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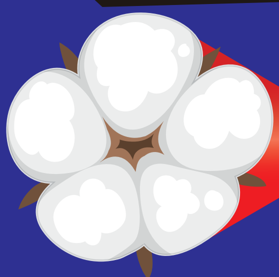
COTTON INNOVATIONS



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Content

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Jassid infestations and management in PR-PICA countries in 2022 and 2023

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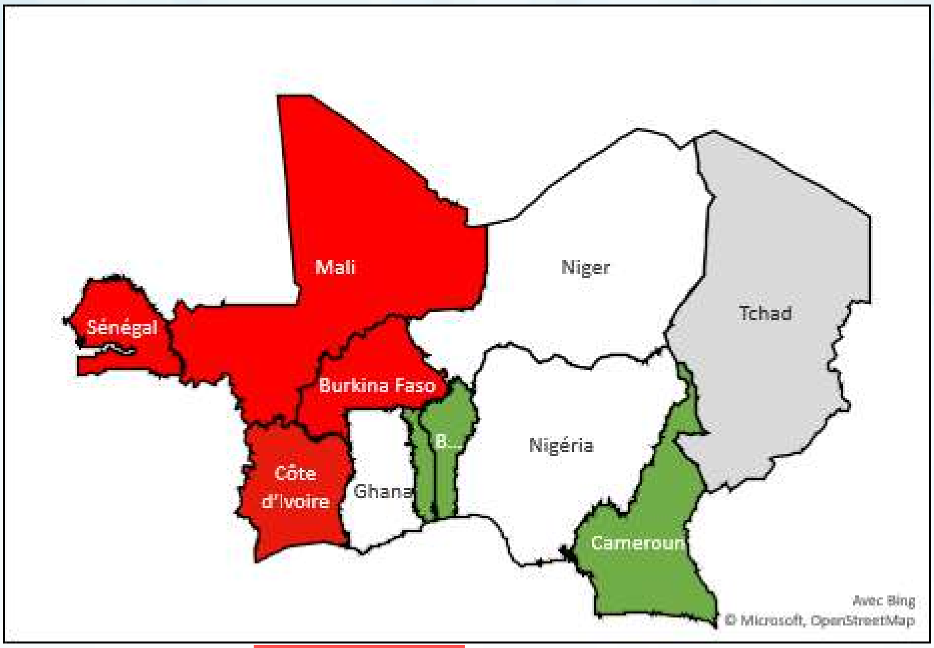
PR-PICA is the regional programme for integrated cotton production in Africa. It brings together inter-professional organizations, cotton companies, cotton producers' organizations and researchers from 8 cotton-producing countries, which are Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Mali, Senegal, Chad and Togo.

In the 2022 cotton season, average crop losses caused by pests in unprotected cotton fields ranged from 22% to 41% depending on the country (PR-PICA, 2022). These decreases in production are due in part to a massive jassids infestation that occurred early as shown on figure 1 (PR-PICA, 2022) and was established throughout the cotton cycle. Chemical control, the main method used for a long time with the three-window treatment program (beginning at 30-35 days after emerging, each window contains 02 sprays with the same product and there are 14 days between two sprays), has proven to be ineffective. Investigations were then set up, including morphological identifications, which revealed a new species of jassid, *Amrasca biguttula* (Ishida, 1913). This leafhopper causes very serious damage in terms of yield loss, fibre and seed quality (Lanjar et *al*, 2014). This loss was estimated at more than $107 million in Burkina Faso.



High level

Low level

Figure 1: Jassids infestation level in 2022 in PR-PICA countries

To control this pest, researchers in the PR-PICA zone have undertaken studies to evaluate new products used alone or in combination to contain the scourge by providing farmers with effective insecticides and helping to improve cotton yield.

In 2023 raining season, Cameroon and Chad, which were spared in 2022, recorded infestations. It was recommended to treat seeds with systemic insecticides like thiamethoxam and imidacloprid with at least 03 g ai/kg seed. Jassid infestations were controlled by the three insecticide products recommended by PR-PICA: Flonicamide 500 WG at the rate of 100 g of commercial product/ha; JACOBIA 350 EC (Pyridine 150 g/l + Diamine 200 g/l) at the rate of 500 ml of commercial product/ha and GRACIA 10 EC (Fluxametamid 100 g/l) at the rate of 300 ml of commercial product/ha. Since these new products are not yet registered in most of the PR-PICA countries, it has been necessary to issue special exemptions to governments for their import and use. These new products are persistent for at least two weeks and can control these jassids until the next insecticide spray; only GRACIA 10 EC can be used to control sucking pests as well as caterpillars; JACOBIA 350 EC and Flonicamide 500 WG are used to control only sucking pests. Farmers mentioned in Burkina Faso an 30% increase in the number and cost of treatment as a result of additional jassid treatments. The effectiveness of popularized protection was 76% whereas it is usually more than 80%.

Recommendations for jassids management were done to address 2024 cotton season.

- For Seed treatment, use one of these products at the right rate:

Active ingredients	Formulation	Dose (g or ml commercial Product/kg seed)	
		Non Delinted	Delinted
Thiamethoxam 600 g/l + Tebuconazole 10 g/l + Metalaxyl-M 5 g/l	FS or WS	7 to 8,5	10,5 to 12,75
Thiamethoxam 440 g/kg + Thiophanate methyl 94 g/kg + Metalaxyl-M 12,5 g/kg	WS	12	18
Flonicamide 315 g/l +Azoxystrobin 50 g/l+ Thiram 100 g/l	FS	6 to 9	9 to 13,5

- Have additional foliar treatment products available to intervene in the event of early attacks before the start of the phytosanitary protection schedule.
- Use seed treatment adhesives to allow the treatment products to adhere well to the seed.

- For foliar sprayings, use these Pest Complex Treatment Products at the right rate:

Matières actives	Formulation	g ou ml p.c/ha	Possible positioning		
			1st window	2nd window	3rd window
Diamine 150 g/l + Pyridine 150 g/l + Indoxacarb 50 g/l	EC	500	X	X	X
Flonicamid 416 g/kg + Chlorantraniliprole 250 g/kg	WG	120	X	X	X
Flonicamid 200 g/l + Chlorantraniliprole 100 g/l	OD	250	X	X	X
Flonicamid 200 g/l + Cyhalodiamid 80 g/l	SC	250	X	X	X
Flonicamid 250 g/l + Cyantraniliprole 250 g/l	SC	200	X	X	*
Flonicamid 200 g/l + Indoxacarb 120g/l	SC	250	X	X	*
Fluxametamid 100 g/l	EC	300	X	X	*

X. Effective All Zones

*. Effective only in exocarpic zones.

Recommendations have been made for future Researches on *Amrasca biguttula*. These are mainly:

1. Find products that are effective against both sucking pests and bollworms to reduce the cost of insecticide treatments;
2. Develop a monitoring mechanism for pests in order to anticipate attacks and prevent damage to farmers;
3. Define an economic threshold for *Amrasca biguttula* infestations;
4. Study the bio-ecology of *Amrasca biguttula* for a better knowledge of the pest in order to set up more effective protection programs;
5. Find products for this pest in organic cotton and other crops cultivation.

Further reading:

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Kouadio H, Kouakou M, Bini KK, Koffi KJ, Ossey CL, Kone PW, Adepo-Gourene AB, Ochou OG (2024) Annual and geographical variations in the specific composition of jassids and their damage on cotton in Ivory Coast. *Scientific Reports* **14**(1), 2094. https://doi.org/10.1038/s41598-024-52127-y

Programme régional de production intégrée du coton en Afrique. https://prpica.org/

Effect of Gin-stand Type on Cotton Fiber Quality and Spinning Waste Ratio

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Abstract

The cotton sector has received great attention from the Egyptian governorate. One of the most important achievements of the cotton sector development plan is renovating the ginneries. Egyptian cotton is characterized by high quality, and to keep, to maintain quality of the Egyptian cotton, its necessary to reduce contamination and the fiber exposure to the mechanical stress. The aim of this investigation is to study how fiber properties, card waste ratio and lea count strength product were affected by gin-stand type and cotton handling at the conventional and modernized gins. The cotton quality evaluation was conducted in the Cotton Research Institute, Agricultural Research Center, Giza, Egypt, during the season of 2023. The cotton was ginned at following four modern gins, El-Zagazig gin-plant, Kafr El-Zayyat, Kafr El-Dawar gin-plant, and New Fayoum gin-plant. For this purpose, three long staple cotton varieties Giza 94, Giza 86 and Giza 95 were used. All samples of Giza 94 and Giza 86 were spun into 60 Ne. While samples of Giza 95 were spun into 40 Ne ring spun yarns with 3.6 twist multiplier. The results showed that the fiber characters measured by HVI specially length and length parameters were significantly affected by gin-stand type, while some characters showed insignificant affected such as, the b+ in El-Zagazig gin, Micronaire reading, uniformity ratio, color attribute, trash and maturity ratio in Kafr El-Zayyat in. The interaction between factors under studied i.e.: gin plant and ginning mechanical processes was significant for short fiber index, fiber strength, trash% and neps/gram.

Key words: *Ginning Types-Modern gin plant- McCarthy gin- card waste ratio*

Introduction

The Egyptian cotton industry is working hard to enhance the Egyptian cotton situation “consumption and demand” worldwide and increase the demand of Egyptian Cotton products. The process of ginning, which involves separating the cotton lint from the seed using a gin stand. The ginning process gives two products “lint and cotton seed” that have cash value.

Cotton fibers are more important, expensive, and valuable products as compared with seed cotton. **Sharma (2008)** reported that the developments in the ginning technology aim to increase lint production, produce lint free of contaminations, obtain optimum fiber length and preserve fiber quality and obtain undamaged clean seed and clean lint. The gin-stand is considered the core of the ginning process. The condition of the gin-stand, and its adjustment play a crucial role in determining the gin's capacity and the performance of the lint in the spinning process. Despite the importance of the ginning process, the cotton ginning industry is grappling with low capacity of conventional gin stands, high operating costs per unit of gin, and difficulty in obtaining lint that is free of contamination, trash, and foreign matter. Moreover, the quality of fiber properties changes during the ginning process, and each machine involved in the process can affect it.

The McCarthy gin was invented to gin extra-long cotton varieties. It has a leather ginning roller, a stationary knife held tightly against the roller, and a reciprocating knife to remove the seed from the lint. Although the capacity of the McCarthy gin was an improvement over the Churka gin, the capacity of the McCarthy gin was limited to about 18 kilograms of lint per hour. This is due to the reciprocating knife which leads to the vibration of the machine and the associated issues in maintenance of the gin-stand.

In the Knife roller gin, the seed cotton is loaded in bulk on the feeder hopper. With the help of compressing roller materials, feed between the rollers. Once the cotton seed encounters the knife roller, the separation of seeds from cotton lint takes place. The knife portion is arranged in such a manner that anything encountering it is given reciprocating motion as well as being sub-iced to shrinking action to its revolution. This roller has a diameter of 10 inches with an rpm of 150,300,150 respectively from left to right. However, the roller's motion is anticlockwise while others are clockwise. The cotton lint travels from the middle roller to the third roller and separates from the knife roller with the help of a stripping board. Finally, the lint falls into a receiver box. The distance between rollers is arranged such that seeds are not moved up to the third roller, ensuring that they are separated from the cotton. Besides, dust and other impurities are removed with the help of grids arranged beneath the middle roller, ensuring that the cotton lint is as clean as possible. Dust and other impurities are removed with the help of grids arranged beneath the middle roller. Knife roller gin have some problems such as the destructive vibration of unbalanced moving knives, difficulties in adjusting and maintaining overlap and clearance settings, ginning roller bending or lack of stiffness, short life of roller covering, and seed crushing or chipping. The single roller ginning was propitiated for all cotton varieties. Also, it gave the best fiber quality properties, but it has a slow rate of production. **Van der Sluijs (2015)** compared the effect of saw gin and roller gin on fiber properties for long staple upland cotton. Results found that there was a significant effect between ginning methods on fiber properties. Roller gin gave longer fiber, higher uniformity index, fewer short fiber, stronger fiber, higher elongation%, smaller seed coat, nep and total trash size. **Delhom *et al*. (2017)** investigated four upland cotton varieties. Saw gin and high-speed roller gin were used to process these varieties. Roller gin exhibited longer fiber, higher uniformity length, and lower short fiber index, and contained 25% less neps than saw gin.

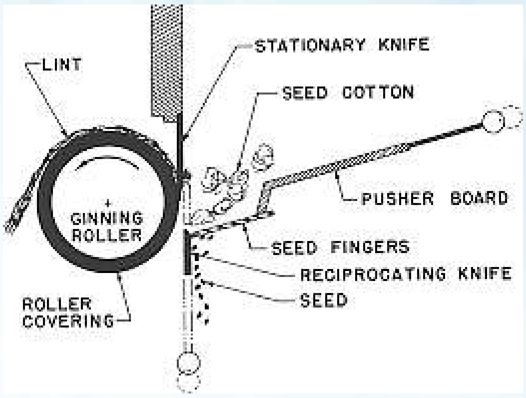

Fig.1.McCarthy roller gin

In the late 1950s and early 1960s, a rotary-knife roller gin, which used a rotary knife instead of the reciprocating knife, was developed. A rotary-knife roller gin used the same roller and stationary knife as the McCarthy gin. The rotary-knife roller gin had higher ginning rate than the McCarthy gin, processing 218 kg (480 lb) of lint per hour (versus 18 kg (40 lb) on a 1-m (40-in) wide stand). However, it still processed cotton at only about one-fifth the rate of a saw gin. Around 2005, a high-speed rotary-knife roller gin was developed, which processed cotton at about 872 kg/m/hr (576 lb/ft/hr), or about four bales per hour, the same rate per unit width as a saw gin. In addition, the rotary-knife roller gin allowed extra-long staple cotton to be ginned more efficiency, and it allowed high quality upland cotton to be ginned more comparable with the saw gin. Also, it achieved better fiber quality. However rotary-knife roller gin have some disadvantages such as seed cut and unginned cotton going with seeds.

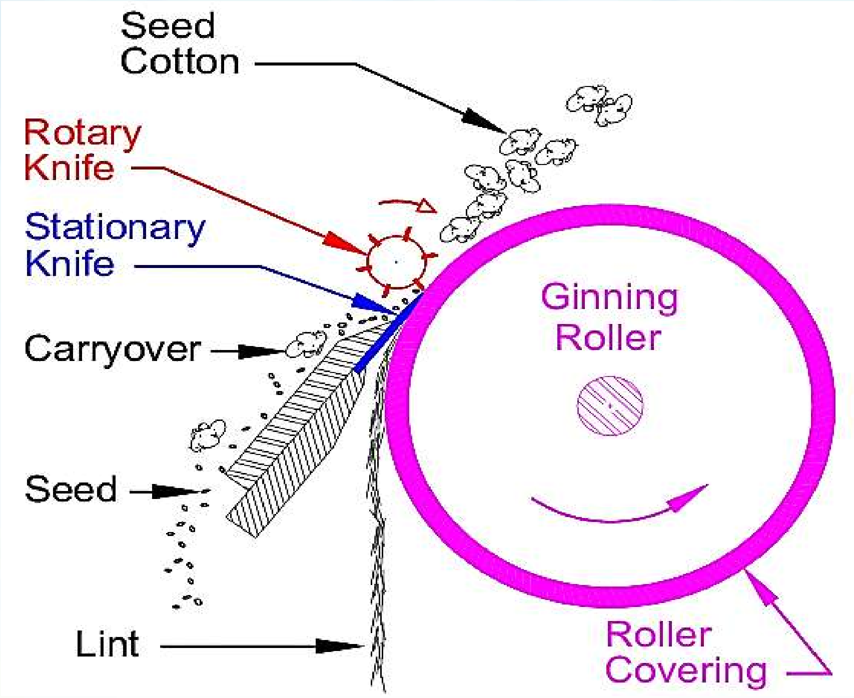

Fig.2. Rotary-knife roller gin

The gin-stand and lint cleaner are the machines that exert the greatest forces on individual fibers and can break them **(Griffin, 1977).** Although a certain degree of fiber damage in the gin-stand is inevitable, some factors can influence fiber quality. Ginning at rates higher than those recommended by the manufacturer tends to increase short-fiber content. (**Griffin and Ramey, 1975**). Roller ginning of upland cotton increased fiber length to one staple at least and it improved the uniformity length % from 1 to 2%. Also, it reduced neps and short fiber content from 2 to 3% as compared with saw ginning (**Armijo and Gillum, 2007, 2010; Armijo et al., 2013; Byler and Delhom, 2012; Hughs et al., 2013).** Cotton samples collected from commercial gins across the United States have shown that the first-stage lint cleaner reduces fiber length by 0.4 mm, which is equal to half the staple length. The second-stage lint cleaner reduces fiber length by an additional 0.2 mm, equal to one-quarter of the staple length **(Whitelock et al., 2011)**. Reciprocating knife gin-stand gave longer upland cotton fibers, better HVI color grade and lower short fiber content, neps and higher turn out as compared with saw ginning **Armijo and Gillum (2007).** Blow room and carding waste values were 9.5% and 4.8% for reciprocating and rotary gin-stand. The rotary gin gave lower ginning out-turn, trash content, short fiber index and higher productivity than reciprocating gin-stand, which resulted in keeping of the fiber and yarn quality. Consequently, low blow-room and carding waste in the rotary gin-stand and high blow-room and carding waste in reciprocating gin due to absence of seed-cotton and lint cleaners **El-Sayed et al (2008).**

The grade, fiber length, and value of fiber produced by roller gin stands were superior to fiber produced by saw gin **Armijo and Gillum (2009).** The capacity of the gin-stand and the lint grade are more affected by the types of roller gins.

Generally, roller gins are used to gin extra-long staple cotton (1 3/8 inch), while saw gins are used to gin upland cotton from short to medium staple (<1 inch to 1 7/32 inch). Also, saw gins gave less amount of trash and increased both short fiber content and neps due to the increased opining during ginning process **(Sharma 2012**). During the first stage of lint cleaning, the short fiber content increases by 0.8%, and uniformity length decreases by 0.7%, while in the second stage, the short fiber content increases by 0.2%, and uniformity length decreases by 0.4%. Another recent study **(Hughs et al., 2013)** found the same length measurement changes in two stages of lint cleaning. **(Mangialardi, 1985; Anthony, 1996; Whitelock et al., 2011)** Showed that each stage of lint cleaning creates approximately 40 neps/gram, although this amount varies depending on the cotton variety. Lint cleaners remove seed coat fragments but break the fragments remaining in the lint **(Anthony, 1990; Boykin, 2008; Whitelock et al., 2011).** It is recommended to use at least one stage of lint cleaning to ensure the removal of seed cotton fragments and other small foreign matter created in the gin stand, as well as to blend cotton fibers and improve the color and lint grade. **Kveton (1986)** the roller ginning of cotton is defined as the mechanical separation process of cotton fibers from their seeds by Means of one or more rollers. The roller gin-stand recorded better fiber length, uniformity index, yellowness degree and reflectance degree. Also, it gave better fiber length measurements and nep count than saw ginning. **Mahgoub (1981)** indicated that using rotary gin-stand improved ginning productivity, physical fiber properties and yarn strength. In addition, using seed and lint cotton cleaners with rotary gin caused an improvement in lint grade, and decreased non lint content. The effect of the types of gin-stand and treatments of cotton cleaning were not significant for Micronaire reading, maturity index, fiber, and yarn strength. The productivity of the conventional roller gin-stand can be improved by adjusting its moving parts to suit each cotton variety and grade. **Hussien (1999)** demonstrated that the reciprocating knife gin-stand gave higher fiber length and uniformity ratio than the rotary knife gin-stand whether the ginned cotton was long staple or extra-long staple. **Arafa (2000)** indicated that the rotary knife gin-stand affected fiber quality properties and ginning efficiency. It decreased the short fiber content. Whereas the extra-long staple cotton recorded the lowest short fiber content. **Tian et al. (2018)** stated that ginning types and lint cleaning had significant effect on fiber length and short fiber index. While it didn’t show significant effect on fiber strength. Lint cotton cleaner decreased fiber length by more than 1.00 mm, and it increased the short fiber index more than 20%. The third lint cleaning caused higher fiber damage as compared with the second lint cleaning. The third lint cleaning decreased fiber length by 0.35 mm and increased short fiber index by 0.65%. Therefore, the lint should be cleaned by one lint cleaner. **Anthony (2000)** found that the lint cleaning stage can be omitted when the lint had a small amount of foreign matter. Lint cleaners decreased foreign matter content and improved color grade, but it caused great fiber damage. **Baker and Brashears 1999; Li *et al*. 2012** showed that lint cleaners significantly decreased fiber length and increased short fiber content. Researchers differed on the effect of lint cleaners on fiber strength. **Xu *et al*. 2014** concluded that lint cleaners caused a decrease in fiber strength. On the contrary, **Krifa and Holt 2013** stated that lint cleaners increased fiber strength.

Immature cotton is more affected by lint cleaning than mature cotton. Mature cotton has less potential for fiber damage **(Wanjura et *al*. 2012; Krifa and Holt 2013). Ethridge et al. (1995)** found that the first lint cleaning reduced fiber strength. On the other hand, the second and third cleaning increased fiber strength because it removed the weaker fibers. While additional stage of lint cleaning caused fiber damage. **Marinus (2015)** showed that there was a significant difference between the roller and saw gin-stand in some fiber properties. Roller ginned gave longer fibers, fewer short fiber content, and more uniform than saw gin stand. These improved fiber properties resulted in significant differences in the fine count combed hosiery ring spun yarn produced. Yarn spun from saw ginned cotton had higher number of thin places, thick places, and number of neps as compared with yarn spun from roller ginned cotton. **El-Banna (2019)** results demonstrated that the effect of two types of roller gin-stand (McCarthy single roller and Indian double roller) was not significant on fiber length, uniformity index, short fiber index, fiber bundle strength and elongation percentage, Micronaire value, yellowness degree and trash area.

Materials and methods

The current investigation was carried out to study the effect of Gin-stand types, seed cotton cleaners and lint cleaners on fiber properties and Lea Count Strength Product-LCSP during 2023 season. According to Ministry of Agriculture role to maintain and trace the Egyptian cotton quality specifications from natural and mechanical crossing between Germplasm of the commercial varieties, assigned one gin for each specific commercial variety so that, Three commercial cotton varieties belonging to long staple super Giza 94, super Giza 86 and Giza 95 were used in this study to be ginned by both of the, two types of roller gin-stands (McCarthy gin-stand and rotary gin stand). McCarthy gin-stand was used as a control to all the mechanical treatments for each variety. Also, seed cotton and lint cotton cleaners were used. The mechanical treatments were:

- McCarthy gin-stand (comparative treatment)
- Rotary gin-stand
- Seed cotton cleaner + Rotary gin stand
- Rotary gin-stand +lint cotton cleaner
- cotton handling at rotary gin from feeding to bale pressing (complete ginning process system)

Four replications each of 100 kilo grams of seed cotton were divided into two parts to ginned by the rotary knife gin-stand at the modernized gin and the other sample to gin using McCarthy gin-stand attached to the modern ginnery after fixing their moving parts according to the methods used with respect to each variety. The four ginnery used on the study were El-Zagazig gin-plant, Sharqia governorate, Kafr El-Zayat gin-plant, Gharbia governorate, Kafr El-Dawar gin-plant, Behira governorate and New Fayoum gin-plant, Fayoum governorate. All the ginning mills under study belonging to Misr for cotton trade and Ginning Co.

Representative samples of ginned lint were drowned; at random to test for fiber and yarn properties at the lab of the cotton research institute, Agric., Res., center. Fiber and yarn properties were tested under controlled atmospheric condition of (21 ± 2˚C temperature) and (65 ± 2%) relative humidity.

HVI 1000 instrument according to ASTM was used to measure all fiber properties i.e. Micronaire reading (MIC.), fiber upper half means length (mm), length uniformity index (UI %), short fiber index (SFI %), fiber strength (g/tex), reflectance degree (Rd%), yellowness degree (+b), trash %, neps / gram and maturity ratio (%).

The cotton samples of Giza 94 and Giza 86 were spun into 60s carded yarns. While the cotton samples of Giza 95 were spun into 40s carded yarns with 3.6 twist multiplier using ring spinning as well as it estimated card waste ratio and sliver at the spinning mill, Cotton Spinning Research Department, Cotton Research Institute, Agriculture Research Center, Giza. Lea count strength product (LCSP) was estimated by Good Brand Tester. All the quality properties were tested according to (ASTM, 2002).

Statistical analysis

The experiment was carried out in a randomized manner with four replications and then analyzed as a factorial experiment using the method described by Gomez and Gomez (1984). The statistical program SPSS 20.0 was utilized for variance analysis. The L.S.D. at the 5% level of probability was used to calculate the significant differences between the mean values of treatments according to Snedecor and Cochran (1981).

Results and Discussion:

Data in Table (1) showed the Influence of ginning mechanical processes on fiber properties of Giza94 in El-Zagazig gin. It's clear that the gin-stand type and the mechanical processes had significant effect on all fiber properties except yellowness degree and maturity ratio. McCarthy ginned lint of Giza 94 gave the highest values of Micronaire values (4.10), Upper Half Mean Length (34.57), fiber strength (43.37) and trash% (0.36), and gave the lowest values of short fiber index (6.20), reflectance degree (75.60%) and neps / gram (106.67). Whereas, complete system gave the lowest values of Micronaire (3.83), upper half mean length (33.60) uniformity index (84.43), fiber strength (39.83) and Trash% (0.09) as well as it gave the highest values of short fiber index (9.60), reflectance degree (79.63), and neps / gram (170.33).

It concluded that, McCarthy gin-stand was better than the rotary gin-stand in term of maintain the fiber quality in El-Zagazig gin. Also, it shown that seed and lint cleaners decreased fiber length, uniformity index, fiber strength, reflectance degree and nep per gram. Whereas, it caused an increase both short fiber content and trash %. These results are in line with **Xu *et al.* (2014)**

Table (1) Influence of mechanical processes on fiber properties of Giza 94 in El-Zagazig gin

	Mechanical processes	MIC	UHML (mm)	UI %	SFI %	Str (g/tex)	Rd %	+b	Trash %	Nep/gram	MAT %
El Zagazig	McCarthy	4.10	34.57	87.10	6.20	43.37	75.60	9.20	0.36	106.67	0.86
	Rotary without cleaning	3.88	34.10	87.87	6.70	41.43	77.07	9.03	0.25	132.33	0.86
	Seed cleaning + Rotary	4.07	33.90	85.70	7.70	41.07	78.73	8.83	0.23	146.33	0.84
	Rotary + lint cleaning	3.93	33.43	84.53	8.03	40.40	78.53	9.10	0.14	161.67	0.84
	complete system	3.83	33.60	84.43	9.60	39.83	79.63	9.03	0.09	170.33	0.84
LSD at 5%		**0.141**	**0.505**	**1.354**	**0.349**	**0.688**	**1.589**	**NS**	**0.058**	**9.01**	**NS**

Abbreviations: Micronaire Reading (MIC), Upper Half Mean Length (UHML), Uniformity Index (UI%) ,Short Fiber index (SFI) ,) Fiber Strength (Str) , Reflectance degree (Rd%),Yellowness degree(+b), Nep per gram(Nep/gram) and Maturity % (MAT).

Table (2) illustrated the Influence of mechanical processes on fiber properties for Giza94 in Kafr El-Zayat gin. Results indicated that significant effect among ginning treatments on upper half mean length, short fiber index, fiber strength, trash % and neps /gram in Kafer El-Zayat gin. The highest mean values of upper half mean (34.77mm) and fiber strength (43.90 g/tex) were obtained from McCarthy gin, while it gave the lowest values of short fiber index (6.40) and Neps /gram (127.33). In contrary, complete ginning mechanical system gave the highest short fiber index (9.60), nep/gram (195.67), and the lowest trash% (0.11%).The difference between the two gin stands types results could be due to the difference in processing speeds which are higher in rotary Knife gin than in the reciprocating Knife gin, as well as the differences in doffing mechanism in the gin-stand types. At the rotary gin, the air used in doffing fibers and withdrawing the lint. While in McCarthy type, the ginning lint is doffed by the gravity. In general, fiber length and uniformity index decreased, and short fiber index increased as a result of the increased mechanical process of gin and seed and lint cleaners due to fiber breakage. These results are in harmony with those obtained by **Sharma (2012).**

Table (2) Influence of mechanical processes on fiber properties for Giza94 in Kafr El-Zayat gin

	Mechanical processes	MIC	UHML (mm)	UI %	SFI %	Str (g/tex)	Rd %	+b	Trash %	Nep /gram	MAT %
Kafr el Zayat	McCarthy	4.10	34.77	87.23	6.40	43.90	76.63	9.33	0.57	127.33	0.85
	Rotary without cleaning	3.85	34.53	85.87	6.97	42.37	77.13	8.97	0.81	155.33	0.86
	Seed cleaning+ Rotary	4.11	33.87	86.23	8.37	41.87	79.23	8.93	0.41	174.33	0.86
	Rotary+ lint cleaning	3.88	33.67	86.33	9.00	41.10	79.33	8.43	0.38	185.67	0.84
	complete system	3.89	33.73	85.20	9.60	40.13	77.77	9.13	0.11	195.67	0.86
LSD at 5%		**NS**	**0.403**	**NS**	**0.498**	**0.415**	**NS**	**NS**	**0.251**	**15.17**	**NS**

Influence of mechanical processes on fiber properties of Giza 86 in Kafr El-Dawar

With regard to results in Table (3), it showed that significant difference between gin-stand types for fiber length, short fiber index, fiber strength and trash % and neps /gram. While the gin-stand type has not induced any significant impact on Micronaire value, uniformity index, reflectance degree, yellowness degree, and maturity ratio. McCarthy gin-stand recorded the highest values of fiber length and trash % (33.40 mm and 0.76%) respectively, followed by rotary gin-stand (32.80mm and 0.61%) respectively. Also McCarthy gin-stand gave the strongest fiber (44.43g/tex) followed by seed cleaning +rotary gin-stand transaction (42.77 g/tex).while, the lowest values of fiber length and trash% (31.29 mm and 0.37%) respectively were obtained from complete ginning system. In contrast, complete ginning system gave the highest values of short fiber index (9.10%) and Neps / g (175.67). It noticed that, the mechanical process of gin-stand and nep count have an inverse relationship. The nep count increased due to the higher mechanical process of gin stand. As well as the use of seed and lint cleaners led to an increase in nep formation. The results obtained agree with **(Mangialardi, 1985; Anthony, 1996; Whitelock et al., 2011)**

Table (3) Influence of mechanical processes on fiber properties of Giza 86 in Kafr el dwar.

	Mechanical processes	MIC	UHML (mm)	UI %	SFI %	Str (g/tex)	Rd %	+b	Trash %	Nep/ gram	MAT %
Kafr el dwar	McCarthy	4.57	33.40	85.63	5.53	44.43	74.03	8.97	0.76	162.67	0.86
	Rotary without cleaning	4.31	32.80	85.10	6.10	42.73	72.80	8.93	0.61	163.33	0.86
	Seed cleaning+ Rotary	4.57	31.77	84.37	7.33	42.77	73.40	9.37	0.47	166.33	0.85
	Rotary+ lint cleaning	3.77	31.33	84.17	8.33	41.90	75.30	9.37	0.42	172.33	0.86
	complete system	4.55	31.29	83.60	9.10	41.97	75.47	9.30	0.37	175.67	0.87
LSD at 5%		**NS**	**0.874**	**NS**	**0.508**	**0.791**	**NS**	**NS**	**0.08**	**8.32**	**NS**

New Fayoum gin plant:

It obvious from Table (4) that, the effect of ginning mechanical processes on fiber length measurements, fiber strength and neps / gram were significant. While the effect of ginning mechanical processes on Micronaire reading, yellowness degree and reflectance degree, trash% and maturity ratio were not significant in El fayoum gin. McCarthy gin-stand gave the highest values of fiber length, uniformity index and fiber strength (31.19 mm, 86% and 39.07g/tex) respectively. However, complete ginning processing system gave the highest values of short fiber index, and neps gram (9.24% and 175.53g) respectively, hence it gave the lowest values of fiber length, uniformity index and fiber strength (28.63mm, 81.80% and 34.64 g/tex) respectively. In this connect, **Griffin, (1977**) reported that each machine in the gin has an effect on the fiber quality properties. The gin-stand and lint cleaner both exert the strongest forces on individual fibers, which makes them more susceptible to breaking.

Table (4) Influence of ginning mechanical processes on fiber properties for Giza95 in El Fayoum

	Mechanical processes	MIC	UHML (mm)	UI %	SFI %	Str (g/tex)	Rd %	+b	Trash %	Nep/ gram	MAT %
El -Fayoum	McCarthy	4.75	31.19	86.00	5.93	39.07	68.43	11.57	0.72	109.50	0.85
	Rotary without cleaning	4.57	30.40	83.91	7.10	37.83	69.09	11.59	0.62	121.87	0.86
	Seed cleaning+ Rotary	4.86	29.13	84.43	8.40	36.10	68.14	11.20	0.52	140.23	0.86
	Rotary+ lint cleaning	4.66	28.80	83.43	8.80	35.37	69.66	11.58	1.99	146.73	0.84
	complete system	4.64	28.63	81.80	9.24	34.64	70.50	11.73	0.41	175.53	0.84
		NS	**0.630**	**1.685**	**0.407**	**0.828**	**NS**	**NS**	**NS**	**10.144**	**NS**

The comparative between El-Zagazig and Kafr El-Zayat gins:

From results in Table (5), significant differences were observed between gin-stand types on short fiber index, fiber strength, trash percentage and nep/gram. While gin types didn't have significant effect on Micronaire value, fiber length, uniformity index yellowness degree, reflectance and maturity ratio. In Kafr El-Zayat gin, Giza94 gave higher short fiber index, fiber strength, trash percentage and neps/gram as compared with the same variety in El-Zagazig these may be due to the growing zone for super Giza 94 was different or could be due to the clearance of the mechanical parts of the two gins. Ginning types didn't have significant effect on lint color this could be due to that lint color seemed to be qualitatively inherited.

Table (5) Influence of gin stands type on fiber properties of super Giza 94 variety

Ginning types	MIC	UHML (mm)	UI %	SFI %	Str (g/tex)	Rd %	+b	Trash %	Nep/ gram	MAT %
El-Zagazig	3.96	33.92	85.93	7.75	41.22	77.91	9.04	0.21	143.47	0.85
Kafr El-Zayat	3.97	34.11	86.17	8.07	41.85	78.02	8.96	0.46	167.67	0.85
LSD at 5%	**NS**	**NS**	**NS**	**0.181**	**0.237**	**NS**	**NS**	**0.076**	**5.223**	**NS**

Data in Table (6) reveled that highly significant differences among the gin-stand type and cleaning treatments for all fiber properties except yellowness degree and maturity ratio. McCarthy gin-stand without using any cleaning machine was the superior in cotton quality. Where, It gave the highest values of Micronaire value, fiber length, uniformity index and fiber strength (4.10, 34.67mm, 87.17% and 43.63g/ tex) respectively. However, it gave the lowest values of short fiber index, reflectance degree % and Neps/ gram (6.30%, 76.12 and 117.00) respectively. On the other hand, the complete system (from seed cotton feeding to bale) gave the lowest Micronaire value, uniformity index, fiber strength and trash % (3.86, 84.82%, 39.98g/tex and 0.10%) respectively. Seed and lint cleaners are important process to improve low grade cottons and to remove foreign matter as well as the use of seed and lint cleaners caused an increased short fiber index, reflectance degree and nep /gram on the other hand it decreased fiber length, uniformity index and trash %.It concluded that, ginning without seed and lint cleaners gave better fiber quality properties as compared with ginning with seed and lint cleaners. These results are in agreement with those obtained by **Mahgoub (1981)** and **Tian et al. (2018).**

Table (6) Influence of gin-stand type and cleaning on fiber properties.

Mechanical processes	MIC	UHML (mm)	UI %	SFI %	Str (g/tex)	Rd %	+b	Trash %	Nep /gram	MAT %
McCarthy	4.10	34.67	87.17	6.30	43.63	76.12	9.27	0.47	117.00	0.86
Rotary without cleaning	3.86	34.32	86.87	6.83	41.90	77.10	9.00	0.53	143.83	0.86
Seed cleaning+ Rotary	4.09	33.88	85.97	8.03	41.47	78.98	8.88	0.32	160.33	0.85
Rotary+ lint cleaning	3.91	33.55	85.43	8.52	40.70	78.93	8.77	0.26	173.67	0.84
complete system	3.86	33.67	84.82	9.60	39.98	78.70	9.08	0.10	183.00	0.85
LSD at 5%	**0.120**	**0.302**	**1.228**	**0.285**	**0.375**	**1.486**	**NS**	**0.120**	**8.260**	**NS**

As for the interaction between gin-stand types and ginning mechanical processes , Results in Table (7) revealed that short fiber index and trash % significantly affected by the interaction between gin-stand types and mechanical treatments .In El-Zagazig gin, McCarthy gin-stand gave the lowest short fiber index (6.20%), and complete system gave the lowest trash % (0.09%). While, in Kafr El-Zayat gin the rotary without cleaning recorded the highest trash % (0.81%) and the highest short fiber index obtained from complete system (9.60%) in both ginning types.

Table (7) the interaction between ginning types and ginning mechanical processes for Giza 94

Ginning types	Mechanical processes	MIC	UHML (mm)	UI %	SFI %	Str (g/tex)	Rd %	+b	Trash %	Nep/ gram	MAT %
El-Zagazig	McCarthy	4.10	34.57	87.10	6.20	43.37	75.60	9.20	0.36	106.67	0.86
	Rotary without cleaning	3.88	34.10	87.87	6.70	41.43	77.07	9.03	0.25	132.33	0.86
	Seed cleaning+ Rotary	4.07	33.90	85.70	7.70	41.07	78.73	8.83	0.23	146.33	0.84
	Rotary+ lint cleaning	3.93	33.43	84.53	8.03	40.40	78.53	9.10	0.14	161.67	0.84
	complete system	3.83	33.60	84.43	9.60	39.83	79.63	9.03	0.09	170.33	0.84
Kafr El-Zayat	McCarthy	4.10	34.77	87.23	6.40	43.90	76.63	9.33	0.57	127.33	0.85
	Rotary without cleaning	3.85	34.53	85.87	6.97	42.37	77.13	8.97	0.81	155.33	0.86
	Seed cleaning+ Rotary	4.11	33.87	86.23	8.37	41.87	79.23	8.93	0.41	174.33	0.86
	Rotary+ lint cleaning	3.88	33.67	86.33	9.00	41.00	79.33	8.43	0.38	185.67	0.84
	complete system	3.89	33.73	85.20	9.60	40.13	77.77	9.13	0.11	195.67	0.86
LSD at 5%		**NS**	**NS**	**NS**	**0.403**	**NS**	**NS**	**NS**	**0.170**	**NS**	**NS**

Concerning El-Zagazig gin, the differences among ginning types were significant effect on the sliver and card waste percentages for super Giza 94 spun yarn Table 8. The rotary gin without cleaning gave the highest value of waste (11.25%) followed by McCarthy gin-stand (11.22%). The lowest sliver % was obtained from rotary gin-stand (88.73%) followed by McCarthy (88.74%). While, the complete system gave the highest sliver (93.48%) followed by rotary + lint cleaning (92.91%) and seed cleaning + rotary. However, the complete system gave the lowest waste (6.59%). It noticed that the use of seed and lint cleaners improved both sliver and card waste percentages.

Table (8) Effect of mechanical processes on lea count strength product, sliver % and waste% of Giza 94

	Mechanical processes	LCSP	Sliver%	Card waste%
El-Zagazig gin	McCarthy	2450	88.74	11.22
	Rotary without cleaning	2400	88.73	11.25
	Seed cleaning+ Rotary	2350	91.16	8.84
	Rotary+ lint cleaning	2400	92.91	7.10
	complete system	2300	93.48	6.59
LSD at 5%		**NS**	**1.41**	**1.51**

Abbreviations: Lea Count Strength Product (LCSP) and Card Sliver % (Sliver)

With regard to results in Table 9 Lea Count Strength Product, card waste and sliver were highly significantly affected by ginning mechanical treatments in Kafr El-Zayat gin. The McCarthy gin-stand (without using each of seed and lint cotton cleaners) gave the highest value of lea count strength product (2570) followed by rotary gin-stand without cleaning (2565) and rotary +lint cleaning (2470). While the complete system gave the lowest values of lea count strength product (2450) and the waste (6.12%). McCarthy gin-stand gave the highest card waste (11.48%) followed by rotary gin (10.94%) and seed cleaning +rotary gin (8.24%). On the other hand, McCarthy gin gave the lowest value of sliver (88.43%). but the highest sliver was obtained by rotary gin (93.87%). It could be concluded that the seed and lint cotton cleaners significantly reduced the lea count strength product. Because it may be attributed to the increase in the floating fiber index. Also, the seed and lint cotton cleaners significantly reduced card waste percentage. While it increased sliver percentage.

Table (9) Effect of ginning mechanical treatments on lea count strength product, sliver % and waste% of Giza 94

	Ginning mechanical treatments	LCSP	Sliver %	Card waste %
Kafr El zayat	McCarthy	2570	88.43	11.48
	Rotary without cleaning	2565	88.78	10.94
	Seed cleaning+ Rotary	2460	92.06	8.24
	Rotary+ lint cleaning	2470	93.40	6.57
	complete system	2450	93.87	6.12
LSD at 5%		**89.58**	**1.33**	**1.93**

Data in Table 10 demonstrated the differences among mechanical treatments, the statistical analysis showed insignificant effect for lea count strength product (LCSP), sliver and card waste percentages for Giza 86 spun yarn in Kafr El-Dawar gin.

Table (10) Effect of Ginning mechanical treatments on lea count strength product, sliver % and waste% of Giza 86

	Ginning mechanical treatments	LCSP	Sliver %	Card waste %
Kafr El dwar	McCarthy	2500	89.45	10.04
	Rotary without cleaning	2550	90.64	9.33
	Seed cleaning+ Rotary	2500	91.60	8.20
	Rotary+ lint cleaning	2450	92.35	7.55
	Complete system	2500	91.75	8.18
LSD at 5%		**NS**	**NS**	**NS**

The results of Giza 95 in Table (11) indicated that lea count strength product (LCSP), sliver and card waste were affected significantly by mechanical treatments in El Fayoum gin. The rotary gin without using two cleaners gave the highest value of lea count strength product (2230) followed by seed cleaning rotary (2220) and McCarthy gin (2215). While the lowest value of the same trait was obtained by the complete system (2100). Also, the complete system gave the highest value of sliver (93.54%) followed by rotary + lint cleaning (92.80%) and seed cleaning + rotary (92.66%). Conversely, McCarthy gin gave the lowest sliver (88.64%). The highest value of card waste was obtained by McCarthy gin (10.78%) followed by rotary gin (9.15%) and seed cleaning +rotary (7.16%). On the other hand, the complete system gave the lowest value of waste (6.43%).

In case of using seed cleaner or lint cleaner with rotary gin, the cotton ginned with rotary recorded lower lea count strength product than the cotton ginned with McCarthy gin. This might be related to the higher speed of rotary gin-stand to increase short fiber index in the ginned lint. Consequently, it decreased fiber length and uniformity index accordingly lea count strength product was decreased.

Table (11) Effect of Ginning mechanical treatments on lea count strength product, sliver % and waste% of Giza95

	Ginning mechanical treatments	LCSP	Sliver %	Card waste %
El-Fayoom	McCarthy	2215	88.64	10.78
	Rotary without cleaning	2230	90.38	9.15
	Seed cleaning+ Rotary	2220	92.66	7.16
	Rotary+ lint cleaning	2200	92.80	6.94
	complete system	2100	93.54	6.43
LSD at 5%		**80.88**	**1.016**	**1.279**

The comparative between El-Zagazig and Kafr El-Zayat gins:

Data in Table 12 cleared that there was significant effect of ginning types on lea count strength product. While, ginning types showed insignificant effect on sliver and card waste for Giza 94 spun yarn. Kafr El-Zayat gin recorded higher value of lea count strength product (2500) as compared with El-Zagazig (2380)

Table (12) impact of ginning types on lea count strength product, sliver % and waste% of Giza94

Ginning types	LCSP	Sliver %	Card waste%
El Zagazig	2380	91.00	9.00
Kafr El-Zayat	2500	91.31	8.67
LSD at 5%	**56.38**	**NS**	**NS**

There were significant differences among mechanical treatments for lea count strength product, sliver % and card waste % as shown in Table 13. McCarthy gin recorded higher lea count strength product (2500) as compared with other ginning mechanical treatments followed by rotary gin (2490) and rotary+ lint cleaning (2425). Whereas the complete system recorded the lowest lea count strength product (2380). The complete system recorded the highest sliver (93.68%) followed by rotary + lint cleaning (93.15%) and seed cleaning + rotary (91.61%) while the lowest value of sliver was obtain by McCarthy gin (88.59%).Also, McCarthy gin recorded the highest waste(11.35%) followed by rotary (11.09%) and seed cleaning+ rotary (8.54%).In contrast, the complete system recorded the lowest card waste% (6.35%). These results refer to the card waste % increase in the McCarthy gin-stand while it decreased in complete system. The complete system gave the lowest (LCSP), card waste and the highest value of sliver.

Table (13). Lea count strength product, sliver % and card waste% as affected by mechanical treatments.

Ginning mechanical treatments	LCSP	Sliver %	Card waste %
McCarthy	2515	88.59	11.35
Rotary without cleaning	2490	88.76	11.09
Seed cleaning + Rotary	2400	91.61	8.54
Rotary + lint cleaning	2425	93.15	6.84
complete system	2380	93.68	6.35
LSD at 5%	**89.14**	**0.909**	**1.146**

From data in Table 14, the interaction between gin types and gin mechanical treatments recorded insignificant effect on lea count strength product, sliver % and card waste%

Table (14) Effect the interaction between ginning types and mechanical treatments on Giza94 spun yarn

Ginning types	Ginning mechanical treatments	LCSP	Sliver %	Card waste%
El zagazig	McCarthy	2460	88.74	11.22
	Rotary without cleaning	2415	88.73	11.25
	Seed cleaning + Rotary	2345	91.16	8.84
	Rotary + lint cleaning	2380	92.91	7.10
	complete system	2310	93.48	6.59
Kafr el zayat	McCarthy	2570	88.43	11.48
	Rotary without cleaning	2565	88.78	10.94
	Seed cleaning+ Rotary	2460	92.06	8.24
	Rotary+ lint cleaning	2470	93.40	6.57
	complete system	2455	93.87	6.12
LSD at 5%		NS	NS	NS

Conclusions

Ginning is the first mechanical process, which involves separating the cotton lint from the seed using a gin stand. The purpose of this research was to compare the impact of ginning types, ginning mechanical treatments and their interaction on fiber quality properties, lea count strength product, card waste ratio, and sliver ratio. Three cotton varieties Giza 94, super Giza 86 and Giza 95 besides, two types of ginning (McCarthy gin-stand and rotary gin stand) and seed and lint cotton cleaners were used in four modern gin-plant. The results concluded that McCarthy gin-stand gave longer fiber, stronger fiber and higher trash %, lower short fiber index, reflectance degree and nep /gram than the ginning mechanical treatments. Whereas, complete system gave the lowest values of Micronaire, fiber length, uniformity index, fiber strength, Trash% and the highest values of short fiber index, reflectance degree and neps / gram. In terms of seed and lint cleaners' results demonstrated that seed and lint cleaners decreased fiber length, uniformity index, fiber strength, reflectance degree and nep per gram. Whereas it caused an increase in both short fiber content and trash %.

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Bioprospecting ferns: harnessing insecticidal proteins for combatting Bt resistance and advancing pest management strategies

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Abstract:

Crop yield losses due to insect infestation pose a significant global challenge, partially mitigated by Bacillus thuringiensis (Bt) insecticidal proteins in genetically modified crops. However, the widespread emergence of Bt resistance threatens the efficacy of these crops. Alternative insecticidal proteins sourced from plants, particularly ferns, offer promising solutions. Ferns, with their ancient lineage and rich secondary metabolites, possess potent defence mechanisms against insects. Recent research has identified novel insecticidal proteins from ferns, such as the IPD083 family and PtIP-50/PtIP-65 complex, demonstrating efficacy against major crop pests. Additionally, proteins like IPD079Ea from *Ophioglossum pendulum* and Tma12 from *Tectaria macrodonta* exhibit promising insecticidal properties with negligible health risks. Furthermore, ferns offer a diverse array of phytoecdysteroids and nonsteroidal compounds with insecticidal activities. Screening of fern and moss species has identified potential candidates for further evaluation in pest management. Notably, fern-derived proteins like IPD113 show effectiveness against Bt-resistant pests, suggesting convergent evolution with bacterial proteins. Exploring non-traditional plant sources for novel insecticidal proteins and compounds, particularly ferns, presents a promising avenue for agricultural innovation in sustainable pest management strategies.

Introduction

Crop yield loss caused by insect infestation is a pervasive global issue. Genetically modified crops incorporating *Bacillus thuringiensis* (Bt) insecticidal proteins have transformed insect-pest management practices, reducing dependency on conventional chemical insecticides. *Bacillus thuringiensis*-derived Cry proteins effectively control larvae of certain lepidopteran and coleopteran pests in transgenic crops. However, there are extensive reports of alarming rise in Bt resistance across the globe. Nonetheless, the emergence of resistance in specific pest populations has compromised the efficacy of Bt crops, marking potential challenges for future pest management strategies. Field-evolved resistance has been documented in numerous instances across various countries and pest species, posing a significant threat to the sustainability of existing transgenic crops tailored for pest management. Field-evolved resistance to Bacillus thuringiensis (Bt) crops has been substantiated across 26 instances encompassing 11 pest species in seven nations (Tabashnik et al., 2023; Tay et al., 2015; Wei et al., 2023). Moreover, Bt-crops are largely ineffective against sap-sucking pests. These observations highlight the ongoing interaction between Bt crops and evolving pest resistance, accentuating the necessity for alternative insecticidal proteins to combat these issues. In this context, screening plant biodiversity may lead to the discovery of novel insecticidal proteins from unconventional sources.

Proteins possessing toxic or insecticidal attributes are prevalent in nature, inclusive of plant species. Extensive research on plant-derived protein toxins has predominantly focused on seed plants, revealing various classes with insecticidal properties. Notably, non-seed plant protein toxins have received less attention, although several reports exist on their insecticidal activities, particularly found in fern and moss species. This article reviews the potential of ferns and other non-seed unconventional plant species as alternative sources of insecticidal proteins to combat insect pests.

Ferns: a rich reservoir for plethora of potential insecticidal proteins

Ferns, tracing their origins back to the Devonian period, are among the most ancient vascular plants. Unlike lycophytes and seed plants (gymnosperms and angiosperms), ferns possess true leaves and reproduce without flowers or seeds, marking a significant botanical divergence. Despite serving as sustenance for approximately 9300 insect species, ferns exhibit resilience against severe insect onslaughts, a trait ascribed to their rich repository of secondary metabolites and suspected presence of insect-resistant macromolecules (Cooper-Driver, 1978; Imbiscuso et al., 2009; Markham et al., 2006; Simmons and Herman, 2023). The secondary metabolites found in ferns, viz. hydrolysable tannins, ferulic acid, terpenes, alkaloids, and compounds mimicking insect hormones like ecdysones, have been extensively studied and documented. Notably, ferns and mosses have emerged as significant reservoirs of insecticidal proteins. Studies have shown that crude protein extracts from various fern and moss species can induce substantial mortality and growth reduction in key agricultural pests like *Spodoptera frugiperda* and *Helicoverpa zea* (Markham et al., 2006). Furthermore, ferns are known to produce insecticidal lectins, and compounds like phytoecdysteroids, cyanogenic glycosides, flavonoids, and enzymes like thiaminase and several insecticidal proteins, provide defence arsenals against hostile herbivores (Castrejón-Varela et al., 2022; Simmons and Herman, 2023). These findings underscore the intricate and multifaceted defence mechanisms that ferns employ to fend off insect attacks and ensure their survival in diverse ecological niches.

Recent studies have uncovered a diverse array of novel insecticidal proteins from ferns. For instance, IPD083 family of insecticidal proteins identified in multiple fern species, *Adiantum pedatum* and its related species belonging to the class Polypodiopsida/Pteridopsida, effectively controlled lepidopteran pests like *H. zea*, *S. frugiperda* and *C. includens* in transgenic maize and soybean plants. Notably, homologous proteins IPD083Aa and IPD083Cb demonstrate distinct interactions with midgut target sites in both *H. zea* and *S. frugiperda* brush border membrane vesicles. This differentiation suggests their potential deployment as a pyramid in pest management strategies aimed at key lepidopteran pests (Liu et al., 2019). Needless to say, this could potentially serve as viable alternatives to conventional Bt-based pest management measures, potentially mitigating insect resistance to Bt proteins.

Protein extracts from 23 plants representing fern and moss species were screened to assess efficacy against corn earworm (*H. zea*) and fall armyworm (*S. frugiperda*). Among the tested species, extracts from sensitive fern (*Onoclea sensibilis*) and ebony spleenwort (*Asplenium platyneuron*), burned ground moss (*Ceratodon purpureus*) and glade fern (*Anthyrium pycnocarpon*), exhibited noteworthy decreases in damage during leaf-disk assays. Furthermore, these extracts displayed inhibitory effects on insect larval growth. These species show promise as potential candidates for further evaluation in subsequent studies (Markham et al., 2006).

Meanwhile, ferns have also emerged as a significant source of phytoecdysteroids, steroidal compounds structurally akin to ecdysone. Phytoecdysteroids, prevalent in various land plants including ferns, exhibit diverse biological activities, influencing the behavior and development of insects. Fern species such as *Pteridium aquilinum*, *Cheilanthes farinosa*, *Polypodium vulgare*, and others are known for synthesizing phytoecdysteroids, which have been identified to possess insecticidal and miticidal properties against notable pests like *S. litura*, *H. armigera* and *Oligonychus coffeae*. Additionally, nonsteroidal compounds like tebufenozide, halofenozide, chromafenozide and methoxyfenozide have demonstrated insecticidal efficacy against lepidopteran pests, with halofenozide exhibiting broad-spectrum activity (Sahayaraj, 2022; Selvaraj et al., 2005).

In one study, a two-protein insecticidal complex comprising PtIP-50 and PtIP-65 proteins from fern *Asplenium australasicum* demonstrated potent pest control capabilities (Barry et al., 2019; Simmons and Herman, 2023). These insecticidal proteins exhibited efficacy against diverse lepidopteran crop pests including *Chrysodeixis includens*, *Ostrinia nubilalis* and *H. zea* (BARRY et al., 2018).

A protein, Tma12, sourced from the edible fern *Tectaria macrodonta*, was discovered to possess insecticidal properties against whiteflies. *In vitro* feeding assays revealed that even at sublethal doses, Tma12 interfered with the whitefly life cycle. Transgenic cotton lines expressing Tma12 exhibited resistance to whitefly infestation in enclosed field trials. The transgenic lines exhibited resistance to cotton leaf curl viral disease, which is disseminated by whiteflies. Testing on rats indicated no observable histological or biochemical changes post Tma12 consumption, suggesting its potential suitability for integration into genetically modified crops for whitefly and virus control (Shukla et al., 2016). In a subsequent investigation, examination of the amino acid sequence and crystallographic structure of Tma12 has provided insight into its fundamental properties (Yadav et al., 2019). Results indicate that Tma12 likely belongs to the AA10 family of lytic polysaccharide monooxygenases (LPMOs), representing the first instance of such proteins identified in plants. Comparative analysis revealed significant sequence similarity between Tma12 and a cellulolytic LPMO from Streptomyces coelicolor, further supporting its classification. The crystal structure of Tma12 exhibited key structural features characteristic of AA10 LPMOs, corroborating its potential enzymatic activity. The discovery of Tma12 highlights the intersection between insecticidal activity and structural similarity with microbial LPMOs, suggesting a novel avenue for exploring LPMOs as potential insecticidal agents in agricultural pest management strategies (Yadav et al., 2019). Recently, in a study conducted by the ICAR-Central Institute for Cotton Research (ICAR-CICR), India various TMA-12 events alongside resistant and susceptible genotypes were assessed for three consecutive years. Compared to the non-Event (Coker-312), the resistant check LK 861 displayed notably lower nymphal and adult whitefly counts, while no significant difference was observed between TMA-12 events and the susceptible check for nymphal counts, although adult whitefly counts were similar between the non-Event and susceptible check. Additionally, no significant variations were observed among different genotypes, and intriguingly, no mortality was observed in whiteflies exposed to cotton genotypes with TMA-12 events (ICAR-CICR, unpublished). These divergent outcomes prompt further investigation into the efficacy of Tma12, necessitating additional research and potentially the evaluation of additional Tma12 events in cotton and other crops, both in controlled environments and field conditions.

A novel insecticidal protein, IPD079Ea, originating from the fern *Ophioglossum pendulum*, has been identified. This protein presents a fresh target for controlling Western Corn Rootworm (WCR) infestations in genetically modified (GM) maize. Its safety profile was evaluated utilizing a comprehensive weight-of-evidence approach, revealing no evidence of toxin or allergen hazards associated with IPD079Ea. Consequently, based on the findings, IPD079Ea is deemed unlikely to pose any health risks to humans or animals (Carlson et al., 2022).

Several other independent investigations documented during the years 1994 and 2020, revealed that around 47 fern and 2 lycophyte species exhibited significant insecticidal, repellent, or insect growth-regulating properties, notably against prominent insect species such as *Helicoverpa armigera*, *Spodoptera litura*, *Aedes aegypti*, *Anopheles stephensi* and *Aedes albopictus*. These data re-affirms the importance of fern and other non-seed plants as potential sources of insecticidal and pest-repellent compounds (Lima et al., 2022).

Another recent study highlighted the discovery of a novel insecticidal protein family, IPD113, originating from fern species (*Pteris*). Laboratory assays reveal that these proteins are capable of combating fall armyworm strains resistant to conventional Bt proteins, such as Cry1Fa and Cry2A.127. Furthermore, transgenic corn plants expressing IPD113 exhibit moderate to strong protection against leaf and ear damage caused by the fall armyworm and corn earworm (*H. zea*). Subsequent transcriptome analysis revealed homologues of IPD113 across 22 fern species spanning multiple orders. Strikingly, structural analyses of IPD113_Cow, a member of the IPD113 family sourced from *Colysis wrightii* (now known as *Leptochilus wrightii*), revealed structural similarities to Bt insecticidal proteins, particularly in two of the three characteristic domains, suggesting possible evolutionary convergence rather than direct gene transfer from bacteria. Additionally, similarities were observed between IPD113_Cow and bacterial proteins called PirB, indicating potential convergent evolution between distantly related bacteria. The emergence of IPD113 proteins, along with other fern-derived insecticidal proteins, highlights the diversity of insecticidal mechanisms beyond Bt proteins, such as chitin digestion. The discovery of IPD113 represents a significant step forward in addressing challenges associated with Bt resistance and enhancing agricultural sustainability (Wei et al., 2023).

Conclusion:

Ferns present a promising avenue for exploring alternative pest management strategies in agriculture due to their rich repository of secondary metabolites and suspected presence of insect-resistant macromolecules. The discovery of novel insecticidal proteins from ferns underscores their potential in mitigating insect infestation in crops. The emergence of novel insecticidal protein families, like IPD113, from fern species provides insights into alternative mechanisms beyond Bt proteins, promising enhanced agricultural sustainability. However, drawbacks with ferns include limited understanding of their insect defense mechanisms and the variability in efficacy across different species. Another limitation pertains to the potential deterrent effect of phytoecdysteroids found in specific ferns on beneficial insects. Nonetheless, future prospects involve further exploration of fern biodiversity to identify additional insecticidal compounds and elucidate the evolutionary drivers of insect resistance in lower plants. The documented effectiveness of fern-derived proteins against Bt-resistant pests underscores their potential in addressing the challenges of evolving pest resistance and enhancing agricultural sustainability. As an alternate pest management option, insecticidal compounds derived from ferns and other unconventional non-seed plants offer a sustainable approach that may complement existing strategies, potentially reducing reliance on chemical insecticides and mitigating the challenges associated with insect resistance to conventional treatments. Moving forward, continued exploration of fern biodiversity and characterization of novel insecticidal proteins hold promise for enhancing agricultural sustainability while minimizing environmental impacts.

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