Plant Archives Vol. 26, No. 1, 2026 pp. 227-232 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.1.030

GROWTH AND YIELD ATTRIBUTES OF HIGH-DENSITY COTTON IN PIGEONPEA-BASED INTERCROPPING SYSTEM

Durgam. Venkatesh[1*], C. Sudha Rani[2], C. Sudhakar[2], T. Ram Prakash[1] and K. Supriya[1]

[1]College of Agriculture, PJTAU, Rajendranagar, Hyderabad-500030, Telangana, India

[2]Agricultural Research Station Tandur, Vikarabad-501141, Telangana, India

*Corresponding author E-mail:durgamvenkateshswaero@gmail.com

(Date of Receiving-17-11-2025; Date of Revision-28-12-2025; Date of Acceptance-05-02-2026)

ABSTRACT

The Research is undertaken to evaluate the growth and yield attributes of high-density cotton under pigeonpea-based intercropping, with the objective of identifying compatible planting geometry and understanding crop interactions. The experiment was conducted at Agricultural Research Station (ARS) Tandur, Vikarabad during *Kharif* 2023-24 and 2024-25. The experiment was laid out in a split-plot design with three replications. Main plots with three different high density cotton spacing and sub plots (six) with varying levels of nitrogen and growth regulators, Among the main plots 60 cm × 15 cm (M_1) recorded the maximum dry matter production, but the number of bolls per plant, boll weight was observed with high density cotton spacing of 100 × 15 cm (M_3) during 2023-24, 2024-25 and mean results, among the sub plots highest dry mater production, number of bolls per plant, boll weight was observed with application of 125%RDN+Mepiquat chloride 50 ppm at square formation and flowering stage (S_3), however it was performing on par with treatments received 100 %RDN+Mepiquat chloride 50 ppm at square formation and flowering stage (S_2) and with application of (125%RDN+Cycocel 60ppm at square formation and flowering stage) (S_6) during 2023-24, 2024-25 and mean data.

***Key words*:** paired row Pigeonpea, high-density cotton, growth regulators, nitrogen management, mepiquat chloride, Cycocel

Introduction

Cotton (*Gossypium hirsutum* L.) is one of the most significant commercial cash crops and a major fibre crop of global importance, cultivated across more than seventy countries worldwide. It is popularly known as the "White Gold" or the "King of Fibres" due to its crucial role as a raw material that contributes substantially to employment generation and foreign exchange earnings. India accounts for the largest share of cotton acreage, occupying nearly 11.4 million hectares, and recorded a production of 29.7 million bales with an average productivity of 440 kg ha^{-1} during the same period. In Telangana, cotton was cultivated over 1.8 million hectares during 2024-25, yielding 5.7 million bales with a productivity of 543 kg ha^{-1} (Indiastat.com, 2024). The relatively low productivity of cotton in India, particularly in Telangana, is largely due to the predominance of rainfed cultivation systems. Although research evidence suggests that cotton performs better on heavy soils (Kavya *et al.*, 2022), farmers in Telangana predominantly grow cotton under rainfed conditions on light-textured soils that are shallow, low in fertility, and highly susceptible to soil and water erosion, resulting in reduced yields. Additionally, practices such as mono-cropping, sub-optimal plant population, imbalanced fertilizer use, delayed sowing caused by late monsoon onset, and the occurrence of intermittent as well as terminal dry spells further contribute to lower cotton productivity.

Plant density plays a very important role in deciding the growth & development and yield of cotton. In cotton, high density planting is a modern approach, for attaining high productivity, which needs critical planning, proper time of sowing, careful monitoring and prompt investigations. It is one of the best alternative production system with a scope to increase productivity, profitability, resource (inputs) use efficiency, high B C ratio and also reduce the problems associated with present production system of India. (Venugopalan *et al.,* 2013). Spatial arrangement of compact and short statured plants by agronomic manipulation of row spacing with increased plant density can obtain higher yield. There is better light interception, greater leaf area, low weed competition and earliness in crop maturity by adoption of ultra-narrow row spacing cotton (Wright *et al.,* 2011).

Whenever the plants per unit area are increased, plants will grow taller and the vegetative growth will be high that leads to inter plant competition for various resources and affect the harmonious balance between vegetative and reproductive stage of cotton. The translocation of sufficient photosynthates are required for proper square, boll development, boll retention and finally the yield. In order to overcome these problems, the source-sink relationship such as leaf-boll connections should be balanced. Plant growth regulators (PGR) are modern day agrochemicals, when applied in lower concentration, alter plant development by promoting or retarding the plant natural growth. Mepiquat chloride and Cycocel application makes the plants compact and helps to produce sufficient photosynthates that are required for proper boll development, boll retention and good harvest.

Paired row Pigeonpea-based intercropping systems with high-density cotton represent a strategically designed cropping pattern that integrates the complementary growth habits of Pigeonpea and cotton to maximize land productivity and resource use efficiency (Potdar *et al.,* 1996). In these systems, Pigeonpea is sown in paired rows with adequate intra-pair spacing, often with the wider spaces between pairs utilized to accommodate high-density cotton rows. This arrangement allows for cultivating two crops simultaneously on the same land, leveraging the vertical structure and deep-rooting ability of Pigeonpea alongside the rapid canopy development and economic yield potential of high-density cotton. (Bhardwaj *et al.,* 2023)

Materials and Methods

The experiment was conducted at Agricultural Research Station (ARS) Tandur, Vikarabad, Telangana. The farm is geographically situated at an altitude of 350 m above mean sea level at 17º 22’ N latitude, 77º 58’ E longitude, in the Southern Agro-climatic zone of Telangana. According to Troll’s climatic classification, it falls under semi-arid tropics (SAT).

Crop Establishment and Treatment Details

The experimental plot was clay loamy soil, slightly alkaline in reaction, medium organic carbon, low available nitrogen, high available phosphorus and medium available potassium, respectively.

The experiment was laid out in a split-plot design during *kharif* 2023-24 and 2024-25. The main plot treatments consisted of high density cotton spacing in paired row pigeonpea*viz.,* M_1: Paired row of Pigeonpea intercropped with high density planting of cotton at 60 cm × 15 cm (1,11,111 plants ha^{-1}), M_2: Paired row of Pigeonpea intercropped with high density planting of cotton at 75 cm × 20 cm (66,666 plants ha^{-1}), M_3: Paired row of Pigeonpea intercropped with high density planting of cotton at 100 cm × 15 cm (66, 666 plants ha^{-1}) and sub plot treatments were consists of growth regulators and nitrogen management (S_1: 100% RDN + Mepiquat chloride 50 ppm at square initiation, peak square formation and flowering stage, S_2: 100% RDN + Mepiquat chloride 50 ppm at square formation and flowering stage, S_3: 125% RDN + Mepiquat chloride 50 ppm at square formation and flowering stage, S_4:100% RDN + Cycocel 60 ppm at square initiation, peak square formation and flowering stage, S_5:100% RDN + Cycocel 60 ppm at square formation and flowering stage, S_6: 125% RDN + Cycocel 60 ppm at square formation and flowering stage are replicated thrice.

ADB-39 cotton variety and TDRG 59 pigeonpea variety were selected for the experiment and sown by dibbling at different spacings of high-density cotton. First paired row of pigeonpea was sown with spacing of 45 cm and the space between the two paired rows of pigeonpea was 3 metres and in between the two paired rows of pigeonpea, 60 cm × 15 cm (5 rows of high density cotton), 75 cm × 20 cm (4 rows of high density cotton), and 100 cm × 15 cm (3 rows of high-density cotton) of high density cotton were grown during both years of the experiment. Recommended dose of fertilizers (RDF) of pigeonpea is 20:50:00 NPK kg ha^{-1}. Pigeonpea RDF of 20 kg of N and 50 kg of P_2O_5 were applied as urea and single super phosphate respectively as basal dose to the all the plots of pigeonpea as per treatments. Weeds were controlled by spraying pre-emergence herbicide, pendimethalin @ 0.75 kg *a.i.* ha^{-1} second day of sowing followed by manual weeding at 40 and 70 DAS during both years of study (*kharif*, 2023-24 and 2024-25). The incidence of sucking pests was controlled by spraying Fipronil 5% SC @ 4 ml lit^{-1}. Later stages Imidacloprid @ 0.45 ml L^{-1}. To check the incidence of bollworms (*Pectinophora gossipella*), spraying was done with

Chlorantraniliprole (10%) + Lambdacyhalothrin 5% ZC @ 0.5 ml lit^{-1} at boll development stage in 2023-24. Emamectin benzoate 5 % SG @ 0.5 g L^{-1} was sprayed against bollworms at 105 DAS and 120 DAS in 2024-25.

Statistical Analysis

Data on different characters, *viz.*, growth, yield attributes, yield, soil and plant analysis, and economics, were subjected to analysis of variance procedures as outlined for split-plot design (Gomez and Gomez, 1984). Statistically significance was tested by F-value at p=0.05 (5 %) level of probability and critical difference was worked out where ever the effect was significant. Non-significant treatment differences were denoted as NS.

Results and Discussion

Dry Matter Production (kg ha^{-1})

The data indicated that, high density cotton spacing of 60 cm × 15 cm (M_1) registered significantly highest dry matter production of (1516, 1341 and 1428 kg ha^{-1}) at 60 DAS, (3795, 3615 and 3705 kg ha^{-1}) at 90 DAS, (5502, 5389 and 5445 kg ha^{-1}) at 120 DAS, (6482, 5988, and 6235 kg ha^{-1}) at harvest during 2023-24, 2024-25 and in the mean data results, respectively. The rest of the treatments with high density cotton spacing of 75 cm × 20 cm (M_2) and 100 cm × 15 cm (M_3) were comparable with each other during both years and in the mean data results, respectively.

Among sub-plot treatments data revealed that, significantly highest dry matter production of (1518, 1355 and 1436 kg ha^{-1}) at 60 DAS, (3786, 3614 and 3700 kg ha^{-1}) at 90 DAS, (5479, 5355 and 5417 kg ha^{-1}) at 120 DAS (6429, 5926 and 6178 kg ha^{-1}) at harvest was recorded with application of 125%RDN+Mepiquat chloride 50 ppm at square formation and flowering stage (S_3) during 2023-24, 2024-25 and in the mean results, respectively. However, it was statistically at par with application of 100% RDN + Mepiquat chloride 50 ppm at square formation and flowering stage (S_2) and with application of 125% RDN+Cycocel 60ppm at square formation and flowering stage (S_6) during both years and in the mean data results. On the other hand, the lowest dry matter production of (1273, 1114 and 1194 kg ha^{-1}) at 60 DAS, (3418, 3236 and 3327 kg ha^{-1}) at 90 DAS, (4680, 4548 and 4614 kg ha^{-1}) at 120 DAS, (5456, 5032 and 5243 kg ha^{-1}) at harvest was observed with plots received 100% RDN + Cycocel 60 ppm at square initiation, peak square formation and flowering stage (S_4) during 2023-24, 2024-25 and in the mean data results, respectively.

Results revealed that significantly highest dry matter production was recorded with high density cotton spacing of 60 cm × 15 cm (M_1) in paired row of Pigeonpea as compared to rest of the treatments, this might be due increased plant population per unit area, leading to greater canopy, enhanced light interception and improved photosynthetic efficiency and overall increased biomass production per unit area. The individual plant biomass production may be less due to competition for resources. Similar findings were reported by Sowmiya and Sakthivel, (2021), they also reported that increased dry matter production in narrow spacing may be due to more accumulation of dry matter in leaves, stem, and reproductive parts. Similar results were reported by Darawsheh *et al.*, (2007), they also reported that, higher dry matter production of cotton at narrow spacing may

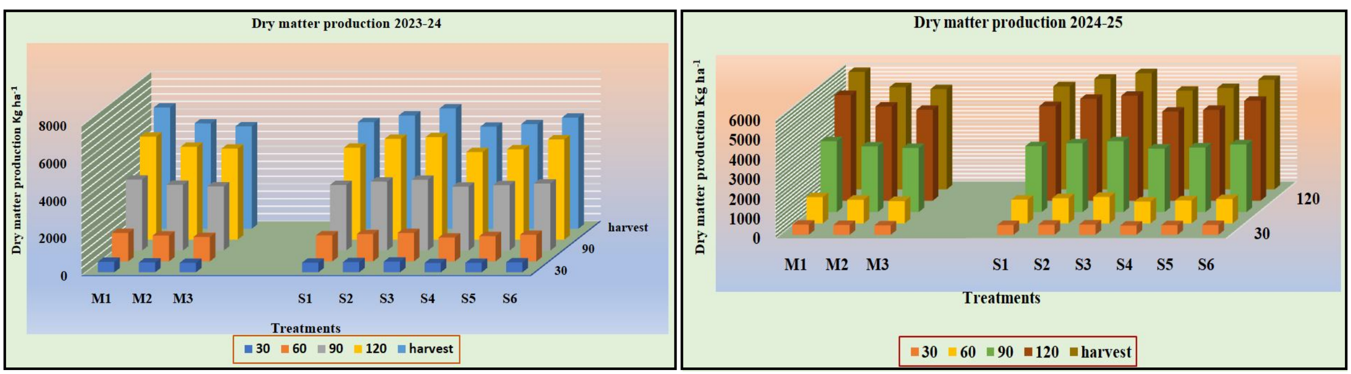

Fig. 1: Dry matter production of high density cotton in paired row of pigeonpea as influenced by growth regulators and nitrogen management during 2023-24 and 2024-25. [**M_1**: Paired row of Pigeonpea intercropped with high density planting of cotton at 60 cm x 15 cm (111,111plants ha^{-1}). **M_2**:Paired row of Pigeonpea intercropped with high density planting of cotton at 75 cm x 20 cm(66,666plants ha^{-1}). **M_3**: Paired row of Pigeonpea intercropped with high density planting of cotton at 100 cm x 15 cm (66,666plants ha^{-1}). **S_1**: 100% RDN + Mepiquat chloride 50 ppm at square initiation, peak square formation and flowering stage. **S_2**:100%RDN+Mepiquat chloride 50 ppm at square formation and flowering stage. **S_3**:125%RDN+Mepiquat chloride 50 ppm at square formation and flowering stage. **S_4**:100% RDN + Cycocel 60 ppm at square initiation, peak square formation, and flowering stage. **S_5**:100%RDN+Cycocel 60 ppm at square formation and flowering stage. **S_6**:125%RDN+Cycocel 60ppm at square formation and flowering stage].

Table 1: Yield attributes of high-density cotton in Pigeonpea-based intercropping system as influenced by growth regulators and nitrogen management.

Treatments	No. of bolls per plant			Boll weight (g)			Seed index (g)		
	2023-24	2024-25	Mean	2023-24	2024-25	Mean	2023-24	2024-25	Mean
Main plots									
M_1	13.7	11.8	12.7	3.18	3.09	3.13	8.43	8.21	8.32
M_2	17.3	15.1	16.2	3.41	3.34	3.37	8.61	8.35	8.48
M_3	18.4	17.1	17.8	3.59	3.48	3.53	8.81	8.55	8.68
SE(m)±	0.52	0.49	0.26	0.07	0.06	0.05	0.19	0.14	0.10
CD(p=0.05)	2.02	1.93	1.01	0.24	0.29	0.21	NS	NS	NS
Sub plots									
S_1	15.3	13.4	14.4	3.28	3.21	3.25	8.61	8.33	8.47
S_2	18.1	16.1	17.1	3.51	3.47	3.49	8.70	8.50	8.6
S_3	19.3	17.2	18.3	3.63	3.54	3.58	8.81	8.56	8.68
S_4	14.1	12.3	13.2	3.18	3.04	3.11	8.42	8.14	8.28
S_5	14.9	13.0	13.9	3.25	3.16	3.21	8.52	8.28	8.4
S_6	17.3	15.7	16.5	3.47	3.41	3.44	8.62	8.40	8.51
SE(m)±	0.92	0.74	0.60	0.11	0.12	0.08	0.22	0.22	0.21
CD(p=0.05)	2.67	2.15	1.74	0.31	0.33	0.22	NS	NS	NS
Interaction									
M×S									
SE(m)±	1.60	1.37	1.04	0.19	0.20	0.13	0.39	0.43	0.37
CD(p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
S×M									
SE(m)±	1.55	1.34	0.99	0.17	0.18	0.11	0.40	0.42	0.35
CD(p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

be related to the better distribution of plant photosynthates.

Among sub-plots, significantly highest dry matter production was recorded with application of 125% RDN + Mepiquat chloride 50 ppm at square formation and flowering stage (S_3). This might be due to the more nutrient demand of cotton under high density planting system, it was also responsive to higher dose of application of nitrogen as compared to 100% RDN. Increased nitrogen application helps in significant improvement of green leaves per plant, sympodial branches and photosynthetic activity that resulted in higher dry matter production. Similar findings were reported by the Malik *et al.*, (2019) and Patel *et al.*, (2021).

Number of Bolls Per Plant

The examination of data among main plots indicated that the effect of high-density cotton spacing was significant concerning the number of bolls per plant during both years and in the mean results. The highest number of bolls per plant (18.4, 17.1 and 17.8), highest boll weight (3.59, 3.48 and 3.53 g) was recorded with high density cotton spacing of 100 cm × 15 cm (M_3) over the rest of the cotton spacings during 2023-24, 2024-25 and in the mean results, respectively. The lowest number of bolls per plant (13.7, 11.8 and 12.7) were recorded with high density cotton spacing of 60 cm × 15 cm (M_1) during both years and in the mean results, respectively.

Among sub-plot treatments, data revealed that application of 125% RDN + Mepiquat chloride 50 ppm at square formation and flowering stage (S_3) produced significantly highest number of bolls per plant (19.3, 17.2 and 18.3). However, it was comparable with application of 100% RDN + Mepiquat chloride 50 ppm at square formation and flowering stage (S_2) and with application of 125% RDN + Cycocel 60 ppm at square formation and flowering stage (S_6) during both years and in the mean results respectively. The lowest number of bolls per plant (14.1, 12.3 and 13.2) was observed with 100% RDN + Cycocel 60 ppm at square initiation, peak square formation and flowering stage (S_4) during both the years and in the mean results, respectively.

Results revealed that highest number of bolls per plant were recorded with high density cotton spacing of 100 cm × 15 cm (M_3) during both years and in the mean data. This might be due to the lesser competition for water, nutrients, space and sunlight for improved photosynthetic efficiency and more vigorous formation of sympodial branches, which directly correlates to higher boll production per plant. These findings were in agreement with the findings of Hussain *et al.*, (2000), they reported that wider spacing increased the number of bolls per plant, which was due to less competition between plants. Similar results were reported by Nagender *et al.,* (2017). Anbarasan *et al.,* (2023) reported that boll number per plant decreased with closer spacing due to greater inter-plant competition.

Among sub-plots highest number of bolls per plant was recorded with application of 125% RDN + Mepiquat chloride 50 ppm at square formation and flowering stage (S_3) during both years and in the mean results. This might be due to with the application of 125% RDN, that enhanced nitrogen supply resulted in more nutrient availability that allows the plants to sustain more sympodial branches and set a greater number of bolls per plant. Similar results were reported by Srikala *et al.* (2023) and Bharathi *et al.,* (2018). Prince *et al.,* (2000) stated that Mepiquat chloride application results in more photosynthetic efficiency and that helps to retain bolls even on lower branches. The similar results were also reported by Malik *et al.,* (2019), they reported that maximum number of bolls per plant was observed at 125% recommended dose of nitrogen, which was on par with 150% recommended dose of nitrogen.

Boll Weight (g)

The data among main plots indicated that boll weight (g) was not significantly influenced by high-density cotton in paired row of Pigeonpea. However, highest boll weight (3.59, 3.48 and 3.53 g) was observed with high density cotton spacing of 100 cm × 15 cm (M_3) during 2023-24, 2024-25 and in the mean results, respectively. The lowest boll weight (3.18, 3.09 and 3.13 g) was observed with high density cotton spacing of 60 cm × 15 cm (M_1) during both years and in the mean results, respectively.

Among the sub-plots, application of 125%RDN+Mepiquat chloride 50 ppm at square formation and flowering stage (S_3) recorded significantly highest boll weight (3.63, 3.54 and 3.58 g). However, it was statistically at par with application of 100% RDN + Mepiquat chloride 50 ppm at square formation and flowering stage (S_2) and with application of 125%RDN+Cycocel 60ppm at square formation and flowering stage (S_6) during both the years and in mean results. On the other hand, the lowest boll weight (3.18, 3.04 and 3.11 g) was recorded with 100% RDN + Cycocel 60 ppm at square initiation, peak square formation and flowering stage (S_4) during both years and in the mean results, respectively.

Results revealed that highest boll weight was recorded with high density cotton spacing of 100 cm × 15 cm (M_3). The increased boll weight may be attributed to reduced competition among plants for water, nutrients and light, which enabled more efficient utilization of available resources. This, in turn, promoted higher photosynthetic activity and enhanced translocation of assimilates to the developing bolls. Similar findings were reported by Devraj *et al.,* (2011) and Maheswari *et al.,* (2019), they reported that an increase in boll weight might be due to higher interception of solar radiation, better utilization of available nutrients and lesser competition for moisture which resulted in higher photosynthetic activity. Reductions in plant-to-plant spacing decreased boll weight due to intense competition for nutrients, water and light under higher plant density as reported by Nagender *et al.,* (2017) and Patel *et al.,* (2021).

Among sub-plots higher boll weight was observed with application of 125% RDN + Mepiquat chloride 50 ppm at square formation and flowering stage (S_3) during both years and in the mean results. This might be due to higher nitrogen levels that have been associated with increased boll weight, indicating a better source-sink relationship facilitated by an adequate nitrogen supply. When the time of split application of nitrogen coincides with application of mepiquat chloride, that also increases boll weight. Similar findings were reported by Devi *et al.,* (2018a) and Srikala *et al.,* (2023). Foliar application of mepiquat chloride found to have more boll weight due to the better partitioning of photo assimilates into reproductive parts. Similar findings are in agreement with the reports of Maheswari *et al.,* (2019) and Malik *et al.,* (2019).

Seed Index (g)

The seed index (g) was remained statistically unaffected by high density cotton spacing in main plots, growth regulators and nitrogen management in sub-plots treatments and their interaction also found to be non-significant during both years and in the mean data. This may be due to increased photosynthetic activity, which in turn increases the accumulation of metabolites and has a direct impact on the seed index. Similar findings are reported by Sawan *et al.,* (2006).

Conclusion

It is concluded that intercropping of paired row pigeonpea intercropping system, high-density cotton spacing of 60 × 15 cm (M_1) in paired row pigeonpea recorded the highest dry matter production, but the lower number of bolls per plant, boll weight and seed index. Among the subplots, application of 125% RDN + Mepiquat chloride 50 ppm at square formation and flowering stage (S_3) recorded the highest dry matter production, number of bolls per plant, boll weight and seed index as compared to the rest of the treatments during both 2023-24, 2024-25 and in mean data. The lowest growth and yield attributes were recorded with the application of 100% RDN + Cycocel 60 ppm at square initiation, peak square formation and flowering stage (S_4). It is concluded that high density cotton in paired row pigeonpea was performing well, with highest growth and yield attributes of high-density cotton, with the application of growth regulators and the recommended dose of nitrogen during both years of the experiment.

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