

Original Research Article

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Influence of Weather Variability, Plant Density and Fertilizer Regimes on Growth and Yield of Cotton under Rainfed Condition

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ABSTRACT

Keywords

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A field experiment was carried out during kharif seasons of 2013-14 and 2014-15 at Research farm of AICRP for Dryland Agriculture, Dr. PDKV, Akola to study the growth and yield of cotton under weather variability, plant density and fertilizer regimes under rainfed condition. The experimental was laid out in split plot design with eighteen treatment combinations in three replications. The soil of experiment was Inceptisols clayey in texture having pH 8.1, organic carbon (0.54%), available nitrogen (187.3 kg ha⁻¹), available phosphorus (14.8 kg ha⁻¹) and available potassium (316.0 kg ha⁻¹). The pooled results indicated that seed cotton and stalk yield was significantly higher in monsoon sowing, 200% plant density and in 200% RDF.

Introduction

Cotton is an important cash crop of Vidarbha region. In Maharashtra state, the area under this crop is 41.98 lakh ha and yielding 85.00 lakh bales next to Gujarat (104.00 lakh bales) with average productivity of 344.0 kg lint ha⁻¹ (Anonymous, 2018). Vidarbha is a major cotton growing region having an area of 15.08 lakh ha with average productivity of 533.0 kg lint ha⁻¹ (Anonymous, 2017). In Vidarbha region of Maharashtra, cotton is grown predominantly as a rainfed crop. As such in

Vidarbha region about 87 per cent cultivable land is under rainfed farming. Weather plays an important role in rainfed agricultural production. Agronomic strategies to cope with changing weather are available but not fully explored, and have more emphasis in view of the happening issue of climate change impacts reportedly inducing regional variability and uncertainty of rainfall affecting agricultural production. As such management of rainfed cotton production system is challenging and is a high-risk enterprise given the uncertainty of rainfall in its onset and distribution during the

growing season. In fact monsoon onset behaviour has direct bearing on the acreage of cotton crop as timely onset with significant amount of sowing rains favours timely sowing of the crop within the normal sowing window. As often observed in recent years, late monsoon onset and/or non-receipt of significant pre-soaking rains pushes cotton crop beyond its normal sowing window (June 30) and cotton growers face a problem of low cotton yield in late planting. This has also resulted in decline in cotton sowing and its stagnating rate of growth. In order to cope with the decline in cotton sowing and its stagnating rate of growth, the strategy is to increase production per unit area rather than increase the absolute area of cotton production. In many countries, narrow row plantings have been adopted after showing improvement in cotton productivity (Ali *et al.*, 2010). Fertilizer management along with high density planting is important because fertilizer requirement is most likely to be higher under HDP (Jost and Cothren, 2000). Hence, within the varying rainfed environment, the potential effects of adopting higher plant population with compatible NPK fertilizer management (as fertilizer requirement is most likely to be higher under HDP) offer a good opportunity to boost the crop output. The aim of the experiment was to study the growth and yield of cotton under weather variability, plant density and fertilizer regimes under rainfed condition.

Materials and Methods

The experiment was carried out at Research farm of All India Coordinated Research Project for Dryland Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola Maharashtra during *kharif* seasons of 2013-14 and 2014-15. The soil of experimental site was medium black (*Inceptisols*), clayey in texture, slightly alkaline in reaction (pH 8.1), organic carbon (0.54%), available nitrogen (187.3 kg

ha⁻¹) and available phosphorus (14.8 kg ha⁻¹) whereas available potassium (316.0 kg ha⁻¹). The experiment was laid out in split plot design with eighteen treatment combinations in three replications. The treatments included weather variability in factor A (two sowing times S₁- monsoon sowing and S₂- late sowing) and plant density in factor B (P₁- 60 cm x 30 cm, 1.11 lakh, P₂- 60cm x 10 cm, 1.66 lakh and P₃- 45 cm x 10cm, 2.22 lakh) as main plot treatments with three fertilizer regimes in factor C (F₁-100% RDF, 60:30:30, F₂-150% RDF, 90:45:45, and F₃-200% RDF, 120:60:60 NPK kg ha⁻¹) as sub plot treatments. The N, P and K were applied through urea, single super phosphate and muriate of potash respectively. Half N, full P and full K was applied at the time of sowing and half N at 30 days after emergence (DAE). Cotton crop variety used was AKH 081. Rainfall during the *kharif* seasons was 821.7mm and 570.1mm during 2013-14 and 2014-15 respectively as against normal rainfall of 688.0 mm.

Results and Discussion

Growth studies

Plant height

Plant height was significantly influenced throughout the crop growth period by weather variability (Table 1). The maximum plant height was recorded with monsoon sowing whereas late sowing produced least plant height at all the stages of crop growth during both the season of experimentation. Increased plant height in monsoon sowing might be due to enhanced vegetative development of crop due to the favourable weather condition, particularly favourable rainfall and hence soil moisture regime throughout the growing period. Similar results regarding difference in plant height were reported by Hallikeri *et al.*, (2009), Pettigrew and Meredith (2009),

Hebbar *et al.*, (2010), Ban *et al.*, (2015) and Pinky Patel *et al.*, (2016).

During 2013-14 differences due to population density on plant height was found to be significant at all growth stages except at maturity. At 30 DAE, higher plant height was recorded in 45 X 10 cm (2,22,222 plants ha⁻¹) being at par with 60 X 10 cm (1,66,666 plants ha⁻¹). Least plant height was recorded in 60 X 15 cm spaced (1,11,111 plants ha⁻¹) population density. During 60 to 120 DAE significantly highest plant height was observed in plant density of 45 X 10 cm (2,22,222 plants ha⁻¹). Plant height did not vary significantly under different plant densities at maturity stage.

During 2014-15, significantly higher plant height was recorded with population density at 45 X 10 cm (2,22,222 plants ha⁻¹) at 60 and 90 DAE, which was at par with 60 X 10 cm (1,66,666 plants ha⁻¹) plant density. Significant influence on plant height due to plant density was not observed at 30 DAE, 120 DAE and at maturity. These results are conformity with Hake *et al.*, (1991) according to whom cotton seedlings tend to grow taller in thick stand. As the season progresses, plant height in thick stand tend to lag behind than that of thin stand and at harvest high density stands have the lowest average plant height. Ruth Kaggwa Asiimwe *et al.*, (2013) observed that plant spacing directly influenced soil moisture extraction, light interception, humidity and wind movement. Zhang *et al.*, (2014) also observed decreased cotton plant height with increased plant density.

Increase in the fertilizer regime increased the plant height progressively during both season of the experimentation. Plant height significantly increased with increase in fertilizer regimes. During 2013-14, fertilizer regime of 120:60:60 NPK kg ha⁻¹ recorded significantly higher plant height however on par with 90:45:45 NPK kg ha⁻¹ fertilizer

regime at all stages of observation. During 2014-15, fertilizer regime of 120:60:60 NPK kg ha⁻¹ recorded significantly higher plant height being at par with 90:45:45 NPK kg ha⁻¹ fertilizer regime at 30, 120 and at maturity stage. Fertilizer regime of 60:30:30 NPK kg ha⁻¹ recorded the least plant height during both the season. Earlier, Singh *et al.*, (2012^b) indicated that the progressive improvement in plant height with every successive increase in nutrient levels. Singh *et al.*, (2012^a) observed that application of 150% RDF recorded significantly higher plant height plant⁻¹ than 100% RDF and 75% RDF but at par with the 125% RDF.

The treatment combination S₁P₃ (monsoon sowing with 2,22,222 plants ha⁻¹) recorded significantly highest plant height than rest of the treatment combinations at 30 DAE during 2013-14 (Table 2).

The treatment combination of P₃F₃ i.e. 45 x 10 cm (2,22,222 plants ha⁻¹) with 120:60:60 NPK kg ha⁻¹ fertilizer regime recorded significantly highest plant height than other treatment combinations (Table 3).

Sympodial branches

Weather variability significantly influenced the number of sympodial branches plant⁻¹ from 60 DAE to harvest stage of crop (Table 4). Monsoon sown crop produced significantly higher sympodial branches plant⁻¹ than late sown crop. Increased sympodial branches plant⁻¹ in June sown crop showed the greater encouragement for reproductive phase that ultimately reflected on promotion of yield and yield components. These findings were supported by the results of Hebber *et al.*, (2002), Dong *et al.*, (2006) and Hallikeri *et al.*, (2009)

During 2013-14 season, sympodial branches plant⁻¹ was significantly higher in plant

density of 60 X 15 cm (1,11,111 plant ha⁻¹) than high plant density of 60 X 10 cm (1,66,666 plant ha⁻¹) and 45 X 10 cm (2,22,222 plant ha⁻¹) at 60 DAE. However, from 90 DAE to harvest stage it proved on par with population density of 1,66,666 plant ha⁻¹ but remained significantly superior to population density of 2,22,222 plant ha⁻¹. During 2014-15 season also population density of 111111 plant ha⁻¹, being at par with population density of 166666 plant ha⁻¹ was significantly superior to 222222 plant ha⁻¹ population density. This shows greater encouragement for reproductive growth in individual plant under lower population density. Under high density planting there may be excess competition for photo-assimilates needed for reproductive development. Stephenson *et al.*, (2011) revealed that number of sympodial branches increased with decreasing plant density. Similar results were also reported by Deotalu *et al.*, (2013) and Jahedi *et al.*, (2013).

Different fertilizer regimes significantly influenced the sympodial branches plant⁻¹. During 2013-14, fertilizer regime of 120:60:60 NPK kg ha⁻¹ recorded highest number of sympodial branches plant⁻¹, however it was statistically at par with 90:60:60 NPK kg ha⁻¹ and significantly more over 60:30:30 NPK kg ha⁻¹. Similar trend prevailed during 2014-15, except that fertilizer regime of 120:60:60 NPK kg ha⁻¹ was also statistically superior 90:60:60 NPK kg ha⁻¹ at 60 and 120 DAE. Increase in fertilizer application had improved nutrient intake in cotton hybrids which in turn might have increased cell division and consequently production of sympodia plant⁻¹. Results were conformity with Bhalerao *et al.*, (2007) and Basavannepa *et al.*, (2012).

The interaction of S X P was found to be significant at 120 DAE during 2014-15. All other interaction during 2013-14 and 2014-15 were found to be non significant.

Data on S X P interaction pertaining to 120 DAE is presented in Table 5. It was observed that S₁P₁ (monsoon sowing with plant density 60 X 15 cm) recorded significantly higher number of sympodial branches plant⁻¹ at 120 DAE during 2014-15 season over rest of the treatments.

Yield attributing characters

Number of picked bolls

Weather variability significantly influenced the number of total picked bolls plant⁻¹ (Table 6). Monsoon sowing (S₁) recorded significantly higher boll numbers than the late sown (S₂) crop. Monsoon sown crop had 21.7% and 23.6% more bolls than late sown crop during 2013-14 and 2014-15 seasons, respectively. This could be due to fact that early planted crop initiated better reproductive growth and produced more sympodia and resultantly more squares that allowed the early planted crop to set more bolls utilizing the more favourable optimal environmental conditions. Hebbler *et al.*, (2010) and Adare *et al.*, (2016) observed similar results.

The number of picked bolls plant⁻¹ were significantly highest in plant density of 60 X 15 cm (1.11,111 plants ha⁻¹, P₁). The number of picked bolls in plant density of 60 X 10 cm (1,66,666 plants ha⁻¹, P₂) was 16.7% less than P₁ which was statistically equal with the plant density of 45X 10 cm (2.22,222 plants ha⁻¹, P₃) with 22.4% less bolls than P₁ and 6.8% less than P₂ during 2013-14. Similar trend prevailed during 2014-15 but P₂ too proved significantly more over P₃. The reduction in number of bolls in P₂ and P₃ were 17.6 and 27.9%, respectively. Higher plant population under high planting density causes competition and fewer shares of limited resources to individual plants. Moreover, lower the plant population ha⁻¹ may increase

light penetration to allow more resources for fruit development lower in the canopy which may increase retention and hence number of bolls. Hake (1991) found that in dense stands fruiting branches are 25% shorter with more fruiting up the plants and slow development of new nodes. Resultantly plants produced fewer fruiting bodies and mature fruit plant⁻¹. Under normal planting density overall favourable plant growth and development reflected in better source-sink relationship, which in turn enhanced the yield attributes. These findings are also in conformity with Reddy *et al.*, (2009) and Naim *et al.*, (2013).

Numbers of picked bolls plant⁻¹ were significantly influenced by different fertilizer regimes. Fertilizer regime of 120:60:60 NPK kg ha⁻¹ recorded significantly higher number of picked bolls than 60:30:30 NPK kg ha⁻¹ and on par with the fertilizer regimes of 90:45:45 NPK kg ha⁻¹. Number of bolls increased by 9.3% and 14.7% in F₂ and F₃ when compared with F₁ during 2013-14. In 2014-15 also the highest number of picked bolls plant⁻¹ was observed in 120:60:60 NPK kg ha⁻¹ and least number of bolls was recorded in fertilizer regime of 60:30:30 NPK kg ha⁻¹. The increase in number of picked bolls was 10.1% and 18.5% in F₂ and F₃ fertilizer regimes. The increase in number of picked bolls plant⁻¹ with increase in fertilizer level was due to improvement in the growth attributes *viz.* plant height, number of monopodia and sympodia, leaf area and dry matter accumulation plant⁻¹. Also the boll retention was more due to the availability of the nutrients to the crop during growth. Similar findings were also reported by Aruna and Reddy (2009) and Nehra and Yadav (2012).

Interaction effects were not significant during 2013-14 but during 2014-15, only S X P interaction was found significant. Interaction of weather variability with the plant density (S X P) significantly influenced number of

picked bolls plant⁻¹ during 2014-15 (Table 7). Treatment combination of S₁P₁ (monsoon sowing with plant density of 60 X 15 cm, 1,11,111 plants ha⁻¹) recorded significantly higher number of picked bolls plant⁻¹ as compared to other treatment combinations.

Boll weight

Monsoon sowing was significantly higher in boll weight than late sowing during both the year of experimentation (Table 6). Reduction in the boll mass were 2.8% and 4.6% during 2013-14 and 2014-15, respectively. Hallikeri *et al.*, (2009) revealed that early planted cotton produced bigger boll size due to higher accumulation of photosynthates and more time was available for boll development and maturity. Because of delayed sowing crop duration and total number of days required for maturity is reduced resulting in production of smaller size bolls. Similar results were observed by Dong *et al.*, (2006), Hebbler *et al.*, (2010) and Ali *et al.*, (2015).

Boll weight was significantly influenced due to different population density during 2014-15 but during 2013-14, differences in boll weight (g) did not reach to the level of significance due to different plant densities. The reduction in boll mass was 2.0 and 3.6%; and 3.3 and 7.0% with the plant density increase in population density from 1,66,666 plants ha⁻¹ to 2,22,222 plants ha⁻¹ respectively during 2013-14 and 2014-15. Reduction in boll mass with higher plant density was lower during 2013-14 due to the sufficient rainfall received at boll development phenophase (242 to 232 mm) and consequent low competition for resource like soil moisture (phenophases wise rainfall data not presented). During 2014-15 lower amount of rainfall coupled with early withdrawal of monsoon rains coincided with boll development which adversely affected the boll growth due to competition for soil moisture being particularly higher in higher

plant density than lower plant density due to which boll mass was higher in lower plant density. According to Rose Roche *et al.*, (2003) under ultra narrow row system in cotton less light is available to leaves lower in the canopy that are important to supporting boll growth. This may also be one of the reasons why boll size is smaller despite there being fewer bolls plant⁻¹. Hakoomat Ali *et al.*, (2011) and Ramzan Ali *et al.*, (2013) reported that boll weight (g) decreased with increase in plant density. In contradiction Molin and Hugie (2010) observed that boll weight was not influenced by plant population.

Differences in boll weight did not reach to the level of significance due to varying fertilizer regime. Hebber *et al.*, (2002) revealed that a non significant relation between fertilizer level and boll weight could be due to the prevailing weather and soil moisture conditions that might have constrained the utilization of nutrients from the soil by plants. Similar results were reported by Ram and Giri (2006) and Sharma (2004). None of the interaction was found to be significant.

Seed cotton weight plant⁻¹

Relevant data on seed cotton weight plant⁻¹ (g) as influenced by different treatments are given in the Table 6. Differences in seed cotton weight plant⁻¹ (g) under monsoon and late sowings were observed to be significant during both the years. Monsoon sowing recorded significantly higher seed cotton weight plant⁻¹ (12.46 and 9.91 g) as compared to late sowing (10.84 and 8.30 g) during 2013-14 and 2014-15, respectively. Earliest sowing had more favourable and optimum environmental condition that allowed the plant to gain more in terms of reproductive growth which reflected in more seed cotton weight plant⁻¹. Better expression of yield components with early sowing was in conformity with the

findings of Hallikari *et al.*, (2009), Damahe *et al.*, (2018) and Kumar *et al.*, (2014).

Among different population densities, seed cotton weight plant⁻¹ was maximum with plant density of 60 X 15 cm (1,11,111 plants ha⁻¹, P₁) during both years of experimentation. Plant density of 60 X 10 cm (1,66,666 plants ha⁻¹, P₂) also recorded numerically higher seed cotton weight plant⁻¹ than plant density of 45 X 10 cm (2,22,222 plants ha⁻¹, P₃) but statistically both were at par. Optimum plant population while optimizing resource use produced more boll number plant⁻¹ and boll weight that reflected in higher seed cotton weight plant⁻¹. Under high density population probably due to reduced availability of resources to individual plant resultantly fewer boll number and smaller boll weight reflected in reduced seed cotton weight plant⁻¹. The aforesaid results are supported by the findings of Hiwale *et al.*, (2016). Seed cotton weight plant⁻¹ was significantly influenced due to fertilizer regimes. Fertilizer regime of 120:60:60 NPK kg ha⁻¹ (F₃) was significantly higher than 60:30:30 NPK kg ha⁻¹ (F₁) and on par with the 90:45:45 NPK kg ha⁻¹ (F₂) during 2013-14. During 2014-15, F₃ fertilizer regime (120:60:60 NPK kg ha⁻¹) was significantly superior over both F₂ (90:45:45 NPK kg ha⁻¹) and F₁ (60:30:30 NPK kg ha⁻¹). Increase in seed cotton yield plant⁻¹ was attributed to increased number of picked bolls per plant and boll weight with 120:60:60 NPK kg ha⁻¹. Similar trend in seed cotton yield plant⁻¹ with increase in fertilizer regimes was reported by Ambati Raju and Soniya Thakare (2012), and Katkar *et al.*, (2005). As regards seed cotton yield plant⁻¹ none of the interaction effects were found to be statistically significant.

Seed cotton yield

Mean seed cotton yield was 1657 kg and 1215 kg ha⁻¹ during 2013-14 and 2014-15 seasons and 1436 kg ha⁻¹ in pooled analysis (Table 8).

Comparatively higher seed cotton yield in 2013-14 might be due to extended crop duration.

Weather created through different sowing time significantly influenced the seed cotton yield. Significantly higher seed cotton yield (1846 and 1359 kg ha⁻¹) was obtained with monsoon sowing and it was significantly decreased in late sowing (1467 and 1071kg ha⁻¹) during 2013-14 and 2014-15 respectively. In pooled data with similar statistical trend, seed cotton yield was observed 1602 and 1269 kg ha⁻¹ in monsoon and late sowing, respectively. Reduction in yield due to delay in sowing was to the extent of 20.5 %, 21.2% and 20.8% respectively during 2013-14, 2014-15 and in pooled. In the present study, mean values were higher as regards growth and yield parameters under monsoon sowing. Reduction of yield in late sowing was also due to shortening of total crop duration which affected reproductive process of the crop adversely. Higher retention of bolls in early sown crop and shedding of floral structure in late sown crop might have also affected the seed cotton yield. By and large, decrease in yield under late sowing was due to significant decrease in growth attributes, number of bolls harvested plant⁻¹, boll weight and seed cotton yield plant⁻¹. This is in conformity with the findings of Hallikaeri *et al.*, (2009), Kumar *et al.*, (2014), Ban *et al.*, (2015), Dalvi *et al.*, (2015) and Pinky *et al.*, (2016).

Population density of 2.22 lakh plants ha⁻¹ (45 X 10 cm) produced significantly highest seed cotton yield over population of 1.66 lakh plants ha⁻¹ (60 X 10 cm) and 1.11 lakh plants ha⁻¹ (60 X 15 cm). Least seed cotton yield was recorded in 60 X 15 cm (1.11 lakh plants ha⁻¹). Similar results were observed during both the years of experimentation and in pooled analysis. High density planting had helped to produce higher biomass at all the growth stages because of optimal light penetration and

uptake of major nutrients which favored for increased photosynthetic efficiency. Higher plant density treatment P₃ (2.22 lakh plants ha⁻¹) though had smaller individual boll mass (weight) and fewer bolls plants⁻¹, however, the increased number of plants compensated for fewer boll number and smaller boll size and cumulatively yield output was higher under high population density. These results are in agreement with reports of Bhalerao *et al.*, (2012), Paslawar *et al.*, (2015), and Sankaranarayanan *et al.*, (2018).

Seed cotton yield was significantly influenced by varying fertilizer regimes. Fertilizer regime of 120:60: 60 NPK kg ha⁻¹ was significantly superior over 60:30:30 NPK kg ha⁻¹ and on par with 90:45:45 NPK kg ha⁻¹ during 2013-14. During 2014-15, fertilizer regime of 120:60:60 NPK kg ha⁻¹ recorded significantly higher seed cotton yield as compared to both lower fertilizer regimes (90:45:45 and 60:30:30 NPK kg ha⁻¹). Similar trend as of 2014-15 prevailed in pooled analysis also. The increase in seed cotton yield was to the extent of 10.7% and 17.1% during 2013-14 and 14.4% and 24.6% in 2014 with increase in fertilizer regimes to 90:45:45 and 120:60: 60 NPK kg ha⁻¹, respectively compared to the lowest fertilizer regime of 60:30:30 NPK kg ha⁻¹. In pooled data, corresponding increase in seed cotton yield was to the extent of 12.2 and 20.2% with increase in fertilizer regimes. Significant increase in seed cotton yield with increase in fertilizer regime was the result of associated increase in various growth and yield attributing characters *viz.* plant height, number of monopodia and sympodia branches, leaf area which produced more photosynthates and that had reflected in higher dry matter, number of bolls, boll weight, seed cotton yield plant⁻¹ and ultimately higher seed cotton yield. The above results also corroborate the findings by Singh *et al.*, (2014) and Hargilas and Saini (2018).

Table.1 Influence of weather variability, plant density and fertilizer regime on plant height (cm) of cotton

	2013-14					2014-15				
	30 DAE	60 DAE	90 DAE	120D AE	At harvest	30 DAE	60 DAE	90 DAE	120 DAE	At harvest
Main plot treatment										
A) Weather variability										
S₁- Monsoon sowing	24.50	54.02	63.74	66.52	69.05	18.13	32.08	43.06	45.99	47.59
S₂- Late sowing	16.83	33.33	49.50	55.04	58.67	15.55	30.41	38.95	40.47	42.18
SE(m)±	0.47	1.04	1.03	1.17	1.48	0.40	0.43	0.52	0.58	0.65
CD (P=0.05)	1.47	3.28	3.23	3.68	4.67	1.25	1.36	1.62	1.83	2.05
B) Plant density										
P₁- 60 X 15 cm(1,11,111 plants ha⁻¹)	19.04	41.84	54.96	58.90	63.39	16.03	29.59	39.63	42.65	44.10
P₂- 60 X 10 cm(1,66,666 plants ha⁻¹)	20.62	42.02	55.34	59.12	61.49	16.71	32.09	41.03	43.38	45.65
P₃- 45X 10 cm (2,22,222 plants ha⁻¹)	22.33	47.17	59.57	64.31	66.70	17.77	32.07	42.35	43.67	44.89
SE(m)±	0.57	1.28	1.26	1.43	1.82	0.49	0.53	0.63	0.71	0.80
CD (P=0.05)	1.81	4.02	3.96	4.51	NS	NS	1.67	1.99	NS	NS
Sub plot treatment										
Fertilizer regime										
F₁- RDF (60:30:30 NPK kg ha⁻¹)	19.45	40.41	53.11	56.86	60.54	15.76	29.17	38.47	40.86	42.96
F₂-150%RDF(90:45:45 NPK kg ha⁻¹)	21.01	44.44	57.54	61.60	65.14	17.13	31.53	41.07	43.64	45.03
F₃-200%RDF(120:60:60 NPK kg ha⁻¹)	21.53	46.18	59.21	63.88	65.90	17.63	33.04	43.48	45.20	46.65
SE(m)±	0.39	1.05	1.26	1.33	1.32	0.27	0.51	0.65	0.58	0.56
CD (P=0.05)	1.15	3.05	3.67	3.88	3.86	0.79	1.50	1.89	1.70	1.64
Interaction										
S X P										
SE(m)±	0.81	1.80	1.78	2.02	2.57	0.69	0.75	0.89	1.01	1.13
CD (P=0.05)	2.55	NS	NS	NS	NS	NS	NS	NS	NS	NS
SX F										

SE(m)±	0.56	1.48	1.78	1.88	1.87	0.38	0.73	0.92	0.83	0.80
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P X F										
SE(m)±	0.68	1.81	2.18	2.30	2.29	0.47	0.89	1.12	1.01	0.98
CD (P=0.05)	1.99	NS	NS	NS	NS	NS	NS	NS	NS	NS
SX P X F										
SE(m)±	0.97	2.56	3.08	3.26	3.24	0.66	1.26	1.59	1.43	1.38
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
GM	20.66	43.68	56.62	60.78	63.86	16.84	31.25	41.01	43.23	44.88

Table.2 Plant height as influenced by S X P interaction at 30 DAE during 2013-14

S/P	P₁	P₂	P₃
S₁	21.73	24.02	27.33
S₂	16.36	17.21	16.93
S.E. (m)±	0.81		
CD (P=0.05)	2.56		

Table.3 Plant height as influenced by P X F interaction at 30 DAE during 2013-14

P/F	F₁	F₂	F₃
P₁	17.53	19.90	19.70
P₂	20.15	21.47	20.23
P₃	20.67	21.67	24.67
S.E. (m)±	0.68		
CD (P=0.05)	1.99		

Table.4 Influence of weather variability, plant density and fertilizer regime on sympodial branches plant⁻¹

Treatment	2013-14				2014-15			
	60 DAE	90 DAE	120 DAE	At harvest	60 DAE	90 DAE	120 DAE	At harvest
Main plot treatment								
A) Weather variability								
S ₁ - Monsoon sowing	7.69	8.63	9.28	9.39	5.36	5.99	6.61	7.01
S ₂ - Late sowing	5.50	6.36	7.38	7.82	4.64	5.62	5.87	5.96
SE(m)±	0.13	0.14	0.22	0.19	0.08	0.10	0.10	0.14
CD (P=0.05)	0.41	0.45	0.68	0.61	0.27	0.31	0.33	0.44
B) Plant density								
P ₁ - 60 X 15 cm (1,11,111 plants ha ⁻¹)	7.03	7.90	8.88	9.13	5.22	6.06	6.60	6.73
P ₂ - 60 X 10 cm (1,66,666 plants ha ⁻¹)	6.46	7.41	8.40	8.73	5.05	5.90	6.20	6.65
P ₃ - 45X 10 cm (2,22,222 plants ha ⁻¹)	6.29	7.17	7.71	7.95	4.74	5.46	5.92	6.08
SE(m)±	0.16	0.17	0.26	0.24	0.10	0.12	0.13	0.17
CD (P=0.05)	0.51	0.55	0.83	0.75	0.33	0.38	0.40	0.54
Sub plot treatment								
Fertilizer regime								
F ₁ - RDF (60:30:30 NPK kg ha ⁻¹)	6.02	6.78	7.89	8.13	4.42	5.44	5.76	6.03
F ₂ -150%RDF (90:45:45 NPK kg ha ⁻¹)	6.80	7.70	8.42	8.68	4.97	5.83	6.26	6.52
F ₃ -200%RDF(120:60:60 NPK kg ha ⁻¹)	6.96	8.00	8.68	9.00	5.62	6.13	6.71	6.92
SE(m)±	0.12	0.22	0.21	0.20	0.16	0.11	0.12	0.19
CD (P=0.05)	0.36	0.65	0.60	0.59	0.45	0.32	0.36	0.54
Interaction								
S X P								
SE(m)±	0.23	0.25	0.37	0.33	0.15	0.17	0.18	0.24
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.57	NS
SX F								
SE(m)±	0.17	0.31	0.29	0.29	0.22	0.16	0.17	0.26
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
P X F								
SE(m)±	0.21	0.38	0.36	0.35	0.27	0.19	0.21	0.32
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
SX P X F								
SE(m)±	0.30	0.54	0.50	0.50	0.38	0.27	0.30	0.46
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
GM	6.59	7.49	8.33	8.60	5.00	5.80	6.24	6.49

Table.5 Number of sympodial branches plant-1 as influenced by S X P interaction at 120 DAE during 2014-15

S/ P	P ₁	P ₂	P ₃
S ₁	7.24	6.56	6.02
S ₂	5.96	5.84	5.82
S.E. (m)±	0.18		
CD (P=0.05)	0.57		

Table.6 Influence of weather variability, plant density and fertilizer regime on yield attributing characters and seed cotton weight plant-1 (g)

Treatment	2013-14			2014-15		
	No. of picked bolls plant ⁻¹	Boll weight (g)	Seed cotton weight plant ⁻¹ (g)	No. of picked bolls plant ⁻¹	Boll weight (g)	Seed cotton weight plant ⁻¹ (g)
Main plot treatment						
A) Weather variability						
S ₁ - Monsoon sowing	5.88	2.47	12.46	4.92	2.40	9.91
S ₂ - Late sowing	4.83	2.40	10.84	3.98	2.29	8.30
SE(m)±	0.12	0.02	0.34	0.07	0.03	0.25
CD (P=0.05)	0.38	0.06	1.06	0.21	0.08	0.79
B) Plant density						
P ₁ - 60 X 15 cm (1,11,111 plants ha ⁻¹)	6.16	2.48	14.14	5.24	2.43	10.75
P ₂ - 60 X 10 cm (1,66,666 plants ha ⁻¹)	5.13	2.43	11.26	4.32	2.35	8.62
P ₃ - 45 X 10 cm (2,22,222 plants ha ⁻¹)	4.78	2.39	9.55	3.78	2.26	7.95
SE(m)±	0.22	0.09	0.41	0.08	0.03	0.31
CD (P=0.05)	0.70	NS	1.30	0.26	0.10	0.97
Sub plot treatment						
Fertilizer regime						
F ₁ - RDF (60:30:30 NPK kg ha ⁻¹)	4.96	2.40	10.37	4.06	2.30	8.34
F ₂ -150%RDF (90:45:45 NPK kg ha ⁻¹)	5.42	2.43	11.93	4.47	2.35	9.14
F ₃ -200%RDF(120:60:60 NPK kg ha ⁻¹)	5.69	2.46	12.65	4.81	2.38	9.84
SE(m)±	0.11	0.02	0.34	0.10	0.03	0.19
CD (P=0.05)	0.32	NS	1.00	0.28	NS	0.56
Interaction						
S X P						
SE(m)±	0.21	0.03	0.58	0.12	0.04	0.43
CD (P=0.05)	NS	NS	NS	0.37	NS	NS
SX F						
SE(m)±	0.15	0.03	0.48	0.14	0.04	0.27
CD (P=0.05)	NS	NS	NS	NS	NS	NS
P X F						
SE(m)±	0.19	0.04	0.59	0.17	0.05	0.33
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SX P X F						
SE(m)±	0.27	0.06	0.84	0.24	0.07	0.47
CD (P=0.05)	NS	NS	NS	NS	NS	NS
GM	5.36	2.43	11.65	4.45	2.35	9.11

Table.7 Number of picked bolls plant-1 as influenced by S X P interaction during 2014-15

S/ P	P ₁	P ₂	P ₃
S ₁	5.80	4.91	4.04
S ₂	4.67	3.73	3.53
S.E(m)±	0.12		
CD (P=0.05)	0.37		

Table.8 Seed cotton yield and stalk yield as influenced by the weather variability, plant density and fertilizer regime

Treatment	Seed cotton yield (kg ha ⁻¹)			Stalk yield (kg ha ⁻¹)		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Main plot treatment						
A) Weather variability						
S ₁ - Monsoon sowing	1846	1359	1602	4096	2933	3514
S ₂ - Late sowing	1467	1071	1269	3445	2390	2917
SE(m)±	32	19	22	106	44	66
CD (P=0.05)	101	61	68	335	139	207
B) Plant density						
P ₁ - 60 X 15 cm (1.11 lakh plants ha ⁻¹)	1328	1041	1185	2818	1948	2383
P ₂ - 60 X 10 cm (1.66 lakh plants ha ⁻¹)	1682	1195	1439	3819	2847	3333
P ₃ - 45 X 10 cm (2.22 lakh plants ha ⁻¹)	1959	1409	1684	4674	3190	3932
SE(m)±	39	24	26	130	54	81
CD (P=0.05)	124	75	83	410	170	254
Sub plot treatment						
Fertilizer regime						
F ₁ - RDF (60:30:30 NPK kg ha ⁻¹)	1516	1075	1296	3452	2362	2907
F ₂ -150%RDF(90:45:45 NPK kg ha ⁻¹)	1678	1230	1454	3789	2668	3229
F ₃ -200%RDF(120:60:60 NPK kg ha ⁻¹)	1775	1340	1558	4070	2955	3512
SE(m)±	38	17	21	79	59	54
CD (P=0.05)	112	49	61	231	172	159
Interaction						
S X P						
SE(m)±	56	34	37	184	76	114
CD (P=0.05)	NS	106	NS	NS	240	NS
SX F						
SE(m)±	54	24	29	112	84	77
CD (P=0.05)	NS	NS	NS	NS	NS	NS
P X F						
SE(m)±	66	29	36	137	102	94
CD (P=0.05)	NS	NS	NS	NS	NS	NS
SX P X F						
SE(m)±	94	41	51	194	145	133
CD (P=0.05)	NS	NS	NS	NS	NS	NS
GM	1657	1215	1436	3770	2662	3216

Table.9 Seed cotton and stalk yield (kg ha⁻¹) as influenced by S X P interaction during 2014-15

S/ P	Seed cotton yield			Cotton stalk yield		
	P ₁	P ₂	P ₃	P ₁	P ₂	P ₃
S ₁	1139	1390	1547	2208	3234	3357
S ₂	943	1001	1270	1687	2461	3023
S.E(m)±	34			76		
CD (P=0.05)	106			240		

Interaction effect of weather variability and plant density (S X P) was found significant during 2014-15 (Table 9). Remaining interaction effects were non significant during 2013-14, 2014-15 and in pooled analysis. The treatment combination of S₁P₃ (monsoon sowing with plant density of 45 X 10 cm, 2.22 lakh plants ha⁻¹) recorded significantly highest seed cotton yield (1547 kg ha⁻¹).

Stalk yield

Data on cotton stalk yield as influenced by different treatments are presented in Table 8. Cotton stalk yield was significantly decreased with the late sowing. Significantly higher stalk yield of cotton was recorded in monsoon sowing (4096 and 2933 kg ha⁻¹) as compared to late sowing (3445 and 2390 kg ha⁻¹). Similar trend of the result was observed during 2013-14, 2014-15 and in pooled data (3514 and 2917 kg ha⁻¹). Hallikeri *et al.*, (2009) and Pinky Patel *et al.*, (2016) also observed that early sown crop recorded higher stalk yield over the subsequent late sowing. High population density of 45 X 10 cm (2.22 lakh plants ha⁻¹) recorded significantly highest stalk yield (4674, 3190 and 3932 kg ha⁻¹) followed by 60 X 10 cm (3819, 2847 and 3333 kg ha⁻¹) and 60 X 15 cm (2818, 1948 and 2383 kg ha⁻¹) during 2013-14, 2014-15 and in pooled result. Similar results were also observed by Hake (2017) and Kharagkharate *et al.*, (2017). The concurrent increase in fertilizer regimes resulted in significant increase in stalk yield over its preceding lower levels during both the years and in pooled data. Significantly highest stalk yield was observed in 120:60:60 NPK kg ha⁻¹ followed by 90:45:45 NPK kg ha⁻¹ and least stalk yield in 60:30:30 NPK kg ha⁻¹. Application of higher quantity of fertilizer, increased vegetative attributes and accumulation of dry matter plant⁻¹ was higher. These results are in conformity with findings of Hiwale *et al.*, (2016).

Weather variability and plant density interaction (S X P) was found significant in respect of stalk yield during 2014-15 (Table 9). The interaction of S₁P₃ i.e. monsoon sowing with plant density of 45 x 10 cm (2.22 lakh plants ha⁻¹) recorded significantly higher stalk yield (3357 kg ha⁻¹) and it was on par with treatment combination of S₁P₂ (monsoon sowing with plant density of 1.66 lakh plants ha⁻¹).

It is concluded that plant height, no. of monopodia and sympodial branches, no. of bolls, boll wt., seed cotton yield plant⁻¹ were significantly higher in monsoon sowing. Growth attributes and yield attributes was also found higher in plant density of 1,11,111 plants ha⁻¹. Fertilizer regimes of 120:60:60 NPK kg ha⁻¹ recorded maximum plant height, no. of monopodia and sympodia, no. of bolls and seed cotton yield plant⁻¹. Pooled seed cotton and stalk yield was significantly higher in monsoon sowing, 200% plant density (2.22 lakh ha⁻¹) and in 200% RDF (120:60:60 NPK kg ha⁻¹).

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