International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 6, No. 1, p. 36-44, 2015

RESEARCH PAPER OPEN ACCESS

# Assessing the impact of agronomic spacing conditions on biophysical and biochemical parameters along with yield and yield components in cotton

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**Article published on January 12, 2015**

**Key words:** Cotton, spacing, biochemical, biophysical, yield.

## Abstract

Spacing, an agronomic factor, is considered as one of the key management components in any cropping system. The experiment was conducted during 2011-2012 to evaluate the effects of different levels of spacing on biophysical and biochemical parameters along with yield and yield components in cotton (*Gossypium spp.*) during kharif season in the fields of Vadodara Taluka. Three different levels of plant spacing 60, 50 and 40 cm with a consistent row width of 210 cm were selected. The soil of the experimental field was black clayey soil. The analysis was carried out during disparate growth stages like square formation, Peak flowering and Boll bursting stages of cotton crop. The Results obtained showed that all the traits were significantly affected by different spacing used. Higher values for biophysical and biochemical parameters were observed at wider and optimum spacing for different growth stages. Furthermore yield and yield components also showed highest values for optimum spacing unlike plant height which attained its apogee at wider spacing. On the basis of findings, growing cotton at plant spacing of 60 and 50 cm remains the prime recommendation.

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**Introduction**

Cotton is the most valuable and major cash crop. It is major source of foreign exchange and plays an important role in agriculture, industry and economic development of the country. The demand of cotton products ensures its survival as world's most widely cultivated crop, despite of the stiff competition given by man-made fibers (Saleem *et al.,* 2010). The crop is grown in about 76 countries which cover more than 32 million hectares of land (Saranga *et al.,* 2001). India along with China, United States, Brazil and Pakistan stand out among the major world cotton producers (United States Department of Agriculture - USDA, 2012). According to a study carried out by International Service for the Acquisition of Agri-biotech Application (ISAAA) it was confirmed that India has overtaken the US to become the second largest cotton producing country in the world, after China. In India, Gujarat has emerged as India's number one cotton producing state. It is the single largest cotton producer state with 36 per cent (101 lakh bales) of the total national production from the area about 25.00 lakh hectares. Among the different districts of Gujarat, Vadodara accounts for 7.7% of the total cotton production of the state.

In cotton, plant spacing affects the growth parameters and yield characteristics of the plant. It is believed to be one of the factor maximizing biophysical, biochemical parameters along with yield and yield components. This may be because cotton yield is believed to be partially determined by crop geometry which is a function of row spacing and plant population. The space available for individual plant growing in field affects the yield and quality of produce and hence proper spacing is one of the key factors resulting into proper and healthy growth of crop (Islam *et al.,* 2011). This important agronomic attribute is also directly related to light interception occurring during photosynthesis (Anyanwu, 2013 and Odabas *et al.,* 2008). Inadequate spacing also leads to clustering of plants and thereby affects photosphere and rhizosphere (Ibeawuchi *et al.,* 2008). Proper spacing improves air flow to plants resulting into moderation of plant temperature and increased photosynthetic levels. It provides right plant density, which refers to the number of plants, allowed on a given unit of land for optimum yield (Obi, 1991).

The growth and stages of plant are directly influenced by the space available to the plants, although the response is species or cultivar specific (Kirby and Faris, 1970). Plants when are too close to each other, they end up being overcrowded leading later to stunting of the crops thereby ensuing to poor yields. Optimum spacing allows plants to develop to their fullest potential both on top and underneath ground by providing adequate space ensuring less competition for sunlight, water and fertilizers (Sabo *et al.,* 2013). It also aids in the prevention of pests and diseases spread from one plant to another. Researches have been carried out wherein spacing and plant population has enhanced disease and pest management along with weed control and ripping resulting in increasing cotton yield. Although previous studies have been conducted to investigate cotton growth and yield response to row spacing, results are often conflicting.

Realizing the importance of plant spacing, an attempt to understand the relevance of cotton with spacing attribute was made. Performance was assessed in terms of different biochemical parameters i.e chlorophyll content, proline content and biophysical parameters i.e relative water content (RWC), leaf area index (LAI) of cotton crop during different stages of crop growth together with yield and yield components.

**Materials and methods**

Study pertaining to the effect of different levels of spacing was carried out in Kharif season at farmer's agricultural field of Vadodara taluka during 2011-2012. The soil of the studied site was black clayey soil. The cotton crop was monitored during three different growth stages viz. (1) square formation (SF) (2) Peak flowering (PF) and (3) Boll bursting (BB).

The experiment consisted of three plant spacing i.e 60, 50 and 40 cm with a consistent row width of 210 cm, and the plant population density was 28000, 31000 and 21000 plants $ha^{-1}$ respectively. Each plot measured 5 x 6m ($30m^2$) with three replications in a randomized block design.

Three plants per plot were sampled for all the parameters and were evaluated one time per 30 days after 30 days of sowing. Biochemical estimations such as chlorophyll content were determined as per Arnon method (1949) and proline content was determined by ninhydrin method as per Bates *et al.* (1973). Biophysical estimations such as Relative water content (RWC) was estimated as per Barrs and Weatherley method (1962), Leaf area index (LAI) was estimated as per Landiver *et al.* (1988). Five plants per replicate were randomly selected during harvest to determine morphometric variables i.e plant height and yield along with yield components.

Data were analysed statistically by applying analysis of variance (ANOVA) at 0.05 significance level (P=0.05) to determine if significant differences existed among means of different treatment. Besides this, correlation coefficient at 0.001 significance level (P<0.01) was also applied to the data.

**Results and discussion**

Analysis of Variance carried out for the studied traits are presented in Table 1. This analysis showed significant effect of spacing on the evaluated characteristics. The results are explained separately for both the parameters.

**Table 1.** Analysis of variance of different traits.

| | | MS of Biochemical and Biophysical parameters at different growth stages | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Chlorophyll (mg/gm) | | | Proline (mg/gm) | | | RWC (%) | | | LAI | | |
| S.O.V | df | SF | PF | BB | SF | PF | BB | SF | PF | BB | SF | PF | BB |
| Replication | 2 | 0.00 | 0.00 | 0.00 | 0.62 | 0.50 | 1.53 | 5.25 | 10.77 | 52.57 | 0.16 | 0.74 | 0.03 |
| Spacing | 2 | 0.36* | 0.05* | 0.14* | 158.38* | 159.05* | 158.58* | 1909.05* | 138.1* | 228.08* | 0.45* | 0.11* | 5.81* |
| Error | 4 | 0.00 | 0.00 | 0.00 | 0.64 | 0.78 | 0.57 | 6.45 | 9.82 | 5.25 | 0.04 | 0.08 | 0.09 |
| C.V (%) | - | 11.53 | 7.53 | 5.58 | 6.85 | 6.74 | 0.58 | 4.67 | 3.98 | 4.78 | 9.63 | 6.12 | 9.69 |

| | | MS of Yield and Yield components | | | | | |
|---|---|---|---|---|---|---|---|
| S.O.V | df | Biological Yield (Kg/ha) | Economic Yield (Kg/ha) | Harvest index | Plant Height (cm) | Number of bolls per plant | Average boll weight per plant (gm) |
| Replication | 2 | 125442.33 | 91481189830.33 | 366.21 | 12 | 5.33 | 0.49 |
| Spacing | 2 | 26122639* | 14039177482* | 24126.29* | 2109* | 63.00* | 1.43* |
| Error | 4 | 107008.83 | 25000907312.34 | 1164.47 | 101.50 | 3.33 | 0.27 |
| C.V (%) | - | 3.28 | 3.22 | 7.16 | 6.72 | 7.94 | 6.81 |

*: significant at 0.05 level (P=0.05).

*Biochemical parameters*

*Chlorophyll (mg/gm)*

Chlorophyll determines the photosynthetic capacity and influence the rate of photosynthesis, dry matter product and yield. It also provides virtuous information regarding physiological status of plants and is fundamentally essential pigment for conversion of light energy to stored chemical energy (Gitelson, 2003). Data pertaining to effect of spacing on chlorophyll in Table 1 indicated that spacing had significant effect on chlorophyll at 0.05 level of significance (P=0.05). Highest content was observed in optimum spacing of 50 cm (Fig 1) during all the three growth stages i.e SF, PF and BB. Similar findings showing association between spacing and chlorophyll, have been documented by Kumar and

Rawat (2002) and Dimri and Lal (1997).

*Proline content (mg/gm)*

Proline accumulating in plants under environmental stress is a proteinogenic amino acid and is essential for primary metabolism with an exceptional conformational rigidity (Ahmed *et al.,* 2012). It plays an important role as storage compound for carbon (C) and nitrogen (N), detoxification of ammonia ($NH_3$), preserving the hydration of proteins in dehydrated tissues thereby contributing to the survival of cellular functions. (Patil *et al.,* 2011). Since proline is linked to N storage, and spacing being known for affecting nitrogen concentration of crop (Seginer, 2004), it can be assumed that proline accumulation is related to spacing. Data pertaining to the effect of spacing on proline in Table 1 indicated that spacing had significant effect on proline at 0.05 level of significance (P=0.05). Results highlighted the fact wherein there occurred variation in proline content with respect to spacing. SF stage exhibited maximum proline content at spacing of 60 cm, whereas during PF and BB stage it was maximum at spacing of 50 cm (Fig 2).

**Table 2.** Correlation coefficients between different traits.

| | Spacing | Chlorophyll | Proline | (RWC) | (LAI) | Biological yield | Economic yield | Harvest index | Plant height | Number of bolls | Boll weight |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Spacing | - | -0.2896 | 0.2453 | 0.8990** | -0.9889** | 0.5316 | 0.3037 | 0.0655 | 0.9500** | 0.3555 | 0.3691 |
| Chlorophyll | | - | 0.8568** | -0.6793 | 0.4285 | 0.6566 | 0.8239** | 0.9361** | 0.0236 | 0.7915 | 0.7825 |
| Proline | | | - | -0.2037 | -0.0986 | 0.9515** | 0.9981** | 0.9834** | 0.5357 | 0.9933** | 0.9915** |
| (RWC) | | | | - | -0.9541** | 0.1072 | -0.1439 | -0.3779 | 0.7174 | -0.0894 | -0.0748 |
| (LAI) | | | | | - | -0.3999 | -0.1589 | 0.0833 | -0.8931** | -0.2128 | -0.2271 |
| Biological yield | | | | | | - | 0.9684** | 0.8799** | 0.7694 | 0.9806** | 0.9834** |
| Economic yield | | | | | | | - | 0.9706** | 0.5860 | 0.9984** | 0.9975** |
| Harvest index | | | | | | | | - | 0.3737 | 0.9559** | 0.9515** |
| Plant height | | | | | | | | | - | 0.6296 | 0.6408 |
| Number of bolls | | | | | | | | | | - | 0.9999** |
| Boll weight | | | | | | | | | | | - |

**: significant at 0.005 level of significance (P<0.01).

*Biophysical parameters*

*Relative Water Content (RWC)*

The water status of leaves in living plants, is usually considered as one of the important information (Puri and Swamy, 2001; Yu *et al.,* 2000). It is probably the most appropriate measure in terms of physiological consequence of cellular water deficit. Normal values of RWC ranges between 98% in fully turgid transpiring leaves to about 30-40% in severely desiccated and dying leaves, depending on plant species. In most crop species, the typical RWC at around initial wilting is about 60% to 70% with exceptions. Data pertaining to the effect of spacing on RWC in Table 1 indicated significance between spacing and RWC at 0.05 level of significance (P=0.05). Results indicated that spacing has an obvious effect on leaf water status. RWC gradually decreased with the growth of crop and the values ranged between 30% to 84%. There was a trend of higher RWC values at wider spacing of 60 cm during SF and PF stage while during BB stage it was high in optimum spacing of 50 cm (Fig 3). Our findings were in antithesis with Zhou *et al.* (2011a) who reported higher level of RWC in narrow spacing.

*Leaf Area Index (LAI)*

Leaf area index (LAI) is related to several leaf variables and can be used as a reference tool for crop growth. It also conveys that a small proportion of the total radiation is used to make raw materials for leaf initiation by plant. In young cotton plant the LAI ranges from 0.01 to 1 at emergence and pinhead square respectively. Once LAI reaches 3, a cotton plant is able to intercept all of incident solar radiation. LAI may reach upto 5 once the blooming peaks. Data pertaining to the effect of spacing on LAI in Table 1 indicated significant effect of spacing on RWC at 0.05 level of significance (P=0.05). Results exhibited the fact wherein maximum LAI values were attained by lowest spacing of 40 cm at SF and BB stage, while at PF stage highest values were attained by optimum spacing of 50 cm (Fig 4). Similar findings regarding negative trend between LAI and spacing, have been documented by many researchers (Zhou *et al.*, 2011b; Darawsheh *et al.,* 2009 and Riahinia *et al.*, 2008).

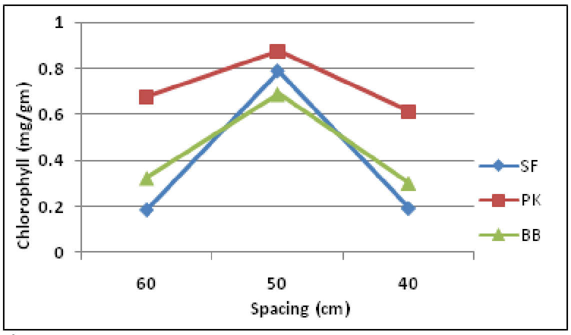


**Fig. 1.** Chlorophyll content at different spacing during different growth stages.

*Yield*

Yield is considered to be the eventual outcome of biophysical, biochemical, morphological and phenological events occurring in the plant system. Under the sort climate, supply of moisture, solar radiation and temperature are substantial components that affects yield.

*Biological yield*

Biological yield is believed to be influenced by climatic, soil and other plant factors. Results of the study depicted highest biological yield as a consequence of optimum spacing of 50 cm which can be attributed to availability of sufficient amount of nutrient to soil, moisture and other necessary factors and less competetion. Al-Dalain *et al.* (2012) outlined that increased plant spacing led to increase in biological yield. On the contrary, Mohamadzadeh *et al.* (2011) reported highest biological yield in narrow row spacing. Munir and Mcneilly (1987) reported that biological yield decreased with wider row spacing which was due to decrease in number of plants in area in wider planting row spacing.

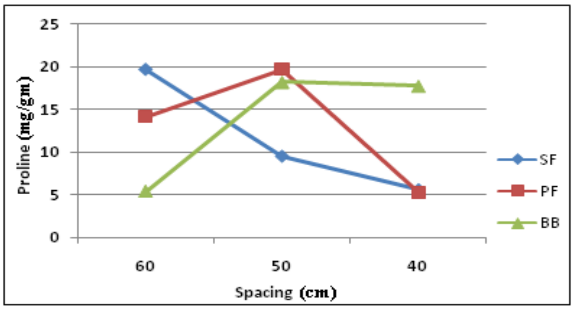


**Fig. 2.** Proline content at different spacing during different growth stages.

*Economic yield*

Economic yield can be increased by increasing total dry matter production or harvest index which is ultimately related to spacing. The relation between economic yield and harvest index can be shown by the equation i.e Economic yield= Biological yield x Harvest index. Results of the study portrayed highest economic yield by optimum spacing of 50 cm. Corresponding results were reported by Nadeem *et al.* (2010) regarding high economic yield in medium spacing.

*Harvest index (%)*

Under favourable environmental conditions, harvest index act as a scale of physiological productivity potential of crop condition and is also used to determine the reproductive efficiency of the crop. Results of harvest index showed correspondence to yield wherein high yield was reported in the plot with optimum spacing of 50 cm. Significant results were reported by Bozorgi *et al.* (2011), Mansoor *et al.* (2010) depicting highest harvest index at medium row spacing. On the other hand Mohamadzadeh *et al.* 2011 reported higher values for plot with narrow spacing.

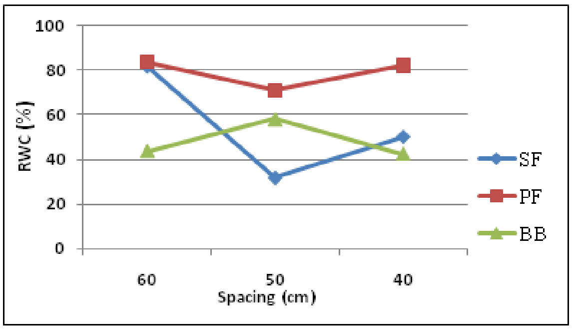


**Fig. 3.** RWC at different spacing during different growth stages.

*Yield Components*

Plant height is a trait which is believed to be controlled by genetic characteristics but it may also be influenced by nutritional and environmental stress. Results offered highest values of plant height for plot with highest spacing. Our findings were in line with Maas *et al.* (2007) who were of the view that wider spacing had significantly taller plants. On the contrary Ibeawuchi *et al.* (2008) reported that maximum plant height is the matter of narrow row spacing. In case of number of bolls per plant and average boll weight per plant, highest values were attained by the plot with spacing of 50 cm. The findings from our study agree with those of Nadeem *et al.* (2010); who reported maximum number of bolls per plant in medium spacing. On the contrary, Alitabar *et al.* (2012) reported that wider spacing results in increased average boll weight.

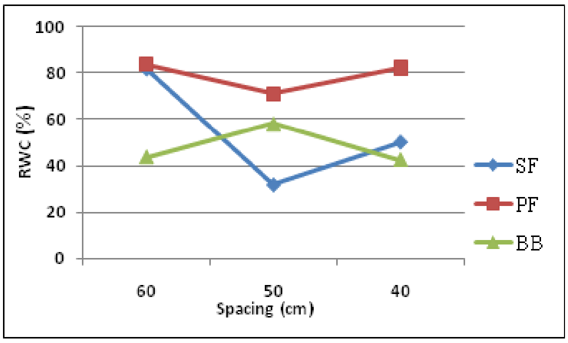


**Fig. 4.** LAI at different spacing during different growth stages.

Correlation analysis (Table 2) showed significant correlation between some of the traits at 0.005 level of significance ($P<0.005$). Analysis showed significant positive correlation of spacing with RWC and plant height which can be attributed to availibilty of adequate nutrients, sunlight, space and other agronomic factors. Along with this chlorophyll also showed significant positive correlation with proline, economic yield and harvest index. Proline showed significant positive correlation with yield and yield components except plant height. Moreover RWC showed negative correlation with LAI, while LAI showed significant negative correlation to plant height. Negative association of LAI to plant height was also reported by Reddy and Kumari (2004). In addition to this, both the yield showed significant positive correlation among themselves and with yield components except plant height. Harvest index showed significant positive correlation with number of bolls per plant and average boll weight per plant.

## Conclusion

It may be concluded from the study that maintenance of proper plant spacing is more important for healthy crop growth. The values for biochemical and biophysical parameters at different growth stages were computed on an average scale. In case of biochemical parameters highest values were observed in plot with optimum spacing of 50 cm, while in case of biophysical parameters highest RWC was attained by wider spacing of 60 cm and LAI was highest in narrow spacing of 40 cm. Thus it is evident from the results that RWC being positively correlated with spacing, increases with increase in spacing and on the contrary, LAI being negatively correlated with spacing decreases with increase in spacing. Yield and Yield components showed highest values for optimum spacing of 50 cm except plant height, which was highest in plot with wider spacing of 240x50 cm. Therefore, the spacing of 60 and 50 cm are favourable.

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