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Impact of High Density Planting and Weed Management Practices on Yield Attributes, Yield and Quality Characters of Bt Cotton

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A B S T R A C T

Vigilant production and economic strategies are important for cotton growing farmers to sustain the productivity due to expanding cost of cultivation and stagnating yields A field experiment was conducted during *kharif*, 2015 to evaluate with four planting densities 55,555 plants ha^{-1}, 1,11,111 plants ha^{-1}, normal planting, and paired row planting, 1,48,148 plants ha^{-1} and 4 weed management practices (pendimethalin 1.0 kg ha^{-1} as PE fb pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 20, 40, 60, DAS, early PoE application of pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 15 DAS fb glyphosate ammomium salt 2.13 kg ha^{-1} at 45 DAS, PE application of pendimethalin 1.0 kg ha^{-1} fb HW at 20 and 45 DAS and unweeded control. Plant density of 1,11,111 plants ha^{-1} (60 cm x 15 cm) produced significantly more kapas yield (3134 kg ha^{-1}), Among the weed management practices, pre emergence application of pendimethalin 1.0 kg ha^{-1} fb PoE tank mix application of pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 20, 40, 60 DAS recorded more kapas yield (3119 kg ha^{-1}) and ginning % and was comparable with two other weed management practices. Plant densities did not influence lint index, ginning % and seed index.

Introduction

Cotton (*Gossypium hirsutum* L.), the 'white gold' or 'money spinner' enjoys a predominant position among all cash crops in India and cultivated since Indus civilization. Cotton is the livelihood for an estimated 60 million Indians including 6 million farmers, mostly small and marginal. Cotton cropping provide 60% of the fibre used in Indian textile industries, supplies more than one million metric ton of cooking oil and another million metric ton of quality animal feed and 40 million metric tons of biomass in the form of cotton stalks. Global demand for cotton consumption continues to grow and was driven by the fiber demands of the fast growing world economies like India and China and the growing world population. It is estimated that, the global demand for cotton will be about 48 million metric tons by 2030 against from current levels of 25 million metric tons. However, considering the issues pertaining to food security and land pressures, the global area under cotton cultivation will largely be constant at the current levels of 34 million hectares (FICCI, 2012).

Almost 95 per cent Indian cotton farmers are being used the genetically modified Bt cotton. But the farmers facing the problem of stagnating yields from Bt cotton hybrids due to increased labour demand, increased labour costs, increased seed costs, and increased costs for cotton picking and nutrient requirements. All these facts point to the dire need for sustainable practices. So, to sustain the productivity, high density planting systems, with narrow and ultra-narrow spacing for rainfed soils and developing suitable management options for improving yields and also to improve input use efficiency is the need of hour. The concept on high density cotton planting, more popularly called Ultra Narrow Row (UNR) cotton was initiated by Briggs *et al.,* (1967). In general, lower plant densities produces high values of growth and yield attributes per plant, but yield per unit area was higher with higher plant densities (Sharma *et al.,* 2001).

However, moderate increase in plant densities may not increase the yield but decrease due to competition between plants for nutrients, water, space and light (Nehra and Kumawat, 2003).

Optimum cotton yield and quality for high-density planting cotton requires good weed control throughout the growing season. The weeds can severely decrease cotton productivity and can negatively affect the lint quality. A number of weed species infest the cotton field includes such as *Cynodon dactylon* (L.) Pers., *Trianthema portulacastrum* L., *Convolvulus arvensis* L., *Cyperus rotundus* L., *Conyza canadensis* L. and *Sorghum halepense* (L.) Pers. can be quoted as the most important examples (Kalivas *et al.*, 2012; Dogan *et al.,* 2014). Four plants of *E. indica* in one meter row of cotton crop were found to decrease number of bolls per plant by 25% and the cotton yield by >20% (Xiao-Yan *et al.,* 2015). HDPS will provide a soil canopy in about 30 days as compared to 60-75 days for conventional row widths, which will shade out weeds and reduce their competitiveness. In view of the above, present research work carried out with the objective to find out the effect of High Density Planting System (HDPS) and weed management practices on on yield and quality of Bt cotton.

Materials and Methods

A field experiment was conducted during *kharif*, 2015 at College farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The farm is geographically situated at an altitude of 542.6 m above mean sea level on 18’ 50^o N latitude and 77.53^o E longitude The soil of the experimental field was sandy loam in texture, low in available N (250 kg ha^{-1}), medium in phosphorus (21.68 kg P_2O_5 ha^{-1}) and high in potassium (685.6 kg K_2O ha^{-1}).

The experiment was conducted to test the impact of four planting densities 55,555 plants ha^{-1} (60 cm×30 cm), 1,11,111 plants ha^{-1} (60 cm×15 cm) normal planting, 1,11,111 plants ha^{-1} (60 cm×15 cm) paired row planting, 1,48,148 plants ha^{-1} (45 cm×15 cm) and weed management practices *viz*., pendimethalin 1.0 kg ha^{-1} as pre emergence fb pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 20, 40, 60, DAS, pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 15

DAS as early post emergence fb glyphosate ammonium salt 2.13 kg ha^{-1} at 45 DAS, pendimethalin 1.0 kg ha^{-1} as pre emergence fb HW at 20 and 45 DAS and unweeded control on yield and quality of *Bt* cotton in randomized block design (factorial), replicated thrice. The crop was sown on 26th June. Other cultural operations and plant protections measures were followed as per the recommendations. During the crop period rainfall of 404.3 mm was received in 28 rainy days in 2015 as against the decennial average of 683.1 mm received in 35 rainy days for the corresponding period. Yield variables include average number of bolls (opened) per plant and unit area, average boll weight. Average boll weight was calculated by dividing the total plant seed cotton yield with respected number of bolls of the plant. Kapas yield per hectare (kg ha^{-1}). Stalk yield (kg ha^{-1}) and harvest index was computed from cotton yield per plot and the data were subjected to statistical analysis and interpretation. Average ginning per cent was calculated treatment wise for four pickings using following formula (Khan *et al.,* 2010).

$$\text{Ginning (\%)} = \frac{\text{Lint yield (Fibre)}}{\text{Seed cotton yield (Fibre+ Seeds)}} \times 100$$

The ginning percent alone does not convey any idea about the total production of fibres hence; lint index was calculated to overcome this drawback by using the following formula given by Panse and Sukhatme (1967).

$$\text{Lint index} - \frac{\text{Weight of 100 seeds x ginning per cent}}{\text{100 – Ginning per cent}}$$

Seed index ensures evaluation of types with properly developed seeds and leads to development of lint index. It was worked out by taking weight of 100 seeds (g) from each net plot after ginning.

Results and Discussion

Yield parameters

Effect of plant densities

Number of opened bolls per plant, average boll weight and seed cotton yield per plant and hectare were significantly influenced by planting density. Cotton planted at 55,555 plants ha^{-1} in wide rows (60 cm x 30 cm) produced more bolls per plant (Table 1). As plant density increased by decreasing intra row and inter row spacing, number of opened bolls per plant decreased as observed in plant density of 1,11,111 plants ha^{-1} (60 cm x 15 cm) normal planting and was significantly superior over 1,11,111 plants ha^{-1} (60 cm x 15 cm) paired row planting, in turn this was on par with 1,48,148 plants ha^{-1} (45 cm x 15 cm) density.

Reduced cotton plant densities typically produce a greater number of bolls outside the first and second position as well as sympodia arising from monopodial branches that may be due to less inter plant competition between cotton plants (Stephenson *et al.,* 2011). However, cotton planted with plant density of 1,11,111 plants ha^{-1} (60 cm x 15 cm) normal planting produced more bolls m^{-2} and proved to be superior over rest of the plant density. This was followed by 1,48,148 plants ha^{-1}(45 cm x 15 cm), this in turn on par with 1,11,111 plants ha^{-1} (60 cm x 15 cm) paired row planting. Significantly less number of bolls m^{-2} was obtained with 55,555 plants ha^{-1} (60 cm x 30 cm) treatment. The results are in conformity with results of Dong *et al.,* (2010), where high plant density increased the number of bolls per unit area relative to low plant densities.

Average boll weight was increased with plant density of 55,555 plants ha^{-1}, and was comparable with 1,11,111 plants ha^{-1} normal and paired row planting, which in turn on par with 1,48,148 plants ha^{-1}. Reductions in plant to plant spacing decreased boll weight due to intense competition for nutrients, water and light at higher plant density (Ogola *et al.*, 2006).

However, Bednarz *et al.*, (2000) accredited decreased boll set and weight due to combined effect of excessive LAI, reduced PPFD (photosynthetic photon flux density) efficiency and reduced mean NAR at higher plant population.

The present results were in conformity with results of Dong *et al.*, (2010), where high plant density reduced the boll weight relative to low plant density.

Effect of weed management practices

More number of boll $plant^{-1}$, number of boll m^{-2} and average boll weight was recorded with pre emergence application of pendimethalin 1.0 kg ha^{-1} fb PoE tank mix application of pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 20, 40, 60 DAS and was on par with pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS and early PoE tank mix application of pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1}at 15 DAS fb directed spray of glyphosate ammonium salt 2.13 kg ha^{-1} at 45 DAS.

These were significantly superior over unweeded control treatment (Table 1). Bolls $plant^{-1}$ was lowest with the unweeded control. This might be due to reduced crop dry matter and increased weed competition as the weeds are allowed freely to compete with cotton plants (Madhu *et al.*, 2014). The increased number of bolls m^{-2} might be due to more weed control efficiency with reduced weed dry matter during critical period of crop weed competition. The reduced boll weight might be due to reduced availability of water, light and nutrients to cotton crop, thereby reduced LAI and crop dry matter leads to the poor portioning of resource to sink (bolls).

Kapas yield (g $plant^{-1}$)

Effect of Plant densities

Cotton planted at 55,555 plants ha^{-1} with wider spacing (60 cm x 30 cm) recorded more kapas yield per plant and was proved superior over rest of the plant densities (Table 1). This was followed by 1, 11,111 plants ha^{-1} (60 cm x 15 cm) normal and paired row planting, plant density of 1,48,148 plants ha^{-1} (45cm x 15cm), recorded the lowest kapas yield $plant^{-1}$. Cotton plant produced more bolls $plant^{-1}$ in wider rows because of substantial space available for growth, more photosynthetic efficiency, frequent availability of water and nutrients, less humidity for efficient control of insect pest attack and boll saving from rottening, which resulted in increase in fruiting points, fruiting period, fruit retention and ultimately greater bolls $plant^{-1}$ and seed cotton yield $plant^{-1}$ (Munir *et al.*, 2015).

However, more kapas yield ha^{-1} was observed with plant density of 1, 11,111 plants ha^{-1} (60 cm x 15 cm) normal planting and was proved superior over rest of the plant densities under study (Table 1). This was followed by 11111 plants ha^{-1} (60 cm x 15 cm) paired row planting, 1,48,148 plants ha^{-1} (45 cm x 15 cm) and 55,555 plants ha^{-1} (60 cm x 30 cm), in turn these two were on par with each other.

More number of bolls m^{-2}, boll weight might have increased the yield in 1, 11,111 plants ha^{-1} normal planting over rest of the densities. Yield increase of 30.31 %, 29.57 % and 17.20 % was observed when plant density was increased to 1,11,111 plants ha^{-1} normal planting from plant density of 55,555 plants ha^{-1}, 1,48,148 plants ha^{-1} and 11111 plants ha^{-1} paired row planting respectively.

Table.1 Yield attributes and yield of Bt cotton under varied plant densities and weed management practices during *kharif*, 2015

Treatment	**Yield attributes and yield**						
Plant densities (D)	Boll No. plant^{-1}	Boll No. m^{-2}	Boll weight (g)	Kapas yield (g plant^{-1})	Yield (Kg ha^{-1})	Stalk yield (Kg ha^{-1})	HI
60 cm×30 cm (55,555)	12	66	5.20	64.00	2184	5,532	27.11
60 cm×15 cm (1,11,111)	10	116	5.20	53.83	3134	9,995	22.58
60 cm×15 cm (1,11,111 Paired row- 45 cm × 75 cm)	8	90	4.89	41.75	2595	8,943	21.83
45 cm×15 cm (1,48,148)	7	100	4.71	35.92	2207	11,387	15.67
S. Em±	0.50	4.17	0.14	2.62	149.43	379.43	1.92
CD (P=0.05)	1.46	12.12	0.41	7.60	433.69	1,101.19	3.46
Weed Management Practices (W)							
Pendimethalin 30% EC 1.0 kg ha^{-1} as PE fb PoE pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 5% EC 50 g ha^{-1} at 20, 40, 60 DAS	12	122	5.42	66.25	3119	11049	22.50
Pyrithiobac sodium 10% EC 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1}at 15 DAS as early PoE fb glyphosate 71% SG 2.13 kg ha^{-1} at 45 DAS	11	110	5.25	58.25	3018	9533	24.41
Pendimethalin 1.0 kg ha^{-1} as PE fb HW at 20 and 45 DAS	12	116	5.16	60.83	3058	10222	24.00
W_4-Unweeded control	2	24	4.18	10.17	925	5054	16.33
S. Em±	0.50	4.17	0.14	2.62	149.43	379.43	1.92
CD (P=0.05)	1.46	12.12	0.41	7.60	433.69	1,101.19	3.38
Interaction (D X W)							
S. Em±	1.01	8.35	0.28	5.24	298.87	758.87	2.46
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

Table.2 Qualitative characters in Bt cotton under varied plant densities and Weed management practices *kharif*, 2015

Treatment	Lint index	Ginning %	Seed index (g)
Plant densities (D)			
60 cm×30 cm (55,555)	9.21	33.84	10.42
60 cm×15 cm (1,11,111)	12.02	37.54	10.33
60 cm×15 cm (1,11,111 Paired row- 45 cm × 75 cm)	8.71	34.37	9.92
45 cm×15 cm (1,48,148)	7.81	33.74	8.08
S. Em±	1.42	2.85	0.881
CD (P=0.05)	NS	NS	NS
Weed Management Practices (W)			
Pendimethalin 30% EC 1.0 kg ha^{-1} as PE fb PoE pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 5% EC 50 g ha^{-1} at 20, 40, 60 DAS	11.60	42.73	11.08
Pyrithiobac sodium 10% EC 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1}at 15 DAS as early PoE fb glyphosate 71% SG 2.13 kg ha^{-1} at 45 DAS	10.49	38.25	11.33
Pendimethalin 1.0 kg ha^{-1} as PE fb HW at 20 and 45 DAS	9.67	40.86	10.50
Unweeded control	5.98	17.66	5.83
S. Em±	1.42	2.85	0.881
CD (P=0.05)	NS	8.29	2.56
Interaction (D X W)			
S. Em±	2.84	5.71	1.761
CD (P=0.05)	NS	NS	NS

Even though, the boll number, boll weight and seed cotton yield $plant^{-1}$ was significantly higher with wider spacing, it could not compensate for the loss in number of plants ha^{-1} and number of bolls m^{-2}, thus recorded lower seed cotton yield ha^{-1} when compared to high density planting. Higher plant density at closer spacing recorded significantly higher seed cotton yield than lower plant density at wider spacing due to significantly more number of bolls m^{-2} and higher plant stand ha^{-1} (Brar *et al.*, 2013).

Stalk yield (kg ha^{-1})

In variance to the kapas yield, significantly higher stalk yield was recorded with 1,48,148 plants ha^{-1} (45 cm x 15 cm) over rest of the plant densities (Table 1). The increased stalk yield at higher density might be due to increased plant population per unit area (Dong *et al.*, 2012). This was followed by 1,11,111 plants ha^{-1} (60 cm x 15 cm) normal planting and paired row planting and were on par with each other. Significantly lower stalk yield was observed with plant density of 55,555 plants ha^{-1}(60 cm x 30 cm).

Effect of weed management practices

Significantly more kapas yield $plant^{-1}$, kapas yield ha^{-1} and stalk yield ha^{-1} was recorded with pre emergence application of pendimethalin 1.0 kg ha^{-1} fb PoE tank mix application of pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 20, 40, 60 DAS and was on par with pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS, which in turn on par with early PoE tank mix application of pyrithiobac sodium 62.5 g ha^{-1} + quizalofop-p-ethyl 50 g ha^{-1} at 15 DAS fb directed spray of glyphosate ammonium salt 2.13 kg ha^{-1} at 45 DAS treatments (Table 1). The lowest kapas yield $plant^{-1}$ was observed with unweeded control treatment. The reduced kapas yield $plant^{-1}$ might be due to poor contribution of harvested bolls, boll weight and seed cotton yield per plant in unweeded control treatment. Similar findings showed that the cotton yield was reduced by 50 to 80 per cent with unchecked weed growth in Bt cotton (Rajendra and Jain, 2004). The increased kapas yield plant^{-1} in other treatments might be due to timely and effective control of weeds by herbicides coupled with cultural methods which resulted in better availability of soil moisture and nutrients. Similar results were reported by Singh *et al.*, (2004) and Gnanavel and Babu (2008) who showed that application of pendimethalin or fluchloralin 1.0 kg ha^{-1} fb one hand weeding at 45 DAS produced significantly higher seed cotton yield. The increased kapas yield due to occurrence of less competition between cotton plants and weeds leading to more number of bolls and resulted in higher seed cotton yield (Madhu *et al.*, 2014). Further, timely and effective control of weeds through herbicides coupled with cultural methods which resulted in better availability of soil moisture and nutrients (Prabhu *et al.*, 2012). Presence of weeds throughout the growing season caused poor crop growth and caused reduced leaf area index and crop dry matter resulted in reduced stalk yield over other weed management practices

Harvest index (%)

Effect of Plant densities

Higher harvest index value (27.11%) was noticed with 55,555 plants ha^{-1} followed by 1,11,111 plants ha^{-1} normal planting and paired row planting. The lowest harvest index was recorded with 1,48,148 plants ha^{-1}. High plant density produced the greatest biological yield but the lowest harvest index (Table 1). Although high plant density increase total plant biomass per unit ground area (biological yield), final reproductive allocation as indicated by harvest index was usually reduced by increased plant density because of luxurious vegetative growth and lower lint yield (Ali *et al.*, 2009). The increased plant density delayed the leaf senescence due to improved leaf photosynthesis, but significantly reduced the boll load. There was a significant negative correlation (r = −0.8014) between boll load and leaf senescence at the onset of boll opening (Dong *et al.*, 2012).

Effect of weed management practices

Higher harvest index was noticed with early PoE tank mix application of pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 15 DAS fb glyphosate ammonium salt 2.13 kg ha^{-1} at 45 DAS and was followed by pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS and pre emergence application of pendimethalin 1.0 kg ha^{-1} fb PoE tank mix application of pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 20, 40, 60 DAS. The lowest harvest index value was recorded with unweeded control treatment due to reduced number of bolls, boll weight and kapas yield plant^{-1}.

Quality characters

The quality characters *viz.*, ginning percentage, lint index and seed index was not affected due to modification of plant densities (Table 2). However weed management practices exert significant influence on ginning percent and seed index. Higher ginning per cent was noticed with pre emergence application of pendimethalin 1.0 kg ha^{-1} fb PoE tank mix application of pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 20, 40, 60 DAS and was on par with pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS and early PoE tank mix application of pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 15 DAS fb directed spray of glyphosate ammonium salt 2.13 kg ha^{-1} at 45 DAS and were significantly superior over unweeded control treatment. But higher seed index values were obtained with early PoE tank mix application of pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1}at 15 DAS fb directed spray of glyphosate ammonium salt 2.13 kg ha^{-1} at 45 DAS, pre emergence application of pendimethalin 1.0 kg ha^{-1} fb PoE application of pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 20, 40, 60 DAS and pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS. The lower seed index values were recorded with unweeded control. Interaction effect of plant densities and weed management practices did not exert any significant influence on any of these parameters.

In conclusion, growing Bt cotton at plant density of 1,11,111 plants ha^{-1} normal planting by adopting spacing of 60 cm x 15 cm, without significant effect on lint index, ginning % and seed index was found to be effective to get significantly higher kapas yield (3134 kg ha^{-1}). pre emergence application of pendimethalin 1.0 kg ha^{-1} fb PoE tank mix application of pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 20, 40, 60 DAS.

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