield was minimum (301 kg ha^{-1}).

2.4. Fertilizer management

Cotton, particularly the hybrids are soil exhaustive crops and therefore require heavy nutrient supplementation. Nutrient requirement however, varies with cultivars, growing conditions and management practices. Sound nutrition is one of the ingredients of high yields in cotton. Nutrition affects the yields of cotton to a greater extent than its quality. Fruiting efficiency (ratio of weight of bolls to dry weight of stems) is one of the important yield parameters influenced by the nutrients. In the country, all cotton growing areas are very poor in organic carbon and N, soils are also very poor in available P and medium to high in available K.

Hence, adequate fertilization based on crop requirement and soil supply capacity needs emphasis for profitable and sustained production.Nutrient uptake is related to yield. Of all the elements, N, P and K are removed in greatest amounts.

Berger (1996) reported that cotton removes 40, 7 and 14 kg ha^{-1} to produce 2.5 bales ha^{-1}, 62, 11 and 22 kg ha^{-1} to produce 3.75 bales ha^{-1}, and 125, 21 and 43 kg ha^{-1} to produce 7.5 bales ha^{-1} of N, P_2O_5 and K_2O respectively. Nearly 260 percent of N and P and 470 percent of K removed should be there in soil for adequate growth i.e. to obtain a minimum yield of 2.5 bales, the soil should have nearly 100kg N, 50 kg , P_2O_5 . In India, under rain fed condition to produce one quintal of economic product cotton uses 4.45 kg N, 0.83 kg , P_2O_5 and 7.47 kg K_2O.

Das *et al*., (1991) reported that hybrid cotton has been found to use 5.81 kg N, 1.97 kg, P_2O_5 and 6.59 kg K_2O per quintal of seed cotton.

Hunsagi (1973) found that the two hybrids and two varieties used in the study responded positively for increased nitrogen with respect to the leaf area and leaf area index and application of 90 kg ha^{-1} N was found optimum.

Halevy *et al.* (1987) reported that the uptake by cotton was 267 and 332 N kg ha^{-1}, 46 and 44 P_2O_5 kg ha^{-1}, 208 and 251 K_2O, kg ha^{-1} at120 and 180 N kg ha^{-1} applications respectively.

Angadi *et al.* (1989) revealed that under rainfed conditions nitrogen application up to 100 kg ha^{-1} to hybrid cotton increased number of bolls, yield per plant and seed cotton yield per hectare.

Patil and Malewar (1994) reported hybrid cotton NHB-12 responded significantly for plant height, dry matter production per plant and number of sympodial branches to application of 160 kg N ha^{-1} and significantly better performance over all lower doses in per plant and per hectare yield of seed cotton

Khan *et al.* (1996) reported seed cotton yield and its components were affected positively with increase in the dose of N, beyond 100 kg N ha^{-1}, the response in the seed cotton yield was non significant.

At Dharwad, Karnataka under rainfed conditions uptake of N by hybrid cotton increased with N application up to 150 kg ha^{-1} (Angadi, 1985). In another experiment Gomase and Patil (1987) noticed that hybrid cotton (H-4) responded significantly to addition of N up to 100 kg ha^{-1}. Response per kg N at 50 and 100 kg N per hectare was 9.72 and 8.82 kg seed cotton kg^{-1} N applied respectively.

Several factors, including soil type, affect cotton response to P. The critical level of P is a function of actual concentration of the labile pool that in turn determines the available P at a given time during the growth of cotton. Several variables, including early P accumulation, biomass, and lint yields, positively responded to P fertilization in calcareous soils. Some positive and notable P effects on lint yield and fibre quality factors. Stewart *et al.* (2005) evaluated different methods of P fertilizer application to cotton and found P fertilizer significantly increased seed cotton yield.

Kharche *et al.* (1990) obtained significantly higher seed cotton yield with the application of 62.5 kg ha^{-1} phosphorus (2023 kg ha^{-1}) over control (1449 kg ha^{-1}) and 50 kg ha-1 phosphorus (1913 kg ha^{-1}) and 25 kg ha^{-1} phosphorus (1721 kg ha^{1}). Increased leaf area index with higher N application rates was attributed to better leaf area development and photosynthetic efficiency. Lower N application resulted in decline in main stem nodes, leaf area and LAI (Jackson and Gerik, 1990).

Potassium is considered as an important element in cotton plant for normal functioning of metabolic process and higher yield. It is particularly a vital element for the fruiting phase of the crop. From flowering to the early boll filling, potassium is required in large amounts. Deficiencies during this time will have detrimental effect on the both yield and fibre quality of cotton. Potassium is also important for cotton lint yield and quality. Potassium is required throughout the growing season, but the demand is highest during the boll set and development stage. The boll size and boll weight increased significantly with increasing application of potash levels (Aneela *et a*l. 2003). Gormus (2002) found that application of K at early boll development increased yields, boll weight and lint turnouts and fibre quality.

Basal application of potassium is being commonly used practice to cultivate cotton in our country. But many scientists suggested (Ping *et al.,* 2003; Krishnan *et al.,* 1997 and Gormus,

2002) suggested split application of potassium in soil as it is more efficient than the basal application.

Pervez *et.al.* (2005) conducted a field experiment in Multan, Pakistan to assess the effectiveness of fruiting positions along sympodia under varying levels of K fertilizer on cotton. Plant mapping data showed that the total number of fruiting positions, number of intact fruit on sympodia or monopodia and percent of bolls per position on sympodia differed greatly under different K fertilizer rates. K fertilizer application stimulated the cotton crop in lengthening sympodial branches and retaining more fruits on the first three positions and also at the bottom of the plant during the early reproductive phase.

Cassman *et al.* (1990) conducted a field experiment on a Grangeville Sandy loam soil in King's county, California to know the potassium nutrition effects on lint yield and fibre quality of Acala cotton. Single cultivar (1985) and two cultivar (1986 and 1987) were grown with 0,120, 240 and 480 kg ha^{-1}. They reported that, there was a significant seed cotton yield response to applied K in each year. Lint yield, however, increased relatively more than seed yield, resulting in greater lint percentage as plant K supply increased. Further, they concluded that K supply to cotton fruit is important from fibre quality under field condition.

Dastur and Dabir (1961) reported that, Buri-147 gave higher yield of seed cotton than Buri-0394 though it bears less number of bolls per plant. Application on N (40 lb N), P (50 lb P_2O_5) and K (50 lb K_2O) significantly increased the yield of kapas. Combined application of N, P and K increased the yield of kapas over individual application.

Sharma *et al.* (1979) carried out an experiment at Agricultural Research Station Surat, Gujarat observed increased yield of cotton with application of fertilizers up to 320:160:160 kg ha^{-1} NPK. However, optimum dose of fertilizer was found to be 280 kg N, 140 kg P_2O_5 and 140 kg K_2O ha^{-1} for maximum production of seed cotton.

Kummur (1981) reported increased plant height in early stage with higher dose of N (250 kg ha^{-1}), but at later stages the plant height, main stem nodes and vegetative branches did not differ significantly due to differential N addition under irrigation. Fibre length of hybrid cotton (DCH-32) was reduced with application of N beyond 225 kg ha^{-1}. Other properties like fibre strength, fineness and maturity co-efficient were not affected by N increments.

Further increase in number of boll per plant and seed cotton yield was very less with increase in N application up to 225 kg ha^{-1}. Both the parameters decreased significantly with further increase in N addition up to 300 kg ha^{-1}.

Vyakarnahal *et al.* (1987) found that the application of 240 kg N, 100 kg , P_2O_5 and 160 kg K_2O ha^{-1} recorded the maximum seed cotton yield as compared to application of 168:80:80 and 80:40:40 kg ha^{-1} NPK in hybrid cotton.

Nehra *et al.* (2006) reported that application of 100 per cent RDF significantly increased seed cotton yield over 75 per cent R.D.F. but remained statistically *at par* with 125 per cent R.D.F. It gave 17.58 per cent higher seed cotton yield over RDF..

Khalequzzaman *et al*.(2012) reported that,closer spacing of 60 cm × 30 cm and a higher fertilizer level of 150: 65:164: 34 kg ha^{-1} gave highest seed cotton yield (2143.90 and 2555.61 kg ha^{-1} respectively). However, when these treatments were combined together a seed cotton yield of 2839.27 kg ha^{-1} was obtained. The yield contributing parameters were significantly influenced by the various spacing and fertilizer levels. Interaction effect was highly significant on yield of seed cotton and yield contributing parameters. Economics analysis showed that plant spacing 60 cm × 30 cm with 150: 65:164: 34 kg NPKS ha^{-1} gave the highest gross margin Tk. 112924/ha and the lowest gross margin (3158 Tk./ha) and benefit cost ratio(1.07) were recorded from treatment T_1 (F_0×S_1), respectively.

Khalequzzaman *et al*. (2015) reported that yield contributing parameters plant height, monopodial branches/plant, sympodial branches/plant, number of boll $plant^{-1}$ and single boll weight were significantly influenced by the highest fertilizer levels. Variety and fertilizer interaction effect was highly significant yield of seed cotton and yield contributing parameters (plant height, monopodia $plant^{-1}$, sympodia branch $plant^{-1}$, boll $plant^{-1}$ and boll wt).

Iqbal *et al.* (2001) carried a study on cotton cultivars varying in plant structure to find their responses to phosphorus fertilizer at Central Cotton Research Institute, Multan. The treatments consisted of two cotton cultivars (CIM-240 and MNH-147) and three phosphorus doses (0,50 and 100 kg P_2O_5 ha^{-1}) and were arranged in split plot design with four replications. The results showed significant increase in seed cotton yield due to phosphorus fertilizer application. Cultivar CIM-240 was more responsive to phosphorus fertilization than that of MNH-147.

Chen *et al.* (2017) reported that endogenous hormones are a key factor in cotton fiber quality. Studying the relationship among endogenous hormone contents and fiber quality can provide a theoretical basis for exploring physiological measurements to improve fiber quality. The relationships among endogenous hormone contents and fiber quality for different boll positions and potassium (K) conditions were investigated for the main cultivar 'Xinluzao 24.' We used eight application rates of K fertilizer (K_2O 0, 37.5, 75, 112.5, 150, 37.5 and sprayed 1% K_2SO_4, 75 and sprayed 1% K_2SO_4, and 150and sprayed 1% K_2SO_4 kg ha^{-1} under field conditions). We then measured the contents of indoleacetic acid (IAA), gibberellin (GA3), zeatin (Z), and abscisic acid (ABA) in relation to changes in fiber quality indices. Results showed that application of K fertilizer significantly increased the contents of IAA, GA3, and Z in the upper and middle boll, and decreased the contents of ABA in the upper, middle, and the lower boll. Compared with the control, applying K fertilizerbetween 37.5 kg K_2O ha^{-1} and 112.5 kg K_2O ha^{-1} can significantly increase the length, uniformity, strength, micronaire, and maturity of fiber in three parts of the plant. However, excessive application of K fertilizer can reduce fiber uniformity, strength, and micronaire in these locations. Through comprehensive comparison, we determined that the optimal application of K fertilizer for regulating endogenous hormones and improving fiber quality was a basal application of 75 kg K_2O ha^{-1} and a spray application of 1% K_2SO_4.The endogenous hormones IAA, GA3, and Z can improve cotton fiber quality, but ABA can inhibit cotton fiber quality.Results indicate that reasonable applications of potassium fertilizer could regulate endogenous hormones and improve fiber quality.

Salee *et al.*(2010) done an experimenr to determine the effect of phosphorus levels on earliness and yield of cotton, three cultivars viz., CIM-496, MNH-786 and FH-901 were grown in field with four phosphorus levels (0, 30, 60 and 90 kg ha^{-1}) following a 3 x 4 factorial arrangement during the year 2008. Cultivars as well as phosphorus levels significantly affected almost all the characters related to earliness and yield. Among the cultivars, FH-901 took minimum days for squaring, appearance of first flower, first boll splition and for boll maturation period. The same variety recorded the lowest node number for first fruiting branch, lowest fruiting branch height and maximum earliness index. Among the phosphorus levels, control took the maximum while 90 kg ha^{-1} took minimum days for all earliness related characters. Earliness index (53.5 %) and seed cotton yield (1879.5 kg ha^{-1}) were highest with 90 kg P ha^{-1}. Production rate index remained unaffected by variety; however it was highest where no phosphorus was added. So, maximum seed cotton yield and earliness in cotton can be achieved by growing a short duration cultivar with higher dose of phosphorus.

Bhalerao and Gaikwad (2010) conducted an experiment to find out the impact of plant geometry and levels of N, P and K fertilization on performance of *Bt*cotton. It was observed that 90 x 45 cm spacing recorded 17.7% higher seed cotton yield than 90 x 90 cm and 90 x 60 cm spacing. Wider spacing of plants had more bolls plant-1 (23.1) than closer spaced (20.8 bolls $plant^{-1}$). Application of 125% RDF was at par with RDF i.e. 50-25-25 kg N-P-K ha^{-1} and significantly higher than 75% RDF. Increase in yield was due to improvement in bolls $plant^{-1}$.

Shukla *et al.* (2014) done a field experiment for study the production potential ofsympodial branches per plant, lint yield kg ha^{-1} of cotton hybrids under different plant spacings and NPK levels. Results indicated that the lint yield was negatively correlated with plant spacings but had a positive correlation with NPK levels. Maximum number of sympodia per plant (16.3) and lint yield (345 kg ha^{-1}) was recorded in closer pacing of 60 x 60 cm, but in wider spacing of 90 x 60 cm lint yield was minimum (301 kg ha^{-1}).

Baskar and Jagannathan (2014) conducted a field experiment to study the effect of crop geometry on the number of sympodial branches per plant in inter specific hybrid *Bt*cotton. The results indicated the maximum number of sympodia per plant (27.4) with wider spacing of 150 x 90 cm by using 125 % RDF water soluble fertilizer (WSF) over other spacing’s.

Nayak *et al.* (1997) found that plant density of 13888 plants/ha with 150:150:150 kg $NPKha^{-1}$ gave the maximum seed cotton yield (2069 kg ha^{-1}) followed by same plant density (13888 plants/ha) with 100:100:100 kg NPK ha^{-1} (1904 kg ha^{-1}) for hybrid cotton DCH-32 (Jayalaxmi) under rainfed condition of Maland tract of Karnataka

From the review a great variability in phenology, growth, yield and fibre quality in cotton which are influenced by genotype, fertilizer and plant spacing has been verified. Yield target can be fixed by looking into the genetic potential of the crop/variety and other factors. Soil testing and soil fertility management are of great importance to any country for sustained cotton production.

Chapter 3

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

3.1. Experimental site

The experiment was carried out at the Central Cotton Research Farm, Sreepur, Gazipur during three consequative years of 2015-16, 2016-17 and 2017-18 in the growing month of July to February. The site was located in the centre of Madhupur Tract (AEZ-4: 24.09 ^{0} N latitude and 90.26 ^{0} E longitude) with an elevation of 8.4 meter above the sea level.

3.2 Climatic conditions

The experimental site was situated in the subtropical climatic zone characterized by hot and dry summer, cold winter and heavy rainfall during the monsoon. The monsoon generally commences from June and continues up to September. Temperature gradually falls from the month of October. The monthly average maximum and minimum temperature, relative humidity and rainfall during the study period were recorded (Appendix I).

3.3 Soil and its characters:

The soil of the experimental site belongs to the Salna series and has been classified as Shallow Red-Brown Terrace type which falls under the order Inceptisols of soil taxonomy (Brammer, 1980; FAO, 1988). The soils are characterized by heavy clays within 15 cm from the surface and are poor in chemical properties. The soil is acidic in nature and red in colour. The detailed information of the basic soil properties are presented in the (Appendixes II-VI).

3.4 Previous crops in the experimental area

Sunhemp crop was cultivated during kharif-2, for both the three years 2015, 2016 and 2017.

3.5 Experimental details

The program was aimed at studying the yield and fibre quality improvement of new cotton varieties through agronomic management. Therefore, in 2015-2016, 2016-2017 and 2017-2018 cotton growing seasons, five experiments were conducted at Central Cotton Research Station, Sreepur, Gazipur. The experiment with titles and treatments are given below-

In the first year (2015-16) two experiments were conducted-

Experiment 1. Yield and fibre quality of newly released cotton varieties at different nutrient levels

Objectives-

i) To determine the effect of fertilizer level on yield and yield contributing characters of newly released cotton varieties and
ii) To find out the optimum doses of fertilizer of newly released cotton varieties.

Experimental procedure

Newly developed two high yielding cotton varieties along with one check variety was involved in this experiment. The varieties were tested under different levels of fertilizers. The factors and treatments were as follows-

Factor A. Cotton variety- 3

i) V_1 = CB-13
ii) V_2 = CB-14
iii) V_3 = CB-12

Factor B. Fertilizer dose-6

i) F_0 = Without fertilizer (control)
ii) F_1 = 90, 34, 98, 20 Kg NPKS ha^{-1} (25% less than RDF)
iii) F_2 = 120, 45, 131, 27 Kg NPKS ha^{-1} (RDF)
iv) F_3 = 150, 56, 164, 34 Kg NPKS ha^{-1} (25% higher than RDF)
v) F_4 = 180, 67, 196, 40 Kg NPKS ha^{-1} (50% higher than RDF)
vi) F_5 = 210, 78, 229, 46 Kg NPKS ha^{-1} (75% higher than RDF)

3.6 Design and lay out:

The experiment was laid out in Split-Plot Design with three replications.Varieties laid in main plot and fertilizers levels were in sub-plot.

3.7 Plot size: Unit plot size was 4.5 m × 3.7 m.

3.8 Spacing

Row to row and plant to plant distances were 90 cm and 45 cm respectively. Block to block and plot to plot distance were maintained as 1 m for easy management of the crop.

3.9 Sources of seed:

Seeds were collected from the Cotton Research Fram, Jagodishpur, Joshore.

3.10 Crop establishment and management:

The experiment field was prepared for sowing by ploughing the field with a tractor drawn cultivator followed by harrowing with a tractor drawn harrow. The land was finally levelled with a wooden plank and plots were laid out manually according to the layout plan.

Cotton seeds were planted on July 13, 2015 by dibbling, three water soaked seeds placed per hill to ensure uniform stand, later thinned to one plant per hill. Gap filling was done immediately after emergence of seedling. Thinning and earthing up were completed by 20 days after emergence. In case of first thinning, two seedlings per hill were kept after 10 days of emergence. Second thinning was done 20 days after emergence keeping one seedling per hill.

The plots were fertilized with NPKS according to the treatments in the form of urea, triple super phosphate, muriate of potash, gypsum and other micro nutrient Zn, Mg, and B @ 3.3-1.5 -1.5 kg ha^{-1} were applied in the form of zinc sulphate, magnesium sulphate and boric acid, respectively. Total amount of gypsum, zinc sulphate, magnesium sulphate, boric acid, one fourth of urea , one third of the muriate of potash and half of triple super phosphate were applied in the furrows during the final land preparation as basal dose.

One fourth of urea, one third of muriate of potash were applied at 25 days after sowing (1^{st} top dressing) in one side of plant by digging farrow and buried fertilizer by soil. At 50 days after sowing one fourth of urea, one third of muriate of potash and half of triple super phosphate were applied in the oposite side of plant where previously fertilizer were applied by same way (2^{nd} top dressing). At 75 days after sowing one fourth of urea and one third of muriate of potash were applied in the other side of plant where previously fertilizer were applied by same way (3^{rd} top dressing)

The experimental field was kept weed free up to 60 days after emergence of seedling by hand weeding. Mulching between two rows was done by inter row cultivator. At 15 October, 2015 and 16 November, 2015 irrigation were given due to draught situation. First spraying of volume flaxy was done at 30 days after emergence against sucking pest like Jassid and Aphid. Other three spray of Aktara in combine with Volume flaxy were applied to control sucking and chewing (Boll worms) pests. In all cases, scouting based spray was followed. Hand picking, light trapping and zollaghur (molasses) traps were also used to kill moths and adults of the insects. As a result, insect reproduction was controlled which encouraged friendly eco-system to some extent. To protect fungal diseases, Cupravit were sprayed at 10 days after emergence as precautionary measure.

3.11 Sampling and harvesting

Ten plants were selected randomly from each plot and tagged for taking data. Harvesting of seed cotton from the net plot and avoiding border were done in three number of picking at 3rd week December, 3rd week January and 3rd week February.

Experiment 2. Effect of different plant spacing on seed cotton yield and fibre quality of some newly released cotton varieties

Objectives

i) To determine the effect of plant spacing on yield and yield contributing characters of cotton varieties and

ii) To find out the optimum plant population for yield optimization of cotton varieties

3.5 Experimental procedure

Newly developed two high yielding cotton varieties along with one check variety was involved in this experiment. The varieties were tested under different plant spacing. The factors and treatments were as follows-

Factor A. Cotton variety-3

i) V_1 = CB-13
ii) V_2 = CB-14
iii) V_3 = CB-12

Factor B. Plant Spacing - 8

i) S_1 = 45 × 30 cm
ii) S_2 = 45 × 45 cm
iii) S_3 = 60 × 30 cm
iv) S_4 = 60 × 45 cm
v) S_5 = 75 × 30 cm
vi) S_6 = 75 × 45 cm
vii) S_7 = 90 × 30 cm
viii) S_8 = 90 × 45 cm

3.6 Design and layout:

The experiment was laid out in RCBD (Factorial) design with three replications.

3.7 Plot size:

Unit lot size was 4.5 m x 3.7 m in this experiment.

3.8 Spacing

Row to row and plant to plant distances were according to the treatments (Shown in section 3.5). Block to block and plot to plot distance were maintained as 1 m for easy management of the crop.

3.9 Sources of seed:

Seeds were collected from the Cotton Research Fram, Jagodishpur, Joshor.

3.10 Crop establishment and management:

Cotton seeds were planted on July 14, 2015 by dibbling, land preparation, crop and other management practices and plant sampling were similar as experiment-1. The seed cotton was harvested in three hand picking on 3rd week of December, 3rd week of January and 3rd week of February.

3.11 Sampling and harvesting:

Same as experiment no-1

In the second year (2016-2017), two experiments were conducted. In this year, treatments were selected on the basis of the performance of the first years experiments.

Experiment 3. Yield and fibre quality of some newly released cotton varieties at different nutrient levels

Objectives-

i) To determine the effect of fertilizer level on yield and yield contributing character of newly released cotton varieties and

ii) To find out the optimum dose of fertilizer of newly released cotton varieties.

Experimental procedure:

This experiment was set up on the basis of the results of the experiment 1. The same varieties as experiment-1 were tested with six different levels of fertilizer doses. Doses were selected on the basis of the results of the experiment 1. The factors and treatments were as follows-

. **Factor A. Cotton variety – 3**

i) V_1 = CB-13
ii) V_2 = CB-14
iii) V_3 = CB-12

Factor B. Fertilizer dose - 6

i) F_1 =120, 45, 131, 27 Kg NPKS ha^{-1} (RDF)

ii) F_2 =150, 56, 164, 34 Kg NPKS ha^{-1} (25% higher than RDF)

iii) F_3 =180, 67, 196, 40 Kg NPKS ha^{-1} (50% higher than RDF)

iv) F_4 =210, 78, 229, 46 Kg NPKS ha^{-1} (75% higher than RDF)

v) F_4 =240, 90, 262, 54 Kg NPKS ha^{-1} (100% higher than RDF)

vi) F_4 =270, 101, 294, 60 Kg NPKS ha^{-1} (125% higher than RDF)

3.6 Design and lay out:

The experiment was laid out in Split-Plot Design with three replications.Varieties laid in main plot and fertilizer levels laid in sub-plot.

Plot size and plant spacing:

Same as experiment-1(section 3.7 and 3.8)

Crop establishment and management:

The experiment field was prepared by ploughing the field with a tractor drawn cultivator followed by harrowing with a tractor drawn harrow. The land was finally levelled with a wooden plank and plots were laid out manually according to the layout plan.

After ploughing fertilizer were applied in the furrows during the final land preparation in the unit plots as per treatment of the experiment.Other fertilizer and methods of applications were as experiment1. Seeds were planted in individual plots on July 23, 2016. Crop and other management practices and plant sampling were similar as experiment 1. The seed cotton was harvested in three hands picking on of 4th week December, 4th week of January and 4th week of February.

Experiment 4. Effect of different planting arrangement on seed cotton yield and fibre quality of some newly released cotton varieties

Objectives-

iii) To determine the effect of plant spacing on yield and yield contributing character of newly released cotton varieties .

iv) To find out the optimum plant population of newly released cotton varieties

3.5 Experimental procedure

This experiment was designed on the basis of the results of the experiment 2. Three varities as experiment 2 were tested under eight different plant spacings. Plant spacings were selected on the performance of the results of the experiment 2. The factors and treatments were as follows -

Factor A. Cotton variety – 3

i) V_1 = CB-13

ii) V_2 = CB-14

iii) V_3= CB-12

Factor B. Plant Spacing - 8

i) S_1 = 45 × 30 cm
ii) S_2 = 45 × 40 cm
iii) S_3 = 60 × 30 cm
iv) S_4 = 60 × 40 cm
v) S_5 = 75 × 30 cm
vi) S_6 = 75 × 40 cm
vii) S_7 = 90 × 30 cm
viii) S_8 = 90× 40 cm

The crop sown on 21 July 2016 following Randomized Complete Block Design (Factorial) with three replications. Plant spacing were according to the treatments. Plot size, crop establishment and management, and sampling procedure were similar as adopted in experiment 2. The seed cotton was harvested in three hand picking on 4th week of December, 4th week of January and 4th week of February, 2017.

In third year (2017-2018), experiment 5 was conducted. This experiment was under taken on the basis of the second years experimental results.

Experiment 5. Yield and fibre quality improvement of newly release cotton varieties through planting arrangement and nutrient management

Objectives-

i) To evaluate the yield and fibre quality performance of newly release varieties,
ii) To find out the optimum spacing for higher yield and better fibre quality of newly released cotton varieties and
iii) To determine the optimum dose of fertilizer on yield contributing character, yield and fibre quality of newly released cotton varieties.

Experimental procedure

There were 27 treatment combinations comprising three varieties (including two newly released inbred cotton variety), three fertilizer levels (selected from experiment 3) and three plant spacing (selected from experiment 4) for maximum yield and better fibre quality of cotton. The factors and treatments were as follows-

Factor A. Cotton variety – 3

i) V_1 = CB-13
ii) V_2 = CB-14
iii) V_3 = CB-12

Factor B. Planting arrangement (spacing) - 3

i) S_1 = 45 × 30 cm
ii) S_3 = 60 × 30 cm
iii) S_5 = 75 × 30 cm

Factor C. Fertilizer dose - 3

i) F_1 = 150, 56, 164, 34 Kg NPKS ha^{-1} (25% higher than RDF)
ii) F_2 = 180, 67, 196, 40 Kg NPKS ha^{-1} (50% higher than RDF)
iii) F_3 = 210, 78, 229, 46 Kg NPKS ha^{-1} (75% higher than RDF)

The experiment was laid out in the field following split-split-plot Design with three replications. The variety was accummodaded in the main plot, plant spacing in the sub plot and fertilizer levels in the sub-sub plot.

Seeds of the test varieties were sown in the unit plots on 18 July, 2017. Harvesting was done in the three picking on 3rd week of December, 3rd week of January and 3rd week of February. Others procedures were that of same as experiment 1.

3.12 Data collection

The following data were recorded during the experimentation-

A. Phenology data

i) Days to squaring
ii) Days to first flowering
iii) Days to first boll opening
iv) Node number of first fruiting branch (NFB)

B. Plant characters data

i) Plant height (at harvest) (cm)
ii) Number of monopodium (vegetative) branch $plant^{-1}$
iii) Number of sympodium (fruiting) branch $plant^{-1}$

C. Yield and yield component

i) Number of bolls plant^{-1}
ii) Individual boll weight (g)
iii) Seed cotton yield (kg ha^{-1})
iv) Lint yield (kg ha^{-1})

E. Fibre quality data

i) Ginning out turn (%)
ii) Staple length (mm)
iii) Fibre strength (g/tex)
iv) Micronaire value (µg/inch
v) Uniformity ratio (%)

3.13 Procedure of data collection

A. Phenology data

Days to first flowering

Days required from seedling emergence to 50% plant of the total plot began to flowering were counted and recorded.

Days to first boll opening

Days required from seedling emergence to 50% plant of the total plot began boll splitting were counted and recorded.

Node number of first fruiting branch (NFB)

Node number of the main stem at which first fruiting branch arose was determined by counting number of nodes above the cotyledonary node (zero node) along the main stem till the one that gave rise to the first fruiting branch.

B. Plant characters data

Plant height

Plant height was measured from 10 sample plants in cm on main shoot from the ground level to the tip of the top of the main shoot at final picking and the average was recorded.

Number of monopodial branch plant^{-1}

The monopodium branches (at least one functional sympodial branch) were counted separately in ten tagged plants and average value was recorded as the number of monopodium branch plant^{-1}.

Number of sympodial branch plant^{-1}

Sympod is generally called fruiting branches. Fruiting branches develop in succession from the first fruiting branch and upward. The sympodial type of growth with a flower bud at each node tends to give a zigzag appearance of these branches where the lower fruiting branches are longer than the upper ones. Number of sympodial branch plant^{-1} is one of the most important factors of yield contributing characters of cotton. The fruiting branches arising on the main stem were counted separately from the ten tagged plants and average value was recorded.

C. Yield component and yield data

Number of bolls plant^{-1}

Total number of boll were recorded by counting separately in ten tagged plants and average value was recorded as the number of bolls plant^{-1}.

Number of droup out bolls plant^{-1}

Total number of droup out bolls were recorded by counting separately in ten tagged plants and average value was recorded as the number of droup out bolls plant^{-1}

Individual boll weight

Fifty (50) bolls of each plot were weighted. Total weight was divided by 50 and the average weight was recorded as individual boll weight**.**

Seed cotton yield

The total seed cotton picked from net plot of each treatment in different pickings was used for working out seed cotton yield plot^{-1} and convert into kg ha^{-1}.

Lint yield

The total seed cotton picked from net plot of each treatment in different pickings was ginned by ginning machine. After separation of seeds, lint was weighted plot^{-1} and converted into kg ha^{-1}.

D. Fibre quality data

Fibre quality data measured by HVI machine (high volume instrument) except GOT.

Ginning out turn (GOT)

Ginning percentage was measured as the weight of lint ginned from the seed cotton and expressed as percent of the seed cotton weight. Therefore, ginning out turn (GOT) was expressed as:

$$\textbf{GOT (\%)} = \frac{\text{Weight of lint}}{\text{Weight of seed}} \times 100$$

Staple length or upper half mean length (mm)

Fiber length is directly related to yarn fineness, strength, and spinning efficiency 9Moore 1996). The staple length represents the average length of the longest one-half of the fibers (Upper half mean length). HVI was uses a fibrosampler to grab a portion of cotton from the whole sample. This sub sample is used to create a beard of approximately parallel fibers that is optically scanned for relevant measurements such as upper-halfmean length (UHML) and uniformity index.

Fibre Strength (g tex^{-1})

It is the force required to break of fibres of unit linear density. The inherent breaking strength of individual cotton fibers is considered to be the most important factor in determining the strength of the yarn span from those fibers (Munro, 1987; Patil and Singh, 1995). Fiber strength varies along the length of the fiber as does fiber fineness measured as perimeter, diameter, or cross section (Hsieh *et al.*, 1995). The fiber strength measurement is made by clamping and breaking a bundle of fibers with a 1/8-inch gage spacing between the clamp jaws. Fiber strength is reported as breaking tenacity or grams of breaking load per tex, where tex is the fiber linear density measured in grams per kilometer of fiber or yarn or simply weight of 1,000 meters of fibre in grams (Munro, 1987). Therefore, the strength reports the force, in grams, required to break a bundle of fibres one tex unit in size, clamped in two sets of jaws (1/8 inch apart). Strength premiums are paid for readings above 29.4, while discounts are incurred for readings below 25.5. Stronger fibers give stronger yarns which enhance productivity by increasing processing speed with less end breakages.

Micronaire value (µg/inch)

Micronaire (also, mike or mic.) is a measurement of the lint surface area and thus an indirect measure of fineness (linear density) and maturity (degree of cell-wall development or thickness). It is the average weight per unit length of fibre. Linear density (often referred to as fineness) of fibre is expressed in micrograms per inch ($\mu g\ inch^{-1}$). The degree of fiber thickening or fiber maturity, contributes to differences in micronaire. Low mike refers to fine fibers, while high mike refers to coarse fibers. Above 4.9 mikes value is undesirable for spinners as it results in too few fibers in yarn cross section, reducing its strength, while mike below 3.7 may mean that fibers are immature, leading to breakages in fibers within the yarn and poor dye uptake during textile processing. Mike values falls outside the optimal range (3.7 to 4.9) are discounted, while premiums are paid for mike readings between 3.7 and 4.2.

Uniformity index/ratio (%)

Uniformity index (UI) is the ratio of the upper one-half mean length to the overall mean length of the fiber in a sample. It indicates the uniformity of fibre length. Fibre uniformity index was estimated by using HVI and expressed in percentage. Low uniformity values are a function of fibers that are more easily broken. It also is an indication of short fiber content (fibers of less than one half inch). A low uniformity number means more short fibers are in sample. If the ratio is higher, yarn is more even and there is a reduced end breakage which improves spinning performance.

Economic Analysis

Net field benefit

Net field benefits were calculated by subtracting the total variable cost from the gross benefits for each treatment combination (CIMMYT. 1988).Input and output cost for each treatment was converted to tk. ha^{-1}.

3.13 Chemical analysis of soil

Soil samples from 0-30 cm soil depth were collected after harvest of the crop from each treatment in all the three replications. The soil samples were analyzed from SRDI. Initial and post experimental soil analytical data have been presented in Appendix ii – vi.

3.14 Statistical analysis of the data

The data obtained from the experiment on different parameters were analyzed statistically following the analysis of variance (ANOVA) technique with the help of computer package, MSTAT C. Means were separated using Duncan's multiple range test at a significance level of 0.05 (Gomez and Gomez, 1984).

Chapter 4
Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

Result were obtained from the present study regarding cotton varieties, fertilizer doses and spacing and their interactions on the growth, yield, lint characters and economic analysis of cotton variety have been presented and discussed parameter wise in this chapter. The results pertaining to the five experiments conducted during 2015-2016, 2016-2017 and 2017-2018 cotton growing season are presented and discussed below.

4.1. Experiment 1.Yield and fibre quality of some newly released cotton varieties at different nutrient levels

4.1.1. Phenological attributes

4.1.1.1. Effect of variety

Squaring, blooming, and boll opening of each cotton genotype expressed in days after planting were summarized in Table1. Days required for squaring and blooming were statistically non-significant among the varieties. There existed significant difference in days from planting to boll splitting. Genotype CB-13 required the longest time (118.33 days) to boll opening which was differed from other genotypes. CB-12 required the lowest time from planting to boll splitting (114.11days) which was statistically similar to CB-14 variety. Node number of first fruiting branch were statistically non significant among the varieties. CB-12 needed minimum days for squiring (55.33 days), boll splitting (114.11) and minimum NFB (5.97) which indicates that CB-12 was the earliest variety. Days required to blooming to boll opening are important characters of cotton as it indicates the earliness of the crop. Although these are inherent characters but sometimes environmental factors also governed the time of blooming and boll opening (Sawan *et al.* 1999). The genotypes took least days to initiate squaring (Godoy and Palomo1,999), flowering (Anjum *et al*.2001; Panhwar *et al*. 2002; Gopang, 2003; Azhar *et al*. 2007; Ahmad *et al.* 2008) and boll opening (Gopang, 2003; Nimbalkor *et al*., 2004; Shakeel *et al.* 2008) considered earliest in crop maturity. Similarly, lower position of first fruiting branch node (Anjum *et al*. 2001; Gopang, 2003; Shakeel *et al*.2008; Ahmad *et al*.2008) and height of first fruiting branch node (Weijun, 1998) indicate earliness in plant maturity.

Table 1. Effect of variety on phenological attributes of cotton varieties

Treatment (Variety)	Days to 1st squaring (days)	Days to first flowering (days)	Days to first boll splitting (days)	Node number of first fruiting branch (no.)
CB-13	55.89	65.05	118.33 a	6.06
CB-14	55.89	66.39	115.39 b	6.05
CB-12	55.33	65.72	114.11 b	5.97
LSD(0.05)	**NS**	**NS**	**1.71**	**NS**
CV (%)	**5.33**	**4.42**	**1.53**	**3.07**

Here, NS= Not significant

4.1.1.1 Effect of fertilizer levels

Number of days to 1st flowering, 1st boll opening and node number of first fruiting branch significantly affected by fertilizer doses (Table 2). The result showed that time needed for 1st flowering and 1st boll opening decreased gradually due to higher doses. The longest time requied for 1st flowering (68.33 days) and 1st boll opening (121.78 days) in control treatment which was significantly higher than other fertilizer rates. The shortest time needed for 1st flowering (64.77 days) in the treatment 75% higher than RDF. The result showed that increasing of fertilizer rates shorter the NFB of plant which indicates that higher fertilizer rate promotes plant maturiety. The highest node number of first fruiting branch (6.20) was recorded in 25% higher than RDF treatment which was significantly similar with control and RDF treatments. Days to squaring observed non- significant differences among the doses. Node number of first fruiting branch significantly affected by fertilizer rates. Similar results were also reported by Clawson *et al*. (2008) who indicated that N rates did not affect the timing of 30, 60, or 85% harvest and argued that longer vertical flowering intervals by virtue of slower node addition may have contributed to reduce boll set which prevented earlier maturity in lower N rates.

Table 2. Effect of fertilizer levels on phenological attributes on cotton varieties

Treatment (Fertilizer levels)	Days to 1st squaring (days)	Days to first flowering (days)	Days to first boll splitting (days)	Node number of first fruiting branch (no.)
Control	56.55	68.33 a	121.78 a	6.11 ab
25% less than RDF	54.66	65.66 ab	115.89 b	6.20 a
RDF	55.77	65.11 b	114.00 c	6.01 a-c
25% higher than RDF	56.77	65.55 ab	114.33 bc	5.91 c
50% higher than RDF	55.22	64.88 b	115.00 bc	5.99 bc
75% higher than RDF	55.22	64.77 b	114.67 bc	5.94 bc
LSD(0.05)	**NS**	**3.0523**	**1.87**	**0.195**
CV (%)	**4.97**	**3.80**	**2.15**	**3.59**

Here, NS= Not significant, RDF= Recommended dose of chemical fertilizers

4.1.1.3. Interaction effect of variety and fertilizer levels

There observed a significant difference in days to squaring, days to 1st flowering, days to 1st boll opening and node number of first fruiting branch due to combined effect of variety and fertilizer levels (Table 3). The result showed that time needed to squaring, 1st flowering and boll opening reduced gradually with the application of increasing fertilizer doses irrespective of varieties. The shortest time for squaring (53.33 days) was found in the combination of CB-13 variety and 75% higher than RDF which was lower than all others treatment combinations. The longest squaring time (58.67days) observed in CB-13 variety and control fertilizer combination.

The longest time of boll opening (122.00 days) found in the interaction of CB-13 and control fertilizer combination. The shortest boll opening time (111.00 days) observed in CB-12 and 75% higher than RDF treatment combination. The highest node numbers of first fruiting branches (6.37) were observed in interaction CB-13 and 50% higher than RDF treatment combination. Similar results were reported by (Meredith *et al.*, 1972) who argued that, more determinate and early maturing cotton cultivars are more responsive to N applications than absolete cultivars because of boll setting and maturation in shorter periods.

Table 3. Interaction effect of variety and fertilizer levels on phonological attributes of cotton

Interaction (Variety × Fertilizer)	Days to 1st squaring (days)	Days to first flowering (days)	Days to first boll splitting (days)	Node number of first fruiting branch (no.)
CB- 13 × Control	58.67 a	69.00 a	122.00 a	6.03 a-c
× 25%less than RDF	54.67 ab	64.33 bc	119.33 ab	6.03 a-c
× RDF	57.67 ab	65.00 a-c	117.67 bcd	6.03 a-c
× 25% higher than RDF	55.67 ab	64.00 bc	115.33 c-g	5.93 bc
× 50% higher than RDF	55.33 ab	65.33 a-c	117.33 b-e	6.37 a
× 75% higher than RDF	53.33 b	62.67 c	118.33 abc	5.97 bc
CB- 14 × Control	55.67 ab	69.00 a	121.67 a	6.10 ab
× 25%less than RDF	55.00 ab	65.33 a-c	115.67 b-f	5.97 bc
× RDF	55.67 ab	66.33 a-c	111.67 gh	5.97 bc
× 25% higher than RDF	57.67 ab	67.00 a-c	114.00 d-h	6.07 a-c
× 50% higher than RDF	56.33 ab	66.00 a-c	114.67 c-h	6.07 a-c
× 75% higher than RDF	55.00 ab	65.00 a-c	114.67 c-h	6.13 ab
CB- 12 × Control	55.33 ab	67.00 a-c	121.67 a	6.20 a
× 25% less than RDF	54.33 ab	67.67 ab	112.67 fgh	5.97 bc
× RDF	54.00 ab	64.00 bc	112.67 fgh	6.03 a-c
× 25% higher than RDF	57.33 ab	65.67 a-c	113.67 e-h	5.73 c
× 50% higher than RDF	54.00 ab	63.33 bc	113.00 fgh	5.73 c
× 75% higher than RDF	57.33 ab	66.67 a-c	111.00 h	6.17 ab
LSD (0.05)	**4.92**	**4.59**	**3.91**	**0.355**
CV (%)	**4.97**	**3.80**	**2.15**	**3.59**

Here, RDF= Recommended dose of chemical fertilizers

4.1.2. Plant characters

4.1.2.1. Effect of variety

Plant height, monopodial branch plant^{-1} and sympodial branch plant^{-1} of different varieties measured at harvest time has been presented in Fig.1, 2 and 3. The figure showed a non significant difference in plant height, vegetative (monopodial) branch plant^{-1} and fruiting (sympodial) branch plant^{-1} of cotton varieties. However, the tallest plant (109.00 cm) observed in variety CB-14. On the other hand, the shortest plant (107.45 cm) and the lowest sympodial (fruiting) branch plant^{-1} (10.54) observed in CB-13 variety. Such differences in number of sympodial branch plant^{-1} of cotton genotypes also reported by Nichols *et al.* (2004) in different cotton growing environments. Brar *et al. (*2002) and Ali *et al*. (2009) reported non-significant results on number of monopdial and sympodial branches per plant among genotypes.

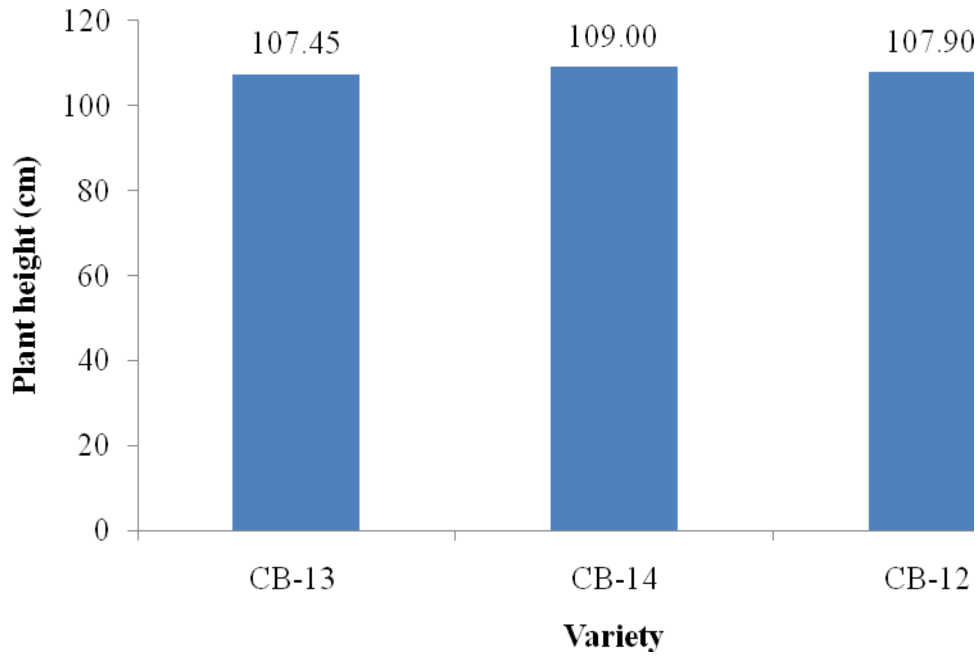

Fig. 1 Effect of variety on plant height of cotton (LSD 0.05= NS)

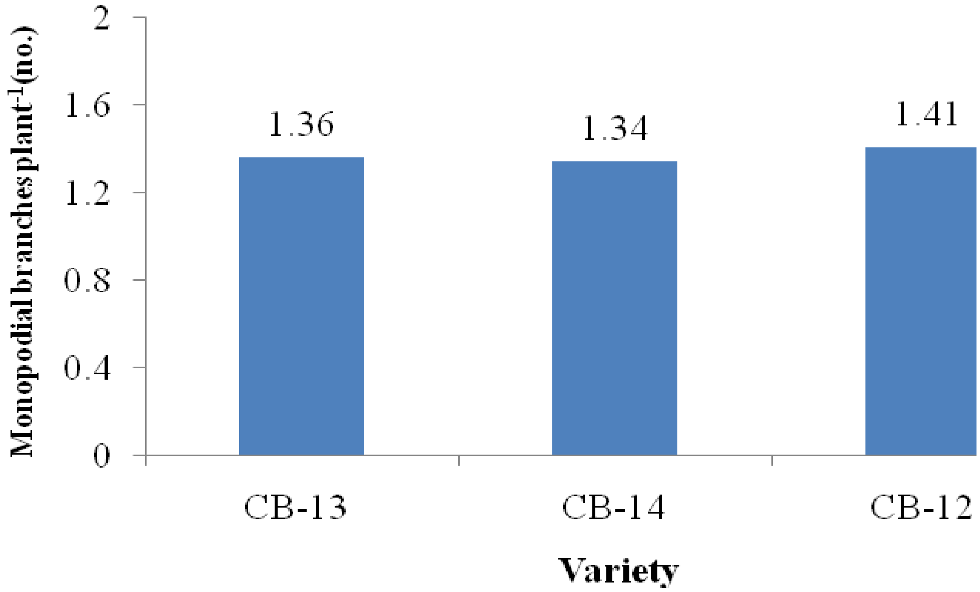

Fig. 2 Effect of variety on monopodial branches plant^{-1} of cotton (LSD 0.05 = NS)

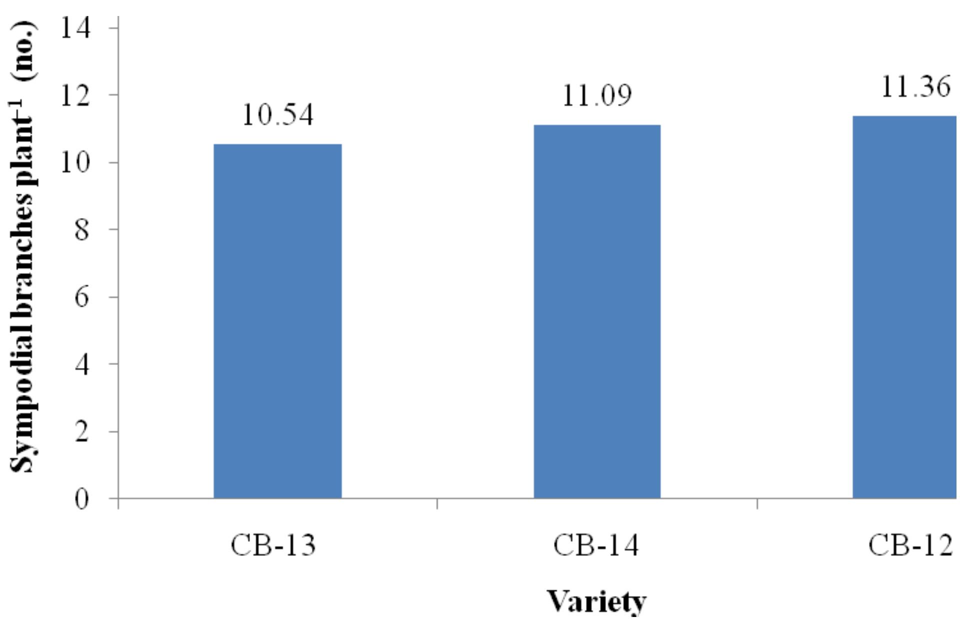

Fig.3 Effect of variety on vegetative (sympodial) branch plant^{-1} of cotton (LSD 0.05 = NS)

4.1.2.2. Effect of fertilizer

Plant height, vegetative (monopodia) branch plant^{-1} and fruiting (sympodial) branch plant^{-1} of cotton genotypes due to application of different levels of fertilizer varied significantly at harvest (Fig 4,5 and 6). Plant height, monopodial branch plant^{-1} and sympodial branch plant^{-1} increased with the increase dose of fertilizer. The tallest plant (126.05 cm), highest monopodial branch plant^{-1} (1.85) and sympodial branch plant^{-1} **(**13.88**)** were recorded in 75% higher than RDF (the highest dose of fertilizer) which was statistically similar to 50% higher than RDF. The lowest plant height (68.09 cm), monopodial branch plant^{-1} (0.63) and sympodial branch plant^{-1} **(**7.30) were observed in control fertilizer. Plant height at harvest (111.11cm), monopodial branch plant^{-1}(1.35) and sympodial branch plant^{-1} (10.86) were recorded in recommended doses. Increasing in plant height, monopodial branch plant^{-1} and sympodial branch plant^{-1} due to application of higher fertilizer might be associated with fertilizer application with stimulating effect on various physiological process including cell division and cell elongation of the plant. The results were similar to Khalequzzaman *et al*. (2012) who reported increasing fertilizer levels increased plant height, monopodial branch plant^{-1} and sympodial branch plant^{-1}. The result is consistent with the findings of Kumbhar *et al*. (2008) who reported that, increase in number of sympodial branches per plant with increased nitrogen application. Most studies signified a positive relationship between plant height and N rates (Clawson *et al*. 2006; Kumbhar *et al*. 2008; Cheema *et al*. 2009; Ibrahim *et al*. 2010).

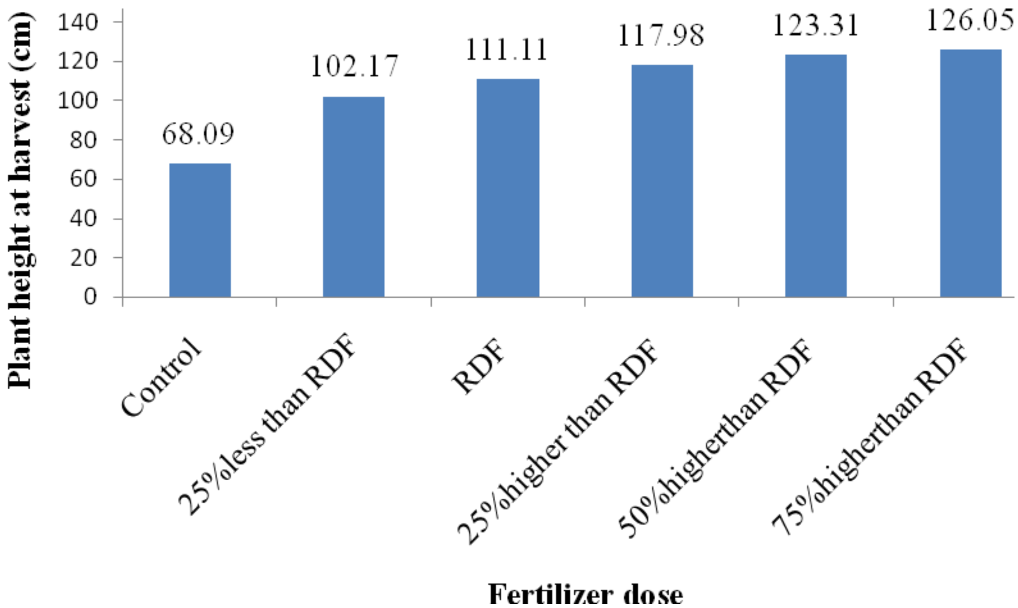

Fig.4 Effect of fertilizer doses on plant height (cm) of cotton (LSD 0.05 = 7.14)

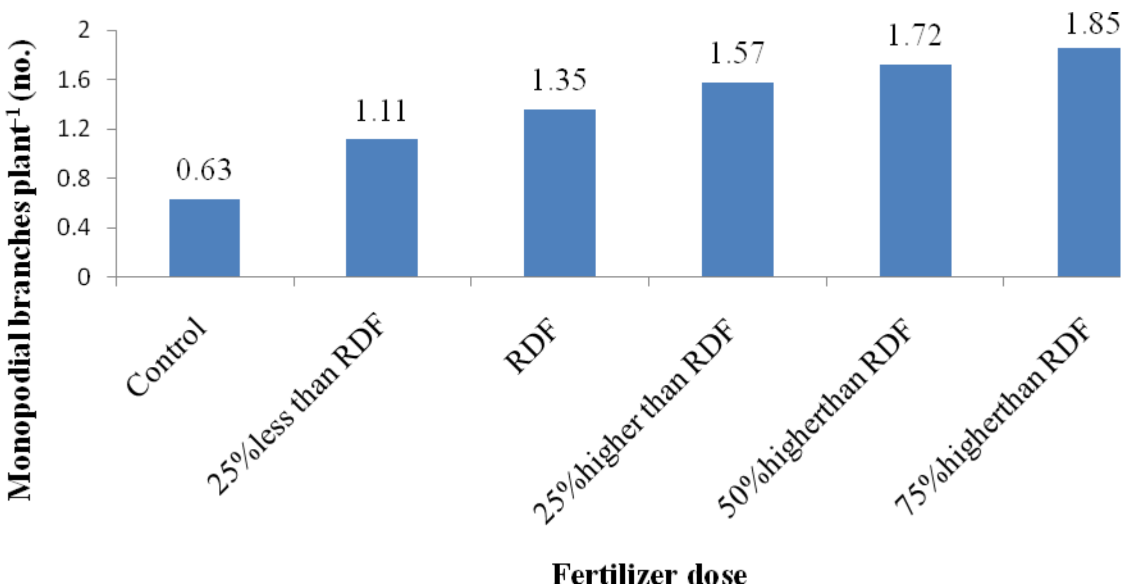

Fig.5 Effect of fertilizer doses on monopodial branch plant^{-1} of cotton (LSD 0.05= 0.21)

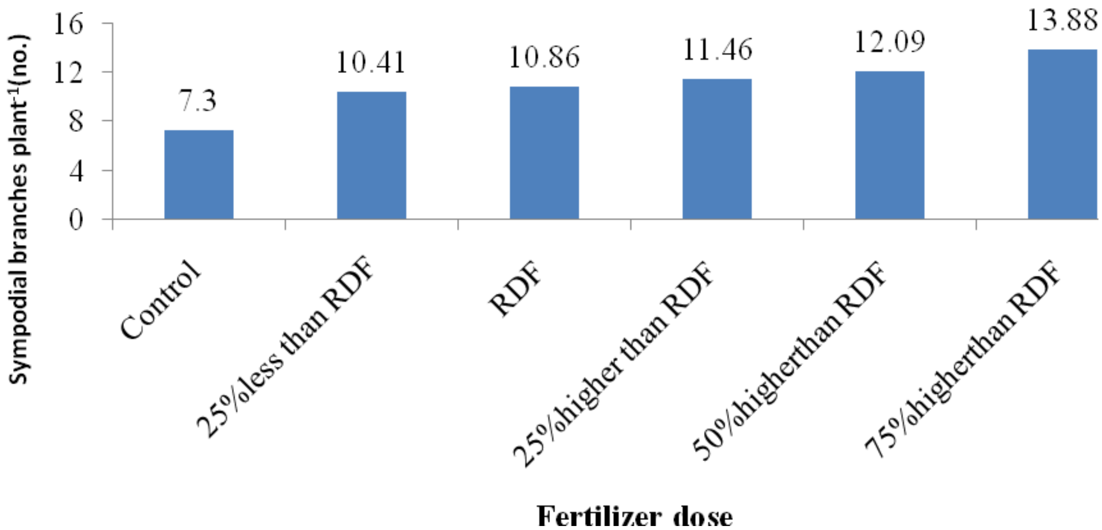

Fig. 6 Effect of fertilizer doses on sympodial branch plant^{-1} of cotton (LSD 0.05 = 0.93)

4.1.2.3. Interaction effect of variety and fertilizer

There observed a significant difference in plant height, monopodial branch plant^{-1}and simpodial branch plant^{-1} due to combined effect of variety and fertilizer levels (Table 4). The result showed that irrespective of varieties plant height, monopodial branch plant^{-1} and sympodial branch plant^{-1} increased gradually with application of increasing fertilizer doses. The tallest plant (127.98 cm) and the highest sympodial branch plant^{-1} (14.90) found in the combined effect of CB-14 and 75 % higher fertilizer than RDF. The highest monopodial branch plant^{-1} (1.90) observed in CB-12 and 75 % higher fertilizer than RDF treatment Combination. The lowest plant height (66.16 cm) and vegetative branch plant^{-1} observed (0.53) in CB-14 and control fertilizer combination. Similar, results reported by Khalequezzaman *et al.* (2015) that, increased of seed cotton yield, plant height number of monopodia and number of sympodia, number of bolls and boll weight for variety and. fertilizer rates.

Table 4. Interaction effect of variety and fertilizer level on plant characters of Cotton

Treatment (Variety× Fertilizer)	Plant height (cm)	Monopodial branches plant^{-1} (no.)	Sympodial branches plant^{-1} (no.)
CB- 13 × Control	68.10 h	0.60 i	6.70 g
× 25% less than RDF	102.65 fg	1.10 fg	9.83 d-f
× RDF	109.55 d-f	1.30 e-g	10.93 c-f
× 25% higher than RDF	118.79 a-d	1.61 a-d	12.43 a-d
× 50% higherthan RDF	122.74 a-c	1.71 ab	9.60 ef
× 75% higherthan RDF	122.90 a-c	1.85 a	13.77 ab
CB- 14 × Control	66.16 h	0.53 i	6.80 g
× 25% less than RDF	108.84 ef	1.06 gh	11.53 b-e
× RDF	113.45 c-e	1.36 d-g	9.87 d-f
× 25% higher than RDF	114.01 b-e	1.60 a-d	12.33 a-e
× 50% higher than RDF	123.55 ab	1.70 a-c	12.73 a-c
× 75% highe rthan RDF	127.98 a	1.81 ab	14.90 a
CB- 12 × Control	70.00 h	0.76 hi	8.40 fg
× 25% less than RDF	95.03 g	1.17 fg	9.87 d-f
× RDF	110.33 d-f	1.40 c-f	11.77 b-e
× 25% higher than RDF	121.14 a-c	1.52 b-e	11.50 b-e
× 50% higher than RDF	123.65 ab	1.75 ab	12.03 b-e
× 75% higher than RDF	127.27 a	1.90 a	12.97 a-c
LSD(0.05)	**9.7554**	**0.3038**	**2.77**
CV (%)	**6.10**	**14.20**	**12.14**

Here, RDF= Recommended dose of chemical fertilizers

4.1.3. Yield and yield contributing characters

4.1.3.1. Effect of variety

A significant difference observed in number of bolls plant^{-1}, boll weight and yield among the cotton variety (Table 5). Variety CB-14 produced the maximum number of bolls plant^{-1} (17.94) which was statistically highest from other varieties. Variety CB-13 produced the minimum number of bolls plant^{-1} (16.2). Bolls plant^{-1} variation among the varieties may be due to genetic make up among the varieties.

Individual boll weight is an important component of the cotton yield and found significant difference among the tested varieties of cotton. The highest single boll weight (4.33g) recorded in CB-14 which was statistically similar to CB-12 variety. The lowest single boll weight (4.12 g) observed in CB-13 variety. Seed cotton yield significantly influenced by different genotypes of cotton. The highest seed cotton yield (1938 kg ha^{-1}) recorded in CB-14. The lowest seed cotton yield (1674 kg ha^{-1}) recorded in CB-13 variety. The highest seed cotton yield of CB-14 was associated with its better yield components like number of bolls per plant and individual boll weight. The results confirmed with the findings of Tan (193) and Dhanda *et. Al* (1984) who observed that seed cotton yield is positively correlated with the number of bolls $plant^{-1}$ and individual boll weight. Afiah and Ghoneim (2000), Badr (2003) and Soomro *et al.* (2008) also correlates seed cotton yield positively with sympodiums per plant, bolls per plant and boll weight.

Differential effects of variety on ginning out turn or lint percentage is well documented. Variety CB-12 gave the highest ginning out turn (41.3 %) where as CB-13 obtained the lowest ginning out turn (40.47 %). Boquet and Clawson, (2009); O'Berry *et al*. (2009) in their experiment found significant differences in ginning out turn among cultivars.

Lint yields were significantly different among cotton genotypes (Table 6). CB-14 out yielded over CB-12 and CB-13 by producing 8.74 % and 15.12 % higher lint yield. However the highest lint yield (946 kg ha^{-1}) observed in variety CB-14 which was significantly higher than other genotypes. The lowest lint yield (803 kg ha^{-1}) obtained from CB-13 variety. Such great variability in lint yield might be due to gene effect as genotypic variation in yield of any crop is primarily governed by genetical characters.The result corresponds well to that of Nichols *et al*. (2004) who observed similar large variability in lint yields of different cotton genotypes.

Table 5. Effect of variety on yield and yield attributes of cotton

Variety	Bolls plant^{-1} (no)	Boll weight (g)	Seed cotton yield (kg ha^{-1})	Ginning out turn (%)	Lint yield (kg ha^{-1})
CB-13	16.27 b	4.12 b	1674 b	40.47 b	803 b
CB-14	17.94 a	4.33 a	1938 a	40.94 ab	946 a
CB-12	16.30 b	4.30 a	1756 b	41.30 a	870 b
LSD(.05)	**0.913**	**0.115**	**123.49**	**0.65**	**49.4**
CV (%)	**9.13**	**3.96**	**12.03**	**1.36**	**12.03**

4.1.3.2 Effect of fertilizer

The result showed that number of bolls plant^{-1} increased gradually with the increase of fertilizer dose (Table 6). The highest bolls plant^{-1} (21.81) produced in 75% higher than RDF which was statistically similar to 50% higher than RDF (21.08). The lowest bolls plant^{-1} (6.51) produced by control treatment. The results corroborates with the findings of Parmer *et al.* (2010) who reported that boll plant^{-1} increased with increased fertilizer doses. Many researchers agreed the present results, they observed increase in bolls per plant by increasing N level (Dar and Khan, 2004; Wiatrak *et al*. 2005; Khan and Dar, 2006; Sawan *et al*. 2006; Kumbhar *et al*. 2008).

Fertilizer doses exerted significant effect on boll weight of cotton (Table 6). The highest boll weight (4.67g) produced in 75% higher than RDF which was statistically similar with 50% and 25% higher than RDF. The lowest boll weight (3.07g) produced from control treatment. The results was consistence with the findings of Khalequzzaman *et al. (*2012) who reported increased fertilizer levels increased with boll weight of cotton. Saleem *et al*. (2010) recorded maximum boll weight at 120 kg N ha^{-1}.

Fertilizer doses showed significant influence on seed cotton yield (Table 6). The results indicated that seed cotton yield increases progressively with the increases of fertilizer dose. The highest seed cotton yield (2448 kg ha^{-1}) observed in 75% higher than RDF which was significantly higher than other doses except 50 % higher than RDF. The lowest seed cotton yield produced in control ferlizer (479 kg ha^{-1}). The highest seed cotton yield in 75% higher than RDF application treatment might be due to the highest number of boll plant^{-1}, highest individual boll weight and highest number of sympodial branch plant^{-1}. This results is in agreement with the findings of Sharma *et al.* (1979) who reported yield of cotton with application of fertilizers up to 320:160:160 kg NPK ha^{-1}. However, optimum dose of fertilizer found to be 280:140:140 kg ha^{-1} NPK for maximum production of seed cotton. The present results supported the findings of Parmer *et al.* (2010) and Angadi *et al.* (1989) who reported fertilizer levels increase yield of hybrid cotton. Kumbhar *et al*. (2008) have obtained significant increase in seed cotton yield due to N application.

The ultimate objective of cotton production is lint production; to increase the lint production, ginning out turn must be increased. Linear increase in ginning out turn with increasing fertilizer rates of crop. Highest ginning out turn recorded for 50% higher than RDF (41.4 %) but it was statistically at par with that of 25% higher than RDF (41.1%). Increasing of ginning out turn due to application of higher level of fertilizers was also reported by Saleem *et al*. (2010).

Table 6. Effect of fertilizer levels on yield and yield attributes

Fertilizer level	Bolls plant^{-1} (no)	Boll weight (g)	Seed cotton yield (kg ha^{-1})	Ginning out turn (%)	Lint yield (kg ha^{-1})
Control	6.51 e	3.073 d	479 e	40.40 b	194 e
25% less than RDF	14.99 d	4.15 c	1498 d	40.80 ab	611d
RDF	16.74 c	4.40 b	1771 c	40.97 a	725 c
25% higher than RDF	19.89 b	4.60 a	2200 b	41.40 a	910 b
50% higher than RDF	21.08 a	4.62 a	2341 ab	41.40 a	969 a
75% higher than RDF	21.81 a	4.67 a	2448 a	40.45 b	990 a
LSD(0.05)	**1.18**	**0.1226**	**146.51**	**0.76**	**58.6**
CV (%)	**7.31**	**3.60**	**9.02**	**1.30**	**9.02**

Here, RDF= Recommended dose of chemical fertilizers

Fertilizer doses exerted significant effect on lint yield (Table 6). The result showed that lint yield gradually increased with the increases of fertilizer dose. The highest lint yield (990 kg ha^{-1}) was produced in 75% higher than RDF which was statistically similar to 50% higher than RDF (969 kg ha^{-1}). The lowest lint yield (194 kg ha^{-1}) produced in control fertilizer. Higher lint yield in 50% and 75% higher than RDF might be due to higher ginning out turn higher number of bolls plant^{-1} and higher boll weight.

4.1.3.3. Interaction effect of variety and fertilizer on yield and yield attributes

There observed a significant difference in bolls plant^{-1} due to combined effect of variety and fertilizer levels in cotton (Table 7). The result showed that bolls plant^{-1} increased gradually with the application of increasing fertilizer dose irrespective of varieties. The highest bolls plant^{-1} (23.95) found in the combination of CB-14 variety and 75% higher than RDF which was significantly higher than all other variety and fertilizer combinations except CB-14 and 50 % higher than RDF. The lowest bolls plant^{-1} (5.61) observed in CB-12 variety and control fertilizer combination.

There observed a significant difference in boll weight due to combined effect of variety and fertilizer (Table 7). The highest boll weight (4.73 g) was found in combination of CB-12 vatiety and 25% higher than RDF treatment which was statistically similar with all other interaction except CB-13 × control, CB-13 × 25 % less than RDF, CB-13 × 25 % ,CB-14× control, CB-12 × control, CB-12 × 25 % less than RDF and CB-13 × RDF .The lowest boll weight (3.04 g) observed in the CB-13 vatiety and control fertilizer combination.

Combined effect of variety and fertilizer level exerted significant effect in seed cotton yield (Table7). The result showed that seed cotton yield increased gradually with the application of increasing fertilizer doses irrespective of varieties. The highest seed cotton yield (2676 kg ha^{-1}) found in the combination of CB-14 and 75% higher than RDF which was signinificantly similar with the combinations of CB-14 × 50% higher than RDF and CB-12 × 75% higher than RDF. Variety CB-12 and control treatment combination gave the lowest yield. These results are consisted with the findings of Khalequezzaman *et al.* (2015) who reported that.

Table7. Interaction effect of variety and fertilizer level on yield and yield attributes of cotton

Interaction (Variety × Fertilizer)	Bolls plant^{-1} (no)	Boll weight (g)	Seed cotton yield (kg ha^{-1})	Ginning out turn (%)	Lint yield (kg ha^{-1})
CB-13 × Control	7.56 h	3.04 f	552 i	40.5	223 i
× 25% less than RDF	14.40 g	3.78 e	1307 h	41.00	535 h
× RDF	16.91 ef	4.26 cd	1735 fg	39.63	685 fg
× 25% higher than RDF	19.00 de	4.48 a-c	2047 de	41.13	835 de
× 50% higher than RDF	19.93 cd	4.54 ab	2175 cd	41.93	904 cd
× 75% higher than RDF	20.00 cd	4.65 ab	2233 cd	38.43	835 cd
CB- 14 × Control	6.35 h	3.12 f	474 i	42.06	195 i
× 25% less than RDF	16.05 fg	4.47 a-d	1722 fg	38.50	719 fg
× RDF	17.20 ef	4.52 a-c	1868 ef	40.63	700 ef
× 25% higher than RDF	20.96 b-d	4.59 ab	2315 b-d	42.00	932 b-d
× 50% higher than RDF	23.13 ab	4.63 ab	2575 ab	41.53	1081 ab
×75% higher than RDF	23.95 a	4.65 ab	2676 a	40.93	1102 a
CB- 12 × Control	5.61 h	3.06 f	412 i	39.83	167 i
×25% less than RDF	14.53 g	4.20 d	1466 gh	41.70	579 gh
× RDF	16.11fg	4.42 b-d	1710 fg	42.46	713 fg
× 25% higher than RDF	19.71 cd	4.73 a	2275 b-d	41.06	950b-d
× 50% higherthan RDF	20.20 cd	4.68 ab	2275 b-d	40.73	919 b-d
× 75% higher than RDF	21.48 bc	4.71 a	2434 a-c	42.00	1022 a-c
LSD(0.05)	**2.173**	**0.262**	**302.50**	**NS**	**121.0**
CV (%)	**7.31**	**3.60**	**9.02**	**1.30**	**9.02**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers

combined effect of variety and fertilizer have positive impact on seed cotton yield, plant height, number of monopodia and number of sympodia, number of bolls and boll weight as well as lint yield

Combination of different variety and fertilizer level exerted non significant effect on ginning out turn (Table 7). The result is similar with the finding of Khan and Dar (2006) who had shown non significant effect of N or NPK on lint seed ratio.

There observed a significant difference in lint yield due to interaction effect of variety and fertilizer level (Table 7). The result showed that seed cotton yield increased gradually with the application of increasing fertilizer doses irrespective of varieties. The highest lint yield (1102 kg ha^{-1}) was found in the combined effect of CB-14 × 75% higher than RDF which was significantly identical to CB-14 × 50% higher RDF and CB-12 × 75% higher RDF treatment combinations. The lowest lint yield (167 kg ha^{-1}) observed in CB-12 variety and control fertilizer combination. These results are consisted with Khalequezzaman *et al.* (2015) who reported that combined effect of fertilizer and variety have positive impact in lint yield.

4.1.4. Lint characteristics

4.1.4.1 Effect of variety

Fibre quality primarily affected by genotype while agronomic practices are secondary (Bednarz *et al.* 2005). Braden *et al*. (2009), Zeng and Meredith, Jr. (2009), Hua *et al*. (2009) Ulloa *et al*. (2009) identified significant variation among genotypes for fibre quality.

Staple length was significantly different among cotton genotypes (Table 8). Fibre length of cotton genotypes varied from 27.98 mm to 28.67 mm. The genotype CB-14 had the longest fibre length (28.67 mm), while fibre length of CB-13 was the shortest (27.98 mm). The results was consisted with the findings of Nichols *et al.* (2004) who reported that there was genotypic variation for staple length of cotton. Bourland and Jones (2009a, b), Smith *et al*. (2010) and Long *et al*. (2010) pointed out that staple length vary across cultivars.

Fibre strength varied significantly due to different cotton genotypes (Table 8). The highest fibre strength (85.36 g/tex) was observed in CB-14 variety and that of lowest (84.67g/tex) found in CB-13 variety. Such differences in genotypes contributing to fibre strength is very important as the genotypes with the highest strength tend to produce longer cellulose molecules, thus providing fewer break points in the lint and greater cross linkage between fibres. This result was in agreement with the findings of Faircloth (2007), Bourland and Jones, (2009a,b) and Saleem *et al*. (2010), who reported that the fibre strength influenced by cultivars.

The fineness of fibre is an important aspect of cotton lint. The finer the thread, the greater the length produces from a pound of cotton. It is one of the evaluation methods of cotton quality. Fineness of cotton can be measured through smoothness of fibre. It is associated with fibre diameter and fiber wall thickness while the micronaire value represents the fibre diameter. There were significant differences of fineness of fibre produced by different genotypes of cotton (Table 8). Among the cotton genotypes, CB-14 was resulted the lowest micronaire value (4.66 µg/inch) and it attained maximum (5.06 µg/inch) in CB-12. This result was in agreement with the findings of Bednarz *et al*. (2005) who reported that both genetical and environmental conditions influences on micronaire value. Cotton genotype which contains micronaire value greater than 5.0 mµ/inch should not consider in selection process of variety development as this produces lower strength yarns.

Length uniformity is now part of the premium /discount valuation of cotton. Short fibre within a process mix of cotton cannot warp around each other and contribute little or nothing to yarn strength. Short fibres indirectly cause product defaults and directly contribute to higher waste and lower manufacturing efficiency. Since short fibre content and length uniformity are devised from length, they are influenced by the same factor as length. Crop management practices that influence where bolls are located on the plant can impact short fibre content levels. Uniform fruit retention patterns encarage beller length uniformity. Uniformity ratio of different cotton genotypes was not significant (Table 8). Hence the highest uniformity ratio (81.35%) was observed in variety CB-14 and the lowest uniformity ratio (80.92%) found in variety CB-12.

Table 8. Effect of variety on lint characteristics of cotton

Variety	Staple length (mm)	Staple strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
CB- 13	27.98 c	28.22 c	4.97 a	81.35
CB- 14	28.67 a	28.45 a	4.66 b	81.37
CB- 12	28.17 b	28.25 b	5.06 a	80.92
LSD (.05)	**0.16**	**0.17**	**0.23**	**NS**
CV (%)	**0.48**	**0.28**	**3.89**	**1.05**

Here, NS= Not significant

4.1.4.1. Effect of fertilizer

There exit a significant effect on staple length of lint due to fertilizer levels (Table 9). The result indicated that staple length showed gradual increasing trend with the increases of fertilizer dose. The highest staple length (28.81 mm) were observed in 75% higher than RDF which was statistically higher than other doses. The lowest staple length (27.79mm) was found in control treatment. Similar result was reported by Li *et al*. (2010) is that fibre length and specific fibre strength increase in N fertilization treatment over control. This result was also consistent with the findings of Goa.Yuan *et al.* (2008) that potassium fertilization may improve fibre quality of long-fibre cotton. Rochester *et al*. (2001), Tewolde and Fernandez (2003), Bauer and Roof (2004) and Kumbhar *et al*. (2008) also observed increase in fibre length with increased N rates.

Fertilizer doses exerted significant effect on fibre strength of cotton (Table 9. The result indicated that fibre strength increases progressively with the increase of fertilizer levels. The highest fibre strength (28.43 g/tex) found in 75% higher than RDF which was statistically similar with 50% higher than RDF and 25% higher than RDF treatments. The lowest fibre strength (28.23 g/tex) was measured with in control treatment which was statistically similar with 25% lower than RDF and RDF. This result is in agreement with the findings of Li. *et al*., (2010) who reported that fibre length and specific fibre strength increase in N fertilization treatment over the control. Rochester *et al*. (2001) and Bauer and Roof (2004) also observed similar finding that fibre strength increased by increasing N rate.

Fertilizer levels affected significantly on micronaire value on cotton staple (Table 9).The highest micronaire value observed (5.01 µg/inch) in RDF which was statistically similar with 25% higher than RDF (4.99 µg/inch). The lowest micronaire value observed in (4.69 µg/inch) 75% higher than RDF treatment which was statistically similar with control treatment (4.75 µg/inch). This result was in agreement with the findings of Phipps *et al*. (1997) and Sawan *et al*.(1997). Boman *et al*. (1997) reported on the basis of 11 year data that nitrogen management effects on micronaire are frequently inconsistent that micronaire readings were reduced by applied N in low-micronaire environments and increased by applied N in high micronaire environments.

Uniformity ratio of cotton was significantly affected due to fertilizer doses (Table 9). Uniformity ratio increased gradually with the increase of fertilizer dose. The significantly highest uniformity ratio (81.90%) found in 50% higher than RDF which was statistically similar with all the fertilizer levels except control treatment. The lowest uniformity ratio (80.54%) was in control treatment. This result is in agreement with the findings of Bauer and Roof (2004) who observed increase in fiber uniformity by increasing N levels.

Table 9. Effect of fertilizer rates on lint characteristics of cotton

Fertilizer levels	Staple length (mm)	Staple strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
Control	27.79 d	28.23 b	4.75 bc	80.54 b
25% less than RDF	28.16 c	28.24 b	4.99 ab	81.35 ab
RDF	28.16 c	28.24 b	5.01 a	81.06 ab
25% higher than RDF	28.18 c	28.32 a	4.99 a	81.07 ab
50% higher than RDF	28.53 b	28.40 a	4.97 ab	81.90 a
75% higher than RDF	28.81a	28.43 c	4.69 c	81.36 ab
LSD (.05)	**0.19**	**0.11**	**0.23**	**1.34**
CV (%)	**0.48**	**0.28**	**3.35**	**1.15**

Here, RDF= Recommended dose of chemical fertilizers

4.1.4.3 Interaction effect

There observed a significant difference in staple length due to combined effect of variety and fertilizer in cotton (Table 10). Significantly the highest staple length (29.46 cm) observed in CB-14 and 75% higher than RDF combined treatment which was statistically at par with that of CB-14 variety and 50 % higher than RDF. Combined effect of CB-13 and control fertilizer showed the lowest staple length (26.96 cm).

Combined effect of CB- 14 and 75% higher than RDF showed the highest level of fibre strength (28.64 g/tex) but statistically at par with that of (28.39 g/tex) and CB-14 × 50% higher than RDF, CB-14 × 25% higher than RDF and CB-12 × 75% higher than RDF treatment combinations. Irrespective of varieties and control treatment showed the lowest level of fibre strength.

Micronaire value affected significantly due to combined effect of variety and fertilizer level (Table10). The significantly highest micronaire value (5.04 µg/inch) observed in CB-14 × 25% less than RDF similar with all other combinations except CB-14 × 50% higher than RDF (4.21 µg/inch) and CB-14 × 75% higher than RDF (4.33 µg/inch). Uniformity ratio showed non-significant variation due to variety × fertilizer level interaction

Table 10. Interaction effect of variety and fertilizer level on lint attributes of cotton

Interaction (Variety× Fertilizer)	Staple length (mm)	Staple strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
CB- 13 × Control	26.96 f	28.23 b-e	5.10 a	80.87
× 25% less than RDF	28.07 cd	28.26 bc	4.97 a	81.85
× RDF	27.79 de	28.00 e	5.0 a	81.02
× 25% higher than RDF	28.35 bc	28.34 b	4.91 a	82.00
× 50% higher than RDF	28.07 cd	28.24 b-d	4.90 a	81.52
× 75% higher than RDF	28.63 b	28.26 bc	4.95 a	80.83
CB- 14 × Control	28.07 cd	28.33 b	4.76 a	81.85
× 25% less than RDF	28.07 cd	28.35 b	5.04 a	79.59
× RDF	28.35 bc	28.36 b	5.01 a	81.49
× 25% higher than RDF	28.63 b	28.41 a	4.73 ab	81.18
× 50% higher than RDF	29.46 a	28.63 a	4.21 bc	82.18
× 75% higher than RDF	29.46 a	28.64 a	4.23 bc	81.92
CB- 12 × Control	28.35 bc	28.07 c-e	5.1 a	81.33
× 25% less than RDF	28.07 cd	28.29 bc	5.08 a	80.18
× RDF	28.35 bc	28.36 b	5.02 a	80.67
× 25% lhigher than RDF	27.56 e	28.03 de	5.33 a	80.03
× 50% higher than RDF	28.35 bc	28.35 b	4.96 a	82.00
× 75% higher than RDF	28.35 bc	28.39 a	4.90 a	81.33
LSD(0.05)	**0.19**	**0.24**	**0.73**	**NS**
CV(%)	**0.48**	**0.28**	**3.35**	**1.15**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers
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4.1.5. Economic analysis

Economic analysis was done with a view to observing the comparative cost and benefit under different treatment combinations of variety and fertilizer levels. For this purpose, the inputs cost for land preparation, cotton seed, manure and fertilizer, pesticide, intercultural operation, harvesting and post harvesting cost and manpower required for all the operations including seed cotton were recorded against each treatment, which were then enumerated into cost per hectare.

Variation in cost of production noted due to the cost of cotton seed and different fertilizer levels (Table 11). The total cost of production ranged between 52500 Tk ha^{-1} to 76390 Tk ha^{-1}. The cultivation cost increased with increasing fertilizer dose. The highest cost of production (76390 Tk ha^{-1}) was involved when used 75 % higher than RDF dose was used with any variety. The lowest cost of production (52500 Tk ha^{-1}) was involved when used no fertilizer with any variety. The highest gross return found when used CB-14 variety and 75 % higher than RDF dose treatment combination (160560 Tk ha^{-1}). The lowest gross return found (24720 Tk ha^{-1}) when used CB-12 variety and no fertilizer treatment combination. The highest gross margin found when used CB-14 variety and 75 % higher than RDF dose treatment combination (84170 Tk ha^{-1}). The lowest gross margin found when used CB-12 variety and no fertilizer (-27780 Tk ha^{-1}) treatment combination. The maximum benefit cost ratio (BCR) involved when used CB-14 variety and 75 % higher than RDF dose treatment combination (2.10). The minimum benefit cost ratio found when used CB-12 variety and no fertilizer treatment combination (0.47). For economic point of view, results indicate that CB-14 inbred variety with 75% and 50% higher than RDF level was more profitable than the other treatment combinations.

Table 11. Economic analysis in cotton production as influenced by cotton variety and fertilizer levels

Treatments (Variety ×fertilizer)	Seed cotton yield (kg ha^{-1})	Gross return (Tk ha^{-1})	Total variable cost (Tk ha^{-1})	Gross margin (Tk ha^{-1})	BCR
CB-13 × Control (no fertilizer)	552	33120	52500	-19380	0.63
× 25% less than RDF	1307	78420	70118	8302	1.12
× RDF	1735	104100	71686	32414	1.45
× 25% higher than RDF	2047	122820	73254	49566	1.67
× 50% higher than RDF	2175	130500	74822	55678	1.74
× 75% higher than RDF	2233	133980	76390	57590	1.75
CB-14 × Control (no fertilizer)	474	28440	52500	-24060	0.54
× 25%less than RDF	1722	103320	70118	33202	1.47
× RDF	1868	112080	71686	40394	1.56
× 25% higher than RDF	2315	138900	73254	65646	1.89
× 50% higher than RDF	2575	154500	74822	79678	2.06
× 75% higher than RDF	2676	160560	76390	84170	2.10
CB -12 × Control (no fertilizer)	412	24720	52500	-27780	0.47
× 25% less than RDF	1466	87960	70118	17842	1.25
× RDF	1710	102600	71686	30914	1.43
× 25% higher than RDF	2275	136500	73254	63246	1.86
× 50% higher than RDF	2275	136500	74822	61678	1.82
× 75% higher than RDF	2434	146040	76390	69650	1.91

Note:

RDF= Recommended dose of chemical fertilizers
Urea = 22 Tk kg^{-1} , MOP = 17 Tk kg^{-1}, Gypsum =12 Tk kg^{-1}, Zink sulphate = 210 Tk kg^{-1}

Borax =214 Tk kg^{-1}, Mac sulpher = 67 Tk kg^{-1}, Ektara = 9300 Tk kg^{-1},

Volume flexy = 5725 Tk kg^{-1} , Cupravit = 2200 Tk kg^{-1}, wage rate = 400 Tk man day

Cotton Seed =24 Tk kg^{-1}, Seed Cotton = 60 Tk kg^{-1}

4.2. Experiment 2. Effect of different plant spacing on seed cotton yield and fibre quality of some newly released cotton varieties

4.2.1. Phenological attributes

2.2.1.1. Effect of variety

Squaring, blooming, and boll opening of each cotton genotype expressed in days after planting have been presented in Table 12. Node number of first fruiting branch plant^{-1}, days required for blooming and boll opening were non significant. There existed significant difference in days from planting to squaring. Variety CB-12 required the longest time (56.75 days) to squaring which differed from CB-13 variety. Days required to blooming and boll opening are important characters of cotton as it indicates the earliness of the crop. The genotypes took least days to initiate squaring are considered earliest in crop maturity (Godoy and Palomo, 1999). Although these are inherent characters but sometimes environmental factors also governed the time of blooming and boll opening (Sawan *et al.* 1999).

Table 12. Effect of variety on phonological attributes of cotton

Treatment (variety)	Days to squaring (days)	Days to first flowering (days)	Days to first boll splitting (days)	Node number of first fruiting branch (no.)
CB-13	54.08 b	67.92	118.46	6.30
CB-14	56.00 ab	68.03	116.12	6.19
CB-12	56.75 a	69.38	116.17	6.26
LSD (0.05)	**2.06**	**NS**	**NS**	**NS**
CV (%)	**6.38**	**6.01**	**3.93**	**6.46**

Here, NS= Not significant

4.2.1.2. Effect of spacing

Number of days to squaring, 1st flowering and 1st boll opening were not affected by plant spacing but node number of first fruiting branch were significantly affected by plant spacing (Table 13). The highest node number of first fruiting branch (6.47) recorded in (45 × 45 cm) plant spacing which was stastically similar with all other plant spacing except (75×30 cm) and (90×30 cm) spacing. Lower position of first fruiting branch node (Shakeel *et al.,* 2008; and Ahmad *et al.* 2008) and height of first fruiting branch node (Weijun, 1998) indicate earliness in plant maturity. The results is consisted with the finding of Kerby *et al*. (1990) who reported that plant spacing had no effect on the earliness of crops on the shorter and more determinate genotypes. However, Clawson *et al*. (2008) reviewed the effect of plant density on the earliness of crop and was of the view that no study suggests strong influences of row spacing, independent of plant population, on crop maturity.

Table 13. Effect of different spacing on phonological attributes of cotton

Treatment (spacing)	Days to squaring (days)	Days to first flowering (days)	Days to first boll splitting (days)	Node number of first fruiting branch (no.)
45 × 30 cm	56.44	68.22	117.78	6.28 ab
45 × 45 cm	54.56	66.89	115.44	6.47 a
60 × 30 cm	55.44	68.44	117.78	6.21 ab
60 × 45 cm	56.78	69.00	118.42	6.28 ab
75 × 30 cm	56.44	69.78	117.00	6.43 a
75 × 45 cm	56	67.89	116.21	6.04 b
90 × 30 cm	53.78	67.79	115.70	6.03 b
90 × 45 cm	55.44	69.67	117.00	6.26 ab
LSD (0.05)	**NS**	**NS**	**NS**	**0.38**
CV (%)	**6.38**	**6.01**	**3.93**	**6.46**

Here, NS= Not significant

4.2.1.3 Interaction effect of variety and spacing

There observed a significant difference in days to squaring, days to 1st boll opening and nod number of first fruiting branch due to combined effect of variety and spacing (Table 14). The shortest time for squaring (52.67 days) was found in the combined effect of CB-13 variety and (60 × 30 cm.) spacing which was stasticallyidentical to CB-13 with 90 × 30 cm spacing.

Table 14. Interaction effect of variety and pacing on phonological attributes of cotton

Interaction (Variety × Spacing)	Days to squaring (days)	**Days to first flowering (days)**	**Days to first boll splitting (days)**	**Node number of first fruiting branch (no.)**
CB-13 × 45 × 30 cm	54 bc	68.00	118.95 ab	6.23 a-c
× 45 × 45 cm	54 bc	67.33	118.95 ab	6.30 a-c
× 60 × 30 cm	52.67 c	67.33	1119.34 ab	6.17 a-c
× 60 × 45 cm	55.67 a-c	66.00	118.56 ab	6.23 a-c
× 75 × 30 cm	53.67 bc	70.67	118.17 ab	6.63 a
× 75 × 45 cm	55.00 a-c	67.33	120.89 a	5.97 bc
× 90 × 30 cm	52.67 c	67.67	116.21 ab	6.40 a-c
× 90 × 45 cm	55.00 a-c	69.00	116.61 ab	6.50 ab
CB-14 × 45 × 30 cm	56 a-c	68.33	115.44 ab	6.23 a-c
× 45 × 45 cm	54.33 a-c	65.00	112.70 b	6.70 a
× 60 × 30 cm	59.33ab	70.67	119.73 ab	6.27 a-c
× 60 × 45 cm	58.33a-c	69.33	118.17 ab	6.20 a-c
× 75 × 30 cm	55.67 a-c	68.00	116.21 ab	6.33 a-c
× 75 × 45 cm	55.00 a-c	66.00	113.49 ab	5.93 bc
× 90 × 30 cm	53.67 bc	66.67	116.04 ab	5.87 bc
× 90 × 45 cm	56.67 a-c	70.67	118.17 a	5.97 bc
CB-12 × 45 × 30 cm	59.33 ab	68.33	118.95 ab	6.37 a-c
× 45 × 45 cm	55.33 a-c	68.33	114.66 ab	6.40 a-c
× 60 × 30 cm	56.33 a-c	67.33	114.26 ab	6.20 a-c
× 60 × 45 cm	56.33 a-c	71.67	118.57 ab	6.40 a-c
× 75 × 30 cm	60.00 a	70.67	116.61 ab	6.33 a-c
× 75 × 45 cm	58.00 a-c	70.33	114.27 ab	6.23 a-c
× 90 × 30 cm	55.00 a-c	69.00	115.83 ab	5.83 c
× 90 × 45 cm	55.67 a-c	69.33	116.21 ab	6.30 a-c
LSD (0.05)	5.82	**NS**	**7.54**	**1.27**
CV 9%)	6.38	**6.01**	**3.93**	**6.46**

Here, NS= Not significant

The longest squaring time (60.00 days) observed in CB-12 variety and (75 × 30 cm) spacing combination. The shortest boll splitting time (112.70 days) observed in CB-14 variety and (45 × 45 cm) spacing combination. The highest node number of first fruiting branch (6.70) observed in CB-14 variety and (45 × 45 cm) spacing combination.

4.2.2. Plant characters

4.2.2.1. Effect of variety

Plant height, vegetative branch plant^{-1} and sympodial branch plant^{-1} of different varieties measured at harvest time have been presented in (Fig.7, 8 and 9). Results showed a non significant difference in plant height, vegetative branch plant^{-1} and sympodial branch plant^{-1} of cotton genotypes. Numarically the tolest plant (130.68 cm), the highest sympodial branch plant^{-1} (16.13) and maximum vegetative branch plant^{-1} (0.8417) were observed in variety CB-13. On the other hand, the lowest values of plant height (125.38 cm), sympodial branch plant^{-1} (15.48) and vegetative branch plant^{-1} (0.76) were observed in CB-12 variety. These results are similar to Brar *et al. (*2002) and Ali *et al*. (2009) who reported non-significant results among genotypes on number of monopdial and sympodial branches plant^{-1}.

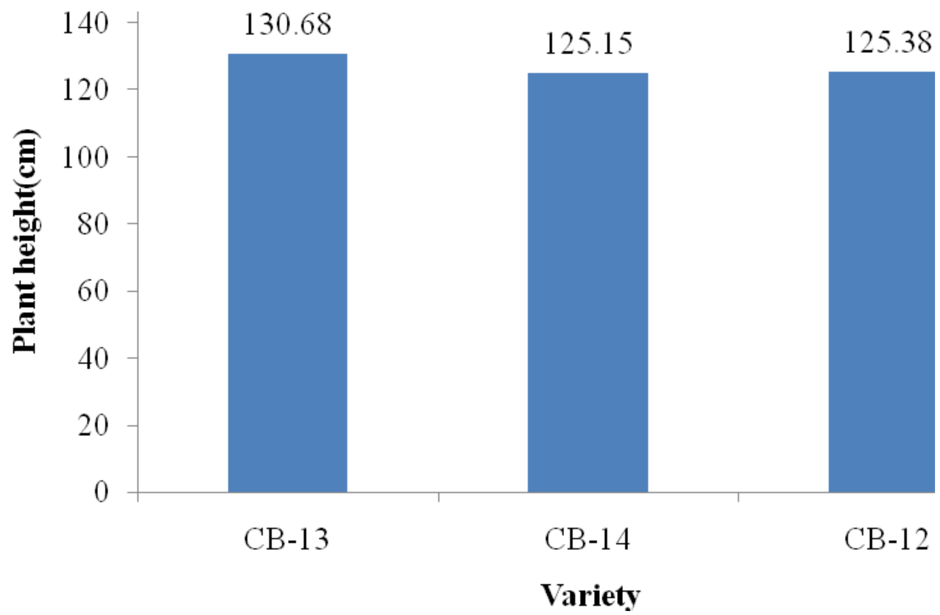

Fig.7 Effect of variety on plant height of cotton (LSD 0.05 =NS)

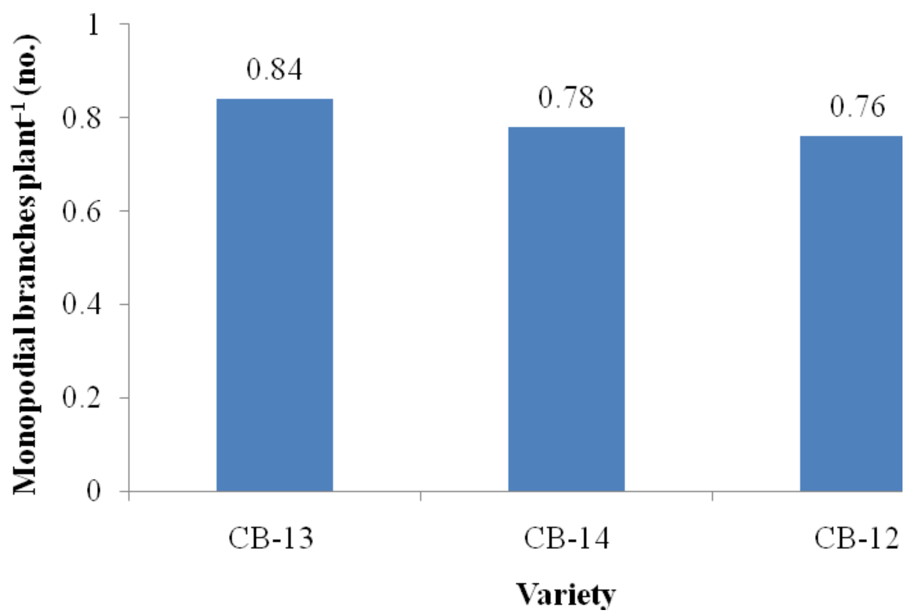

Fig.8. Effect of variety on monopodial branch plant^{-1} of cotton (LSD 0.05 = NS)

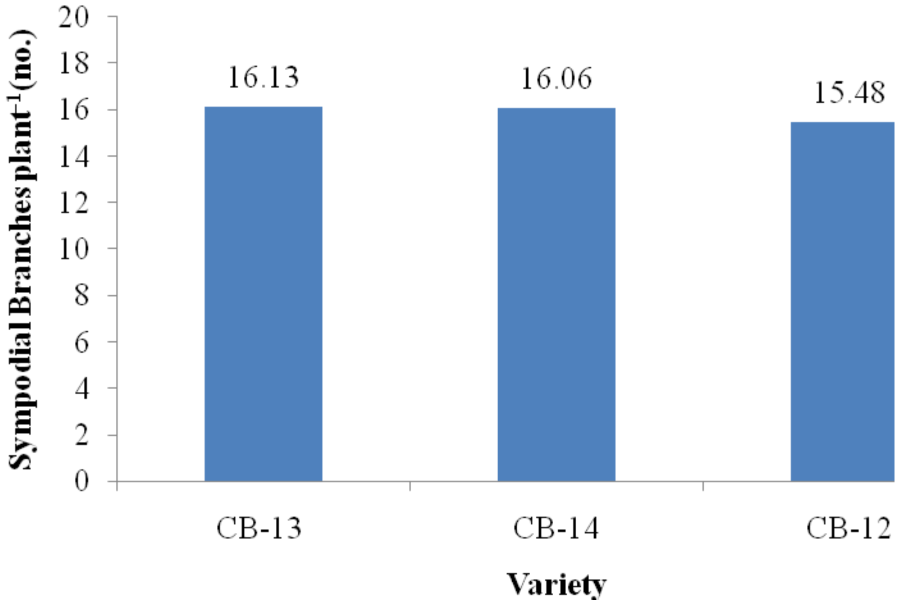

Fig.9. Effect of variety on sympodial branch plant^{-1} of cotton (LSD 0.05= NS)

4.2.2.2. Effect of spacing

Plant height and sympodial branches plant^{-1} showed non-significant variation due to spacing of cotton (Fig.10 and12). Monopodial branch plant^{-1} of cotton genotypes due to different spacing varied significantly at harvest (Fig.11) and the figure indicate that monopodial branch plant^{-1} increased gradually with the increases of spacing. The highest monopodial branch plant^{-1} (1.11) recorded in the widest spacing. The lowest monopodial branch plant^{-1} (0.53) observed in narrowest spacing. The results is consistant with the finding of Siebert *et al.*, (2006) who reported that plant spacing is inversely related to number of monopodial and sympodial branches per plant. Plant height at harvest and simpodial branch plant^{-1} were not affected by planting geometry. This result was similar to Anjum (2003) and Siebert and Stewart (2006) who found no significant effect of plant density or row spacing on plant height.

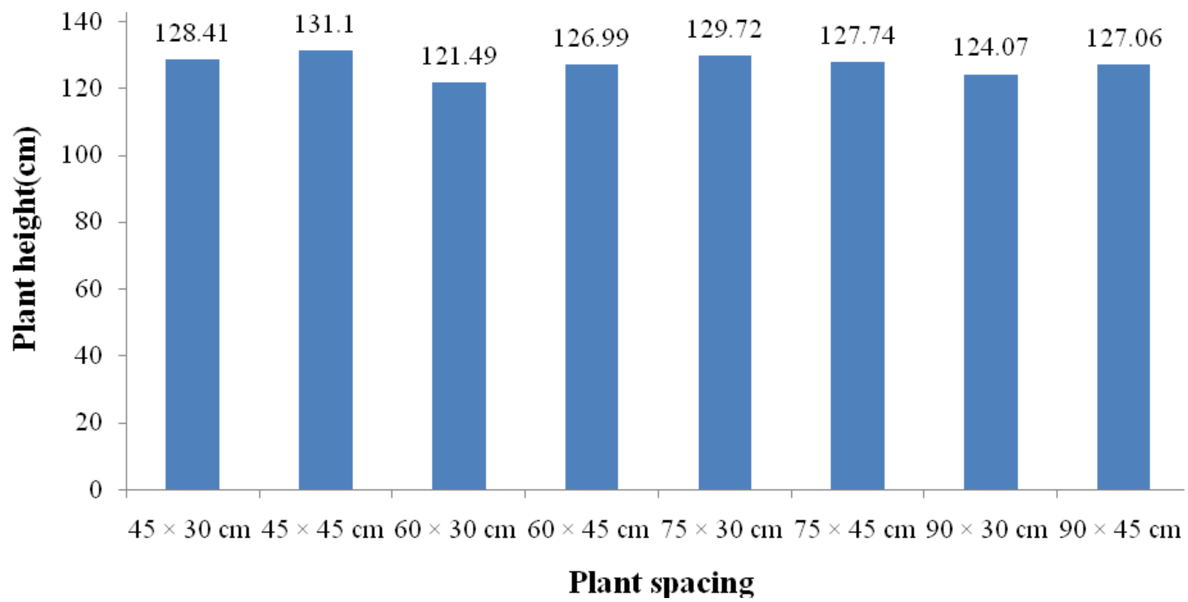

Fig. 10 Effect of plant spacing on plant height (cm) of cotton (LSD 0.05=NS)

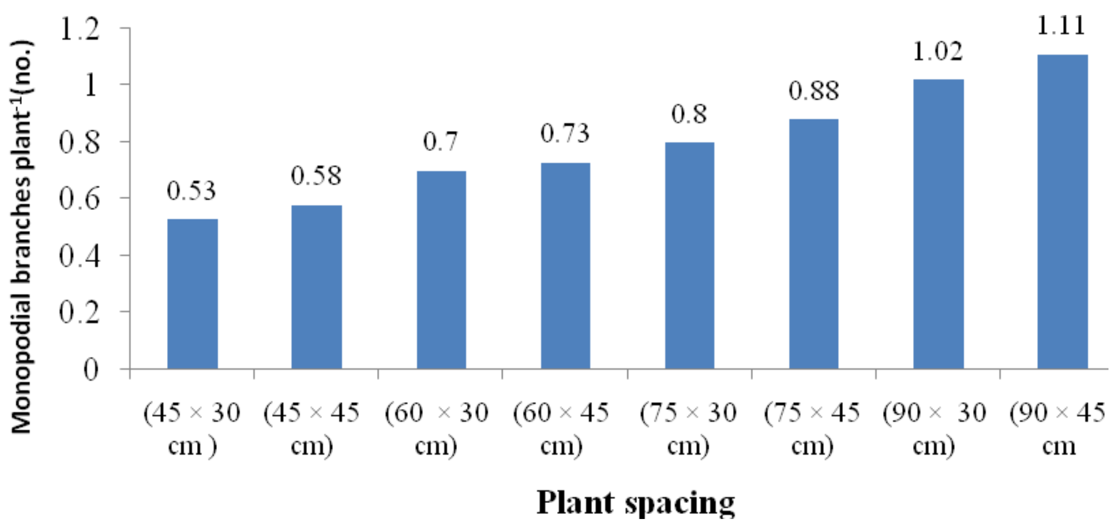

Fig.11 Effect of plant spacing on monopodial branch plant^{-1} of cotton (LSD 0.05 = 0.137)

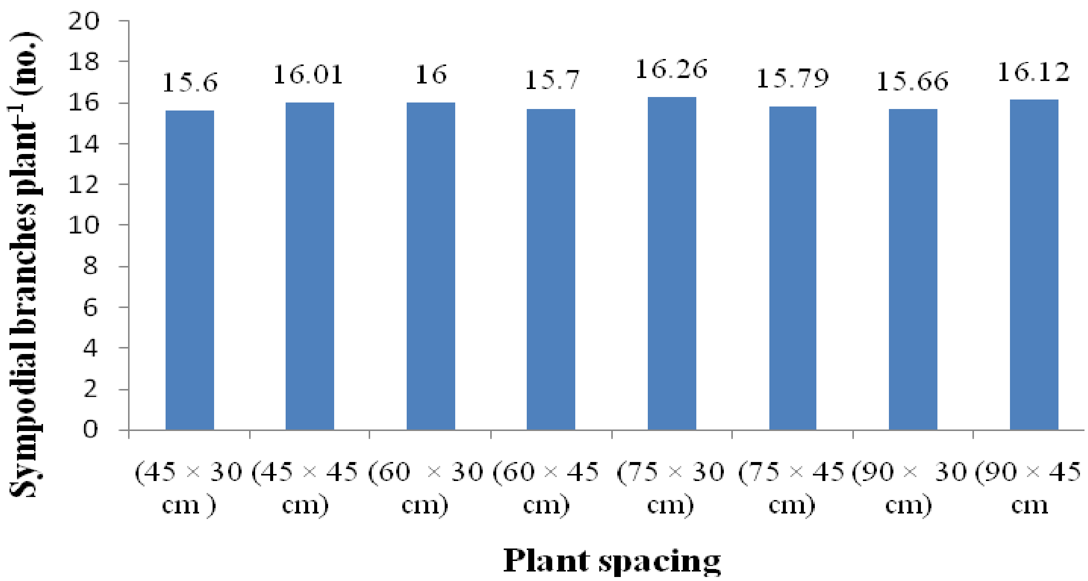

Fig. 12 Effect of plant spacing on sympodial branch plant^{-1} of cotton (LSD 0.05= NS)

4.2.2.3. Interaction effect of variety and spacing

There observed a significant difference in plant height, monopodial branch plant^{-1} and sympodial branch plant^{-1} due to interaction effect of variety and spacing (Table 15). The tallest plant (137.67 cm) and the highest sympodial branch plant^{-1} (17.60) were found in the treatment combination of CB-13 variety and 45 × 45 cm spacing and the highest monopodial branch plant^{-1} (1.23) observed in CB-13 and 90×45 cm spacing combination. The result is consisted with Nichols *et al.* (2004) who reported that cotton growth as affected by row spacing and cultivar. Plant population is a production factor which affects canopy structure, canopy photosynthesis and yield formation (Board, 2001; Zhang *et al*. 2006) by exploiting plant photosphere and rhizosphere. In a fertile soil, wide spacing (inter and intra row) can lead to extensive growth of fruiting branches with a good setting of early bolls and highly developed monopodial and sympodial branches (Ogola *et al*. 2006).

Table 15. Interaction effect of variety and spacing on plant characters of cotton

Interaction (Variety × Spacing)	Plant height (cm)	Monopodial branch plant^{-1} (no.)	Sympodial branch plant^{-1} (no.)
CB-13 × 45 × 30 cm	134.18 ab	0.56 f-h	16.07 a-c
× 45 × 45 cm	137.67 a	0.56 f-h	17.60 a
× 60 × 30 cm	125.93 a-c	0.66 d-h	16.43 a-c
× 60 × 45 cm	135.00 ab	0.73 c-h	15.93 a-c
× 75 × 30 cm	134.43 ab	0.83 b-h	16.73 ab
× 75 × 45 cm	129.07 a-c	0.96 a-e	15.77 a-c
× 90 × 30 cm	118.80 bc	1.16 ab	15.13 bc
× 90 × 45 cm	130.38 a-c	1.23 a	15.40 bc
CB-14 × 45 × 30 cm	115.80 c	0.50 h	15.17 bc
× 45 × 45 cm	127.23 a-c	0.60 e-h	15.37 bc
× 60 × 30 cm	113.33 c	0.63 d-h	16.30 a-c
× 60 × 45 cm	127.13 a-c	0.76 c-h	14.49 a-c
× 75 × 30 cm	129.73 a-c	0.83 b-h	16.50 a-c
× 75 × 45 cm	129.27 a-c	0.90 a-g	15.97 a-c
× 90 × 30 cm	128.87 a-c	0.96 a-e	15.87 a-c
× 90 × 45 cm	129.87 a-c	1.10 a-c	16.80 a
CB-12 × 45 × 30 cm	135.27 ab	0.53 gh	15.57 bc
× 45 × 45 cm	128.40 a-c	0.60 e-h	15.07 bc
× 60 × 30 cm	125.20 a-c	0.80 b-h	15.27 bc
× 60 × 45 cm	118.83 bc	0.70 d-h	14.67 c
× 75 × 30 cm	125.00 a-c	0.73 c-h	15.53 bc
× 75 × 45 cm	124.90 a-c	0.80 b-h	15.63 bc
× 90 × 30 cm	124.53 a-c	0.93 a-f	15.97 a-c
× 90 × 45 cm	120.93 a-c	1.00 a-d	16.17 a-c
LSD (0.05)	**17.99**	**0.432**	**1.32**
CV (%)	**8.62**	**16.76**	**7.16**

Here, NS= Not significant

4.2.3. Yield and yield attributes

4.2.3.1. Effect of variety

A significant difference in number of bolls plant^{-1}, boll weight and yield among the cotton variety were observed (Table 16). Variety CB-14 produced the maximum number of bolls plant^{-1} (22.69) which was significantly higher than other varieties.This means CB-14 produced 14.13 % and 11.88 % higher bolls plant^{-1} than CB-13 and CB-12 respectively. Many studies authenticate that cotton cultivars varied markedly for boll production due to genetic transformation (Taohua and Haipeng, 2006; Meena *et al*. 2007; Arshad *et al*. 2007; Hussain *et al*. 2007; Bednarz *et al*. 2007; Ahmad *et al*. 2008). No significant effect on boll weigh were found among the varieties. The result was consisted with Saleem *et al*. (2010) who found non-significant differences in boll weight due to cultivars.

Seed cotton yield was significantly influenced by different genotypes of cotton. The highest seed cotton yield (2713 kg ha^{-1}) was recorded in CB-14. The lowest seed cotton yield (2354 kg ha-1) was recorded in CB-13 variey. The highest seed cotton yield of CB-14 was associated with its better yield components like number of bolls per plant and individual boll weight. These resuls are consisted with the findings of Campbell and Bauer (2007); Ali *et al*. (2009); O'Berry *et al*. (2009) who reported that varietal variation significantly affect yield potential of upland cotton. The findings also confirmed with the results of Soomro *et al*. (2008) who correlated seed cotton yield positively with sympodiums per plant, bolls per plant and boll weight.

Ginning out turn showed insignificant effect on cotton variety. Numerically the highest ginning out turn was found with CB-12 (40.84%) and that of lowest was calculated from CB-13 (40.03). This result was inoccardance to Saleem *et al*. (2010) who found non-significant differences in GOT among cultivars.

Lint yields differed significantly among the tested three cotton genotypes (Table 16). The highest lint yield (1099 kg ha^{-1}) observed in the variety CB-14 which was significantly higher than other genotypes which indicates CB-14 out yielded over CB-13 and B-12 by producing 9.57 and 13.89 % higher lint yield. However, the lowest lint yield (965 kg ha^{-1}) obtained from CB-13 variety. Such great variability in lint yield might be due to gene effect as genotypic variation in yield of any crop is primarily governed by genetic make up of the varieties. The result corresponds well to that of Nichols *et al*. (2004) who observed similar large variability in lint yields of different cotton genotypes.

Table 16. Effect of variety on yield and yield attributes of cotton

Treatment (variety)	Bolls $plant^{-1}$ (no.)	Single boll weight (g)	Seed cotton yield (kg ha^{-1})	Ginning out turn (%)	Lint yield (kg ha^{-1})
CB-13	19.88 b	4.73	2354 b	40.03	965 b
CB-14	22.69 a	4.81	2713 a	40.53	1099 a
CB-12	20.28 b	4.74	2457 b	40.84	1003 b
LSD(0.05)	**1.47**	**NS**	**188.08**	**NS**	**75.2**
CV (%)	**12.10**	**5.34**	**12.90**	**4.39**	**0.57**

Here, NS= Not significant

4.2.3.2. Effect of spacing

The result showed that number of bolls $plant^{-1}$ increased gradually with the increase of plant spacing (Table 17). The highest bolls $plant^{-1}$ (25.90) produced at 90 × 45 cm which was statistically different from all other spacings. The lowest bolls $plant^{-1}$ (14.93) produced by the lowest spacing (45 × 30 cm). The result corroborates with the findings of Khalequzzaman *et al. (*2012) who reported that increased spacing increased with bolls per plant of cotton. Previously reported studies suggest that wider plant spacing increased bolls per plant (Boquet, 2005; Obasi and Msaakpa 2005; Siddique *et al*. 2007; Rajakumar and Gurumurthy, 2008; Ali *et al*. 2009).

Plant spacing exerted significant effect on boll weight of cotton (Table17). The heaviest boll (4.98 g) was produced in (75 × 30 cm).spacing. The lowest boll weight (4.44 g) was found by the closest spacing (45 × 30 cm). The result was supported by the findings of Unay and Inan (1994) who determined that plant density affected the boll number and boll weight. Several reports reveal that boll size is inversely related to population density (Boquet *et al*., 2005; Obasi and Msaakpa, 2005; Bednarz *et al*. 2006). The increase of plant density decreased the individual seed mass and lint mass per boll (Boquet *et al*. 2005; Bednarz *et al*. 2006; Darawsheh *et al*.2009b).

Plant spacing showed significant influence on seed cotton yield (Table 16). Results indicated that seed cotton yield showed an increasing trend with the decreases of plant spacing. The highest seed cotton yield (3120 kgha^{-1}) observed in (75 × 30 cm) spacing which was statistically similar to spacing (45 × 30 cm) and (60 × 30 cm.) The lowest seed cotton yield (1814 kg ha^{-1}) produced in the widest spacing (90 × 45 cm). The result was consisted with the results of Delaney *et al.* (1999) who found that high plant density in early sowing increased seed cotton yield. The result supported to comment of Hall and Ziska (2000) who observed that plant density should be increased in order to minimize yield losses. Nichols *et al*. (2004); Khan *et al*. (2005); Kaur and Brar, (2008) suggested that, seed cotton yield increases by closer spacing or narrow rows.

Table 17. Effect of spacing on yield and yield attributes of cotton

Treatment (spacing)	Bolls plant^{-1} (no.)	Single boll weight (g)	Seed cotton yield (kg ha^{-1})	Ginning out turn (%)	Lint yield (kg ha^{-1})
45 × 30 cm	14.93 d	4.44 d	2939 a	40.64	1194 a
45 × 45 cm	18.52 c	4.77 a-c	2605 b	41.01	1068 b
60 × 30 cm	18.33 c	4.94 ab	3013 a	41.08	1237 a
60 × 45 cm	21.67 b	4.89 a-c	2339 b	40.23	940 b
75 × 30 cm	23.34 b	4.98 a	3120 a	39.94	1246 a
75 × 45 cm	22.02 b	4.74 a-c	1884 c	41.02	772 c
90 × 30 cm	22.80 b	4.64 cd	2351 b	41.07	965 b
90 × 45 cm	25.90 a	4.72 bc	1814 c	41.44	751 c
LSD (0.05)	**2.40**	**0.24**	**188.08**	**NS**	**77**
CV (%)	**12.10**	**5.34**	**12.90**	**4.39**	**12.90**

Here, NS= Not significant

Ginning out turn showed insignificant effect on plant spacing. This result was similar to Sawan *et al*. (2008), Ahmad *et al*. (2009), and Ali *et al*. (2009) who reported that, GOT was not affected either by inter or intra row spacing.

Different spacing exerted significant effect on lint yield (Table 17). The result showed that lint yield gradually increased with the decreases of plant spacing. The highest lint yield (1246 kg ha^{-1}) in 75 × 30 cm spacing which was statistically identical with 60 × 30 cm and 45 × 30 cm plant spacings. The lowest lint yield (751 kg ha^{-1}) produced in 90 × 45 cm spacing.

4.2.3.3. Interaction effect of variety and spacing

There observed a significant difference in bolls $plant^{-1}$ due to combined effect of variety and spacing (Table 18). Result showed that, bolls $plant^{-1}$ increased gradually with increasing of plant spacing. The highest bolls $plant^{-1}$ (27.30) found in the combined effect of CB-14 and (90 × 45 cm) which was significantly differed from all other treatment combinations. The lowest bolls $plant^{-1}$ (14.27) observed in CB-12 variety and (45×30cm) spacing treatment combination.

There observed a significant difference in boll weight due to combined effect of variety and spacing (Table18). The highest boll weight (5.17g) found in the combination of CB-14 variety and (75 × 30 cm) spacing. The lowest boll weight (4.34 g) observed in the combined effect of CB-14variety and (90 × 45 cm) spacing.

Combined effect of variety and spacing exerted significant effect in seed cotton yield (Table 18). The highest seed cotton yield (3609 kg ha^{-1}) found in the combination of CB-14 variety and (75 × 30 cm) spacing which was statistically similar with CB-14 variety with 60 × 30 cm and CB-13 with 75 × 30 cm spacing interaction (3420 and 3098 kg ha^{-1}) respectively. It was found that all the three varieties gave the highest yield with 75× 30 cm plant spacing which was followed by 60 × 30 cm plant spacing. These results are similar to the findings of Ahmad *et al*. (2009) who harvested maximum yield of BH-160 at 22.5 cm spacing in 75 cm apart rows. Soomro *et al.* (2000a) found that 23 and 30 cm plant spacings gave higher seed cotton yield.

Table18. Interaction effect of variety and spacing on yield and yield attributes of cotton

Interaction (Variety × Spacing)	Bolls plant^{-1} (no.)	Single boll weight (g)	Seed cotton yield (kg ha^{-1})	Ginning out turn (%)	Lint yield (kg ha^{-1})
CB-13 × 45 × 30 cm	15.13 k	4.47 e-g	2998 b-d	40.30	1208 b-d
× 45 × 45 cm	18.10 g-k	4.86 a-e	2610 c-g	41.4	1080 c-g
× 60 × 30 cm	17.00 jk	4.92 a-c	2783 c-e	41.42	1152 c-e
× 60 × 45 cm	20.93 d-j	4.70 b-g	2186 f-j	41.00	896 f-j
× 75 × 30 cm	23.13 b-f	5.00 ab	3098 a-c	39.93	1237 a-c
× 75 × 45 cm	21.30 d-i	4.77 a-f	1827 ij	41.06	750 ij
× 90 × 30 cm	21.83 c-h	4.79 a-f	2334 e-i	41.20	961 e-i
× 90 × 45 cm	24.87 a-d	4.95 a-c	1823 ij	42.20	769 ij
CB-14 × 45 × 30 cm	15.40 k	4.35 g	2972 b-d	40.70	1209 b-d
× 45 × 45 cm	19.73 f-j	4.53 c-g	2641 c-g	41.10	1085 c-g
× 60 × 30 cm	20.50 e-j	5.01 ab	3420 ab	40.93	1399 ab
× 60 × 45 cm	24.33 a-e	5.03 ab	2718 c-f	39.40	1070 c-f
× 75 × 30 cm	26,07 ab	5.17 a	3609 a	39.46	1424 a
× 75 × 45 cm	23.87 a-f	4.79 a-f	2069 h-j	41.20	852 h-j
× 90 × 30 cm	24.33 a-e	4.67 b-g	2525 d-h	41.50	1047 d-h
× 90 × 45 cm	27.30 a	4.34 g	1750 j	40.00	700 j
CB-12 × 45 × 30 cm	14.27 k	4.44 fg	2654 c-f	40.93	1086 c-f
× 45 × 45 cm	17.73 h-k	4.50 d-g	2565 d-h	40.53	1039 d-h
× 60 × 30 cm	17.50 i-k	4.75 b-g	2836 c-e	41.10	1165 c-e
× 60 × 45 cm	19.73 f-j	4.84 a-f	2112.6 g-j	40.43	854 g-j
× 75 × 30 cm	20.20 d-j	4.66 b-g	2847 c-e	40.80	1161 c-e
× 75 × 45 cm	20.90 d-j	4.89 a-d	1756.9 j	40.80	716 j
× 90 × 30 cm	22.23 b-g	4.87 a-e	2194 f-j	40.50	888 f-j
× 90 × 45 cm	25.80 a-c	4.91 a-d	1867.9 ij	42.13	786 ij
LSD (0.05)	**4.17**	**0.41**	**531.97**	**NS**	**212**
CV (%)	**12.10**	**5.34**	**12.90**	**4.39**	**0.56**

Here, NS= Not significant

Ginning out turn showed nonsignificant variation on combined effect of cotton variety and plant spacing. Hussain *et al.* (2000), Sawan *et al*. (2008), Ahmad *et al*. (2009), and Ali *et al*. (2009) reported that GOT was not affected either by inter or intra row spacing. Darawsheh *et al*. (2009b) found non significant difference for lint percentage under regular or suitable weather conditions but in rainy year lint percentage decreased by increasing plant density independent of row spacing.

There observed a significant difference in lint yield due to combined effect of variety and spacing (Table18). Result showed that lint yield decreased gradually with the increasing plant spacing. The highest lint yield (1424 kg ha^{-1}) found in combined effect of CB-14 variety and 75 × 30 cm spacing which was statistically similar with the combinations of CB-14 variety and 60 × 30 cm spacing and CB-13 variety and75 × 30 cm spacing(1399 and 1237 kg ha^{-1} respectively. The lowest lint yield (700 kg ha^{-1}) observed in CB-14 variety and 90 × 45 cm spacing combination.

4.2.4. Lint characteristics

4.2.4.1 Effect of variety

Fibre quality primarily affected by genotype while agronomic practices are secondary aspect (Bednarz *et al.* 2005). Braden *et al*. (2009), Zeng and Meredith, Jr. (2009), Hua *et al*. (2009) and Ulloa *et al*. (2009) identified significant variation among genotypes for fibre quality.

Staple length significantly differed among cotton varieties (Table 19). Fibre length of cotton genotypes varied from 28.66 mm to 28.82 mm. variety CB-12 had the longest fibre length (28.82 mm) which was statistically at per to CB-14 (28.80 mm). While fibre length of CB-13 was the shortest (28.66 mm). The results are consisted with the findings of Nichols *et al.* (2004) who reported that, there was genotypic variation for staple length of cotton. Several researchers pointed out that staple length vary across cultivars (Bourland and Jones 2009; Smith *et al*. 2010 and Long *et al*. 2010).

Fibre strength of different cotton varieties exerted non-significant variation (Table 19). However, the highest fibre strength (28.43g/tex) was observed in CB-12 variety. The lowest fibre strength (28.41 g/ tex) found in CB-13 variety.

The fineness of fibre is an important aspect of cotton lint. The finer the thread, the greater the length produces from a pound of cotton. It is one of the evaluation methods of cotton quality. Fineness of cotton can be measured through smoothness of fibre. It is associated with fibre diameter and fibre wall thickness while the micronaire value represents the fibre diameter.

There were significant differences of fineness of fibre produced by different varieties of cotton (Table 19). Among the cotton varieties, CB-12 showed the lowest micronaire value (4.92 **µ**g/inch) and it attained maximum (4.92 **µ**g/inch) in CB-14. This result is in agreement with the findings of Bednarz *et al*. (2005) who reported that both genetic and environmental conditions have influence on micronaire value,

Uniformity ratio of different cotton genotypes was not significant (Table 19). Numarically, the highest uniformity ratio (81.92) observed in variety CB-12. The lowest uniformity ratio (81.78) found in variety CB-14.

Table19. Effect of varieties on lint characteristics of cotton

Variety	Staple length (mm)	Staple strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
CB-13	28.66 b	28.41	4.91 a	81.83
CB-14	28.80 a	28.42	4.92 a	81.78
CB-12	28.82 a	28.43	4.75 b	81.92
LSD (0.05)	**0.047**	**NS**	**0.24**	**NS**
CV(%)	**0.57**	**0.23**	**0.71**	**0.29**

Here, NS= Not significant

4.2.4.2. Effect of spacing

Plant spacing showed significant effect on staple length of cotton (Table 20). Result indicated that staple length showed gradual increasing trend with the increases of plant spacing. The highest staple length (29.28 mm) observed in 90 × 45 cm spacing which was statistically at per in 75 × 45 cm spacing (29.08 mm). The lowest staple length (28.05 mm) observed in 45 × 30 cm spacing. These results was similar to those (Bednarz *et al*. 2000), Larson *et al*. (2004), Bednarz *et al*. (2006) and Darawsheh *et al*. (2009b) who reported that increased plant population decreased the fibre length of otton.

Plant spacing exerted significant effect on fibre strength of cotton (Table 20). Fibre strength showed an increasing trend with the increases of spacing. The highest fibre strength (28.49 g/tex) was found in 90 × 45 cm spacing. The lowest fibre strength (28.24 g/tex) in 45 × 30 cm spacing. This result was in agreement with the findings of Nicholas *et al*. (2004) and Clawson *et al*. (2006) who found little impact of various row spacing on fibre quality.

Spacing affect significantly on staple micronaire value of cotton (Table 20). The highest micronaire value (5.03 µg/inch) was cbserved in 60 × 45 cm spacing. On the other hand, the lowest micronaire value (4.66 µg/inch) was observed in 90 × 45 cm spacing. This result was in agreement with the findings of Bednarz *et al*. (2006) and Darawsheh *et al*. (2009b) who observed decreased micronaire in response to increased plant population.

Uniformity ratio was significantly affected due to plant spacing (Table 20). The significantly highest uniformity ratio (82.26 %) was found in 90 × 45 cm spacing which was statistically similar with 90 × 30 cm spacing. The lowest uniformity ratio (81.57%) found in 45 × 30 cm spacing. This result was in agreement with the findings of Nichols *et al*. (2004) and Jost and Cothern (2001) who reported negative impact of increased plant density on lint uniformity.

Table 20. Effect of spacing on lint characteristics of cotton.

Treatment (Spacing)	Staple length (mm)	Staple strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
45 × 30 cm	28.05 e	28.24 c	4.78 e	81.57 c
45 × 45 cm	28.63 d	28.43 ab	4.83 d	81.81 bc
60 × 30 cm	28.72cd	28.38 b	4.79d e	81.87 bc
60 × 45 cm	28.82 cd	28.44 ab	5.03 a	81.61 c
75 × 30 cm	28.63 d	28.45 ab	4.89 c	81.71 c
75 × 45 cm	29.08 ab	28.48 ab	4.95 b	81.82 bc
90 × 30 cm	28.89 bc	28.40 ab	4.97 b	82.11 ab
90 × 45 cm	29.28 a	28.49 a	4.66 f	82.26 a
LSD (0.05)	**0.24**	**0.1**	**0.052**	**0.35**
CV%	**0.57**	**0.23**	**0.71**	**0.29**

Here, NS= Not significant

4.2.4.3. Interaction effect of variety and spacing

There observed a significant difference in staple length due to combined effect of variety and spacing of cotton (Table 21). The significantly highest staple length (30.02 mm) was observed in CB-13 and 90 × 45 cm combination effect which was statistically at par with that of C-12 variety and 90 × 45 cm spacing combination. Combined effect of CB-13 and 60 × 45 cm spacing showed the lowest staple length (27.51mm).

Table 21. Iinteraction effect of variety and spacing on lint attributes of cotton

Treatment (Variety × Spacing)	Staple length (mm)	Staple strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
CB-13 × 45 × 30 cm	29.19 bc	28.62 a	4.56 h	82.12 ab
× 45 × 45 cm	29.19 bc	28.52 a-f	4.81 fg	82.12 ab
× 60 × 30 cm	28.35 ef	28.34 e-i	4.82 f	81.67 b-d
× 60 × 45 cm	27.51 i	28.08 j	5.36 b	81.20 d
× 75 × 30 cm	28.07 gh	28.32 f-i	5.1 c	81.52 b-d
× 75 × 45 cm	28.63 d-f	28.34 e-i	5.02 cd	81.83 a-d
× 90 × 30 cm	28.35 e-g	28.4 c-i	5.32 b	81.67 b-d
× 90 × 45 cm	30.02 a	28.68 a	4.21 i	82.54 a
CB-14 × 45 × 30 cm	28.91 bc	28.21 ij	4.89 ef	81.97 a-c
× 45 × 45 cm	29.19 bc	28.54 a-e	4.68 h	81.78 b-d
× 60 × 30 cm	28.63 d-f	28.54 a-e	4.93 de	81.83 a-d
× 60 × 45 cm	28.29 f-h	28.36 d-i	4.80 fg	81.97 a-c
× 75 × 30 cm	29.19 bc	28.65 ab	4.61 h	81.78 b-d
× 75 × 45 cm	28.91 cd	28.4 c-i	5.02 cd	81.97 a-d
× 90 × 30 cm	29.46 b	28.56 a-d	4.89 ef	81.26 cd
× 90 × 45 cm	28.79 gh	28.11 j	5.56 a	81.69 b-d
CB-12 × 45 × 30 cm	29.13 b-d	28.60 a-c	4.81 fg	82.26 a
× 45 × 45 cm	28.07 gh	28.23 h-j	5.01 d	81.52 b-d
× 60 × 30 cm	29.19 bc	28.44 b-h	4.63 h	82.12 ab
× 60 × 45 cm	28.35 e-g	28.27 g-j	4.93 de	81.67 b-d
× 75 × 30 cm	28.63 d-f	28.39 c-i	4.95 de	81.83 a-d
× 75 × 45 cm	28.35 e-g	28.4 c-i	4.81 fg	81.67 b-d
× 90 × 30 cm	28.86 c-e	28.46 b-g	4.71 gh	81.78 b-d
× 90 × 45 cm	30.02 a	28.67 a	4.20 i	82.54 a
LSD (0.05)	**0.51**	**0.21**	**0.10**	**0.74**
CV (%)	**0.57**	**0.23**	**0.71**	**0.29**

Here, NS= Not significant

Combined effect of CB-13 and 90 × 45 cm spacing showed the highest level of fibre strength (28.68 gm/tex) but this was statistically at par with that of CB-12 variety and 90 × 45 cm spacing (28.67gm/tex), CB-13and 45 × 30 cm spacing (28.67 gm/tex), 45 × 45 cm spacing(28.65 gm/tex), CB-14 and 45 × 45 cm spacing (28.54 gm/tex), CB-14 and 60 × 30 cm spacing (28.54 gm/tex), CB-14 and 90 × 30 cm spacing (28.56 gm/tex) and CB-12 and 45 × 30 cm spacing (28.60 gm/tex) treatment combinations.

Micronaire value affected significantly due to interaction effect of variety and spacing (Table 21). Significantly the highest micronaire value (5.56 µg/inch) observed in CB-14 variety and 90 × 45 cm spacing combination. The lowest micronaire value (4.20 µg/inch) observed in CB-12 variety and 90 × 45 cm spacing combination which was significantly similar with CB-13 and 90 × 45 cm spacing combination (4.21 µg/inch).

Uniformity ratio showed significant impact due to interaction of variety and spacing (Table 21). The result revealed that widest spacing 90 × 45 cm showed the highest uniformity rario with combination of the three tested varieties (82.54,82.26, and 82.54% with CB-13 and 90 × 45 cm, CB-14 and 90 × 45 cm and CB-12 and 90 × 45 cm, respectively). The lowest value (81.20%) was recordd with CB-13 and 60 × 30 cm spacing combination. This result was contradictory with the findings of Valco *et al*. (2001) who found no differences in fibre uniformity due to varied row spacing or plant density.

4.2.5 Economic analysis

Economic analysis was done with a view to observing the comparative cost and benefit under different treatment combinations of variety and plant spacing. For this purpose, the inputs cost for land preparation, cotton seed, manure and fertilizer, pesticide, intercultural operation, harvesting and post harvesting cost and manpower required for all the operations including seed cotton were recorded against each treatment, which were then enumerated into cost per hectare.

Table 22. Economic analysis in cotton production as influenced by cotton variety and plant spacing

Interaction (Variety× Spacing)	Seed cotton yield (Kg ha^{-1})	Gross return (Tkha^{-1})	Total variable cost (Tk ha^{-1})	Gross margin (Tkha^{-1})	Benefit cost ratio (BCR)
CB-13 × 45 × 30 cm	2998	179880	74550	105330	2.41
× 45 × 45 cm	2610	156600	73950	82650	2.11
× 60 × 30 cm	2783	166980	73950	93030	2.25
× 60 × 45 cm	2186	131160	73550	57610	1.78
× 75 × 30 cm	3098	185880	73000	112880	2.54
× 75 × 45 cm	1827	109620	72500	37120	1.51
× 90 × 30 cm	2334	140040	72500	67540	1.93
× 90 × 45 cm	1823	109380	71686	37694	1.52
CB-14 × 45 × 30 cm	2972	178320	74550	103770	2.39
× 45 × 45 cm	2641	158460	73950	84510	2.14
× 60 × 30 cm	3420	205200	73950	131250	2.77
× 60 × 45 cm	2718	163080	73550	89530	2.21
× 75 × 30 cm	3609	216540	73000	143540	2.96
× 75 × 45 cm	2069	124140	72500	51640	1.71
× 90 × 30 cm	2525	151500	72500	79000	2.09
× 90 × 45 cm	1750	105000	71686	33314	1.46
CB-12 × 45 × 30 cm	2654	159240	74550	84690	2.13
× 45 × 45 cm	2565	153900	73950	79950	2.08
× 60 × 30 cm	2836	170160	73950	96210	2.30
× 60 × 45 cm	2112	126720	73550	53170	1.72
× 75 × 30 cm	2847	170820	73000	97820	2.34
× 75 × 45 cm	1756	105360	72500	32860	1.45
× 90 × 30 cm	2194	131640	72500	59140	1.81
× 90 × 45 cm	1867	112020	71686	40334	1.56

Note:

RDF= Recommended dose of chemical fertilizers

Urea = 22 Tk kg^{-1} , MoP = 17 Tk kg^{-1}, Gypsum =12 Tk kg^{-1}, Zink sulphate = 210 Tk kg^{-1}

Borax =214 Tk kg^{-1}, Mac sulpher = 67 Tk kg^{-1}, Ektara = 9300 Tk kg^{-1},

Volume flexy = 5725 Tk kg^{-1} , Cupravit = 2200 Tk kg^{-1}, wage rate = 400 Tk man day

Cotton Seed =24 Tk kg^{-1}, Seed Cotton = 60 Tk kg^{-1}

The total cost of production ranged between 71681 – 74550 Tk ha^{-1}. Production cost increased with decreasing of plant spacing. The highest cost of production involved when used 45 × 30 cm spacing (74550 Tk ha^{-1}). The lowest cost of production involved when used . 90 × 45 cm plant spacing (71681Tk ha^{-1}). The highest gross return was found with CB-14 variety and 75 × 45 cm spacing combination (216540 Tk ha^{-1}). The lowest gross return was found (105000 Tk ha^{-1}) with CB-14 variety and 90 × 45 cm spacing combination. The highest gross margin found when used CB-14 variety and 75 × 30 cm spacing combination (143540 Tk ha^{-1}). The lowest gross margin (32860 Tk ha^{-1}) found when used CB-12 variety and 75 × 45 cm spacing combination. The maximum benefit cost ratio (BCR) involved when used CB-14 variety and 75×30 cm spacing treatment combination (2.96). The minimum benefit cost ratio found when used CB-12 variety and 75 × 45 cm spacing treatment combination (1.45). Plant spacing 75×30 cm gave the highest gross return, the highest gross margin and the highest benefit cost for both the three varieties. For economic point of view, results indicate that plant spacing 75 × 30 cm was more profitable for the three varieties but CB-14 and 75×30 spacing, CB-14 and 60 ×30 cm spacing and CB-13 and 75 × 30 cm spacing showed better economic return.

4.3. Experiment 3. Yield and fibre quality of some newly released cotton varieties at different nutrient levels

4.3.1. Phenological attributes

4. 3.1.1.Effect of variety

There existed significant difference in days to flowering and boll splitting (Table 23). Variety CB-14 required the longest time to flowering (53.72) and boll opening (126.61) which was significantly longer than other variety. CB-13 needed minimum days for flowering (52.83 days). CB-12 required the shortest time (122.33 days) from planting to boll splitting which indicates that CB-12 was the earliest variety. Days required to blooming to boll opening are important characters of cotton as it indicates the earliness of the crop. The genotypes took least days to boll opening are considered earliest in crop maturity (Gopang, 2003; Nimbalkor *et al*. 2004; Shakeel *et al.* 2008).

Table 23. Effect of variety on phenologcal attributes of cotton

Variety	Days to first flowering (days)	Days to first boll splitting (days)
CB-13	52.83 b	124.17 b
CB-14	53.72 a	126.61 a
CB-12	53.33 ab	122.33 c
LSD (0.05)	**0.76**	**1.08**
CV (%)	**2.68**	**1.38**

4.3.1.2. Effect of fertilizer levels

Number of days to 1st flowering, and 1st boll opening were not significantly affected by fertilizer doses (Table 24). However, result showed that time needed for 1st flowering and 1st boll opening increased gradually due to higher fertilizer doses up to 50% higher than RDF after that the value began to decrease with with further increasing fertilizer. Similar results were reported by Clawson *et al*. (2008) who indicated that N rates did not affect the timing of 30, 60, or 85% harvest and argued that longer vertical flowering intervals by virtue of slower node addition may have contributed to reduce boll set which prevented earlier maturity in lower N rates.

Table 24. Effect of fertilizer levels on Phenology attribute

Treatment	Days to first flowering (days)	Days to first foll splitting (days)
RDF	53.11	123.78
25% higher than RDF	53.22	124.00
50% higher than RDF	53.44	125.33
75% higher than RDF	53.44	124.33
100% higher than RDF	53.33	123.89
125% higher than RDF	53.22	124.89
LSD (0.05)	**NS**	**NS**
CV (%)	**1.51**	**1.09**

Here, NS= Not significant, RDF= Recommended dose of chemical fertilizers

4.3.1.3. Interaction effect of variety and fertilizer levels

There observed a significant difference in days to 1st boll opening due to interaction effect of variety and fertilizer level (Table 25). The longest time for boll opening (127.33 days) was found in the interaction of CB-14 × 50% higher than RDF interaction. The shortest boll opening time (121.33 days) observed in CB-12 × 25% higher than RDF interaction. CB-14 showed the longest time for boll opening with all fertilizer rates and CB-12 showed the shortest time irrespective of fertilizer rates. Similar results were reported by (Meredith *et al.*1997) who argued that, more determinate and early maturing cotton cultivars are more responsive to N applications than obsolete cultivars because of boll setting and maturation in shorter periods.

Table 25. Interaction effect of variety and fertilizer on phonological attributes of cotton

Interaction (Variety × Fertilizer)	Days to first flowering (days)	Days to first boll splitting (days)
CB-13 × RDF	53.00	122.67 c-e
× 25% higher than RDF	52.33	124.33 b-d
× 50%higher than RDF	53.00	126.00 ab
× 75% higher than RDF	53.00	124.67 bc
× 100% higher than RDF	53.33	122.67 cd
× 125% higher than RDF	52.33	124.67 bc
CB-14 × RDF	53.66	126.67 ab
× 25% lhigherthan RDF	54.00	126.33 ab
× 50% higher than RDF	53.33	127.33 a
× 75% higher than RDF	53.33	126.33 ab
× 100% higher than RDF	53.66	126.33 ab
× 125% higher than RDF	54.33	126.67 ab
CB-12 × RDF	52.66	122.00 de
× 25%higher than RDF	53.33	121.33 e
× 50% higher than RDF	54.00	122.67 c-e
× 75% higher than RDF	54.00	122.00 de
× 100% higher than RDF	53.00	122.67 c-e
× 125% higher than RDF	53.00	123.33 c-e
LSD (0.05)	**NS**	**2.47**
CV (%)	**1.51**	**1.09**

Here, NS= Not significant, RDF= Recommended dose of chemical fertilizers

4.3.2. Plant characteristcs

4.3.2.1. Effect of variety

Plant height, monopodial branches plant^{-1} and sympodial branches plant^{-1} of different varieties measured at harvest time. The results showed a non significant difference in plant height (Fig.13). However, numerically the tallest plant (124.10 cm) observed in variety CB-13. On the other hand the shortest plant was observed in CB-12 variety (105.60 cm). Monopodial branches plant^{-1} showed a significant difference among cotton varieties (Fig.14). CB-13 produced the highest number of monopodial branches (0.82) which was statistically similar to CB-14 (0.77). The lowest monopodial branches were observed in CB-12 (0.56) variety. Sympodial branches plant^{-1} showed a significant difference among cotton varieties (Fig 15) CB-14 produced the highest sympodial branches plant^{-1} (16.32) which was statistically identical to CB-13 (16.0). The lowest sympodial branch plant^{-1} were observed in CB-12 variety (15.23). The results are consisted with the findings of the researchers (Taohua and Haipeng, 2006; Meena *et al*. 2007; Boquet and Clawson, 2009) who reported that, plant height vary due to variation in genetic make up of cultivars. Number of monopdial and sympodial branches per plant differ significantly due to genotypes was also reported by Arshad *et al.* (2007).

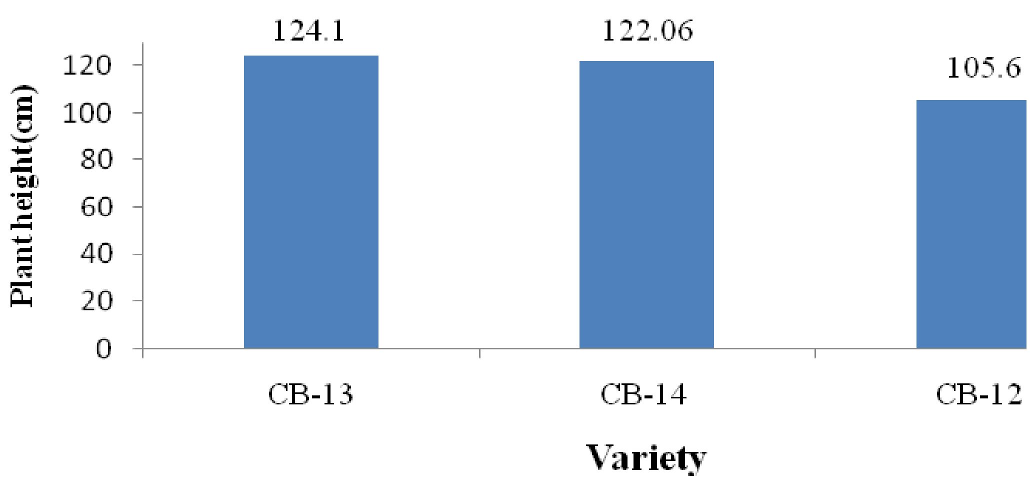

Fig.13 Effect of variety on plant height of cotton (LSD 0.05 = NS**)**

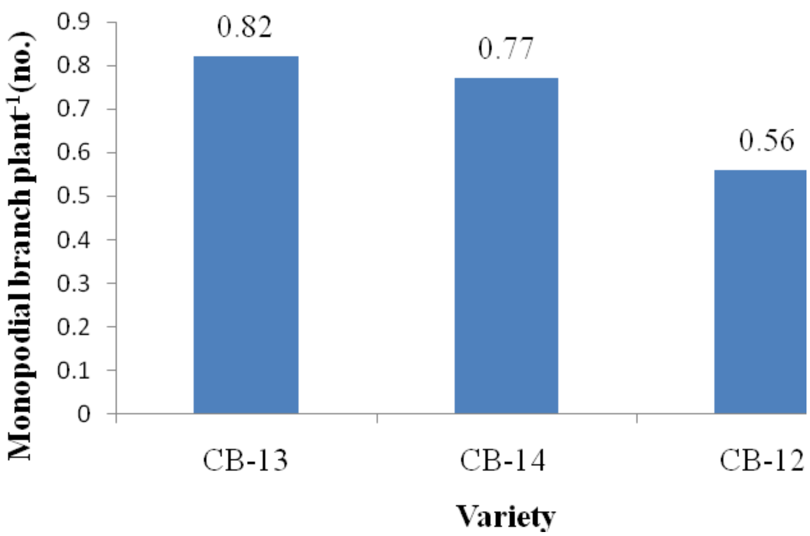

Fig.14 Effect of variety on monopodial branch plant^{-1} of cotton (LSD 0.05 = 0.18**)**

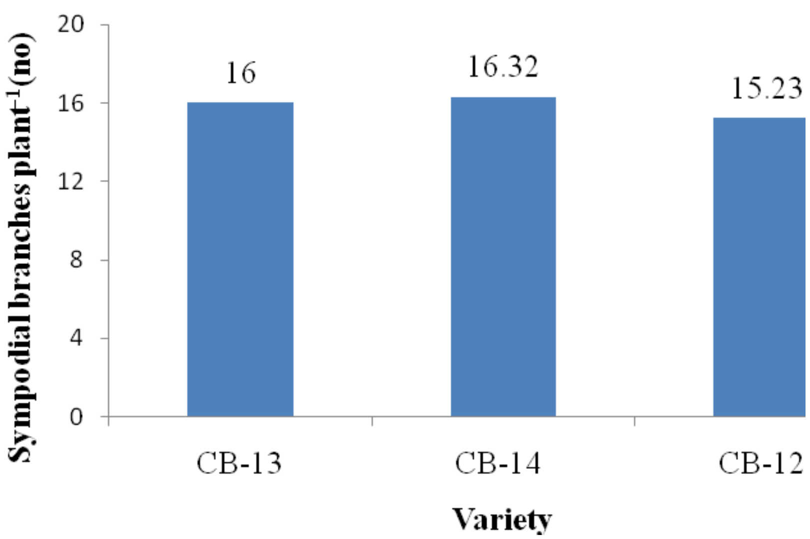

Fig.15 Effect of variety on sympodial branch plant^{-1} of cotton (LSD 0.05 = 0.80**)**

4.3.2.2. Effect of fertilizer

Plant height, monopodial branches plant^{-1} and sympodial branches plant^{-1} of cotton varieties varied significantly due to application of different levels of fertilizer (Fig. 16, 17 and 18). . the result revealed that plant height increased gradually with the increases of fertilizer doses. The highest value was recorded from the gighest dose and that of lowest was with RDF. Monopodial branches plant^{-1} and sympodial branches plant^{-1} increased rapidly with the increase dose of fertilizer up to 50% higher than RDF. After that rate of increase was much slower with further higher doses.

The tallest plant (128.61 cm), highest monopodial branches plant^{-1} (.91) and sympodial branches plant^{-1} (17.10) were recorded in the highest dose of fertilizer. The shortest plant (68.09 cm), lowest monopodial branches plant^{-1} (0.50) and sympodial branches plant^{-1} (13.93) were observed in recommended fertilizer dose. The increase in plant height, monopodial branches plant^{-1} and sympodial branches plant^{-1} due to application of fertilizer might be associated with fertilizer application with stimulating effect on various physiological process including cell division and cell elongation of the plant. The results are similar to Khalequzzaman et al. (2012) who reported increasing fertilizer levels increased plant height, monopodial branches plant-1 and sympodial branches plant^{-1}. The result is consistent with the findings of Kumbhar *et al.* (2008) who reported that, increase in number of sympodial branches per plant with increased nitrogen application. Most studies signified a positive relationship between plant height and N rates (Clawson *et al*. (2006); Kumbhar *et al.* (2008), Cheema *et al*.(2000); Ibrahim *et al.* (2010).

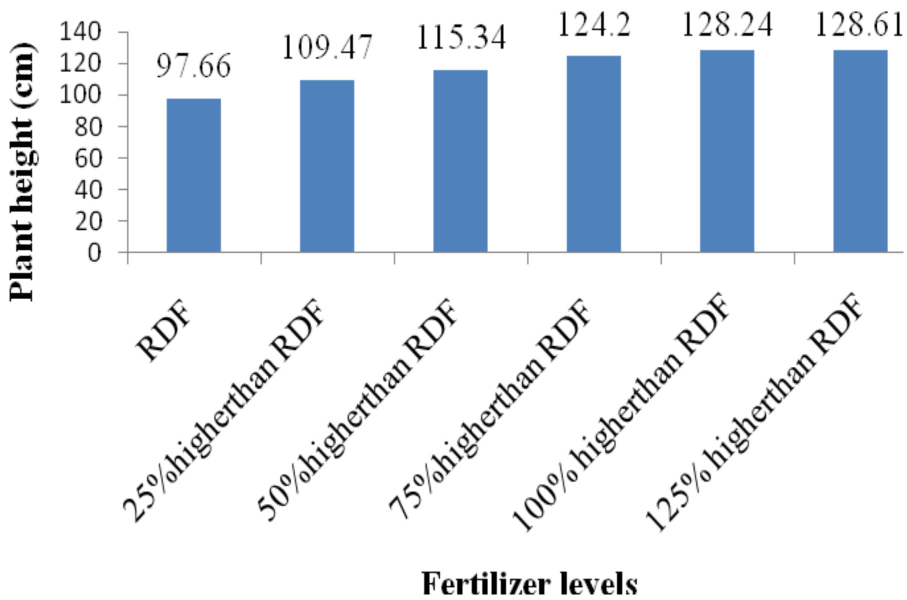

Fig.16 Effect of fertilizer levels on plant height of cotton (LSD 0.05 = 13.86**)**

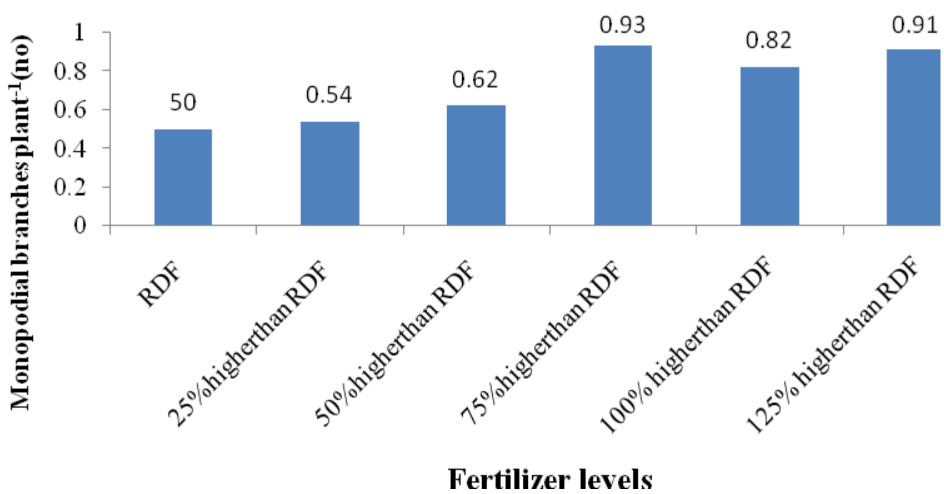

Fig.17 Effect of fertilizer on monopodial branches plant^{-1} of cotton (LSD 0.05 = 0.41**)**

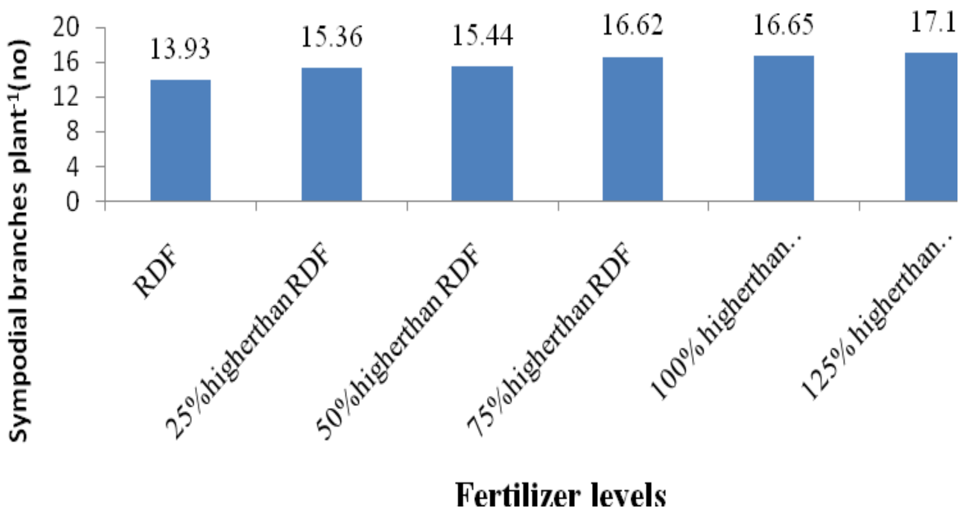

Fig.18 Effect of fertilizer on sympodial branches plant^{-1} of cotton (LSD 0.05 = 1.89**)**

4.3.2.3. Interaction effect of variety and fertilizer

There observed a significant difference in plant height, monopodial branches plant^{-1} and sympodial branches plant^{-1} due to combined effect of variety and fertilizer levels (Table 26). The result showed that plant height, monopodial branches plant^{-1} and sympodial branches plant^{-1} increased gradually with application of increasing fertilizer doses irrespective of varieties. The shortest plant (81.03 cm), monopodial branches plant^{-1} (0.23) and sympodial branches plant^{-1}(12.53) were observed in CB-12 and RDF treatment combination.

All treatment combinations produced statistically at per sympodial branches plant^{-1} except CB-12 and RDF treatment combination. This combination produced the lowest number of sympodial branches plant^{-1}. Combination of higher fertilizer doses and with all varieties varieties produced statistically identical monopodial and sympodial branches and also taller plant. Similar, results were reported by Khalequezzaman *et al.* (2015) that sympodial branches plant^{-1} increased due to increased use of fertilizers irrespective of varieties.

Table 26. Interaction effect of variety and fertilizer on plant characters of cotton

Interaction (Variety × Fertilizer)	Plant height (cm)	Monopodial branches plant^{-1} (no.)	Sympodial branches plant^{-1} (no.)
CB-13 × RDF	102.00 bc	0.80 a-d	14.36 ab
× 25% higher than RDF	116.47 ab	0.60 a-d	15.53 ab
× 50%higher than RDF	127.40 ab	0.70 a-d	15.50 ab
× 75% higher than RDF	130.93 ab	1.26 a	16.76 a
× 100% higher than RDF	135.43 a	0.53 a-d	16.93 a
× 125% higher than RDF	132.37 ab	1.06 a-c	16.93 a
CB-14 × RDF	109.93 a-c	0.46 b-d	14.90 ab
× 25% lhigherthan RDF	110.53 a-c	0.56 a-d	15.66 ab
× 50% higher than RDF	110.00 a-c	0.76 a-d	15.56 ab
× 75% higher than RDF	128.07 ab	0.63 a-d	17.13 a
× 100% higher than RDF	128.07 ab	1.20 ab	17.067a
× 125% higher than RDF	138.87 a	1.03 a-c	17.60 a
CB-12 × RDF	81.03 c	0.23 d	12.53 b
× 25%higher than RDF	101.40 bc	0.46 b-d	14.90 ab
× 50% higher than RDF	108.63 a-c	0.40 cd	15.26 ab
× 75% higher than RDF	113.60 ab	0.90 a-d	15.96 ab
× 100% higher than RDF	114.33 ab	0.73 a-d	15.96 ab
× 125% higher than RDF	114.60 ab	0.63 a-d	16.76 a
LSD (0.05)	**32.365**	**0.79**	**3.48**
CV (%)	**8.90**	**30.32**	**6.07**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers

4.3.3. Yield and yield contributing characters

4.3.3.2. Effect of variety

A significant difference in number of bolls plant^{-1}, boll weight and seed cotton yield among the varieties were observed in cotton (Table 27). Inbred CB-14 produced maximum number of bolls plant^{-1} (20.45) which was statistically similar with CB-12 variety (19.80). The lowest bolls plant^{-1} (19.26) produced by CB-13 variety. The result indicates that CB-14 variety was superior than CB-13 by producing 6.18 % higher bolls plant^{-1}.

Individual boll weight is an important component of the yield and was varied significantly among the tested varieties of cotton. The highest single boll weight (5.24 g) recorded in CB-14 which was statistically similr with CB-12 variety (5.17g). The lowest single boll weight (5.07 g) was observed in the CB-13 variety.

Seed cotton yield was significantly influenced by different cotton varieties. The highest seed cotton yield (2436 kg ha^{-1}) recorded in CB-14 which was statistically similar with CB-12 variety (2240 kg ha^{-1}). The lowest seed cotton yield (2127 kg ha^{-1}) recorded in CB-13 variety. The result clearly indicates that CB-14 variety out yielded over CB-13 and CB-12 by producing 14.53 % and 8.75 % higher seed cotton yield. The highest seed cotton yield of CB-14 was associated with its better yield components like number of bolls per plant and individual boll weight. The present findings confirmed with the results of Tan (1993) and Dhanda *et al*, (1984) who observed that seed cotton yield is positively correlated with the number of bolls per plant and individual boll weight. On the other hand, Afiah and Ghoneim (2000), Badr (2003) and Soomro *et al.* (2008) also correlates seed cotton yield positively with symposiums per plant, bolls per plant and boll weight.

Table 27. Effect of variety on yield and yield attributes of cotton

Variety	Bolls plant^{-1} (no)	Individual boll weight (g)	Seed cotton yield (kg ha^{-1})
CB-13	19.26 b	5.07 b	2127 b
CB-14	20.45 a	5.24 a	2436 a
CB-12	19.80 ab	5.17 ab	2240 ab
LSD (0.05)	**1.16**	**0.16**	**253.17**
CV (%)	**10.56**	**7.82**	**13.41**

4.3.3.1. Effect on fertilizer

Result showed that number of bolls plant^{-1}, individual boll weight and seed cotton yield increased gradually with the increases of fertilizer dose up to 75% higher than RDF and when exceed this level bolls plant^{-1}, individual boll weight and seed cotton yield decreased gradually (Table 28). The highest bolls plant^{-1} (21.53) produced at 75% higher than RDF which was statistically similar with 100% higher than RDF and 50% higher than RDF (21.38 and 20.46 respectively). The lowest bolls plant^{-1} (18.14) produced by RDF treatment. The results are similar to Anwar *et al*., (2002); Anwar and Afzal, (2003); Iqbal *et al*., (2003) who reported that number of bolls per plants increased significantly up to a certain higher doses of N after that no significant increase or diminishing return was observed with higher N rates.

Fertilizer doses exerted significant effect on boll weight of cotton (Table 28). The highest boll weight (5.41g) produced in 75% higher than RDF which was statistically similar with 50% higher than RDF (5.22g) and 100% higher than RDF (5.32g). The lowest boll weight (4.88 g) produced from RDF treatment. The results are similar to the findings of Saleem *et al*. (2010) who recorded maximum boll weight at 120 kg N ha^{-1}. However, Cheema *et al*., (2009) observed that boll weight increased by increasing N level upto 150 kg ha^{-1}.

Fertilizer doses showed significant influence on seed cotton yield (Table 27). The highest seed cotton yield (2728 kg ha^{-1}) observed in 75% higher than RDF which was statistically similar with 50% higher than RDF (2492 kg ha^{-1}) and 100% higher than RDF (2604 kg ha^{-1}). It can be inferred from the result that fertilizer applied 75 % higher than RDF proved its superiority than other lower and higher doses. The lowest seed cotton yield produced in RDF treatment (1659 kg ha^{-1}). The findings of Sharma *et al.* (1979) supported the present result is that application of fertilizers up to 320:160: 160 kg ha^{-1} NPK increased the yield of cotton. The results are also similar to Nehra *et al.* (2006) who reported that, application of 100 per cent RDF significantly increased seed cotton yield over 75 per cent RDF but remained statistically at par with that of 125 per cent RDF.

Table 28. Effect of fertilizer levels on yield and yield attributes of cotton

Fertilizer level	Bolls $plant^{-1}$ (no)	Individual boll weight (g)	Seed cotton yield (kg ha^{-1})
RDF	18.14 c	4.88 b	1659 d
25 % higher than RDF	19.15 bc	5.12 b	2053 cd
50% higher than RDF	20.46 ab	5.22 a	2492 ab
75% higher than RDF	21.53 a	5.41 a	2728 a
100% higher than RDF	21.38 a	5.32 a	2604 ab
125% higher than RDF	19.34 b	5.07 b	2462 b
LSD(0.05)	**1.609**	**0.27**	**257.83**
CV (%)	**5.74**	**8.38**	**12.21**

Here, RDF= Recommended dose of chemical fertilizers

4.3.3.3. Interaction effect of variety and fertilizer

A significant difference was found in bolls $plant^{-1}$ due to combined effect of variety and fertilizer in cotton (Table 29). Result showed that irrespective of varieties, bolls $plant^{-1}$ increased gradually with the application of increasing fertilizer dose. The highest bolls $plant^{-1}$ (22.00) was found in the combined effecf of CB-14 × 75% higher than RDF which was statistically similar to others treatment combination, except CB-13 × RDF treatment combination. The lowest bolls $plant^{-1}$ (17.20) observed in CB-13 variety × RDF treatment combination.

Most of the treatment combinations produced statistically at per in boll weight due to interaction effect of variety and fertilizer (Table 29). The highest boll weight (5.70g) was found in the combination of CB-14 × 75% higher than RDF. Again CB-14 × 50% hgher than and 100% higher than RDF also gave higher level of boll weight (5.30 and 5.43g, respectively). The lowest boll weight (4.53 g) was observed in CB-12 × RDF treatment combination.

Table 29. Interaction effect of fertilizer and variety on yield and yield attributes of cotton

Interaction (Variety × Fertilizer)	Bolls plant^{-1} (no)	Individual boll weigh (g)	Seed cotton yield (kg ha^{-1})
CB-13 × RDF	17.20 b	4.83 a-c	1627 cd
× 25% higher than RDF	18.83 ab	5.00 a-c	1705 b-d
× 50%higher than RDF	19.16 ab	5.16 a-c	2151 a-d
× 75% higher than RDF	21.16 ab	5.40 ab	2430 a-d
× 100% higher than RDF	19.46 ab	5.16 a-c	2404 a-d
× 125% higher than RDF	19.76 ab	4.86 a-d	2367 a-d
CB-14 × RDF	18.73 ab	4.90 a-c	1884 b-d
× 25% lhigherthan RDF	19.50 ab	5.03 a-c	2101 a-d
× 50% higher than RDF	19.80 ab	5.30 ab	2293 a-d
× 75% higher than RDF	22.00 a	5.70 a	3031 a
× 100% higher than RDF	21.96 a	5.43 ab	2743 a
× 125% higher than RDF	20.70 ab	5.10 a-c	2563 a-c
CB-12 × RDF	18.50 ab	4.53 a-c	1466 d
× 25%higher than RDF	19.06 ab	5.10 a-c	1953 b-d
× 50% higher than RDF	19.13 ab	5.30 ab	2151 a-d
× 75% higher than RDF	21.43 a	5.40 ab	2782 ab
× 100% higher than RDF	20.70 ab	5.36 ab	2665 ab
× 125% higher than RDF	19.96 ab	5.33 ab	2424 a-d
LSD (0.05)	**4.16**	**0.85**	**1014**
CV (%)	**5.74**	**8.38**	**12.21**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers

Interaction of variety and fertilizer exerted significant effect in seed cotton yield (Table 29). Result showed that seed cotton yield increased gradually with the application of increasing fertilizer doses irrespective of varieties. The highest seed cotton yield (3031 kg ha^{-1}) found in the combined effect of CB-14 × 75% higher than RDF. The interaction of CB-14 × 100 % higher than RDF also gave higher level of seed cotton yield (2743 kg ha^{-1}). CB-12 × RDF treatment combination gave the lowest seed cotton yield (1466 kg ha^{-1}). These results are consisted with Khalequezzaman *et al.* (2015) who reported that combined effect of fertilizer and variety have positive impact on seed cotton yield, plant height, number of monopodia and number of sympodia, number of bolls and boll weight as well as lint yield.

4.3.4. Lint characteristics

4.3.4.2. Effect of variety

Staple length was affected significantly among the cotton varieties (Table 30). Fibre length of cotton varieties varied from 28.25 mm to 28.96 mm. Genotype CB-14 had the longest fibre length (28.96 mm), while fibre length of CB-13 was the shortest (28.25 mm). The present results are consisted with the findings of Nichols *et al.* (2004) who reported that there was genotypic variation for staple length of cotton. Several researchers also pointed out that staple length vary across cultivars (Bourland and Jones 2009a,b; Smith *et al*. 2010; Long *et al*.2010).

Fibre strength of different cotton varieties was found significant (Table 30). The highest fibre strength (28.74 (g/tex) observed in CB-14 variety. The lowest fibre strength (28.50 g/tex) was found in CB-13 variety. Such differences in genotypes to fibre strength is very important as the genotypes with the highest strength tend to produce longer cellulose molecules, thus providing fewer break points in the lint and greater cross linkage between fibres. This result correlated with the findings of (Faircloth, 2007; Bourland and Jones, 2009a,b; Saleem *et al*. 2010) who reported that fibre strength influenced by cultivars.

The fineness of fibre is an important aspect of cotton lint. The finer the thread, the greater the length produces from a pound of cotton. It is one of the evaluation methods of cotton quality. Fineness of cotton can be measured through smoothness of fibre. It is associated with fibre diameter and fiber wall thickness while the micronaire value represents the fibre diameter. There were significant differences of fineness of fibre (micronaire value) produced by different varieties of cotton (Table 30). Among the cotton varieties, CB-14 resulted the lowest micronaire value (4.61 μg/inch) and it attained maximum (5.01 μg/inch) in CB-12. This result is in confirmatory with the findings of Bednarz *et al*. (2005), who reported that the influence of both genetics and environmental conditions on micronaire value of cotton fibre.

Length uniformity is now a part of the premium /discount valuation of cotton. Short fibre within a process mix of cotton cannot warp around each other and contribute little or nothing to yarn strength. Short fibres indirectly cause product defaults and directly contribute to higher waste and lower manufacturing efficiency. Since short fibre content and length uniformity are devised from length, they are influenced by the same factor as length. Crop management practices that influence where bolls are located on the plant can impact short fibre content levels. Uniform fruit retention patterns encarage beller length uniformity. Uniformity ratio of different cotton genotypes was not significant (Table 30). Numerically the highest uniformity ratio (82.18%) was observed in variety CB-14. The lowest uniformity ratio (81.72%) was found in variety CB-12.

Table 30. Effect of variety on lint characteristics of cotton

Variety	Staple length (mm)	Fibre trength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
CB- 13	28.25 c	28.50 c	4.92 a	82.16
CB- 14	28.96 a	28.74 a	4.61 b	82.18
CB- 12	28.45 b	28.51 b	5.01 a	81.72
LSD	**0.16**	**0.17**	**0.23**	**NS**
CV	**0.48**	**0.28**	**3.35**	**1.05**

Here, NS= Not significant

4. 3.4.1. Effect of fertilizer

Fertilizer doses exerted significant effect on staple length of cotton (Table 31). Result indicated that staple length showed a gradual increasing trend with the increases of fertilizer dose up to 75% higher than RDF and after that further increase of fertilizer levels decrease the staple length significantly. The highest staple length (29.09 mm) observed in 75% higher than RDF which was statistically higher than other doses. The lowest staple length (28.07mm) in 125% higher than RDF.

Fertilizer doses showed significant effect on fibre strength of cotton (Table 31). Fibre strength showed an increasing trend with the increases of fertilizer dose up to 75% higher than RDF and when exceed this level decreased the fibre strength significantly. The highest fibre strength (28.71 g/tex) was found in 75% higher than RDF which was statistically similar with 25% higher than RDF (28.60 g/tex) and 50% higher than RDF (28.68 g/tex). The lowest fibre strength (28.51 g/tex) wasobservedin 125% higher than RDF.

Micronaire value was affected significantly due to fertilizer doses in cotton fibre (Table 31). The highest micronaire value (4.95 µg/inch) in RDF which was statistically similar with 25% higher than RDF treatment and also 50% higher than RDF(4.93 and 4.90 µg/inch, respectively). The lowest micronaire value observed in 75% higher than RDF treatment.

Table 31.Effect of fertilizer levels on lint characteristics of cotton

Fertilizer level	Staple length (mm)	Fibre strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
RDF	28.44 c	28.52 b	4.95 a	81.87 ab
25% higher than RDF	28.46 c	28.60 ab	4.93 a	81.88 ab
50% higherthan RDF	28.81 b	28.68 a	4.90 ab	82.72 a
75% higher than RDF	29.09 a	28.71 a	4.64 c	82.17 ab
100% higher than RDF	28.44 c	28.52 b	4.92 ab	82.16 ab
125% higherthan RDF	28.07 d	28.51 b	4.69 bc	81.34 b
LSD (0.05)	**0.19**	**0.11**	**0.23**	**1.35**
CV (%)	**0.48**	**0.28**	**3.62**	**1.15**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers

Uniformity ratio was significantly affected due to fertilizer doses (Table 31). The significantly highest uniformity ratio (82.72 %) found in 50% higher than RDF which was statistically similar with all the doses except 125 % higher than RDF. The lowest uniformity ratio (81.34 %) observed in 125% higher than RDF. This result are in agreement with the findings of Pettigrew, (2001), and Tewolde and Fernandez, (2003) who reported that poor quality of fibre was observed for plants grown under low N concentrations and the high quality of fibre at optimum N concentrations.

4.3.4.3. Interaction effect of variety and fertilizer

There observed a significant difference in staple length due to combined effect of variety and fertilizer (Table 32). The significantly highest staple length (29.75 mm) was observed in CB-14 × 75% higher than RDF combined effect which was statistically at par with the combination of CB-14 variety × 100 % higher than RDF. Combined effect of CB-13 × 125% higher than RDF showed the lowest staple length (27.22 mm).

Combined effect of CB-14 × 75% higher than RDF showed the highest level of fibre strength (28.92 g/tex) which was statistically at par with CB-14 variety × 100 % higher than RDF and CB-12 × 75% higher than RDF combinations (28..92 and 28.67 g/tex, respectively). Irrespective of varieties, 125 % higher than RDF treatment showed the lowest level of fibre strength.

Micronaire value was found significant due to combine effect of variety and fertilizer levels(Table 32). The highest microniare value (5.27 µg/inch) was found with the combination of CB-12 × 25% higher than RDF, which was statistically similar with all the combinations of variety × fertilizer levels except CB-14 × 75% higher than RDF, CB-14 × 100 % higher than RDF and CB-14 × 125 % higher than RDF. Uniformity ratio was found non-significant due to variety × fertilizer levels (Table 32). Numarically, the highest uniformity ratio (83.00%) was observed with CB-14 × 50% higher than RDF and that of the lowest was with CB-14 × 100 % higher than RDF(80.38%).

Table 32. Interaction effect of variety and fertilizer on lint attributes of cotton

Interaction (Variety× Fertilizer)	Staple length (mm)	Fibre strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
CB- 13 × RDF	28.06 de	28.28 e	4.95 a	81.83
× 25% higher than RDF	28.63 bc	28.62 b	4.81 a	82.82
× 50% higher than RDF	28.35 cd	28.53 b-d	4.85 a	82.33
× 75% higher than RDF	28.91 b	28.55 bc	4.90 a	81.63
× 100% higher than RDF	28.35 cd	28.55 bc	4.92 a	82.66
× 125% higher than RDF	27.22 f	28.52 bc	5.04 a	81.67
CB- 14 × RDF	28.63 bc	28.65 b	4.95 a	82.30
× 25% higher than RDF	28.91 b	28.64 b	4.68 ab	81.99
× 50% higher than RDF	28.35 cd	28.69 ab	4.98 a	83.00
× 75% higher than RDF	29.75 a	28.92 a	4.18 bc	82.73
× 100% higher than RDF	29.75 a	28.92 a	4.16 bc	80.38
× 125% higher than RDF	28.35 cd	28.62 b	4.16 bc	82.66
CB- 12 × RDF	28.63 bc	28.64 b	4-96 a	81.47
× 25% higher than RDF	27.83 e	28.31 de	5.27 a	80.83
× 50% higher than RDF	28.63 bc	28.64 b	4.91 a	82.82
× 75% higher than RDF	28.63 bc	28.67 a	4.85 a	82.14
× 100% higher than RDF	28.35 cd	28.58 bc	5.02 a	80.98
× 125% higher than RDF	28.63 bc	28.35 c-e	5.04 a	82.14
LSD (0.05)	**0.19**	**0.24**	**0.72**	**NS**
CV (%)	**0.48**	**0.28**	**3.62**	**1.15**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers

4.3.5. Economic analysis

Economic analysis was done with a view to observing the comparative cost and benefit under different treatment combinations of variety and fertilizer levels. For this purpose, the inputs cost for land preparation, cotton seed, manure and fertilizer, pesticide, intercultural operation, harvesting and post harvesting cost and manpower required for all the operations including seed cotton were recorded against each treatment, which were then enumerated into cost per hectare.

Variation in cost of production was noted due to the cost of cotton seed and different fertilizer levels (Table 33). The total cost of production ranged between 71686 - 79526 Tk ha^{-1}. The cultivation cost increased with increasing fertilizer dose. The highest cost of production involved when used variety × 125 % higher than RDF dose combination (79526 Tk ha^{-1}). The lowest cost of production involved when used variety × RDF combination (71686 Tk ha^{-1}). The highest gross return was found when used CB-14 variety × 75 % higher than RDF dose treatment combination (181860 Tk ha^{-1}). The lowest gross return found (87960 Tk ha^{-1}) when used CB-12 variety × RDF fertilizer treatment combination. The highest gross margin found when used CB-14 variety × 75 % higher than RDF dose treatment combination (105470 Tk ha^{-1}). The lowest gross margin found when used CB-12 variety × RDF (16274 Tkha^{-1}) treatment combination. The maximum benefit cost ratio (BCR) involved when used CB-14 variety × 75 % higher than RDF dose treatment combination (2.38). The minimum benefit cost ratio was found when used CB-12 variety × RDF treatment combination (1.22). For economic point of view, results indicate that CB-14 inbred variety with 75 % higher than RDF level was more profitable than the other treatment combination.

Table 33. Economic analysis in cotton production as influenced by cotton variety and fertilizer levels

Interaction (Variety× Fertilizer)	Seed cotton yield (kg ha^{-1})	Gross return (Tk ha^{-1})	Total variable cost (Tk ha^{-1})	Gross margin (Tk ha^{-1})	BCR
CB- 13 × RDF	1627	97620	71686	25934	1.36
× 25% higher than RDF	1705	102300	73254	29046	1.39
× 50% higher than RDF	2151	129060	74822	54238	1.72
× 75% higher than RDF	2430	145800	76390	69410	1.91
× 100% higher than RDF	2404	144240	77958	66282	1.85
× 125% higher than RDF	2367	142020	79526	62494	1.78
CB- 14 × RDF	1884	113040	71686	41354	1.57
× 25% higher than RDF	2101	126060	73254	52806	1.72
× 50% higher than RDF	2293	137580	74822	62758	1.84
× 75% higher than RDF	3031	181860	76390	105470	2.38
× 100% higher than RDF	2743	164580	77958	86622	2.11
× 125% higher than RDF	2563	153780	79526	74254	1.93
CB- 12 × RDF	1466	87960	71686	16274	1.22
× 25% higher than RDF	1953	117180	73254	43926	1.60
× 50% higher than RDF	2151	129060	74822	54238	1.72
× 75% higher than RDF	2782	166920	76390	90530	2.18
× 100% higher than RDF	2665	159900	77958	81942	2.05
× 125% higher than RDF	2424	145440	79526	65914	1.83

Note:

RDF= Recommended dose of chemical fertilizers
Urea = 22 Tk kg^{-1} , MoP = 17 Tk kg^{-1}, Gypsum =12 Tk kg^{-1}, Zink sulphate = 210 Tk kg^{-1}

Borax =214 Tk kg^{-1}, Mac sulpher = 67 Tk kg^{-1}, Ektara = 9300 Tk kg^{-1},

Volume flexy = 5725 Tk kg^{-1} , Cupravit = 2200 Tk kg^{-1}, wage rate = 400 Tk man day

Cotton Seed =24 Tk kg^{-1}, Seed Cotton = 60 Tk kg^{-1}

4.4. Experiment 4. Effect of different planting arrangement on seed cotton yield and fibre quality of some newly released cotton varieties.

4.4.1 Phenological attributes

4. 4.1.1. Effect of variety

Days to first flowering and boll opening of each cotton varieties expressed in days after planting summarized in Table 34. There existed significant difference in days required for first flowering and boll opening. variety CB-14 required the longest time (58.83 days) to flowering and (125.36 dayes) for boll splitting which differed from other varieties. Variety CB-12 required the shortest time (57.16 days) to flowering and (119.35 dayes) for boll splitting. Days required to blooming and boll opening are important characters of cotton as it indicates the earliness of the crop. Genotypes took least days to initiate squaring (Godoy and Palomo, 1999), flowering (Panhwar *et al*. 2002, Gopang 2003, Azhar *et al*. 2007 and Ahmad *et al.* 2008) and boll opening (Gopang 2003; Nimbalkor *et al*. 2004 and Shakeel *et al.* 2008) are considered earliest in crop maturity. Although these are inherent characters but sometimes environmental factors can also governed the time of blooming and boll opening (Sawan *et al.*1999). The results were consisted with the findings of above scientists.

Table 34. Effect of variety on phonological attributes of cotton

Variety	Days to first flowering (days)	Days to first boll splitting (days)
CB-13	57.95 b	123.00 b
CB-14	58.83 a	125.36 a
CB-12	57.16 c	119.35 c
LSD (0.05)	**0.39**	**0.52**
CV (%)	**0.98**	**0.62**

4.4.1.2. Effect of spacing

Number of days to 1st flowering, and 1st boll opening were not affected by plant spacing (Table 35). However the shortest time for flowering (57.66 days) found in the spacing 90 × 30 cm. The longest flowering time (58.22 days) observed in 45 × 30 cm spacing. The shortest boll opening time (122.30 days) observed in 45 × 30 cm spacing and the longest boll opening time in (123.10 days) observed in 60 × 40 cm spacing. The results is consisted with the finding of Kerby *et al*. (1990) who reported that plant spacing had no effect on the earliness of crops on the shorter and more determinate genotypes. However, Clawson *et al*. (2008) reviewed the effect of plant density on the earliness of crop and was of the view that no study suggests strong influences of row spacing independent of plant population, on crop maturity.

Table 35. Effect of different spacing on phonological attributes of cotton

Spacing	Days to first flowering (days)	Days to first boll splitting (days)
45 × 30 cm	58.44	122.30
45 × 40 cm	58.22	122.40
60 × 30 cm	57.88	122.79
60 × 40 cm	58.00	123.10
75 × 30 cm	57.88	122.59
75 × 40 cm	58.00 .	122.49
90 × 30 cm	57.66	122.40
90 × 40 cm	57.77	122.49
LSD (0.05)	**NS**	**NS**
CV (%)	**0.98**	**0.62**

Here, NS= Not significant

4.4.1.3. **Interaction effect of variety and spacing**

There observed a significant difference in days to 1st flowering and boll opening due to combined effect of variety and spacing (Table 36). The shortest time for blooming (57.00 days) was found in the combinations of CB-12 × (60 × 30 cm), CB-12 × (75 × 30 cm) and CB-12 × (90 × 30 cm) spacing. The longest 1st flowering time (59.66) days) were observed in

CB-14 variety × (45 × 40 cm) spacing combination. The shortest boll opening time (118.80 days) were observed in CB-12 × (45 × 40 cm) spacing combination. The longest boll opening time (126.29 days) were observed in CB-14 variety × (60 × 40 cm) spacing combination.

Table 36 Interaction effect of variety and spacing on phonologcal attributes of cotton

Interaction (Variety × Spacing)	Days to first flowering (days)	Days to first boll splitting (days)
CB-13 × 45 × 30 cm	58.66 a-d	122.4 d
× 45 × 40 cm	57.66 b-d	123.00 cd
× 60 × 30 cm	57.66 b-d	123.59 b-d
× 60 × 40 cm	58.00 a-d	123.00 cd
× 75 × 30 cm	58.33 a-d	123.00 cd
× 75 × 40 cm	58.0 a-d	122.697
× 90 × 30 cm	57.66 b-d	123.30 d
× 90 × 40 cm	57.66 b-d	123.00 cd
CB-14 × 45 × 30 cm	59.33 ab	125.39 ab
× 45 × 40 cm	59.66 a	125.39 ab
× 60 × 30 cm	59.00 a-c	125.39 ab
× 60 × 40 cm	58.66 a-d	126.29 a
× 75 × 30 cm	58.33 a-d	125.10 a-c
× 75 × 40 cm	58.66 a-d	125.10 a-c
× 90 × 30 cm	58.33 a-d	125.10 a-c
× 90 × 40 cm	58.66 a-d	125.10 a-c
CB-12 × 45 × 30 cm	57.33 cd	119.09 e
× 45 × 40 cm	57.33 cd	118.80 e
× 60 × 30 cm	57.00 d	119.403
× 60 × 40 cm	57.33 cd	119.99 e
× 75 × 30 cm	57.00 d	119.70 e
× 75 × 40 cm	57.33 cd	119.70 e
× 90 × 30 cm	57.00 d	119.70 e
× 90 × 40 cm	57.33 cd	119.70 e
LSD (0.05)	**1.79**	**2.37**
CV (%)	**0.98**	**0.62**

4. 4.2.Plant characters

4.4.2.1. Effect of Variety

Plant height, vegetative branches plan^{-1} and sympodial branches plan^{-1} of different varieties measured at harvest time has been presented in (Fig.19, 20 and 21). Results showed a non significant difference in plant height, monopodial branches plant^{-1} and sympodial branches plant^{-1}. Numerically, the tallest plant (123.24 cm), the highest sympodial branches plan^{-1} (15.34) and the highest monopodial branches plan^{-1} (0.53) were observed in variety CB-14. On the other hand the shortest plant (115.50 cm) and the loest sympodial branches plan^{-1} (14.25) were observed in CB-13 variety. These results are similar to Brar *et al. (*2002) and Ali *et al*. (2009) reported non-significant results among genotypes on number of monopdial branches plant^{-1} and simpodial branches plan^{-1} .

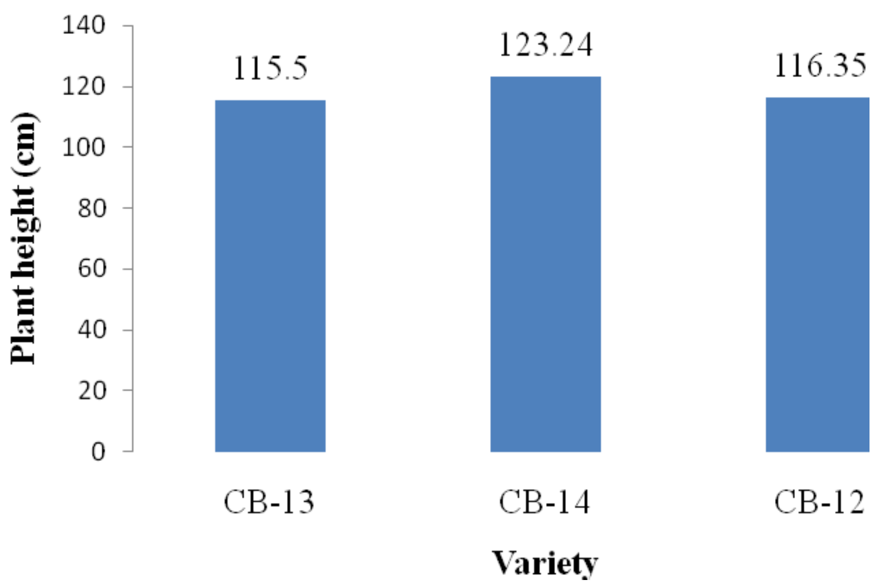

Fig. 19 Effect of variety on plant height of cotton (LSD 0.05 = NS)

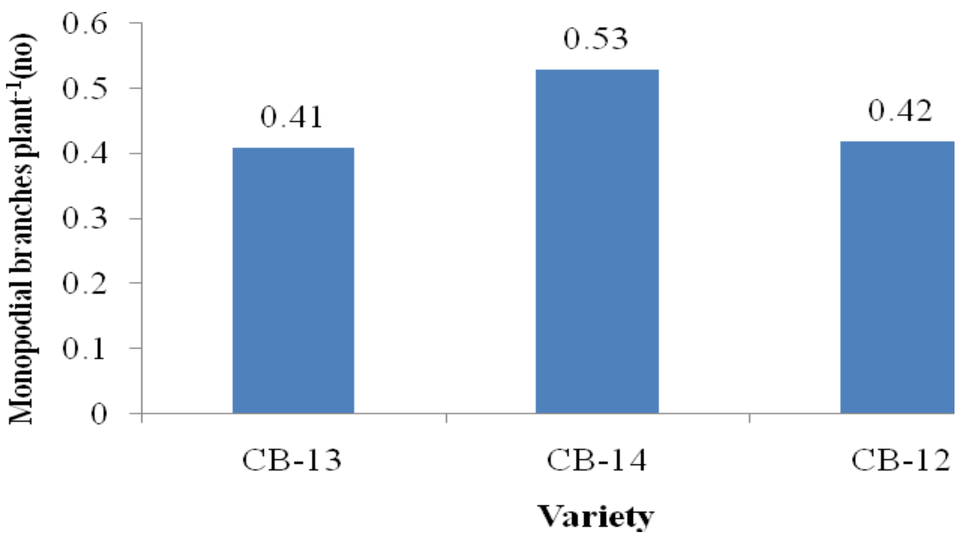

Fig. 20 Effect of variety on monopodial branches plant^{-1} of cotton (LSD 0.05 = NS)

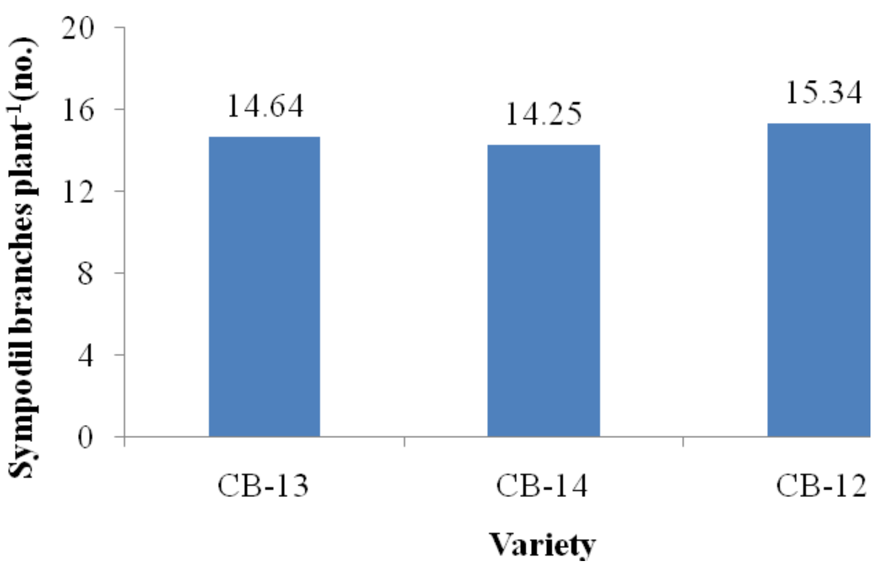

Fig. 21 Effect of variety on sympodial branches plant^{-1} of cotton (LSD 0.05 = NS)

4.4.2.2. Effect of spacing

Plant height, monopodial branches plan^{-1} and sympodial branches plan^{-1} of cotton due to different spacing were not significantly affected by plant spacing (Fig. 22, 23 and 24). This result are similar to Anjum (2003) and Siebert and Stewart (2006) who found no effect of plant density or row spacing on plant height.

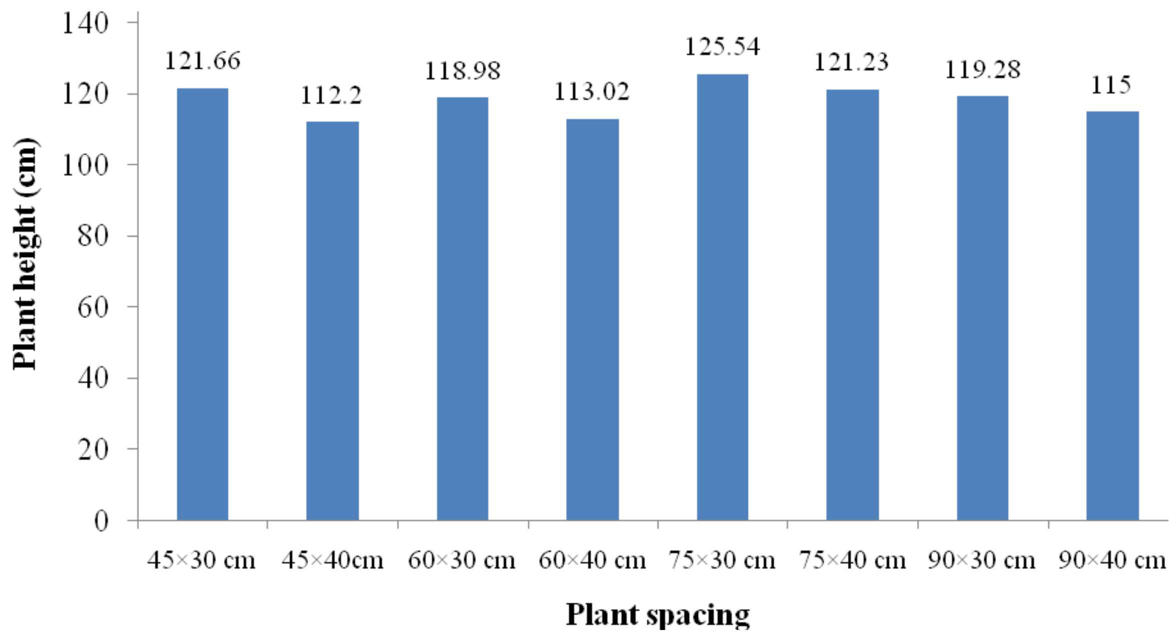

Fig. 22 Effect of plant spacing on plant height of cotton (LSD 0.05 = NS)

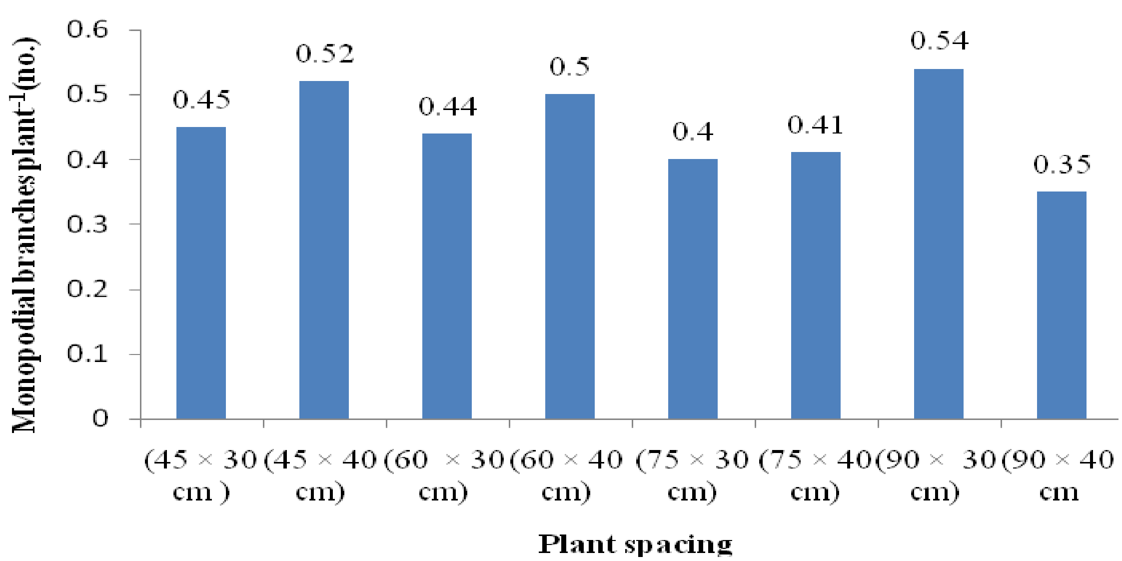

Fig. 23 Effect of plant spacing on monopodial branches plant^{-1}of cotton (LSD 0.05 = NS)

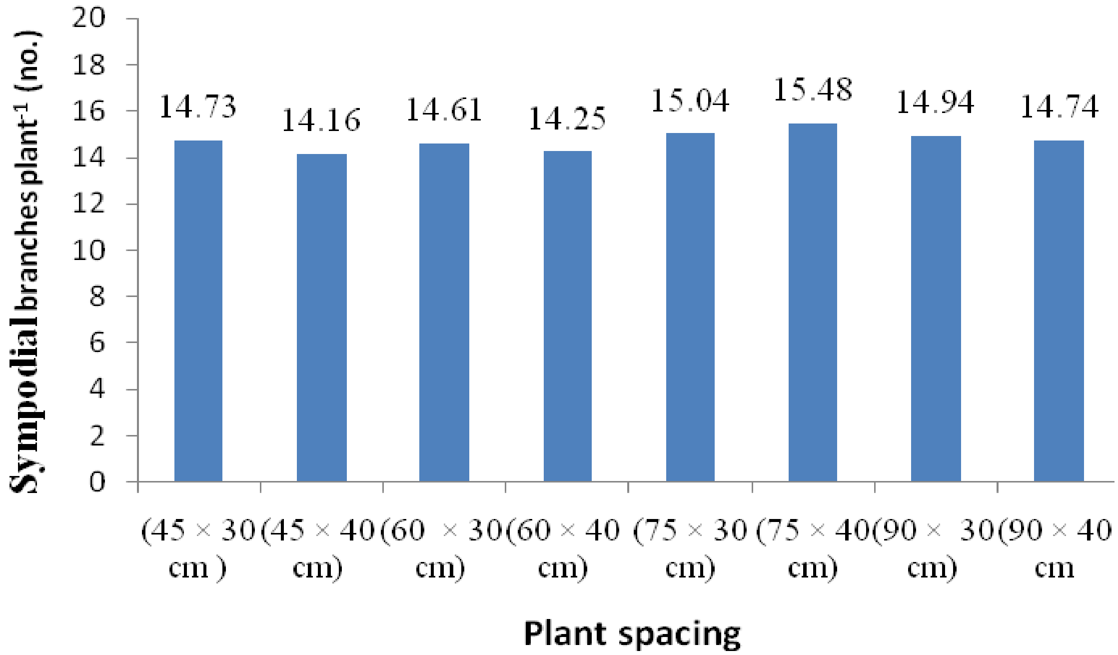

Fig. 24 Effect of plant spacing on sympodial branches plant^{-1} of cotton (LSD 0.05 = NS)

4.4.2.3. Interaction effect of variety and spacing

There observed a significant difference in plant height due to combined effect of variety and spacing. But monopodial branches plant^{-1} and sympodial branches plant^{-1} showed insignificant difference due to interaction effect of variety and spacing (Table 37). The tallest plant (143.03 cm) observed in CB-14 variety × (75 × 30 cm) spacing combination which was statistically similar with all the combinations except CB-12 × (60 × 40 cm) spacing combination and the shortest plant (101.70 cm) was observed in CB-12 variety × (60 × 40cm) spacing combination. The result consisted with Nichols et al (2004) who reported that cotton growth as affected by row spacing and cultivar. However, some other researchers found non significant effect of plant density or spatial arrangement on monopodial branch number (Anjum, 2003; Ahmad *et al.* 2009).

Table 37.Interaction effect of variety and spacing on growth attributes of cotton

Interaction (Variety × Spacing)	Plant height (cm)	Monopodial branches plan^{-1} (no.)	Simpodial branches plant^{-1} (no.)
CB-13 × 45 × 30 cm	115.10 ab	0.56	14.06
× 45 × 40 cm	116.83 ab	0.40	14.23
× 60 × 30 cm	118.27 ab	0.53	14.23
× 60 × 40 cm	119.03 ab	0.56	13.73
× 75 × 30 cm	122.93 ab	0.26	14.96
× 75 × 40 cm	117.50 ab	0.33	14.96
× 90 × 30 cm	105.93 ab	0.40	14.00
× 90 × 40 cm	108.37 ab	0.30	13.86
CB-14 × 45 × 30 cm	127.87 ab	0.50	13.86
× 45 × 40 cm	104.77 ab	0.53	14.33
× 60 × 30 cm	122.63 ab	0.46	14.33
× 60 × 40 cm	118.33 ab	0.64	15.70
× 75 × 30 cm	143.03 a	0.56	15.90
× 75 × 40 cm	122.13 ab	0.53	15.63
× 90 × 30 cm	129.93 ab	0.63	15.80
× 90 × 40 cm	117.23 ab	0.36	15.80
CB-12 × 45 × 30 cm	122.00 ab	0.30	14.76
× 45 × 40 cm	115.00 ab	0.63	13.93
× 60 × 30 cm	116.03 ab	0.33	14.50
× 60 × 40 cm	101.70 b	0.30	13.33
× 75 × 30 cm	110.67 ab	0.36	14.26
× 75 × 40 cm	124.07 ab	0.36	15.86
× 90 × 30 cm	121.97 ab	0.60	15.03
× 90 × 40 cm	119.40 ab	0.40	15.46
LSD (0.05)	**40.424**	**NS**	**NS**
CV (%)	**10.84**	**4.10**	**6.97**

Here, NS= Not significant

4.4.3. Yield and yield attributes

4.4.3.1.. Effect of variety

A significant difference in number of bolls plant^{-1}, boll weight and seed cotton yield among the cotton varieties were observed in the experiment (Table 38). Inbred CB-14 produced the maximum number of bolls plant^{-1} (26.46) which was significantly higher than other varieties.

CB-13 produced minimum boll plant^{-1} (20.22) which was statistically at per with CB-12. Many studies authenticate that cotton cultivars varied markedly for boll production due to genetic transformation (Taohua and Haipeng, 2006; Meena *et al*. 2007; Arshad *et al*. 2007; Hussain *et al*. 2007; Bednarz *et al*. 2007; Ahmad *et al*. 2008).

Significant effect on boll weight was found among the varieties in cotton (Table 38). CB-14 variety produced the heaviest boll (5.57g) which was statistically higher than other varieties. Variety CB-13 produced the litest boll (5.03g) which was statistically similar with CB-12 (5.11g). The results are disagreed with the findings of Saleem *et al*. (2010) who found in-significant differences in boll weight due to cultivars.

Seed cotton yield was significantly influenced by different varieties of cotton (table 38). Variety CB-14 showed its superiority over CB-13 and CB-12 by producing 14.87 % and 6.42% higher seed cotton yield. However the highest seed cotton yield (3051 kg ha^{-1}) recorded in CB-14. The lowest seed cotton yield (2656 kg ha^{-1}) recorded in CB-13 variey. The highest seed cotton yield of CB-14 was associated with its better yield components like number of bolls per plant and individual boll weight. These resuls are consisted with the findings of Campbell and Bauer (2007), Ali *et al*. (2009) and O'Berry *et al*. (2009) who reported that varietal variation significantly affect yield potential of upland cotton. The findings also confirmed with the results of Soomro *et al*. (2008) who copted that seed cotton yield has positively correlation with sympodia per plant, bolls per plant and boll weight.

Table 38. Effect of variety on yield and yield attributes of cotton

Variety	Bolls plant^{-1} (no.)	Individual boll weight (g)	Seed cotton yield (kg ha^{-1})
CB-13	20.22 b	5.03 b	2656 b
CB-14	26.46 a	5.57 a	3051 a
CB-12	22.48 b	5.11 b	2867 ab
LSD (0.05)	**2.67**	**0.20**	**318.26**
CV (%)	**6.57**	**5.54**	**12.01**

4.4.3.2. Effect of spacing

Result showed that number of bolls plant^{-1} increased gradually with the increase of plant spacing (Table 39). The highest bolls plant^{-1} (28.76) produced from (90 × 40 cm) spacing which was at per with (90 × 30 cm), (75 × 40 cm) and (75 × 30 cm) spacing (28.48, 24.01 and 23.54, respectively). The lowest bolls plant^{-1} (17.27) produced by the closest spacing (45× 30 cm). The results supports the findings of Khalequzzaman *et al. (*2012) who reported that increased spacing increased the bolls per plant. Previously reported studies suggest that wider plant spacing increased bolls per plant (Boquet, 2005; Obasi and Msaakpa 2005; Siddiqui *et al*. 2007; Rajakumar and Gurumurthy, 2008; Ali *et al*. 2009).

Plant spacing exerted significant effect on boll weight of cotton (Table 39). The highest boll weight (5.38g) produced from 90 × 40 cm spacing. It was found from the result that boll weight reduced gradually with reduced spacing and the lowest boll weight (4.96 g) produced by the lowest spacing (45 × 30 cm). It was also observed from the result that except two closest spacings (40 × 30 cm and 45 × 30 cm) all the spacings produced statistically similar values of boll weight,. The result confirm the findings of Unay and Inan (1994) who determined that plant density affected on number of bolls plant^{-1} and boll weight. Several reports reveal that boll size is inversely related to population density (Boquet *et al*., 2005; Obasi and Msaakpa, 2005; Bednarz *et al*., 2006). The increase of plant density decreased the individual seed mass and lint mass per boll (Boquet *et al*., 2005; Bednarz *et al*., 2006; Darawsheh *et al*., 2009b).

Significant influence on seed cotton yield was observed due to spacings. (Table 39). The results indicated that seed cotton yield showed an increasing trend with the increases of plant spacing upto75 × 30 cm spacing. After that the yield reduced gradually upto 90 × 40 cm spacing. The highest seed cotton yield (3414kg ha^{-1}) observed in (60 × 30 cm) spacing which was statistically at per with (75 × 30 cm), (45 × 30 cm), (45 × 40 cm) and (60 × 40 cm) spacings. The lowest seed cotton yield (2188 kg ha^{-1}) produced in the widest spacing (90 × 40 cm). The result are consistent with the findings of Delaney *et al.* (1999) who found that high plant density in early sowing increased seed cotton yield. The result also supported to the comment of Hall and Ziska (2000) who proposed that plant density should be increased in order to minimize yield losses. Nichols *et al*.(2004), Khan *et al*.(2005) and Kaur and Brar (2008) suggested that seed cotton yield increases by closer spacing or narrow rows.

Table 39. Effect of spacing on yield and yield attributes of cotton

Spacing	Bolls plant^{-1} (no.)	Individual boll weight (g)	Seed cotton yield (kg ha^{-1})
45 × 30 cm	17.27 cd	4.96 b	3190 ab
45 × 40 cm	18.08 cd	5.02 b	3032 ab
60 × 30 cm	22.20 b	5.25 a	3414 a
60 × 40 cm	22.08 b	5.28 a	2767 a-c
75 × 30 cm	23.54 ab	5.32 a	3325 a
75 × 40 cm	24.01 ab	5.33 a	2643 bc
90 × 30 cm	28.48 a	5.34 a	2306 c
90 × 40 cm	28.76 a	5.38 a	2188 c
LSD (0.05)	**5.71**	**0.33**	**680.94**
CV (%)	**6.57**	**5.54**	**12.1**

4.4.3.3. Interaction effect of variety and spacing

Bolls plant^{-1} obtained due to interaction of variety and spacing is presented in Table 40. The result showed that bolls plant^{-1} for all the varieties increased gradually with the increase of plant spacing but the rate of increase were much higher in three widest spacings. The highest bolls plant^{-1} (29.80) found in the combined effect of CB-14 ×(90 × 40 cm) spacing. The lowest bolls plant^{-1} (15.00) observed in CB-13 × (45 × 30 cm) spacing combination.

Boll weight exerted significant variation due to combined effect of variety and spacing (Table 40). The highest boll weight (5.83 g) was found in the combination of CB-14 × (90 × 40 cm) spacing which was statistically at per with all the combinations except CB-12 × (45 × 30 cm). The lowest boll weight (4.80g) observed in the combination of CB-12 × (45 × 30 cm) spacing.

Table 40. Interaction effect of variety and spacing on yield and yield attributes of cotton

Interaction (Variety × Spacing)	Bolls plant^{-1} (no.)	Individual boll weight (g)	Seed cotton yield (kg ha^{-1})
CB-13 × 45 × 30 cm	15.00 de	4.96 a-c	2898 a-c
× 45 × 40 cm	17.50 c-e	5.00 a-c	2709 a-c
× 60 × 30 cm	19.76 c	5.06 a-c	2812 a-c
× 60 × 40 cm	19.96 cd	5.10 a-c	2809 a-c
× 75 × 30 cm	21.90 bc	5.16 a-c	2930 a-c
× 75 × 40 cm	22.03 ab	5.16 a-c	2687 a-c
× 90 × 30 cm	22.80 a	5.16 a-c	2154 bc
× 90 × 40 cm	23.83 a	5.26 a-c	1970 c
CB-14 × 45 × 30 cm	17.30 cd	5.13 a-c	3338 a-c
× 45 × 40 cm	18.63 c	5.33 a-c	3178 a-c
× 60 × 30 cm	21.76 b-d	5.50 a-c	3382 a-c
× 60 × 40 cm	22.26 bc	5.60 a-c	2993 a-c
× 75 × 30 cm	24.13 b	5.63 a-c	3597 a
× 75 × 40 cm	25.33 ac	5.73 ab	2883 a-c
× 90 × 30 cm	26.73 ab	5.80 a	2498 b-c
× 90 × 40 cm	27.70 a	5.83 a	2436 b-c
CB-12 × 45 × 30 cm	19.53 d	4.80 c	3181 a-c
× 45 × 40 cm	22.13 c-d	4.86 a-c	2989 a-c
× 60 × 30 cm	24.36 c	4.96 a-c	3546 ab
× 60 × 40 cm	26.73 bc	5.03 a-c	2798 a-c
× 75 × 30 cm	28.93 a	5.06 a-c	3342 a-c
× 75 × 40 cm	29.46 a	5.13 a-c	2658 a-c
× 90 × 30 cm	29.76 a	5.16 a-c	2266 a-c
× 90 × 40 cm	29.80 a	5.26 a-c	2159 bc
LSD (0.05)	**2.038**	**0.915**	**1434.2**
CV (%)	**6.57**	**5.54**	**12.01**

Interaction of variety and spacing showed significant effect in seed cotton yield (Table 40). The highest seed cotton yield (3597 kg ha^{-1}) produced in combination of CB-14 × (75 × 30 cm) spacing. The lowest seed cotton yield obtained from (1970 kg ha^{-1}) CB-13 × (90 × 40 cm) spacing combination. It is interesting that plant spacing in 90 cm apart rows showed remarkable yield reduction all the three varieties. These results are similar with that of Ahmad *et al*. (2009) who harvested maximum yield of BH-160 at 22.5 cm spacing in 75 cm apart rows .Soomro *et al.* (2000a) also found that 23 and 30 cm plant spacings gave higher seed cotton yield.

4.4.4. **Fibre quality attributes**

4.4.4.1 Effect on variety

Fibre quality primarily affected by genotype while agronomic practices are secondary (Bednarz *et al.,* 2005). Braden *et al*. (2009), Zeng and Meredith, Jr. (2009), Hua *et al*. (2009) Ulloa *et al*. (2009) identified significant variation among genotypes for fibre quality.

Staple length was significantly differed among the cotton varieties (Table 41). Fibre length of cotton genotypes varied from 28.95 mm to 29.11 mm. Variety CB-12 had the longest fibre length (29.11 mm) which was statistically at per with that of CB-14 (29.11 mm), while CB-13 showed the shortest (28.95mm) length. Nichols *et al.* (2004) reported similar result that there was genotypic variation for staple length of cotton. Several researchers pointed out that staple length vary across cultivars (Bourland and Jones 2009a,b; Smith *et al*., 2010; Long *et al*., 2010) which has been supported the present findings.

Fibre strength of different cotton varieties showed insignificant result (Table 41). Numerically the highest fibre strength (29.38g/tex) observed in CB-12 variety that of lowest (28.37g/tex) found in CB-14 variety.

There were significant differences of fineness of fibre produced by different varieties of cotton (Table 41). Among the cotton varieties, CB-12 resulted the lowest micronaire value (4.70 µg/inch) and it attained maximum (4. 87µg/inch) in CB-14. This result are in agreement with the findings of Bednarz *et al*. (2005) who reported the influence of both genetics and environmental conditions are responsible for micronaire value/ finess of cotton fibre.

Uniformity ratio of different cotton varieties was not significant (Table 41). However, the highest uniformity ratio (82.74 %) observed in variety CB-12 and that of the lowest uniformity ratio (82.60 %) found in variety CB-14.

Table 41. Effect of variety on lint characteristics of cotton

Variety	Staple length (mm)	Fibre strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
CB-13	28.95 b	28.69	4.86 a	82.65
CB-14	29.09 a	28.37	4. 87 a	82.60
CB-12	29.11 a	29.38	4.70 b	82.74
LSD (0.05)	**0.047**	**NS**	**0.24**	**NS**
CV	**0.57**	**0.23**	**0.71**	**0.29**

Here, NS= Not significant

4.4.4.2. Effect of spacing

Plant spacing had significant effect on staple length (Table 42). The table indicated that staple length showed a gradual increasing trend with the increases of plant spacing. The highest staple length (29.57mm) was observed in 90 × 40 cm spacing which was statistically at per with 75 × 40 cm spacing (29.37mm). The lowest staple length (28.33mm) was recorded with 45 x 30 cm spacing. The studies of Bednarz *et al*. (2000), Larson *et al*. (2004), Bednarz *et al*. (2006) and Darawsheh *et al*. (2009b) are in agreement with the findings of the present study in that increased population reduced the fibre length of cotton.

A significant effect was found on fibre strength of cotton due to plant spacing (Table 42). Fibre strength showed an increasing trend with the increases of spacing. The highest fibre strength (28.77g/tex) was found in 90 × 40 cm spacing and that of lowest (28.52 g/tex) was in 45 x 30 cm spacing. This result firely agree with the findings of Nicholas *et al*. (2004) and Clawson *et al*. (2006), who observed a little impact of various row spacing on fibre quality.

Spacing affect significantly on staple micronaire value of cotton (Table 42). Result showed that the highest micronaire value (4.98 µg/inch) was in 60 × 40 cm spacing. The spacing lower and higher than 60 × 40 cm gave significantly lower values of microniare value. Bednarz *et al*. (2006) and Darawsheh *et al*. (2009b) pointed out that microniare value decreases with the increased plant population.

The results of the uniformity ratio presented in table 42 indicates that the value of uniformity ratio increased gradually with increases of plant spacings. The significantly highest uniformity ratio (83.08 %) was found in 90 × 40 cm spacing. The lowest uniformity ratio (82.39 %) was observed in 45 × 30 cm spacing. This result is in agreement with the findings of Nichols *et al*. (2004) and Jost and Cothern (2001) who observed negative impact of increased plant density on lint uniformity.

Table 42.Effect of spacing on lint characteristics of cotton

Spacing	Staple length (mm)	Fibre strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
45 × 30 cm	28.33 e	28.52 c	4.73 e	82.39 c
45 × 40 cm	28.92 d	28.71 ab	4.78 d	82.63 bc
60 × 30 cm	29.01 cd	28.66 b	4.74 e	82.69 bc
60 × 40 cm	29.11 cd	28.72 ab	4.98 a	82.43 c
75 × 30 cm	28.92 d	28.74 ab	4.84 c	82.53 c
75 × 40 cm	29.37 ab	28.76 ab	4.90 b	82.64 bc
90 × 30 cm	29.18 bc	28.69 ab	4.92 b	82.93 ab
90 × 40 cm	29.57 a	28.77 a	4.61 f	83.08 a
LSD (0.05)	**0.242**	**0.101**	**0.051**	**0.35**
CV (%)	**0.5757**	**0.2323**	**0.70**	**0.29**

4.4.4.3. Interaction effect of variety and spacing

There observed a significant difference in staple length due to combined effect of variety and spacing (Table 43). The significantly highest staple length (30.32 mm) was observed in CB-13 × (90 × 40 cm) spacing combined effect which was statistically at par with that of C-12 × (90 × 40 cm) spacing. Combined effect of CB-13 × (60 × 40 cm) spacing showed the lowest staple length (27.78 mm).

Combined effect of CB- 13×(90 × 40 cm) spacing showed the highest level of fibre strength (28.97gm/tex) which was statistically at par with CB-12 × (90 × 40 cm). CB-13 × (45 × 30 cm), CB-13 × (45 × 40 cm). CB-14 × (45× 40 cm), CB-14 × (60 × 30 cm), CB-14 × (75 × 30 cm), CB-14 × (75 × 40 cm), CB-14 × (90 × 30 cm) and CB-12 × (45× 30 cm) spacing (28.97, 28.96, 28.81, 28.83, 28.82, 28.93, 28.85, 28.85, 28.89 g/tex respectively) . However, the lowest value (28.36g/tex) was recorted with CB-13× (60× 40 cm) spacing.

Table 43. Interaction effect of variety and spacing on lint attributes of cotton

Interaction (Variety × Spacing)	Staple length (mm)	Fibre strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
CB-13 × 45 × 30 cm	29.48 bc	28.91 a	4.51 h	82.94 ab
× 45 × 40 cm	29.48 bc	28.81 a-f	4.76 fg	82.94 ab
× 60 × 30 cm	28.63 ef	28.62 e-i	4.77 f	82.49 b-d
× 60 × 40 cm	27.78 i	28.36 j	5.30 b	82.01 d
× 75 × 30 cm	28.35 gh	28.61 f-i	5.04 c	82.34 b-d
× 75 × 40 cm	28.92 d-f	28.62 e-i	4.96 cd	82.65 a-d
× 90 × 30 cm	28.63 e-g	28.68 e-i	5.27 b	82.49 b-d
× 90 × 40 cm	30.32 a	28.97 a	4.16 i	83.37 a
CB-14 × 45 × 30 cm	28.20 bc	28.49 ij	4.84 ef	82.79 a-c
× 45 × 40 cm	29.48 bc	28.83 a-e	4.63 h	82.60 b-d
× 60 × 30 cm	28.91 d-f	28.82 a-e	4.88 de	82.65 a-d
× 60 × 40 cm	28.57 f-h	28.65 d-i	4.75 fg	82.79 a-c
× 75 × 30 cm	29.48 bc	28.93 ab	4.56 h	82.60 b-d
× 75 × 40 cm	29.20 cd	28.85 a-d	4.96 cd	82.79 a-d
× 90 × 30 cm	29.75 b	28.85 a-d	4.84 ef	82.07 cd
× 90 × 40 cm	29.08 gh	28.39 j	5.50 a	82.51 b-d
CB-12 × 45 × 30 cm	29.42 b-d	28.89 a-c	4.76 fg	83.08 a
× 45 × 40 cm	28.25 gh	28.51 h-j	4.96 d	82.34 b-d
× 60 × 30 cm	29.48 bc	28.72 b-h	4.58 h	82.94 ab
× 60 × 40 cm	28.63 e-g	28.56 g-j	4.88 de	82.49 b-d
× 75 × 30 cm	28.91 d-f	28.68 c-i	4.90 de	82.65 a-d
× 75 × 40 cm	28.63 e-g	28.68 c-i	4.76 fg	82.49 b-d
× 90 × 30 cm	29.15 c-e	28.41 b-g	4.66 gh	82.60 b-d
× 90 × 40 cm	30.32 a	28.96 a	4.20 i	83.37 a
LSD (0.05)	**0.51**	**0.21**	**0.10**	**0.74**
CV (%)	**.57**	**0.076**	**0.71**	**0.29**

Micronaire value affect significantly due to combined effect of variety and spacing. The significantly highest micronaire value (5.50 µg/inch) observed in CB-14 × (90 × 40 cm) spacing combination. The lowest micronaire value (4.20 **µ**g/inch) was observed in CB-12 × (90 × 40 cm) spacing combination which was at per with CB-13 × (90 × 40 cm) spacing combination.

Uniformity ratio varied significantly due to interaction effect of variety and spacing (Table 43). The highest uniformity ratio (83.37%) observed in CB-13 × (90 × 40 cm) spacing combination which was significantly at per to that of CB-12 × (90 × 40 cm), CB-12 × (60 ×

30 cm), CB-12 × (75 × 30 cm), CB-12 × (45 × 30 cm), CB-13 × (45 × 30 cm), CB-13 × (45 × 40 cm), CB-13 × (75 × 40 cm), CB-14 × (45 × 30 cm), CB-14 × (60 × 40 cm), CB-14 × (60 × 30 cm) and CB-14 × (75 × 40 cm) spacing combination (83.37, 82.94, 82.65, 83.08, 82.94, 82.94, 82.65, 82.89, 82.65, 82.79 and 82.79 respectively) The lowest uniformity ratio (82.01%) was found in CB-13 × (60 × 40 cm) treatment combination. This result is contradictory with the findings of Valco *et al*. (2001) who found no differences in fibre uniformity due to varied row spacing or plant density.

4.4.5. Economic analysis

Economic analysis was done with a view to observing the comparative cost and benefit under different treatment combinations of variety and plant spacing. For this purpose, the inputs cost for land preparation, cotton seed, manure and fertilizer, pesticide, intercultural operation, harvesting and post harvesting cost and manpower required for all the operations including seed cotton were recorded against each treatment, which were then enumerated into cost per hectare.

Economic analysis of variety and plant spacing experiment has been presented in Table 44. The total cost of production ranged between 71686 Tk ha^{-1} to 74550 Tk ha^{-1}. The result revealed that cultivation cost increased with decreasing plant spacing. The highest cost of production involved when used 45 × 30 cm spacing (74550Tk ha^{-1}). The lowest cost of production involved when used 90 × 45 cm plant spacing (71686Tk ha^{-1}). The highest gross return found when used CB-14 variety and 75 × 30 cm plant spacing treatment combination (215820 Tk ha^{-1}). The lowest gross return found (118200 Tk ha^{-1}) when used CB-13 variety and 90 × 40 cm spacing treatment combination.The highest gross margin found when used CB-14 variety and 75 × 30 cm spacing treatment combination (142820 Tk ha^{-1}). The lowest gross margin (1.64Tk ha^{-1}) was found when used CB-13 variety and 90 × 40 cm spacing treatment combination. The maximum benefit cost ratio (BCR) involved when used CB-14 variety and 75×30 cm spacing treatment combination (2.95). The minimum benefit cost ratio found when used CB-13 variety and 90 × 40 cm spacing treatment combination (1.64). Plant spacing 75 × 30 cm gave the highest gross return, the highest gross margin and the highest benefit cost for all the three varieties. For economic point of view, results indicate that plant spacing 75 × 30 cm was more profitable of these three varieties.

Table 44. Economic analysis in cotton production as influenced by cotton variety and spacing

Interaction (Variety × Spacing)	Seed cotton yield (kg ha^{-1})	Gross return (tk ha^{-1})	Total variable cost (tk ha^{-1})	Gross margin (tk ha^{-1})	BCR
CB-13 × 45 × 30 cm	2898	173880	74550	99330	2.33
× 45 × 40 cm	2709	162540	73950	88590	2.19
× 60 × 30 cm	2812	168720	73950	94770	2.28
× 60 × 40 cm	2809	168540	73550	94990	2.29
× 75 × 30 cm	2930	175800	73000	102800	2.41
× 75 × 40 cm	2687	161220	72500	88720	2.22
× 90 × 30 cm	2154	129240	72500	56740	1.78
× 90 × 40 cm	1970	118200	71686	46514	1.64
CB-14 × 45 × 30 cm	3338	200280	74550	125730	2.68
× 45 × 40 cm	3178	190680	73950	116730	2.57
× 60 × 30 cm	3382	202920	73950	128970	2.74
× 60 × 40 cm	2993	179580	73550	106030	2.44
× 75 × 30 cm	3597	215820	73000	142820	2.95
× 75 × 40 cm	2883	172980	72500	100480	2.38
× 90 × 30 cm	2498	149880	72500	77380	2.06
× 90 × 40 cm	2436	146160	71686	74474	2.03
CB-12 × 45 × 30 cm	3181	190860	74550	116310	2.56
× 45 × 40 cm	2989	179340	73950	105390	2.42
× 60 × 30 cm	3546	212760	73950	138810	2.87
× 60 × 40 cm	2798	167880	73550	94330	2.28
× 75 × 30 cm	3342	200520	73000	127520	2.74
× 75 × 40 cm	2658	159480	72500	86980	2.20
× 90 × 30 cm	2266	135960	72500	63460	1.87
× 90 × 40 cm	2159	129540	71686	57854	1.80

Note:

Urea = 22 Tk kg^{-1} , MoP = 17 Tk kg^{-1}, Gypsum =12 Tk kg^{-1}, Zink sulphate = 210 Tk kg^{-1}
Borax =214 Tk kg^{-1}, Mac sulpher = 67 Tk kg^{-1}, Ektara = 9300 Tk kg^{-1},

Volume flexy = 5725 Tk kg^{-1} , Cupravit = 2200 Tk kg^{-1}, wage rate = 400 Tk man day

Cotton Seed =24 Tk kg^{-1}, Seed Cotton = 60 Tk kg^{-1}

4.5. Experiment 5. Yield and fibre quality improvement of newly released cotton varieties through planting arrangement and nutrient management

4. 5.1. Plant characters

4.5.1.1. Effect of variety

Plant height, monopodial branches plant^{-1} and sympodial branches plant^{-1} of different varieties measured at harvest time. The results showed a non significant difference in plant height, monopodial branches plant^{-1} and sympodial branches plant^{-1} of cotton varieties. The talest plant (126.51cm) was observed in variety CB-14 (Fig. 25). On the other hand, the shortest plant (118.37) was observed in CB-12. Such differences in number of sympodial branches per plant of cotton genotypes were also reported by Nichols *et al.* (2004) in different cotton growing environments. Brar *et al. (*2002) and Ali *et al*. (2009) reported non-significant results on number of monopdial and sympodial branches per plant among cotton genotypes.

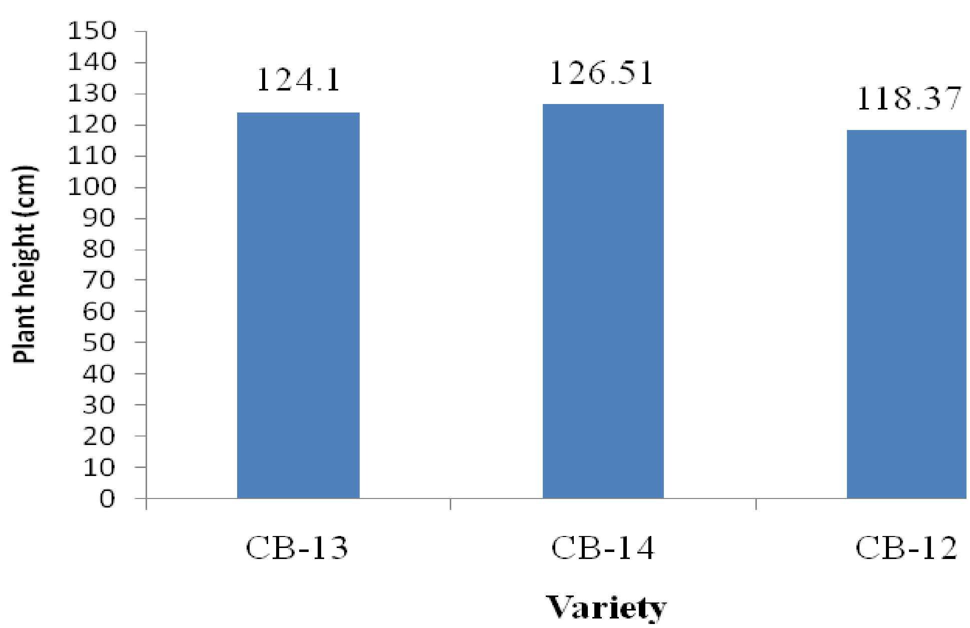

Fig.25 Effect of variety on plant height of cotton (LSD 0.05 = NS)

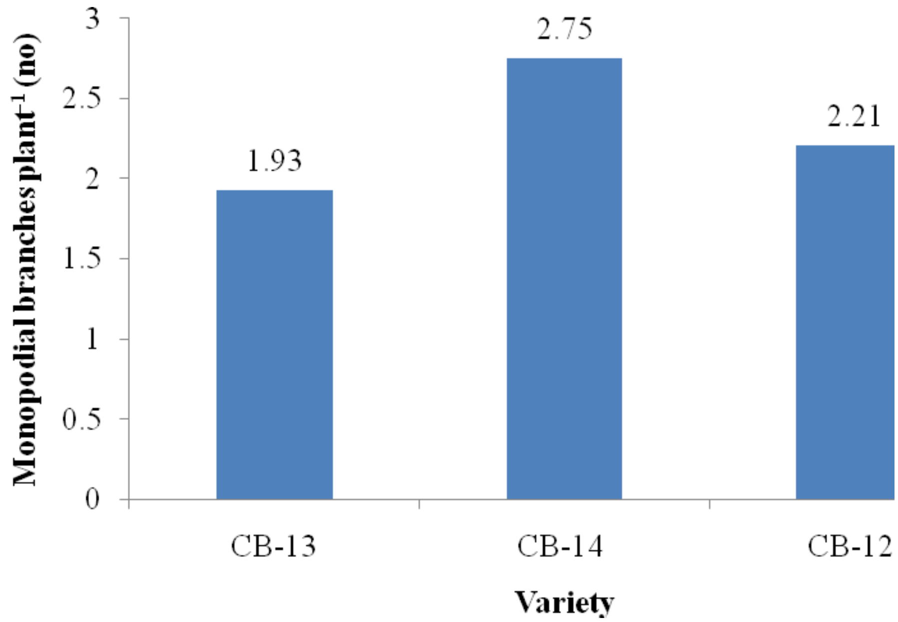

Fig. 26 Effect of variety on monopodial branches plant^{-1} of cotton (LSD 0.05 = NS)

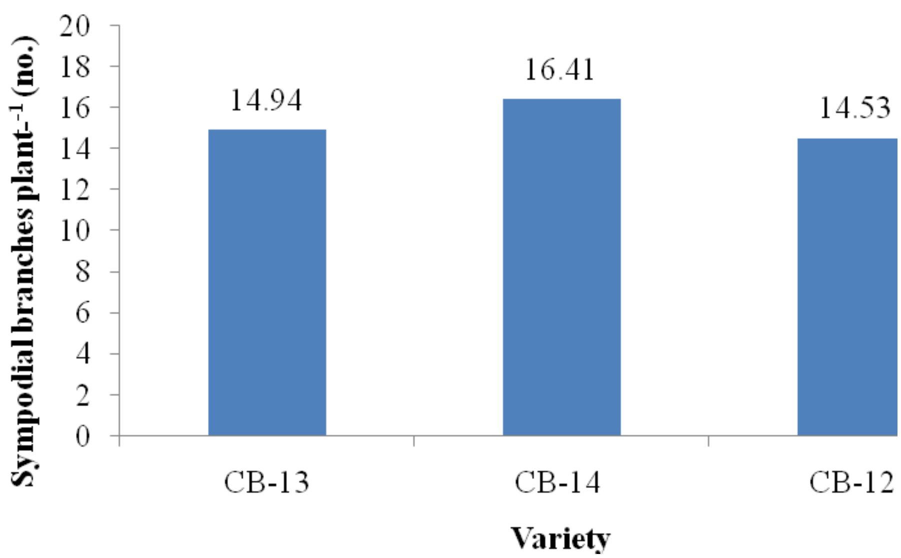

Fig.27 Effect of variety on sympodial branches plant^{-1} of cotton (LSD 0.05 = NS)

4.5.1.2. Effect of fertilizer

Plant height and monopodial branches plant^{-1} of cotton genotypes due to application of different levels of fertilizer varied significantly (Fig 28 and 29). But sympodial branches plant^{-1} showed insignificant variation due to fertilizer doses (Fig.30). Plant height at harvest, monopodial branches plant^{-1} and sympodial branches plant^{-1} increased with the increase dose of fertilizer. The tallest plant (132.27cm) recorded in 75% higher than RDF which were significantly higher than other doses. The shortest plant (117.45 cm) observed in 25% higher than RDF. The highest monopodial branches plant^{-1} (2.82) produced in 75% higher than RDF (Fig.29).

The increase in plant height, monopodial branches plant^{-1} and sympodial branches plant^{-1} due to application of different levels of fertilizer might be associated with fertilizer application with stimulating effect on various physiological process including cell division and cell elongation of the plant. The results are similar to Khalequzzaman *et al*. (2012) who reported increasing fertilizer levels increased plant height, monopodial branches plant^{-1} and sympodial branches plant^{-1}. Most studies signified a positive relationship between plant height and N rates (Clawson *et al*. 2006, Kumbhar *et al*. 2008; Cheema *et al*. 2009; Ibrahim *et al*.2010) that increased N rate improves the plant characters of cotton.

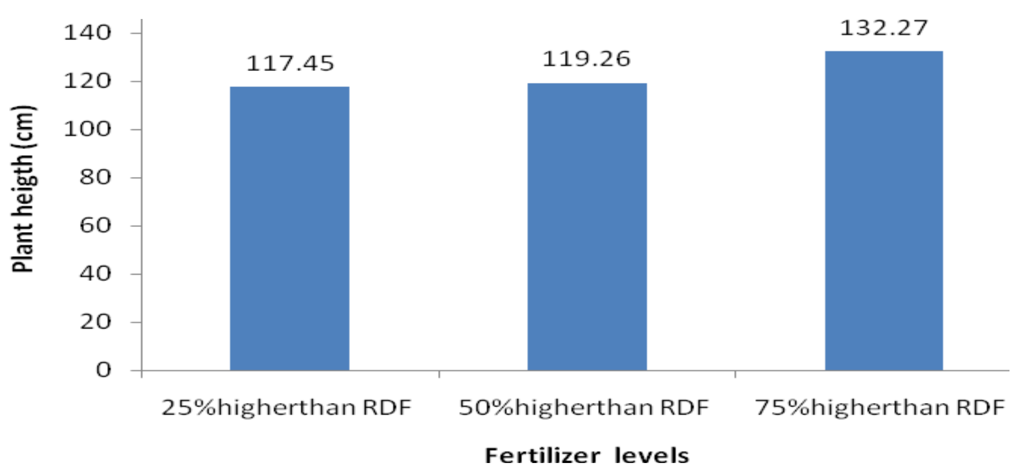

Fig.28 Effect of fertilizer levels on plant height of cotton (LSD 0.05 =9.64**)**

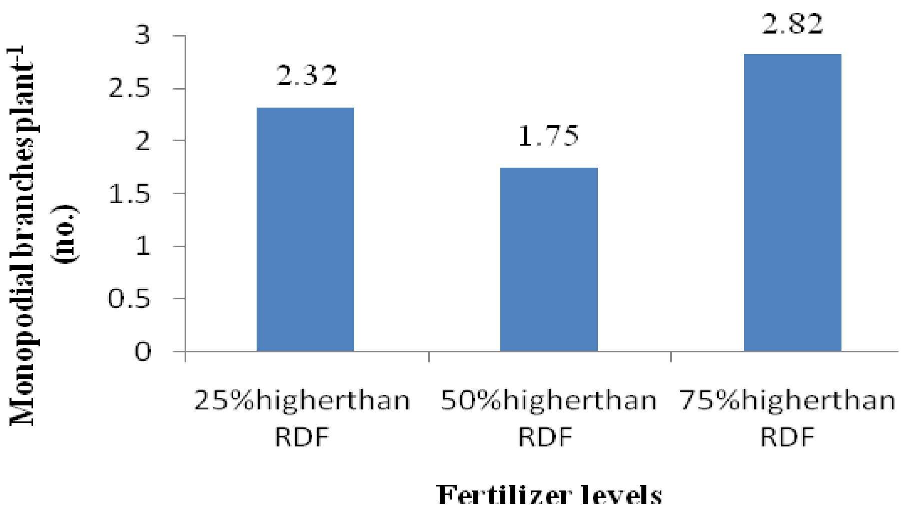

Fig.29 Effect of fertilizer on monopodial branches plant^{-1} of cotton (LSD 0.05 = 0.83**)**

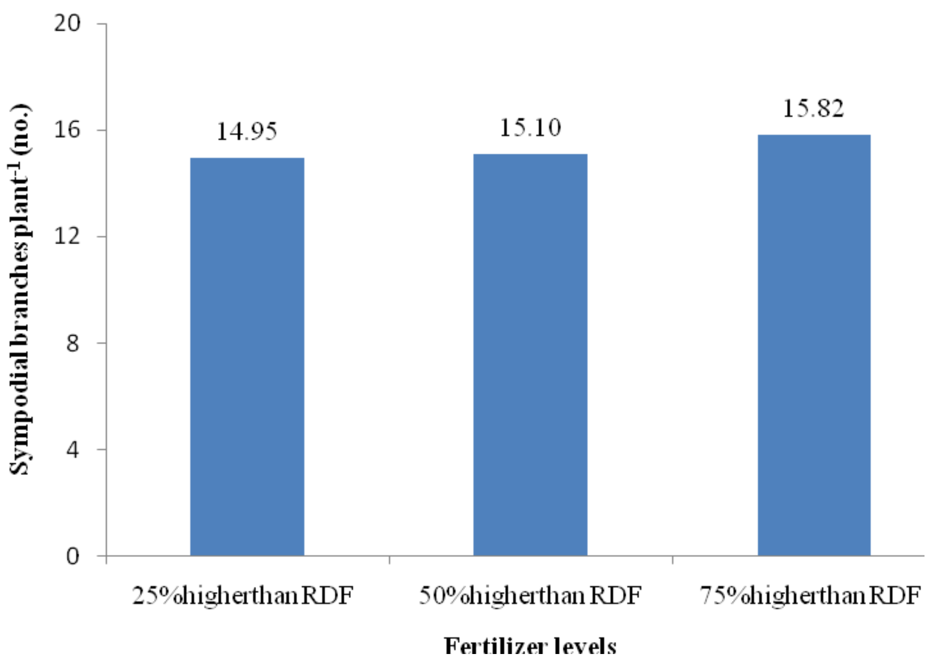

Fig.30 Effect of fertilizer levels on sympodial branches plant^{-1} of cotton (LSD 0.05= NS)

4.5.1.3. Effect of spacing

Plant height at harvest and sympodial branches plant^{-1} were not affected by planting geometry (Fig. 31 and 33). This result was similar to Anjum (2003) and Siebert and Stewart (2006) who found no effect of plant density or row spacing on plant height.

Monopodial branches plant^{-1} of cotton genotypes due to different spacing varied significantly at harvest. Monopodial branches plant^{-1} increased with the increases of spacing. The highest monopodial branches plant^{-1} (3.21) recorded in the widest spacing which was statistically similar with 60 × 30 cm spacing (Fig. 32). The lowest monopodial branches plant^{-1} (1.52) observed in the narrowest spacing (45 × 30 cm). The results is consistant with the finding of Siebert *et al*., (2006), who reported that plant spacing is inversely related to number of monopodial and sympodial branches plant^{-1}.

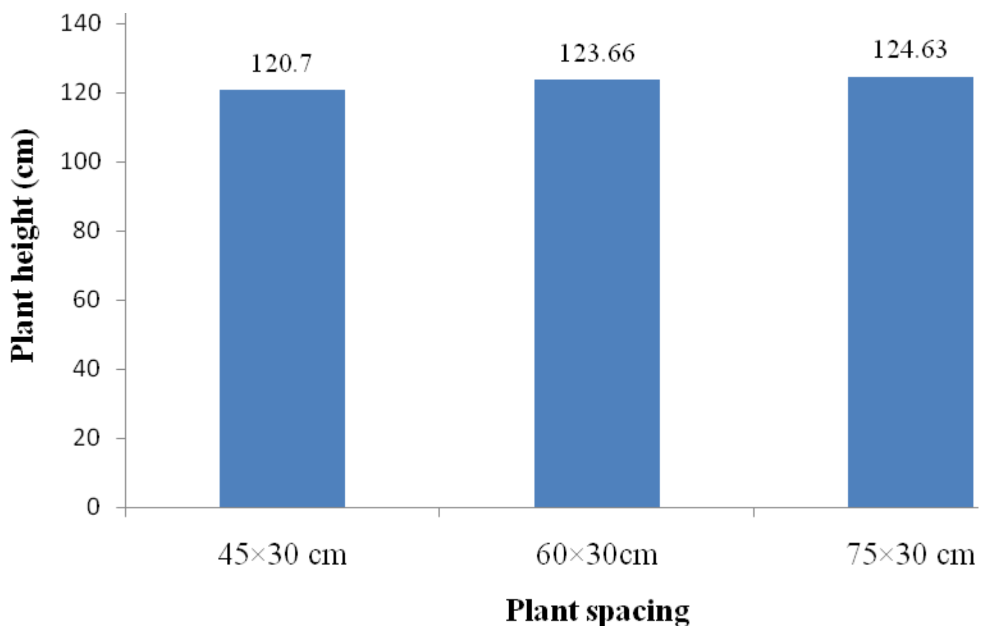

Fig. 31 Effect of spacing on plant height of cotton (LSD 0.05= NS)

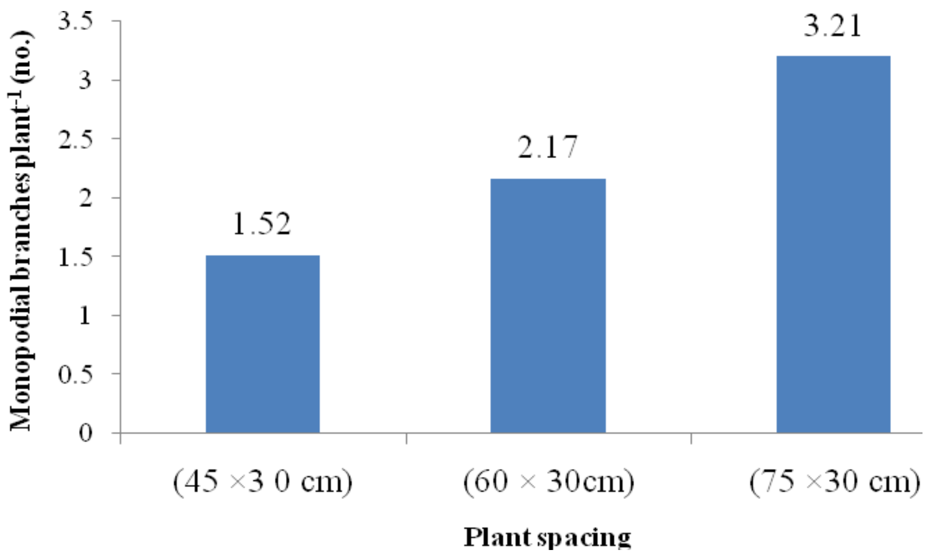

Fig. 32 Effect of spacing on monopodial branches plant^{-1} of cotton (LSD 0.05 = 1.09**)**

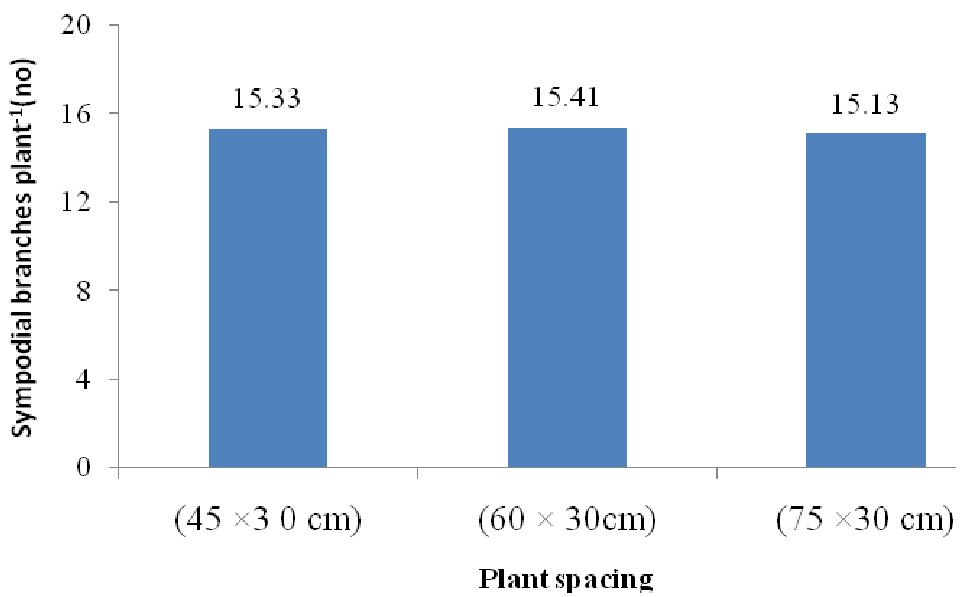

Fig. 33 Effect of spacing on sympodial branches plant^{-1} of cotton (LSD 0.05= NS)

4.5.1.4. Interaction effect of variety and fertilizer

There observed an insignificant difference in plant height, monopodial branches plant^{-1} and sympodial branches plant^{-1} due to interaction effect of variety and fertilizer in cotton (Table

45). Numerically the tallest plant (137.03 cm), the highest monopodial branches plant^{-1} (3.43) and the highest sympodial branches plant^{-1} (16.86) found in the combination of CB-14 × 75 % higher fertilizer than RDF. The lowest plant height (110.17cm) ovserved in CB-12 × 25% higher than RDF treatment combination and the lowest monopodial branches plant^{-1} observed in CB-13 × 25% higher than RDF treatment combination (1.19).

Table 45. Interaction effect of variety and fertilizer on plant characters of cotton

Interaction (Variety × Fertilizer)	Plant height (cm)	Monopodial branches plant^{-1} (no.)	Sympodial branches plant^{-1} (no.)
CB- 13 × 25% higher than RDF	117.80	1.19	14.86
× 50% higher than RDF	122.80	1.24	15.16
× 75% higher than RDF	131.69	2.64	14.82
CB- 14 × 25% lhigher than RDF	124.38	3.2	15.82
× 50% higher than RDF	118.13	1.64	16.56
× 75% higher than RDF	137.03	3.43	16.86
CB- 12 × 25% higher than RDF	110.17	1.85	14.2
× 50% higher than RDF	116.86	2.29	13.60
× 75% higher than RDF	128.09	2.41	15.79
LSD (0.05)	**NS**	**NS**	**NS**
CV (%)	**11.79**	**53.19**	**15.19**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers

4.5.1.5. **Interaction effect of variety and spacing**

There observed a significant difference on sympodial branches plant^{-1} due to combined effect of variety and spacing (Table 46). The highest sympodial branches plant^{-1} (17.53) was found in the combination of CB-14 × (45 × 30 cm) which was statistically similar with all other treatment combinations except CB-13 × (45 × 30 cm) and CB-12 × (75 × 30 cm) combination. The lowest sympodial branches plant^{-1} (13.78) was observed in CB-12 × (75 × 30 cm) combination which was statistically similar with CB-13 × (45 × 30 cm) treatment combination (13.9). Plant height and monopodial branches plant^{-1} showed insignificant difference. The results are consisted with Manjappa *et al*. (1997), who reported non significant response of row spacing on cultivars. Some other researchers found non significant effect of plant density or spatial arrangement on monopodial branch number (Anjum, 2003; Ahmad *et al*., 2009). Conversely, Ahmad *et al*. (2009) reported more number of sympodias per plant in lower plant spacing.

Table 46. Interaction effect of variety and spacing on plant characters of cotton

Interaction (Variety × Spacing)	Plant height (cm)	Monopodial branches plant^{-1} (no.)	Sympodial branches plant^{-1} (no.)
CB-13× 45 × 30 cm	124.23	1.73	13.9 b
× 60 × 30 cm	119.34	1.57	14.89 ab
× 75 × 30 cm	128.71	2.5	16.04 ab
CB-14 × 45 × 30 cm	119.11	1.44	17.53 a
× 60 × 30 cm	129.26	2.48	16.13 ab
× 75 × 30 cm	131.18	4.34	15.57 ab
CB-12 × 45 × 30 cm	118.74	1.39	14.58 ab
× 60 × 30 cm	122.38	2.45	15.23 ab
× 75 × 30 cm	113.99	2.81	13.78 b
LSD(0.05)	**NS**	**NS**	**3.50**
CV (%)	**11.79**	**63.76**	**14.51**

Here, NS= Not significant

4.5.1.6. Interaction effect of spacing and fertilizer

There observed a significant difference on plant height and monopodial branches plant^{-1} due to combined effect of spacing and fertilizer doses but sympodial branches plant^{-1} showed non significant variation (Table 47). The tallest plant (136.27cm) observed in (45 × 30 cm) × 75% higher than RDF treatment combination. The shortest plant (111.93cm) was observed in (45× 30 cm) × 50% higher than RDF treatment combination The highest monopodial branches plant^{-1} (4.03) found in (75 × 30 cm) spacing × 75 % higher than RDF treatment combination which was statistically similar with all other treatments combinations except (45 × 30 cm) spacing × 25 % higher than RDF, (45 × 30 cm) spacing × 50 % higher than RDF and (45 × 30 cm) spacing × 75 % higher than RDF. The lowest monopodial branches plant^{-1} (1.20) was observed in (45 × 30 cm) spacing × 50 % higher than RDF fertilizer combinations. Increasing plant height of cotton with spacing and nutrient management has been reported by Kaur *et al.*(2010) and Sharma *et al.* (2004). Singh (2017) reported significantly higher number of monopodial branches plant^{-1} was obtained with the application 125% recommended dose of fertilizers +25% less than normal spacing+ foliar spray of 2% urea and 2% DAP as compared to rest of the levels of spacing and nutrient management. The increased in monopodia and sympodia might be due to the fact the optimum nutrient helped in cell division and cell elongation leading to increased number of lateral branches. These results are close conformity with the findings of Ram and Giri (2006) and Kaur *et al.* (2010).

Table 47. Interaction effect of spacing and fertilizer on plant characters of cotton

Interaction (spacing × Fertilizer)	Plant height (cm)	Monopodial branches plant^{-1} (no.)	Sympodial branches plant^{-1} (no.)
45 × 30 cm × 25 % higher than RDF	113.89 ab	1.49 b	14.6
× 50 % higher than RDF	111.93 b	1.20 b	15.15
× 75% higher than RDF	136.27 a	1.87 b	16.26
60 × 30 cm × 25 % higher than RDF	119.46 ab	2.02 ab	14.86
× 50 % higher than RDF	120.47 ab	1.90 ab	15.41
× 75 % higher than RDF	131.06 ab	2.58 ab	15.98
75 × 30 cm × 25% higher than RDF	119.00 ab	3.46 ab	15.41
× 50 % higher than RDF	125.39 ab	2.17 ab	14.74
× 75 % higher than RDF	129.49 ab	4.03 a	15.23
LSD(0.05)	**29.24**	**2.15**	**NS**
CV (%)	**11.79**	**53.19**	**15.18**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers

4.5.1.7. Interaction effect of variety, spacing and fertilizer

There observed a significant difference on sympodial branches plant^{-1} due to interaction effect of variety, spacing and fertilizer in cotton (Table 48). The highest sympodial branches plant^{-1} (20.23) found in the interaction of CB-14 × 75 % higher than RDF × (45 × 30 cm) which was statistically similar with all other treatments combinations except CB-12 × 50 % higher than RDF × (75 × 30 cm). The lowest sympodial branches plant^{-1} (11.13) observed CB-12 × 50 % higher than RDF × (75 × 30 cm) (11.13). Plant height and monopodial branches plant^{-1} showed insignificant difference among the interactions. The result is consisted with Ahmad *et* *al*. (2009) who reported non significant effect of plant density or spatial arrangement on monopodial branch number. Conversely, Ahmad *et al*. (2009) reported more number of sympodial branches plant^{-1} in lower plant spacing.

Table 48. Interaction effect of variety, fertilizer and spacing on plant characters

Interaction Variety × Spacing ×Fertilizer	Plant height (cm)	Monopodial branches plant^{-1} (no.)	Sympodial branches plant^{-1} (no.)
CB-13 × 25 % higher than RDF× (45 × 30 cm)	111.20	1.50	14.23 ab
× 25 % higher than RDF × (60 × 30 cm)	117.70	1.67	14.6 ab
× 25% higher than RDF × (75 × 30 cm)	124.50	2.57	15.73 ab
× 50 % higher than RDF× (45 × 30 cm)	124.10	1.40	14.76 ab
× 50 % higher than RDF × (60 × 30 cm)	115.17	0.87	14.60 ab
× 50 % higher than RDF × (75 × 30 cm)	129.13	1.47	16.10 ab
× 75% higher than RDF × (45 × 30 cm)	137.40	2.30	12.70 ab
× 75 % higher than RDF× (60 × 30 cm)	125.17	2.17	15.47 ab
× 75 % higher than RDF× (75 × 30 cm)	132.50	3.47	16.30 ab
CB-14 × 25 % higher than RDF× (45 × 30 cm)	124.30	1.80	16.03 ab
× 25 % higher than RDF × (60 × 30 cm)	125.93	2.67	15.43 ab
× 25% higher than RDF × (75 × 30 cm)	122.90	5.13	16.00 ab
× 50 % higher than RDF× (45 × 30 cm)	93.17	0.89	16.33 ab
× 50 % higher than RDF × (60 × 30 cm)	128.47	1.40	16.33 ab
× 50 % higher than RDF × (75 × 30 cm)	132.77	2.63	17.00 ab
× 75% higher than RDF × (45 × 30 cm)	139.87	1.63	20.23 a
× 75 % higher than RDF× (60 × 30 cm)	133.37	3.40	16.63 ab
× 75 % higher than RDF× (75 × 30 cm)	137.87	5.26	13.70 ab
CB-12 × 25 % higher than RDF× (45 × 30 cm)	106.17	1.17	13.53 ab
× 25 % higher than RDF × (60 × 30 cm)	114.73	1.73	14.57 ab
× 25% higher than RDF × (75 × 30 cm)	109.60	2.67	14.5 ab
× 50 % higher than RDF× (45 × 30 cm)	118.53	1.33	14.37 ab
× 50 % higher than RDF × (60 × 30 cm)	117.77	3.43	15.30 ab
× 50 % higher than RDF × (75 × 30 cm)	114.27	2.40	11.13 b
× 75% higher than RDF × (45 × 30 cm)	131.53	1.67	15.83 ab
× 75 % higher than RDF× (60 × 30 cm)	134.63	2.20	15.83 ab
× 75 % higher than RDF× (75 × 30 cm)	118.10	3.37	15.7 ab
LSD(0.05)	**NS**	**NS**	**7.57**
CV (%)	**11.79**	**53.19**	**15.18**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers

4.5. 2.Yield and yield attributes

4.5.2.1. Effect of variety

There exist a non significant variation on bolls plant^{-1}, drop out bolls plant^{-1}, seed cotton yield and lint yield of cotton among the tested three cultivars (Table 49). The presented result indicates that CB-12 showed the highest boll weight (5.50 g) which was statistically at per with CB-14. The cultivar CB-13 showed the lowest (5.31) bolls plant^{-1}. Variety CB-13 gave the highest ginning out turn (41.93%) which was statistically similar with CB-12 (41.40 %) . The cultivar CB-14 showed the lowest (39.97%) ginning out turn. Boquet and Clawson, (2009) and O'Berry *et al*. (2009) in their experiment found significant differences in ginning out turn among the cultivars. On the other hand, numarically the highest lint yield (1108 kg ha^{-1}) was observed for the hybrid CB-14 and the lowest lint yield (1096 kg ha^{-1}) was obtained from CB-13 variety.

Table 49. Effect of variety on yield and yield attributes of cotton

Variety	Boll plant^{-1} (no.)	Drop out boll plant^{-1} (no.)	Inbividual boll weigh (g)	Seed cotton yield (kg ha^{-1})	Ginning out turn (%)	Lint yield (kg ha^{-1})
CB-13	21.41	5.15	5.31 b	2615	41.93 a	1096
CB-14	22.13	4.45	5.44 a	2773	39.97 b	1108
CB-12	19.20	4.2	5.50 a	2771	41.40 ab	1107
LSD(.05)	**NS**	**NS**	**.10**	**NS**	**1.43**	**NS**
CV (%)	**17.98**	**61.09**	**1.87**	**24.67**	**2.61**	**24.67**

Here, NS= Not significant

4.5.2.2. Effect of fertilizer

The result showed that number of bolls plant^{-1} increased gradually with the increases of fertilizer dose (Table 50). The highest increase (22.99) was observed with at the highest dose of 75% higher than RDF which was statistically higher than other doses. The lowest bolls plant^{-1} (19.37) produced by the lowest dose that was 25% higher than RDF which was statistically similar with 50% higher than RDF (20.40). The results are similar to Parmer *et* *al*. (2010) who reported that boll plant^{-1} increased with increased fertilizer doses. It was observed by many researchers that bolls per plant increases by increasing N level (Dar and Khan, 2004; Wiatrak *et al*. 2005; Khan and Dar, 2006; Sawan *et al*. 2006; Kumbhar *et al*. 2008). Drop out boll plant^{-1}showed insignificant effect on fertilizer doses.

Fertilizer doses exerted significant effect on individual boll weight of cotton (Table 49). The highest boll weight produced (5.45g) in 75% higher than RDF which was statistically at per with 50% higher than RDF (5.44g). The lowest boll weight (5.36g) produced from 25% higher than RDF. The results are similar to Khalequzzaman *et al.* (2012) who reported increased fertilizer levels increased the boll weight of cotton. The present findings also supported by the findings of Saleem *et al*. (2010) who recorded maximum boll weight at 120 kg N ha^{-1}.

Fertilizer doses showed significant influence on seed cotton yield (Table 49). The results indicated that seed cotton yield showed an increasing trend with increases of fertilizer dose. The highest seed cotton yield (2891 kg ha^{-1}) observed in 75% higher than RDF which was statistically higher than other doses. The lowest seed cotton yield (2611 kg ha^{-1}) produced 25% higher than RDF which was statistically at per with that of (2655kg ha^{-1}) 50% higher than RDF. The highest seed cotton yield in 75% higher than RDF application might be due to the highest number of boll plant^{-1}, highest individual boll weight and highest number of sympodial branch plant^{-1}. The results are in agreement with the findings of Sharma *et al.* (1979) reported higher seed cotton yield with application of fertilizers up to 320:160: 160 kg ha^{-1} NPK. However, optimum dose of fertilizer was found to be 280:140:140 kg ha^{-1} NPK for maximum production of seed cotton. The results are similar to Parmer *et al.* (2010) and Angadi *et al.* (1989) reported fertilizer levels increase yield of hybrid cotton. Kumbhar *et al*. (2008) have obtained significant increase in seed cotton yield due to N application.

The highest ginning out turn recorded from 75% higher than RDF (41.41%) which was statistically similar to 50% higher than RDF (41.18%). The lowest ginning out turn recorded from 25% higher than RDF (40.65%). The increase in ginning out turn due to application of higher level of fertilizers was also reported by Saleem *et al*.(2010).

Fertilizer doses exerted significant effect on lint yield (Table 50). Result showed that lint yield showed an increasing trend with the increases of fertilizer dose. The highest lint yield

(1197kg ha^{-1}) obtained from 75% higher than RDF which was statistically higher than other doses. The lowest lint yield (1061kg ha^{-1}) produced in 25% higer than RDF. Higher lint yield in 75% higher than RDF might be due to higher ginning out turn and higher boll weight.

Table 50. Effect of fertilizer levels on yield and yield attributes of cotton

Fertilizer levels	Bolls plant^{-1} (no.)	Drop out boll plant^{-1} (no.)	Inbividual boll weigh (g)	Seed cotton yield (kg ha^{-1})	Ginning out turn (%)	Lint yield (kg ha^{-1})
25%higherthan RDF	19.37 b	4.40	5.36 b	2611 b	40.65 b	1061 b
50%higherthan RDF	20.40 b	4.67	5.44 a	2655 b	41.18 ab	1093 b
75%higherthan RDF	22.99 a	4.74	5.45 a	2891 a	41.41 a	1197 a
LSD(0.05)	**2.08**	**NS**	**0.06**	**163.63**	**0.66**	**66.83**
CV (%)	**14.97**	**12.07**	**1.67**	**9.04**	**2.42**	**9.04**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers

4.5.2.3. Effect of spacing

The result showed that number of bolls plant^{-1} increased gradually with the increases of plant spacing (Table 51). The highest bolls plant^{-1} (23.76) produced with (75×30 cm) spacing which was statistically similar with (60×30 cm) spacing (20.03). The lowest bolls plant^{-1} (18.96) produced by the lowest spacing (45×30 cm). The results are similar to Khalequzzaman *et al. (*2012) who reported that increased spacing increases the bolls per plant of cotton. Previous studies of many scientist suggest that wider plant spacing increased bolls per plant of cotton (Boquet 2005, Obasi and Msaakpa 2005; Siddiqui *et al*. 2007,Rajakumar and Gurumurthy, 2008; Ali *et al*. 2009).

Plant spacing exerted significant effect on boll weight of cotton (Table 51). The highest boll weight (5.46g) produced in the widest spacing (75 × 30 cm) which was statistically identical to (60 × 30 cm) spacing (5.43g). The lowest boll weight (5.36g) produced by the lowest spacing (45 × 30 cm). The result is similar to Unay and Inan (1994) who determined that plant density affects on number of bolls plant^{-1} and boll weight. Several reports reveal that boll size is inversely related to population density (Boquet *et al*. 2005; Obasi and Msaakpa, 2005; Bednarz *et al*. 2006). On the other hand, the increase of plant density decreased the individual seed mass and lint mass per boll (Boquet *et al*. 2005; Bednarz *et al*. 2006; Darawsheh *et al*. 2009b).

Plant spacing showed significant influence on seed cotton yield (Table 51). Results indicated that seed cotton yield showed an increasing trend with decreases of plant spacing. The highest seed cotton yield (3099 kg ha^{-1}) observed in (45×30 cm) spacing which was statistically higher than other spacings. The lowest seed cotton yield (2412 kg ha^{-1}) produced in the widest spacing (75×30 cm). The result is consisted with the results of Delaney *et al.* (1999) who found that high plant density in early sowing increased seed cotton yield. The result supported to comment of Hall and Ziska (2000), who proposed that plant density should be increased in order to minimize yield losses. Nichols *et al*. (2004); Khan *et al*.,(2005); Kaur and Brar, (2008) suggested that seed cotton yield increases by closer spacing or narrow rows.

Ginning out turn showed insignificant effect on plant spacing. Numarically, the lowest ginning out turn (40.96%) was recorted with closer spacing (45×30 cm) and that of highest with the widest spacing (75 × 30 cm). This result is similar with the findings of Sawan *et al*. (2008), Ahmad *et al*. (2009), and Ali *et al*. (2009) who reported that GOT was not affected either by inter or intra row spacing.

Different spacing exerted significant effect on lint yield (Table 51). Result showed that lint yield gradually increased with the decreases of plant spacing. The highest lint yield (1269 kg ha^{-1}) in (45 × 30 cm) spacing which was statistically higher than other plant spacings. The lowest lint yield (995 kg ha^{-1}) produced in (75×30 cm) spacing.

Table 51. Effect of spacing on yield and yield attributes of cotton

Spacing	Bolls plant^{-1} (no.)	Drop out boll plant^{-1} (no.)	Inbividual boll weigh (g)	Seed cotton yield (kg ha^{-1})	Ginning out turn (%)	Lint yield (kg ha^{-1})
45×30 cm	18.96 b	4.87	5.36 b	3099 a	40.96	1269 a
60×30cm	20.03 a	4.47	5.43 a	2646 b	41.06	1086 b
75×30 cm	23.76 a	4.47	5.46 a	2412 b	41.29	995 b
LSD(0.05)	**3.07**	**NS**	**0.03**	**362.40**	**NS**	**148**
CV (%)	**20.22**	**30.29**	**1.61**	**18.30**	**2.38**	**18.30**

4.5.2.4. Interaction effect of variety and fertilizer

An insignificant difference exerted in bolls plant^{-1} and drop out bolls plant^{-1} due to interaction effect of variety and fertilizer in cotton (Table 52). Result showed that numerically bolls plant^{-1} increased gradually with the application of increasing fertilizer dose irrespective of varieties. The highest bolls plant^{-1} (24.10) found in the interaction of CB-14 ×75% higher than RDF. The lowest bolls plant^{-1} (17.53) observed in CB-12 × 25% higher than RDF. In some studies number of bolls per plant increased significantly up to a certain doses of N after which no significant increase or diminishing return was observed with higher N rates (Anwar *et al*. 2002; Anwar and Afzal, 2003; Iqbal *et al*. 2003).

There observed a significant difference in boll weight of cotton due to interaction effect of variety and fertilizer (Table 52). The highest boll weight (5.51g) found in the interaction of CB-12 × 50 % higher than RDF which was statistically similar with all the interaction except CB-13 × 25% higher than RDF(5.26 g). The lowest boll weight (5.26g) was observed in the interaction of CB-13 × 25% higher than RDF treatment combination. Cheema *et al*., (2009) observed that boll weight increased by increasing N level upto 150 kg ha^{-1}.

Interaction of variety and fertilizer exerted insignificant effect in seed cotton yield (Table 52). However, numerically the highest seed cotton yield (3020 kg ha^{-1}) found in the interaction of CB-14 × 75% higher than RDF. On the other hand CB-13 × 50% higher than RDF treatment gave the lowest yield (2500 kgha^{-1}). Saleem *et al*. (2010) recorded maximum seed cotton yield per plant (69.3 g) at 120 kg N ha^{-1} which corroborates the present finding that higher dose showed higher yield irrespective of varieties.

Table 52.Interaction effect of variety and fertilizer on yield and yield attributes of cotton

Interaction (Variety × Fertilizer)	Bolls plan^{-1} (no.)	Drop out boll plant^{-1} (no.)	Individual boll weight (g)	Seed cotton yield (kg ha^{-1})
CB- 13 × 25% higher than RDF	19.81	4.69	5.26 b	2549
× 50% higher than RDF	20.76	5.33	5.34 ab	2500
× 75% higher than RDF	23.69	5.23	5.33 ab	2796
CB- 14 × 25% lhigher than RDF	20.78	4.33	5.37 ab	2654
× 50% higher than RDF	21.53	4.34	5.47 a	2644
× 75% higher than RDF	24.10	4.70	5.48 a	3020
CB- 12 × 25% higher than RDF	17.53	3.99	5.47 a	2761
× 50% higher than RDF	18.92	4.31	5.51 a	2692
× 75% higher than RDF	21.16	4.30	5.51a	2859
LSD (0.05)	**NS**	**NS**	**0.18**	**NS**
CV (%)	**14.97**	**12.07**	**1.67**	**9.04**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers

4.5.2.5. Interaction effect of variety and spacing

A significant difference was found in bolls plant^{-1} due to combined effect of variety and spacing (Table 53). Result showed that bolls plant^{-1} increased gradually with increasing of plant spacing irrespective of variweties. The highest bolls plant^{-1} (24.93) found in the combined effect of CB-13 × (75× 30 cm) spacing which was significantly higher than all other variety and spacing combinations. The lowest bolls plant^{-1} (16.42) observed in CB-12× (45 × 30 cm) spacing interaction. The result is consisted with the findings of Kumara *et al.* (2014) who reported a positive response on growth and yield of *Bt* cotton hybrids with increased planting density.

There observed a significant difference in boll weight due to interaction effect of variety and spacing (Table 53). The highest boll weight (5.60g) found in the interaction of CB-12 × (75× 30 cm) spacing which was statistically similar with CB-14 × (75× 30 cm), CB-14 × (60× 30 cm) and 12 × (60× 30 cm) interaction (5.48, 5.46 and 5.51g, respectively). The lowest boll weight (5.31g) observed in the interaction of CB-13× (45 × 30 cm) spacing. The result is consisted with the findings of Jadhav *et al.* (2015) who reported that, boll weight was significantly influenced by plant geometries.

Interaction of variety and spacing exerted insignificant effect in seed cotton yield (Table 53). The higher level seed cotton yield (3221 and 3079 kg ha^{-1}) was found in CB-12 × (45 × 30 cm) and CB-14× (45 × 30 cm) spacing treatment combinations. It was found that both the three varieties gave the highest yield in (45 × 30 cm) plant spacing which followed by 60×30 cm plant spacing. These results are similar to the findings of Soomro *et al.* (2000) who found that, 23 and 30 cm plant spacings gave higher seed cotton yield.

Table 53.Interaction effect of variety and spacing on yield and yield attributes of cotton

Interaction (Variety × Spacing)	Bolls plant^{-1} (no.)	Drop out boll plant^{-1} (no.)	Individualboll weight (g)	Seed cotton yield (kg ha^{-1})
CB-13× 45 × 30 cm	20.13 ab	5.18	5.31 c	3000
× 60 × 30 cm	19.19 ab	5.24	5.31c	2505
× 75× 30 cm	24.93a	5.03	5.32 bc	2340
CB-14 × 45 × 30 cm	20.33 ab	5.37	5.37 bc	3079
× 60 × 30 cm	22.07 ab	3.92	5.46 a-c	2795
× 75× 30 cm	24.01 ab	4.08	5.48 a-c	2443
CB-12 × 45 × 30 cm	16.42 b	4.05	5.39 bc	3221
× 60 × 30 cm	18.83 ab	4.25	5.51 ab	2638
× 75 × 30 cm	22.36 ab	4.29	5.60 a	2453
LSD (0.05)	**7.42**	**NS**	**0.19**	**NS**
CV (%)	**20.22**	**30.29**	**1.61**	**18.30**

Here, NS= Not significant

4.5.2.6. Interaction effect of fertilizer and spacing

Bolls plant^{-1} varried significantly due to interaction of fertilizer levels and spacing (Table 54). The highest boll plant^{-1} (25.80) found in the interaction of 75% higher than RDF × (75× 30 cm) spacing which was statistically similar with all the interactions except 25% higher than RDF (45× 30 cm), 50% higher than RDF (45× 30 cm) and 50% higher than RDF (60 × 30 cm) spacing treatments combinations.The lowest boll plant^{-1} (17.36) observed in (45 × 30 cm) × 25% higher than RDF. Drop out boll plant^{-1} and GOT showed insignificant result due to interaction of fertilizer levels and spacing.

There observed a significant difference on boll weight due to interaction effect of spacing and fertilizer. The highest boll weight (5.49 g) found in the interaction of 50% ×(75×30 cm) higher than RDF which was statistically similar with all other interaction except 25% higher than RDF × (45×30 cm). The lowest boll weight (5.27 g) observed in 25% higher than RDF × (45 × 30 cm) treatment combination.

Interaction of fertilizer and spacing exerted significant effect in seed cotton yield (Table 54). It can be inferred from the table that irrespective of spacing seed cotton yield increases with the increases of fertilizer levels. The highest seed cotton yield (3240 kg ha^{-1} was recorded with highest dose (75% higher than RDF) with closer specings. Among the spacings closest spacing showed higher yield over other higher spacings irrespective of fertilizer doses. However, the highest seed cotton yield (3240 kg ha^{-1}) found in the interaction of (45 × 30 cm) × 75% higher than RDF combination. The lowest seed cotton yield (2282 kg ha^{-1}) found in the treatment combination of 50% higher than RDF × (75×30 cm) spacing. The findings of Kumari *et al.* (2008) supported the present result, who reported balanced fertilization and crop geometries has been proved to be kingpin in agricultural production under rain fed condition and contributed to nearly 50% of overall increase in production systems.

Table 54. Interaction effect of spacing and fertilizer on yield and yield attributes of cotton

Interaction (Fertilizer × spacing)	Bolls plant^{-1} (no.)	Drop out boll plant^{-1} (no.)	Individual boll weight (g)	Seed cotton yield (kg ha^{-1})
25% higher than RDF × 45 × 30 cm	17.36 c	4.57	5.27 b	3032 ab
× 60 × 30 cm	18.62 ba	4.42	5.38 ab	2562 bc
× 75 × 30 cm	22.14 a-c	4.21	5.45 a	2369 c
50 % higher than RDF × 45 × 30 cm	19.10 bc	5.02	5.38 ab	3028 ab
× 60 × 30 cm	18.76 bc	4.42	5.46 a	2526 bc
× 75 × 30 cm	23.36 ab	4.54	5.49 a	2282 c
75% higher than RDF × 45 × 30 cm	20.43 a-c	5.01	5.43 a	3240 a
× 60 × 30 cm	22.71 a-c	4.58	5.44 a	2851a-c
× 75 × 30 cm	25.80 a	4.64	5.46 a	2585 bc
LSD(0.05)	**5.83**	**NS**	**0.14**	**592.14**
CV (%)	**14.97**	**12.07**	**1.67**	**9.04**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers

4.5.2.7. Interaction effect of variety, spacing and fertilizer

There observed a significant difference on boll weight due to interaction effect of spacing and fertilizer. The highest boll weight (5.92g) found in the interaction of CB-14 × (75 × 30 cm) × 50% higher than RDF. The lowest boll weight (5.29g) observed in CB-13 × (45 × 30 cm) × 25% higher than RDF treatment combination. Interaction of variety, spacing and fertilizer exerted insignificant effect in seed cotton yield, boll plant^{-1}, drop out bolls plant^{-1} and Ginning out turn (Table 55).

Table 55. Interaction of variety×fertilizer×spacing on yield and yield attributes of cotton

Interaction Variety × Spacing ×Fertilizer	Bolls plant^{-1} (no.)	Drop out boll plant^{-1} (no.)	Individual boll weight (g)	Seed cotton yield (kg ha^{-1})
CB-13 × 25 % higher than RDF× (45 × 30 cm)	17.77	4.30	5.20 b	2904
× 25 % higher than RDF × (60 × 30 cm)	17.77	5.57	5.27 ab	2363
× 25% higher than RDF × (75 × 30 cm)	23.9	4.7	5.31 ab	2381
× 50 % higher than RDF× (45 × 30 cm)	20.07	5.70	5.31 ab	2942
× 50 % higher than RDF × (60 × 30 cm)	17.10	5.10	5.37 ab	2341
× 50 % higher than RDF × (75 × 30 cm)	25.1	5.20	5.35 ab	2215
× 75% higher than RDF × (45 × 30 cm)	22.57	5.53	5.41 ab	3153
× 75 % higher than RDF× (60 × 30 cm)	22.70	4.97	5.29 ab	2812
× 75 % higher than RDF× (75 × 30 cm)	25.8	5.20	5.30 ab	2423
CB-14 × 25 % higher than RDF× (45 × 30 cm)	19.5	5.50	5.27 ab	2914
× 25 % higher than RDF × (60 × 30 cm)	21.07	3.87	5.38 ab	2692
× 25% higher than RDF × (75 × 30 cm)	21.77	3.63	5.45 ab	2355
× 50 % higher than RDF× (45 × 30 cm)	20.33	5.20	5.37 ab	3067
× 50 % higher than RDF × (60 × 30 cm)	20.50	3.70	5.49 ab	2588
× 50 % higher than RDF × (75 × 30 cm)	23.77	4.13	5.92 a	2277
× 75% higher than RDF × (45 × 30 cm)	21.17	5.40	5.47ab	3258
× 75 % higher than RDF× (60 × 30 cm)	24.63	4.20	5.50 ab	3105
× 75 % higher than RDF× (75 × 30cm)	26.50	4.46	5.47 ab	2698
CB-12 × 25 % higher than RDF× (45 × 30cm)	14.80	3.93	5.32 ab	3278
× 25 % higher than RDF × (60 × 30 cm)	17.03	3.73	5.49 ab	2633
× 25% higher than RDF × (75 × 30 cm)	20.77	4.30	5.60a	2372
× 50 % higher than RDF× (45 × 30 cm)	16.90	4.16	5.45 ab	3076
× 50 % higher than RDF × (60 × 30 cm)	18.67	4.47	5.50 ab	2647
× 50 % higher than RDF × (75 × 30 cm)	21.20	4.30	5.59 a	2353
× 75% higher than RDF × (45 × 30 cm)	17.57	4.06	5.42ab	3308
× 75 % higher than RDF× (60 × 30 cm)	20.80	4.57	5.52 ab	2634
× 75 % higher than RDF× (75 × 30 cm)	25.10	4.26	5.61 a	2634
LSD(0.05)	**NS**	**NS**	**.33**	**NS**
CV (%)	**14.97**	**12.07**	**1.67**	**9.04**

Here, NS= Not significant, RDF= Recommended dose of chemical fertilizers

4. 5.3 Fibre quality attributes

4.5.3.1. Effect of variety

Fibre quality primarily affected by genotype while agronomic practices are secondary (Bednarz *et al.* 2005). On the other hand, Braden *et al*. (2009), Zeng and Meredith, Jr. (2009), Hua *et al*. (2009) and Ulloa *et al*. (2009) identified significant variation among genotypes for fibre quality.

Staple length differed significantly among cotton varieties (Table 56). Fibre length of cotton genotypes varied from 30.39 mm to 31.03mm. Variety CB-14 had the longest fibre length (31.03mm), while fibre length of CB-12 was the shortest (30.39mm). The results was consisted with the findings of Nichols *et al.* (2004) who reported that there was genotypic variation for staple length of cotton. Several researchers pointed out that staple length vary among cultivars (Bourland and Jones 2009, Smith *et al*. 2010; Long *et al*. 2010). Staple strength, uniformity ratio and micronaire value showed insignificant difference among the tested three cultivars. However, CB-14 showed numerically the highest values of fibre strength (32.25g/tex) and uniformity ratio (84.77%). On the other hand, CB-14 showed the lowest micronaire value (3.99 µg/inch)

Table 56.Effect of variety on fibre quality attributes of cotton

Variety	Staple length (mm)	Fibre strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
CB-13	30.83 b	30.91	4.29	84.57
CB-14	31.03 a	32.25	3.99	84.77
CB-12	30.39 c	31.81	4.41	84.15
LSD 0.05)	**0.0534**	**NS**	**NS**	**NS**
CV (%)	**0.18**	**-**	**-**	**-**

Here, NS= Not significant

4.5.3.1. Effect of fertilizer levels

Fertilizer doses exerted significant effect on staple length of cotton (Table 57). The highest staple length (30.98mm)) observed in 50% higher than RDF which was significantly higher than other doses. The lowest staple length (30.6mm) in 25% higher than RDF. These results are similar to those of Li *et al*. (2010) who reported that fibre length and specific fibre strength increase in N fertilization treatment over the control. This result was also in agreement with the findings of Goa.Yuan *et al* (2008) who reported potassium fertilization may improve fibre quality of long-fibre cotton. Rochester *et al*. (2001), Tewolde and Fernandez (2003), Bauer and Roof (2004) and Kumbhar *et al*. (2008) observed increase in fibre length with increased N rates. Staple strength, uniformity ratio and micronaire value showed insignificant difference among the treatment.

Table 57. Effect of fertilizer levels on fibre quality attributes of cotton

Fertilizer levels	Staple length (mm)	Fibre strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
25% higher than RDF	30.60 c	31.91	4.26	84.38
50% higher than RDF	30.98 a	31.58	4.22	84.72
75% higher than RDF	30.66 b	31.49	4.21	84.38
LSD(0.05)	**0.030**	**NS**	**NS**	**NS**
CV (%)	**0.18**	**-**	**-**	**-**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers

4.5.3.3 Effect of spacing

Plant spacing exerted significant effect on staple length of cotton (Table 58). The highest staple length (30.90 mm)) observed in 60×30 cm spacing which was statistically higher than other spacings. The lowest staple length (30.64 mm) was found in (75 × 30 cm) spacing treatment. These results are similar to those as observed the decreased fiber length in response to increased plant population (Bednarz *et al*. 2000, Larson *et al*. 2004, Bednarz *et al*. 2006 and Darawsheh *et al*. 2009. Staple strength, uniformity ratio and micronaire value showed insignificant difference due to spacing treatments.However numerically, the highest fibre strength (31.99 g/tex), micronaire value (4.25 µg/inch) and uniformity ratio (84.67%) was recorded with 60 × 30 cm spacing treatment.

Table 58. Effect of spacing on fibre quality attributes of cotton

Spacing	Staple length (mm)	Fibre strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
45 × 30 cm	30.70 b	31.30	4.15	84.49
60 × 30cm	30.90 a	31.99	4.25	84.67
75 × 30 cm	30.64 c	31.73	4.21	84.38
LSD(0.05)	**0.04**	**NS**	**NS**	**NS**
CV (%)	**0.18**	**-**	**-**	**-**

Here, NS= Not significant

4.5.3.4. Interaction effect of variety and fertilizer

There observed a significant difference in staple length due to combined effect of variety and fertilizer of cotton (Table 59). Significantly the highest staple length (31.42 mm) was observed in CB-14 × 50% higher than RDF combination which was significantly higher than other treatment combinations. Combined effect of CB-12 × 75% higher than RDF showed the lowest staple length (30.19mm). Staple streangth, uniformity ratio and micronaire value showed insignificant difference among the treatment combinations of variety and fertilizer levels.

Table 59. Interaction effect of variety and fertilizer on lint attributes of cotton

Interaction (Variety × Fertilizer)	Staple length (mm)	Fibre strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
CB- 13 × 25% higher than RDF	30.49 e	31.34	4.36	84.24
× 50% higher than RDF	31.05 b	30.56	4.29	84.77
× 75% higher than RDF	30.96 c	30.83	4.22	84.70
CB- 14 × 25% lhigher than RDF	30.83 d	32.67	4.03	84.7
× 50% higher than RDF	31.42 a	32.06	3.94	85.09
× 75% higher than RDF	30.85 d	32.03	4.01	84.53
CB- 12 × 25% higher than RDF	30.48 e	31.70	4.39	84.21
× 50% higher than RDF	30.49 e	32.11	4.44	84.32
× 75% higher than RDF	30.19 f	31.62	4.4	83.92
LSD (0.05)	**0.1043**	**NS**	**NS**	**NS**
CV (%)	**0.18**	**-**	**-**	**-**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers

4.5.3.5. Interaction effect of variety and spacing

There observed a significant difference in staple length due to combined effect of variety and spacing in cotton (Table 60). The significantly highest staple length (31.37mm) observed in CB-14 and (60 × 30 cm) combined effect which was statistically higher than all other treatments combinations. On the other hand, combined effect of CB-12 × (75 × 30 cm) spacing showed the lowest staple length (30.25 mm). Other quality attributes like staple strength, uniformity ratio and micronaire varied insignificantly due to interaction of variety and spacing. Similar tesult was observed by Nicholas *et al*. (2004) and Clawson *et al*. (2006), who found little impact of various row spacing on fibre quality.

Table 60. Interaction effect of spacing and variety on Lint characteristics of cotton

Interaction (Variety × Spacing)	Staple length (mm)	Fibre strength (g/tex)	Micronaire value (μg/inch	Uniformity ratio (%)
CB-13× 45 × 30 cm	30.90 c	30.24	4.22	84.66
× 60 × 30 cm	30.940c	31.86	4.31	84.68
× 75× 30 cm	30.65d	30.64	4.34	84.37
CB-14 × 45 × 30 cm	30.69 d	31.42	3.95	84.42
× 60 × 30 cm	31.37 a	32.84	4.11	85.07
× 75× 30 cm	31.03 b	32.5	3.92	84.82
CB-12 × 45 × 30 cm	30.50 e	32.09	4.52	84.22
× 60 × 30 cm	30.41 e	31.28	4.34	84.25
× 75 × 30 cm	30.25 f	32.07	4.37	83.97
LSD (0.05)	**0.1118**	**NS**	**NS**	**NS**
CV (%)	**0.18**	**-**	**-**	**-**

Here, NS= Not significant

4.5.3.6. Interaction effect of fertilizer level × spacing

There observed a significant difference in staple length due to combined effect of spacing and fertilizer (Table 61). Significantly the highest staple length (31.29 mm) observed in (60 × 30 cm) spacing × 50% higher than RDF treatment combination which was statistically higher than all other treatments combination. Combined effect of (75 × 30 cm) spacing × 25% higher than RDF showed the lowest staple length (30.47 mm) Other quality attributes like staple strength, uniformity ratio and micronaire varied insignificantly due to interaction of spacing and fertilizer. The results is consisted with the findings of Clawson *et al*. (2006) who found little impact of various row spacing on fibre quality.

Table 61. Interaction effect of fertilizer and spacing on lint attributes of cotton

Interaction (Fertilizer × spacing)	Staple length (mm)	Fibre strength (g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)
25 % higher than RDF× 45 × 30 cm	30.52 f	31.02	4.27	84.23
25 % higher than RDF ×60 × 30 cm	30.82 c	32.68	4.22	84.62
25% higher than RDF× 75 × 30 cm	30.47 f	32.01	4.29	84.30
50 % higher than RDF× 45 × 30 cm	31.04 b	31.30	4.18	84.74
50 % higher than RDF ×60 × 30 cm	31.29 a	31.59	4.27	85.04
50 % higher than RDF × 75 × 30 cm	30.64 d	31.83	4.21	84.38
75% higher than RDF × 45 × 30 cm	30.54 ef	31.42	4.24	84.33
75 % higher than RDF ×60 × 30 cm	30.62 de	31.70	4.27	84.34
75 % higher than RDF × 75 × 30 cm	30.84 c	31.35	4.11	84.47
LSD(0.05)	**0.09**	**NS**	**NS**	**NS**
CV (%)	**0.18**	**-**	**-**	**-**

Here, NS= Not significant
RDF= Recommended dose of chemical fertilizers

4.5.3.7. Interaction effect of variety × spacing × fertilizer level

There observed a significant difference in staple length due to combined effect of variety × spacing ×fertilizer (Table 62). The significantly highest staple length (31.64 mm) was observed in CB-14× (60 × 30 cm) × 50% higher than RDF treatment combination which was statistically at par with that of CB-13 × (75 × 30 cm) × 75% higherthan RDF (31.52 mm). Combined effect of CB-13 × (75 × 30 cm) × 25% lhigher than RDF treatment showed the lowest staple length (29.94 mm). The results is consisted with the findings of Bauer and Roof (2004) and Kumbhar *et al*. (2008) who observed increase in fibre length with increased N rates. Staple strength, uniformity ratio and micronaire value showed insignificant difference among the treatment combinations (Table 62).

Table 62 .Interaction effect of variety× fertilizer × spacing level on fibre quality attributes of cotton

Interaction Variety × Spacing ×Fertilizer	Staple length (mm)	Fibre strength (g/tex)	Micronaire value (μg/inch)	Uniformity ratio (%)
CB-13 × 25 % higher than RDF× (45 × 30 cm)	30.15 k-m	29.49	4.53	83.91
× 25 % higher than RDF × (60 × 30 cm)	31.39 b-d	33.85	4.14	85.06
× 25% higher than RDF × (75 × 30 cm)	29.94 n	30.69	4.41	83.77
× 50 % higher than RDF× (45 × 30 cm)	31.42 bc	30.47	3.98	85.07
× 50 % higher than RDF × (60 × 30 cm)	31.21 d-f	29.96	4.52	85.00
× 50 % higher than RDF × (75 × 30 cm)	30.51 i	31.26	4.38	84.23
× 75% higher than RDF × (45 × 30 cm)	31.14 e-g	30.75	4.16	85.00
× 75 % higher than RDF× (60 × 30 cm)	30.22 j-l	31.77	4.28	83.98
× 75 % higher than RDF× (75 × 30 cm)	31.52 ab	29.96	4.23	85.12
CB-14 × 25 % higher than RDF× (45 × 30 cm)	30.41 ij	31.59	3.87	84.12
× 25 % higher than RDF × (60 × 30 cm)	31.06 fg	33.41	4.12	85.00
× 25% higher than RDF × (75 × 30 cm)	31.02 fg	33.02	4.11	84.98
× 50 % higher than RDF× (45 × 30 cm)	31.30 c-e	30.83	3.95	85.05
× 50 % higher than RDF × (60 × 30 cm)	31.64 a	33.06	3.99	85.15
× 50 % higher than RDF × (75 × 30 cm)	31.33 b-e	32.29	3.87	85.06
× 75% higher than RDF × (45 × 30 cm)	30.38 ij	31.84	4.04	84.10
× 75 % higher than RDF× (60 × 30 cm)	31.42 bc	32.06	4.21	85.07
× 75 % higher than RDF× (75 × 30cm)	30.75 h	32.19	3.77	84.42
CB-12 × 25 % higher than RDF× (45 × 30cm)	31.00 g	31.97	4.42	84.65
× 25 % higher than RDF × (60 × 30 cm)	30 .00 mn	30.8	4.40	83.80
× 25% higher than RDF × (75 × 30 cm)	30.44 i	32.34	4.35	84.17
× 50 % higher than RDF× (45 × 30 cm)	30.40 ij	32.61	4.61	84.11
× 50 % higher than RDF × (60 × 30 cm)	31.02 fg	31.77	4.30	84.98
× 50 % higher than RDF × (75 × 30 cm)	30.07 l-n	31.96	4.40	83.87
× 75% higher than RDF × (45 × 30 cm)	30.1 k-n	31.68	4.52	83.89
× 75 % higher than RDF× (60 × 30 cm)	30.22 j-l	31.28	4.33	83.98
× 75 % higher than RDF× (75 × 30 cm)	30.09 jk	31.91	4.35	83.88
LSD(0.05)	**0.20**	**NS**	**NS**	**NS**
CV (%)	**0.18**	**-**	**-**	**-**

Here, NS= Not significant, RDF= Recommended dose of chemical fertilizers

4.5.4. Economic analysis

Economic analysis have been done with a view to observing the comparative cost and benefit under different treatment combinations of variety, fertilizer and plant spacing. For this purpose, the inputs cost for land preparation, cotton seed, manure and fertilizer, pesticide, intercultural operation, harvesting and post harvesting cost and manpower required for all the operations including seed cotton were recorded against each treatment, which were then enumerated into cost per hectare.

The total cost of production ranged between 73254 – 76590 Tk ha^{-1}. The cultivation cost increased with decreasing plant spacing and increasing fertilizer dose. The highest cost of production involved when used 75% higher than RDF× (75×30 cm) treatments combination (76590 Tk ha^{-1}) for all the three varieties. The lowest cost of production involved when used 25% higher than RDF × (45×30 cm spacing) treatments combination (73254 Tk ha^{-1}). The highest gross return (198480 Tk ha^{-1}) was found when used CB-12 × 75% higher than RDF × (45 × 30 cm) treatment combination. The lowest gross return was found (132900 Tk ha^{-1}) when used CB-13 × 50% higher than RDF× (75 × 30 cm) treatment combination. The highest gross margin was found when used CB-12 × 25% higher than RDF×(45 × 30 cm) treatment combination (123426Tk ha^{-1}). The lowest gross margin (57078Tk ha^{-1}) was found when used CB-13 ×50% higher than RDF × (75 × 30 cm) treatment combination. Maximum benefit cost ratio (2.68) involved when used CB-12 × 25% higher than RDF× (45 × 30 cm) treatment combination. The minimum benefit cost ratio (1.75) was calculated when used CB-13 × 50% higher than RDF× (75 × 30 cm) treatment combination. Its was observed that all the variety gave higher yield, higher gross return and higher BCR in 75% higher than RDF and (45 × 30 cm) spacing treatment combination. For economic point of view, results indicate that 75% higher than RDF and (45 × 30 cm) spacing treatment combination is more profitable for all the three varieties.

Table 63. Economic analysis in cotton production as influenced by cotton variety, fertilizer levels and spacing

Interaction Variety × Spacing ×Fertilizer	Seed cotton yield (kg ha^{-1})	Gross return (Tkha^{-1})	Total variable cost (Tkha^{-1})	Gross margin (Tkha^{-1})	BCR
CB-13 × 25 % higher than RDF × (45 × 30 cm)	2904	174240	73254	100986	2.37
× 25 % higher than RDF× (60 × 30 cm)	2363	141780	73654	68126	1.92
× 25% higher than RDF× (75 × 30 cm)	2381	142860	73654	69206	1.93
× 50 % higher than RDF× (45 × 30 cm)	2942	176520	74822	101698	2.35
× 50 % higher than RDF× (60 × 30 cm)	2341	140460	75322	65138	1.86
× 50 % higher than RDF × (75 × 30 cm)	2215	132900	75822	57078	1.75
× 75% higher than RDF × (45 × 30 cm)	3153	189180	76390	112790	2.47
× 75 % higher than RDF× (60 × 30 cm)	2812	168720	76490	92130	2.20
× 75 % higher than RDF × (75 × 30 cm)	2423	145380	76590	68890	1.90
CB-14 × 25 % higher than RDF× (45 × 30 cm)	2914	174840	73254	101586	2.38
× 25 % higher than RDF× (60 × 30 cm)	2692	161520	73654	87866	2.19
× 25% higher than RDF× (75 × 30 cm)	2355	141300	73654	67646	1.91
× 50 % higher than RDF× (45 × 30 cm)	3067	184020	74822	109198	2.45
× 50 % higher than RDF × (60 × 30 cm)	2588	155280	75322	79958	2.06
× 50 % higher than RDF× (75 × 30 cm)	2277	136620	75822	60798	1.80
× 75% higher than RDF× (45 × 30 cm)	3258	195480	76390	119090	2.55
× 75 % higher than RDF× (60 × 30 cm)	3105	186300	76490	109710	2.43
× 75 % higher than RDF × (75 × 30 cm)	2698	161880	76590	85390	2.11
CB-12× 25 % higher than RDF× (45 × 30 cm)	3278	196680	73254	123426	2.68
× 25 % higher than RDF × (60 × 30 cm)	2633	157980	73654	84326	2.14
× 25% higher than RDF× (75 × 30 cm)	2372	142320	73654	68666	1.93
× 50 % higher than RDF× (45 × 30 cm)	3076	184560	74822	109738	2.46
× 50 % higher than RDF × (60 × 30 cm)	2647	158820	75322	83498	2.10
× 50 % higher than RDF× (75 × 30 cm)	2353	141180	75822	65358	1.86
× 75% higher than RDF× (45 × 30 cm)	3308	198480	76390	122090	2.59
× 75 % higher than RDF × (60 × 30 cm)	2634	158040	76590	81450	2.06
× 75 % higher than RDF× (75 × 30 cm)	2634	158040	76490	81550	2.06

Note: RDF= Recommended dose of chemical fertilizers
Urea = 22 Tk kg^{-1} , MoP = 17 Tk kg^{-1}, Gypsum =12 Tk kg^{-1}, Zink sulphate = 210 Tk kg^{-1}
Borax =214 Tk kg^{-1}, Mac sulpher = 67 Tk kg^{-1}, Ektara = 9300 Tk kg^{-1},
Volume flexy = 5725 Tk kg^{-1} , Cupravit = 2200 Tk kg^{-1}, wage rate = 400 Tk man day
Cotton Seed =24 Tk kg^{-1}, Seed Cotton = 60 Tk kg^{-1}

Chapter 5

Summary and Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The research study comprising of five experiments carried out at Cotton Research Training and Seed Multiplication Farm, Sreepur, Gazipur during the periods of July 2015 to February, 2016, July 2016 to February, 2017 and July 2017 to February, 2018, with a view to investigate the performance of different levels of fertilizer and plant spacing, on newly released inbred varieties of cotton in respect of phenology, plant characters, yield components, yield and lint quality attributes. The experimental site was located in the centre of Madhupur Tract (AEZ-4 which is 24.09 ^{0}N latitude and 90.26 ^{0} E longitude) with an elevation of 8.4 meter above the sea level. The soil of the experimental site belongs to the Salna series and has been classified as Shallow Red-Brown Terrace type which falls under the order Inceptisols of soil taxonomy (Brammer, 1980; FAO, 1988).

The first experiment was conducted by employing a split-plot design with three replications to investigate the effect of 6 levels of fertilizers viz; {$T_{1=}$ 00 : 00 : 00 : 00 kg NPKS ha^{-1} (Control), T_2 = 90 : 34 : 98 : 20 kg NPKS ha^{-1} (25% less than recommended dose), T_3 = 120 : 45 : 131 : 27 kg NPKS ha^{-1} (Recommended dose of fertilizer), T_4 = 150 : 56 : 164 : 34 kg NPKS ha^{-1} (25% higher than RDF), $T_{5\,=}$ 180 : 67: 196 : 40 kg NPKS ha^{-1} (50% higher than RDF), T_6 = 210 : 78 : 229 :46 kg NPKS ha^{-1} (75% higher than RDF)} on 3 cotton varieties i.e. (V_1 = CB-13, V_2 = CB-14, and V_3 = CB-12) by assigning variety in main plot and fertilizer laid in sub-plot. The result revealed that among the tested three varieties highest days to squiring (55.89 days), first boll splitting (118.33 days) and node number of first fruiting branch (6.06) was found in CB-13 and that of lowest was in CB-12 and CB-14, respectively. The tallest plant (109.00 cm) was found in CB-14, on the other hand, CB-12 produced the maximum monopodial and sympodial branches per plant (1.41 and 11.36, respectively).The maximum bolls per plant (17.94), boll weight (4.33g), seed cotton yield (1938 kg ha^{-1}), lint yield (946 kg ha^{-1}), was recorded in CB-14 variety and this variety showed intermediate level of ginning out turn. Highest ginning out turn (41.30%) was observed with CB-12 variety. In case of lint characters, maximum fibre length (28.67 mm) and strength (28.45 g/tex) recorded in CB-14 and minimum staple length (27.98 mm) and staple strength (28.22 g/tex) was recorded in CB-13 variety. Maximum micronaire value (5.06 µg/inch) recorded in CB-12 and the minimum micronaire value (4.66 µg/inch) recorded in CB-14 variety. Highest uniformity ratio (81.37%) recorded in CB-14 variety and minimum uniformity ratio (80.92) recorded in CB-12 variety.

Among the six fertilizer level treatments, increasing the levels of fertilizer increase most of the parameters. Increasing of fertilizer rates shorter the node number of first fruiting branch (NFB) (5.91), days to 1st flowering (64.77), days to 1st boll opening (114.67) of plant which indicates that higher fertilizer rate promotes plant maturity. The tallest plant (126.05cm), maximum monopodial branch plant^{-1} (1.85) and sympodial branch plant^{-1} **(**13.88**)** was recorded with 75% higher than RDF (the highest dose of fertilizer). Maximum number of bolls plant^{-1} (21.81), boll weight (4.67g), seed cotton yield (2448 kg ha^{-1}), lint yield (990 kg ha^{-1}), staple length (28.81mm), minimum micronaire value (4.69 µg/inch) was recorded in 75% higher than RDF. But 50% higher than RDF also showed similar performance on yield and yield attribute parameters. Maximum ginning out turn (41.4%), fibre strength (28.40 g/tex) uniformity ratio (81.90%) was recorded in 50 % higher than RDF. Again, 75% higher than RDF treatment also showed better performance in respect of quality parameters.

The combined effect of different varieties and fertilizer levels on all the studied parameters such as phenological, plant characters, yield attributes and yield, and lint characters in the experiment were significant except ginning out turn and uniformity ratio (%). The highest seed cotton yield (2676 kg ha^{-1}) and lint yield (1102 kg ha^{-1}) obtained in CB-14 × 75% higher than RDF treatment combination. The significantly highest staple length (29.46 cm), the higher level of fibre strength (28.64 g/tex) and lower micronaire value (4.23g/inch) was observed in CB-14 × 75% higher than RDF interaction. Similar to CB-14 × 75% higher than RDF interaction, CB-14 × 50% higher than RDF interaction also showed the higher level of quality performance. Combined effect of CB-13 × control fertilizer showed the lowest staple length (26.96cm).

The total cost of production ranged 52500 - 76390 Tk ha^{-1}. The highest cost of production involved when used 75% higher than RDF dose with all the three varieties (76390 Tk ha^{-1}). The lowest cost of production was involved when used no fertilizer and both the varieties (52500 Tk ha^{-1}). The highest gross return and gross margin were found with the combination of CB-14 × 75 % higher than RDF dose (160560 and 84170 Tk ha^{-1}, respectively). Maximum benefit cost ratio (BCR) was recorded with CB-14 × 75 % higher than RDF dose combination (2.10). Again, CB-14 × 50 % higher than RDF dose interaction showed second highest gross return (154500 Tk ha^{-1}), gross margin (79678 Tk ha^{-1}) and BCR (2.06). Minimum benefit cost ratio found when used CB-12 variety and no fertilizer treatment combination (0.47). For economic point of view, results indicate that CB-14 inbred variety with 75 % and 50% higher than RDF level were more profitable than the other treatment combinations.

The second experiment was conducted with a view to observe the effect of spacing on cotton varieties. This was a two factors experiment where varieties were same as experiment varieties viz: V_1 = CB-13, V_2 = CB-14, and V_3 = CB-12 and eight row spacings viz T_1 = (45 × 30 cm) ; T_2 = (45 × 45 cm) ; T_3 = (60 × 30 cm) ; T_4 = (60 × 45 cm) ; T_5 = (75 × 30 cm) ; T_6 = (75 × 45 cm) ; T_7 = (90 × 30 cm) ; T_8 =. (90 × 45 cm) was used using randomized completely block design (factorial) with three replications. Experimental location and cultivation techniques were same as experiment no 1. Considering the tested varieties CB-13 showed the shortest time (54.08 days) from planting to squaring and genotype CB-12 required the longest time (56.75 days) from planting to squaring. The tallest plant (130.68cm), the highest sympodial branch $plant^{-1}$ (16.13) and the highest monopodial branches $plant^{-1}$ (0.8417) observed in variety CB-13. On the other hand the shortest plant (125.38cm) and lowest sympodial branch $plant^{-1}$ (15.48) and the lowest vegetative branch $plant^{-1}$ (0.76) observed in CB-12 variety. Maximum bolls $plant^{-1}$ (22.69), boll weight (4.81g), seed cotton yield (2713 kg ha^{-1}), lint yield (1099 kg ha^{-1}) was recorded in genotype CB-14. However, minimum bolls $plant^{-1}$ (19.88), boll weight (4.73), seed cotton yield (2354 kg ha^{-1}) and lint yield (965 kg ha^{-1}) recorded in genotype CB-13. Genotype CB-13 obtained the highest ginning out turn (41.03%). In case of quality parameters, maximum fibre length (28.82 mm), fibre strength (28.43 g/tex) and uniformity ratio (81.92%) was recorded in CB-12 and on the other maximum micronaire value (4.92 µg/inch) and minimum uniformity ratio (81.78) was observed in CB-14 variety. Minimum staple length (28.66 mm) and staple strength (28.41g/tex) were recorded in CB-13 variety. Number of days to 1^{st} flowering, 1^{st} boll opening did not significantly affected by plant spacing. But node number of first fruiting branch significantly affected by plant spacing. The tallest plant (131.10 cm) was found with

45 × 45cm spacing treatment, but, maximum monopodial branches plant^{-1}(1.11) and sympodial branches plant-^{1} **(**16.12**)** and bolls plant^{-1}(25.90) was recorded in (90 × 45 cm) plant spacing. But maximum boll weight (4.98), seed cotton yield (3120 kg ha^{-1}) and lint yield (1246 kg ha^{-1}) was recorded in (75 × 30 cm) plant spacing. On the other hand, 60 × 30 cm) plant spacing showed similar result with 75 × 30 cm) plant spacing. Maximum staple length (29.28mm), fibre strength (28.49g/tex), minimum micronaire value (4.66µg/inch) and maximum uniformity ratio (82.26%) recorded in (90 × 45 cm) plant spacing. The highest single boll weight (5.17 g), seed cotton yield (3609 kg ha^{-1}) and lint yield (14242 kgha^{-1}) was obtained in the treatment combination of CB-14× (75 × 45 cm) spacing. Again, 75 × 45 cm spacing with CB-13 variety also gave higher yield and yield attributes. Cosidering quality parameters, the highest staple length (30.02 mm) and the maximum staple strength (28.68 gm/tex) and maximum uniformity ratio (82.54%) was observed in CB-13 × (90 × 45 cm) spacing combination effect but statistically at par with that of CB-12 × (90 × 45 cm) spacing interaction. The significantly highest micronaire value (5.56 µg/inch) observed in CB-14 × (90 × 45 cm) spacing combination. The lowest micronaire value (4.20 µg/inch) was observed in CB-12 × (90 × 45 cm) spacing treatment combination. The highest cost of production (74550 Tk ha^{-1}) involved when used (45 × 30 cm) spacing and that of the lowest (71681Tk ha^{-1}) was with 90 × 45 cm plant spacing. The highest gross return (216540Tk ha^{-1}) was found when used CB-14 × (75 × 45 cm) plant spacing treatment combination. The lowest gross return (105000 Tk ha^{-1}) was found when used CB-14 × (90 × 45 cm) spacing treatment combination. The highest gross margin (143540 Tk ha^{-1}) was found when used CB-14 × (75 × 30 cm) spacing treatment combination. The lowest gross margin (32860 Tk ha^{-1}) was found when used CB-12 × (75 × 45 cm) spacing treatment combination. The maximum benefit cost ratio (BCR) involved when used CB-14 × (75 × 30 cm) spacing treatment combination (2.96). The minimum benefit cost ratio was found when used CB-12 × (75 × 45 cm) spacing treatment combination (1.45). Plant spacing (75 × 30 cm) gave the highest gross return, the highest gross margin and the highest benefit cost for all the three varieties. For economic point of view, results indicate that plant spacing (75 × 30 cm) was more profitable for all the three varieties.

The third experiment was conducted to investigate the effect of fertilizer level on cotton varieties. This was the follow up trial of the first experiment, where varieties were same as first experiment and the fertilizer levels were taken on the basis of the result of the first experiment. This was a two factors experiment, where factor A: variety-3, viz. V_1 = CB-13, V_2 = CB-14 and V_1 = CB-12 and factor B: fertilizer level-6, viz. T_1 = 120: 45: 131: 27 kg NPKS ha^{-1} (Recommended dose of fertilizer); T_2 = 150: 56: 164: 34 kg NPKS ha^{-1} (25% higher than RDF); T_3 = 180: 67: 196: 40 kg NPKS ha^{-1} (50% higher than RDF); T_4 = 210: 78: 229: 46 kg NPKS ha^{-1} (75% higher than RDF); T_5 = 240: 90: 162: 92 kg NPKS ha^{-1} (100% higher than RDF); T_6 = 270: 101: 294: 60 kg NPKS ha^{-1} (125% higher than RDF) were tested following split- plot design with three replications by assigning variety in main plot and fertilizer in sub-plot.

Considering the varieties, CB-12 required the shortest time (122.33days) from planting to boll splitting and genotype CB-14 required the longest time (126.61days) from planting to boll splitting. The tallest plant (124.10 cm) and the highest monopodial branches per plant (0.82) were observed in variety CB-13. On the other hand the shortest plant (105.60cm), the lowest monopodial branches $plant^{-1}$ (0.56) and the lowest sympodial branches $plant^{-1}$ (15.23) were observed in CB-12 variety. CB-14 variety produced the highest number of sympodial branches $plant^{-1}$(16.32). Maximum bolls $plant^{-1}$ (20.45), boll weight 5.24 g) and seed cotton yield (2436 kg ha^{-1}) recorded in genotype CB-14. However, minimum bolls $plant^{-1}$ (19.26), boll weight (5.07g) and seed cotton yield (2127 kg ha^{-1}) recorded in genotype CB-13. Maximum fibre length (28.96 mm) and strength (28.74 g/tex) was recorded in CB-14 and minimum staple length (28.25 mm) and staple strength (28.50 g/tex) were recorded in CB-13 variety. Maximum microniare value (5.01µg/inch) was recorded in CB-12 and the minimum microniare value (4.61µg/inch) recorded in CB-14 variety. Maximum uniformity ratio (82.18%) was recorded in CB-14 variety and minimum uniformity ratio (81.72%) recorded in CB-12 variety.

The result relevant that increasing the levels of fertilizer increase most of the parameters. The tallest plant (128.61cm), highest monopodial branches $plant^{-1}$(.91) and sympodial branches $plant^{-1}$ **(**17.10**)** were recorded in the highest dose of fertilizer. The shortest plant (68.09 cm), the lowest monopodial branches $plant^{-1}$ (0.50) and the lowest sympodial branches $plant^{-1}$ **(**13.93) observed in recommended fertilizer dose. Maximum number of bolls $plant^{-1}$ (21.53), boll weight (5.41 g), seed cotton yield (2728 kg ha^{-1}), staple length (29.09 mm), fibre strength (28.71g/tex) and minimum micronaire value (4.64 µg/inch) were recorded in 75% higher than

RDF. Again, 50% and 100% higher than RDF also showed higher level of yield attributes, yield and better quality fibre in cotton. Maximum uniformity ratio (82.72 %) recorded in 50% higher than RDF. On the other hand, yield and fibre quality decrease with excessive higher fertilizer doses.

The combined effect of different variety and fertilizer level on all the studies parameters such as phenological, plant characters, yield and yield attributes, and lint characters in the experiment were significant except ginning out turn and uniformity ratio (%). The highest seed cotton yield (3031 kg ha^{-1}) obtained in the treatment combination of CB-14 × 75% higher than RDF treatment.

A significant differences observed in staple length, staple streanth and micronaire value among cotton genotypes and fertilizer doses. The significantly highest staple length (29.75mm), the highest level of fibre strength (28.92 g/tex) and minimum micronaire value (4.16 µg/inch) were observed in CB-14 × 75% higher than RDF combination. On the other hand, interaction of CB-14 × 100% higher than RDF, CB-14 × 50% higher than RDF and CB-14 × 25% higher than RDF showed similar result with CB-14 × 75% higher than RDF combination. Combined effect of CB-13 and 125% higher than RDF showed the lowest staple length (27.22 mm). Irrespective of varieties, 125% higher than RDF lowest level of fibre strength.

The total cost of production ranged 71686 - 79526 Tk ha^{-1}. Cultivation cost increased with increasing fertilizer dose. The highest cost of production involved when used any variety with 125 % higher than RDF dose (79526 Tk ha^{-1}). The lowest cost of production involved when used any variety with RDF fertilizer (71686 Tk ha^{-1}). The highest gross return (181860 Tk ha^{-1}) found when used CB-14 × 75% higher than RDF dose combination and that of lowest (87960 Tk ha^{-1}) recoded with CB-12 × RDF fertilizer treatment combination. The highest gross margin (105470 Tk ha^{-1}) was found with CB-14 ×75% higher than RDF dose treatment combination. The lowest gross margin (16274 Tk ha^{-1}) was found with CB-12 × RDF treatment combination. The maximum BCR (2.38) was involved when used CB-14 × 75 % higher than RDF dose treatment combination, but combinations of CB-12 × 75% higher than RDF and CB-14 × 100% higher than RDF also showed higher BCR (2.18 and 2.11%, respectively) and that of minimum (1.22) was found with CB-12 × RDF treatment combination .For economic point of view, results indicate that both the three inbred varieties with 75% higher than RDF level was more profitable than the other treatment combinations.

In fourth experiment, treatments were arranged in RCBD (factorial) design to evaluate the effect of eight row spacing's viz T_1 = (45 × 30 cm) ; T_2 = (45 × 40 cm) ; T_3 = (60 × 30 cm) ; T_4 = (60 × 40 cm) ; T_5 = (75 × 30 cm) ; T_6 = (75 × 40 cm) ; T_7 = (90 × 30 cm) ; T_8 =. (90 × 40 cm with 3 cotton varieties, viz. V_1 = CB-13, V_2 = CB-14 and V_3 = CB-12. In this experiment, spacings were selected on basis of the results of the experiment two and other managements were as experiment two.

Considering varieties CB-12 required the shortest time from planting to flowering (57.16 days) and boll splitting (119.35 days). Variety CB-14 required the longest time from planting to flowering (58.83 days) and boll splitting (125.36days). The tallest plant (123.24 cm), maximum sympodial branches plant^{-1} (15.34) and minimum monopodial branches plant^{-1} (0.53) observed in variety CB-14.On the other hand the shortest plant (115.50 cm) and minimum sympodial branch plant^{-1} (14.25) and minimum monopodial branches plant^{-1} (0.42) was observed in CB-13 variety.Maxium bolls plant^{-1} (26.46), boll weight (5.57g) and seed cotton yield (3051 kg ha^{-1}) was recorded in variety CB-14.However,minimum bolls plant^{1} (20.22), boll weight (5.03g) and seed cotton yield (2656kg ha^{-1}) was recorded in genotype CB-13. In case of lint characters, maximum fibre length (29.11mm), maximum fibre strength (29.38 g/tex) and minimum micromere value (4.70 µg/inch) recorded in CB-12 variety. Higher level of staple length (29.09 mm), minimum fibre strength (28.37 g/tex), maximum micronaire value (4.87 µg/inch) and minimum uniformity ratio (82.60%) was observed in CB-14 variety. Minimum staple length (28.95 mm) and moderate staple strength (28.69 g/tex) was recorded in CB-13 variety.

Considering plant spacing, increasing of plant spacing at (90 × 40 cm) shorter days to 1st flowering (57.77), days to 1st boll opening (122.49) of plant which indicates that wider spacing promotes plant maturity. The tallest plant (125.54 cm) and higher sympodial branch plant^{-1} **(**15.04) was recorded in (75 × 30 cm) plant spacing. Maximum number of bolls plant^{-1} (28.76) and maximum boll weight (5.38) recorded in (90 × 40 cm) plant spacing. But maximum seed cotton yield (3414 kg ha^{-1}) recorded in (60 × 30 cm) plant spacing which was identical with (75 × 30 cm) plant spacing. Maximum staple length (29.57mm), fibre strength

(28.77 g/tex), maximum uniformity ratio (83.08 %) and minimum micronaire value (4.61µg/inch) recorded in (90 × 40 cm) plant spacing. On the other hand, (75 × 30 cm) spacing was also better in respect of quality aspects.

In case of interaction of variety and plant spacing, all the studies parameters such as phenological, growth, yield and yield attributes, and lint characters in the experiment were significant except monopodial branches plant^{-1}, sympodial branch plant^{-1} and ginning out turn. The highest seed cotton yield (3597 kg ha^{-1}) obtained in the treatment combination of CB-14 × (75 × 30 cm) spacing, at the same time (75 × 30 cm) spacing showed better yield with other two varieties. The highest staple length (30.32 mm) and staple strength (28.97 gm/tex), uniformity ratio (83.37%) and the lowest micronaire value (4.16 µg/inch) observed in CB-13 × (90 × 40cm) interaction which was statistically at par with that of C-12 × (90 × 40 cm) interaction. The significantly highest micronaire value (5.50µg/inch) observed in CB-14 × (90 × 40cm) interaction. Interaction of CB-14 × (90 × 40 cm) also showed better in lint quality perospective.

The total cost of production ranged 71681 - 74550 Tk ha^{-1}. The cultivation cost increased with decreasing plant spacing. The highest cost of production (74550 Tk ha^{-1}) was calculated with (45 × 30cm) spacing. The lowest cost of production (71686 Tk ha^{-1}) was calculated with (90 × 40 cm) plant spacing The highest gross return (215820 Tk ha^{-1}) found when used CB-14 × (75 × 30cm plant spacing treatment combination and that of lowest (118200 Tk ha^{-1}) was found with CB-13 × (90 × 45cm) spacing treatment combination. The highest gross margin (142820 Tk ha^{-1}) was found with CB-14 × (75 × 30cm) spacing treatment combination and that of lowest (46514 Tk ha^{-1}) was found with CB-13 × (90 × 40 cm) spacing treatment combination. Maximum benefit cost ratio (2.95) involved with CB-14 × (75 × 30 cm) spacing treatment combination. Minimum benefit cost ratio (1.64) was found when used CB-13 × (90 × 40 cm) spacing treatment combination. Plant spacing (75 × 30 cm) gave the highest gross return, the highest gross margin and the highest benefit cost ratio with all the three varieties. For economic point of view, results indicate that plant spacing (75 × 30 cm) was more profitable among the three tested varieties.

The fifth and final experiment was conducted to find out the effect of fertilizer levels and plant spacings of newly released cotton varieties. In this experiment same varieties as previous experiments were used, but fertilizer and spacing treatments were selected from experiment 3 and 4 on the basis of their performances. Thus the three factors were, Factor A: Cotton varieties-3 viz. i) V_1 = CB-13, ii) V_2 = CB-14 and iii) V_3 = CB-12; Factor B: plant spacings-3 viz. i) T_1 = (45 × 30 cm); ii) T_2 = (60 × 30 cm) and iii) T_3 = (75 × 30 cm) and Factor C: Fertilizer levels- 3 viz. i) F_1 = 150: 56 :164: 34 kg NPKS ha^{-1} (25% higher than RDF); ii) F_2 = 180: 67: 196: 40 kg NPKS ha^{-1} (50% higher than RDF) and iii) F_3 = 210: 78: 229: 46 kg NPKS ha^{-1} (75% higher than RDF). The experiment was arranged following split-split plot design with three replications. Crop management procedure was similar with previous experiment.

A non significant variation observed among the three cotton genotypes in majority of the observed parameters. The tallest plant (126.51 cm), maximum monopodial branch plant^{-1} (2.75) and sympodial branch plant^{-1} (16.41) were observed in variety CB-14. On the other hand, the shortest plant (118.37cm) and lowest sympodial branch plant^{-1} (14.53) were observed in CB-12. Maximum of bolls plant^{-1} (22.13), seed cotton yield (2773 kg ha^{-1}) and lint yield (1108 kg ha^{-1}) recorded in CB-14 variety. Maximum ginning out turn (41.93) recorded in CB-13 variety. Maximum boll weight (5.50) recorded in CB-12 variety. Maximum fibre length (31.03 mm) and fibre strength (32.25g/tex) recorded in CB-14 and minimum staple length (30.39 mm) recorded in CB-12 variety.

Among the fertilizer doses the tallest plant (132.27 cm), the highest monopodial branch plant^{-1} (2.82) and sympodial branch plant^{-1} (15.82) were produced in 75% higher than RDF treatment. Maximum number of bolls plant^{-1} (22.99) and maximum boll weight (5.45g) maximum seed cotton yield (2891 kg ha^{-1}), the highest ginning out turn (41.41%) and maximum lint yield (1197 kg ha^{-1}) were observed in 75% higher than RDF. Maximum staple length (30.98mm mm) observed in 50% higher than RDF. Staple strength, uniformity ratio and micronaire value showed insignificant difference among fertilizer rates.

In respect of spacing, the tallest plant (124.36 cm) and monopodial branches plant^{-1} **(**3.21) was recorded in (75 × 30 cm) plant spacing. Maximum number of bolls plant^{-1} (23.76) and boll weight (5.46 g) was recorded in (75 × 30 cm) plant spacing. But maximum seed cotton yield (3099 kg ha^{-1}) and lint yield (1269 kg ha^{-1}) recorded in (45 × 30 cm) plant spacing. The highest staple length (30.90 mm) observed in (60 × 30 cm spacing and the lowest staple length (30.64 mm) observed in (75 × 30 cm) spacing.

The tallest plant (137.03 cm), the highest monopodial branches plant^{-1} (3.43) and sympodial branches plant^{-1}16.86) and highest bolls plant^{-1} (24.10) were found in the combined effect of CB-14 × 75 % higher fertilizer than RDF. Significantly highest staple length (31.42mm) was observed in CB-14 × 50% higher than RDF treatment combination.

The shortest plant (110.17cm) was ovserved in CB-12 × 25% higher than RDF treatment combination and the lowest monopodial branches plant^{-1}(1.19) observed in CB-13 × 25% higher than RDF treatment combination. The lowest bolls plant^{-1} (17.53) was observed in CB-12 × 25% higher than RDF. The highest seed cotton yield (3020 kg ha^{-1}) found in the interaction of CB-14 × 75% higher than RDF. Interaction of CB-13 × 50% higher than RDF gave the lowest yield (2500 kg ha^{-1}). Combined effect of CB-12 × 75% higher than RDF showed the lowest staple length (30.19 mm).

On this case there observed a significant difference on sympodium branches plant^{-1}, boll weight, seed cotton yield, and staple length due to combined effect of variety and spacing. The highest fruiting branch plant^{-1}(17.53) found in the combined effect of CB-14 × (45 × 30 cm) spacing and that of lowest (13.78) was observed in CB-12 × (75 × 30 cm) spacing combination. The highest bolls plant^{-1} (24.93) was found in the combined effect of CB-13× (75 × 30 cm) spacing. The highest boll weight (5.60 g) was found in the interaction of CB-12 × (75 × 30 cm) spacing. The highest seed cotton yield (3221 kg ha^{-1}) was found in CB-12 × (45 × 30 cm) spacing combination. It was found that both the three varieties gave the highest yield in (45 × 30 cm) plant spacing which followed by (60 × 30 cm) plant spacing. The significantly highest staple length (31.37 mm) was observed in CB-14 × (60 × 30 cm) spacing combination. Staple strength, uniformity ratio and micronaire value showed insignificant difference among the treatment combinations.

The highest monopodial branches plant^{-1}(4.03) found in the interaction of (75 × 30 cm) spacing × 75% higher than RDF combination. The tallest plant (136.27 cm) was observed in (45 × 30 cm) spacing × 75% higher than RDF combination. The highest boll plant^{-1} (25.80) found in the interaction of (75 × 30 cm) × 75% higher than RDF combination. The highest boll weight (5.49g) was found in the interaction of (75 × 30 cm) × 50% higher than RDF. The highest seed cotton yield (3240 kg ha^{-1}) was found in the interaction of (45 × 30 cm) × 75% higher than RDF. It was found that both the three varieties gave the highest yield with (45 × 30 cm) × 75% higher than RDF which was statistically higher than other treatment combinations. The significantly highest staple length (31.29 mm) was observed in (60 × 30 cm) × 50% higher than RDF treatment combination.

The highest sympodial branches $plant^{-1}$(20.23) was found in the interaction of CB-14 × 75% higher than RDF × (45 × 30 cm) spacing. The highest boll weight (5.92 g) was found with the interaction of CB-14 × 50% higher than RDF × (75 × 30 cm) spacing. Interaction of variety × spacing × fertilizer exerted insignificant effect in seed cotton yield, bolls $plant^{-1,}$ drop out bolls $plant^{-1}$, staple strength, uniformity ratio and micronaire value. The highest staple length (31.64 mm) was observed in CB-14 × 50% higher than RDF × (60 × 30cm) spacing treatment combination.

The total cost of production ranged 73254 - 76590 Tk. ha^{-1}. The highest cost of production (76590 Tk ha^{-1}) was calculated with 75% higher than RDF × (75 × 30 cm) treatment combination for all the three varieties. The lowest cost of production (73254 Tk. ha^{-1}) was found with 25% higher than RDF × (45 × 30 cm) treatments combination. The highest gross return (198480 Tk ha^{-1}) was found in CB-12 × 75% higher than RDF × (45 × 30 cm) treatment combination. The lowest gross return (132900 Tk ha^{-1}) was found in CB-13 × 50% higher than RDF × (75 × 30 cm) treatment combination. The highest gross margin (123426 Tk ha^{-1}) was found when used CB-12 × 25% higher than RDF × (45 × 30 cm) treatment combination. The lowest gross margin (57078 Tk ha^{-1}) was found when used CB-13 × (75 × 30 cm) × 50 % higher than RDF treatment combination. Maximum benefit cost ratio (2.68) was involved when used CB-12 × 25% higher than RDF × (45 × 30 cm) treatment combination. The minimum benefit cost ratio (1.75) was found when used CB-12 × 25% higher than RDF × (45 × 30 cm) treatment combination. It was found that all the varieties gave higher yield, higher gross return and higher BCR in (45 × 30 cm) spacing and 75% higher than RDF treatment combination. For economic point of view, results indicated that (45 × 30 cm) spacing and 75% higher than RDF treatment combination is more profitable for all the three varieties.

CONCLUSIONS

Based on the experimental results, it might be concluded that-

1. The inbred variety CB-12, CB-13, and CB-14 may be recommended for cultivation in agro-ecological zones -4 (AEZ -4) of Bangladesh for their higher seed cotton yield, higher ginning out turn (GOT) and spinning quality fibre,
2. 75% higher than the recommended dose of fertilizer (210, 78, 229, 46 Kg NPKS ha^{-1}) is suggested for higher seed cotton yield.
3. Plant spacing 45 × 30 cm or 60 × 30 cm are recommended for maximum seed cotton yield.
4. 75% higher dose of fertilizer with closer spacing (45 × 30cm) may be used for maximum seed cotton yield and 75% higher fertilizer dose along with 75 × 30 cm or 60 × 30 cm spacing are recommened for quality fibre production.
5. Irrespective of varietal differences 75% higher than RDF under (45 × 30 cm) spaced cotton gave maximum benefit cost ratio (BCR).

Recommendations

The following recommendations may be made for future research-

1. These three varieties might be considered for fertilizer trial in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance.
2. More genotypes with different crosses with different environment may be included for further study.
3. More geometic planting arrangements may be practices for further investigation.
4. Different fertilizer doses and management practices should be include for further investigation.

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Appendices

APPENDICES

Appendix I. Mean monthly temperature, relative humidity and monthly rainfall from June

2015 to March 2018

Month	**Air Temperature (^oC)			**Humidity (%)	*Rain Fall (mm)
	Max.	Min.	Ave.		
June/15	32.78	26.7	29.74	84.83	643.13
July/15	32.33	26.70	29.5	86.41	565.41
August/15	31.75	26.90	29.33	83.96	420.05
September/15	32.7	26.76	29.73	79.2	132.0
October/15	31.11	23.58	27.34	83	48.68
November/15	29.85	17.6	23.72	81.2	0.00
December/15	24.63	11.53	18.08	86.4	0.00
January/16	24.7	12.15	18.88	89.41	6.49
February/16	29.8	17.1	23.4	84.6	0.0
March/16	33.2	20.9	27.0	78.5	100.0
June/16	34.05	26.80	30.43	83.47	273.21
July/16	32.31	26.66	29.48	86.20	425.16
August/16	33.37	26.84	30.10	84.23	171.92
September/16	32.53	26.50	29.52	87.21	293.51
October/16	32.77	24.79	28.78	86.11	72.08
November/16	29.63	17.97	23.80	85.86	9.42
December/16	27.11	14.55	20.83	90.62	0.00
January/17	26.21	12.11	19.16	85.04	0.00
February/17	29.39	14.59	21.99	80.56	2.27
March/17	29.85	18.61	24.23	83.11	82.63
June/17	33.23	26.25	29.74	85.38	408.12
July/17	32.19	27.10	29.65	87.43	436.69
August/17	32.66	27.03	29.85	77.03	554.87
September/17	32.77	27.17	29.97	85.63	357.63
October/17	31.98	24.74	28.36	87.00	14.96
November/17	29.65	18.13	23.89	89.87	13.31
December/17	26.02	15.37	20.69	90.03	47.40
January/18	23.18	10.68	16.93	79.42	0.00
February/18	28.51	15.92	22.22	84.5	0.56
March/18	33.12	19.61	26.37	84.29	0.99

*Monthly total, **Monthly average

Sourc : Department of Agricultural Engineering, **:** BSMRAU, Salna, Gazipur

Appendix 2. Physical and chemical properties of the experimental soil (0-30 cm depth) .

Soil properties	Content
Organic matter	2.42%
P^h	6.5
Total N	0.10%
Available P	6.6 microgram/g soil
Exchangeable K	0.30 me/100 g soil
Available Zn	3.14 microgram/g soil
Available S	3.73 microgram/g soil
Available B	0.15 microgram/g soil
Exchangeable Ca	4.4 me/100 g soil
Exchangeable Mg	1.9 me/100 g soil
Texture	Clay loam

Source: SRDI, (2015)

Appendix 3. Physical and chemical properties of the experimental soil (0-30 cm depth)

Soil properties	Content
Organic matter	2.15%
P^h	6.3
Total N	0.09%
Available P	4.93 microgram/g soil
Exchangeable K	0.30 me/100 g soil
Available Zn	3.14 microgram/g soil
Available S	1.22 microgram/g soil
Available B	0.24 microgram/g soil
Exchangeable Ca	4.4 me/100 g soil
Exchangeable Mg	1.9 me/100 g soil
Texture	Clay loam

Source: SRDI, (2016)

Appendix 4. Soil test value after cotton harvest (fertilizer 1st year)

Treatment	P^H	O.M	Total N	K	P	S
		%		me/100 g soil	microgram/g soil	
CB- 13 × Control	5.3	2.69	0.11	0.24	8.61	1.24
×25% less than RDF	5.4	2.69	0.12	0.35	10.61	1.98
× RDF	6.3	1.88	0.07	0.29	6.80	1.77
×25% higher than RDF	6.5	2.42	0.10	0.26	6.18	2.15
×50% higherthan RDF	6.4	2.42	0.09	0.26	6.80	3.38
×75% higherthan RDF	6.3	2.69	0.11	0.24	3.50	1.99
CB- 14× Control	5.4	1.34	0.07	0.35	18.61	3.12
×25% less than RDF	5.2	1.88	0.09	0.23	6.07	2.74
× RDF	6.4	3.23	0.13	0.28	5.48	1.36
×25% higher than RDF	6.3	2.42	0.10	0.26	16.61	2.85
×50% higher than RDF	6.2	2.42	0.10	0.27	9.08	1.36
×75% highe rthan RDF	6.4	2.69	0.11	0.26	5.56	1.87
CB- 12× Control	5.3	2.42	0.11	0.43	1.51	3.15
×25% less than RDF	5.1	2.15	0.09	0.37	13.51	5.02
× RDF	6	2.15	0.08	0.22	4.36	2.88
×25% higher than RDF	6.2	2.15	0.09	0.27	5.96	1.08
×50% higher than RDF	6.2	2.42	0.10	0.34	7.87	0.95
×75% higher than RDF	6.3	2.69	0.12	0.28	6.46	1.05

Source: SRDI, (2016)

Appendix 5. Soil test value after cotton harvest (fertilizer 2nd year)

Treatment	P^H	O.M	Total N	K	P	S
		%		me/100 g soil	microgram/g soil	
CB-13 × RDF	6.1	2.69	0.11	0.30	8.03	1.34
× 25% higher than RDF	6.3	2.42	0.10	0.32	5.46	2.32
× 50% highert han RDF	6.3	1.88	0.07	0.29	6.80	1.77
× 75% higher than RDF	6.5	2.42	0.10	0.26	6.18	2.15
× 100% higher than RDF	6.4	2.42	0.09	0.26	6.80	3.38
× 125% higher than RDF	6.3	2.69	0.11	0.24	3.50	1.99
CB-14 × RDF	6.5	.0.94	0.05	0.29	4.19	1.74
× 25% higher than RDF	5.6	3.35	0.13	0.28	6.82	4.17
× 50% higher than RDF	6.4	3.23	0.13	0.28	5.48	1.36
× 75% higher than RDF	6.3	2.42	0.10	0.26	16.61	2.85
× 100% higher than RDF	6.2	2.42	0.10	0.27	9.08	1.36
× 125% higher than RDF	6.4	2.69	0.11	0.26	5.56	1.87
CB-12 × RDF	6.3	2.42	0.09	0.30	5.97	2.31
× 25%higherthan RDF	6.3	2.96	0.11	0.24	5.81	2.40
× 50% higher than RDF	6	2.15	0.08	0.22	4.36	2.88
× 75% higher than RDF	6.2	2.15	0.09	0.27	5.96	1.08
× 100% higher than RDF	6.2	2.42	0.10	0.34	7.87	0.95
× 125% higher than RDF	6.3	2.69	0.12	0.28	6.46	1.05

Source: SRDI, (2017)

Appendix 6. Soil test value after cotton harvest (Spacing experiment)

Treatment	P^H	O.M	Total N	K	P	S
		%		me/100 g soil	microgram/g soil	
CB-13×.45m×.30m	6.2	2.96	0.11	0.21	7.08	2.04
× .45m×.45m	6.0	1.88	0.08	0.38	9.48	2.55
×.60m×.30m	6.0	1.34	0.07	0.76	3.72	3.63
×.60m×.45m	5.7	1.61	0.08	0.38	9.26	2.70
×.75m×.30m	5.7	1.88	0.08	0.27	10.21	2.67
×.75m×.45m	5.8	1.34	0.07	0.51	5.96	5.31
×.90m×.30m	5.6	2.69	0.11	0.85	8.29	3.50
×.90m×.45m	5.5	.89	0.05	0.28	3.86	3.82
CB-14×.45m×.30m	5.7	2.15	0.09	0.47	2.81	1.13
× .45m×.45m	5.9	2.15	0.08	0.37	6.41	3.41
×.60m×.30m	5.8	1.88	0.07	0.35	1.17	4.53
×.60m×.45m	5.8	1.88	0.08	0.40	8.71	7.26
×.75m×.30m	5.7	2.15	0.09	0.39	3.08	3.55
×.75m×.45m	5.8	1.61	0.07	0.34	1.63	2.56
×.90m×.30m	5.7	1.88	0.09	0.40	5.61	3.31
×.90m×.45m	5.9	1.88	0.08	0.35	15.47	1.66
CB-12 ×.45m×.30m	6.4	2.15	0.09	0.30	3.11	3.93
× .45m×.45m	5.7	2.69	0.12	0.39	4.01	3.81
×.60m×.30m	5.3	1.61	0.07	0.34	3.76	6.25
×.60m×.45m	5.8	2.69	0.11	0.46	5.38	2.73
×.75m×.30m	6.5	2.15	0.10	0.22	13.62	2.08
×.75m×.45m	5.8	1.61	0.08	0.39	9.94	1.09
×.90m×.30m	5.9	2.15	0.09	0.49	20.21	1.41
×.90m×.45m	5.7	1.34	0.07	0.49	7.43	4.02

Source: SRDI, (2016)

Appendix 7. Cotton Production Area in Bangladesh

(Red Box) Indicate the place of the research field.