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Effect of manual topping on insect pest incidence and cotton yield

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ABSTRACT

Bollworms and sap-sucking insect pests are a significant constraint to cotton production in Africa. Manual topping of cotton plants, which consists of cutting off the top of the plant, i.e. the terminal bud of the main stem, is a promising alternative to chemical control by removing resources for certain pests or inducing plant defences. In this study, we evaluated the level of protection by topping against bollworms and sap-sucking insect pests and the effect of topping on seed cotton yield. Six experiments combining insecticide protection (sprayed vs. unsprayed plots) and topping (topped vs. non-topped plots) were conducted in Mali and Senegal. Topping by itself conferred weak protection against bollworms with an 11% reduction in the proportion of damaged shed squares and bolls, compared to insecticide protection (−55%). Topping had a low to moderate effectiveness in reducing the incidence of sap-sucking pests (−20 to −48%), but equivalent to insecticide treatments. Although topping significantly reduced the proportion of damaged bolls (−31%) at harvest in the absence of insecticide protection, this did not substantially affect seed cotton yield (+4%), unlike insecticide protection (+52%). However, this technique could be advantageously combined with threshold-based interventions integrating biopesticides to reduce the environmental impact of crop protection in cotton.

1. Introduction

Among tropical crops, cotton takes a heavy toll from pest damage. Cotton is subject to pest threat during the vegetative, flowering, and fruiting stages (Vaissayre and Cauquil, 2000; Brévault et al., 2019). In Africa, south of the Sahara, more than 200 insect species have been recorded on cotton (Renou and Brévault, 2016), but around ten species of economic importance can cause severe crop losses. In Mali, pests cause average losses of between 35 and 55% of production if left uncontrolled, but these averages cover wide variations from year to year and region to region (Renou et al., 2012). This high pest pressure, particularly from bollworms such as *Helicoverpa armigera* Hübner, *Earias* spp., and *Diparopsis watersi* Rothschild, makes cotton cultivation highly dependent on the use of synthetic insecticides. The second most important group of pests includes sap-sucking insects such as aphids (*Aphis gossypii* Glover), whiteflies (*Bemisia tabaci* Gennadius), and leafhoppers (e.g., *Empoasca* spp.). They can significantly reduce production by weakening plant vigor, abscission of fruiting bodies, transmission of diseases, or development of agents responsible for rots destroying boll contents, and honeydew deposits on fibre.

Most insect control strategies are based on calendar applications of insecticides. This approach recommends an insecticide application every 14 days, from 35 days after emergence until boll opening (Brévault et al., 2019). Other methods have been proposed, such as the "Targeted staggered control" (LEC), which consists of applying an insecticide treatment every 14 days, with half the prescribed dose, the other half being used in the following week, when populations of certain pests exceed the specified threshold (Silvie et al., 2013). The second approach, called the "Threshold intervention program," is based on applying an insecticide when target pest populations exceed the prescribed threshold (Brévault et al., 2009; Silvie et al., 2013). Despite their advantages, these two approaches to plant protection for cotton are spreading slowly among growers (Renou et al., 2012; Brévault et al., 2019). Chemical control is often seen as the immediate solution for securing production. In Mali, 99% of cotton acreage was protected by insecticide applications according to a calendar program in 2016

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(CMDT, 2016). However, the widespread use of insecticides has led to cases of resistance in target insects in the cotton-growing zone of West Africa, particularly with the widespread use of pyrethroids (Martin et al., 2000, 2005; Brévault et al., 2008). In addition, insecticides have an increasingly negative impact on human health and ecosystems and play a significant role in the loss of biodiversity (Gilden et al., 2010; Kim et al., 2017; Le Bars et al., 2020).

Finding alternatives to synthetic pesticides is a significant challenge for designing productive, environmentally friendly cotton-based cropping systems. With this in mind, the technique of cotton topping was tested in Mali (Renou et al., 2011). Topping consists of cutting off the top of the plant, i.e. the terminal bud of the main stem, thus reducing plant height and vegetative growth. In addition to removing resources for certain pests, such as non-productive squares and young leaves, topping can stimulate plant defences. Several mechanisms can be activated following mechanical damage, such as the production of secondary compounds toxic to insect pests, the emission of volatile organic compounds that repel insect pests, or the production of extra-floral nectar to attract their natural enemies (Llandres et al., 2018). In West Africa, cotton topping was recommended at the beginning of the 20th century to improve yields and reduce the incidence of pests, particularly bollworms and aphids (Vayssières and Mimeur, 1926). This practice has gradually disappeared. In Mali, cotton topping is carried out manually by pinching the still, very tender end of the main stem just above the 15th fruiting branch of the cotton plants ten days after the appearance of the first flower (Renou et al., 2011). Earlier topping may result in a loss of cotton production, while later topping leaves the plant to form new fruiting bodies that will not contribute to production (abscission), reducing the expected benefits. Experiments carried out from 2002 to 2008 showed (in 7 out of 12 tests) a significant reduction in the abundance of bollworms on topped cotton plants (*H. armigera*, *D. watersi*, and Earias spp.) but with no effect on seed cotton yield (Renou et al., 2011). As most of the trials received insecticide applications, we can hypothesize that cotton topping facilitates insecticide penetration within the plant canopy, increasing the efficacy of end-of-cycle applications. Some publications, often not very detailed, point to a depressive effect of topping on the incidence of certain insect pests, such as bollworms in Egypt (Nasr and Azab, 1969; Naguib and ESA, 1978), India (Sundaramurthy, 2002) and China (Hao, 1985), boll weevils in South America (Neves et al., 2010, 2013) or aphids at the end of the cropping season in Central Africa (Deguine et al., 2000). More recently, Llandres et al. (2023) have shown a depressive effect of topping on the abundance of aphid populations, *Aphis gossypii* Glover, on topped and neighboring non-topped cotton plants.

In Mali, some growers have already adopted this technique, sometimes even without technical support from extension services. The main advantages mentioned are the increase in income (linked to higher yields) and the effectiveness of treatments against pests (Diarra et al., 2020). Agronomic studies show that this operation has several advantages, such as reducing vegetative exuberance and the risk of lodging, ensuring earlier production, and increasing yield through increased retention of fruiting bodies (Bennett et al., 1965; Kittock and Fry, 1977; El-Shahawy, 2000; Abou-El-Nour et al., 2001; Obasi and Msaakpa, 2005; Dai et al., 2022). The increase in yield could be explained by the reallocation of nutrients in the plant through the inhibition of vegetative growth in favor of reproductive growth (Selvaraj et al., 1977; Kletter and Wallach, 1982; Yang et al., 2008). Topping is widespread in China, often combined with removing vegetative branches, senescent leaves, and fruiting branches without fruit (plant training) to increase the retention rate and boll weight (Dai et al., 2014, 2022).

This study aimed to evaluate the effect of topping on the incidence of the main insect pests and cotton yield compared with the application of insecticides. To this end, six experiments combined insecticide protection (treated vs. untreated plots) and topping (topped vs. untopped plots).

2. Material and methods

2.1. Experimental sites

Field trials were carried out at the IER (Institute of Rural Economy) experimental stations at Sikasso (11°16′10.2 N, 5°30′43.6 W) and N'Tarla (12°35′20.8 N, 5°42′07. 0 W) in Mali and at the Sodefitex experimental station at Koussanar (13°55′14.0 N, 14°03′26.8 W) and the Sangalkam ISRA station (14°47′23.4 N, 17°13′41.5 W) in Senegal. In all four sites, the climate is characterized by two contrasting seasons: a dry season from November to April or May and a rainy season from May or June to October. Annual rainfall is 1200–1800 mm at Sikasso, 800–1100 mm at N'Tarla, 600–800 mm at Koussanar, and 500–600 mm at Sangalkam. The soils are ferralitic or leached tropical ferruginous, generally characterized by a sandy texture and low organic matter content, but have a pH favourable to cotton growing. At Sangalkam, an irrigation system supplemented plant needs.

2.2. Experimental design

In Sikasso and N'Tarla in 2020 and Koussanar and Sangalkam in 2016, trials were set up as a randomized complete block design, with 4 and 5 blocks as replicates in 2020 and 2016, respectively (Table 1). Each trial contained the following four objects: non-topped unsprayed cotton plants (NT-NS), topped unsprayed cotton plants (T-NS), non-topped sprayed cotton plants (NT-S) and topped sprayed cotton plants (T-S). Each plot comprised eight lines of 15 m in Sikasso and N'Tarla and 11 lines of 10 m at Koussanar and Sangalkam. Cotton was sown at 80 cm between rows and 30 cm (25 cm at Koussanar and Sangalkam) between hills, with two plants per hill. In 2021, trials were set up in Sikasso and N'Tarla using a split-plot design with four blocks, i.e., 32 plots. The large-plot factor was insecticide protection (untreated vs. treated), and each large plot was subdivided into four sub-plots receiving the combination of the two topping levels (non-topped vs. topped) and two levels of sowing density (20 vs. 30 cm between hills on the row). Plots comprised ten lines of 15 m. In the Sikasso and N'Tarla trials, the cotton variety (*Gossypium hirsutum*) N'TA MS334, popularized in Mali for several years, was sown. At Koussanar and Sangalkam, the STAM 59A variety, also popularized in Mali, was planted. Standard protection, which involves spraying all plots every 14 days with an insecticide based on spirotetramat 15 g/ha + flubendiamide 20 g/ha (emamectin benzoate 10 g/ha in Koussanar and Sangalkam), was applied from the 30th day after emergence using an ultra-low volume sprayer (10 L/ha). After cotton topping and until the first boll opening, sprayed plots (S) were treated every seven days on the central 4 and 8 lines in 2020 and 2021 respectively, with a product based on cypermethrin 36 g/ha + acetamiprid 8 g/ha (profenofos 150 g/ha + lambdacyhalothrin 15 g/ha + acetamiprid 8 g/ha on the five central lines in Koussanar and Sangalkam in 2016), while unsprayed plots (NS) received no insecticide application.

The flowering date was determined from the follow-up of 10 plants marked on the central line of each plot (one of the two central lines when the number of lines were even). The flowering date of the trial is the average date at which the plots reached flowering ($\geq$5 flowering plants). In topped plots (T), all plants of the 5, 4, and 8 central lines were topped ten days after first flower, which corresponds to the emergence of the 15th sympodial branch, according to Renou et al. (2011), in 2016, 2020, and 2021 trials, respectively.

2.3. Observations

Bollworm damage was assessed by collecting and counting fruiting bodies (square and boll shedding) dropped to the ground between two selected cotton lines, three times a week from topping to boll opening (around 115 days after emergence). Squares and bolls were individually inspected for bollworm damage. The presence of sap-sucking insects (adults and larvae of aphids -*Aphis gossypii*- and leafhoppers – mainly

Table 1
Experimental designs were set up to evaluate the effect of topping on bollworm damage to cotton squares and bolls, the incidence of sap-sucking insects, and cotton yield components.

Trial	Country	Site	Statistical design	Cultivar	Sowing date	Topping (days)	Subplot size (m^2)	Rep.	Pest obs.	Harvested rows
1	Mali	Sikasso	SPP	NTA MS334	6/17/21	69	120	8	4	4
2		N'Tarla	SPP	NTA MS334	6/21/21	70	120	8	5	4
2		Sikasso	RCB	NTA MS334	6/23/20	66	96	4	5	2
4		N'Tarla	RCB	NTA MS334	6/20/20	63	96	4	5	2
5	Senegal	Sangalkam	RCB	STAM 59A	7/5/16	65	88	5	2	3
6		Koussanar	RCB	STAM 59A	7/21/16	66	88	5	2	5

SPP: Split-plot (topping * density subplots in sprayed and unsprayed plots). RCB: Randomized complete block.

Jacobiella fascialis, and whitefly nymphs - *Bemisia tabaci*) was assessed on the five terminal leaves of 4 series of 5 consecutive cotton plants (5 series of 6 successive cotton plants in Sangalkam and Koussanar). A total of 20 cotton plants observed per plot (30 cotton plants in Sangakam and Koussanar), 2 to 5 times after topping (Table 1). At harvest, the number of harvestable bolls, bollworm-damaged bolls, and seed cotton weight were measured on 2 to 5 central lines of each plot (Table 1).

2.4. Data analysis

Experiments were analysed separately as environmental conditions and experimental designs were different. Generalized linear mixed-effects models were used to examine the effects of insecticide protection, topping, and sowing density (2021 trials) on the proportion of fruiting bodies attacked by bollworms, on the incidence of sap-sucking insects and seed cotton yield and its components. Each model was fitted by taking into account the type of distribution: binomial ("logit" link) for the proportion of fruiting bodies attacked, Poisson ("log" link) for the incidence of sap-sucking insects, and gaussian for yield and its components. Block, sub-block, and observation date effects for sap-sucking insects were considered random effects. The models were fitted by maximum likelihood (ML), and their relevance was assessed by checking the normality and randomness of the residuals. Wald tests were performed to assess the significance of fixed-effect explanatory variables. Comparisons of means were made using Tukey pairwise comparisons. All statistical analyses were performed using the "lmerTest", "car" and "multcomp" packages of R software version 4.1.2 (R Core Team, 2022).

3. Results

3.1. Sanitary status of shed fruiting bodies

In all trials, insecticide protection significantly reduced the proportion of shed squares and bolls attacked by bollworms (−55% in non-topped plots) (Table 2). Topping also reduced the proportion of shed fruiting bodies attacked by bollworms (−11% in unsprayed plots), but the effect was significant only in Trial 3 and Trial 5 (−23% in unsprayed plots). The interaction between insecticide spraying and topping observed in Trial 5 indicated that the effect of topping was only visible in the absence of insecticide spraying. In 2021, the proportion of fruiting bodies attacked by bollworms was higher at density 30 than at density 20 in Sikasso ($P < 0.001$), while no effect of plant density was noted in N'Tarla ($P = 0.808$). No interaction with insecticide spraying or topping was observed.

3.2. Incidence of sap-sucking pests

Overall, insecticide spraying had low to moderate efficacy against sap-sucking insects, with incidence reduced by 40, 17, and 40% in non-topped plots for aphids, whiteflies, and leafhoppers, respectively (Table 3). The effect was significant in only 2/6, 2/5, and 3/6 trials for aphids, whiteflies, and leafhoppers, respectively. Topping reduced the incidence of aphids, whiteflies, and leafhoppers by 38, 20, and 48%, respectively, in unsprayed plots. Topping significantly affected the incidence of sap-sucking insects in only 2/6, 3/5, and 3/6 trials for aphids, whiteflies, and leafhoppers, respectively.

In 2021, no effect of plant density on the incidence of sap-sucking insects was observed, except in Sikasso, where more leafhoppers were observed in the lowest plant density ($P < 0.001$) plots.

3.3. Effect of treatments on seed cotton yield and its components

In all trials, insecticide spraying significantly increased the number of harvestable bolls per unit area (+52% in non-topped plots) (Table 4). In Trial 4, topping significantly increased the number of harvestable bolls (+49% in unsprayed plots). The interaction between insecticide spraying and topping observed in Trial 4 indicates that the positive effect of topping was not visible in the presence of insecticide protection. In three trials out of four, insecticide spraying and topping significantly reduced the proportion of bolls with holes at harvest (−63% and −42%, respectively). Interactions between insecticide spraying and topping again showed that the effect of topping was only visible in the absence of insecticide protection.

Insecticide spraying significantly increased boll weight at harvest in three trials out of six (+15% in non-topped plots). Topping had little effect on boll weight, with only a negative effect on Trial 4. Insecticide protection significantly increased seed cotton yield (+52% in non-

Table 2
Effect of topping and insecticide spraying on the percentage of squares and bolls damaged by bollworms (harvesting and sorting of fruiting bodies fallen between two rows from topping to early boll opening). (NS) unsprayed and (S) sprayed plots. (NT) non-topped and (T) topped plots.

Parameter	Trial	NS		S		S	T	S*T
		NT	T	NT	T	*P*	*P*	*P*
Damaged squares and bolls (%)	1	6.6 ± 1.4 a	6.8 ± 0.7 a	2.1 ± 0.3 b	1.5 ± 0.3 b	***	0.767	0.092
	2	5.8 ± 0.5 a	5.3 ± 0.8 a	1.4 ± 0.2 b	1.4 ± 0.3 b	***	0.508	0.632
	3	17.0 ± 2.5 a	12.3 ± 1.1 b	8.9 ± 1.2 c	6.7 ± 0.4 c	***	***	0.540
	4	Not observed						
	5	28.6 ± 2.5 a	23.3 ± 2.1 b	8.4 ± 0.7 c	7.5 ± 0.7 c	***	***	*
	6	69.4 ± 3.2 a	73.1 ± 1.8 a	60.9 ± 1.6 b	59.4 ± 5.0 b	***	0.260	*

Results of generalized linear mixed-effects models. ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$. Different letters in the same row indicate a significant difference between treatments ($P < 0.05$).

Table 3
Effect of topping and insecticide spraying on the incidence of sap-sucking insects. (NS) unsprayed and (S) sprayed plots. (NT) non-topped and (T) topped plots.

Parameter	Trial	NS		S		S	T	S*T
		NT	T	NT	T	*P*	*P*	*P*
Number of infested plants (aphids)	1	0.8 ± 0.3 a	0.1 ± 0.1 b	0.5 ± 0.2 ab	0.1 ± 0.1 b	0.169	***	0.480
	2	2.0 ± 0.4 a	1.6 ± 0.4 ab	0.9 ± 0.3 bc	0.5 ± 0.1 c	***	*	0.435
	3	5.0 ± 1.1	4.6 ± 1.1	5.3 ± 1.1	4.4 ± 1.0	0.919	0.184	0.543
	4	3.7 ± 0.8 a	2.5 ± 0.7 a	0.6 ± 0.2 b	0.8 ± 0.2 b	**	0.122	0.112
	5	1.1 ± 0.6	1.1 ± 0.5	1.7 ± 0.8	1.5 ± 0.7	0.177	0.786	0.821
	6	1.3 ± 0.7	0.3 ± 0.3	0.5 ± 0.2	0.5 ± 0.2	0.278	0.101	0.097
Number of infested plants (whiteflies)	1	3.3 ± 1.0 b	4.8 ± 1.1 a	3.7 ± 1.0 ab	3.8 ± 1.1 ab	0.930	***	0.560
	2	7.7 ± 0.5 a	6.6 ± 0.7 a	6.8 ± 0.6 a	4.3 ± 0.4 b	**	***	*
	3	6.1 ± 1.2	5.7 ± 1.1	6.1 ± 1.2	6.5 ± 1.1	0.496	0.964	0.438
	4	1.9 ± 0.4 a	0.7 ± 0.2 b	0.8 ± 0.2 b	0.5 ± 0.1 b	**	***	0.364
	5	3.9 ± 1.0	3.2 ± 0.8	3.4 ± 1.1	2.7 ± 0.7	0.380	0.220	0.925
	6	Not observed						
Number of infested plants (jassids)	1	7.6 ± 0.6 a	5.6 ± 0.6 b	5.5 ± 0.6 b	3.7 ± 0.4 c	***	***	0.602
	2	4.1 ± 0.6 a	0.8 ± 0.2 c	2.1 ± 0.4 b	0.4 ± 0.1 c	***	***	0.935
	3	5.7 ± 1.1	5.4 ± 1.1	5.4 ± 0.9	5.2 ± 1.0	0.630	0.700	0.930
	4	3.5 ± 0.4 a	1.2 ± 0.2 b	1.5 ± 0.2 b	0.7 ± 0.7 b	***	***	0.415
	5	3.3 ± 0.9	2.0 ± 0.4	2.2 ± 0.4	2.0 ± 0.3	0.265	0.129	0.331
	6	1.3 ± 0.9	0.4 ± 0.3	0.4 ± 0.3	0.4 ± 0.2	0.098	0.098	0.180

Results of generalized linear mixed-effects models. ***P < 0.001; **P < 0.01; *P < 0.05. Different letters in the same row indicate a significant difference between treatments (P < 0.05).

Table 4
Effect of insecticide spraying and topping on seed cotton yield and its components. (NS) unsprayed and (S) sprayed plots. (NT) non-topped and (T) topped plots.

Parameter	Trial	NS		S		S	T	S*T
		NT	T	NT	T	*P*	*P*	*P*
Number of bolls (.m-^{2})	1	47.4 ± 3.1 ab	36.8 ± 3.0 b	58.0 ± 4.1 a	52.9 ± 4.1 a	*	*	0.368
	2	66.9 ± 2.2 b	69.1 ± 2.6 b	77.5 ± 1.7 a	78.0 ± 1.5 a	***	0.446	0.645
	3	27.8 ± 3.4 a	29.1 ± 4.4 a	37.0 ± 1.9 a	38.3 ± 4.6 a	**	0.69	0.992
	4	29.9 ± 1.6 c	44.4 ± 1.1 b	62.4 ± 2.4 a	67.4 ± 1.4 a	***	***	**
	5	35.4 ± 2.2 b	39.2 ± 3.5 b	58.4 ± 2.4 a	63.7 ± 5.5 a	***	0.264	0.844
	6	23.8 ± 2.1 b	26.1 ± 5.3 b	39.1 ± 7.7 a	31.9 ± 2.3 a	*	0.640	0.371
Damaged bolls (%)	1	Not observed						
	2	Not observed						
	3	10.9 ± 2.1 a	5.7 ± 0.8 c	7.6 ± 0.9 b	8.4 ± 1.7 b	0.515	***	***
	4	26.2 ± 3.9 a	20.2 ± 2.5 b	10.8 ± 1.4 c	9.6 ± 0.6 c	***	***	*
	5	13.1 ± 1.0 a	5.9 ± 1.4 b	1.5 ± 0.4 c	1.1 ± 0.6 c	***	***	*
	6	26.0 ± 4.4 a	26.1 ± 2.5 a	15.1 ± 2.6 b	13.6 ± 2.7 b	***	0.427	0.224
Boll weight (g)	1	3.8 ± 0.1 b	3.9 ± 0.1 ab	4.5 ± 0.2 a	4.3 ± 0.2 ab	*	0.872	0.563
	2	4.4 ± 0.1	4.4 ± 0.1	4.6 ± 0.1	4.6 ± 0.1	0.272	0.334	0.948
	3	3.7 ± 0.1	3.9 ± 0.1	4.0 ± 0.1	4.2 ± 0.2	*	0.116	0.977
	4	4.6 ± 0.2 a	3.6 ± 0.1 b	3.6 ± 0.2 b	3.2 ± 0.1 b	***	***	0.082
	5	2.8 ± 0.1	2.9 ± 0.1	3.3 ± 0.1	3.1 ± 0.3	*	0.730	0.452
	6	2.9 ± 0.2 a	2.9 ± 0.4 a	2.7 ± 0.3 a	3.1 ± 0.1 a	0.909	0.472	0.508
Seed-cotton yield (kg.ha-1)	1	1800 ± 144 bc	1453 ± 131 c	2643 ± 245 a	2325 ± 273 ab	**	0.087	0.941
	2	2980 ± 124 b	3030 ± 111 b	3592 ± 107 a	3567 ± 86 a	**	0.868	0.629
	3	1026 ± 117 b	1164 ± 214 ab	1469 ± 45 ab	1614 ± 202 a	**	0.311	0.980
	4	1378 ± 90 b	1583 ± 72 b	2288 ± 186 a	2165 ± 192 a	***	0.741	0.188
	5	996 ± 98 b	1140 ± 149 b	1941 ± 119 a	1944 ± 159 a	***	0.574	0.594
	6	683 ± 45 b	675 ± 31 b	972 ± 76 a	978 ± 44 a	***	0.986	0.902

Results of generalized linear mixed-effects models. ***P < 0.001; **P < 0.01; *P < 0.05. Different letters in the same row indicate a significant difference between treatments (P < 0.05).

topped plots). On the other hand, topping did not significantly increase yield in sprayed or unsprayed plots in any of the trials.

4. Discussion

To assess the level of protection against pests afforded to cotton plants by topping, as well as its effect on yield in the presence (unsprayed plots) and absence (plots sprayed every seven days) of pests, we set up six experiments in Mali and Senegal combining insecticide protection (sprayed vs. unsprayed plots) and topping (topped vs. non-topped plots). Overall, results showed that insecticide treatments were only moderately effective in protecting fruiting bodies against bollworms (−55% in non-topped plots) and only somewhat effective in protecting the plant against sap-sucking insects (−17 to −48%) (Fig. 1). Topping (in the absence of insecticide protection) conferred weaker protection than insecticide spraying against bollworms, with a 11%

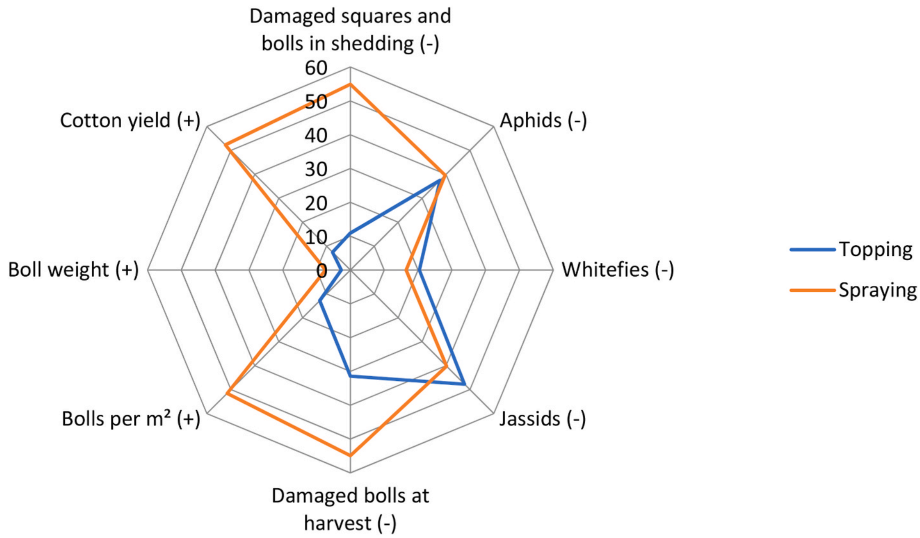

Fig. 1. Average benefits (%) for cotton protection against insect pests and yield components provided by insecticide spraying (relative to unsprayed-non topped plots) and topping (relative to non topped-unsprayed plots). Aphids, whiteflies, and leafhoppers are sap-sucking pests. Bollworms cause damage to squares and bolls.

reduction in the proportion of pierced squares and bolls (compared with non-topped), i.e. five times less than insecticide protection. Topping also had a low to moderate effectiveness in reducing the incidence of sucking pests (20–48%) but was nevertheless equivalent to insecticide treatments (Fig. 1). On the other hand, topping did not affect bollworm damage in the presence of insecticide protection. In trials under insecticide protection according to the standard program (treatment every 14 days), Renou et al. (2011) found a significant effect of topping on bollworm abundance in 7 out of 12 trials. Two major hypotheses have been put forward to explain the reduced incidence of bollworms on topped cotton plants: a reduction in moth egg-laying due to the suppression of oviposition sites (terminal leaves) or to the emission of repellent volatile compounds (in response to wounding or changes in plant physiology), and increased mortality of eggs or young larvae due to a change in the quality of resources (constitutive defences), or to the recruitment of natural enemies via the emission of specific volatile compounds (De Moraes et al., 2001; Renou et al., 2011; Llandres et al., 2018). Another hypothesis is that reducing cotton plant size following topping allows better penetration of insecticides into the canopy.

Although topping (in the absence of insecticide protection) reduced the proportion of damaged bolls at harvest (−31%, versus −55% for insecticide protection), it did not significantly increase seed cotton yield (+4%), unlike insecticide protection (+52%) (Fig. 1). The increase in seed cotton yield with insecticide protection was mainly due to a higher number of harvestable bolls (+52% vs. 13% for topping). In the present study, no topping effect on yield was observed, either in the absence or presence of insecticide protection. This result contradicts some studies showing a positive effect of topping on yield, in particular through a higher boll load (Bennett et al., 1965; Obasi and Msaakpa, 2005, for *Gossypium barbadense*; Dai et al., 2022), but is in line with other studies showing no effect (Kittock and Fry, 1977; Siddique et al., 2002). Similarly, Renou et al. (2011) showed no effect of topping on seed cotton yield following 12 trials conducted in Mali under insecticide protection (treatment every 14 days) despite the higher abundance of bollworms on non-topped plots. Likely, the supernumerary bollworms observed on the non-topped plants (compared with the topped plants) attacked fruiting bodies that do not contribute to yield, such as squares at the top of the plant that will not have time to reach maturity.

This raises the question of the results of the survey on the perception of topping carried out in Mali by Diarra et al. (2020), who reported that the main benefits of topping mentioned by farmers were increased income related to higher yields and the effectiveness of treatments against pests. Why would topping affect yield in farmers' plots? At least three non-exclusive hypotheses can be put forward: (i) a perception that is out of sync with reality or poorly expressed (e.g., visually larger bolls), (ii) a positive effect of topping on the retention of bolls in a context of low soil fertility, (iii) more significant development of fruit-bearing branches in a context of lower than recommended plant density, and (iv) greater effectiveness of insecticide treatments against pests due to better penetration of the product into the canopy. These hypotheses must be verified by monitoring a network of on-farm trials (e.g., plots divided into two parts: topped vs. non-topped) to identify the environmental or crop management factors that modulate cotton yield response to topping.

5. Conclusion

This study shows that, without phytosanitary protection, topping can reduce pest incidence or damage but this effect remains insufficient to affect seed cotton yield. In the presence of insecticide protection, topping did not affect yield. However, this technique could be advantageously combined with a strategy of threshold intervention and integration of biopesticides to reduce the environmental impact of crop protection in cotton.

CRediT authorship contribution statement

Daouda S. Maiga: Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Moribo Coulibaly:** Methodology, Investigation. **Amadou Traoré:** Writing – original draft, Resources, Methodology, Investigation, Conceptualization. **Djibril Badiane:** Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Idrissa Tereta:** Methodology, Investigation. **Bernard Sodio:** Project administration. **Thierry Brévault:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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