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Growth and yield of *Bt* cotton (*Gossypium hirsutum* L.) as influenced by mulching and various weed management practices

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Abstract : During *kharif* 2020 and 2021, a field experiment was conducted at the cotton research area of CCS Haryana Agricultural University, Hisar to study the effect of mulching and various weed management practices on the growth and yield of *Bt* cotton as a tool to determine the best weed management strategy for *Bt* cotton. The experiment was carried out in a factorial randomised block design with three replications included two levels of mulching and seven levels of weed management techniques. It was discovered that using rice straw as mulch at 7.5 t/ha significantly increased plant height, dry matter accumulation, leaf area index, seed cotton yields (3189 and 3084 kg/ha) and its characteristics than without mulch in both years. Among the weed control levels, apart from weed free, pendimethalin (PRE) 1.5 kg/ha *fb* one hoeing at 45 DAS *fb* glyphosate 1 per cent (protected spray) at 90 DAS recorded significantly higher boll wt. (4.4 and 4.2 g) and seed cotton yield (3323 and 3233 kg/ha) as compared to weedy check (1840 and 1757 kg/ha) but *at par* with all other treatments during 2020 and 2021, respectively. However, both mulching and weed management levels failed to show any significant difference in number of monopodia per plant during both years of experiment.

Key words: Cotton, growth, mulching, weed management, yield

Cotton is grown on around 12 million hectares of land in India, which ranks first in the world in output with 34 million bales (each weighing 170 kg). In comparison, the global crop area is 31.6 million hectares, with 113.1 million bales produced. The average cotton productivity in India is 469 kg/ha, which is lower than the global average of 778 kg/ha (Anonymous, 2021). Cotton is widely grown in Karnataka, Madhya Pradesh, Maharashtra, Gujarat, Punjab, Uttar Pradesh, Rajasthan, Haryana, and Tamil Nadu. Maharashtra is the state that produces the most cotton in India, followed by Gujarat and Andhra Pradesh. Haryana's crop area was 6.48 lakh ha, with an output of 1.89 million bales (170 kg) and a lint yield of 497 kg/ha (Anonymous, 2021).

Cotton suffers from significant weed competition since it is a wide-spaced and somewhat slow-growing crop during its early growth phases. The essential period for weed competition was discovered to be 15 to 60 days (Sharma, 2008). This competition can reduce seed cotton yields by as much as 69 per cent. (Srinivasulu and Rao, 2000). Weeds are the main cause of losses in seed cotton output. Weeds hinder the growth and productivity of cotton because they not only compete with the crop for nutrients, light, moisture, space, and energy but also host insects and disease organisms (Papamichail *et al.,* 2002). Early on in its growth, cotton typically needs weed control. Controlling weeds in cotton from planting to 8 weeks may result in a 30- to 40 per cent increase in seed cotton production (Jarwar *et al.*, 2005). In the current agricultural production system, manual weed management without herbicide treatment is the most labor-intensive and unworkable option. In these situations, herbicides have continued to be the key instrument and the cornerstone of the most successful weed control programmes (Zhang 2003, Norsworthy *et al.,* 2012).

When ecological or cultural tactics like mulching are used in conjunction with chemical techniques, weeds can be effectively managed.

Mulching is the process of adding a layer of mulch to the soil surface to promote plant growth. Mulch acts as a physical deterrent for weeds. Mulch is used for a variety of purposes, including weed control (Lamont, 2005). Cultural weed control is time-consuming, laborious, and expensive; chemical weed control is easy, quick, and efficient. Weeds sprout in various periods when there are no cross cultural interactions and consistent monsoon rains, outcompete crop plants, and ultimately lower the yield of seed cotton. To manage late emerging weeds, it is necessary to apply pre emergence herbicides followed by post emergence herbicides in a sequential manner to remove weed competition throughout the critical period (Pawar *et al.*, 2000). According to Singh *et al.,* (2013), herbicides or integrated strategies could be utilised as an alternative to the time-consuming and expensive traditional ways to manage weeds efficiently. Finding novel solutions to the weed infestation issue is now important. One of the best methods to handle this is to adopt weed control strategies that are more effective and affordable, and management techniques like mulching are used to defeat the weeds.

MATERIALS AND METHODS

Site description and experimental setup

The experiment was carried out at cotton research area of CCS HAU, Hisar during *kharif* season 2020 and 2021. It is situated in the sub-tropics at longitude 75°46'E, latitude 29°10'N and altitude of 215.2 m above mean sea level in Haryana. The experimental design used was factorial randomized block design having two factors with different levels replicated thrice. Gross plot size was 8.0 x 9.0 m.

Treatment details and crop management

The experiment was laid out in factorial randomized block design. First factor was different levels of mulching *i.e.* M_1: No mulching, M_2: Mulching with paddy straw 7.5 t/ha and second was weed management *i.e.* W_1: Weedy check, W_2: Weed free, W_3: Pendimethalin (PRE) 1.5 kg/ha *fb* two hoeing at 45 and 90 DAS, W_4:Two hoeing at 30 and 60 DAS *fb* quizalofop-p-ethyl 62.5 g/ha at 90 DAS, W_5: Two hoeing at 30 and 60 DAS *fb* propaquizafop-p-ethyl 50 g/ha at 90 DAS, W_6: Pendimethalin (PRE) 1.5 kg/ha *fb* one hoeing at 45 DAS *fb* paraquat 0.5% (protected spray) at 90 DAS and W_7: Pendimethalin (PRE) 1.5 kg/ha *fb* one hoeing at 45 DAS *fb* glyphosate 1 per cent (protected spray) at 90 DAS. All the treatments replicated three times. Pre-sowing irrigation was given. At proper moisture condition, Seed bed was prepared by a primary harrowing tillage operation with tractor drawn disc harrow followed by cultivator and planking. Sowing was done by dibbling method on well prepared bed with row to row spacing of 100 cm and plant to plant spacing of 45cm. Thinning was done to keep the good crop stand. Recommended dose of fertilizer for *Bt* cotton was 175:60:60 kg/ha applied in the field. One third quantity of nitrogen, full amount of phosphorus and potassium is supplied through urea, DAP and murate of potash, respectively at the time of sowing. Remaining 2/3 quantity of nitrogen was top dressed in two equal splits; at first and second irrigation. RCH 776 genotype of *Bt* cotton were grown as per the recommended package of practices.

Biometric observations

Plants in each plot were selected randomly as true representative of the whole plot and labelled. The height of five tagged plants was measured periodically from each plot. Two plants were uprooted at ground level from each plot to measure the dry matter accumulation. The samples were first dried under sun and then in an oven at a temperature of 70°C till constant weight were o*bt*ained. For leaf area index, leaves of these plants were used for the measurement of leaf area by using LI-3000 Leaf Area Meter, LICOR Ltd., Nebraska, USA.

Bolls/plant were counted from five tagged plants in each plot by adding the mean number of good and fully opened bolls picked/ plant. Five completely opened bolls from tagged plants/plot were picked randomly, weighed and averaged to obtain boll weight in grams. Monopodial branches in each plot were counted at maturity stage from the five tagged plants and mean was determined and expressed as per plant basis. The sympodial branches are known as the reproductive branches and were counted at maturity stage from the five tagged plants in each plot and expressed as average sympodial branches/plant. After ginning weight of 100 cotton seeds taken randomly from each plot and it was expressed in grams. Total seed cotton harvested from two pickings/plot was registered and expressed as seed cotton yield in kg/ha.

Statistical Analysis

The experimental data recorded for growth, yield and quality characters were subjected to statistical analysis in accordance with the help of "Analysis of Variance" Technique Suggested by Fisher (1950). The critical difference (CD) for the treatment comparisons were worked out wherever the variance ratio (t-test) was found significant at 5 per cent level of probability. The significance of treatment effects was tested with the help of "F" (variance ratio) test. Appropriate standard errors (SE) along with critical differences (CD at 5%) were worked out for differentiating the treatment effects from those of change effects.

$$CD = \sqrt{\frac{2 \text{ Error Variance}}{n}} \times \text{t-value for error d.f. at 5\% level of significance}$$

Where,

CD = is the critical difference.

n = is number of observations of that factor for which CD is to be calculated.

t at 5 per cent = is the value of percentage point of 't' distribution for error degree of freedom at 5 per cent of significance

RESULTS AND DISCUSSION

Growth

Growth is an irreversible process in which there is an increase in size or dry weight or volume. Plants get their energy for growth from the sun through photosynthesis. However, the plant uses its energy depending on the developmental stage and on environmental conditions to produce higher yields. Plant height is a genetically controlled character and ultimate height of a crop or a genotype is dependent on its genetic makeup. Plant height varied significantly under different weed management and mulching levels (Table 1). Cotton crop produced taller plants during first year in comparison to second year. Mulching with rice straw 7.5 t/ha produced significantly taller plants throughout crop growing season than with no mulch throughout the growing season in both the years. This increase in plant height might be due to proper soil moisture availability, less number of weeds and more nutrient uptake by the plant which make favourable environment for better growth and development of plant. The results also get supported by the findings of Ahmad *et al.*, (2015) and Singh *et al.,* (2021). Among the weed management levels, significantly lower plant height was observed in weedy check as compared to other treatments upto 135 DAS. There is no significant effect on plant height was recorded at maturity. However, cotton crop at harvest with weed free showed 18.7 and 21.34 per cent higher plant height than weedy check in first and second year respectively. According to Mahar *et al.,* (2007), plant height of cotton was significantly reduced under untreated check. Considerable reduction in plant height due to weeds was

Table 1: Effect of mulching and weed control treatments on plant height (cm) of *Bt* cotton hybrid

Treatments	Plant height (cm)									
	45 DAS		75 DAS		105 DAS		135 DAS		At harvest	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Mulching levels										
M_1	34	33	98	95	143	136	188	181	208	201
M_2	36	35	104	101	156	147	202	195	221	216
SEm±	**0.56**	**0.55**	**1.47**	**1.53**	**2.85**	**2.89**	**4.11**	**4.23**	**4.24**	**4.8**
CD (p = 0.05)	**1.64**	**1.6**	**4.3**	**4.48**	**8.33**	**8.45**	**12**	**12.37**	**12.39**	**14.14**
Weed management										
W_1	32	30	90	88	126	117	167	160	187	178
W_2	36	34	104	100	155	147	202	195	222	216
W_3	37	35	103	101	152	143	203	196	221	216
W_4	36	34	101	100	153	145	199	192	220	214
W_5	35	34	102	98	155	146	197	192	218	213
W_6	36	34	103	101	153	145	197	190	216	211
W_7	36	34	102	100	152	145	198	191	218	213
SEm±	**1.05**	**1.02**	**2.75**	**2.87**	**5.33**	**5.41**	**7.68**	**7.92**	**7.93**	**12.71**
CD (p = 0.05)	**3.08**	**2.99**	**8.05**	**8.39**	**15.58**	**15.8**	**22.46**	**23.15**	**NS**	**NS**

reported by Khan *et al.,* (2001) and Leela *et al.*, (2016).

The data pertaining to dry matter accumulation at different growth stages are presented in Table 2 for the crop season *kharif* 2020 and 2021. It was clear from the data that there is a continuous increase in dry matter accumulation upto maturity. Mulching had a significant effect on the dry matter accumulation at all the crop growth stages. Mulching with rice straw 7.5 t/ha recorded significantly higher dry matter accumulation than no mulch at different crop growth stages during both the years. Numerically at harvest, dry matter accumulation with mulch was 12.58 and 13.20 per cent higher as compared with no mulch treatment during first and second year, respectively. However during both the years of experimentation, there

Table 2: Effect of mulching and weed control treatments on dry matter accumulation (g $plant^{-1}$) of *Bt* cotton hybrid

Treatments	Matter accumulation (g/plant)									
	45 DAS		75 DAS		105 DAS		135 DAS		At harvest	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Mulching levels										
M_1	4.5	5.3	99.0	96.0	135.5	131.4	290.5	263.8	489.1	459.1
M_2	5.7	6.5	112.9	109.5	157.2	149.6	345.9	317.8	550.7	519.7
SEm±	**0.32**	**0.30**	**2.63**	**2.54**	**4.66**	**4.00**	**14.00**	**13.75**	**18.45**	**18.46**
CD (p = 0.05)	**0.92**	**0.88**	**7.69**	**7.44**	**13.61**	**11.69**	**40.93**	**40.18**	**53.93**	**53.95**
Weed management										
W_1	4.7	5.5	87.8	85.1	113.8	113.6	223.0	198.8	419.1	389.1
W_2	4.5	5.4	112.1	108.8	154.0	146.8	349.1	321.6	538.3	508.3
W_3	5.1	5.6	109.8	106.7	152.6	144.6	342.1	315.5	535.0	505.0
W_4	4.7	5.6	107.6	104.4	150.3	142.5	328.3	298.3	538.3	505.0
W_5	6.1	6.9	108.5	105.1	149.0	145.1	324.5	295.8	533.3	503.3
W_6	5.4	6.2	108.1	104.8	152.1	144.5	322.5	296.6	538.3	508.3
W_7	5.3	6.1	107.6	104.3	153.0	146.5	338.3	309.1	537.0	507.0
SEm±	**0.59**	**0.57**	**4.92**	**4.76**	**8.71**	**7.49**	**26.20**	**25.71**	**34.52**	**34.53**
CD (p = 0.05)	**NS**	**NS**	**14.4**	**13.93**	**25.46**	**21.88**	**76.57**	**75.16**	**NS**	**NS**

was no significant variation among weed management levels in terms of dry matter accumulation at 45 DAS and at harvest. At 75 DAS, 105 DAS and 135 DAS similar pattern was observed, significantly higher dry matter accumulation obtained in weed free as compared to weedy check but significantly at par with all other weed management levels during both years. This might be because weed competition was reduced by mulching and other weed control measures, which encouraged vigorous growth and ultimately enhanced crop dry matter yield. Bukun (2004), Soliman *et al.*, (2013), and Leela *et al.,* (2016) all reported findings that were similar.

Leaf area index (LAI) is the important growth parameter which decides the dry matter production of crop. The data pertaining to leaf area index (Table 3) revealed that the leaf area index in *kharif* 2021 was more than *kharif* 2020. From the data it is amply clear that the leaf area index of cotton crop increased with the advancement of crop growth with a steep increase seen from 75 DAS to 105 DAS. Both the mulching and weed management levels failed to show significant variation in terms of leaf area index at 45 DAS and at harvest. During both the years, leaf area index was recorded significantly higher in cotton crop mulched with rice straw 7.5 t/ha as compared to no mulch at 75 DAS, 105 DAS and 135 DAS. Among the weed management levels, significantly lowest leaf area index was recorded in weedy check at 75 DAS, 105 DAS and 135 DAS in both the crop seasons. This might be probably due to better control of grasses and broad-leaved weeds. Due to intense weed competition for nutrients and light that resulted in small leaves and a decrease in leaf area, the unweeded control had the lowest LAI after 45 DAS. Anjum *et al.*, (2007), Nadanassababady (2001) and Prabhu *et al.,* (2012) all reported similar findings.

Yield and yield attributes

The data on number of bolls per plant at maturity have been presented in Table 4. Critical analysis of data revealed that bolls/plant markedly lower in first year than the second year. Maximum bolls/plant were recorded in cotton crop mulching with rice straw 7.5 t/ha (44.6 and 45.8) which was significantly higher than cotton crop with no mulch (38.5 and 40.3) during both the crop seasons. A decrease in 13.78 per cent in first year and 11.89 per cent in second year was recorded maximum bolls/plant when we compare cotton crop mulching with rice straw

Table 3: Effect of mulching and weed control treatments on leaf area index (LAI) of *Bt* cotton hybrid

Treatments	Treatmentsleaf area index (LAI)									
	45 DAS		75 DAS		105 DAS		135 DAS		At harvest	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Mulching levels										
M_1	0.06	0.06	0.74	0.76	1.80	1.84	2.49	2.54	0.62	0.62
M_2	0.06	0.06	0.82	0.85	2.13	2.17	2.74	2.79	0.68	0.70
SEm±	**0.001**	**0.002**	**0.02**	**0.02**	**0.01**	**0.01**	**0.06**	**0.06**	**0.02**	**0.03**
CD (p = 0.05)	**NS**	**NS**	**0.06**	**0.06**	**0.04**	**0.04**	**0.17**	**0.18**	**NS**	**NS**
Weed management										
W_1	0.06	0.06	0.64	0.66	1.45	1.48	1.84	1.88	0.62	0.65
W_2	0.06	0.07	0.82	0.84	2.06	2.09	2.72	2.77	0.66	0.69
W_3	0.06	0.06	0.79	0.82	1.99	2.02	2.81	2.86	0.66	0.69
W_4	0.06	0.06	0.79	0.81	2.00	2.05	2.89	2.95	0.63	0.56
W_5	0.06	0.06	0.82	0.85	2.05	2.09	2.73	2.77	0.64	0.67
W_6	0.06	0.06	0.78	0.81	2.19	2.23	2.67	2.71	0.67	0.70
W_7	0.06	0.06	0.81	0.85	2.02	2.05	2.64	2.70	0.67	0.70
SEm±	**0.003**	**0.003**	**0.04**	**0.04**	**0.02**	**0.03**	**0.11**	**0.11**	**0.04**	**0.05**
CD (p = 0.05)	**NS**	**NS**	**0.11**	**0.108**	**0.07**	**0.07**	**0.33**	**0.33**	**NS**	**NS**

Table 4: Effect of mulching and weed control treatments on yield and yield attributes of *Bt* cotton hybrid

Treatments	Bolls/ plant		boll wt. (g)		Monopodia /plant^{-1}		Sympodia /plant^{-1}		seed index (g)		seed cotton yield (kg/ha)	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Mulching levels												
M$_1$	38.5	40.3	4.2	4.1	2.1	2.2	34.0	34.9	9.2	8.5	2990	2904
M$_2$	44.6	45.8	4.6	4.2	2.0	1.9	36.0	36.9	9.6	9.1	3189	3084
SEm±	**1.52**	**1.74**	**0.06**	**0.02**	**0.13**	**0.12**	**0.49**	**0.44**	**0.10**	**0.11**	**67**	**55**
CD (p = 0.05)	**4.44**	**5.10**	**0.16**	**0.05**	**NS**	**NS**	**1.43**	**1.29**	**0.29**	**0.31**	**196**	**162**
Weed management												
W$_1$	28.0	28.8	4.0	3.9	2.5	2.5	27.5	28.4	8.73	8.12	1840	1757
W$_2$	45.4	46.9	4.3	4.2	1.5	1.7	37.4	38.2	9.52	8.97	3343	3235
W$_3$	43.7	46.9	4.3	4.1	2.1	2.1	35.4	36.4	9.60	8.95	3217	3133
W$_4$	42.7	44.2	4.4	4.2	2.1	2.1	35.2	36.2	9.58	8.93	3315	3222
W$_5$	43.4	44.4	4.4	4.1	2.0	2.0	36.6	37.6	9.48	8.92	3277	3167
W$_6$	44.4	45.7	4.4	4.2	2.1	2.0	35.3	36.0	9.47	9.05	3308	3213
W$_7$	43.3	44.5	4.4	4.2	2.0	2.0	37.7	38.6	9.50	9.10	3323	3233
SEm±	**2.84**	**3.26**	**0.10**	**0.03**	**0.24**	**0.22**	**0.92**	**0.83**	**0.19**	**0.20**	**125**	**103**
CD (p = 0.05)	**8.30**	**9.53**	**0.30**	**0.09**	**NS**	**NS**	**2.68**	**2.42**	**0.54**	**0.58**	**367**	**303**

7.5 t/ha with crop without mulch. Among the weed management levels, weed free produced maximum bolls/plant (45.4 and 46.9), which was significantly higher than weedy check (28.0 and 28.8) but *at par* with all other treatments. Cotton crop in weed free, thus produced 61.98 per cent (first year) and 62.46 per cent (second year) higher bolls/plant as compared to weedy check. This may be due to mulching in cotton which changes the microclimate of cotton crop and leads to less shedding of bolls. This was well demonstrated by Devi *et al.* (2021).

The data of boll weight of cotton has been presented in the Table 4. It is clear from the data that boll weight is higher during *kharif* 2020 as compared to *kharif* 2021. Between mulching levels, significantly highest boll weight (4.6 and 4.2 g) was recorded in cotton mulching with rice straw 7.5 t/ha as compared to no mulch treatment (4.2 and 4.1 g), respectively during first and second season of crop experimentation. Among the weed management levels, significantly lowest boll weight was obtained in weedy check i.e. 4 g and 3.9 g during first and second year, respectively while all other treatments were statistically *at par* with each other. This might be because weeds that emerge later are better controlled, and a favourable environment is created through intercultural activities and mulching. The outcomes are consistent with Ahmad *et al.,* (2015) research findings.

The data pertaining to monopodial branches/plant of cotton for two seasons are presented in Table 4.5. Both mulching and weed management levels failed to produced significant differences in terms of monopodial branches/plant during both the crop seasons. Numerically, lower (2.0 and 1.9) monopodial branches observed in cotton mulching with rice straw 7.5 t/ha as compared with no mulch treatment (2.1 and 2.2) during both years. Among weed management levels, the highest monopodia/plant observed in weedy check (2.5 and 2.5) and lowest in weed frees (1.5 and 1.7) during first and second year respectively.

The data presented in Table 4 revealed about the sympodia/plant. Cotton produced less sympodial branches/plant in *kharif* 2020 than *kharif* 2021. Between mulching levels, significantly higher sympodia/plant were recorded in cotton crop mulching with rice straw 7.5 t/ha as compared with no mulch treatment. Among the weed management levels, stress due to weeds in cotton crop in weedy check resulted in 26.4 per cent and 25.8 per cent reduction in sympodial branches/plant when compared to weed free during the first and second year respectively. Significantly higher sympodia/plant obtained in cotton treated with pendimethalin (Pre) 1.5 kg/ha *fb* one hoeing at 45 *fb* glyphosate 1 per cent (Protected spray) at 90 DAS (37.7 and 38.6) than weedy check (27.5 and 28.4) but statistically at par with all other treatments. This may be because there are more weeds in the weedy check, and this result is consistent with what Maqbool *et al.*, found (2001).

The perusal of data (Table 4) revealed that seed index differed significantly with mulching and weed management levels. It was clear from the data that the seed index is higher in first year than the second year. Significantly higher seed index was recorded in cotton crop mulching with rice straw 7.5 t/ha (9.6 and 9.1 g) as compared to cotton crop with no mulch during both the years of crop experimentation. Among the weed management levels, boldest seeds were recorded with pendimethalin (Pre) 1.5 kg/ha *fb* two hoeing at 45 and 90 DAS (9.6 g) during the first crop season and it produced 9.96 per cent bolder seeds when compared to weedy check. During the second year, seed index was significantly higher in cotton crop treated with pendimethalin (Pre) 1.5 kg/ha *fb* one hoeing at 45 *fb* glyphosate 1% (Protected spray) at 90 DAS (9.1 g) but it was *at par* with all other treatment except weedy check (8.1 g) and produced 12.0 per cent bolder seeds than weedy check.

The seed cotton yield as influenced by mulching levels and weed management levels is given in Table 4. The data revealed that seed cotton yield of *kharif* 2020 was higher than *kharif* 2021. The cotton seed yield during both the crop season significantly reduced with increased weed stress at any growth stage of crop. Cotton crop mulching with rice straw 7.5 t/ha recorded 6.65 and 6.19 per cent higher seed cotton yield in first and second year, respectively as compared to the cotton without mulching. Among the weed management levels, Apart from weed free, cotton treated with pendimethalin (Pre) 1.5 kg/ha *fb* one hoeing at 45 *fb* glyphosate 1 per cent (Protected spray) at 90 DAS produced the highest yield (3323 kg/ha and 3233 kg/ha) during both the year that was significantly higher than weedy check (1840 kg/ha and 1757 kg/ha), but statistically *at par* with all other treatments. Intense weed competition in the early stages is the main factor reducing cotton output. Weeds acquired a higher concentration of mineral resources than crops, which reduced yield and quickly depleted soil nutrients. Mukhtar *et al.,* (2006) found that untreated check had a lower seed cotton production than other treatments. Anjum *et al.,* (2007), Mahar *et al.,* (2007), Maqbool *et al.*, (2001) and Prabhu, (2010) all reported the same results.

Future perspective

By incorporating both new and old weed management technologies into more diverse weed management systems based on a better understanding of weed biology and ecology, it is possible to develop integrated weed management and resistance management strategies that are more long-lasting than the technologies that are currently failing.

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