ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

**MSc THESIS**

**Mohamud Ali IBRAHIM**

# PERFORMANCE OF DIFFERENT SPRAY NOZZLES IN THE APPLICATION OF DEFOLIANT ON COTTON PLANTS

**DEPARTMENT OF AGRICULTURAL MACHINERY AND TECHNOLOGY ENGINEERING**

**ADANA-2021**

# ABSTRACT

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Supervisor : Prof. Dr. Ali BAYAT
Year: 2021, Pages: 57
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: Prof. Dr. Ahmet İNCE



Defoliant spraying is a key link in the mechanized cotton harvest, as sufficient and uniform spraying can improve the defoliation quality and decrease the cotton trash content. In defoliant application, application volume and spraying technology are extremely important. In this study, the effectiveness of defoliant application to cotton plant that has come to harvest with two different application volumes and three different types of nozzles with a standard field crop sprayer was determined. Experiments were carried on two phases as field area trials and laboratory analysis. Application rates were 250 l/ha and 400 L/ha and spraying nozzles were (1) Standard flat fan nozzle (TP8006), (2) Air induction nozzle (AI 11002-VS) and (3) Dual Pattern nozzle (AI307003VP). A tracer (BSF) and Defoliant were applied to mature cotton with approximately 60% open bolls and samplings for BSF deposition and spray coverage on cotton plant were done at two plant height (Upper layer, lower layer) of plant. Before and after spraying, bolls open and leaves rate on cotton plants were calculated and filter papers were used to detect BSF deposition and water sensitive papers (WSP) were used to measure coverage rate of spraying methods used. Spectrofluorophotometer was used to detect the amount of tracer deposition on targets and an image process computer programme was used to measure coverage rate on WSP. In analysis conclusions showed that air induction nozzle (AI 11002-VS), achieved better results than the dual pattern and standard flat fan nozzles in terms of higher depositions, coverages and leaf defoliations and boll opening rates. AI Nozzles operating at 250 L/ha application rate provide the highest deposition and coverage rate on applications of defoliant, in addition, BSF as an indicator of the defoliant used reached on leaf beneath in merely this spray nozzle. After defoliation boll opining rate was 85 % on the $7^{th}$ and $12^{th}$ days after spraying and falling rate of leaves was 76 % at application rate of 250 L/ha with Air Induction (AI1102) nozzle.



**Key Words**: Cotton defoliant, Air induction nozzle, Dual pattern nozzle, Standard flat fan nozzle, Coverage rate, Spray deposition, Boll opening rate and leaves falling rate.

# ÖZ

## YÜKSEK LİSANS TEZİ

## PAMUK BİTKİSİNE DEFOLİANT UYGULAMASINDA FARKLI PÜSKÜRTME MEMELERİNİN ETKİNLİĞİ

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**ÇUKUROVA ÜNIVERSITESİ**
**FEN BİLİMLERİ ENSTİTÜSÜ**
**TARIM MAKİNELERİ VE TEKNOLOJİLERİ MHÜHEDİSLİĞİ ANA BİLİM DALI**

Danışman : Prof. Dr. Ali BAYAT
Yıl: 2021, Sayfa: 57
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Yaprak dökücü ve kolza açıcı olarak kullanılan defoliant, makinalı pamuk hasadında önemli bir yere sahiptir, Eğer defoliant etkin bir şekide uygulanırsa pamuk bitkisinin yaprak dökümü oranı artar ve çıtırık kolza sayısı azaltılabilir. Yaprak dökücü uygulamada, uygulama hacmi ve püskürtme teknolojisi son derece önemlidir. Bu çalışmada, iki farklı uygulama hacmi ve üç farklı tip meme ile hasadı yaklaşan pamuk bitkisine standart tarla pülverizetörü ile defoliant uygulanarak sağlanan etkinlik belirlenmiştir. Deneyler, tarla denemeleri ve laboratuvar analizleri olmak üzere iki aşamada gerçekleştirilmiştir. Defoliant uygulama oranları 250 l/ha ve 400 L/ha ve püskürtme memeleri (1) Standart yelpaze hüzmeli meme; (TP8006), (2) Hava emişli meme (AI 11002-VS) ve (3) İkiz jetli meme; (AI307003VP) olarak seçilmiştir. Yaklaşık %60 oranında açık kozalı olgun pamuğa bir izleyici (BSF) ve defoliant uygulanmıştır. Pamuk bitkisi üzerinde biriken defoliantı temsilen BSF birikimi ve pamuk bitkisi üzerine püskürtülen damlaların kaplam oranını belirlemek için bitkinin iki yüksekliğinde (Üst bölge, alt bölge) örneklemeler yapılmıştır. Püskürtmeden önce ve sonra, pamuk bitkilerinde koza açma ve yaprak oranları hesaplanmış ve BSF birikimini tespit etmek için filtre kağıtları ve kullanılan püskürtme yöntemlerinin kaplama oranını ölçmek için suya duyarlı kağıtlar (WSP) kullanılmıştır. Hedefler üzerindeki izleyici birikimi miktarını saptamak için spektroflorofotometre kullanılmış ve WSP'deki kaplama oranını ölçmek için bir görüntü işleme bilgisayar programı kullanılmıştır. Analiz sonuçlarında, 250 L/ha uygulama hacminde hava emişli meme (AI 11002-VS), İkiz jetli meme ve Standart yelpaze hüzmeli memeden daha yüksek birikim, kaplama oranı, yaprak dökümü ve koza açılma oranları sağlamıştır, Ayrıca kullanılan yaprak dökücünün bir göstergesi olarak sadece hava emişli memede yaprak alt yüzeyinde daha fazla BSF birikimi sağlanmıştır. Çalışmada kullanılan defoliant, 250 l/ha uygulama hacminde hava emişli meme ile uygulamadan sonraki 7. ve 12. günlerde koza açma oranı % 85 ve yaprak dökme oranı % 76 olarak ölçülmüştür.

**Anahtar Kelimeler:** Pamuk defolyant, Hava emişli meme, ikiz jetli meme yelpaze hüzmeli meme, ilaç birikimi, Kaplama oranı, yaprak dökme oranı, kolza açma oranı

## EXTENDED ABSTRACT

The International Cotton Advisory Committee (ICAC) predicts that 33.7 million hectares of cotton were planted globally during the 2019-2020 production period, with India accounting for 37% of this amount. India was followed by the United States, China, Pakistan, and Brazil in terms of cultivated area. The growth of cotton cultivation areas in African countries in recent years has resulted in an increase in the amount of cotton produced as well as their overall contribution to global cotton output. According to 2019 data, Turkey is a large cotton producer, with 4.778.681 ha of cotton production area. Machine cotton harvesting is common in developed countries with high levels of industrialization. Manual harvesting, on the other hand, allows workers to pick cotton over several days, whereas machine harvesting is finished in a single day (in one traffic). As a result, the cotton plant's leaves must be shed, and the rapeseed must be fully bloomed in order for machine harvesting to extract the seed neatly and efficiently. To achieve this state, chemicals known as defoliants are sprayed with various field sprayers after the rapeseed on the plant has opened naturally at a rate of 60-70 percent in Turkey and many other industrialized nations.

In this study, defoliation rates and boll opening rates of cotton plants were investigated utilizing various application volumes and spray nozzles in the use of defoliant applied before machine harvesting. The research was carried out on the fields of the Eastern Mediterranean Agricultural Research Institute in 2020, using the cotton variety DP-332. Following the technique's planting, the necessary fertilization, watering, and other maintenance activities were carried out under usual conditions. Defoliants with the brand names Dropp Ultra and Finish PRO were applied with a standard kind of field sprayer in two different application volumes (250 and 400 l/ha) and with three different spray nozzles (Spraying Sys.Co. Standard fan jet nozzle TP8006 (M1), Air induction nozzles AI11002 (M2), and Twin jet nozzle AI307003 are available (M3). Because it is difficult to measure the accumulation and distribution of the sprayed defoliant on the leaf surface, Birillantsulfolavin (BSF) trace material was used to represent the actual defoliant in defoliant applications, and water-sensitive cards (Syngenta, WSP size 26x76 mm) were used to determine the defoliant coverage rate on the leaf.

The research was planned to use a random blocks experimental design, with 5 plants chosen for each plot, and each plant divided into two vertical regions (upper region and lower region), with samples made by attaching filter papers and similarly water-sensitive cards to the lower and upper surfaces of 4 leaves in each region. A Spectrofluorophotometer was used to quantify the quantity of BSF trace material reflecting the amount of defoliant on the samples, and an image processing tool was used to compute the drop coverage rate on the water-resistant cards. Furthermore, cotton plant defoliation and rapeseed opening rates were calculated in the plots before and after defoliant application. To compare the averages of the gathered data, three methods were used.

According to the research results, the highest defoliant coverage and deposition rate in the application of defoliant to cotton was reached in the application volume produced with the M3 nozzle. Considering the defoliation and boll opening rates obtained on the first, fourth, seventh, and twelfth days after defoliant application; Spraying method that demonstrates both effects simultaneously (76 percent defoliation and 85 percent boll opening rate) at 250 L/ha application volume with air-induction nozzle and 1,4,7, and 12 applications after 1-4 days of spraying Afterwards, it was verified that the defoliant point was reasonable and the defoliant rate was high in 7-12 days. In the higher and lower sections of the plant, various levels of defoliant build-up and coverage rates were produced using each approach. Given that the most intensive rapeseed in the cotton plant is generated in the lower section of the plant, the highest BSF accumulation and coverage rate in this region was reached with a 250 l/ha application volume and air induction nozzle spraying.

## GENİŞLETİLMİŞ ÖZET

Uluslararası Pamuk Danışma Komitesi'nin (ICAC) 2019-2020 üretim dönemi verilerine göre, dünyada 33,7 milyon hektar pamuk üretilmiş ve bu ekimin %37'si Hindistan'da gerçekleştirilmiştir. Hindistan'ı ekili alanların genişliğinde ABD, Çin, Pakistan ve Brezilya izlemiştir. Afrika ülkelerinde son yıllarda pamuk ekim alanlarının genişlemesi, üretilen pamuk miktarının ve bunların küresel pamuk üretimine genel katkısının artmasıyla da sonuçlanmıştır. Türkiye öenemli bir pamuk üreticisi ülke olup 2019 yılı verilerine göre pamuk üretim alanı 4.778.681 ha Endüstrileşmenin yoğun yaşandığı gelişmiş ülkelerde pamuk hasadı yaygın olarak makina ile yapılmaktadır. Ancak elle yapılan hasatta toplama yapan işçiler bir kaç periyodda pamuk toplayabilmekte iken, makinalı hasat tek periyotta (tek trafikte) yapılmaktadır. Bu nedenden dolayı makinalı hasat gerek kütlünün temiz toplanması gerekse toplama veriminin yüksek olması için pamuk bitkisi üzerindeki yaprakların dökülmüş ve kolzaların da tamamen açmış olması gerekmektedir. Bu durumu sağlayabilmek için gerek Türkiye de gerekse gelişmiş birçok ülkede bitki üzerindeki kolzaların yaklaşık %60-70 oranında doğal olarak açmış olmasının ardından çeşitli tarla pülverizatörü ile defoliant olarak adlandırılan kimyasal maddeler püskürtülmektedir. Ancak püskürtülen defolonattan beklenen sonucun alınması çoğunlukla püskürtme yöntemi, kullanılan uygulama hacmi ve defoliantın etki biçimine göre değişmektedir.

Bu çalışmada, pamukta makinalı hasattan önce uygulanan yaprak döktürücü (defolyant) kullanımında farklı ugulama hacimleri ve püskürtme memeleri ile yapılan uygulamlarda pamuk bitkisinde yaprak dökme oranları ve kolza açma oranları tespit edilmiştir. Çalışma Doğu Akdeniz Tarımsal Araştırma enstitüsüne bağlı araziler üzerinde 2020 yılında DP-332 pamuk çeşidi ile yürütülmüştür. Tekniğine uygun olarak yapılan ekimden sonar gerekli gübreleme, sulama ve diğer bakım işlemleri geleneksel koşullarda yürütülmüştür. Deneme alanında yapılan fiziksel gözlemlerde %60 oranında kolza açım oranından sonra ticari adı Dropp Ultra ve Finish PRO olan defoliantalar standart tip bir tarla pülverizetörü ile 2 farklı uygulam hacminde (250 ve 400 l/ha) ve 3 farklı püskürtme memesi ile (Spraying Sys.Co,USA' ait Hava emişli meme; AI11002, (M2) İkiz jetli meme; AI307003 (M3) ve Standart yelpaze hüzmeli meme; TP8006,) (M3) uygulanmıştır. Püskürtülen defoliantın yaprak yüzeyi üzerindeki birikimi ve dağılımını doğrudan ölçmek zor olduğundan, defoliant uygulamlarında gereçek defoliantı temsilen Birillantsulfolavin (BSF) iz maddesi kullanılmış ve defoliantın yaprak üzerinde sağladığı kaplama oranını belirlemek için ise suya duyarlı kartlar (Syngenta,WSP size 26x76 mm) kullanılmıştır.

Araştırma tesadüfü bloklar deneme desinine göre planlanmış, beher parselde 5 adet bitki seçilmiş ve her bitki düşeyde iki bölgeye (üst bölge ve alt bölge olarak) ayrılarak her bölgede 4 Adet yaprağın alt ve üst yüzeyine filter kağıtları ve benzer şeklilde suya duyarlı kartlar takılarak örneklemler yapılmıştır. Örnekler üzerinde defoliant miktarını temsilen BSF iz maddesi miktarı Spectrofluorophotometer ile, suya duralı kartlar üzerindeki damla kaplam oranı bir görüntü işleme programı ile saptanmıştır. Ayrıca denen parsellerinde defoliant uygulam öncesi ve sonrası, pamuk bitkisi yaprak dökme oranı ve kolza açma oranları heseplanmıştır. Elde edilen verilerin ortalamalarının karşılaştırılmasında 3 yöntemi kullanılmıştır.

Araştırmada elde edilen sonuçlara göre, pamuk birkisine defoliant uygulamada en yüksek defoliant kaplama ve birikim oranı uygulama hacminde M3 memesi ile yapılan uygulamada sağlanmıştır. Defolyant uygulamlarında uygulama sonrası 1.,4, 7, ve 12 günlerde yapılan sayılarda elde edilen yaprak dökme oranları ve kolza açma oranları dikkate alındığında; her iki etkiyi bir arada ( %76 yaprak dökme ve %85 kolza açma oranı) en yüksek gösteren püskürtme yöntemi Hava emişli meme ile 250 L/ha uygulama hacminde ve uygulamdan sonra 1,4,7,ve 12, 1-4 günde yapılan sayımlarda, 1 ve 4. günde orta düzeyde, 7 ve 12. günende en yüksek yaprak döküme oranı ve kolza açma oranı sağlamıştır. Her bir yöntemte bitki üst bölgesinde ve alt bölgesinde farklı miktarlarada defoliantı temsilen BSF iz maddesi birikimi ve kaplam oranları sağlanmıştır. Pamuk bitkisinde en yoğun kolzaların bitki alt bölgesinde oluştuğu dikkate alındığında, bu bölgede en fazla ilaç birikimi ve kaplam oranı 250 l/ha uygulama hacmi ve hava emişli püskürtme memesi ile sağlanmıştır.

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**CONTENTS** **PAGE**

**LIST OF TABLES** **PAGE**

**LIST OF FIGURES** **PAGE**

**LIST OF ABBREVIAYIONS**

| | |
|---|---|
| FAO | : Food and Agriculture Organization of United Nations |
| LSD | : Least Significant Difference |
| TUIK | : Turkish Statistical Institute |
| CV | : Coefficient Variation |
| ICAC | : International Cotton Advisory Committee |
| FAOSTAT | : Food and Agriculture Organization Corporate Statistical Database |
| ha | : Hectare |
| kg | : Kilogram |
| µg | : Microgram |
| cm | : Centimetre |
| AI | : Air Induction Nozzle |
| min | : Minute |
| VMD | : Volume median diameter |
| ppm | : parts per million |
| km/h | : Kilometre per hour |
| M1 | : Standard flat fan nozzle |
| M2 | : Air induction nozzle |
| M3 | : Dual pattern nozzle |

# 1. INTRODUCTION

## 1.1. Cotton production in the world and Turkey

Cotton plants are classified as belonging to the order Malvales, tribe Malvaceae, genus Gossypium, and species Gossypium hirsutum L.

Although the most pressing issue confronting the world's rapidly growing population today is definitely the demand for fibers used for various purposes, particularly textiles, the need for fibers used for various purposes, particularly textiles, is not less than the nutritional requirement. Despite continuous increases in synthetic fiber production, cotton (Gossypium hirsutum L.) plants are always first among raw materials used in the world textile industry, because it has unique fiber properties that are unmatched for the industry's and its users' expectations and demands, and it has extraordinary structural properties that can never be imitated by human beings. Cotton's quality parameters, which are so vital, should be high, as should yield. Cotton is an industrial commodity that has major contributions to the textile industry with its fiber, to the oil industry with its seed oil, to the livestock sector with its pulp, and to our export and international commerce, despite giving a wide range of business with its agricultural and industry. Cotton fibers are now employed as raw materials in a wide range of industries, including varied textile, fabric, tulle, diverse garments, yarn, twine, bedding, quilting, and smokeless gunpowder. Furthermore, the potential of using the stems that remain in the field after harvest as particleboard, crude fiber, and fuel should be considered (Denizdurduran, 2008).

According to the International Cotton Advisory Committee (ICAC) figures, 33.7 million hectares of cotton were produced in the world between 2019 and 2020, with India accounting for 37% of this crop. In terms of cultivated land, India was followed by the United States, China, Pakistan, and Brazil. In recent years, the expansion of cotton acreage in African countries has resulted in an increase in the amount of cotton produced and their overall contribution to global cotton output.

Despite recent increases in acreage, Turkey is placed 11th, after Mali, Benin, and other African peers. However, this does not appear to have harmed their production ability, since they continue to produce more than most of the aforementioned African countries, as seen in Table 1.1.

For many years, China was the world's biggest cotton producer, but in recent years, India has caught up to, if not surpassed, China in terms of output growth. According to estimates for the 2018/19 season, China, India, the United States, Brazil, and Pakistan are the world's top five cotton producers. The first five rows of consumption are occupied by China, India, Pakistan, Bangladesh, and Turkey.

According to the proved 1.2 in the average of six periods, as seen in Turkey placing sixth world cotton output, it is placed 5th among the major cotton producing countries after China in terms of yield (Tüik and FAOSTAT, 2019).

Table 1.1. World cotton cultivation areas (1,000 ha)

| No | Countries | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 |
|---|---|---|---|---|---|---|
| 1 | India | 11.638 | 10.845 | 12.235 | 12.600 | 12.700 |
| 2 | America | 3.291 | 3.848 | 4.492 | 4.130 | 4.177 |
| 3 | China | 3.793 | 3.100 | 3.350 | 3.367 | 3.300 |
| 4 | Pakistan | 2.670 | 2.496 | 2.665 | 2.325 | 2.631 |
| 5 | Brazil | 1.007 | 939 | 1.175 | 1.618 | 1.662 |
| 6 | Uzbekistan | 1.272 | 1.250 | 1.208 | 900 | 900 |
| 7 | Burkina Faso | 631 | 740 | 879 | 646 | 735 |
| 8 | Mali | 573 | 656 | 704 | 698 | 782 |
| 9 | Turkmenistan | 534 | 545 | 545 | 534 | 545 |
| 10 | Benin | 372 | 418 | 530 | 656 | 700 |
| 11 | Turkey | 440 | 420 | 462 | 520 | 520 |
| | Other | 4.942 | 4.610 | 4.950 | 4.992 | 5.100 |
| | Total | 31.163 | 29.867 | 33.195 | 32.986 | 33.752 |

Table 1.2. World cotton lint yields (kg/ha)

| No | Countries | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 |
|---|---|---|---|---|---|---|
| 1 | Australia | 2.196 | 1.598 | 2.088 | 2.071 | 2.231 |
| 2 | China | 1.427 | 1.581 | 1.758 | 1.764 | 1.758 |
| 3 | Brazil | 1.506 | 1.629 | 1.707 | 1.640 | 1.718 |
| 4 | Mexica | 1.449 | 1.575 | 1.580 | 1.587 | 1.644 |
| 5 | Turkey | 1.475 | 1.674 | 1.714 | 1.944 | 1.567 |
| 6 | Greece | 997 | 1.009 | 906 | 1.132 | 1.268 |
| 7 | America | 963 | 972 | 1.014 | 964 | 1.032 |
| 8 | Argentina | 575 | 727 | 688 | 773 | 737 |
| 8 | Sudan | 600 | 561 | 444 | 578 | 722 |
| 10 | Uzbekistan | 641 | 631 | 662 | 712 | 712 |
| | World Averages | 700 | 772 | 805 | 778 | 767 |

According to the data in tables 1.1 and 1.2, cotton is grown on an average of 33.7 million hectares worldwide, with a daily lint production of 76.8 kg. In recent years, cotton has been produced on an average of 519 thousand hectares in Turkey, providing 976,000 tons of lint. The average daily fiber production is 496 kg.

Table 1.3. Cotton cultivation in Turkey, production, yield (Tüik 2020)

| Years | Cultivation area (da) | Harvest area (da) | Production (ton) | Yield (kg/da) |
|---|---|---|---|---|
| 2015 | 4.340.134 | 4.340.004 | 2.050.000 | 472 |
| 2016 | 4.160.098 | 4.160.023 | 2.100.000 | 505 |
| 2017 | 5.018.534 | 5.014.784 | 2.450.000 | 489 |
| 2018 | 5.186.342 | 5.186.342 | 2.570.000 | 496 |
| 2019 | 4.778.681 | 4.778.069 | 2.200.000 | 460 |
| 2020 | 3.592.200 | 3.592.414 | 1.773.646 | 494 |

Cotton cultivation in Turkey has continuously increased since 2015. In 2019, the acreage grew from 4.340.134 hectares to 4.778.681 per acre. When it comes to cotton output, it increased from 2.050.000 tons in 2014 to 2.200.000 tons in 2015. The yield from the unit area has risen in exact proportion to these figures (Table 1.3).

### 1.2. Harvesting Machine and Situation in Turkey

According to Aydemir (1982), the notion of collecting cotton by machine was implemented in the 1850s. Rambert and Prescott created the first cotton harvester in the United States. However, because manual cotton harvesting is inexpensive and simple to obtain, harvesters were unable to find a wide range of applications. Harvesting machines became widely used in the years that followed, owing to rising shortages of gathering labor in developed countries, particularly during the 1950s (Denizdurduran, 2008).

According to Chaundhry (1997), all cotton harvesting is done by machine in countries such as the United States, Australia, and Israel. Furthermore, in Argentina, 75 percent is harvested by machines; in Brazil, 5-10% is harvested by machinery; in Greece, 92 percent is harvested by machinery; and in Uzbekistan, 30-40% is harvested by machinery (Denizdurduran, 2008).

Table 1.4 shows the number of cotton harvesters in Turkey during the last five years, which has increased by around 550 units. As a result, machine-harvesting of cotton is becoming more widespread, leading in an increase in the use of defoliant applied prior to machine-harvesting.

Table 1.4. The number of cotton harvesters in Adana province by years (Tüik, 2019)

| Years | Number of Cotton Harvesting Machines | |
|---|---|---|
| | Turkey | Adana |
| 2009 | 508 | 81 |
| 2010 | 595 | 86 |
| 2011 | 730 | 96 |
| 2012 | 910 | 101 |
| 2013 | 950 | 103 |
| 2014 | 1.050 | 103 |
| 2015 | 1.080 | 98 |
| 2016 | 1.155 | 97 |
| 2017 | 1.245 | 98 |
| 2018 | 1.285 | 102 |
| 2019 | 1.297 | 100 |

In 2009, the number of cotton pickers in Turkey increased almost 35-fold to 508. In 2019, the cotton picker was sighted 1.297 times. Similarly, while the number of cotton harvesters in Adana province was 81 in 2018, it grew to 100 in 2019 and increased by 15.

Cotton harvesting times vary depending on geography, variety, start of autumn rainfall, cultural treatments used, type of product to be seeded after the cotton, planting period, and collection methods. Cotton harvesting begins in the Çukurova region from August 15-20 in dry weather and from the first week of September in wet conditions; cotton harvesting begins in the Harran plain from September 10-15. Cotton production expenses have always been dominated by harvesting.

The cost of collecting, which was 15-20% of total cotton income in prior years, has risen to 25-30% in recent years, increasing its relevance and making machine harvesting the only way to minimize costs. Furthermore, quality and output losses caused by harvesting that cannot be completed on time and in a short period of time are other considerations that keep the mechanical harvest current (Evcim, 1999). However, in order to achieve positive outcomes from mechanical harvesting endeavors, some mechanical harvesting-appropriate production practices must be used at the right place and at the right time. The dried leaf fragments are the most important factor that reduces fiber quality in mechanical harvesting. In order for the fibers in the opened bolls to be collected cleanly and to increase harvest efficiency, cotton leaves must be shed, that is, leaves must be removed from the plant before machine harvest time.

Cotton suffers from harsh environmental circumstances, most notably early fall rains, due to its long vegetation. Cotton yield and quality suffer as a result of this circumstance. On the other hand, incorrect producer techniques such as sowing too late, too early, and too much irrigation, as well as imbalanced fertilizer, stimulate the perpetual inclination of the plant and extend the vegetation period.

## 1.3. Cotton Properties and Management Practices

### 1.3.1. The Cotton Plants

Cotton is a tropical plant; thus, its growth is mostly determined by the amount of heat it receives, which can be measured by growing degree days (DD-60s), which can be computed using equation 1.1:

$$DD - 60s = \frac{°\text{F}\ Max + °\text{F}\ Min}{2} - 60 \tag{1.1}$$

where,

*DD-60s* = growing degree days for single day
*°F Max* = high temperature for a specified day (°F)
*°F Min* = low temperature for a specified day (°F)

Cotton will produce a node every 50 DD-60s, or roughly every three days, if there is enough moisture. It takes approximately 900 DD-60s for a boll to mature from white bloom to full maturity. Cotton is a perennial plant; therefore, it will continue to grow until it is stopped by a deadly frost or another environmental condition. Cotton is also notable for its ability to grow indefinitely. Unlike determinate crops such as corn, the plant does not go through a stage of vegetative development before flowering and producing fruit. Cotton plants, on the other hand, generate greenery and fruit at the same time during the growing season. Cotton requires significant crop management due to its perennial nature and uncertain growth pattern, which necessitates the use of plant growth regulators and defoliants (Edmisten et al., 2019a).

### 1.3.2. Plant Growth Regulators

Plant growth regulators are synthetic compounds that are used to control plant height and are typically some types of Pix (mepiquat chloride). Mepiquat chloride, when applied to cotton, inhibits cell elongation in the stems, hence limiting height. Cotton's preferred level ending height is 95 – 120 cm (38 – 48 in) (Edmisten et al., 2019b). Controlling plant height with PGRs encourages the plant to concentrate its energy on fruit retention in the lower parts of the plant rather than creating additional vegetation and bolls in the upper parts. Alternatively, utilizing PGRs to manage plant height and focus energy on boll retention may boost cotton lint yield. Growth regulators are regularly sprayed during early bloom, 5-6 blooms for every 8 m of row, with a follow-up application 2-3 weeks later at mid-bloom. In general, all applications are run at a set rate across the entire field. Typically, the rates are determined mostly by the predicted average plant height for the field (Edmisten et al., 2019b). Even when plant biomass changes across a field, immovable rate applications are employed, resulting in inefficient chemical use and wasted inputs (Vellidis et al., 2009).

### 1.3.3. Defoliants

Defoliants are often administered prior to harvest to cause plant leaf loss. These defoliants can be hormonal or herbicidal in nature, but both enhance ethylene production in the plant. Increased ethylene promotes abscission around the leaf stem, causing the leaf to fall off the plant (Yang et al., 2003). Hormonal defoliants cause the plant to produce more ethylene on its own. Herbicidal defoliants, on the other hand, injure the plant, increasing ethylene production in reaction to the injury (Young et al., 2006). Defoliants are frequently used in conjunction with other harvest aids as a three-chemical cocktail: a defoliant, a regrowth inhibitor, and a boll opener. The defoliant removes cotton leaves, which are a major source of trash and a lint stain. The regrowth inhibitor prevents new growth following defoliation and can improve boll quality, whilst the boll opener promotes boll opening and can boost yield. Defoliant applications are normally carried out at predetermined rates determined by the air temperature at the time of application (Edmisten et al., 2019c). Additional use of PGRs and defoliants may raise the risk of nonpoint source contamination (Vellidis et al., 2009).

Foreign components incorporated into the mass are one of the most important factors impacting cotton fiber quality, and the majority of them are leaves and petioles. Removing the leaves from the plant before harvesting will result in higher quality. Çiçek (2000) underlined that the use of chemical defoliants, referred to as 'defoliants,' is favored since it is more practical and applicable, along with methods like as burning, mechanical stripping, or cutting for defoliation. Chemical defoliants cause leaf fall by promoting the formation of a separation layer through which the petiole travels to the branch or main stem under the influence of the drug absorbed through the stomata of the leaves (Denizdurduran, 2008). There is a need for chemicals that stimulate the opening of the bolls and cause the leaves to fall off before the harvest begins; in areas where hand harvesting is done, it helps to harvest the cotton to encourage delayed boll opening and to collect early before rainy weather; there is a need for chemicals that stimulate the opening of the bolls and cause the leaves to fall off.

To prepare cotton for harvest, the last procedure is defoliation, in which all the leaves on the cotton are shed and the plant's force is diverted from the green area to the boll opening.

Although supplemental chemicals in harvesting have been employed for more than 40 years, achieving the necessary defoliation remains a challenge. Plant, air, chemical, and application elements, as well as their interactions with one another, confound the results and make the reaction to defoliates rather inconsistent. Among the critical decisions that the producer must make are the choice of auxiliary chemicals in the harvest and the timing of application. Plants must be physiologically mature and vegetatively dormant before being used. Early defoliation may result in production loss and lower lint quality in young bolls, late treatments result in early harvest and, as a result, fiber losses. Because early defoliation causes a loss in micronaire and yield quality, defoliation decisions should be made in order to strike a balance between timely harvest and late-season production gains. Before deciding on defoliation, growers will sometimes wait until the bolls on the top of the plant have matured. However, the yield contribution of these bolls is rather minimal (Robertson et al., 2003). Foliar application delays might result in yield and quality losses owing to bad weather conditions (Faircloth et al., 2004).

Cotton defoliation typically begins in a field when 50-60% of the plants have reached boll opening. Variability in product development, on the other hand, can distinguish this idea. Boll maturation in the near-harvest stage may occur at different times due to the cotton plant's infinite growth (Stewart et al., 2000). Defoliation can begin earlier (at 40-50 percent boll opening) in fields where most of the boll attitude occurs in a short period of time, but defoliation occurs later (at 40-50 percent boll opening) in fields where the boll attitude develops over a longer period of time (70-80 percent at boll opening).

Defoliation should begin before 60 percent boll opening if the flowering cycle is short and the plant is compact. Defoliation applied at a higher boll opening of 60%, on the other hand, may be more effective in circumstances when the flowering phase is prolonged (Kerby et al. 1992).

Environmental factors, variety ripening group, use of plant growth regulators, and application time all influence bolt opening. With the application of boll opener products, timely defoliation increases boll opening and allows for an earlier harvest (Supak, 1996). Delayed harvest has an impact on the lint quality qualities and lowers the quality grade. As a result, the cotton must be harvested as soon as all of the harvestable bolls have opened. However, the rate of boll opening varies based on the field and variety, and the effectiveness of the boll opener or defoliate changes depending on plant age and environmental circumstances. Williford (1992) discovered that delayed harvesting is linked to degree losses.

In addition to these factors, the defoliant type, application volume, and spraying technologies employed in defoliate application all have an impact on the rate of defoliation of cotton plant leaves and the pace of boll opening. Many farmers are unaware of the impact of defoliant application equipment on defoliate efficacy. They generally use their existing field crop sprayer on their farm with the same application volume as regular pesticide applications without altering the nozzles or sprayer.

In this thesis, the defoliant effect (leaf defoliation and boll opening rate), the amount of defoliant deposit on leaves, and the defoliate coverage rate on cotton plants were determined by applying defoliants to cotton plants with two different application volumes and three different spray nozzles.

# 2. LITERATURE REVIEW

Pesticide applications that are unintentional and unregulated, particularly defoliants, generate a variety of issues. These issues are critical in terms of environmental degradation and human health. Non-target creatures are also harmed as a result of pesticide exposure in the environment (Güler, 2002).

According to Matthews (1979), nozzle height is crucial in terms of drift in field sprayers. The residue of little drops gathered in the wind direction rises as nozzle height increases. Spraying nozzles having a wide volumetric diameter are used to reduce drift.

Nurs (2006) stated that using low pressure and a big nozzle aperture reduces the amount of tiny drips that cause drift.

According to Deligönül and Salam (1991), the volumetric mean diameter value characterizes the drop distribution better and is more realistic than the other diameters in terms of expressing the area and volume sizes of the drops together. According to recent research, computerized image analysis systems are utilized to assess droplets on water-sensitive sheets. Researchers appreciated the procedure because of its speed and capacity to work within acceptable boundaries.

Tripathi and Singh (1976), Chemical defoliants in cotton induce maturity to occur 10-15 days earlier, seed cotton output reduces with defoliants made at 20% boll opening, and the maximum yield is found with defoliants made at 40-60% boll opening.

Gençer and Yelin (1982) discovered that defoliation performed while 50-60% of the bolls were open had no effect on seed cotton yield.

Williford (1992) discovered that the timing of defoliation impacts fiber yield and quality; they reported that defoliation performed too early can result in considerable losses in fiber yield and quality.

Karahan and Salam (1997) In their investigation on the determination of drop dispersion using various methodologies, they employed water-sensitive papers as the sampling surface. They used a micrometer microscope, an overhead projector, and a computer-based image processing tool to analyze physical drops. As a consequence of the evaluations, it was discovered that measurements and analyses performed with the micrometer microscope were more dependable, whereas overhead magnification could not provide an exact measurement due to copying. Computer analyses may be done in a very short time using the image analysis tool, and characteristic values can be obtained throughout the whole surface of the water-sensitive paper. This condition gives the droplet analysis method an advantage over the other two methods.

Bayat and Akkuş (1998) used a micronex spray head attached to a motorized mist blower to study the quantity of droplets on plant leaves, pesticide losses, and biological efficiency. Six flowerpots were chosen to calculate the amount of pesticide deposit on both sides of the bean plant's leaves. Before spraying the tracer material, each plant was divided into three zones, and nine leaves from each plant were tagged. Filter papers were placed on both sides of the leaves. The filter papers were collected separately after spraying and placed in jars with 50ml of distilled water. After shaking the jars for 15 minutes, solution samples were obtained from each jar and quantitatively evaluated using a fluorometer. The pesticide losses were calculated by placing the filter paper on the soil. The amount of deposit on the filter papers and leaves was determined using the following equation:

$$fk = m.VL.\frac{l}{A} \qquad (2.1)$$

Where fK = Fluorometric coefficient at sensitivity level (µg/c$m^2$)

m = concentration factor at the sensitivity (µg/c$m^2$)

VL = quantity of distilled water for washing out the spray deposit (50 ml for 3 filters)

A = Area of filter papers with 40 mm diameter (c$m^2$)

For calculating the spray deposition fK was multiplied with fluorometer reading of spray solution.

Jain (2002) determined the droplet size of several hydraulic nozzles using a computerized particle size analyzer. It was thought of as a camera via which a sample of droplets in the area 3.2 mm2.4 mm was taken into a computer while a magnifying glass was placed between the sample and the camera. For droplet size analysis, the software "Image pro" was utilized.

Franz (1993) developed a portable optical scanner for digitizing spray deposit patterns on water-sensitive paper and kromekote spot cards. The image from the completed scan was saved, and the image data was transformed to spot counts, size, and coverage data using standard software.

Blodgett and Mader (1934) explored the spread of the Bordeaux copper mixture by printing directly from sprayed leaves on paper. Two grams of potassium Ferro cyanide and 5 cc of acetic acid were added to 100 cc of water. The solvent was entirely soaked into the bond papers. For five to ten minutes, the leaves taken from the Bordeaux-sprayed field were squeezed between two moist bond papers. The acid in moist paper dissolved the copper of Bordeaux mixture, and potassium Ferro cyanide in the paper reacted to form brown precipitate. That precipitate stayed on to the paper's surface. The Bordeaux dots on the leaf were represented by the brown spot on the paper. The spray marks on the prints were magnified, and the outlined drawings were created with a camera and a low-power lens. The spots were cut out and weighed to determine the percentage of the entire area covered by spray.

Zhang et al (1994) used image processing techniques to investigate a method for assessing nozzle spray pattern uniformity based on the degree of non-uniformity (DNU) model. To measure non-uniformities at different boom heights, with varying nozzle materials and pressure settings, the DNU model for spray distribution non-uniformity based on spectral analysis of the spray profiles was utilized. They discovered that there was an optimum boom height for each pressure setting in which the DNU was minimized. The distribution homogeneity produced at higher compression settings was significantly greater than that obtained at lower pressure settings.

According to Bindra and Singh (1977), the spacing and height of the nozzles influence uniform spraying. Spray-pattern requires adequate overlapping to create equal spacing. Spraying height should be no more than 53 cm to avoid drift and no less than 40 cm to acquire the entire width of the spray pattern.

according to Oosterhuis et al (1991), Spray coverage, canopy penetration, volatilization, photodecomposition, absorption, and translocation, can all have an impact on harvest-aid performance.

According to Brecke et al (2001), The percent open boll approach specifies that defoliant treatment should take place when 65 to 90 percent of harvestable bolls on the plant are open. This technique, however, does not account for gaps in the fruiting pattern or variances in boll maturity.

According to Matthews (1979), nozzle height in field sprayers is critical in terms of drift. The residue of little drops gathered in the wind direction grows in direct proportion to nozzle height. To reduce drift, sprayer nozzles with large volumetric diameters are used. Minimal pressure and a big nozzle opening are used to reduce the quantity of tiny droplets that cause drift (Nurs, 2006).

Deogirikar (2001) studied the performance of three types of rotary nozzles (cone type, cage type and disc type). In the tractor-mounted sprayer, cone type rotary nozzles were utilized, while cage type and disc type rotary nozzles were used in the engine-operated sprayer. The cone type rotating nozzle showed superior spray penetration on the upper surface of the leaves with larger droplets and higher densities compared to the lower surface of the leaves in the front side of the plant canopy, but the opposite behavior was observed on the back side of the plant canopy.

Jain (2002) investigated the differences between three distinct nozzles: triple action, spinning disc atomizer, and Italian turbo nozzle. More uniform spray droplets were produced by the spinning disc atomizer than by the triple action and Italian turbo nozzles. The droplet size range of the spinning disc atomizer (0 to 450mum) was smaller than that of the triple action (0 to 650mum) and the Italian turbo nozzle (0 to 750/mum).

Bayat and Zeren (1994) In their study on the evaluation of different chemical application methods in cotton spraying determined the efficacy of classical, under-leaf nozzle classical, mechanical herbicide, pneumatic, airflow vegetative, and carrier airflow applications in terms of chemical adhesion and chemical losses. I. In the chemical application (aphid time), the classical application, mechanical plant depositor, and carrier air flow method yielded the highest amount of residue; II. In the application (whitefly period), the mechanical herbicide application method yielded the highest amount of residue. The pneumatic application method produced the least amount of residue in both applications. The pneumatic application produced the greatest amount of residue on other portions of the plant that were dragged out of the field by the wind. Furthermore, it has been claimed that chemical losses due to evaporation are larger in pneumatic applications since the drop diameter created is smaller than in other methods.

# 3. MATERIALS AND METHODS

## 3.1. Materials

### 3.1.1. Site description of the Trial Area

In 2020, (Doğankent/Adana) research field experiments were carried out in the experimental field of the Eastern Mediterranean Agricultural Research Institute, which is located around Karataş area, which administratively comes under Çukurova Region. Karataş is located at 36.566429°N and 35.383986°E latitude and longitude. Karataş is in the southern direction of Adana-Turkey. Figure 3.1 depicts a satellite view of the Eastern Mediterranean Agricultural Research Institute's experimental fields, where the experiment was conducted.

Figure 3.1. Eastern Mediterranean Agricultural Research Institute, Field trials (Google Earth Program)

### 3.1.2. Spraying Methods and Operating Parameters

Three distinct spraying nozzle methods were used in the scope of the study. All approaches were employed with a conventional field crop sprayer. The sprayer had a tank capacity of 600 l, a 50-bar diaphragm pump, a hydraulic agitation system, an adjustable mechanic boom height attachment mechanism, and a folding boom (Fig3.2). The nozzle types and sizes employed in the research were standard flat fan (size 8006), air induction (size 11002 ), and dual Pattern (size 307003), and nozzles (Fig 3.3). Each nozzle was set to two different application rates (250 and 400 l/ha). Table 3.1 lists the other sprayer operating parameters. Sprayer speed was modified to achieve the same spraying pressure and application rates for different nozzle sizes.

In this study the following abbreviations were used for spraying methods:

M1: Standard Flat Fan Nozzle Spraying System
M2: Air Induction Nozzle Spraying System
M3: Dual Pattern Nozzle Spraying System

Figure 3.2. A boom field sprayer (road position)


A B C

Figure 3.3. Spray nozzle types (Spraying system Co.) used in the research (A. Standard flat fan nozzle, B. Air induction nozzle, C. Dual pattern nozzle).

Standard flat fan nozzle.

Features:

Tapered edge flat spray pattern provides uniform coverage when broadcast spraying. VisiFlo color-coded versions are available in stainless steel, ceramic, and polymer with spray angles of 80° or 110° in select sizes.

Ceramic 80° capacities 01–02 and 110° capacities 01–015 are available. For greater capacity, see the XR and XRC TeeJet® advice on pages 12–13.

Figure 3.4. Standard flat fan TP8006 Spray Tip (Cross Section View) Air Induction nozzle.

Features:

Stainless steel insert creates a tapered edge flat spray pattern for uniform coverage when broadcast spraying.

VisiFlo® color-coded polymer insert holder and pre-orifice.

Larger droplets result in less drift.

There are eight capacities available, with a suggested pressure rating of 30–115 PSI (2–8 bar).

Figure 3.5. Air Induction nozzle AI11002 ( Cross Section View)

Dual Pattern nozzle.

Features:

For fungicide spraying on cereal crops, it has great penetration and seed head coverage.

In broadcast applications, the AI3070 generates two wide angle, flat spray patterns for uniform coverage.

A 30° forward inclined spray penetrates dense crop canopies, whereas a 70° backward tilted spray maximizes crop seed head coverage.

The employment of a venturi air aspirator produces drift resistant drops. All acetal construction for high chemical and wear resistance.

Removable pre-orifice allows for quick and easy cleaning.

Spray pressures of 20–90 PSI (1.5–6 bar) are recommended.

Figure 3.6. Dual Pattern nozzle AI3070 VP Spray Tip ( Cross Section View)

Figure 3.7. A boom field sprayer ( field position)

Table 3.1. According to Methods of Field Crop Sprayer Operating Conditions

| Spraying Method | Operating Pressure (bar) | Nozzle follow rate (l/min) | Droplet size class | Forward Speed (km/hr) | |
|---|---|---|---|---|---|
| | | | | 250l/ha | 400l/ha |
| Standard flat fan nozzle (Size TP 8006) | 4 | 2.0 | Medium | 9.6 | 6.0 |
| Air induction nozzle (Size VS 11002) | 4 | 0.9 | Extremely Coarse | 4.3 | 2.7 |
| Dual Pattern nozzle (Size VP 307003) | 4 | 1.3 | Coarse | 6.2 | 3.9 |

### 3.1.3. Cotton plant and chemicals used for defoliation

An experimental driller sowed cotton seeds at 2-4 cm deep in each plot on April 19, 2020. At planting, 8-kilogram N da-1 and 8 kg P2O5 da-1 were applied as 20-20-0 fertilizer to each plot, followed by 8 kg N da-1, N as urea applied at blooming start. Cotton was furrow-irrigated twice per season, in June and early July. Soil tillage and other cultural methods such as hoeing, weeding, and insect management were used. Defoliant application rates were determined using two distinct types of chemicals: Dropp Ultra and Finish PRO. Dropp ULTRA's active ingredient is 120 g/l Thidiazuron + 60 g/l Diuron. Finish PRO is 720 g/l Ethephon + 45 g/l Cyclanilide. In the experiments, two application volumes were used with different application dosages of Dropp ULTRA 1400 ml/ha mixed with Finish PRO 480 ml/ha to the tank 250 l/ha, and 400 l/ha also used the same method but with different application dosage and application volume Dropp ULTRA 875 ml/ha mixed with Finish PRO 300 ml/ha. During defoliant applications, the average cotton plant height was 150 cm (Fig 3.8). The distance between the row and the plant was 70 cm and 15 cm, respectively.

Figure 3.8. A view from cotton field during defoliant applications

### 3.1.4. Instruments Used.

#### 3.1.4.1. Spectrofluorophotometer

A RF-6000 brand spectrofluorophotometer was utilized in laboratory analyses, with values taken at 500 nm wavelength. To calculate the amount of trace particles in the pure water BSF dye solution in the jars, spectrofluorophotometer values were transferred to 4.5 ml spectrofluorophotometer cuvettes.


Figure 3.9. Spectrofluorophotometer

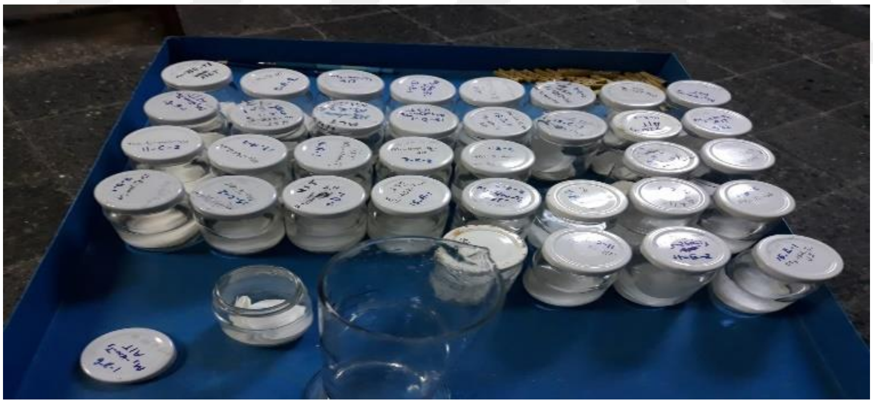

Figure 3.10. Spectrofluorophotometer cuvettes

#### 3.1.4.2. Scanner

The droplet analyzer is a device that consists of a scanner, deposit scan software, a computer, and a display to control the analyzed image. The droplets were analyzed using a deposit scan digital scale. Each droplet's attributes include the number of spots, maximum diameter, minimum diameter, equal diameter, area, average diameter of each spot, and so on. The software could be used to measure.

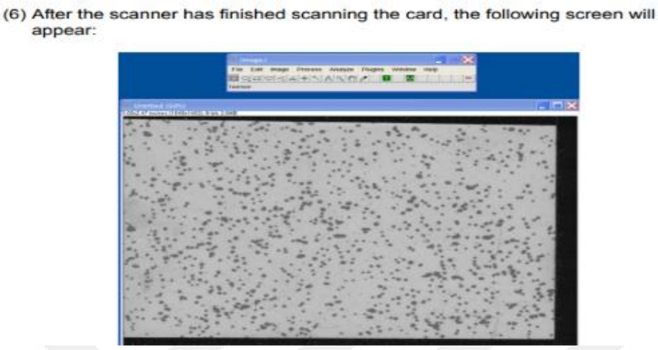


Figure 3.11. Deposit scan software

In order to evaluate the water sensitive papers used in the studies in the Image Tool program, the appropriate scans were made with a Canon Pixma MP280 brand Printer-Scanner (Figure 3.12).


Figure 3.12. Canon Pixma MP280

### 3.1.5. Other Laboratory Equipment's and Tools

Laboratory tools and equipment include automatic micropipettes, 3.5 ml disposable Pasteur pipettes, 4 ml disposable cuvette Spectro fluorophotometer tubs, and various beakers.

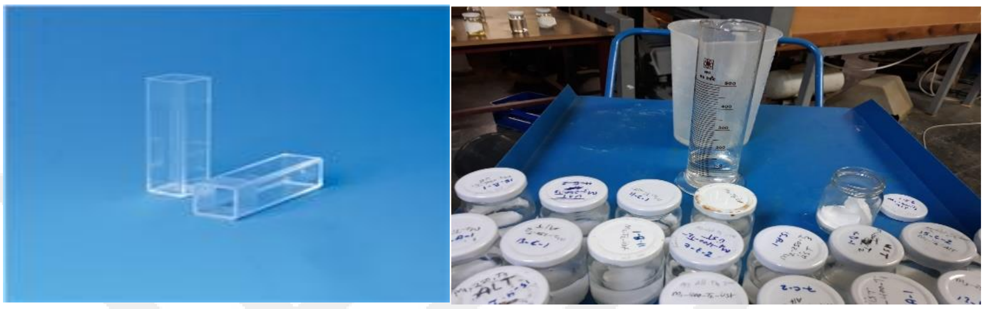

Figure 3.13. Instruments and materials for laboratories

## 3.2. Methods

### 3.2.1 Trial Plan of Study Site

In the experiment within the scope of the research, it was established separately for each application volume, with three replications in accordance with the divided plots the experimentations were designed as randomized block with split-split plot arranged. The trial area consisted of 5 blocks and 25 plots (Figure 3.14). In the experiment within each block consisted of 5 plots and the size of each plot (2.8m X10m) was established as 28 $m^2$.

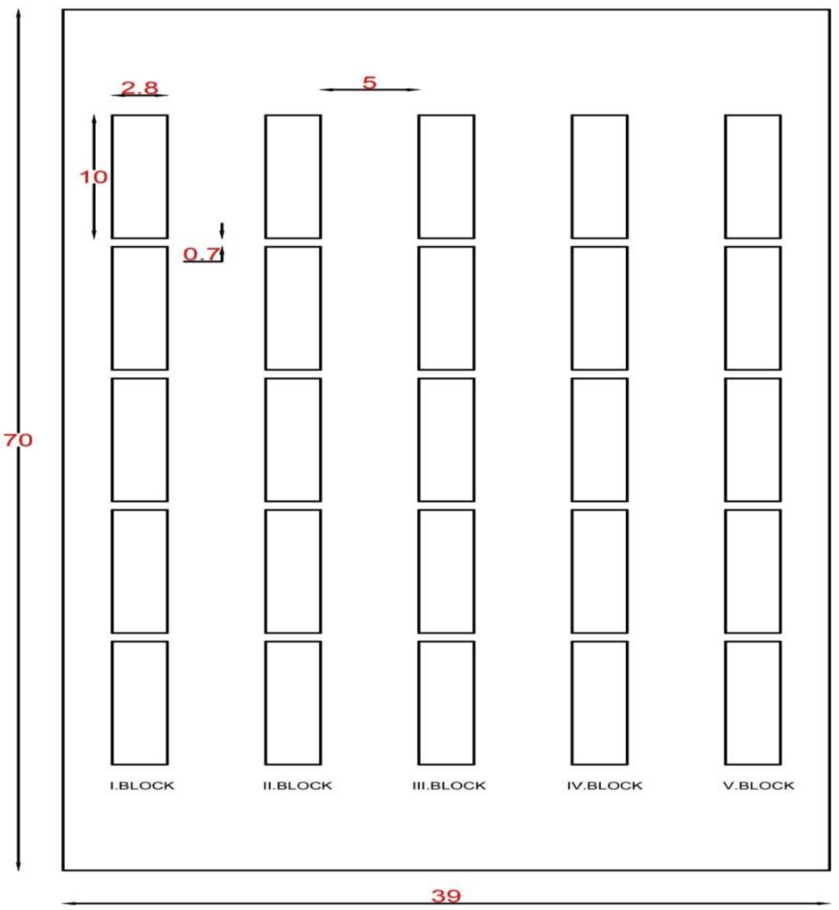


Figure 3.14. Trial plan schematic view

Cotton planting was carried out by leaving a gap of 5 meters between the blocks in the experimental area and 0.7 meters between the plots within the block (Figure 3.15).

Figure 3.15. Trial area sideview

### 3.2.2. Sprayer Calibration

The data to be obtained from the spray nozzles were determined for each application volume determined within the scope of the research. Their nozzles flow rate was measured in 3 repetitions and the average flow rate was determined for each nozzle. The required tractor speeds were determined for the determined liquid amounts and the targeted application volumes. Equation 3.1 was used to calculate the tractor spraying speeds for targeted application rates to be achieved within the scope of the trial.

$$N = \frac{600*Q}{V*B} \qquad (3.1)$$

Where;

N: Application volume (l / ha),

V: Forward speed (km/h),

B: The working width of the sprayer boom (m),

Q: The amount of liquid sprayed from the nozzles (l / min).

### 3.2.3. Measuring Defoliant Deposition, and Coverage Rate

In the research, sampling was done on 5 plants in each plot. at two layers of plants (Upper and lower layer) on upper and lower surfaces of leaves on the selected each plant. The research was carried out in two stages in each phase of plant development. In the first stage, to detect BSF deposition which was an indicator of defoliant deposition, a solution containing BSF of 0.1 % instead of the real defoliant was sprayed and filter papers were attached to the selected cotton plants to collect the BSF tracer, In the second stage, real application (with defoliant) consisting of Dropp ULTRA plus Finish PRO was applied at the recommended dosages. The volumetric mean diameter of droplets and coverage rate (%) were determined by using water-sensitive papers on the targets just like deposit sampling ( Fig 3.16).

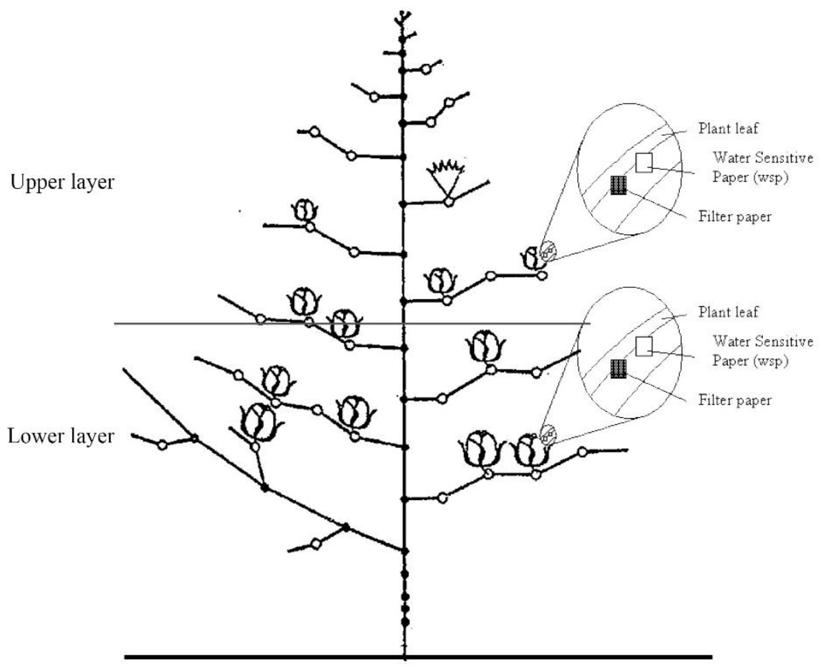


Figure 3.16. Schematic view of sampling targets on cotton plant

As the plants were not much high, sampling was done on 5 plants in each parcel and 4 leaves on each plant. Thus, filter papers and water sensitive papers were attached on upper, and lower surfaces leaves randomly selected. the plants were divided into 2 zones vertically and in each zone filter paper and water sensitive papers were attached on four leaves on both upper and lower surfaces (Fig 3.16). After having attached the testing materials mentioned above, the BSF solution was sprayed on each spraying method parcel.

WSP papers were cut in 5x2.6 cm dimensions and attached to the leaf with paper clips.

Filter papers were circular in shape with diameter of 4.25 cm and had a 10 $cm^2$ surface area. Filter papers and water sensitive papers were placed in 18 parcels, as in water sensitive papers, in the upper, and lower sections of the left, center, and right sides of the plant as shown in the Fig 3.13. Filter papers (Whatman no. 2) were also placed in 6 interference areas between three plants. to measure the drift to the ground. Filters and water sensitive paper were collected 15 minutes after the spraying process is completed, filter papers were put into jars and water sensitive papers are put into envelopes and samples were taken to laboratory for analyzing deposits and coverage rate. A solution of %3.33 methyl alcohol and 50 ml pure water were poured into the filter paper jars and the jars were shaken by a hand. Then, samples are taken from the jar with standard quartz fluorometer tubes and amount of BSF was measured by the spectrofluorophotometer (a RF-6000 ). The mean deposits were calculated the total deposits on the target surfaces by dividing number of targets for each plant. In order to determine the coverage rate, stains on the water sensitive papers were scanned in a 600dpi resolution scanner (Canon Pixma MP280.) and the images achieved were evaluated in an image processing program ( ImageJ tool Version 1.38x) to calculate the coverage percent. In the evaluations, the water sensitive papers which turned completely from yellow to blue were presumed to be 100%. The data were evaluated according to one-way Anova variance analyze in statistic program and LSD test was used for the differences among averages.

#### 3.2.3.1. Defoliant Coverage Rate

Images were generated by scanning the water-sensitive papers (Figure 3.17) collected during the trials. The coverage rate values, and drop diameters were determined using the Image Tool software to evaluate the stain marks on these collected photographs.

Figure 3.17. In the trials, water sensitive paper samples were collected.

First, as shown in Figure 3.18, the image of the water sensitive paper to be analyzed with 'Open Image' is opened from the File command in the Image Tool J version 3.0 program.

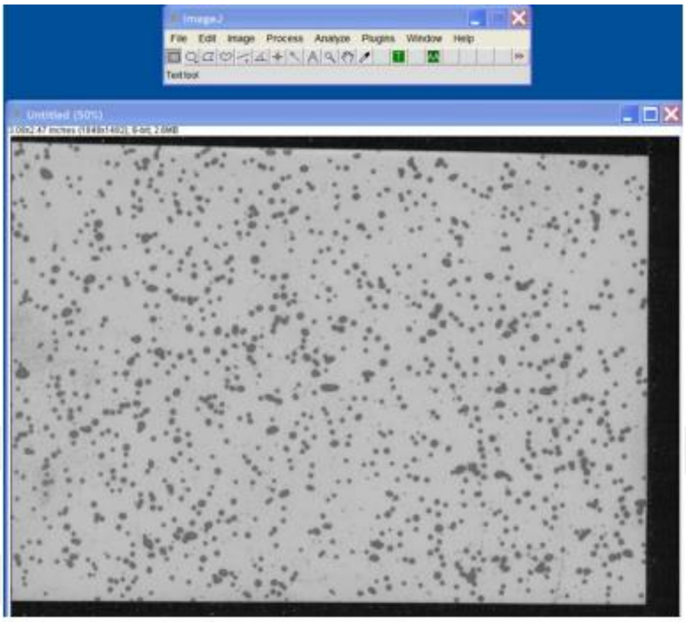


Figure 3.18. Image Tools 'Open Image' command (screenshot)

After the image file is opened, the image is converted to black and white with Color to Grayscale from the Processing menu (Figure 3.19). Later, drops are obtained manually from the Threshold command (Figure 3.20) with a threshold value of 60 (Figure 3.21).

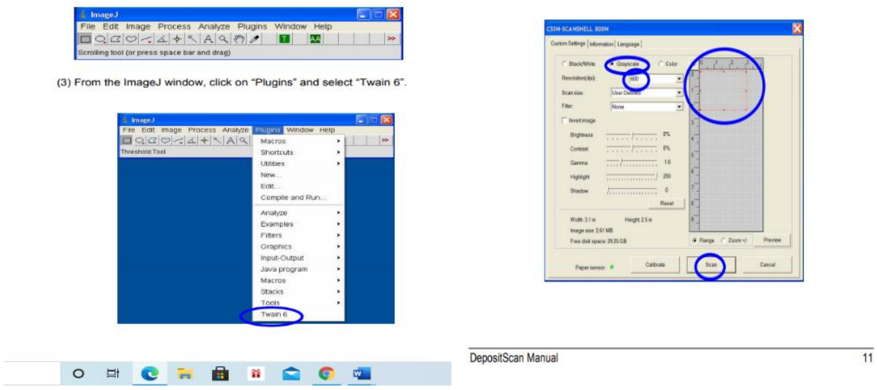


Figure 3.19. Image Tool's 'Processing-Color to Grayscale' command is seen in this screenshot.

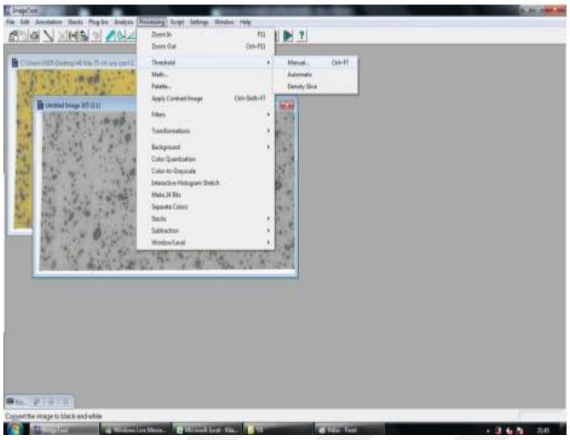

Figure 3.20. Image Tool's 'Processing-Threshold' command is seen in this screenshot.

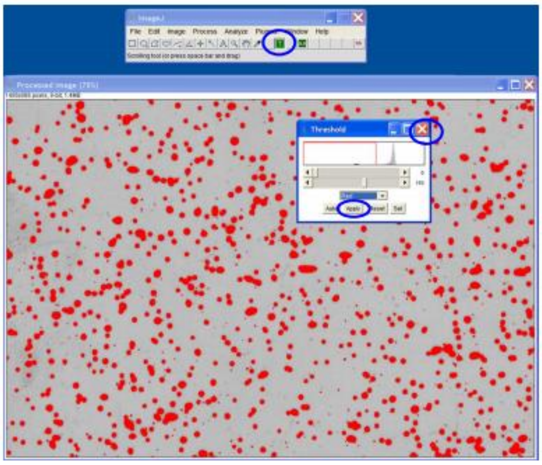

Figure 3.21. Threshold value collection screenshot from Image Tool's 'Threshold' command

Coverage rate was calculating as following equation;

Coverage rate (%) = $Stain\ area\ of\ droplets/Total\ WSP\ area * 100$

### 3.2.4. Calculating Defoliation and Boll Opening

To calculate defoliation and boll opening rate method were used Prior to treatment application, 5 plants were randomly tagged to count the number of leaves on each plant. The number of leaves was counted again 1,4,7, and 12days after spraying on the same tagged plants. Defoliation rate was calculated by Equation (3.2).

$$Defoliation\,rate\ (\%) = ((Na - Nb)/Na)) * 100\% \qquad (3.2)$$

where Na = Number of leaves before treatment, Nb = Number of leaves after treatment.

Boll opening rates were determined on the same tagged 5 plants. Bolls on each plant were examined and recorded as either opened or closed and the boll opening rate was calculated by Equation (3.3).

$$Boll\ opening\ rate\ (\%) = (Nc/Nd) * 100\% \qquad (3.3)$$

where Nc = Number of opened bolls, Nd = Number of Total bolls.

#### 3.2.4.1 Yield Characters and Fiber Quality

The cotton yield was measured after all the cotton bolls opened where 100 cotton bolls from the canopies (upper, and lower layer) were randomly tagged and collected in each experimental area to determine the cotton yield characteristic and fiber quality. As cotton yield characteristics, UHML/mm, UI, Mic, Str, Elg, MR, SFI were considered.

### 3.2.5. Laboratory Analysis

Spectrofluorophotometer was used to calculate the amount of trace material on the dyed filter papers obtained in the experiments of the research area.

#### 3.2.5.1. Measuring the Amount of Deposition Provided on Target Surfaces of Cotton Plants

The Spectrofluorophotometer method was used to determine the amount of deposits on the filter papers from the trace substance applications of the research. In the spraying laboratory of Çukurova University Faculty of Agriculture, Department of Agricultural Machinery and Technologies, a RF-6000 brand was used to determine the readings of fluorescein of BSF on the filter papers. In order to converts the Spectrofluorophotometer readings values to deposits on the target surfaces, a calibration chart was first created by using some standard solutions containing BSF. Standard solutions given in Table 3.2 were used in the creation of the Spectrofluorophotometer calibration graph. Standard solutions were prepared by diluting the solution formed by adding 33.3 ml of methyl alcohol and 1 g of BSF trace material to 1 liter of distilled water. For detecting spectrofluorophotometer readings intensity of BSF solutions, Excitation 460 nm and Emission 500 nm filters were used and Graph was created. Acording to calibration graph there is a fairly linear relationship between amont of BSF and its fluoroscein intensity at $R^2$ =0,99 level. The follwing equation was used to convert sample readings to unknown consantrations.

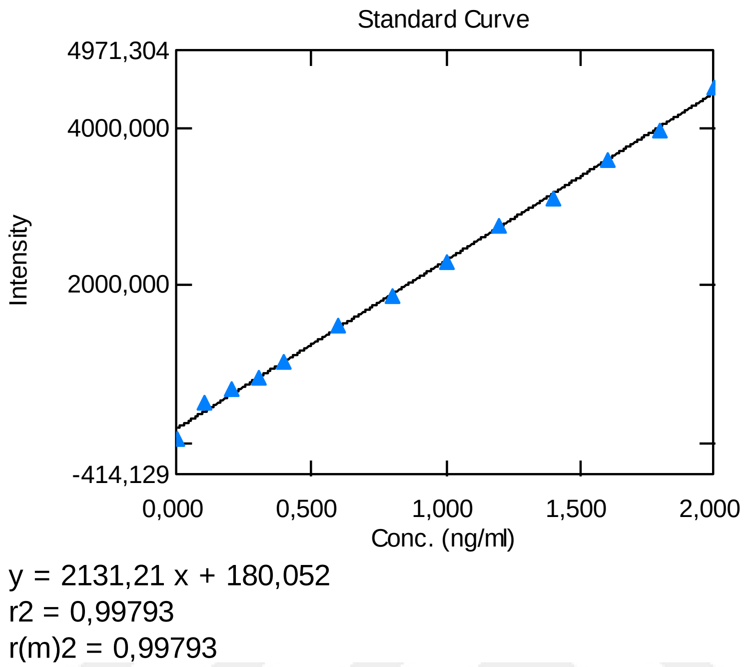


Figure 3.22. Spectrofluorophotometer curve

According to the following equation used by Bayat (1997), the fluorometric values of each solution were converted to the deposit amount in µg/cm$^2$.

$$f_x = m.V_L.\frac{1}{A} \quad (3.4)$$

$f_x$: The spectrofluorimetric coefficient (µg/cm$^2$) depending on the sensitivity step.

m: Tilt of line given on graph.

$V_L$: The amount of distilled water (ml) used to wash the trace material on the filter paper.

*A:* Trace material collection surface area (cm$^2$).

In this research, the surface area of filter papers, each of which has a diameter of 42 mm, was calculated, and 50 ml of distilled water with 3.3% methyl alcohol was used as the trace substance washing liquid.

Table 3.2. BSF Calibration

| Sample Name | Sample ID | Option | Type | Conc | EX460,0_EM500,0 | Wgt.Factor |
|---|---|---|---|---|---|---|
| standart1 | SampleID1 | Option1 | Standard | 0,000 | 34,657 | 1,000 |
| standart2 | SampleID2 | Option2 | Standard | 0,100 | 496,510 | 1,000 |
| standart3 | SampleID3 | Option3 | Standard | 0,200 | 682,361 | 1,000 |
| standart4 | SampleID4 | Option4 | Standard | 0,300 | 828,280 | 1,000 |
| standart5 | SampleID5 | Option5 | Standard | 0,400 | 1030,786 | 1,000 |
| standart6 | SampleID6 | Option6 | Standard | 0,600 | 1474,083 | 1,000 |
| standart7 | SampleID7 | Option7 | Standard | 0,800 | 1867,870 | 1,000 |
| standart8 | SampleID8 | Option8 | Standard | 1,000 | 2293,778 | 1,000 |
| standart9 | SampleID9 | Option9 | Standard | 1,200 | 2740,895 | 1,000 |
| standart10 | SampleID10 | Option10 | Standard | 1,400 | 3108,499 | 1,000 |
| standart11 | SampleID11 | Option11 | Standard | 1,600 | 3601,510 | 1,000 |
| standart12 | SampleID12 | Option12 | Standard | 1,800 | 3954,669 | 1,000 |
| standart13 | SampleID13 | Option13 | Standard | 2,000 | 4522,518 | 1,000 |

In the research with disposable pasteur pipettes, samples were taken from the sample jars in which the trace material was homogeneously dispersed in the orbital shaker to the spectrofluorophotometer cuvettes. The basic logic of spectrofluorophotometer is based on the principle of transmitting light in various spectrums from a prepared solution and determining how much of this beam is absorbed by the solution. The absorbance of trace materials can be measured in parts per million (ppm). On this basis, a spectrofluorophotometer was selected for trace material analysis, and analyses were carried out at a wavelength of 500 nm (Figure

3.23). Disposable plastic Spectro-cuvettes were used for the readings, and special care was taken not to introduce foreign substances or bubbles into the liquid, which are critical in trace material measurements. The smooth surface of the cuvettes to be read was not touched in any way, and they were positioned with care to avoid liquid leakage. Otherwise, by inducing light refractions, it would be possible to obtain incorrect values.

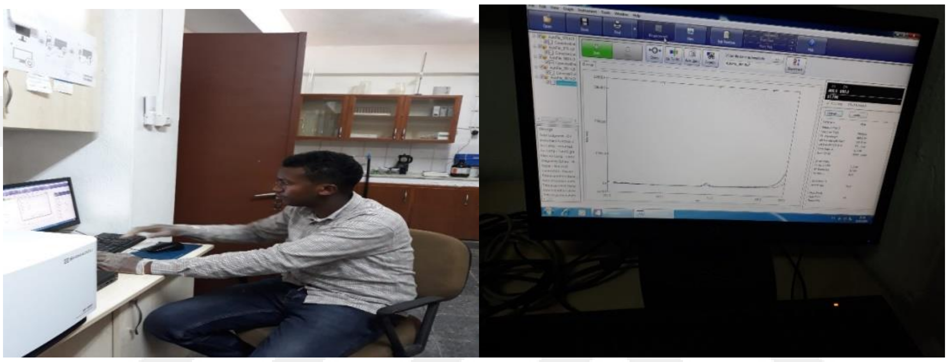

Figure 3.23. Taking readings with a spectrofluorophotometer

### 3.2.5.2. Scanner Tool J Calibration

When the calibration has completed, the following screen appears.
Insert the water sensitive paper or Kromekote® card face down into the scanner. Select "Grayscale", choose a Resolution (dpi) of "600", and adjust the scanning area to approximately the scan area of the scan source (e.g., 2 by 3 inches).

- Click "Scan". The program will automatically save the settings for future runs.
- Insert the water sensitive paper or Kromekote® card face down into the scanner.
- Open your "DepositScan" folder and double-click on "DepositScan.bat" to run the program.
- The ImageJ window will appear on the screen.

# 4. RESULTS AND DISCUSSIONS

This chapter describes the results obtained from laboratory and field investigations.

## 4.1. BSF Deposition

BSF tracer as Defoliant indicator on targeted was used and among of BSF depositions according to selected application rates and spraying nozzles are given the below with subtitles.

### 4.1.1. BSF depositions of Standard Flat Fan Nozzle, Air induction, and Dual pattern, Nozzles at an application rate of 250 L/ha

The average amounts of tracer material accumulated on the filter papers in the upper-and lower-layers of the cotton plant are given in Table 4.1. at a 250 L/ha application rate via standard flat fan nozzle, air induction, and dual Pattern nozzle.

M1 (Standard flat fan nozzle) the average BSF deposit, that is the average of all selected sampling surfaces of cotton plants according to upper and lower layers, was 5.48 µg/cm$^2$ in the experiment, and M2 (Air induction nozzle) The average trace material accumulation on the filter papers was 6.08 µg/cm$^2$, while M3 (Dual pattern nozzle) was 4.67 µg/cm$^2$.

According to M1, and M3, the highest deposit result of the upper layer is M2, which is the best performance of the upper layer.

In addition, M2 (Air induction nozzle) achieved better in the lower layers than M1 (Standard flat fan nozzle) and M3 (Dual pattern nozzle).

Table 4.1. Deposits (µg/cm$^2$) in Standard flat fan nozzle, Air induction, and Dual pattern, spraying based on a 250 L/ha Deposit application rate.

| Methods | Mean Deposit(µg/cm$^2$) | | |
|---|---|---|---|
| | Plant layers | | |
| | Top | Bottom | Average.* |
| M1 | 6.43 | 4.52 | 5.48 b |
| M2 | 7.20 | 4.95 | 6.08 a |
| M3 | 5.52 | 3.82 | 4.67 c |
| LSD | 1.59* | | |

* : the values shown with the same letters on a vertical column are not significant in the level of $p<0.05$

When Table 4.1 is examined, the air induction nozzle method showed the highest average deposit amount at 250 l/ha application volume, with a value of 6.08 µg/cm$^2$, followed by the standard flat fan nozzle method, which is in a statistical subgroup, with a value of 5.48 µg/cm$^2$. The average deposit amount obtained from the study ranged between 6.08 and 5.48 µg/cm$^2$, with the air induction nozzle method providing the highest value, followed by the dual pattern nozzle method, which is in a statistical subgroup with a value of 4.67 µg/cm$^2$. During the period of the experiment, at 250 l/ha application volume, the deposit amounts obtained from the air induction nozzle method were higher than the standard flat fan nozzle method, as well known as the classical method.

#### 4.1.2. Findings of BSF in Standard flat fan nozzle, Air induction, and Dual pattern Spraying at an application rate of 400 L/ha

This Table 4.2. indicates that the deposit rate provided by all of the methods used is highest on the upper and lower surface of the leaf. It was found that the amount of BSF adhering on the plant, particularly in the air induction nozzle method, was significantly (3.48 µg/cm$^2$) adhered to the upper surface of the leaf. According to the experiment's a significant portion of the spray sprayed with the dual pattern nozzle method was adhered to the upper leaf surfaces (2.97 µg/cm$^2$), while standard flat fan nozzle methods was adhered to the upper leaf surfaces (2.97 µg/cm$^2$). As can be seen from these results, while the majority of the deposit measured on the plant using the air induction nozzle method was adhered to the upper surface of the leaf, a better deposit amount of BSF was obtained on the plant using the air induction nozzle method.

Table 4.2. Deposits (µg/cm$^2$) in Standard flat fan nozzle, Air induction, and Dual pattern spraying at a deposit application rate of 400 L/ha.

| Methods | Mean Deposit(µg/cm$^2$) | | |
|---|---|---|---|
| | Plant layers | | |
| | Top | Bottom | Average.* |
| M1 | 3.63 | 2.32 | 2.97 b |
| M2 | 4.31 | 2.65 | 3.48 a |
| M3 | 3.86 | 2.09 | 2.97 b |
| LSD | 1.06* | | |

* : the values shown with the same letters on a vertical column are not significant in the level of $p<0.05$

## 4.2. Coverage Rates

The coverage rate values on the water sensitive papers used in the trials are presented in this section for the standard flat fan nozzle, air induction, and dual pattern, positions in both 250 L/ha and 400 L/ha application rate. For determining coverage rate achieved by methods, water sensitive papers with 26*52 mm size (water sensitive paper, Syngenta) were used.

### 4.2.1. Coverage Rates in Standard flat fan nozzle, Air induction, and Dual pattern, Spraying at 250 L/ha application rate

Likewise, the Table 4.3.illustrates that the air induction nozzle method obtained the highest average coverage in 250 l/ha application volume with 26.9 %, followed by the standard flat fan nozzle method, which is statistically the same and in the upper group with a value of 18.6 %. The dual pattern nozzle method, on the other hand, was statistically included in a subgroup with a 10.4 % average coverage rate. When the average coverage rates obtained in 400 l/ha application volume were examined in the same method, the air induction nozzle method obtained the optimal value with 17.1 %.

Table 4.3. Coverage rate values (%) at 250 L/ha Standard flat fan, Air induction, and Dual pattern nozzle.

| Methods | Coverage rate (%) | | |
|---|---|---|---|
| | Plant layers | | |
| | Top | Bottom | Average.* |
| M1 | 25.70 | 11.51 | 18.6 b |
| M2 | 38.99 | 14.84 | 26.9 a |
| M3 | 16.65 | 4.22 | 10.4 c |
| LSD | 2.90* | | |

* : the values shown with the same letters on a vertical column are not significant in the level of $p<0.05$

**4.2.2. Coverage Rates in Standard flat fan, Air induction, and Dual pattern nozzle Spraying at 400 L/ha application rate**

When Table 4.4 is examined, the standard flat fan nozzle method obtained the highest average coverage rate of 19.7 %, followed by the air induction nozzle method, which statistically belongs to the same group with a value of 17.1 %. The dual pattern nozzle method, on the other hand, was statistically included in a subgroup with an average coverage rate of 7.5 %. It is seen that this value is low in the dual pattern nozzle method both of the upper and lower leaf of the plants.

When the standard flat fan nozzle both upper and lower leaf coverage rate values are considered, it is observed that the highest value is 19.7 %. The lowest value in dual pattern nozzle both upper and lower leaf coverage rate is 7.5 %. The optimal coverage rate in air induction nozzle is 17.1 %. When all coverage rates in a standard flat fan nozzle are considered, it is clear that upper and lower leaf coverage rates are superior.

Table 4.4. Coverage rate values (%) at 400 L/ha Standard flat fan, Air induction, and Dual pattern nozzle

| Methods | Coverage rate (%) | | |
|---|---|---|---|
| | Plant layers | | |
| | Top | Bottom | Average.* |
| M1 | 21.20 | 18.13 | 19.7 a |
| M2 | 25.96 | 8.31 | 17.1 b |
| M3 | 8.50 | 6.48 | 7.5 c |
| LSD | 4.94* | | |

* : the values shown with the same letters on a vertical column are not significant in the level of $p<0.05$

### 4.3. Effect of Defoliant Spraying methods on Defoliation Efficacy

#### 4.3.1. Defoliation Efficacy

Efficacy of defoliation was affected strongly by overall defoliant application rate and different spraying methods. Analysis of variance in relation to cotton parameters among defoliation efficacy and defoliant different spraying methods is presented in Table 4.5. The leaf abscission began to form at four days after spraying, and the application rate had a great effect on the defoliation effect; the defoliation rate of upper layer leaves was more than 76 % in three spraying methods. The defoliation rate then rose gradually, through seven and twelve days of spraying the defoliation rate of upper layer leaves was more than 76% of three different spraying nozzles. The defoliation rate was 76 % by the application rate of 250 l/ha, through the air induction nozzle method which was significantly higher than that of two low spraying methods. Defoliation rates were 72 %, 76 % and 70 % for 250 and 400 l/ha, respectively. Interestingly, the upper leaves of the cotton canopy with 250 l/ha showed good defoliation effect, and 400 l/ha lower leaves showed moderate defoliation effect. The results indicated the defoliation effect was influenced by defoliant different spraying methods. In general, it was possible to achieve better defoliation by reducing the defoliant application rate of the spraying.

Table 4.5. Defoliant application rate both 250 and 400 l/ha, effect on defoliation efficacy by PTO field crop sprayer

| Methods | Leaf (count) | | % Defoliation rate |
|---|---|---|---|
| | Before treatment | After treatment | |
| M1 | 155 | 60 | 61 |
| M2 | 160 | 55 | 65 |
| M3 | 158 | 63 | 60 |

Table 4.6. Cont.

| Methods | Leaf (count) | | % Defoliation rate |
|---|---|---|---|
| | Before treatment | After treatment | |
| M1 | 185 | 50 | 72 |
| M2 | 187 | 45 | 76 |
| M3 | 160 | 48 | 70 |

### 4.3.2. Boll Opening

As demonstrated in Table 4.4. the cotton bolls opening effect increased significantly after spraying by different spray nozzles. The boll opening rate was slightly higher with the high-dose Thidiazuron treatment, but not significantly different. However, the highest spray Air induction nozzle method caused the cotton leaves to wither without falling, improving the impurity content in the cotton. Defoliants like thidiazuron/diuron and ethephon/cyclanilide have optimal activity when maximum and minimum daily temperatures are above 27 ◦C degrees and above 10 ◦C, respectively (Wright, S.D. et al).

Table 4.7. Effect of defoliant application rate on boll opening by different spray nozzles

| Methods | Number of bolls opening (Number) | Number of total bolls (Number) | Boll Opening rate (%) |
|---|---|---|---|
| M1 | 50 | 60 | 83 |
| M2 | 72 | 84 | 85 |
| M3 | 70 | 85 | 82 |

### 4.3.3. Yield Characters and Fiber Quality

Defoliant application timing has a significant effect on cotton yield and quality. However, there are few reports on the effects of defoliant application rate and different spraying methods on cotton yield and quality. The study indicates defoliants application rate and different spraying methods had no significant effect on seed cotton yield and fiber quality (Table 4.7). All the treatments had similar results for each of these parameters when applied at three different spraying methods. Therefore, this showed that the treatments could be applied safely at either of the application timings without affecting these cotton fiber quality parameters.

Table 4.8. Effect of defoliant different spraying methods on yield characters and fiber quality of cotton sprayed by PTO field crop sprayer.

| Treatment | UHML/mm | UI/% | Mic | Str/g·tex | Elg/% | MR | SF (%) |
|---|---|---|---|---|---|---|---|
| M1 | 27.36 b,c | 83.8 b | 4.72 a | 28.4 b | 5.9 a | 0.87 a | 7.9 a |
| M2 | 28.70 a | 86.7 a | 4.75 a | 29.2 b | 5.9 a | 0.87 a | 7.2 b |
| M3 | 28.44 b | 84.8 b | 4.76 a | 31.3 a | 5.0 a | 0.88 a | 7.6 b |

a–c ($p < 0.05$; Duncan’s Test); UHML, Upper half mean length; UI, Uniformity index; Mic, Micronaire; Str, Strength; Elg, Elongation; MR, Maturity; SFI, Short fiber index.

## 5. CONCLUSIONS AND RECOMMENDATIONS

The aim of the present study was to seek the relations of three different nozzle with the spray quality and efficacy in cotton defoliant spraying using PTO tractor mounted sprayer.

There are many factors that affect the success of the spraying business. The main criteria used to express the success of the sprayer; the amount of deposits on the target plant, the surface coverage rates, the evenness of deposit on the target plant, the number of drops per unit area and the drop diameters. Researchers use one or more of these criteria in their studies to decide on the quality of the spraying work.

According to the research results of this thesis study, the highest performance of the spray nozzles in standard flat fan and air induction nozzle increased the amount of accumulation on the plant and the upper leaf coverage rate values. It was found that increasing the application rate in the dual pattern nozzle method had little effect on the leaf coverage rate and resulted in a decrease in the amount of deposits.

The BSF deposition and coverage rate increase with spraying volume in the range of 250 l/ha. When the spraying volume is less than 400 l/ha, the deposits and coverage rate of BSF are increased. According to the experiment results and combined with the cotton defoliation, boll opening, fiber quality and BSF deposits and coverage rate in cotton leaves and spraying volume of 250 l/ha will be recommended to the farmers for air induction nozzle defoliant application. The research results could provide a reference for further optimization of the spraying parameters of cotton defoliant.

In this study, it was observed that the air induction nozzle makes a good coverage under the leaf in both high and low chemical application rate (250L/ha, 400 L/ha) while dual pattern nozzle systems perform worse under-leaf coverage in both low and high chemical application rate (250 L/ha 400 L/ha).

In this thesis study, it was found that the air induction nozzle followed by standard flat nozzle provided the best deposition and coverage rate value at both low and high chemical application rate. The best coverage rates values in under-foliar spraying were also in the air induction nozzle. In addition, the fact that the penetration of the defoliant to the underside of the plant leaves increases the chemical efficacy, it is concluded that this nozzle position is indispensable for defoliant spraying.

In this thesis the follwing results can be drown:

- The average amounts of tracer material accumulated on the filter papers in the upper-and lower-layers of the cotton plant are given in Table 4.1. at a 250 L/ha application rate via standard flat fan nozzle, air induction, and dual Pattern nozzle.
- When the standard flat fan nozzle both upper and lower leaf coverage rate values are considered, it is observed that the highest value is 19.7 %. The lowest value in dual pattern nozzle both upper and lower leaf coverage rate is 7.5 %. The optimal coverage rate in air induction nozzle is 17.1 %. When all coverage rates in a standard flat fan nozzle are considered, it is clear that upper and lower leaf coverage rates are superior.
- Likewise, the Table 4.3.illustrates that the air induction nozzle method obtained the highest average coverage in 250 l/ha application volume with 26.9 %, followed by the standard flat fan nozzle method, which is statistically the same and in the upper group with a value of 18.6 %. The dual pattern nozzle method, on the other hand, was statistically included in a subgroup with a 10.4 % average coverage rate.

### 5.1. Recommendation

1. For farmers the air induction nozzle is the better option for defoliant application.
2. In order to improve the efficiency of defoliant application rate on the cotton plant, spray as the maturing time approaches 60-70 percent.
3. To reduce the effect of drift, use the standard flat fan nozzle, air induction nozzle, and dual pattern nozzle.
4. In terms of the amount of deposits, coverage rates, and defoliant application values provided by air induction nozzle and standard flat fan nozzles, it was determined that they could not be compared to the classical method.

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