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Research Paper

Incidence of insect-pests in response to plant density and nutrient levels in *Desi* cotton (*Gossypium arboreum*) under rainfed condition

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ABSTRACT

The field experiment was conducted to study the effect of spacing and nutrients on insect-pests infestation on compact *desi* cotton (*Gossypium arboreum*) grown under rainfed condition during *kharif* seasons of 2019–20 to 2021–22 at the Main Cotton Research Station, Navsari Agricultural University, Surat. The experiments were carried out in factorial randomized block design with nine treatment combinations with three replicates comprised of three levels of spacing viz., 60 cm × 15 cm, 60 cm × 30 cm and 120 cm × 45 cm and three nutrient levels, viz. 120, 150 and 180 kg N/ha. The population of sucking pests viz., leafhopper, thrips, whitefly and mealy bug as well as open boll and locule damage by bollworms was recorded significantly lower in plant density at normal (recommended) spacing, 120 cm × 45 cm and *vice a versa*. Only the aphid population was found significantly lowest in closer spacing (60 cm × 15 cm). Amongst nitrogen levels, there was a significant difference with respect to N levels and the highest population of sucking pests as well as open and locule damage was recorded at N level of 180 kg N/ha. With respect to treatment combinations, there was no significant difference in sucking pests (aphids, thrips, whitefly and mealybugs) and open boll and locule damage amongst different treatment combinations of spacing and nitrogen levels. However, the treatment combination comprising the spacing of 120 × 45 cm and 120 kg N/ha recorded significantly lowest population of leafhopper followed by treatment combination of spacing 120 cm × 45 cm with nitrogen level of 150 kg/ha. Hence, proper interventions for leafhopper control is required when compact *desi* cotton was sown at closer spacing under rainfed condition.

Key words: Desi cotton, bollworms, nutrient, spacing, sucking pests

Cotton (*Gossypium arboreum*) is an important commercial crop in India and stands first in the world with a production of 377.2 lakh bales and grown in an area of 13 m ha. However, India's average productivity is about 439 kg lint/ha combining both irrigated and rain fed situations, which is much lower than the world average of 581 kg lint/ha (Anon., 2023) Cotton largely cultivated under rainfed situations resulting in is low productivity in India. Under this context, the concept of 'High-Density Planting System' (HDPS) in cotton that is ideally suitable for both rainfed and irrigated ecosystems has the potential of improving the yield by increasing the plant population by 3 to 4 folds over recommended 18,518 plants/ha. This concept of HDPS is widely adopted by several countries such as China, Brazil, Uzbekistan, Australia, Argentina and many others where in a plant population of 1,00,000 to 2,00,000 per hectare is maintained and a high seed cotton yield of 40 to 50 q/ha is realized. The high density planting system is analternate production system having a potential for improving the productivity and profitability, increasing input use efficiency, reducing input costs and minimizing the risks associated with the current cotton production system in India (Venugopalan *et al.*, 2014). Increasing plant density in cotton is a potential method for improving cotton yields and net profits (Rossi *et al.*, 2004).

Compact cotton varieties provide a great scope to mechanize the cotton cultivation which is a labour intensive and increase the profitability. Compact genotypes are ideally suited for machine pickings and high density planting because of their short stature, lesser vegetative growth, fewer and shorter fruiting branches, short inter branch and inter boll distance and synchronous maturity (Coffey and Davis, 1981). Due to their earliness it can be harvested in two or three pickings (Patil *et al.*, 2007). Cotton plants require the same mineral elements but quantity vary with crop, variety, climate and soil characteristics. It is necessary to find whether the demand for nutrients is greater under high density planting system (HDPS) with higher plant densty. So, to sustain the cotton productivity with economic and environmental safety, there is a need to optimize

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the nutrient requirement for *Gossypium arboreum* of compact variety.

The incidence and development of insect pests is dependent on the prevailing physical environmental factors and crop stand. The sucking pests and bollworms are major threats to cotton production under normal planting. Changes in plant density modify the microclimate and this may alter the incidence of pests and diseases (Venugopalan *et al.*, 2014). However, there was concern over the fact that altered micro-climate under high density planting would aggravate insect-pests and diseases. Studies on the influence of high density planting system and different nutrient levels in cotton on insect pest incidence across agro ecological systems are scanty. Hence, the study was taken up to explore the impact of HDPS with different nutrient levels on pest incidence in cotton. Keeping these points in view, field investigation under irrigated conditions was carried out to know the sucking pest and bollworm reaction with different planting geometry with varrable nutrient levels to get a sustained higher yield under the HDPS system.

MATERIALS AND METHODS

The present study on the incidence of sucking pests and bollworm in high density planting system (HDPS) of cotton was conducted during *kharif*, 2019–20 to 2021–22 seasons at (located at 2012' latitude and 7252' longitude).The experiment was carried out in factorial randomized block design with popular cotton variety GN.Cot.29 (Semi compact, bushy plant type, small boll variety) at three different spacing (60 x 15 cm, 60 x 30 cmand 120 x 45 cm) and three nutrient levels (120 kg N/ha, 150 kg N/ha and 180 kg N/ha). The experiment was repeated thrice with an individual plot size of 32.40 sq. m area; buffer distance of 1.5 m was maintained between adjacent plots. The crop was grown following all recommended agronomic practices exceptnutrient levels and plant protection measures. Sowing was done on 26-06-2019 during *kharif*, 2019, 10-06-2020 during *kharif*, 2020 and on 19-06-2021 during *kharif*, 2021. No insecticidal sprays were given during all the seasons. Observations on insect pests were recorded on five randomly selected plants in each plot at 10 days interval starting from 20 days after sowing. Number of aphids, Jassid, thrips, whiteflies were recorded on three leaves one each from top, middle and bottom of the plant. Mealy bug was recorded in grade from whole plant basis. Incidence of bollworm was recorded at harvest on the basis of open boll damage and locule damage. Mean of the observations recorded on insect pests across the seasons was calculated and the data were transformed using square root and arc sign transformation before effecting statistical analysis. The collected data were subjected to the analysis.

RESULTS AND DISCUSSION

The influence of different spacing i.e. 60 cm × 15 cm, 60 cm × 30 cm and 120 cm × 45 cm and nutrient levels i.e. 120 kg N/ha, 150 kg N/ha and 180 kg N/ha on the incidence of sucking pests and bollworms was observed during 2019–20 to 2021–22. The aphid population was above ETL in closer spacing and higher level of nutrients during *kharif*, 2019 to 2021. The highest number of aphid (38.09, 38.51 and 37.82 per three leaves) were observed in 120 cm × 45 cm spacing during 2019, 2020 and 2021, respectively. While it was 32.40, 32.58 and 31.42 per three leaves during 2019, 2020 and 2021, respectively with higher nutrient level (180 kg N/ha). The least aphid population was observed with closer spacing (18.98, 19.60 and 18.95 per three leaves) and lower level of nutrient (24.44, 24.62 and 23.41 per three leaves) during 2019, 2020 and 2021, respectively (Table 1, 2, 3). The interaction effect of spacing and nutrient level was non significant except *kharif* 2019. On the bases of pooled data, the incidence of aphids decreased with increase in spacing and decreased nutrient levelsin GN.Cot.29 (*Gossypium arboreum*) during *kharif* 2019–20 to 2021–22. The highest number of aphids were observed 38.26 and 32.39 per three leavesat closer (60 cm × 15 cm) spacing and highest nutrient level (180 kg N/ha) respectively,while the lowest 19.24 and 24.41 per three leaves was observed at wider (120 cm × 45 cm) spacing and highest nutrient level (180 kg N/ha) respectively (Table 4). The interaction effect of spacing and nutrient on aphid population was non significant. The present findings are in agreement with Kalaichelvi (2008) and Shwetha *et al.* (2009) who reported that the highest aphid population in cotton grown is observed in closer spacing. There was also conformity with the results of Federico (1978); Cui *et al.* (2004) and Kalaichelvi (2008) who reported higher population of aphid in crop fertilized with the higher doses of nitrogen.

Jassid population was above ETL in closer spacing and higher level of nutrients during *kharif,* 2019 to 2022. During *kharif,* 2019 to 2021, highest number of jassid (6.22, 8.78 and 8.86 per three leaves, respectively) were observed in 60 cm × 15 cm spacing and decreased with increase in row spacing of 120 cm in general, The jassid population was observed maximum (5.18, 6.29 and 6.16 per three leaves, respectively) during *kharif,* 2019 to 2021 in higher nutrient levels (180 kg N/ha). The jassid population was observed least with wider spacing (2.18, 2.49 and 2.63 per three leaves) and lower level of nutrient (3.73, 4.76 and 4.56 per three leaves) during 2019, 2020 and 2021, respectively (Table 1, 2, 3). The interaction effect of spacing and nutrient level was non significant except *kharif* 2019. The pooled data on jassid population indicated that the highest

Table 1. Population of sucking pests and bollworms damage in different plant density and nitrogen levels for *Arboreum* cotton (2019–20)

Treatment	Jassids/3 leaves		Aphids/3 leaves		Thrips/3 leaves		Whitefly/3 leaves		Mealybug (Grade/plant)		Open boll damage (%)		Locule damage (%)	
	OV	TV*	OV	TV*	OV	TV*	OV	TV*	OV	TV*	OV	TV**	OV	TV**
Plant Density (D)														
D_1 (60 cm × 15 cm)	6.22	2.59	18.98	4.40	13.58	3.69	11.31	3.36	1.20	1.30	24.42	29.60	15.08	22.83
D_2 (60 cm × 30 cm)	4.69	2.27	27.07	5.24	9.02	3.07	6.49	2.62	0.67	1.07	19.03	25.84	10.85	19.22
D_3 (120 cm × 45 cm)	2.18	1.61	38.09	6.19	3.56	1.98	1.62	1.42	2.27	0.87	13.21	21.00	8.98	17.42
SEm±	–	0.04	–	0.12	–	0.18	–	0.19	–	0.04	–	0.74	–	0.09
CD (P =0.05)	–	0.13	–	0.36	–	0.53	–	0.56	–	0.11	–	2.21	–	0.27
Nitrogen Levels (N)														
N_1 (120 kg N/ha)	3.73	1.99	24.44	4.93	7.51	2.66	5.56	2.25	0.53	1.00	17.89	24.56	10.87	19.16
N_2 (150 kg N/ha)	4.18	2.11	27.29	5.23	8.64	2.92	6.36	2.45	0.69	1.07	18.79	25.50	11.73	19.93
N_3 (180 kg N/ha)	5.18	2.36	32.40	5.66	10.00	3.16	7.51	2.71	0.91	1.17	19.98	26.38	12.30	20.38
SEm±	–	0.04	–	0.12	–	0.18	–	0.19	–	0.04	–	0.74	–	0.09
CD (P =0.05)	–	0.13	–	0.36	–	NS	–	NS	–	0.11	–	NS	–	0.27
Interaction (D × N)														
D_1N_1	6.13	2.57	33.67	5.83	12.40	3.50	10.40	3.19	1.00	0.22	23.86	29.23	13.81	21.81
D_1N_2	6.13	2.57	35.93	6.02	13.33	3.65	11.07	3.33	1.13	1.27	24.14	29.42	14.94	22.73
D_1N_3	6.40	2.62	44.67	6.71	15.00	3.92	12.47	3.57	1.47	1.40	25.28	30.17	16.48	23.94
D_2N_1	3.73	2.06	24.53	5.00	7.87	2.87	5.33	2.39	0.47	0.98	18.17	25.22	10.08	18.50
D_2N_2	4.60	2.26	25.13	5.06	9.00	3.08	6.53	2.64	0.67	1.08	18.84	25.71	10.97	19.33
D_2N_3	5.73	2.49	31.53	5.66	10.20	3.27	7.60	2.84	0.87	1.17	20.07	26.60	11.50	19.81
D_3N_1	1.33	1.34	15.13	3.95	2.27	1.62	0.93	1.17	0.13	0.79	11.64	19.22	8.72	17.16
D_3N_2	1.80	1.51	20.80	4.61	3.60	2.02	1.47	1.39	0.27	0.87	13.39	21.38	9.28	17.73
D_3N_3	3.40	1.97	21.00	4.63	4.80	2.29	2.47	1.70	0.40	0.94	14.61	22.38	8.93	17.37
SEm±	–	0.07	–	0.21	–	0.31	–	0.32	–	0.06	–	1.28	–	0.15
CD (P =0.05)	–	0.22	–	NS	–	NS	–	NS	–	NS	–	NS	–	0.46

OV, Original mean values; TV* $\sqrt{X + 0.5}$ and TV** Arc sin transformed values

population was found in closer spacing (8.01 per three leaves) and higher nutrient levels (6.00 per three leaves). On the bases of pooled data, the incidence of jassid was observed highest (8.01 per three leaves) at closer (60 x 15 cm) spacing and highest nutrient level (8.01 per three leaves), while the lowest population count of 2.47 and 4.50 per three leaves was observed at wider (120 cm × 45 cm) spacing and highest nutrient level (180 kg N/ha), respectively (Table 4). These results are comparable with Mahalakshmi and Prasad (2018) who reported that seasonal mean population of leafhoppers was 6.67 ± 2.02/3 leaves (mean ±SD) in HDPS as against 5.30 ± 2.08/3 leaves in recommended (wider) spacing. The population of jassid, whitefly and thrips were significantly influenced by plant spacing and decreased with the increase in plant spacing (Muhammad *et al.*, 2006). The maximum population of leafhopper was recorded from those plots where lower dose of fertilizer was applied. The leafhopper population decreased with the application of the highest fertilizer dose. Similar trends of this pest in cotton were also reported by Mohite and Uthamaswamy (1997); Rustamani *et al.* (1999) and Sohail *et al.* (2004).

Regarding occurrence of thrips across different spacing and nutrient level, specific trend was observed in relation to spacing and nutrient level during *karif* 2019 to 2021. The highest number of thrips (13.58, 16.51 and 16.15 per three leaves, respectively during 2019, 2020 and 2021) was observed at 60 cm × 15 cm, while lowest (3.56, 6.87 and 2.63 per three leaves,

Table 2. Population of sucking pests and bollworms damage in different plant density and nitrogen levels for *Arboreum* cotton (2020–21)

Treatment	Jassids/3 leaves		Aphids/3 leaves		Thrips/3 leaves		Whitefly/3 leaves		Mealybug (Grade/ plant)		Open boll damage (%)		Locule damage (%)	
	OV	TV*	OV	TV*	OV	TV*	OV	TV*	OV	TV*	OV	TV**	OV	TV**
Plant Density (D)														
D_1 (60 cm × 15 cm)	3.02	19.60	4.46	16.51	4.11	8.55	2.99	1.27	1.32	21.16	27.36	11.88	8.78	20.12
D_2 (60 cm × 30 cm)	2.44	26.75	5.21	12.49	3.60	5.47	2.42	0.73	1.10	16.67	24.07	8.81	5.62	17.24
D_3 (120 cm × 45 cm)	1.69	38.51	6.22	6.87	2.69	1.40	1.35	0.29	0.88	10.46	18.62	6.50	2.49	14.70
SEm±	0.08	–	0.13	–	0.05	–	0.11	–	0.04	–	0.53	–	–	0.20
CD (P=0.05)	0.25	–	0.40	–	0.14	–	0.33	–	0.11	–	1.58	–	–	0.61
Nitrogen Levels (N)														
N_1 (120 kg N/ha)	4.76	2.18	24.62	4.94	10.16	3.19	4.33	2.06	0.53	0.99	14.29	21.74	8.00	16.24
N_2 (150 kg N/ha)	5.84	2.43	27.67	5.26	11.91	3.47	5.07	2.25	0.78	1.11	16.16	23.52	8.93	17.29
N_3 (180 kg N/ha)	6.29	2.53	32.58	5.69	13.80	3.74	6.02	2.45	0.98	1.20	17.82	24.78	17.82	18.53
SEm±	–	0.08	–	0.13	–	0.05	–	0.11	–	0.04	–	0.53	–	0.20
CD (P=0.05)	–	0.25	–	0.40	–	0.14	–	NS	–	0.11	–	1.58	–	0.61
Interaction (D × N)														
D_1N_1	8.40	2.97	33.73	5.83	15.07	3.94	7.87	2.86	1.07	1.25	19.69	26.32	11.03	19.38
D_1N_2	8.93	3.03	36.80	6.08	16.40	4.11	8.20	2.94	1.27	1.32	20.73	27.07	11.13	19.47
D_1N_3	9.00	3.05	45.00	6.74	18.07	4.30	9.60	3.16	1.47	1.40	23.06	28.68	13.48	21.53
D_2N_1	4.40	2.19	24.67	5.01	10.73	3.35	4.20	2.14	0.47	0.98	15.39	23.07	7.69	16.09
D_2N_2	6.00	2.53	25.20	5.06	12.40	3.59	5.73	2.48	0.73	1.11	16.56	23.99	9.01	17.45
D_2N_3	6.47	2.59	30.40	5.56	14.33	3.85	6.47	2.63	1.00	1.22	18.06	25.13	9.73	18.16
D_3N_1	1.47	1.39	15.47	3.98	4.67	2.27	0.93	1.18	0.07	0.75	7.81	15.84	5.29	13.26
D_3N_2	2.60	1.73	21.00	4.63	6.93	2.72	1.27	1.32	0.33	0.91	11.20	19.50	6.66	14.93
D_3N_3	3.40	1.95	22.33	4.76	9.00	3.08	2.00	1.56	0.47	0.98	12.36	20.53	7.54	15.91
SEm±	–	0.14	–	0.23	–	0.08	–	0.19	–	0.06	–	0.91	–	0.35
CD (P=0.05)	–	NS	–	NS	–	NS	–	NS	–	NS	–	NS	–	NS

OV- Original mean values TV* $\sqrt{X + 0.5}$ and TV** Arc sin transformed values

respectively during 2019, 2020 and 2021) was observed at 120 cm × 45 cm. The maximum thrips population (10.00, 13.80 and 13.19 per three leaves, respectively during 2019, 2020 and 2021) was observed in 180 kg N/ha, while lowest (7.51, 10.16 and 9.23 per three leaves, respectively during 2019, 2020 and 2021) was observed in 180 kg N/ha (Table 1, 2 and 3). The interaction effect of spacing and nutrient level was found statistically non significant. In pooled data, the same trend was found at different spacing and nutrient levels. The pooled data on incidence of thrips was observed highest (15.43 and 12.44 per three leaves) at closer (60 cm × 15 cm) spacing and highest nutrient level, respectively, while the lowest 5.64 and 9.15 per three leaves was observed at wider (120 cm × 45 cm) spacing and lowest nutrient level (120 kg N/ha) respectively (Table 4). Similarly, observations were made that the highest seasonal average population of 5.48 and 5.56 thrips per leaf from narrow plant-to-plant spacing of 75 cm was observed during crop season of 2006 and 2007, respectively and wider plant-to-plant spacing of 105 cm caused significant reduction in thrips population of 4.51 and 4.44 per leaf during 2006 and 2007, respectively (Singh *et al.*, 2015). Muhammad *et al.* (2006) and Shwetha *et al.* (2009) also reported the higher population of thrips in cotton grown at the closer spacing.

Whitefly population was below ETL throughout the experimental period during *kharif*, 2019 to 2021. Mealy bug incidence ranged from 0.67 to 2.27 grade during *kharif*, 2019; 0.29

Table 3. Population of sucking pests and bollworms damage in different plant density and nitrogen levels for *Arboreum* cotton (2021–22)

Treatment	Jassids/3 leaves		Aphids/3 leaves		Thrips/3 leaves		Whitefly/3 leaves		Mealybug (Grade/plant)		Open boll damage (%)		Locule damage (%)	
	OV	TV*	OV	TV*	OV	TV*	OV	TV*	OV	TV*	OV	TV**	OV	TV**
Plant Density (D)														
D_1 (60 cm × 15 cm)	8.86	3.06	18.95	4.41	16.15	4.08	8.62	3.02	1.35	1.36	13.20	21.30	4.29	11.96
D_2 (60 cm × 30 cm)	5.70	2.49	26.23	5.17	12.10	3.55	5.70	2.49	0.82	1.15	8.34	16.79	2.38	8.87
D_3 (120 cm × 45 cm)	2.63	1.77	37.82	6.19	2.63	1.77	1.66	1.47	0.35	0.92	3.50	10.79	1.35	6.68
SEm±	–	0.08	–	0.13	–	0.05	–	0.11	–	0.03	–	0.51	–	0.23
CD (P=0.05)	–	0.25	–	0.40	–	0.15	–	0.33	–	0.10	–	1.52	–	0.69
Nitrogen Levels (N)														
N_1 (120 kg N/ha)	4.56	2.25	23.41	4.89	9.23	3.12	4.08	2.14	0.60	1.05	6.21	14.43	2.00	8.13
N_2 (150 kg N/ha)	5.70	2.49	26.75	5.22	11.20	3.42	4.93	2.33	0.80	1.14	7.91	16.33	2.51	9.11
N_3 (180 kg N/ha)	6.16	2.58	31.42	5.65	13.19	3.70	5.70	2.49	1.01	1.23	9.66	18.11	3.18	10.28
SEm±	–	0.08	–	0.13	–	0.05	–	0.11	–	0.03	–	0.51	–	0.23
CD (P=0.05)	–	0.25	–	0.40	–	0.15	–	NS	–	0.10	–	1.52	–	0.69
Interaction (D × N)														
D_1N_1	8.50	3.00	33.14	5.80	14.63	3.89	7.91	2.90	1.19	1.30	11.35	19.69	3.66	11.03
D_1N_2	8.92	3.07	36.22	6.06	16.06	4.07	8.26	2.96	1.32	1.35	12.82	20.98	3.97	11.49
D_1N_3	9.11	3.10	44.52	6.71	17.82	4.28	9.68	3.19	1.52	1.42	15.56	23.23	5.35	13.38
D_2N_1	4.61	2.26	24.30	4.98	10.39	3.30	4.43	2.22	0.60	1.05	7.14	15.50	1.82	7.76
D_2N_2	6.10	2.57	24.70	5.02	11.96	3.53	6.05	2.56	0.80	1.14	8.24	16.68	2.49	9.08
D_2N_3	6.42	2.63	29.97	5.52	14.02	3.81	6.63	2.67	1.06	1.25	9.73	18.18	2.89	9.79
D_3N_1	1.72	1.49	14.63	3.89	4.25	2.18	1.24	1.32	0.12	0.79	1.99	8.10	0.96	5.61
D_3N_2	2.81	1.82	20.57	4.59	6.52	2.65	1.66	1.47	0.38	0.94	3.87	11.34	1.39	6.76
D_3N_3	3.58	2.02	21.87	4.73	8.68	3.03	2.12	1.62	0.54	1.02	5.00	12.92	1.79	7.68
SEm±	–	0.14	–	0.23	–	0.09	–	0.19	–	0.06	–	0.88	–	0.40
CD (P=0.05)	–	NS	–	NS	–	NS	–	NS	–	NS	–	NS	–	NS

OV- Original mean values TV* $\sqrt{X + 0.5}$ and TV** Arc sin transformed values

to 1.27 grade during *kharif*, 2020 and 0.35 to 1.35 grade during *kharif*, 2021 at different spacing, consistent trend in relation to nutrient levels was observed during 2019 to 2021 (Table 1, 2 and 3). The pooled data on incidence of mealybug was observed highest (1.27 and 0.98 grade) at closer (60 cm × 15 cm) spacing and highest nutrient level, respectively, while the lowest 0.30 and 0.57 grade was observed at wider (120 cm × 45 cm) spacing and lowest nutrient level (120 kg N/ha) respectively (Table 4). Among bollworms damage, open boll damage and locule damage was observed in relation to different spacing and nutrient levels during all years of study. The closer spacing of 60 cm × 15 cm recorded highest open boll damage (24.42, 21.16 and 13.20%, respectively) during 2019 to 2021 while it was found lowest 13.21, 10.46 and 10.79% during 2019 to 2021, respectively with wider spacing. The nutrient level of (180 kg N/ha) recorded the highest locule damage (12.30, 17.82 and 3.18%, respectively) during 2019 to 2021 while it was found lowest 10.87, 8.00 and 2.00 per cent during 2019 to 2021, respectively with nutrient level 120 kg N/ha (Table 1, 2 and 3). On the basis of pooled data, the highest open boll damage was observed at closer spacing (22.30%) and highest nutrient level (18.64%), while it was lowest at wider spacing (11.48%) and lowest nutrient level (15.54%). In pooled data, the highest locule damage was found at closer spacing (12.97%) and highest nutrient level (10.94%), while it was lowest at wider spacing (7.38%) and lowest nutrient

Table 4. Population of sucking pests and bollworms damage in different plant density and nitrogen levels for *Arboreum* cotton (pooled over years)

Treatment	Jassids/3 leaves		Aphids/3 leaves		Thrips/3 leaves		Whitefly/3 leaves		Mealybug (Grade/plant)		Open boll damage (%)		Locule damage (%)	
	OV	TV*	OV	TV*	OV	TV*	OV	TV*	OV	TV*	OV	TV**	OV	TV**
Plant Density (D)														
D_1 (60 cm × 15 cm)	8.01	2.89	19.24	4.42	15.43	3.96	9.53	3.12	1.27	1.33	22.30	28.14	12.97	21.05
D_2 (60 cm × 30 cm)	5.39	2.40	26.73	5.21	11.21	3.40	5.91	2.51	0.74	1.11	17.49	24.69	9.51	17.92
D_3 (120 cm × 45 cm)	2.47	1.69	38.26	6.20	5.64	2.43	1.58	1.41	0.30	0.89	11.48	19.52	7.38	15.68
SEm±	–	0.04	–	0.07	–	0.06	–	0.08	–	0.02	–	0.34	–	0.11
CD (P=0.05)	–	0.12	–	0.20	–	0.18	–	0.23	–	0.10	–	0.95	–	0.32
Nitrogen Levels (N)														
N_1 (120 kg N/ha)	4.50	2.14	24.41	4.92	9.15	2.99	4.84	2.15	0.57	1.01	15.54	22.73	9.00	17.26
N_2 (150 kg N/ha)	5.37	2.34	27.42	5.24	10.70	3.27	5.60	2.34	0.77	1.11	17.10	24.23	9.92	18.22
N_3 (180 kg N/ha)	6.00	2.49	32.39	5.67	12.44	3.54	6.59	2.55	0.98	1.20	18.64	25.39	10.94	19.16
SEm±	–	0.04	–	0.07	–	0.06	–	0.08	–	0.02	–	0.34	–	0.12
CD (P=0.05)	–	0.11	–	0.20	–	0.17	–	0.22	–	0.10	–	0.96	–	0.33
Interaction (D × N)														
D_1N_1	7.71	2.85	33.60	5.82	14.04	3.78	8.78	2.98	1.09	1.26	21.08	27.29	11.95	20.19
D_1N_2	8.09	2.89	36.42	6.05	15.27	3.94	9.20	3.08	1.24	1.31	21.95	27.91	12.52	20.67
D_1N_3	8.22	2.93	44.76	6.72	16.98	4.17	10.62	3.31	1.49	1.41	23.86	29.22	14.45	22.30
D_2N_1	4.27	2.17	24.51	5.00	9.67	3.17	4.69	2.25	0.51	1.00	16.35	23.82	8.51	16.92
D_2N_2	5.60	2.46	25.04	5.05	11.13	3.40	6.13	2.56	0.73	1.11	17.36	24.59	9.68	18.10
D_2N_3	6.29	2.57	30.62	5.58	12.84	3.64	6.91	2.71	0.98	1.21	18.77	25.65	10.34	18.73
D_3N_1	1.51	1.41	15.13	3.94	3.73	2.02	1.04	1.23	0.11	0.78	9.18	17.08	6.54	14.69
D_3N_2	2.42	1.69	20.80	4.61	5.69	2.46	1.47	1.39	0.33	0.91	11.98	20.17	7.57	15.90
D_3N_3	3.49	1.98	21.80	4.71	7.49	2.80	2.22	1.63	0.47	0.98	13.29	21.30	8.05	16.45
SEm±	–	0.07	–	0.12	–	0.10	–	0.13	–	0.03	–	0.56	–	0.20
CD (P=0.05)	–	0.19	–	NS	–	NS	–	NS	–	NS	–	NS	–	NS
SEm± (Y × T)	–	0.12	–	0.22	–	0.19	–	0.24	–	0.06	–	1.04	–	0.33
CD (P=0.05) (Y × T)	–	NS	–	NS	–	NS	–	NS	–	NS	–	NS	–	NS

OV, Original mean values; TV* $\sqrt{X + 0.5}$ and TV** Arc sin transformed values

Table 5. Effect of different plant density and nitrogen levels for *Arboreum* cotton onseed cotton yield

Treatment	Seed cotton yield (kg/ha)			
	2019–20	2020–21	2021–22	Pooled
Plant Density (D)				
D_1, 60 cm × 15 cm	908	944	1,157	1,003
D_2, 60 cm × 30 cm	869	912	1,027	936
D_3, 120 cm × 45 cm	764	759	823	782
SEm±	27.23	27.14	24.64	26.37
CD (P=0.05)	78.31	78.07	70.87	NS
Nitrogen levels (N)				
N_1, 120 kg N/ha	784	787	912	828
N_2, 150 kg N/ha	860	888	1,043	930
N_3, 180 kg N/ha	898	939	1,052	963
SEm±	27.23	27.14	24.64	26.37
CD (P=0.05)	78.31	78.07	70.87	NS
Interaction (D × N)				
D_1N_1	873	857	1,067	933
D_1N_2	927	962	1,184	1,024
D_1N_3	925	1013	1,219	1,052
D_2N_1	791	817	961	857
D_2N_2	866	926	1,072	955
D_2N_3	950	992	1,048	997
D_3N_1	688	688	709	695
D_3N_2	785	775	871	810
D_3N_3	819	814	889	840
SEm±	47.16	47.02	42.68	26.23
CD (P=0.05)	NS	NS	NS	NS
SEm± (Y × T)	-	-	-	1.17
CD (P=0.05) (Y × T)	-	-	-	NS

level (9.00%). The present finding was in confirmation with Butter *et al.*, (1992) who reported that the incidence of bollworms was more in closer spacing (75 cm × 15 cm) in comparison with wider spacing (75 cm × 30 cm).

The highest seed cotton yield was recorded at closer spacing of 60 cm × 15 cm compared to wider spacings due to more number of bolls per unit area. GN. Cot. 29 have recorded the highest seed cotton yield at closer spacing of 60 cm × 15 cm (908, 944 and 1157 kg/ha respectively during 2019, 2020 and 2021) compared to other wider spacings. While it was recorded the highest at higher dose of nutrients (898, 939 and 1,052 kg/ha respectively, during 2019, 2020 and 2021) as compared to lower dose of nutrients. The owing to higher number plants per unit area which contributed more number of bolls per unit area under HDPS (Table 5). These findings are in accordance with those obtained by Giri and Gore (2006); Buttar and Singh (2007); Narayana and Aparna (2011).

The results appear to be typical with regard to the incidence of sucking pests in HDPS cotton, all sucking pests as well as open boll damage and locule damage at harvest have shown increasing trend with decrease in spacing (except aphids) and increase in nutrient levels trend. Regarding yield, the highest yields were recorded at closer spacing and higher nutrient levels than wider spacing and lower nutrient levels.

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