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Impact of High Density Planting and Weed Management Practices on Weed Density, Weed Drymatter and Yield of Bt Cotton

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ABSTRACT

An experiment was conducted on Bt cotton during kharif, 2015 at College farm, College of Agriculture, Rajendranagar, Hyderabad,india comprised of four population densities 55,555 plants ha^{-1} (D_1-60 cm×30 cm), 1,11,111 plants ha^{-1} (D_2-60 cm×15 cm) normal planting, 1,11,111 plants ha^{-1} (D_3-60 cm×15 cm - 45 cm×75 cm) paired row planting, 1,48,148 plants ha^{-1} (D_4-45 cm×15 cm) and weed management practices (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 (W_1), pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 15 DAS as early post emergence fb glyphosate ammomium salt 2.13 kg ha^{-1} at 45 DAS (W_2), pendimethalin 1.0 kg ha^{-1} as pre emergence fb HW at 20 and 45 DAS (W_3) and unweeded control (W_4) in randomized block design (factorial), replicated thrice. The plant density of normal planting 1,11,111 plants ha^{-1} (60 cm x 15 cm) produced significantly more kapas yield (3134 kg ha$^{-1)}$ with reduced weed drymatter and density over high plant density of 1, 11,111 plants ha^{-1} paired row planting and 1, 48,148 plants ha^{-1}(45 cm×15 cm). However, remaining three plant densities showed comparable yields. 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}) with reduced weed drymatter, and density.

Key words: *High density, Bt cotton,Weed density, Weed drymatter*

INTRODUCTION

India is the second largest producer of cotton in the world after China accounting for about 25.73 per cent of the world cotton production. In India, cotton is being cultivated in an area of 105 lakh ha with production of 351 lakh bales and 568 kg ha-1 productivity[1]. In India, Maharashtra stands first in area of cotton followed by Gujarat and Telangana state. Area in Telangana under cotton is 12.50 lakh ha with production of 48 lakh bales and productivity 653 kg ha^{-1} [1].

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Sustain the cotton productivity in rainfed soils need to practice high density planting systems, with narrow and ultra-narrow spacing. Weed competition is severe during its initial growth stage. Venugopalan *et al*[11]., reported the reduction in yield due to weeds in cotton crop to an extent of 50 to 85 per cent. Jain[3] reported that, weeds remove as high as 48-50 kg N, 8-15 kg P and 48-50 kg K ha^{-1}. Thus, if proper weed control measures are followed, there would be greater availability of nutrients and moisture for the benefit of crop[4].

In cotton First 60 DAS was the most critical period for crop-weed competition, mostly in *kharif* season due to incessant rains, hand weeding and intercultivation become difficult in cotton. Farmers were forced to use herbicides for weed control in cotton. Hence, there is a need for selection of herbicides to control emerging weeds during the crop growth period. So to attain a season long weed control, integration of chemical, mechanical and cultural methods holds a great promise in crop production. Hence, integrated weed management in cotton play important role in increasing crop production. Pre emergence herbicides at recommended doses are generally capable of controlling annual weeds upto a period of 30 days[7].

The concentration of PRE emergence herbicide was decreased beyond 30 days after application, so which effect the increases the weed population. Due to regular monsoon rains farmers were unable to intercultivate which leads to increase the weeds population and compete with crop plants and finally reduce the seed cotton yield. Hence, there is a need to go for sequential application of PRE followed by POE herbicides to manage the late emerging weeds to eliminate weed competition throughout the critical period[7]. 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 Weed density, Weed dry matter and Yield of *Bt* cotton.

MATERIALS AND METHODS

An experiment was conducted during *kharif*, 2015 at College farm, College of Agriculture, Rajendranagar , Hyderabad in telangana state of india, the farm is geographically situated an altitude of 542.6 m above mean sea level on 18’ 50o 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 available phosphorus (21.68 kg P_2O_5 ha^{-1}) and high in available potassium (685.6 kg K_2O ha^{-1}). The treatments comprised of four planting densities 55,555 plants ha^{-1} (D_1-60 cm×30 cm), 1,11,111 plants ha^{-1} (D_2-60 cm×15 cm) normal planting, 1,11,111 plants ha^{-1} (D_3-60 cm×15 cm - 45 cm×75 cm) paired row planting, 1,48,148 plants ha^{-1} (D_4-45 cm×15 cm) and weed management practices (pendimethalin 1.0 kg ha^{-1} as pre emergence fb pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-ethyl 50 g ha^{-1} at 20, 40, 60, DAS (W_1), pyrithiobac sodium 62.5 g ha^{-1}+quizalofop-p-ethyl 50 g ha^{-1} at 15 DAS as early post emergence fb glyphosate ammomium salt 2.13 kg ha^{-1} at 45 DAS (W_2), pendimethalin 1.0 kg ha^{-1} as pre emergence fb HW at 20 and 45 DAS (W_3) and unweeded control (W_4) in randomized block design (factorial), replicated thrice. The crop was sown on 26th June of 2015. Crop prophylactic measures were taken as and when necessary. The weed density and dry matter of weeds were evaluated besides observations on seed cotton yield and the data were subjected for statistical analysis and interpretation. The, important monocotyledonous weeds observed in the experiment were; *Parthenium hysterophorus, Celosiaargentea, Alternanthera paronychioides, Cyperus rotundus, Trianthema portulacastrum, Dactyloctenium aegyptium, Cynodon dactylon, Digera arvensis, Commelina benghalensis, Trichodesma indicum and Euphorbia hirta* were found comprising of broad leaf weeds 12%, grasses 34% and 54% sedges.

RESULTS AND DISCUSSION

Density of Broad Leaf Weeds

Effect of Plant densities

In general the total density of BLW weeds were gradually decreased from 60 DAS to harvest (Table 1). However, at 30, 60, 90 and 120 DAS plant densities did not show any significant influence on density of BLWs but at final harvest significantly lower density of BLWs was recorded with 1,11,111 plants ha^{-1} (D_2) normal planting and was on par with 1, 11,111 plants ha^{-1} (D_3) Paired row planting and plant density of 1,48,148 plants ha^{-1} (D_4). Significantly higher density of BLWs was observed with 55,555 plants ha^{-1} (D_1). This lower density of BLWs at high plant population might be due to smothering effect of crop over the weeds.

Effect of Weed management practices

Weed management practices showed significant influence on density of BLW (Table 1). Significantly lower BLWs density was observed at 30 DAS 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 (W_2), at 60 DAS with pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3) and at 90 DAS 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 (W_1) and were on par with other weed management practices at the respective stages and were significantly superior compared to the unweeded control (W_4) treatment with higher density of BLWs. But at 120 DAS and at final harvest weed management practices did not show any significant influence on density of BLWs. The reduced density of BLWs during early stages was due to selective and non selective herbicide usage to control BLWs along with hand weeding.

Interaction effect

Interaction effect was found to be significant at 60 DAS only where the lowest density of BLWs were observed with plant density of 1,11,111 plants ha^{-1} paired row planting along with application of pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (D_3W_3) and was on par with D_2W_2 and D_4W_3. The highest density of BLWs was observed with D_4W_4 (Table 1a).

Density of Grassy Weeds

Effect of Plant densities

Plant density did not show significant influence on density of grasses at 30, 60, 120 DAS and at final harvest, but at 90 DAS the lowest density of grasses was recorded with 55,555 plants ha^{-1} (D_1), and was on par with 1,48,148 plants ha^{-1} (D_4) and 1,11,111 plants ha^{-1} (D_2) normal planting, in turn this was on par with 1,11,111 plants ha^{-1} (D_3) paired row planting (Table 2).

Effect of Weed management practices

Density of grasses was influenced under various weed management practices (Table 2). Significant decrease in grassy weeds was observed at 30 and 60 DAS 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 (W_2) and was on par 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 (W_1) and pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3) and were significantly superior over unweeded control (W_4) treatment. However, at 30 DAS this showed on par density of grassy weeds 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 (W_1).

However, from 90 DAS to final harvest less grass weed density was observed 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 (W_1) and showed on par density of grassy weeds with W_2 and W_3 at 120 DAS, but at 90 DAS and at final harvest this was significantly superior over pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3) and unweeded control

(W_4) treatments. The highest grass weed population was present in this treatment, the reduced density of grassy weeds in W_1 treatment might be due to treatment imposition with tank mix application of herbicides meant for specific control for BLWs and grasses up to 60 DAS.

Interaction effect

Interaction effect of plant densities and weed management practices on grass weed density was found to be not significant.

Density of Sedges

Effect of Plant densities

Perusal of data at 30, 60, 120 DAS and at final harvest, plant density did not show significant influence on density of sedges but at 90 DAS the lowest density of sedges was recorded with 1,11,111 plants ha^{-1} (D_3-60 cm×15 cm - 45 cm×75 cm) paired row planting and was on par with 1,11,111 plants ha^{-1} (D_2-60 cm×15 cm) normal planting and 1,48,148 plants ha^{-1} (D_4-45 cm×15 cm), which in turn on par with 55,555 plants ha^{-1} (D_1-60 cm×30 cm) data in Table 3.

Effect of Weed management practices

Weed management practices exert significant influence on sedge population at 60 DAS and at final harvest only, at the remaining stages they did not differ significantly (Table 3). But, at 60 DAS and at final harvest reduced sedge population was observed with unweeded control (W_4) treatment and was significantly superior over all other weed management practices except at 60 DAS, where it showed on par sedge population with pendimethalin1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3). The decreased sedge population might be due to dominance of grasses and BLWs.

Interaction effect

Interaction effect of plant densities and weed management practices did not show any significant influence on density of sedges in Bt cotton at all the crop growth stages.

Total Weeds Density (No. m^{-2})

Effect of Plant densities

Plant density showed significant effect on total weed density at 90 DAS only (Table 4). At the remaining stages they did not exert any influence. However, at 90 DAS the lowest total weed density was reported with 1,11,111 plants ha^{-1} (D_2) normal planting and was on par with 1,48,148 plants ha^{-1} (D_4), in turn these were significantly superior over plant density of 55,555 plants ha^{-1} (D_1), but population density of 1,48,148 plants ha^{-1} (D_4) was on par with 1,11,111 plants ha^{-1} (D_3) paired row planting, in turn this was on par with 55,555 plants ha^{-1} (D_1).

Effect of Weed management practices

Among the weed management practices at 30 and 60 DAS less total weed density was observed with pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3) and was significantly superior over 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 (W_2), 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 (W_1) and unweeded control (W_4) treatments at 30 DAS, and only with unweeded control (W_4) treatment at 60 DAS (Table 4).

At 90,120 DAS and at final harvest significantly lower weed density observed 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 (W_2) and showed on par total weed density 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 (W_1), in turn this was on par with pendimethalin 1.0 kg ha^{1} (PE) fb HW at 20 and 45 DAS (W_3) and significantly superior over and unweeded control (W_4) treatment at 90 DAS, whereas at 120 DAS this was on par with other weed management practices under study and were significantly superior over unweeded control (W_4) treatment. However, at harvest W_2 was comparable with pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3) and were significantly superior over 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 (W_1) and unweeded control (W_4). The reduce density in this treatment was might be due to application of non-selective herbicide at 45 DAS. Similar results also reported by Poddar *et al*[8]., with ammonium salt of glyphosate 3.5 l ha^{-1}+1 HW recorded the lesser grasses, sedges and broad leaved weed density.

Interaction effect

Plant density and weed management practices did not show any significant influence on density of total weeds in Bt cotton at all the crop growth stages.

Weed Drymatter

Drymatter of broad leaf weeds

Effect of Plant densities

Plant densities did not exert any significant influence on drymatter of BLWs at all the stages (Table 5).

Effect of Weed management practices

At 30 DAS less drymatter of BLWs was recorded with 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 (W_1) and was on par with pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3) 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 (W_2). These were significantly superior over unweeded control (W_4) treatment with higher drymatter of BLWs (Table 5).

At 60 DAS the lowest and on par drymatter of BLWs was observed with pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3) and early PoE 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 (W_2), this in turn on par with 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 (W_1) treatment.

However, at 90 DAS 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 (W_2) recorded the less drymatter of BLWs and was on par 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 (W_1) and pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3) treatments respectively. Significantly higher drymatter of BLWs was recorded with unweeded control (W_4) at all the stages. But at 120 DAS and at final harvest stage weed management practices did not show any significant influence on drymatter of BLWs.

Interaction effect

Plant densities and weed management practices did not show any significant influence on drymatter of BLWs in Bt cotton at all the crop growth stages.

Drymatter of Grassy Weeds

Effect of Plant densities

Plant density did not affect the grass weed drymatter at 30 and 60 DAS (Table 6). But, at 90 DAS the lowest drymatter of grasses was recorded with 55,555 plants ha^{-1} (D_1) and was significantly superior over 1,11,111 plants ha^{-1} (D_2) normal planting, 1,48,148 plants ha^{-1} (D_4) and 1,11,111 plants ha^{-1} (D_3) paired row planting. However, at 120 DAS significantly less drymatter of grassy weeds was noticed with 1,11,111 plants ha^{-1} (D_2) normal planting and was at par with 1,11,111 plants ha^{-1} (D_3) paired row planting, 1,48,148 plants ha^{-1} (D_4) and 55,555 plants ha^{-1} (D_1). But, at final harvest even though less drymatter of grasses was observed with 1,11,111 plants ha^{-1} (D_2) normal planting and was on par with 1,11,111 plants ha^{-1} (D_3) paired row planting, which in turn on par with 1,48,148 plants ha^{-1} (D_4) and again this was on par with 55,555 plants ha^{-1} (D_1).

Effect of Weed management practices

Weed management practices affect the drymatter of grasses at all the stages (Table 6). At 30 and 60 DAS the less weed dry matter of

grasses was observed 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 (W_2) and was on par 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 (W_1) and pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3). These were significantly superior over unweeded control (W_4) treatment.

But at 90, 120 DAS and at final harvest significant decrease in grass weed dry matter was observed 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 (W_1) and was on par with remaining weed management practices except unweeded control (W_4) treatment at 120 DAS. However, at 90 DAS and at final harvest 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 (W_1) was comparble 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 (W_2), in turn this was on par with pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3) and were significantly better than unweeded control (W_4) treatment, which recorded the highest weed drymatter of grasses at all the stages.

Interaction effect

Plant densities and weed management practices did not show any significant influence on drymatter of grasses in Bt cotton at all the crop growth stages.

Dry Matter of Sedges

Effect of Plant Densities

Plant density did not exert any influence on drymatter of sedges at all the stages except at 90 DAS, where less weed drymatter of sedges was observed with 1,11,111 plants ha^{-1} (D_3) paired row planting, and was on par with 1,11,111 plants ha^{-1} (D_2) normal planting and 1,48,148 plants ha^{-1} (D_4). Significantly more drymatter of sedges was recorded with 55,555 plants ha^{-1} (D_1) (Table 7).

Effect of Weed management practices

Weed management practices showed significant effect on drymatter of sedges at all the stages except at 90 DAS (Table 7). At 30 DAS, less drymatter of sedges was observed with pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3), and was 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 (W_2) treatment. This produced comparable sedge drymatter 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 (W_1) and were significantly superior over unweeded control (W_4) treatment.

However, at 60, 120 DAS and at final harvest significant decrease in drymatter of sedges was noticed with unweeded control (W_4) treatment and was on par with pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3), in turn this was on par 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 (W_1) treatment 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 (W_2) treatment.

At final harvest similar trend was observed, where on par drymatter of sedges was observed with unweeded control (W_4) and pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3) in turn this was on par with 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 (W_2), again this was in turn on par 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 (W_1) treatment. The non-significant drymatter of sedges was due to non-significant sedge density at 90 DAS from the present experiment.

Interaction effect

Plant density and weed management practices did not show any significant influence on drymatter of sedges in Bt cotton at all the crop growth stages.

Drymatter of Total Weeds

Effect of Plant densities

Plant densities did not influence drymatter of total weeds up to 90 DAS, but there after they showed significant effect on weed drymatter (Table 8). At 120 DAS, significantly less dry matter of total weeds was noticed with plant density of 1,11,111 plants ha^{-1} (D_2) normal planting and was on par with 1,11,111plants ha^{-1} (D_3) paired row planting. In turn this was on par with 1, 48,148 plants ha^{-1} (D_4) and 55,555 plants ha^{-1} (D_1). But, at final harvest stage significant decrease in drymatter of total weeds observed with population of 1,11,111 plants ha^{-1} (D_3) paired row planting and was on par with 1,11,111 plants ha^{-1} (D_2) normal planting, in turn this was on par with 1,48,148 plants ha^{-1} (D_4). This was again on par with 55,555 plants ha^{-1} (D_1), which recorded more drymatter at the end of crop growing season. This might be due to sufficient space provided to crop resulted in better nourishment for growth of crop, thereby creating smothering effect on weeds population and its growth[6] (Patel, 2009).

Effect of Weed management practices

Weed management practices showed significant difference in weed drymatter of total weeds at all the stages (Table 8). At 30 DAS, less drymatter of total weeds was observed with pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3) and was 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 (W_2), this in turn on par with 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 (W_1) and was significantly superior over unweeded control (W_4) treatment.

But, at 60, 90, 120 DAS and at final harvest stage less drymatter of total weeds was observed with 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 (W_1) and was on par with pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3) 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 (W_2) at 60 and 120 DAS but at final harvest it was comparable 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 (W_2) and pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3) respectively. These were significantly superior over unweeded control (W_4) treatment, which recorded higher weed drymatter at all the stages. This reduced dry matter in W_1 treatment might be due to imposition of treatment up to 60 DAS using selective broad leaf and grass control herbicides.

Interaction effect

Plant densities and weed management practices did not show any significant influence on drymatter of total weeds in Bt cotton at all the crop growth stages.

Kapas Yield (kg ha^{-1})

Effect of Plant densities

Significant increase in kapas yield was observed with plant density of 1, 11,111 plants ha^{-1} (D_2) normal planting and was superior over rest of the plant densities under study (Table 8). This was followed by 11111 plants ha^{-1} (D_3) paired row planting, 1, 48,148 plants ha^{-1} (D_4) and 55,555 plants ha^{-1} (D_1), in turn these 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} (D_2) 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} (D_2) normal planting from plant density of 55,555 plants

ha^{-1} (D_1), 1,48,148 plants ha^{-1} (D_4) and 11111 plants ha^{-1} (D_3) paired row planting respectively. 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}[1[2]].

Effect of Weed management practices

Higher kapas yield 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 (W_1) and was on par with pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS (W_3) 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 (W_2) and were significantly superior over unweeded control (W_4) treatment. The yield reduction of 70.34% was observed from unweeded control (W_4) treatment (Table 8). Cotton being a widely spaced and relatively slow growing crop during its initial stages suffers from severe weed competition and causing substantial reduction in seed cotton yields[10].

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[5]. Further, timely and effective control of weeds through herbicides coupled with cultural methods which resulted in better availability of soil moisture and nutrients[9].

Table 1: Density of BLW and Grasses in Bt cotton under varied plant densities and weed management practices (*kharif*, 2015)

Treatment	Broad leaf weeds (No. m^{-2})					Grasses (No. m^{-2})				
Plant densities (D)	30 DAS	60 DAS	90 DAS	120 DAS	At harvest	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
D_1-60 cm×30 cm (55,555)	1.73 (3.50)	3.78 (17.33)	3.45 (16.67)	1.86 (4.00)	1.8 (2.83)	5.67 (39.00)	6.35 (68.17)	4.96 (52.67)	5.50 (34.33)	5.01 (30.33)
D_2-60 cm×15 cm (1,11,111)	1.91 (6.00)	3.39 (15.67)	2.07 (6.17)	1.93 (6.00)	1.00 (0.00)	4.48 (29.17)	6.07 (47.67)	7.86 (78.67)	3.91 (22.33)	5.21 (30.67)
D_3-60 cm×15 cm (1,11,111 Paired row- 45 cm × 75 cm)	2.14 (12.33)	3.32 (13.00)	2.18 (6.33)	1.78 (3.33)	1.00 (0.00)	4.64 (31.17)	6.33 (51.00)	9.45 (130.33)	4.69 (32.83)	5.78 (40.50)
D_4-45 cm×15 cm (1,48,148)	2.66 (17.50)	4.23 (25.83)	2.47 (9.67)	1.48 (2.00)	1.2 (0.67)	4.81 (33.83)	5.15 (38.33)	6.74 (74.67)	5.96 (41.00)	5.56 (34.00)
S. Em±	0.57	0.46	0.52	0.38	0.13	0.90	0.95	1.07	0.69	0.50
CD (P=0.05)	NS	NS	NS	NS	0.37	NS	NS	3.09	NS	NS
Weed Management Practices (W)										
W_1-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	1.12 (0.33)	4.16 (20.17)	1.55 (2.33)	1.73 (3.00)	1.00 (0.00)	5.46 (36.83)	3.96 (21.50)	2.28 (7.50)	3.51 (16.83)	3.27 (13.83)
W_2-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	1.06 (0.17)	3.14 (11.33)	1.88 (5.83)	1.91 (4.17)	1.27 (1.00)	3.53 (14.33)	3.68 (20.33)	4.70 (24.00)	4.11 (19.16)	4.55 (21.00)
W_3-Pendimethalin 1.0 kg ha^{-1} as PE fb HW at 20 and 45 DAS	1.19 (0.83)	1.73 (3.83)	2.56 (8.17)	2.14 (7.00)	1.24 (0.83)	3.71 (17.50)	5.75 (40.50)	8.34 (86.00)	4.58 (24.83)	5.86 (38.17)
W_4-Unweeded control	5.06 (38.00)	5.67 (36.50)	4.24 (22.50)	1.29 (1.17)	1.46 (1.67)	6.89 (64.50)	10.5 (122.83)	13.71 (218.33)	7.86 (69.66)	7.87 (62.50)
S. Em±	0.57	0.46	0.52	0.38	0.13	0.90	0.95	1.07	0.69	0.50
CD (P=0.05)	1.66	1.33	1.51	NS	NS	2.62	2.77	3.09	2.02	1.46
Interaction (D X W)										
S. Em±	1.14	0.92	1.04	0.77	0.26	1.80	1.91	2.14	1.39	1.01
CD (P=0.05)	NS	2.67	NS	NS	NS	NS	NS	NS	NS	NS

Table 1a. Interaction effect of plant densities and weed management practices on density of BLWs in Bt cotton (*kharif*, 2015)

Plant densities	Weed management practices				
	W_1	W_2	W_3	W_4	Mean
D_1	38.67	12.67	10.00	8.00	17.33
D_2	12.67	2.00	4.67	43.33	15.67
D_3	14.00	12.00	0.00	26.00	13.00
D_4	15.33	18.67	0.67	68.67	25.83
Mean	20.17	11.33	3.83	36.50	
S. Em±	0.92				
CD (P=0.05)	2.67				

Table 2: Density of sedges and total weeds in Bt cotton under varied plant densities and weed management practices (*kharif*, 2015)

Treatment	Sedges (No. m^{-2})					Density of total weeds (No. m^{-2})				
Plant densities (D)	30 DAS	60 DAS	90 DAS	120 DAS	At Harvest	30 DAS	60 DAS	90 DAS	120 DAS	At Harvest
D_1-60 cm×30 cm (55,555)	9.32 (96.50)	6.12 (52.58)	9.03 (113.83)	3.07 (12.50)	3.07 (35.00)	11.53 (139.00)	11.37 (138.08)	12.83 (183.17)	7.09 (50.83)	8.04 (68.17)
D_2-60 cm×15 cm (1,11,111)	6.83 (63.00)	6.46 (57.50)	4.47 (26.00)	4.73 (31.17)	4.73 (25.17)	9.35 (98.00)	10.31 (120.83)	9.97 (110.83)	7.68 (59.50)	7.38 (55.83)
D_3-60 cm×15 cm (1,11,111 Paired row- 45 cm × 75 cm)	8.38 (79.67)	7.67 (70.00)	4.03 (25.50)	3.79 (21.00)	3.79 (22.17)	10.76 (123.00)	11.60 (134.00)	11.96 (162.17)	7.30 (57.17)	7.93 (62.67)
D_4-45 cm×15 cm (1,48,148)	8.73 (85.33)	9.18 (96.17)	5.69 (52.00)	3.30 (13.67)	3.30 (22.67)	11.15 (137.00)	12.54 (160.00)	10.73 (136.33)	7.43 (56.67)	7.58 (57.33)
S. Em±	0.86	0.99	1.29	0.65	0.63	0.67	0.68	0.59	0.36	0.34
CD (P=0.05)	NS	NS	3.74	NS	NS	NS	NS	1.706	NS	NS
Weed Management Practices (W)										
W_1-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	8.98 (91.33)	9.25 (98.58)	8.61 (78.67)	5.25 (32.50)	5.25 (67.00)	11.1 (129.00)	11.65 (140.00)	9.27 (88.50)	7.25 (52.00)	8.23 (68.00)
W_2-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	9.76 (103.83)	8.50 (82.67)	5.22 (38.67)	3.62 (19.83)	3.62 (24.17)	10.6 (118.00)	10.38 (114.00)	7.80 (65.500)	6.53 (4.003)	6.78 (46.17)
W_3-Pendimethalin 1.0 kg ha^{-1} as PE fb HW at 20 and 45 DAS	6.55 (46.17)	7.18 (61.33)	4.86 (30.83)	3.45 (13.67)	4.42 (12.83)	7.8 (65.00)	10.01 (106.00)	10.81 (125.00)	6.75 (45.00)	7.17 (51.83)
W_4-Unweeded control	7.98 (83.17)	4.50 (33.67)	4.53 (72.17)	2.58 (12.33)	1.59 (1.00)	13.3 (186.00)	13.68 (162.00)	17.60 (313.50)	8.98 (83.00)	8.75 (78.00)
S. Em±	0.86	0.99	1.29	0.65	0.63	0.67	0.68	0.59	0.36	0.34
CD (P=0.05)	NS	2.89	NS	NS	1.84	1.95	1.96	1.70	1.04	0.98
Interaction (D X W)										
S. Em±	1.72	1.99	2.59	1.30	1.27	1.34	1.35	1.18	0.73	0.68
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Drymatter of BLW weeds and Grasses in Bt cotton under varied plant densities and weed management practices (*kharif*, 2015)

Treatment	BLW drymatter (g m^{-2})					Grasses drymatter (g m^{-2})				
Plant densities (D)	30 DAS	60 DAS	90 DAS	120 DAS	At Harvest	30 DAS	60 DAS	90 DAS	120 DAS	At Harvest
D_1-60 cm×30 cm (55,555)	1.86 (4.25)	2.93 (9.58)	2.41 (7.05)	1.79 (5.13)	1.75 (3.88)	4.76 (32.75)	5.80 (56.18)	3.86 (31.79)	7.56 (65.73)	5.82 (38.43)
D_2-60 cm×15 cm (1,11,111)	1.65 (4.00)	2.48 (8.70)	1.93 (5.13)	1.81 (4.88)	1.65 (3.43)	3.29 (14.58)	6.39 (58.60)	6.13 (49.15)	4.50 (30.98)	3.62 (18.30)
D_3-60 cm×15 cm (1,11,111 Paired row- 45 cm × 75 cm)	1.89 (11.25)	2.69 (9.29)	1.89 (6.44)	1.85 (3.85)	1.59 (2.16)	5.74 (45.08)	6.11 (48.57)	7.29 (74.64)	5.73 (44.58)	3.83 (20.45)
D_4-45 cm×15 cm (1,48,148)	2.13 (10.06)	4.02 (22.21)	2.21 (9.59)	1.93 (5.01)	1.40 (1.33)	3.95 (20.67)	4.97 (36.56)	6.85 (57.73)	7.04 (58.33)	5.43 (34.94)
S. Em±	0.55	0.45	0.52	0.47	0.30	0.77	0.87	0.73	0.72	0.56
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	2.13	2.10	1.67
Weed Management Practices (W)										
W_1-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	1.00 (0.00)	3.35 (13.02)	1.49 (2.00)	1.63 (3.62)	1.43 (1.37)	4.85 (30.80)	3.85 (22.03)	2.65 (9.13)	3.66 (19.58)	3.21 (14.68)
W_2-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	1.10 (0.33)	2.49 (7.20)	1.37 (1.42)	2.26 (7.57)	1.90 (4.43)	2.88 (11.30)	3.57 (18.99)	4.32 (22.88)	5.55 (35.70)	3.47 (14.42)
W_3-Pendimethalin 1.0 kg ha^{-1} as PE fb HW at 20 and 45 DAS	1.06 (0.17)	1.46 (2.20)	1.83 (3.29)	1.76 (4.79)	1.47 (3.0)	3.25 (13.48)	5.05 (30.88)	5.91 (41.22)	5.33 (36.0)	4.56 (25.22)
W_4-Unweeded control	4.37 (29.00)	4.82 (27.33)	3.74 (21.51)	1.72 (2.91)	1.57 (2.00)	6.77 (57.50)	10.82 (128.00)	11.25 (140.09)	10.29 (108.35)	7.46 (57.80)
S. Em±	0.55	0.45	0.52	0.47	0.30	0.77	0.87	0.73	0.72	0.56
CD (P=0.05)	1.6	1.31	1.52	NS	NS	2.26	2.54	2.13	2.10	1.67
Interaction (D X W)										
S. Em±	1.10	0.90	1.05	0.95	0.61	1.55	1.75	1.47	1.45	1.13
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4: Drymatter of sedges, drymatter of total weeds and Kapas yield of Bt cotton under varied plant densities and weed management practices (*kharif*, 2015)

Treatment	Sedges drymatter (g m^{-2})					Total weed drymatter (g m^{-2})					Yield Kg ha^{-1}
Plant densities (D)	30 DAS	60 DAS		120 DAS	At harvest	30 DAS	60 DAS	90 DAS	120 DAS	At harvest	
D_1-60 cm×30 cm (55,555)	5.06 (29.55)	2.76 (8.57)	4.97 (36.86)	1.82 (2.98)	1.92 (4.53)	7.54 (66.55)	7.14 (74.34)	7.87 (75.70)	8.29 (73.84)	6.62 (45.90)	2184
D_2-60 cm×15 cm (1,11,111)	3.28 (14.43)	3.13 (12.50)	2.64 (8.59)	2.34 (5.73)	2.49 (7.03)	5.89 (33.02)	7.93 (79.80)	7.23 (63.00)	6.04 (41.60)	5.16 (27.10)	3134
D_3-60 cm×15 cm (1,11,111 Paired row- 45 cm × 75 cm)	3.89 (19.00)	3.74 (17.17)	1.82 (3.30)	2.08 (4.92)	1.93 (3.83)	8.06 (75.33)	8.49 (75.02)	8.17 (84.00)	6.84 (53.36)	5.13 (28.10)	2595
D_4-45 cm×15 cm (1,48,148)	4.84 (24.92)	4.35 (22.26)	2.68 (9.47)	1.90 (3.27)	1.90 (3.57)	6.95 (55.58)	8.67 (81.03)	8.13 (77.00)	7.76 (66.61)	6.29 (41.50)	2207
S. Em±	0.54	0.48	0.67	0.28	0.26	0.57	0.63	0.54	0.52	0.33	149.43
CD (P=0.05)	NS	NS	1.957	NS	NS	NS	NS	NS	1.51	1.00	433.69
Weed Management Practices (W)											
W_1-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	5.57 (34.17)	4.21 (19.77)	3.95 (18.75)	2.62 (6.77)	2.94 (8.47)	7.98 (64.97)	6.56 (54.83)	5.35 (30.00)	5.16 (29.97)	4.85 (24.40)	3119
W_2-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	4.11 (20.83)	4.35 (22.64)	3.18 (12.68)	2.18 (5.01)	2.19 (5.34)	5.45 (32.47)	6.68 (48.83)	5.84 (37.00)	6.68 (48.27)	5.13 (26.69)	3018
W_3-Pendimethalin 1.0 kg ha^{-1} as PE fb HW at 20 and 45 DAS	3.30 (12.38)	3.27 (12.85)	2.39 (6.87)	2.04 (4.05)	1.99 (4.64)	4.89 (26.03)	6.56 (45.95)	6.90 (51.00)	6.44 (44.83)	5.54 (31.19)	3058
W_4-Unweeded control	4.09 (20.52)	2.13 (5.24)	2.60 (19.93)	1.30 (1.07)	1.11 (0.52)	10.13 (107.02)	12.42 (160.57)	13.33 (182.00)	10.51 (112.32)	7.67 (60.32)	925
S. Em±	0.54	0.48	0.67	0.28	0.26	0.57	0.63	0.54	0.52	0.33	149.43
CD (P=0.05)	1.58	1.41	NS	0.82	0.76	1.65	1.83	1.57	1.51	1.00	433.69
Interaction (D X W)											
S. Em±	1.09	0.97	1.34	0.57	0.52	1.14	1.26	1.09	1.04	0.76	298.87
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

CONCLUSION

Plant density of 1, 11,111 plants ha^{-1} (D_2) normal planting was effective to reduce the weed density and drymatter during critical period of crop weed competition.Among the weed management practices either 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 or pendimethalin 1.0 kg ha^{-1} (PE) fb HW at 20 and 45 DAS or 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 was found to be effective to reduce weed density and drymatter during critical period of crop weed competition.

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