ABSTRACT

LUONG VU, VICTORIA QUYNH NHU. Protégete: Development of Pesticide Protective Clothing for Migrant Farmworkers on Tobacco Farms (Under the direction of Dr. Kate Annett-Hitchcock).

The tobacco industry relies heavily on human labor, particularly migrant farmworkers, requiring them to work in extreme weather conditions and heavily utilize chemical pesticides (Mobed & Schenker, 1992; Fisher, 2000; Novotny et al, 2015). Migrant farmworkers are therefore at high risk of experiencing acute pesticide poisoning, green tobacco sickness, dehydration, and heat stroke while working in the fields. Migrant farmworkers are currently wearing cotton t-shirts, button down shirts, Tyvek coveralls and sometimes trash-bags as protective garments, which are not suitable for preventing exposure to the hazards on the field.

In order to address the lack of available proper protective clothing against pesticide exposure for migrant farmworkers, this research continued the development of a pesticide repellent garment against flumetralin, a common pesticide used in tobacco farming. This study utilized hemp woven fabric modified with a Poly(acrylic acid) (PAA) finish on the surface that acts as a barrier by preventing dermal absorption of flumetralin. Mixed methods were carried out in two phases. The first phase involved performing standard physical, chemical, and laundering tests to determine the durability and effectiveness of the treated hemp against the flumetralin pesticide. The second phase involved holding a focus group with six tobacco growers from North Carolina to determine their value perception of the garment.

Analysis of the data revealed that the PAA treated hemp is effective in protecting from the pesticide and durable enough to withstand laundering and tearing compared to fabrics currently worn in the fields. Data from the focus group showed that participants perceived the garment to have high value but had many suggestions to improve the value of the garment. This study will prove useful for not only migrant farmworkers on tobacco farms, but tobacco farmers in protecting against exposure to flumetralin pesticide. The researcher recommends that future development of this protective garment should consider protection against green tobacco sickness as well.

Protégete: Development of Pesticide Protective Clothing for Migrant Farmworkers on Tobacco Farms

by
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DEDICATION

To my mom, my dad, my sister, and my fiancé. Thank you for your endless support and for always pushing me to strive for the best.

BIOGRAPHY

Victoria Quynh Nhu Luong Vu was born and raised in San Jose, California and became a west coast transplant when she moved to Raleigh, North Carolina with her family at age 11. She attended North Carolina State University where she graduated with a Bachelor of Science in Fashion and Textile Management with a focus in Brand Management and Marketing. Victoria has always had a passion for art and design. During her junior year of college, she decided to study abroad in Prague where she explored her interest in fashion and costume design. Through her studies abroad she was able to experience the fashion industry through a global lens, visit fashion houses, and experience different cultures in Europe.

After graduation, Victoria moved to Milwaukee, Wisconsin to freeze and work as a product developer at Kohl's. It was during that time she realized her passions were in the area of design and sustainability. With a renewed sense of curiosity for learning and research, she returned to North Carolina State University's Wilson College of Textiles to complete her Master's degree. During her graduate career, she has had the opportunity to explore many aspects of the design field and sustainability within the supply chain.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Tobacco is one of the oldest commercially grown crops in the United States dating back to the 1600s (USDA, 2000). Currently the United States is the fourth leading producer of tobacco behind China, India, and Brazil (Food and Agriculture Organization of the United Nations, 2019). The tobacco industry relies heavily on human labor (Fisher, 2000), particularly migrant farmworkers (Mobed, Gold & Schenker, 1992). Labor requirements include working in extreme weather conditions (Mirabelli et al., 2010), and heavy utilization of chemical pesticides to control diseases, suckers, and pests (United States General Accounting Office, 2003). The most labor-intensive stages of tobacco cultivation are topping, priming, and harvesting (Shew, Toennisson & Vann, 2015). These stages involve exposure to toxic products, which is where farmworkers are the most prone to being exposed to pesticides and nicotine sap (McKnight & Spiller, 2005; Fotedar & Fotedar, 2017). In addition, topping, priming, and harvesting are typically carried out during the hottest times of the year, July through September, which makes workers more susceptible to health hazards when working out in the field (M. Vann, personal communication, 2019).

Farmworkers are at risk of pesticide exposure, green tobacco sickness, dehydration, and heat stroke while working under extreme conditions (Arcury & Quandt, 2011). Pesticide and nicotine poisoning can be contracted through dermal exposure to chemical pesticides and nicotine sap while working in the field (Gehlbach, Williams, Perry &Woodall, 1974; Nesheim, Fishel, & Mossler, 2017). Moisture from sweat and tobacco leaves can increase the risk of transferring the pesticides and nicotine onto the skin. Depending on the proper use of protective equipment, the moisture containing nicotine and pesticides can seep into the exposed skin and into the farmworker's bloodstream (Gehlbach, Williams, Perry & Woodall, 1974; Gehlbach et al, 1975). Wearing proper protective barriers can reduce exposure to pesticides and nicotine (EPA, 2015). Lesions on the skin, particularly on the hands and armpits, can also facilitate nicotine and pesticides into the bloodstream. Pesticide exposure also occurs through ingestion or inhalation (EPA, 2016). When acute pesticide and nicotine poisoning occur, farmworkers experience symptoms such as vomiting, dizziness, and fatigue (Khan et al., 2009). Symptoms can occur anywhere within an hour or more after exposure (OSHA, n.d.). Effects from both pesticide and nicotine poisoning impacts individual health and slows down worker productivity in the field (NIOSH, 2011).

Wearing proper protective barriers can reduce exposure to pesticides and nicotine. The Worker Protection Standard (WPS), issued by the Environmental Protection Agency (EPA), recommends farmworkers wear a combination of long sleeves, long pants, shoes, and socks as their protective system against exposure to pesticides. Growers are required by the EPA to provide gloves, head and face protection, and other protective gear for certain tasks as specified on the pesticide labels (EPA, 2015). Protective gear such as rubber rain suits and Tyvek suits are available for purchase on the market from local hardware stores or online from U-Line for approximately $7 per unit (M. Vann, personal communication, 2019). These suits are typically required for pesticide handling (EPA, 2015). While these suits protect against pesticide exposure, material durability is low and does not allow any airflow, trapping heat and sweat. The suits are also wasteful as farmworkers typically wear them once and discard at the end of the day (M. Vann, personal communication, 2019).

Cotton jeans and shirts are the most common form of working apparel for migrant farmworkers (EPA, 2015). These items may be somewhat protective but is not suitable for the required labor in hot conditions due to material moisture absorbency. Cotton is known to be a comfortable and breathable fabric; however, it is highly absorbent (Stanhope, 2011). When in the presence of large amounts of moisture, cotton becomes heavy, uncomfortable, less breathable and may prolong exposure to pesticides and nicotine if not changed and washed frequently. Therefore, this makes cotton an unsuitable fabric for tobacco farming operations. (Quandt, Arcury, Pressier, Norton & Austin, 2000; M. Vann, personal communication, 2019). Due to the lack of proper protective clothing available in the market, there is a need for improved protective gear in tobacco farming. In order to address the issues with cotton and other protective clothing available in the market, this study utilizes hemp as the fabric of choice for the protective garment. Hemp and cotton are both natural fibers, however, unlike cotton, hemp offers higher durability and moisture wicking properties making it a more sustainable fiber for long term use (Stanhope, 2011). Hemp is also more sustainable in terms of cultivation as it uses little water and replenishes the soil rather than depletes it (Ranalli & Venturi, 2004).

1.2 Purpose of this study

The purpose of this research is to further develop a protective garment with the potential to improve the lives of tobacco farmworkers, particularly migrant tobacco farmworkers, when they are exposed to toxic substances in the field. Prior investigation in this area has led to a garment design and proof of concept. The proof of concept included an application of protective finish of Poly(acrylic acid) to counteract flumetralin pesticides through adsorption. Flumetralin is a common pesticide used in tobacco farming for the topping process (removal of tobacco suckers). Flumetralin is classified as a low toxic pesticide, however, constant exposure could increase the possibility of farmworker health complications. Previous researchers determined that flumetralin could react with the Poly(acrylic acid) (PAA) to retain the flumetralin from coming in contact with the farmworkers skin. Therefore, the combination of flumetralin and PAA was concluded to be a potential protective barrier to reduce pesticide exposure. The previous study was limited to the design of the garment and did not include full physical testing of the finish and its effectiveness. In addition, this study will explore growers' value perception of the protective garment to determine its potential to both wearers and purchasers.

1.2.1 Research Questions

Two research questions are explored in this study through qualitative and quantitative approaches:

RQ1: What is the effectiveness of the combination of 100% hemp woven material and a Poly(acrylic acid) (PAA) finish on garments in protecting migrant farmworkers from pesticide exposure?

RQ1A: What is the effectiveness of the adsorption of the pesticide flumetralin by the PAA?

RQ1B: What is the durability of the PAA finished hemp?

(Effectiveness in this study is defined as the ability of the PAA to adsorb the flumetralin, the resiliency of the PAA finish on the hemp fabric against abrasion, and the durability of the finished fabric against physical testing)

RQ2: What is the tobacco growers' acceptance, or value perception, of the garment design?

1.3 Limitations

This study is limited to North Carolina, which is only one region where tobacco farming takes place. Because the study is limited to one region, soil, plant and climate are limited as the weather and properties of the environment differs from region to region.

Field Testing of the garment on human subjects was not conducted to understand the true effects of the developed garment. All tests were conducted in a lab setting; therefore, a true representation of exposure to pesticides and physical exertion on the garment could not be concluded.

Migrant farmworkers were not interviewed to understand the struggles they face daily on the tobacco farms and their recommended needs to include in the garment. Due to the language and sensitivity of scope beyond the reach of this project, the study was limited to gaining the growers' input and determining the critical needs of the garment through their perspectives. The interview study only consists of the perception of one user group.

1.4 Definitions

For the purpose of this study the following terms are operationalized for this study as follows:

Assay: To analyze an object for one or more components (van Grieken & de Bruin, 2009).

Adsorb: Holding a molecule, gas, or liquid on the surface of the material (Calvert, 2009).

Growers: Growers are defined as the farm owners, or employers.

Migrant Farmworker: Migrant farmworkers are people who work temporarily or seasonally; they travel from job to job. The farmworker is not able to return to their permanent residence within the same day. Guestworkers on H-2A visas are also considered migrant farmworkers (Migrant Clinician Network, 2017).

Seasonal Farmworker: Seasonal farmworkers are employed in temporary agricultural work, but do not move from their permanent residence (Migrant Clinician Network, 2017).

CHAPTER 2

LITERATURE REVIEW

This chapter explores the current state of tobacco farming including the risks of pesticide and nicotine exposure, the situation of migrant farmworkers at work in the fields, and research on protective garments.

2.1 Tobacco Cultivation

Dating back to the early 1600s, tobacco is one of the oldest commercially grown crops in the United States (USDA, 2000). According to the Food and Agriculture Organization of the United Nations (FAO), the United States (US) is the fourth largest tobacco producer in the world behind China, India, and Brazil respectively. Table 1 lists top ranked countries based on total tobacco production quantities from 2007 to 2017 (Food and Agriculture Organization of the United Nations, 2019).

Table 1. Production Quantities of Tobacco in China, India, Brazil and the US 2007-2017

Country /Region	**Sum Production Quantities of Tobacco, Unmanufactured* (tonnes)**
China	31,896,349
India	7,821,791
Brazil	9,311,893
US	3,695,821

*Unmanufactured tobacco: Unmanufactured dry tobacco, including refuse that is not stemmed or stripped, or is partly or wholly stemmed or stripped.

(Food and Agriculture Organization of the United Nations, 2019)

In 2018, the US produced an estimated 533 million pounds of tobacco with North Carolina producing the most (251,925,000 pounds) (United States Department of Agriculture, 2018).

The major tobacco classifications include, Virginia, or flue-cured, burley, and oriental (Davis & Nielsen, 1999, p. 32). In the US, specifically in North Carolina, both flue-cured and burley tobacco are the main types of tobacco produced (Fisher, 2000; Shew, Toennisson &

Vann, 2015). In 2015, North Carolina ranked number one for production of flue-cured tobacco and sixth in production of burley tobacco in the US (USDA, 2015). The gross income from North Carolina tobacco production in 2018 was over $478 million (USDA, 2018).

Looking closely at how tobacco is grown and harvested, nearly 80% of the tobacco crop is grown on a two-year rotation (Vann, 2015; Toennisson & Burrack, 2016). The tobacco farming process begins with sowing the seeds, which is typically done in a greenhouse from mid-February to mid-March (Shew, Toennisson & Vann, 2015).

Approximately six to eight weeks after seeds are sown, they are transplanted. The process of transplanting consists of moving the seed from the greenhouse to the field, which can be done mechanically or manually (Shew, Toennisson & Vann, 2015). Tobacco can be grown on a wide variety of soils ranging from very sandy soil to clay soil (Shew, Toennisson & Vann, 2015). Depending on the type of tobacco crop, the levels of soil, or amount of soil used to build up the soil bed, will differ (Shew, Toennisson & Vann, 2015). Flue-cured tobacco is typically grown on a high soil bed with wide rows, in order to allow for proper drainage and root aeration (Shew, Toennisson & Vann, 2015).

After transplanting, the crop moves into the layby stage (Shew, Toennisson & Vann, 2015). During the layby stage, which occurs four to six weeks after transplanting is complete, the tobacco plants can grow 15 to 20 inches in height (Shew, Toennisson & Vann, 2015).

Between the time of transplanting and layby, the cultivation of the tobacco crop occurs. During this time, weeds are removed, crop protection agents (CPA) are incorporated, soil crusting is removed, aeration and drainage is improved, and the plant bed is continuously raised by adding more soil (Shew, Toennisson & Vann, 2015). CPAs are pesticides used to protect crops from various diseases and pests which include herbicides, insecticides, fungicides, sucker control agents, and other products applied to tobacco during the season (Walker, Brown, Beeler & Hensley, 2017). CPAs are typically applied through watering the plants during transplanting process to increase growth rate (Shew, Toennisson & Vann, 2015). Once pesticides are applied, farmworkers must follow the restricted entry interval (REI). REI refers to the amount of time farmworkers must wait before re-entering the field following the application of a pesticide. The REI differs depending on the toxicity level which is specified on the pesticide label (EPA, 2019). Additionally, farmworkers must follow pre-harvest intervals (PHI) in order to reduce the risk of exposure to pesticides during harvesting. The PHI is the time in days that must pass between the last application of a pesticide and harvesting food or feed crop. This time allows the pesticide to breakdown in the plant or on its surface, therefore, minimizing the amount of pesticide residue that farmworkers may be exposed to. Farmworkers can find the PHI on the pesticide label (National Pesticide Information Center, 2018). The difference between REI and PHI are as follows: REI is the amount of time farmworkers are restricted from entering the field after a pesticide is applied (EPA, 2019), and PHI is the amount of time necessary for pesticides to breakdown and leave an acceptable amount of pesticide residue which is set by the Environmental Protection Agency (EPA) (National Pesticide Information Center, 2018).

About eight to ten weeks after transplanting, flower heads begin to appear and are removed to increase the leaf yield and quality; this process is called topping. This is typically done in the first two weeks of July (Collins and Hawks, 1993). Suckers, the flower heads that grow on tobacco crops, are removed to increase yield quality of the tobacco leaves by allowing the leaves to grow larger and the roots to grow longer (Novotny et al, 2015). Pesticide chemicals are typically used to control the suckers. Removal of suckers by hand is commonly carried out by farmworkers in which a knife is used to remove the flower at the top of the plant (Shew, Toennisson & Vann, 2015). Topping takes place in the early morning when plants are wet with morning dew (Gehlbach, Williams & Freeman, 2013). There are risks with topping the buds on the tobacco plant as farmworkers are brushing up against the tobacco plant. The topping stage is a major step in the tobacco farming process where farmworkers come into contact with chemical pesticides and nicotine from the tobacco plant. The leaves of the plant carry chemical pesticides and sap, which contains nicotine, on its surface (EPA, 2019; Gehlbach, Perry, Williams & Woodall, 1974; Gehlbach et al 1975). The sap excretes from the stem and leaves of the tobacco crop and passes onto exposed skin through moisture from dew on the leaves or sweat from the body as the workers brush against the tobacco leaves and carry them to the trailer (Fotedar & Fotedar, 2017). The pesticides and nicotine transfers onto the skin, seeps into the skin through moisture absorption, and can cause hazardous effects, which will be explored later in this chapter.

Depending on the type of tobacco, leaves are harvested differently. Flue-cured tobacco and oriental tobacco crops are harvested leaf by leaf. While Burley tobacco is harvested by cutting the entire stalk, which can be done mechanically or manually. During the harvesting stage, almost the entire farmworker's body can come in contact with green tobacco leaves as they reach under the tall crops and large leaves to harvest. As leaves are being picked and stalks cut, workers are brushing against the tobacco plant as they walk between the rows of bulky leaves and reach under the leaves to cut the stalk or leaf stems. The picked leaves and stalks are held under their arms and against their chest as the farmworkers continue to harvest until their carrying capacity is reached. The tobacco is then placed onto a cart, or trailer, and transferred to the barns for curing (van Willigen & Eastwood, 1998). High exposure to the hazardous chemical pesticides and nicotine can be experienced during this stage (Quandt, Arcury, Preisser, Norton, Austin, 2000).

Once harvested, tobacco leaves are set to cure. The curing stage defines the leaf quality and character. There are three main types of curing: air curing, flue curing, and sun curing. Burley tobacco is typically air cured by hanging the leaves in a barn. Virginia tobacco is flue cured, in a heated barn for about one week where it will turn a golden yellow or deep orange color. Oriental tobacco is sun cured in the open-air (Davis & Nielsen, 1999). Once cured, leaves are sorted and stored based on stalk position and quality. Eventually the leaves are packed into bales and evaluated by leaf buyers. Exposure to pesticides and nicotine can occur during this stage. Due to the PHI level, pesticide residue can still be present on the leaves while being harvested and transferred. The process of transferring the leaves from cart, or trailer, to the barn requires workers to handle the leaves which are still sticky with nicotine sap and may have pesticide residue present. (Fenske, 1997; Fotedar & Fotedar, 2017). Therefore, farmworkers are still at risk of pesticide exposure as they handle the leaves and stalks.

2.2 Farmworker Profile

Since the beginning of the 21^{st} century, most tobacco farms have become large consolidated operations worked by seasonal migrant farmworkers. Today, migrant farmworkers typically travel from Mexico or Central America for eight to twelve weeks out of the year during harvesting season as reported in the National Agricultural Workers Survey (NAWS) (2018).

The number of farmworkers per farm can vary between farms and regions. It is estimated that there are as few as three to as many as a dozen farmworkers per acre in the US on tobacco farms (M. Vann, personal communication, 2018). In 2018, NAWS reported that a majority of the farmworkers surveyed were of Hispanic background (83%), and 69% of farmworkers were born in Mexico (NAWS, 2018). Of the farmworkers surveyed, 19% reported a migrant status and 68% reported as men with an average age of 38 years (NAWS, 2018). The average education level of farmworkers was reported no higher than 8^{th} grade. Over half of the farmworkers were reported to be married (57%) and had children (55%) (NAWS, 2018). Their average personal income ranged between $17,500 to $19,999 and 47% reported having health insurance coverage. (NAWS, 2018). It would be worth noting that the National Agricultural Workers Survey is only a representation of the farmworkers across the nation, not specific to tobacco farming, and not a survey of all farmworkers. The survey utilizes a random sampling method to interview farmworkers across the nation.

2.2.1 H-2A Work Visas

A number of farmworkers in the United States (US) hold H-2A visas. In 2013, it was estimated there were approximately 74,859 H-2A visa holders in the United States (Costa & Rosenbaum, 2017). H-2A work visas are designed for lawful admission of migrant agricultural workers through the request of agricultural employers who do not have enough qualified workers willing to do the work. The H-2A visa allows foreign guest workers to temporarily work in the US, specifically to perform agricultural labor (U.S. Department of Labor, n.d.).

Under the H-2A visa, employers are required to provide housing to the workers and daily transportation, at no cost if workers are unable to return to their home within the same day. The employers must provide or pay for inbound transportation and daily meals. Workers should receive a copy of their contract with the pay amount listed. Employers are required to pay the employees at least twice per month. The employers must provide workers' compensation and any required tools, supplies, and equipment at no cost to the worker. Employers are not allowed to require workers to pay for any employer cost related to obtaining the H-2A labor certification which includes agent, application, and recruitment fees. Once the contract is complete, employers must provide or pay for the workers return home (U.S. Department of Labor, n.d.).

2.3 Chemical Pesticides

In effort to increase crop productivity, pesticides are used extensively in modern day agriculture (Kocaman & Bucak, 2015). Different pesticides are used at a specific time and for a certain control factor for each crop stage which includes fungicides, herbicides, insecticides, fumigants, sucker control agents, and ripening agents (Shew, Toennisson & Vann, 2015).

Tobacco farming utilizes a number of chemical pesticides, with varying degrees of toxicity to humans. To minimize the amount of exposure to pesticides, farmworkers should follow the Worker Protection Standard as well as the label on the pesticide bottle. The label describes the toxicity level of the pesticide, proper handling methods, and necessary protective barriers to wear while handling the pesticide (Buhler, 2019). The toxicity level of the pesticide is denoted with one of the following signal words typically printed on the front side of the label in bold words: Caution, Warning, or Danger (Danger Poison). Caution indicates the pesticide product is toxic if it causes eye irritation, is eaten, absorbed through the skin or inhaled. Warning signals the product is moderately toxic if eaten, inhaled, absorbed through the skin or causes moderate eye or skin irritation. Danger denotes the pesticide is highly toxic which can result in irreversible damage and can be corrosive or cause severe burning to the eyes. Danger-poison defines the pesticide as highly toxic but only if ingested, absorbed through the skin or inhaled (EPA, 2016).

Dermal exposure is the most common way pesticides enter the body, as exposed skin comes in contact with pesticides during regular crop maintenance and harvesting. Drifts from nearby fields, carrying pesticide residue, can also cause pesticide exposure (Wilk, 1986). Aside from skin exposure, pesticides can also enter the body through the eyes, inhalation, and swallowing (Buhler, 2019). The toxicity level of each pesticide in conjunction with the amount of exposure determine the level of pesticide poisoning and severity of symptoms (Buhler, 2019). The effects and severity of pesticide exposure symptoms will be discussed in-depth in section 2.4.

Before handling pesticides or beginning work in the field, farmworkers must go through required pesticide training (EPA, 2015). Most training guides on pesticides are difficult to understand, especially for migrant farmworkers who have little education and have limited literacy in English (National Agricultural Workers Survey, 2018). The communication barriers create challenges when providing farmworkers with general workplace safety information or specific pesticide safety information (Arcury, Quandt, Cravey, Elmore, & Russell, 2001). In order to combat this, a team from North Carolina State University's Cooperative Extension developed a training guide to allow people of all levels to understand, displayed in Figure 1.

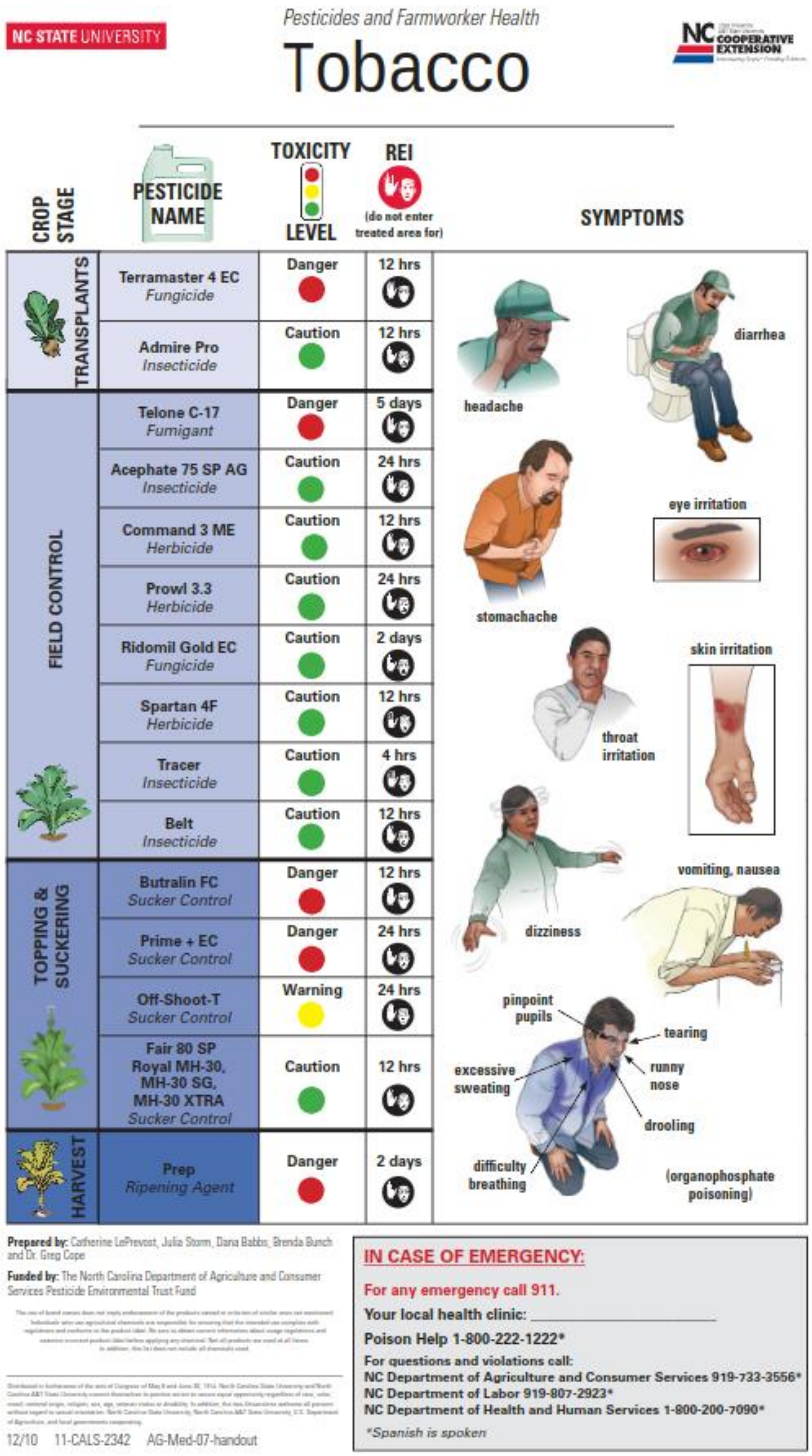

Figure 1. Pesticides and Farmworkers Health Tobacco Training Toolkit (LePrevost, Storm, Babbs, Bunch, & Cope, 2010).

Figure 1 illustrates common pesticides used in tobacco farming for specific crop stages. It also demonstrates the toxicity level if exposed to the pesticide and illustrates the symptoms the farmworker may experience if exposed. The guide also conveys how long the farmworker should stay out of the field before re-entering after a pesticide has been applied, which is also known as the restricted entry level (REI). While there are many pesticides used in tobacco farming, some more common than others, this study will focus on flumetralin as previous research focused on creating a finish that protects from flumetralin.

2.3.1 Flumetralin

Flumetralin is a synthetic plant growth regulator commonly used in tobacco farming for its herbicidal activity; it belongs to the 2,6 dinitroaniline class of chemicals under the halogenated hydrocarbons (Kocaman & Bucak, 2015). Dinitroaniline is the generic name for flumetralin (Appendix V, 2009). Product names include Prime+, Flupro, and Drexalin Plus (NC State Extension, 2011). Flumetralin is widely used for the control of suckers and is considered a contact local systematic suckercide because it must touch the suckers in order to be effective (Fisher, Vann, Whitley, & Seagroves, 2019). The chemical is applied to the suckers when they are in an "elongated-button-to-early-flower-stage" (NC State Extension, 2011).

Flumetralin can be applied to the suckers mechanically or manually. Mechanical application includes overtop spray and drop line applications (Fisher, Vann, Whitley, & Seagroves, 2019). Over top spray applies flumetralin in bigger quantities at one time using a three-nozzle arrangement (Fisher, Vann, Whitley, & Seagroves, 2019). While manual application can soak the sucker more efficiently, mechanical application is much quicker as it can deliver up to 50 gallons per acre at low pressure with less labor involved (Fisher, Vann, Whitley, & Seagroves, 2019). Drop line application is a mix of mechanical and manual application used to apply the flumetralin to the suckers. The drop line mechanism consists of a power sprayer with nozzles, attached to the tractor. As the tractor moves through the rows of tobacco, the power sprayer nozzles are aligned over each plant row. Farmworkers manually hold the nozzles over the center of the plant, open the valve and apply the flumetralin solution to the plant, saturating the suckers with pesticide (Fisher, Vann, Whitley, & Seagroves, 2019). Drop line is generally the most efficient way to apply flumetralin due to the consistent application to each leaf. Manual application requires farmworkers to walk down the rows of tobacco crops and apply the solution by reaching the top of the plant and applying the flumetralin directly onto the sucker (Fisher, Vann, Whitley, & Seagroves, 2019). In any form of application, the flumetralin solution must saturate sucker and leaf axils, in order to stop the cells from dividing and grow larger (NC State Extension, 2011).

Flumetralin is classified as noncarcinogenic, however, it still poses a risk to tobacco farmers and smokers (Kocaman & Bucak, 2015). Flumetralin has a high toxicity level and typically requires a 24 hour period of no entry into the field after application (NC State Extension, 2011).

Prime+EC Plant Growth Regulator by Syngenta is a commercial brand of flumetralin used to control tobacco suckers. The plant growth regulator has a REI of 12 hours and is labeled with a danger signal work. The worker safety label on Prime+EC requires applicators to wear coveralls over a long-sleeved shirt and long pants. It also requires protective eyewear and chemical-resistant headgear for overhead exposure. When cleaning equipment, mixing the pesticide solution, or loading the pesticide mix into the spray mechanism, the label requires the handler to wear a chemical resistant apron. Similar to the personal protective equipment required for Prime+EC applicators, mixers or loaders, early-entry workers are also required to wear coveralls over a long-sleeved shirt and long pants. They are also required to wear chemical-resistant gloves, such as barrier laminate or Viton, chemical resistant footwear with socks, and chemical resistant headgear for overhead exposure (Syngenta, 2019).

2.4 Effects of Tobacco Farming on Farmworkers

Tobacco farmworkers, particularly harvesters, are constantly at risk to pesticide exposure due to labor intensive farming in hot climates. Pesticide exposure can affect the workers' health. Farmworkers are not only at risk of hazardous chemical pesticide exposures; they are also at risk for Green Tobacco Sickness (GTS). GTS occurs from exposure to the nicotine of the tobacco plant and causes serious health effects. These effects from both pesticide and nicotine poisoning impacts individual health and slows down worker productivity in the field; therefore, the productivity of the tobacco farm system suffers as well due to the inability of farmworkers to work to their full potential (NIOSH, 2011). Further details are provided in Section 2.4.2.

2.4.1 Pesticides Exposure and Effects

Pesticide exposure can lead to pesticide poisoning with varying severity depending on the amount of exposure the farmworker has to the chemicals as well as its toxicity level. A low level of exposure to a very toxic pesticide may be as dangerous as a high level of exposure to a relatively low toxicity pesticide (Sarwar, 2015).

Pesticides can enter the body dermally (through the skin), orally (through the mouth and digestive system), or by inhalation (through the nose and respiratory system) (Nesheim, Fishel, & Mossler, 2017). Dermal exposure is the most common entry point among farmworkers with the hands often accounting for most of the dermal exposure (Buhler, 2019; Popendorf et al., 1979; Zwieg et al., 1983; Winterlin et al., 1984). Dermal exposure accounts for approximately 90% of the exposure pesticide handlers receive (Nesheim, Fishel, Mossler, 2017).

Pesticide handlers and farmworkers who carry out topping and harvesting the tobacco leaves are at highest risk to pesticide poisoning. Farmworkers who handle the pesticides are typically in direct contact with the pesticides as they mix, load, or apply pesticides. While handling the pesticides the farmworkers are exposed due to spills, splashes, direct spray contact as a result of faulty equipment, or even drift (Mobed, Gold, & Schenker, 1992; Nesheim, Fishel, & Mossler, 2017). Farmworkers who perform the hand-labor tasks, such as topping, priming, or harvesting, are also at high risk as they encounter pesticide residue while coming in contact with the leaves. The absorption of pesticide will continue as long as the pesticide is in contact with the skin (Nesheim, Fishel, & Mossler, 2017).

There are three classifications for pesticide toxicity, or poisoning: acute, subchronic, and chronic. Acute pesticide toxicity refers to the systemic damage that occurs from a single, short-term exposure to a chemical pesticide. Subchronic toxicity refers to the effects of repeated exposure to chemical pesticides over a week or months. Chronic toxicity refers to the effects caused by long-term exposure to the pesticides (Damalas & Koutroubas, 2016; Nesheim, Fishel, & Mossler, 2017). Little research has been conducted to understand the long-term effects of chronic toxicity of seasonal and migrant farmworkers compared to the short-term effects of acute toxicity (Mull, 2001). As mentioned in Mull, Engel, Outterson, and Zahm's research (2001), the researchers believe that the scarcity of studies on long-term health effects of pesticide poisoning is, in part, due to the "perceived difficulties in tracking such a mobile population (migrant farmworkers) (p. 616)".

Signs or symptoms of sickness from pesticide exposure may occur if the farmworker is exposed to a critical amount of the pesticide. Short term effects of acute pesticide poisoning can range from mild symptoms to more severe effects. Mild symptoms include headaches and dizziness, redness in the eyes and skin, or burning sensations in the throat (Ecobichon,1999). More severe effects include convulsions and respiratory distress (Nesheim, Fishel & Mossler, 2017). This is especially true if the farmworker has been exposed to organophosphates or carbamates type pesticides (Srivastava & Kesavachandran, 2019).

Few studies have been conducted to determine the long term effects of chronic pesticide poisoning. In the 2019 updated Agricultural Health Study on cancer incidence, it was found that farmers, particularly pesticide applicators and their spouses, have a higher incidence of specific cancers which included prostate cancer, lip cancer, multiple myeloma, diffuse large B-cell lymphoma and chronic lymphocytic leukemia (Lerro et al., 2019). Further studies are continuing to be conducted to understand the long term effects of pesticide exposure.

2.4.1.1 Worker Protection Standard

To address the pesticide exposure issue, the Worker Protection Standard (WPS) was issued by the Environmental Protection Agency in 1992 to reduce the risks of illness or injury to farmworkers and pesticide handlers that were resulting from occupational exposures to pesticides used in the production of agricultural plants on agricultural establishments. The pesticide handlers in the WPS are defined as those working directly with pesticides such as mixing, loading, or applying pesticides. Workers, or farmworkers, are defined as those who perform hand-labor tasks in pesticide-treated crops such as harvesting, priming, and topping. The foundation of the WPS is made up of three basic principles: inform, protect, and mitigate.

The WPS requires that farm employers (growers) keep their employees (farmworkers) informed about exposure to pesticides. Employers are required to train employees, specifically workers and handlers, on pesticide safety. Training should be given within five days before the worker begins fieldwork. All workers are required to receive pesticide safety training annually and must be given the training before their yearly mark. Through the training, workers are advised to wash their hands before eating, drinking, smoking, or using the toilet. They are also given training on types of protective barriers to use in the field during different actions such as applying pesticide. Workers are advised to shower and change clothes immediately after work; it is also suggested to wash their work clothes separately from their other laundry. This training is given in-person or through video, and farmworkers are provided with a brochure to refer to after the training. Employers are also required to inform employees about pesticides application and hazard information through creating a central location where all information is located. A notification should be given to employees about treated areas in the field; this should be done through posting signs or providing an oral notification.

Employers are required to provide protection against exposures to pesticides through the WPS. Employers are required to provide personal protective equipment (PPE) to employees who handle pesticides based on what the pesticide label requires workers to wear while handling the pesticide; this can include respirators, masks and coverall suits. Long-sleeved shirts, short sleeved shirts, long pants, short pants, shoes and socks are considered standard attire and do not have to be provided by the handler employer even though such work clothes may be required by a pesticide product labeling. Based on the WPS, handlers should not apply pesticides in a way that would expose workers and other persons and are responsible for wearing the PPE, specified on the pesticide product labeling, while handling pesticides.

The WPS also require employers to mitigate exposure that employees may experience. The employers are required to provide decontamination supplies such as water, soap and towels for employees to wash any pesticide exposure off, and eyewash water. Employers are to provide emergency assistance to employees through providing transportation to a medical care facility if an agricultural worker or handler may have been poisoned or injured by a pesticide. Employers are required to provide information about the pesticides that the employee may have been exposed to (EPA, 2015).

2.4.2 Tobacco Exposure and Effects

GTS, introduced at the beginning of Section 2.4, is also known as an acute form of nicotine poisoning. GTS is a form of nicotine poisoning that affects workers who have direct contact with tobacco plants during cultivation and harvesting (McBride, Altman, Klein, & White, 1998). GTS has been linked to nicotine and symptoms connected to acute nicotine poisoning since the first reported illness in the 1970's where it was reported as cropper sickness (Weizeneckerand Deal, 1970). In 1975, Gehlbach et al. cited their own unpublished data to prove that approximately 9% of North Carolina tobacco growers reported illness among their farmworkers; this was out of 60,000 farmworkers and growers. In 1998, an interview with 144 migrant Latino farmworkers in North Carolina was held where researchers found that 41% of the 144 Latino workers suffered GTS at least once during the season (Quandt et al., 2000).

Green tobacco refers to the tobacco growing in the field or tobacco in its uncured state. Prolonged direct contact to green tobacco plants with bare skin can be toxic (Fotedar, 2017). Farmworkers who are new to handling tobacco are at higher risk of suffering from GTS as they may have lower tolerance to nicotine (United Stated Department of Labor, 2018). GTS occurs primarily when people handle wet tobacco (Gelbach, Williams, Perry, 1974; Gehlbach et al., 1979). Although tobacco is handled during many stages of production, GTS occurs primarily among workers who handle the leaves and stalks in the field or during the process of transferring green tobacco to the curing barn (Gehlbach, Williams, Perry, 1974). As mentioned previously, GTS typically occurs during the topping and harvesting stage of the tobacco farming cycle where the risk of exposure to nicotine is the highest.

Similar to pesticide poisoning, prolonged direct contact to green tobacco plants with bare skin can be toxic. GTS is contracted by the absorption of nicotine through the skin when handling tobacco leaves (Weizenrecker & Deal, 1970). Nicotine is soluble in water. Therefore, when there is moisture from rain or dew, it causes the nicotine to be drawn to the surface of the tobacco leaves where it can come into contact with the skin (Gehlbach S., Williams W., Perry L. &Woodall J. 1974). When nicotine from leaves mix with rain, dew, or sweat, it increases the risk of GTS as the moisture allows for the nicotine to get onto the skin and seep into the bloodstream more easily (United States Department of Labor, 2018). Once the nicotine is absorbed into the bloodstream, it leads up to the brain and alters brain activity (Gehlbach et al, 1975). The body will begin to react by showing symptoms. Symptoms typically occur a few hours to a day after exposure depending on the severity of exposure (OSHA, n.d.).

Symptoms of GTS include short-term effects which include non-specific symptoms (common symptoms not specific to diagnosing an illness) such as nausea, vomiting, chills, dizziness, headaches, increased perspiration, abdominal pain, diarrhea, increased salivation, prostration, weakness, breathlessness, and occasional lowering of blood pressure. These symptoms are typically experienced in the afternoon to several hours after the workday has ended as exposure can occur in the early morning with the moisture from morning dew and throughout the day while sweating (Arcury et al., 2000). GTS is self-limited and of short duration, therefore, illness only lasts for approximately 12-24 hours (Gehlbach et al., 2003). Long-term effects have not been prevalently studied. Currently, there are no established diagnostic criteria except for matching symptoms back to the patient's history with tobacco (Arcury et al., 2000). Depending on the amount of exposure and the severity of the symptoms, it can result in dehydration, the need for emergency medical treatment, and especially loss of work time (Arcury et al., 2000).

2.5 Protective Clothing

2.5.1 Personal Protective Equipment (PPE)

Personal protective equipment, as defined by OSHA, is equipment worn in order to minimize exposure to hazards that cause serious workplace injuries and illnesses which can result from workplace hazards such as chemical, mechanical, electrical exposure, etc. (OSHA, n.d.). PPE can include a number of items in various combinations (OSHA, n.d.). Examples include safety glasses, gloves, earplugs or earmuffs, hard hats, coveralls, respirators, vests, and full body suits (OSHA, n.d.).

2.5.2 Current Farm Working Protection

During training, farmworkers are advised to wear PPE to protect themselves from hazardous chemicals based on the Worker Protection Standard (WPS) recommendations and the pesticide safety label requirements. The PPE may differ for workers handling the materials, applying the materials, or re-entering the field during restricted entry level. By law, the Environmental Protection Agency (EPA) requires workers, who apply the pesticide, to wear protective clothing and respirators based on the WPS in addition to specifications required by the specific pesticide label (EPA, 2015). On a typical day in the tobacco field, farmworkers are instructed to wear a combination of long sleeves, long pants, and shoes with socks as protective system as stated in their training (EPA, 2015). Combining the various PPE with the high heat temperatures, and physical exertion of farm labor, discomfort and heat stress occurs as many of the garments do not allow for proper ventilation (Arcury & Quandt, 2011).

Aside from clothing, the Worker Protection Standard (WPS) requires that training should also teach protective behaviors such as washing hands before eating, drinking, or using the toilet, showering or changing clothing immediately after work and washing work clothes separately from other laundry to protect themselves and their family from the exposure to pesticides (EPA, 2015).

In 2016, Lee Walton et al. studied pesticide protective behaviors of 71 Latino migrant and seasonal farmworkers through observing the farmworkers protective behaviors and collecting self-reported behaviors. The observed and self-reported behaviors were compared. It would be worth noting that farmworker participants of this study may have had higher than average safety orientations and trainings. Many of the farmworkers reported high average years of experience and being in the US on H-2A visas, which are associated with safer working conditions. The farms that were observed were also participants of the Certified Safe Farms which could mean that the workers on the farms observed were more motivated toward safety compared to a farm that may not be. The study found that protective clothing behaviors were widely practiced and reported. Hats, water-resistant outerwear and gloves were observed to be worn in the field. Baseball caps were observed to be worn rather than wide brimmed hats. Gloves were observed to be worn inconsistently throughout the workday. The researchers observed that one farm had zero farmworkers utilize gloves while they worked while a second farm had less than half of their farmworkers utilize gloves. It was also observed that water-resistant outerwear was used to keep clothing from becoming wet to reduce green tobacco sickness (GTS) and pesticide exposure. The water-resistant barriers used by farmworkers included raincoats or trash bags with belts was observed. The farmworkers reported high adoption of washing behaviors prior to eating and drinking, however, the observation of engagement of washing of hands was less. 33% of observations found that washing supplies were not available for the farmworkers, which is against WPS requirements (Lee Walton et al., 2016). The WPS requires growers to provide washing stations (soap & water) for farmworkers to wash their hands throughout the day (EPA, 2015). Even when supplies were provided, it was observed that only a small percentage or farmworkers used them to wash their hands before eating or drinking (Lee Walton et al., 2016).

In an interview with Jerry Hartsell, who works closely with tobacco migrant farmworkers through the Episcopal Ministry, it was mentioned that migrant farmworkers wear everyday clothing such as jeans and long sleeve cotton t-shirts, which is in line with WPS requirements, but are not suitable protective gear for the conditions of tobacco farming (Figure 2). A majority of the clothing worn is made of cotton, which is highly absorbent. This becomes an issue as the cotton absorbs the moisture from sweating, which is caused by the intensive labor in the heat, and moisture as well as sap from the tobacco plants (J. Hartsell, personal communication, 2018). The clothing becomes soaked and heavy from absorbing moisture (from worker sweat and dew on leaves) in addition to sap, which results in the workers removing their shirts in the afternoon work hours. The removal of clothing results in their skin being directly exposed to the tobacco leaves that hold the pesticide and nicotine sap (Quandt, Arcury, Pressier, Norton & Austin, 2000).

Due to the lack of protective clothing provided, often times, plastic bags are worn over the migrant farmworkers' clothing to help reduce the skin exposure to pesticides or nicotine (J.

Hartsell, personal communication, 2018). This is impractical as the plastic bag is not durable or thermally comfortable. It may protect the migrant farmworkers from pesticides and nicotine temporarily but is not a sustainable protective barrier for the wearer or the environment.

Figure 2. Tobacco Farmworker Apparel in the Fields

Figure 3. Tyvek Coveralls and Rain Suits Worn by Tobacco Farmworkers

Figure 3 pictures tobacco farmworkers wearing coverall Tyvek suits and a rain suit. Tyvek suits are only required to be provided by the employers for pesticide handling if the pesticide label requires a protective suit (EPA, 2015). However, this photo was taken by the primary researcher at an NC State University affiliated farm, where the farmworkers were wearing the suit while harvesting the tobacco. The Tyvek coverall suit pictured on the right was completely soiled and torn by midday, providing evidence that the coveralls are not durable enough for tobacco farming labor.

2.5.3 Market Analysis of Farming Industry Workwear - Protective "systems"

Training for farmworkers advises that they wear protective gear when working on the farm. Occupational Safety and Health Administration (OSHA) recommends wearing gloves for handling the plants to protect farmworkers' skin from being exposed to pesticide chemical residue on the leaves, sap from the tobacco leaves which contain nicotine, and any cuts or abrasions (OSHA, n.d.). According to the WPS, protective equipment should be provided for the farmworker by the growers if required by the pesticide label when handling the specific pesticide. Protective barriers that have been found to be effective in decreasing pesticide exposure included wearing a combination of long sleeves, long pants, shoes and hat (Salvator et al., 2008).

There are a number of protective products on the market for purchase, which are not provided by the growers unless it is required for a specific task (EPA, 2015). Through a market analysis, conducted by the primary researcher, it was found that farmworkers are able to buy chemical protection suits from home improvement stores such as Home Depot, Lowes, or Walmart. While there are protective suits on the market, the materials are not suitable for the end-use of tobacco farmworkers. These suits typically run from $7-$10 and are not practical for tobacco farming as they provide poor thermal comfort in the heat. Nonwovens offer an alternative material substrate, which can be breathable, but are not durable from cuts and wear, moisture wicking, or protective from chemicals seeping through. Due to these reasons, it is important for a solution to be made for this gap in the industry to help protect the farmworkers on tobacco farm, particularly the migrant farmworkers.

2.6 Designing a functional garment

There are several considerations when designing a garment. Fashion garments, as defined by Gupta (2011), are essentially a product of a designer's creative instincts. Functional garments, however, are designed around the end user's specific requirements depending on the environment and movements of the activity that the user performs in (Gupta, 2011). There are various approaches to a garment design process, especially when designing a fashion garment versus a functional garment. This section discusses the stages of garment design for a functional garment.

2.6.1 Stages of a Garment Design

The main phases of garment design, as discussed by Koberg & Bagnall (1978) includes: accepting the problem, analyzing the problem, defining the problem, ideation, selection, implementation, evaluation (Watkins, 1998).

Accepting, analyzing and defining the problem is the problem identification stage (Lamb & Kallal, 1992). This is the stage where the designer would identify a problem in general terms, such as clothing for an agricultural worker applying pesticides (Watkins, 1984). During this stage, the design situation identified is thoroughly explored. Steps in exploring and defining the situation includes defining the target market, developing a profile of the user, conducting ergonomic studies, determining faults in existing designs, interviewing people to understand the issues, and reviewing the literature. (Watkins, 1984; Lamb & Kallal, 1992).

The ideation stage is where the preliminary ideas are generated for finding a solution to the problem being addressed. The purpose of this is to identify as many different solutions as possible while understanding the user requirements (Watkins, 1984; Lamb & Kallal, 1992; Gupta, 2011). Brainstorming with others can be helpful in identifying possible clothing design solutions. In this stage, it is important to assess both the physical and social-physiological preferences. It is also important to determine potential materials choices that would be appropriate for the function or end use identified (Gupta, 2011). Technical textile materials are the primary building blocks of functional clothing, so it is important to explore potential material solutions with physical properties that can provide the functions required for the end use (Gupta, 2011). A requirement that is common to all functional clothing is includes the material specification should fit the end use of the garment (Gupta, 2011). Materials, along with garment design options, are narrowed down in the selection stage (Lamb & Kallal, 1992).

The selection stage is where the ideas generated in the ideation stage are refined (Lamb & Kallal, 1992; Watkins, 1984). During this stage, it is important to narrow down critical factors constituting the problem to address, including the physical and social-physiological specifications (Watkins, 1984). Lamb and Kallal's (1992) apparel design model explain how to design a functional garment with physical and social physiological preferences by breaking it up into three criteria the designer should consider: functional, expressive, and aesthetic (FEA). These criteria should be considered based on the end use and consumer needs.

The functional considerations for an apparel product are related to its utility (Lamb & Kallal, 1992). This includes functional properties such as thermal comfort, fit, and ease of movement (Lamb & Kallal, 1992). The situation that the garment will be used in will determine the specific functional demands to be included in the garment (Lamb & Kallal, 1992).

Expressive considerations relate to the communicative symbolic aspects of the garment (Lamb & Kallal, 1992). Research has shown that the way a person dresses communicates a variety of messages about the wearer; therefore, apparel consumers often seek garments that convey messages about themselves (Lamb & Kallal, 1992). Many times, in cases where uniforms are required, people desire a visual statement of their individuality as well as the feeling of belonging to a community (Lamb & Kallal, 1992).

Aesthetic considerations are human desires for beauty (Lamb & Kallal, 1992). This aspect relates to elements such as color, line, form, pattern, and other elements that come together to create a design that is pleasing to the eye (Lamb & Kallal, 1992). For a fashion garment, aesthetic is typically the primary importance, however, it is secondary in terms of importance for functional garments (Gupta, 2011).

Once functional, expressive, and aesthetic criteria have been considered, and the ideas that hold the most promise have been chosen, the designer can move to the implementation stage. During the implementation stage, the designer attempts the ideas that address the garment end use in the best way (Lamb & Kallal, 1992). This entails creating prototypes, running tests to determine if the fabric, any finishes, and garment construction are specified correctly for the intended end use (Watkins, 1984; Lamb & Kallal, 1992; Gupta, 2011). Tests should be run at a lab level and on human subjects (Watkins, 1984). Once results are collected from running tests and observations are made, the designer moves into the evaluation stage.

The evaluation stage allows the designer to analyze the test results (Lamb & Kallal, 1992). This will allow designers to understand if the garment is a proper fit for the end use or if they need to return to the ideation stage and adjust their design or brainstorm new ideas (Lamb & Kallal, 1992).

2.6.2 Designing a Chemical Protective Suit (CPS)

When designing a functional and protective garment, it is important to understand the needs of the target market and the end use of the garment, but also the classifications for the specific end use. Since this research aims to create a garment that protects from chemical pesticide exposure, it is important to review the numerous levels and types of chemical protective clothing systems that have been developed.

Protective clothing is designed with the intention to protect the wearer from environmental effects that can result in injuries or death (Adanur, 1995). When designing chemical protective clothing it is important to consider the amount of chemical permeation, breakthrough time for penetration and physical properties of the chemical protective clothing in specific chemical conditions (Carrol, 2001). Fiber, fabric type, fabric finishes, coatings and lamination are factors that can have a major influence on the level of protection (Khalil, 2015). There is not one chemical protective clothing that can protect against all levels of chemical risk due to different exposure scenarios, the chemical properties, the different types of barriers and other aspects (Van Wely, 2017).

The EPA classifies protective clothing based on the level of protection (EPA, 2017). There are four levels of chemical protective clothing from highest protection to lowest protection: A, B, C, and D (EPA, 2017). Level A is a full ensemble that is fully encapsulating with a self-contained breathing apparatus and should be worn when the highest level of protection for skin, eyes, and inhalation is required (EPA, 2017). Level B are either suits that are fully encapsulating or are only partially protective and can be worn with or without a self-contained breathing apparatus (EPA, 2017). An example of level B suits includes splash protection suits. Level C suits provides an adequate measure of protection against moderate splashes and are not required to be worn with a breathing apparatus but can be if needed (EPA, 2017). Level D chemical protective suits offer the lowest amount of protection (EPA, 2017). Suits in this level are not specialized suits as they are just ordinary industry-specific protective gear (EPA, 2017). Examples of Level D suits include boiler suits and face masks.

Various types of garment design systems exist with different constructions to protect the user. Garment types include one-piece garments, two-piece garments, over garments, undergarments, multi-layer garments, and closures and interfaces (EPA, 2017).

One-piece garments allow for quick donning and doffing (EPA, 2017). It eliminates the penetration of the hazardous substance through the opening between two-piece garments, such as trousers and pants, and has a simplified sewing process (EPA, 2017). Unfortunately, with a one-piece garment, there is no option to open a jacket or pants for a quick release of heat (EPA, 2017). The entire garment must also be replaced when it becomes defective and loses it protection (EPA, 2017).

Two-piece garments allow greater flexibility in fitting users with different dimensions and allow for exchange of torn or defective jacket or pants; it also allows for donning and doffing for quick release of heat stress (EPA, 2017). However, two-piece garments require more sewing and stitching when joining the pieces of the garments together and requires a closure system to seal the opening between the jacket and pants (EPA, 2017).

Under garments include underwear and other liner fabrics (EPA, 2017). They provide protection from the inside and are best used in situations where the concealment of the protective clothing is required (EPA, 2017). Multi-layer garments are the most popular. They are made for a specific mission of different environments and the various layers can be removed or added on for various protection levels (EPA, 2017). Multi-layer garments provide options for quick release of heat or stress, but the user should be conscious of adding more layers to prevent heat stress injuries (EPA, 2017).

Closures and interfaces on these garments are very important because protection is a function of fabric, activity level, motions of the user, as well as closures and interfaces (EPA, 2017). Closures and interfaces are especially important between the gloves, jackets, trousers, boots, masks, etc., keeping chemicals from getting through any openings (EPA, 2017).

2.6.2.2 Conclusion

This study focuses on developing a two-piece ensemble to protect migrant farmworkers from pesticide exposure on tobacco farms. The garment in development falls under Level C protection as its objective is to protect the migrant farmworkers' skin from coming in contact with chemical pesticides, particularly flumetralin. As farmworkers apply the chemical pesticide, splattering can occur, and the chemicals can become airborne if there is any breeze. During harvesting, pesticide residue rubs off onto the workers as they handle leaves.

2.7 Selection of Fabrics for Personal Protective Equipment

As mentioned in previous sections, fabric selection for a functional garment with chemical protective properties is important. There are many different types of fabrics that would be suitable for use in a protective garment, however, to meet the sustainability needs, this research focuses on the use of a natural fiber that has biodegradable capabilities, high durability and moisture wicking properties. The fiber selected for the garment was hemp.

2.7.1 Hemp Fabric

Similar to linen, hemp is a bast fiber (Kramer, 2017). Hemp's microstructure is filled with holes and notches, which gives it its properties (Stanhope, 2011). Its porous nature allows it to be very breathable and moisture wicking. The pores that allow air flow also hinder the growth of the bacteria, making hemp naturally antimicrobial. The surface area of hemp compared to other natural fibers such as flax and cotton is greater and more absorbent (Stanhope, 2011). Hemp can absorb up to 20% of its weight which allows it to have better dye intake and color retention (Weiner, Kovacic, Dejlova, 2003). Hemp has a hollow core which allows it to have excellent insulating properties for thermal comfort. Its insulation is superior to that of cotton and linen, which allows wearers to be cooler in warmer weather and warmer in cooler weather (Stanhope, 2011). Like linen, hemp can be rough to touch; however, over the course of time and use, it becomes softer while staying durable (Stanhope, 2011).

Hemp is a highly sustainable crop to grow (Stanhope, 2011). Compared to cotton, hemp is a far more productive crop to grow on a per acre basis and can be grown in all climate types. Hemp has a deep root structure which does not deplete the soil of nutrients, but rather it helps aerate the soil which improves soil fertility and structure. Hemp overall requires less water, and little to no pesticides. It helps absorb the pollutants in the soil, such as heavy metals, to keep it out of water run-off. Just like cotton the entire crop can be used. Hemp reaches maturation much more quickly than cotton and flax. There are many varieties of the hemp plant including a northern and southern type. Northern type hemp is better in cultivation and gives a higher yield. Southern type hemp has more branches and is a taller plant. This means that it has longer fibers suitable for fiber creation and higher fabric yield (Stanhope, 2011).

Hemp gained popularity in the 1920s, particularly in Europe, and has continued to be more prevalent in Europe compared to the US. Traditionally, it has been used as a raw material for industrial end uses due to its high strength (Stanhope, 2011). Examples of end uses include rope, twine, and bags. During World War II, hemp fibers were used for uniforms for its antibacterial and durable properties. Today, hemp is not as highly used as it is illegal to grow in many areas due to its negative associations with marijuana use; however, hemp seeds have no way of being used as a recreational drug (Stanhope, 2011).

2.8 Material Testing

When selecting a final material for a functional garment, it is important to evaluate the materials durability, or level of strength, in order to determine if it is a suitable fabric for the rigorous conditions that it will go through when worn. Testing should be done in a lab setting and on human subjects. This section discusses the different physical testing methods suitable to determine the strength, abrasion resistance, breathability and dimensional stability of a material in a lab setting. It should be noted that each test follows ASTM standards, which are discussed in Chapter 3.

2.8.1 Tear Strength

Tearing is the most common type of strength failure in fabric use (Saville, 1999). Since fabrics are exposed to rough handling and use in industrial settings such as farming or outdoor sports, it is important for these fabrics to have higher tear strengths. Tear strength is typically measured through the force required to propagate an existing tear and not the force that is required to initiate the tear because initiating a tear usually requires the cutting of threads (Saville, 1999).

There are various tear tests to determine the tear strength, however, the most simple and common test to use is the tongue tear test (Saville, 1999). Based on the ASTM D2261 standard, fabric samples are cut to a specific size in the warp and weft directions and a slit is cut into the fabric to begin the tear. The two tails created from the slit are then placed into the testing apparatus and pulled in opposite directions by the tensile tester. Results are recorded through the tensile tester program. There are three ways to express the results: average of the five highest peaks, median peak height, and average force by used of an integrator. The results given are the tearing strength of the filling yarns or warps yarns based on the direction of the fabric placed into the apparatus (Saville, 1999).

2.8.2 Tensile Strength

Tensile strength is the resistance of a material breaking under tension (Saville, 1999). The level of strength that is required from a yarn or a fabric will depend on the intended end use. The tensile strength of a fabric allows researchers to determine the maximum amount of tensile force it takes to rupture the fabric by extending the test piece to its breaking point (Saville, 1999).

There are three ways of carrying out tensile tests depending on the type of testing instrument available, however, this discussion focuses on Constant Rate of Extension (CRE). CRE testing instruments use a rate of increase of specimen length that is uniform with time and a load measuring mechanism that moves a small, but insignificant, distance with increasing load (Saville, 1999). This influences the measured breaking load and extension of the material. For woven fabrics, common tensile strength tests used are the grab test (ASTM D5034-09) and the strip test. These tests are acceptable for wovens and nonwovens, however, they are not acceptable tests for knits as knit fabrics have high levels of stretch. Due to this fact, the burst strength test (ASTM D6797-15) is an alternative method of measuring strength as it stresses the material in all directions at the same time (Saville, 1999).

2.8.3 Dimensional Stability

Dimensional stability can help researchers evaluate the effect that laundering can have on it in terms of shrinkage (Saville, 1999). There are no specific test methods for dimensional stability, however, the many tests that exist follow very similar lines that are differentiated by the treatment given to the fabric. Saville (1999), suggests that a sample size 500mm by 500mm is considered a sufficient sample size tested for dimensional stability. A benchmark square should be marked in the center of the fabric measuring approximately 350mm by 350mm. The edge of the fabric should be finished on three sides of the fabric with an overlock stitch and placed into the washing machine with the researcher's choice of washing machine settings and detergent. The drying process is also determined by the researcher based on the end use. Once the fabric is dried, the fabric should be measured and the percent change, or percent shrinkage, should be calculated (Saville, 1999). AATCC TM96 is typically used as the standard in the United States.

2.8.4 Abrasion Resistance

Abrasion resistance tests allow researchers to understand the effects of abrasion on the fabric samples. There has been poor correlation found between different abrasion testers and wear tests. Therefore, it is recommended that wear tests be carried for true abrasion results (Saville, 1999). Abrasion lab tests can only imitate wear conditions, and not replicate the conditions. While abrasion tests carried out in the lab cannot give an exact measurement of abrasion resistance on a material for a specific end use, abrasion lab tests can be carried out to rate various fabrics under specific objectives in a controlled setting. Lab tests are also much more rapid as most tests can be completed in a day and can be reproduced if necessary (Saville, 1999).

There are two approaches that have been used to assess the effects of abrasion. This includes abrading the sample until it reaches a predetermined endpoint, such as a hole. Or, abrading the sample for a set number of fabrics and assessing an asset of a fabric such as change in mass, change in fabric appearance, thickness, or other relevant properties. The Martindale Abrasion test (ASTM D737-16) is one of the most common abrasion tests used. This test is designed to give a controlled amount of abrasion between a fabric in continuously changing directions. Pressure put on the fabric as it is being abraded is low. Abrasion can be assessed in two ways: measuring in intervals or assessing the average rate of loss in mass. When measuring in intervals, the fabric should be observed at about every 1000 cycles up to 5000 cycles, or to desired set amount of cycles (Saville, 1999).

2.8.5 Air Permeability

Measuring the fabric permeability to air involves measuring the rate of diffusion, or flow of air, through a fabric (Waters, 1959). There have been several instruments designed to evaluate the airflow of fabric. Two methods are generally used to measure air permeability of a fabric: Frazier Air Permeator and Gurley Densometer (Waters, 1959). This section will discuss the Frazier Air Permeator.

The Frazier Air Permeator forces the air through the fabric sample at a constant pressure to measure the rate of the air flow passing through the fabric (Waters, 1959). The method uses a suction fan to draw air through the sample of fabric clamped over a circular orifice. The speed of the air can be adjusted to various speeds. There are several orifice sizes; depending on how porous the fabric is will determine the size of the orifice (Waters, 1959). There are two manometers located on the test apparatus. The first manometer measures the pressure drop across the fabric and the second measures the pressure-drop of the calibrated orifice (Waters, 1959). To run the test, the fan is started, and speed is increased until the specified pressure drop is reached on the first manometer; this is typically 0.5 inches of water. The orifice manometer, the second manometer, is then read and the number is converted to the flow of air in cubic feet per minute square foot of fabric at the stated pressure drop through the calibration chart. Ten measurements of different areas of each sample are taken. Test results of various fabrics can be compared for their air permeability levels (Waters, 1959).

2.8.6 Conclusion

Conducting physical tests are an important step when developing a garment, particularly a functional garment. The methods explored in this section allows the researcher to understand the various physical tests used in industry to determine the performance of the fabric. The tear strength, air permeability, tensile strength, abrasion resistance and dimensional stability tests are commonly carried out when analyzing the physical properties of a fabric for a functional garment. It is important to understand the appropriate fabric type and expected outcome when choosing the correct physical test for research. The researcher should perform the physical tests based on the industry standards and guidelines for each test type. By following the standards, it ensures consistency and minimal variability in the results. Through conducting the tests explored in section 2.8, the researcher can understand the following properties of a fabric: amount of force it requires to tear a fabric, the amount of stress and weight the fabric can handle before experiencing fiber breakage, the breathability of the fabric, the abrasion resistance of the fabric, and the ability to withstand physical change when laundered.

2.9 Focus Group

In addition to the quantitative methods mentioned in section 2.8, a qualitative procedure will be carried out to answer research question 2 which consists of holding a focus group. Literature discussing focus group methods will be reviewed in this section to understand how to design and conduct a focus group, as well as how to interpret the qualitative data.

Qualitative interviews can involve researchers conducting face to face interviews with participants, holding telephone interviews, or engaging in focus group interviews with six to eight interviewees. There are advantages and disadvantages to conducting interviews. Interviews are useful when participants cannot be directly observed. They have the advantage of allowing participants to provide historical information and they allow researchers to control the line of questioning. On the contrary, interviews provide indirect information filtered through views of interviewees. They provide information in a designated place rather than a natural field setting where the researchers' presence may create bias responses, and not all participants in an interview are equally articulate and perceptive. It is important that the researcher of the focus group study must be aware of their own bias they may have based on past experiences before beginning. There are four ways to collect qualitative data: observations, interviews, documents, and audiovisual and digital materials. This section will focus on interviews as a focus group will be conducted as part of the research methods.

Focus groups are a type of qualitative interview which involve unstructured and generally open ended questions. Questions discussed during a focus group are typically few in number and are intended to elicit views and opinions from the participants. To hold a focus group, or any qualitative interview, the researcher should develop an interview protocol for asking questions which is typically two pages in length. Researchers will typically record information from the interview by making hand-written notes, audiotaping, or videotaping. It is important that researchers take notes during the interview in case the equipment fails if they are recording. If audiotaping is used, researchers should plan ahead for the transcription. The total number of questions should stay between five and ten. It is suggested to memorize all the questions, so the researcher does not appear to be reading off the paper. Once the interview is held and data is recorded, the data will need to be analyzed.

Five steps are involved in the data analysis process. Step one includes organizing and preparing the data for analysis through transcribing. The second step involves reading the data to gain a sense, or general idea, of the information. Once general thoughts are made, the data should be coded. Coding data is the process of organizing the data by bracketing chunks and writing a word representing the category. The codes should then be processed into themes for analysis. Themes can then be interpreted to summarize overall findings (Creswell & Creswell, 2018).

CHAPTER 3

METHODOLOGY

3.1 Introduction

The purpose of this thesis research was to continue development of a protective “suit” for tobacco farmworkers against pesticide exposure, specifically flumetralin. This chapter will explain the design of the study, which addresses the testing of the fabric with the protective chemical and pesticide, and the voice of consumer component, following an explanation of work that has previously been carried out on the suit.

3.1.1 Previous Work on the Protective Suit

The original *Protégete* protective garment was conceptualized, designed and developed by an undergraduate Fashion and Textile Design student from the Wilson College of Textiles, with another undergraduate student in Textile Technology assisting with the chemical finish research. These student researchers designed and developed prototype garments and determined the most effective chemical finish, however, they had not yet carried out physical testing on the fabric.

Through their initial research, the researchers chose to focus on the pesticide flumetralin as it was determined to be one of the most commonly used chemicals for tobacco sucker control in the industry (Maurice, 2018; Nguyen, 2018). Flumetralin is labeled to have a low toxicity level, however, when workers are continuously exposed to the pesticide in large amounts it can have toxic side effects on the farmworkers’ health. To protect farmworkers from the flumetralin pesticide, a Poly(acrylic acid) (PAA) protective finish was selected since its chemical structure allows for the flumetralin to chemically bond to the PAA. The chemical structure of flumetralin includes a nitro group that has a positive nitrogen atom that is strong enough to bond with PAA. The PAA contains a carboxyl group in its chemical structure which bonds with the nitro group in the flumetralin. The bonding of the two structures allows for the adsorption of the pesticide on the PAA treated hemp fabric (Nguyen, 2018). The testing of the PAA's effectiveness, in initial research, was done on woven cotton fabric rather than woven hemp fabric due to the limitation of the final material being available. Cotton was selected as a cellulosic substitute for the planned hemp (Nguyen, 2018).

The initial design was created with the objective of protecting migrant farmworkers from pesticides while minimizing the risk of heat. Through a video analysis conducted by the previous researcher to determine workers' movements, functional values and symbolic values were prioritized. The video analysis involved watching videos of workers in the field and tobacco worker safety videos to determine exact movements involved in topping (Maurice, 2018). Functional garments are designed with the users' needs in mind (Lamb & Kallal, 1992). The below functional properties were determined most crucial:

- Under arm gusset to allow for more flexible movement (shaded in figure 4)
- Snap closures for easy removal (Figure 6 and 8)
- A high neck collar to reduce exposure of skin around the neck (Figure 7)
- Close-fitting cuffs to keep sleeves from moving while working and keeping skin around the wrists from being exposed to pesticides (Figure 6)
- A placket and extended zipper cover over the jacket zipper and pant closure as an extra barrier to prevent pesticides from penetrating the fastening system. (Figure 8)

These functional properties were determined to be the most important based on the movements that migrant tobacco farmworkers make while carrying out the topping process (Maurice, 2018).

A garment's symbolic values relate to the communicative and expressive aspects of the garment. Previous research has shown that the way a person dresses communicates a variety of messages about the wearer. The symbolic values are typically determined based on the users' culture, therefore, not everyone seeks apparel protection from the same environmental elements (Lamb & Kallal, 1992). Through exploring secondary data about farmworker culture, previous researchers derived symbolic values and properties to incorporate into the design of the garment. This protective suit was designed with the following symbolic values:

- Self esteem
- Respectability
- Group Membership

Symbolic properties included in the design of the suit include:

- A resemblance to standard clothing
- The ability for the wearer to understand how the garments should be worn for optimal protection
- Aesthetic appeal that gives the wearer pride (Maurice, 2018)

The previous researchers also constructed a prototype of the two parts of the suit – an upper body and a lower body garment. Figure 4 shows a technical flat front and back view of the prototype. The final prototype of the garment is pictured in Figure 5. Detailed photos of the suit are shown in Figure 6, Figure 7 and Figure 8.

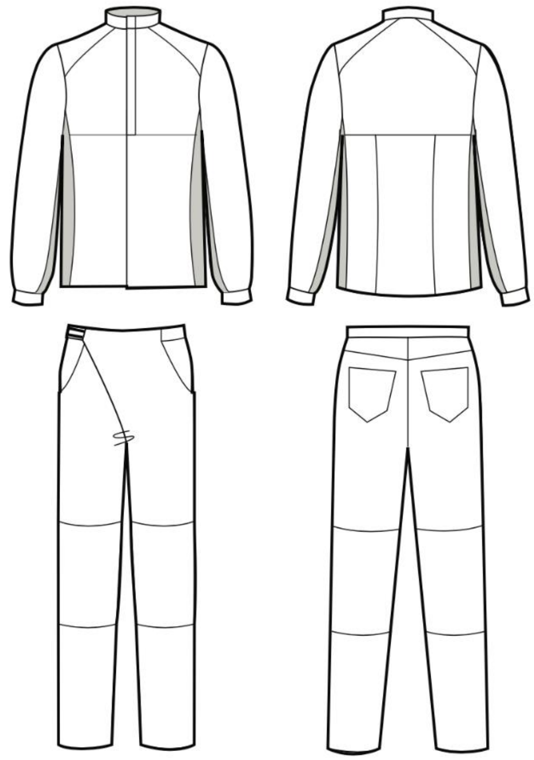

Figure 4. Technical Flat of the Protégete Garment (Maurice, 2018)

Figure 5. Front and Back View of Final Garment Prototype (Maurice, 2018)

Figure 6. Detail of Prototype Cuff (Maurice, 2018)

Figure 7. Detail of Prototype Placket & High Neck Collar (Maurice, 2018)

Figure 8. Detail of Prototype Pant Closure & Covering (Maurice, 2018)

3.1.2 Research Design of Current Study

To continue the work of prior research (Maurice, 2018; Nguyen, 2018), two main research questions were determined for this study, with the first questions divided into two parts:

RQ1: What is the effectiveness of the combination of 100% hemp woven material and a Poly(acrylic acid) finish on garments in protecting migrant farmworkers from pesticide exposure?

RQ1A: What is the effectiveness of the adsorption of the pesticide flumetralin by the PAA?

RQ1B: What is the durability of the PAA finished hemp?

RQ2: What is the tobacco growers' acceptance, or value perception, of the garment design?

In order to address each question, both quantitative (RQ1) and qualitative (RQ2) approaches were taken. The quantitative approach consisted of conducting physical lab tests with the PAA treated hemp woven fabric to determine the PAA's effectiveness and to test the durability of the treated hemp fabric. The hemp woven fabric was treated with Poly(acrylic acid) using a pad-dry-cure method with settings the previous researchers had found to be successful.

RQ1 was supported by conducting assays using the Beer-Lambert law and running physical tests on the fabrics. Fabrics that were tested are listed in table 2 below:

Table 2. Descriptions of Fabrics Used in this Research

Fabric Name	**Fiber Content**	**Fabric Weight (oz/yd^2)**	**Thread Count (picks per inch) (warp x weft)**	**Fabric Structure**	**Origin of Fabric**
hemp woven	100% hemp	7.0	30 x 30	Plain weave	Dharma Trading Co.
cotton woven	100% cotton	3.8	80 x 111	Plain weave	Recycled shirting fabric
cotton jersey	100% cotton	4.8	46 x 32	Jersey knit	Hanesbrand T-shirt purchased from Wal-mart
Tyvek	100% high density polyethylene	1.2	N/A	Nonwoven	Tyvek coverall suit purchased from Home Depot

The hemp woven fabric used in this research was determined by previous researchers as a suitable fabric to be used for the protective suit (Maurice, 2018; Nguyen, 2018). The cotton woven, cotton jersey, and Tyvek were fabrics chosen based on what migrant tobacco farmworkers typically wear on the field. The purpose of testing these fabrics is to test how the performance of typical fabrics worn on the field compare to the performance of the hemp fabric chosen for the development of the protective suit under physical testing.

The qualitative approach, to explore RQ2, consisted of holding a focus group to determine initial tobacco grower perceptions of the garment and its features to determine part of the consumers’ perception of the product. Figure 9 outlines the framework of methodology to answer RQ1 and RQ2 of this research. Each method is described in detail in the following sections.

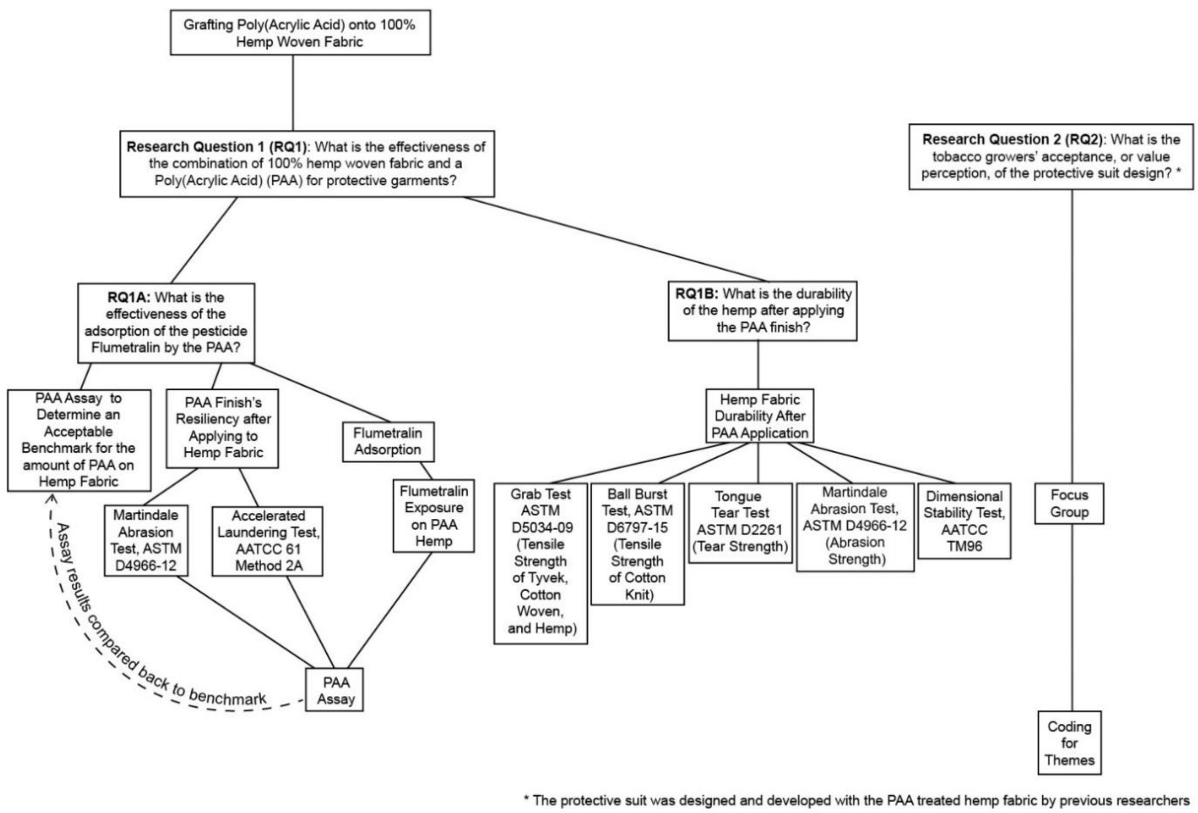

Figure 9. Development of Pesticide Protective Clothing for Migrant Tobacco Farmworkers Methodological Framework Diagram

3.2 Research Question 1 (RQ1)

3.2.1 Grafting Poly(acrylic acid) onto 100% Hemp Woven Fabric

Previous research had determined that PAA was an effective finish to combat the effects of flumetralin, however, testing had been carried out on cotton (Maurice, 2018; Nguyen, 2018). To prepare for the testing the efficacy of PAA against flumetralin on hemp fabric, the hemp woven fabric was treated with a Poly(acrylic acid) finish using a pad-dry-cure method. The pad-dry-cure process settings were predetermined by the previous researchers (Maurice, 2018; Nguyen, 2018). Optimal drying temperature and curing time had been determined to successfully set the finish on hemp without altering the hand and the color of the fabric. Details of this process is explained in the following section.

3.2.1.1 Creating the PAA Solution Based on Fabric Weight

A PAA solution for application was created based on fabric weight (g/L). Six yards of 100% hemp summercloth, which was selected due to previous research, were ordered from Dharma Trading Co. with a total weight of 1.9kg. The process of creating a solution based on fabric weight requires determining the percent wet pick up (%WPU) of the hemp. Wet pick up is the amount of liquid absorbed by a fabric.

To determine the %WPU, the fabric needed to be weighed before (1.9kg) and after padding (3.42kg) at 1 bar pressure, equivalent to atmospheric pressure. The following formula was used to determine % WPU:

$$\%WPU = \left[\frac{\text{weight of wet fabric - weight of dry fabric}}{\text{weight of dry fabric}}\right] \times 100$$

$$\%WPU = \left[\frac{3.249\text{kg} - 1.9\text{kg}}{1.9\text{kg}}\right] \times 100$$

$$\%WPU = \left[\frac{1.349\text{kg}}{1.9\text{kg}}\right] \times 100$$

$$\%WPU = 71\%$$

The %WPU was used to determine the amount of PAA needed for even distribution throughout the fabric. Based on the WPU of the hemp (71%), the amount of PAA needed to create a 2L solution was calculated. In the previous research, 0.1% PAA was grafted onto cotton. Therefore, to graft 0.1% PAA on 1.9kg of hemp fabric means that 1.9g [(0.1% x 1.9kg) x

(1000g/1kg)] of PAA needs to be added onto the hemp. At 71% WPU, that means that 1.35L of solution will deposit on hemp [1.9kg x 0.71 = 1.35L solution]. To calculate the amount of PAA needed to Liters of solution, 1.9g PAA was divided by 1.35L of solution. This meant that 1.41g of PAA was needed per Liter of solution. To create a two liter solution, 1.41g PAA/L was doubled, meaning that 2.82g PAA/ 2L solution was needed. Therefore, 2.82g of PAA soluble was mixed with 2L of H_2O to create the padding solution.

3.2.1.2 Grafting Poly(acrylic acid) onto 100% Hemp Woven Fabric

The solution was grafted onto the fabric using a pad-dry-cure process. The 2L of PAA solution, described in section 3.2.1, was poured into the padding machine and padded onto the fabric at 1 bar pressure. As the fabric was fed through the padder, it continuously conveyed into the dryer. Optimal drying time for the fabric was 1 minute at 150 ℃. After drying, the fabric was cured at 185 ℃ with a duration of one minute. These settings were based on previous research that found this to be the most effective without changing the hand and color of the fabric.
Once the fabric was cured, it was rolled onto a cardboard roll and prepared for testing (see Figure 10).

Figure 10. Pad-Dry-Cure Process of PAA onto Hemp

3.2.2 Quantitative Assays

Quantitative assays were conducted on hemp samples to analyze the effectiveness of PAA in adsorbing the flumetralin and the resiliency of the PAA finish on hemp. The four assays analyzed:

1. The total concentration of PAA that was grafted onto finished hemp samples.
2. The amount of flumetralin adsorbed by the PAA.
3. The amount of PAA remaining after being tested to determine the finish's resiliency through a variety of treatments.
4. The amount of PAA remaining after accelerated laundering to determine the finish's resiliency.

The Beer-Lambert Law was used in the quantitative assays to measure the amount of PAA on each sample. This law states that there is a linear relationship between light absorbency and concentration of an absorbing species. Therefore, as concentration increases, light absorbency should increase at the same rate. The relationship between chemical concentration and light absorbency of any solution can be used to determine the concentration of a soluble in that solution using the spectrophotometer. While the concentration of a soluble in solution can be calculated through the Beer-Lambert Law equation, it must be noted that solutions with high concentrations are not valid through this law (Helmenstine, 2019). This is because once the light absorbency is greater than 1, deviations begin to occur, and readings are typically no longer linearly accurate (Helmenstine, 2019). A calibration curve was created to validate that the TBO dye concentrations followed the Beer-Lambert Law. This is described in detail in Appendix A.

Toluidine Blue O (TBO) solution was used in the assays to represent the concentration of PAA, or its -COOH chemical structure, that was grafted onto the fabric. This relationship, between the TBO dye and PAA's -COOH group, is assuming that the molar ratio of TBO to the -COOH groups of PAA is 1:1. This method was based on assay methods conducted by previous researchers (Nguyen, 2018). In order to determine the amount of TBO dye needed to dye each sample, the amount of PAA that was grafted onto each fabric was determined first. Each fabric sample, from the set of four samples, was weighed and the average weight was calculated. Because the hemp was finished with 0.1% PAA, that meant that the amount of PAA that was grafted onto the hemp should be 0.1% of its weight. The amount of PAA based on the average weight of the hemp sample was calculated though multiplying the average weight of the hemp samples (0.2769g) by 0.1% of PAA on hemp. Therefore, (0.1%/100) x 0.2679g = 0.0002769g of PAA present on the hemp sample.

There are multiple -COOH groups on a PAA, which is made of multiple acrylic acid monomer structures. The amount of -COOH groups present on each sample was needed to be determined to calculate how much TBO dye was needed to dye each sample. The molar mass of acrylic acid (72.06 g/mol) was needed to calculate how many -COOH groups were present. The average weight of the samples was then divided by the molar mass of acrylic acid to as shown in the calculations below. It should be noted that the average weight of the sample was rounded up to 0.0003g in this calculation.

Molar Mass (n) of Acrylic Acid: 72.06 g/mol

$$n = (m(mass)) / (M(g/mol))$$

$$= (0.0003g) / (72.06g/mol)$$

$$= 0.00000416 \text{ mol or } 4.16x10^{-6} \text{ mol}$$

This tells the researcher that there are approximately $4.16x10^{-6}$ mol of -COOH groups present on the fabric. Because this research works under the assumption that there is a 1:1 reaction between the TBO dye and the -COOH groups of PAA, it can be assumed that 0.001273g of dye is needed to dye 100% of a PAA treated hemp sample for the assay. This number was calculated through multiplying the molar mass of Acrylic Acid to the molecular weight of TBO dye, which is 305.83 g/mol. For precaution, 20% more of dye was added to the amount of dye in the test tube. Therefore, 0.001528g of dye was needed to be added to a test tube to dye one sample.

3.2.3 Creating the stock solution for Assay Procedure

A 1L stock solution of 50/50% volume acetic acid and Di water was created to dye the samples for the assay procedures discussed below. The 1L stock solution contained 0.5g of TBO dye. Calculations were made to determine how much TBO dye, with an excess of 20% of dye, was needed to dye each sample. The excess of dye was added as a precautionary measure in case there was not enough dye in the dye bath. Once the stock solution was created, the proper amount of dye was pipetted from the stock solution into the test tube for the assay.

3.2.4 Poly(acrylic acid) Assay Procedure

The assay procedure was run on a set of four PAA hemp treated samples to determine an average amount of PAA that was grafted onto the hemp material through dyeing the samples with TBO dye. The four samples used for this PAA assay were cut from the six yards of PAA treated hemp fabric. Each sample measured 1in by 2in, or 2.54cm by 5.08cm. The average amount of PAA was taken from the assay and used as a benchmark to compare the sample sets that were assayed after undergoing physical testing.

After adding in the proper amount of dye into the test tube (0.001528g), as calculated in section 3.2.2, the test tube was filled the rest of the way with 20mL of pH10 Di water. The fabric samples were then placed into each test tube as pictured in Figure 11.

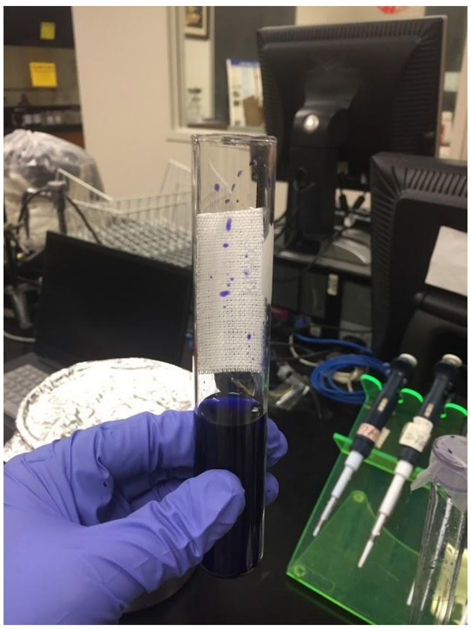

Figure 11. Placing PAA Finished Hemp Samples into Test Tube to be Dyed

After placing the fabric into the dye solution, the test tubes were sealed with paraffin wax and placed onto the vortex. Each sample was held on the vortex at a medium-high speed (Figure 12) in 2-minute increments up to 8 minutes or until the solution color was no longer changing (Figure 13).

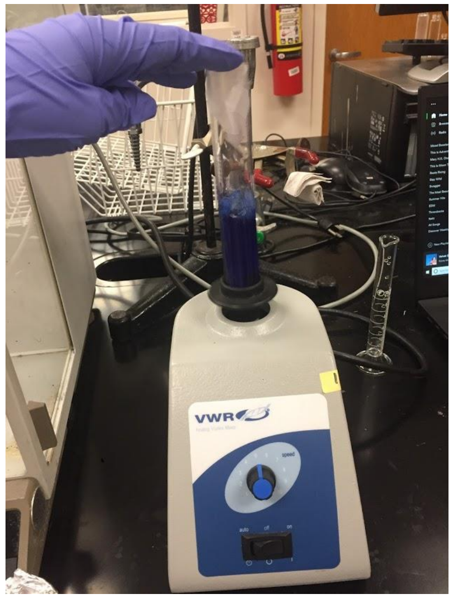

Figure 12. Test Tube Placed on Vortex to Shake the Solution

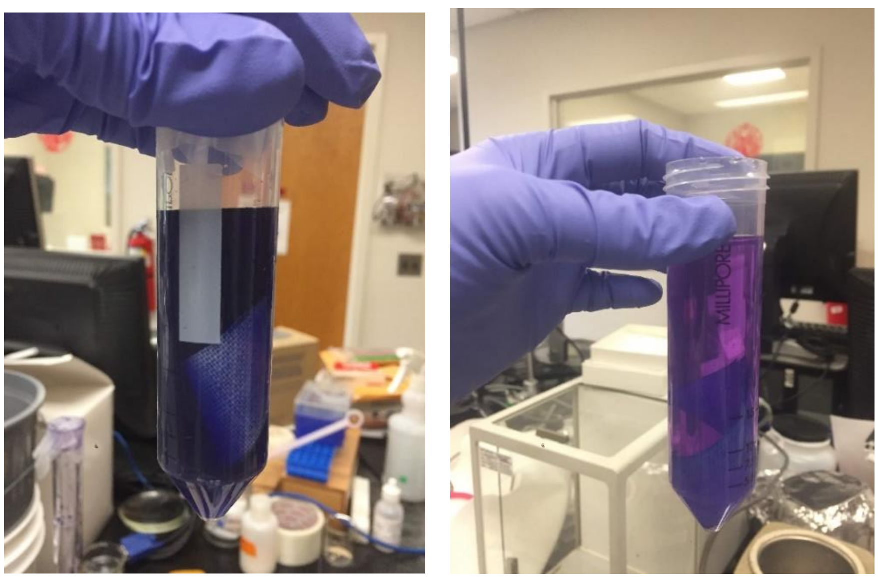

Figure 13. Dyeing of PAA Finished Hemp Samples Before and After Placed on the Vortex

After dyeing the samples, each sample was thoroughly rinsed with pH 10 Di water until there was no more excess dye being visibly washed off. The samples were set to dry overnight and then extracted.

Extraction required the dyed PAA finished hemp to be placed into a test tube filled with 30mL of 50/50% volume acetic acid and Di water (Figure 14). The test tubes containing the samples were then placed onto the vortex to allow the acetic acid to pull the TBO dye molecules away from the PAA molecules. The samples were placed on the vortex on a medium-high speed in increments of 2 minutes for a total of 12 minutes each, or until the solution no longer changed color.

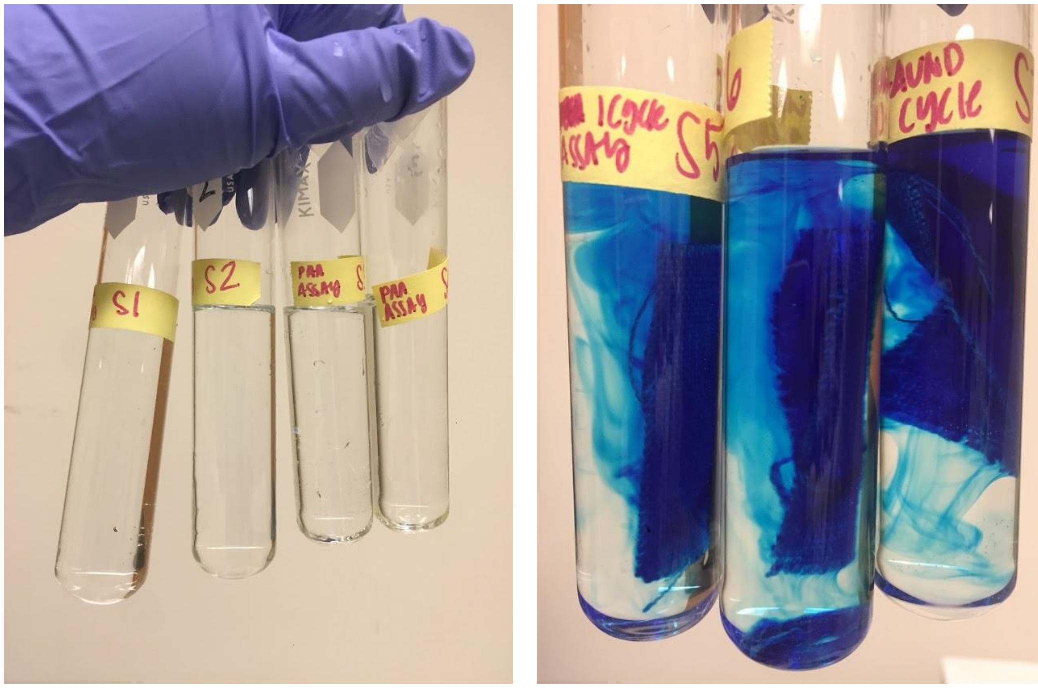

Figure 14. Removing TBO Dye With 50/50% Volume Acetic Acid and Di Water Solution

The fabric sample was then removed and the solution in the test tube was diluted. Each extraction concentration was diluted 3:1 in order to make the concentrations lighter, thereby keeping the absorbency level closer to being below 1. This is crucial as absorbencies that are read at an absorbency level higher than 1, the readings are not considered as accurate due to higher possibilities of there being variation in the data. Once each solution was diluted, the solution concentrations were read on the UV-Vis Spectrophotometer

3.2.5 Flumetralin Assay Procedure

Four samples of PAA treated hemp were exposed to flumetralin. The expectation was that flumetralin would be adsorbed by the PAA and consequently the TBO dye would show how many PAA sites did not adsorb flumetralin. The exposed samples were assayed to determine the amount of PAA sites with which the TBO dye reacted post flumetralin adsorption. This assay works under the assumption that any decrease in the TBO dye concentration observed is due to the adsorption of flumetralin. If the flumetralin molecules have been adsorbed by the PAA molecules, then the TBO dye molecules would only react with the remaining PAA molecules; therefore, a decrease in TBO dye should be observed. The decrease was determined by comparing the difference between the TBO concentration extracted to the benchmark sample concentration.

In order to expose the samples to the flumetralin, a 500mL solution of 1% flumetralin was mixed using 495mL if water and 5mL of flumetralin Prime + EC from Syngenta. The solution was prepared in a 1L Zep Professional Spray Bottle. The weight of the PAA treated hemp samples was weighed before and after spray. The samples were sprayed with two full sprays under a fume hood. Once the samples were completely dried (Figure 15), the weights of the pesticide exposed fabric samples were recorded.

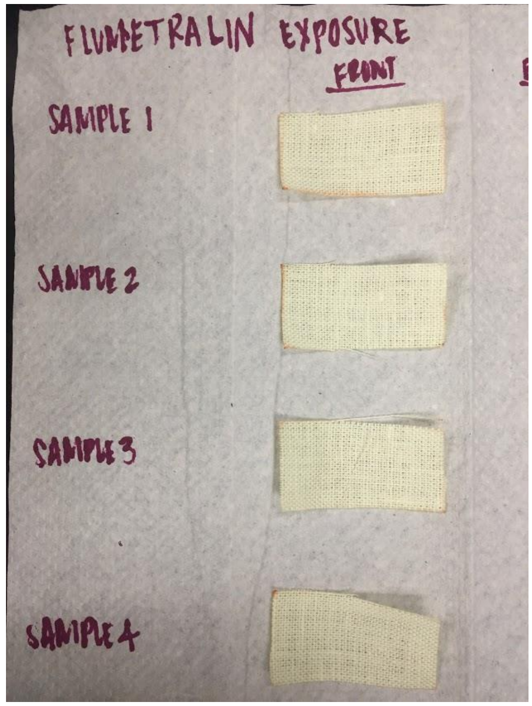

Figure 15. Dried Flumetralin Exposed Samples

After recording, the assay was carried out through dyeing the sample with the TBO dye using the same setup as described in section 3.2.2. Because the fabric samples were the same size as the samples used in the PAA Assay, the amount of solution used to dye and extract remained the same.

3.2.6 Martindale Abrasion Test

The Martindale Abrasion Test was conducted on PAA treated hemp samples to determine the resiliency of the PAA finish on the hemp fabric. All steps in this test followed a modified ASTM D4966 standard test method. The modification to the test involved abrading the fabric to the same fabric being tested rather than using the standard wool abradant. Fabrics were tested against the same fabric being abraded to mimic the abrasion that would occur on the garments while the farmworkers are out on the field. Typically, this abrasion occurs on the garment around the armpit area and in between the legs. The Martindale Abrasion Tester used in this process is located in the Physical Testing Lab of the Wilson College of Textiles.

3.2.6.1 Surface Finish Abrasion Test Procedure

Standard procedure requires that the testing material be cut into a circle 1.5 inches in diameter to fit in the apparatus using a provided Martindale Abrasion Tester cutter. Six samples were cut from the PAA treated hemp material measuring 1.5 inches in diameter. Each sample was placed into the apparatus with a foam backing. The self-fabric abradant was used as the standard abrasion material. Samples in sets of two were run in three separate tests. Each test had a different set number of abrasion movements. The first set of samples were run with 1000 abrasion cycles, the second 3000 abrasion cycles, and the third 5000 abrasion cycles. Once the abrasion cycles were complete for each trial, an assay was conducted on the fabrics to determine the amount of PAA still existing on the fabric. Assay methodology is detailed in section 3.2.6.2.

3.2.6.2 Abrasion Test Assay Procedure

After samples were retrieved from the Martindale Abrasion Tester, the samples were assayed to determine if any of the PAA finish had abraded off during the test. An unabraded sample, cut to the same diameter as the tested samples, was first assayed to determine a benchmark concentration. Because the samples weighed approximately the same as the 1-inch x 2-inch samples from the PAA Assay and the flumetralin assay, the same measurements and procedure was carried out for the abrasion assay. Fabrics were dyed with TBO dye solution and extracted after drying. The extracted solutions were diluted, and concentrations were read using the UV-Vis Spectrophotometer. The abraded sample concentrations were compared to the benchmark concentration to determine if any PAA loss occurred due to the abrasion test.

3.2.7 Accelerated Laundering

The resiliency of PAA finish on hemp fabric was tested through an accelerated laundering process and assayed to determine if the PAA sites decreased after laundering. PAA treated hemp samples were laundered using an accelerated laundering method to determine the durability of the PAA finish under rigorous laundering settings. AATCC 61 test standard was followed under method 2A; it is the most typical test method approach used in the industry for color fastness and surface change through using detergent solution and abrasive action. Compared to the other methods available under AATCC 61, it is the most rigorous. Each accelerated cycle under this method represents 5 home launderings at a warm(medium) setting. For this test, the researcher was not evaluating color fastness, but rather change to the surface finish.

Six PAA treated hemp samples were cut into 3-inch by 6-inch pieces. Following the AATCC method, a 2L solution consisting of 3g of AATCC standard laundry detergent and 2L of warm water was created. Each beaker was filled with 150mL of solution and 50 ball bearings. The ball bearings were used to simulate abrasive action. A single piece of fabric was placed into each beaker, sealed tightly, and then placed into the Atlas Metal Test Instrument LEF Launder-Ometer. Following the standard, the water bath within the Launder-Ometer was set at 120 degrees Fahrenheit to heat up the beakers to the same temperature. The machine was then set to run for one cycle at 45 minutes. Samples were laundered at 1, 2, and 3 cycles in sets of 2. Once the 45-minute cycle was completed, the samples were removed from each beaker and rinsed rigorously. Once the samples were rinsed, they were placed on a rack to dry as to replicate hang drying.

3.3.7.2 Assaying Accelerated Laundered Samples

After the completion of laundering cycles, 3 samples were cut from each of the 3-inch by 6-inch laundered samples to evaluate how much PAA was still present on the fabric after going through the various laundering cycles. Each sample was dyed with TBO dye, diluted and solutions were read with the UV- Vis Spectrophotometer in the Analytical Testing Lab as described in section 3.2.2.1. This allowed researchers to compare the amount of PAA washed off after different amounts of laundering cycles.

3.3 Research Question 1B: Physical Testing

In order to respond to RQ1B, physical testing was conducted on PAA treated hemp woven, untreated hemp woven, untreated cotton jersey, untreated cotton woven, and Tyvek. The cotton jersey knit, cotton woven, and Tyvek are often used in garments that migrant farmworkers wear in the field to perform tobacco farming tasks (See Figures 2 & 3). Physical testing was carried out to compare the tensile strength, tear strength, abrasion strength, and breathability of the treated and untreated materials, in order to assist in product development choices for the protective suit design. The abrasion tests were also run on PAA treated hemp samples to evaluate the resiliency of the surface finish.

Table 3 details out physical tests conducted to answer RQ1B. The table lists the name of the test, the test standard that was followed, and the materials that were tested for each test.

Table 3. RQ1B List of Fabrics Tested for Each Physical Test

	Fabric				
Test	**PAA Treated Hemp Woven Fabric**	**Untreated Hemp Woven Fabric**	**Cotton Jersey Knit Fabric**	**Cotton Woven Fabric**	**Tyvek**
Grab Test (ASTM D5034-09)	X	X		X	X
Ball Burst Test (ASTM D6797-15)			X		
Air Permeability Test (ASTM D737-16)	X	X	X	X	X
Martindale Abrasion Test (ASTM D4966-12)	X	X	X	X	X
Dimensional Stability Test (AATCC TM96)	X	X			

ASTM standard test methods were conducted for each physical test on finished hemp samples. All tested fabrics were conditioned in the Physical Testing Lab on The Wilson College of Textiles 24 hours prior to testing at 70 degrees Fahrenheit and 65% relative humidity. Test methods are detailed in the following sections.

3.3.1 Tongue Tear Test

The Tongue Tear Test was selected to evaluate the tear strength of the PAA treated hemp, untreated hemp, cotton woven, and Tyvek. The tests were conducted based on ASTM D2261 Standard test method.

Fabric samples were cut into 3-inch by 5-inch squares with a 1-inch slit at the top through tracing a template set by the ASTM D2261 standard. Five samples were cut in the weft direction and five samples were cut in the warp direction for the untreated and treated hemp fabric. Once the fabric samples were cut, each fabric was tested for its tear strength using the Q-test machine. Taking one of the fabric samples, the sample was placed into the Q-Test apparatus and clamped on the bottom and top with very little slack (Figure 16). Once the fabric was set up on the apparatus, the grip pressure was set at 80 psi and the machine was started the sample. As samples were being torn, measurements of the tear strength were recorded digitally through the Q-Test interface program. This was repeated for each fabric in the warp and weft direction.

Figure 16. Cotton Woven Set-Up on Tongue Tear Tester

3.3.2 Grab Test

The Grab Test was performed on the PAA treated hemp, untreated hemp, cotton woven, and Tyvek to evaluate their breaking strength and elongation. This test allows researchers to determine the effective strength of the fabric. The test was conducted based on ASTM D5034-09(2017) test method. The test is applicable to woven, nonwovens, and felted fabrics.

Each fabric was cut into ten samples, 5 samples cut in the warp direction and 5 samples cut in the weft direction, where they each measured 4-inches x 6-inches. The long edge of each sample was parallel to the direction of testing and force application. The Q-test machine was set-up for the grab test, with a jaw face size of 1-inch x 1-inch based on the ASTM standard. The material was placed half an inch into the jaw faces and clamped in place (Figure 17). Once the fabric was set, the machine was run with a grip pressure of 80 psi and results were recorded through the program interfaced with the Q-Test machine. This was repeated for each fabric in the warp and weft direction. Knit fabrics were not run on this test as the grab test does not accommodate for knits due to their high level of elongation.

Figure 17. Hemp Sample on Grab Tester

3.3.3 Ball Burst Test

ASTM D6797-15 Standard Test Method for Bursting Strength of a Textile – Constant-Rate-of-Extension (CRE) Ball Burst Test was followed to determine the tensile strength of the cotton jersey knit samples. The ball burst test is designed to test the bursting strength of textiles that have a high degree of elongation. The Ball Burst Test was performed on the Q-Test apparatus in the Physical Testing Lab located in the Wilson College of Textiles.

For this test, the clamping mechanism, on the Q-Test CRE Machine, was changed to the Ball-Burst Attachment. One 20x20 inch sample was cut from the knit fabric and tested in 5 different areas of the sample. For each test run, the sample specimen was placed into the ring clamp, without tension, and fastened securely. The Q-Test CRE machine was run at a maintained speed of 300mm per minute until the specimen burst. The bursting strength was recorded electronically through the program interfaced with the Q-Test machine. This was repeated five times.

3.3.4 Air Permeability

Air Permeability was selected to evaluate the air flow of the PAA treated hemp in comparison to the untreated hemp fabric, cotton woven, cotton jersey, and Tyvek. The fabrics were tested for air flow according to ASTM D737-18 testing standards. The Air Permeability Testing Apparatus used for this test is located in the Physical Testing Laboratory in the Wilson College of Textiles.

3.3.4.1 Air Permeability Test Procedures

A 16 by 16-inch fabric swatch was cut out from each of the tested fabrics. The Air Permeability Testing Apparatus was set-up to suit the hemp material. In doing so, an orifice needed to be chosen based on the rate of air flow through the fabric. For the hemp material used in this test, an orifice with a diameter of 11mm was chosen. Once the orifice size was chosen, it was inserted into the chamber and the fabric was placed into the test area and clamped. The air pressure was turned on and gradually increased until there was a 0.5 pressure drop. The reading of the vertical bar was recorded and converted to determine the air flow measurement in cubic feet per minute per square feet of fabric (cfm). Once recorded, the clamp was lifted, and the fabric was shifted so another part of the fabric was over the hole where the air flowed through and the steps previously described were repeated again. Ten different measurements were recorded and converted to cfm for the treated and untreated hemp.

3.3.5 Martindale Abrasion Test

The Martindale Abrasion Test was conducted on the PAA treated hemp, untreated hemp, cotton woven, cotton jersey, and Tyvek fabrics to compare the abrasion resistance of each fabric. All steps in this test followed a modified ASTM D4966 standard test method. As described in section 3.2.6, the modification to the test involved abrading the fabric to the same fabric being tested rather than using the standard wool abradant. Fabrics were tested against the same fabric being abraded to mimic the abrasion that would occur on the garments while the farmworkers are out on the field. Typically, this abrasion occurs on the garment around the armpit area and in between the legs.

3.3.5.1 Material Durability Abrasion Test Procedure

Similar to the Abrasion Test run to determine the PAA finish's resiliency, samples for the fabrics, listed in section 3.3.5, were run on the Martindale Abrasion Tester to determine the overall abrasion resistance of each fabric. Six test samples were cut into circles measuring 1.5 inches in diameter. The samples were placed into the apparatus with a foam backing. The samples were abraded against the same fabric being tested until it reached its set endpoint, which was when the fibers of the fabric began to experience breakage or where the fibers began to wear down. The amount of cycles was recorded once the samples reached the point of breakage.

3.3.6 Dimensional Stability

PAA treated hemp and untreated hemp samples were tested for dimensional stability through running a normal laundering following the AATCC TM96 method. Accelerated laundering and dimensional stability tests were run in the Pilot Lab at the Wilson College of Textiles.

Two 16-inch x 16-inch samples of untreated hemp and PAA treated hemp samples were cut to be laundered for dimensional stability testing. The samples were secured on three sides and marked with a benchmark square in the center, measuring 6-inch x 6-inch. The samples were labeled and placed into a top loading commercial laundry machine. The machine was filled with filler fabric to mimic the weight of a typical load of laundry. The water temperature was set to hot and AATCC standard laundry detergent was added into the bath. The samples were run on hot to determine the stability of the fabric under the most rigorous laundering condition. Once the samples were washed, they were placed on a rack to air dry as to mimic the laundering procedure that farmworkers would carry-out on a typical day. The samples were then measured to determine if any shrinkage had occurred.

3.3.7 Summary

Research Question One was addressed through the physical testing and assays described throughout this section. Assays were carried out to determine how much PAA finish remained on the various sets of samples that were exposed to flumetralin and samples that underwent physical testing. This allowed the researcher to understand the effectiveness of the PAA in protecting against flumetralin and the resiliency of the PAA finish. In order to evaluate the durability of the PAA finished fabric and how it compared to fabrics that are currently worn in the field, various physical tests were conducted in the Physical Testing Lab. These were all ran according to the ASTM and AATCC standards assigned to each test.

3.4 Research Question 2: Focus Group

To answer RQ2, a focus group was held to gain an understanding the tobacco growers' initial value perception of the current protective ensemble in development. Growers were selected because they hire migrant farmworkers and could give insight to the work experiences and value perception of the garment from the perspective of the supervisors and potential purchasers. The focus group discussion only consists of the perception of one user group. Migrant farmworkers were not evaluated in this study due to the language and sensitivity of scope beyond reach of this project. The focus group was approved by the Institutional Review Board and held at a location on University property.

3.4.1 Institutional Review Board (IRB) Approval

An application to hold a focus group with tobacco growers was submitted to the Institutional Review Board for determination of ethical human subjects research. The application outlined the communication type, focus group objectives, target audience, and how the focus group discussion would be run. Attached to the IRB application was a flier for recruiting (Appendix A), consent form for participants (Appendix B), and focus group guide detailing out how the focus group would be run (Appendix C). After the IRB application review, the focus group was found to be exempt due to minimal risk to participants. The approved IRB application and documents can be viewed in Appendix B, C, and D for this study.

3.4.2 Recruiting Focus Group Participants

Once the IRB approved the focus group study, participants were recruited through convenience sampling method with a goal of recruiting five to six participants for the focus group. Through a contact on the Tobacco Growers Association of North Carolina (TGANC) Board, researchers were given permission to hold the focus group upon the conclusion of the 2019 TGANC meeting. The TGANC meeting occurs annually at the State Club on North Carolina State’s Centennial Campus. During this meeting there are discussions about current issues in the tobacco industry, the growing season outlook, and upcoming news about the tobacco industry. This was the considered to be the best opportunity to have a group of tobacco growers from different areas of rural North Carolina participate in the focus group to give valuable feedback. Six participants, out of approximately 30 attendees, volunteered to participate in the focus group discussion following the conclusion of the TGANC meeting. All participants were tobacco growers located in North Carolina.

3.4.3 Focus Group Process

The focus group was held on Tuesday, June 11, 2019, where a brief presentation was given to the entire group of TGA meeting attendees about Protégete, the protective ensemble in development. Once the presentation was over, the meeting was concluded, and the six participant volunteers stayed back to participate in the focus group. The participants were given consent forms to complete. The participants were given the chance to ask questions before signing the consent form. They were handed $20 gift cards as an incentive for participating. Once the focus group participants provided consent and the facilitator had described the ground rules, the facilitator moved into the focus group questions. The facilitator of the focus group was the primary researcher. The facilitator began with asking a series of three major questions and follow-up questions in between:

- **Question 1:** What are current protective practices or protective systems that are used on your farm by the tobacco harvesters?
    - **Question 1A:** What challenges do you and the farmworkers face with using these protective systems?
    - **Question 1B:** Is pesticide exposure a problem for your workers and how do you deal with it currently?

Part two consisted of three questions. Before asking the questions, the garments were passed around for the participants to feel and evaluate. The three questions asked included:

- **Question 2:** What are your initial thoughts about the garment?
- **Question 3:** Do you see any benefits to having a protective garment like this versus what is being currently used as personal protective equipment?
- **Question 4:** Do you foresee any issues in laundering this protective garment?

The questions asked throughout the focus group discussion were based on objectives of the focus group. Researchers aimed to understand the current protective clothing systems used on tobacco farms; the main issues growers and farmworkers face out in the field, and growers' initial reactions to the garment.

To determine reaction, participants were presented with the prototype of the protective suit which they could touch and feel. Participants were then asked their opinion about the protective suit, whether they perceived any laundering challenges, and their overall value perception. Once all questions were asked, the focus group was concluded, and participants were dismissed. The audio was collected and stored on a password protected computer. It was fully transcribed by the facilitator to a Word document. The transcription can be found in Appendix D.

3.5 Focus Group Data Analysis

Audio recording of focus group discussion was uploaded into a password-protected Google Drive folder for transcription. The transcription was carried out by the researcher who listened to the audio and transcribed speech into a Word document. The transcription was then coded by the researcher into themes. The document was coded using different colors to highlight the various topics that were discussed during the focus group. While reading through the transcript, the researcher highlighted each comment made by the participants with a color unique to the topic, or theme, of the comment. This resulted in nine separate themes that were further collapsed into the following themes which emerged from analyzing the focus group data:

- Toxin Exposure
- Current Protective Wearable Systems
- Recommendations for Future Development of Protective Wearable Systems
- Laundering and Care for Protective Wearable Systems
- Economic Impact of Protective Wearable Systems

The focus group data was coded and converted into themes for analysis. Responses are reported thematically in the results section.

CHAPTER 4

RESULTS

4.1 Research Questions

This study explored two research questions:

RQ1: What is the effectiveness of the combination of 100% hemp woven fabric and a Poly (acrylic acid) finish on garments for protective garments?

RQ1A: What is the effectiveness of the adsorption of the pesticide flumetralin by the PAA?

RQ1B: What is the durability of the hemp after applying the PAA finish?

RQ2: What is the tobacco growers' acceptance, or value perception, of the protective suit design?

To address each research question, both quantitative (RQ1) and qualitative (RQ2) approaches were taken. To answer RQ1, quantitative assays were carried out on multiple sample groups to determine how much PAA remained after undergoing physical testing or being exposed to flumetralin. Physical testing was carried out on fabric samples to understand the tear and tensile strength of the PAA treated and untreated hemp fabrics compared to fabrics used in the industry. The results of the tests for each research question are described in the following sections.

4.2 Assays

Assays were carried out to answer RQ1.

4.2.1 Calibration Curve

Before conducting the assays with the Toluidine Blue O (TBO) dye, a calibration curve was created to validate that the TBO dye concentrations followed the Beer-Lambert Law. This is described in detail in Appendix A. The Toluidine Blue O (TBO) dye solution was used in the assays to represent the concentration of PAA, or its -COOH chemical structure, that was grafted onto the fabric. Figure 18 represents the concentration readings that make up the TBO calibration curve. The absorbance wavelength that each concentration was measured at is 634 nanometers(nm) and plotted as a linear direct plot graph. The linear regression line was forced through zero to ensure the starting point was at zero. Through this method, the R-Squared value of the standard curve was 0.9748. This shows that the absorbance used to generate the curve is linear. While the high R-Squared value signifies a very strong linear relationship between the concentration of TBO dye and light absorbency, a linear regression line was fit to the data to test for the significance of this relationship. When the TBO dye concentration was regressed against light absorbency using Excel, the p-value of the parameter estimate for the TBO dye concentration was found to be < .01 (.0000829). This indicates the linear relationship between the TBO dye concentration and light absorbency is significant at the 95% significance level, confirming the validity of the data satisfying the Beer Lambert Law.

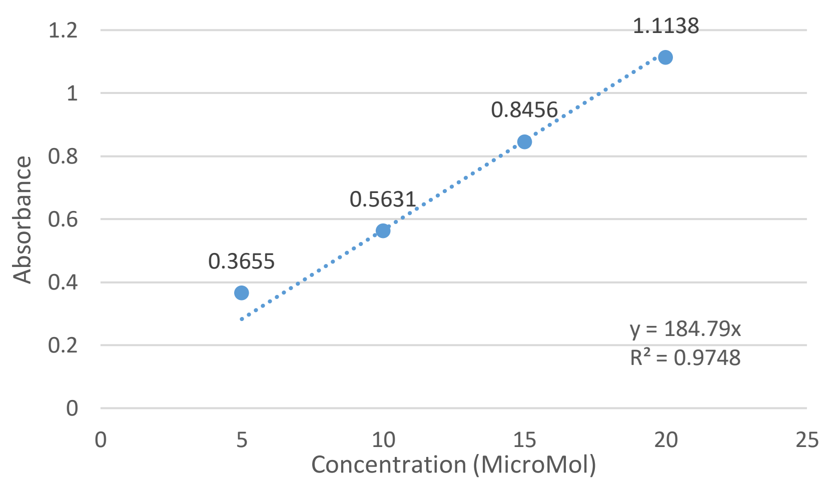

Figure 18. TBO Dye Calibration Curve

With the curve considered as linear, this means that there is an accurate representation of the molar concentration through the Beer Lambert Law. Therefore, this allows researchers to assume that the absorbency level has a linear correlation to the concentration of the dye and the concentration of the dye can be determined based on the absorbency reading.

4.2.2 PAA Assay

Four trials were carried out for the PAA Assay determining the concentration of TBO dye that stained/reacted with the PAA. Because the solutions were diluted 3:1 prior to reading the concentration, they need to be scaled back up to the original concentration extracted. This means multiplying the concentration reading by three. The scaled concentration readings for each sample can be seen in Table 4. As an average result, the 0.1% concentration of PAA that was grafted onto the 100% hemp woven fabric was 0.0182g/L. When converted to Micromols, it is about 79.46 Micromols/L. The mean concentration of PAA present on the hemp samples was determined to allow the researcher to understand how much PAA was grafted onto the sample. This result was used as a benchmark for the flumetralin assay, described in section 4.1.3, and laundering assay, described in section 4.1.4.

Table 4. PAA Assay Concentration

Sample #	Concentration (Scaled) (g/L)
1	0.0177
2	0.0186
3	0.0177
4	0.0189
Mean	0.0182

4.2.3 Flumetralin Assay

Four samples were exposed to flumetralin and assayed. Results can be seen in Table 5. Each sample was weighed before and after exposure to the flumetralin. The average percent change in weight was 0.7%. The average concentration of PAA sites that reacted with the TBO dye was 0.01425 g/L or 238.37 Micromol/L. Compared to the PAA average of the benchmark sample, the amount of -COO sites, from the PAA, available for the TBO dye to bond with decreased. The control sample average concentration was 0.0182 g/L. The average TBO that reacted with PAA sites left on the flumetralin exposed samples were 0.01425 g/L. The concentration of TBO decreased 21.70% compared to the control sample.

Table 5. Assay of PAA Sites Left After Exposure to Flumetralin

	Original Weight	Number of Flumetralin Sprays	Weight After Flumetralin Exposure	% Change in Weight	Wavelength (nm)	Concentration (Scaled) (g/L)
Mean	0.3326	2	0.3352	0.7%	634	0.01425

4.2.4 Laundering Assay

Six samples of PAA treated hemp were run through accelerated laundering cycles. Samples in sets of two were run through one, two, and three cycles. Once the samples were laundered, three 1-inch by 2-inch samples were cut from the larger samples of each laundering cycle. They were assayed using the TBO dye and reading the concentrations. Results are shown in Table 6.

Table 6. Assay of PAA Present on PAA Treated Hemp After Accelerated Laundering

Number of Laundering Cycles	Wavelength (nm)	Mean Concentration (Scaled) (g/L)
1	634	0.0159
2	634	0.0135
3	634	0.0189

The mean concentration for one laundering cycle was 0.0159 g/L. The mean for two laundering cycles resulted in a concentration of 0.0135 g/L, and for three laundering cycles it was reported at 0.0189 g/L.

4.3 Dimensional Stability

4.3.1 Untreated Hemp

Once the fabric was dried, it was remeasured to determine the amount of shrinkage that occurred. The sample started as a 16-inch x 16-inch square and measured at 15.25 inch by 15.74 inch after laundering. Therefore, using the % shrinkage formula, results of the laundered untreated hemp resulted in 4.7% shrinkage in the warp direction and 1.6% shrinkage in the weft direction. Overall, there was a 6% loss in terms of shrinkage.

4.3.2 PAA Treated Hemp

The PAA treated hemp was also remeasured to determine the amount of shrinkage after drying. Similar to the untreated hemp sample, the PAA treated hemp sample began as a 16-inch x 16-inch square and measured 15.75-inches in the warp direction and 16-inches in the weft direction after laundering. This translates to a 1.6% loss in the warp direction and 0% loss in the weft direction. Overall, there was only a 2% loss in terms of shrinkage.

4.4 Tongue Tear

The tongue tear test was run to determine the tear strength of the PAA treated hemp, untreated hemp, and various fabrics typically worn by farmworkers. The results of this test allowed the researcher to understand the tear strength of the PAA treated hemp compared to the untreated hemp and fabrics typically worn by farmworkers. The results also revealed the integrity of the PAA treated hemp in withstanding further tearing after an initial tear occurs. The mean test results for each fabric tested are shown below in Table 7. The mean peak load reveals the average weight it took to break the fibers in continuation of the pre-cut slit. The higher the mean peak load, the more weight, or force, it can withstand before tearing. The standard deviation allows the researcher to understand the variation in the peak load measurement between the five samples tested for each fabric in the warp and weft direction. The tongue tear results for each fabric are discussed in the following sections.

Table 7. Tongue Tear Results

Fabric Type	Test Direction	Peak Load (lbf) Mean	Peak Load (lbf) Std. Dev.
PAA Hemp Woven	Across Warp	26.25	2.64
PAA Hemp Woven	Across Fill	33.79	3.53
Untreated Hemp Woven	Across Warp	33.31	3.2
Untreated Hemp Woven	Across Fill	40.51	6.17
Tyvek	Across Warp	3.34	0.93
Tyvek	Across Fill	3.66	0.96
Cotton Woven	Across Warp	2.91	0.41
Cotton Woven	Across Fill	2.62	0.42

4.4.1 PAA Treated Hemp

The tongue tearing of PAA treated hemp in the across warp direction resulted in a mean peak load of 26.25 lbf, or pound-force, and mean standard deviation of 2.64 lbf (Table 7). Peak load is the amount of weight it took to tear the material.

The tongue tearing of PAA treated hemp in the across fill direction resulted in a mean peak load of 33.79 lbf and mean standard deviation of 3.53 lbf. Peak load is the amount of weight it took to tear the material Results are listed in Table 7.

4.4.2 Untreated Hemp

The tongue tearing of untreated hemp in the across warp direction resulted in a mean peak load of 33.31 lbf and mean standard deviation of 3.20 lbf. Peak load is the amount of weight it took to tear the material.

The tongue tearing of untreated hemp in the across fill direction resulted in a mean peak load of 40.51 lbf and mean standard deviation of 6.17 lbf. Peak load is the amount of weight it took to tear the material.

4.4.3 Tyvek

The tongue tearing of Tyvek in the machine direction, also known as across warp direction in this case, resulted in a mean peak load of 3.66 lbf and mean standard deviation of 0.96 lbf. Peak load is the amount of weight it took to tear the material.

The tongue tearing of Tyvek in the across fill direction, also known as the cross direction, resulted in a mean peak load of 3.34 lbf and mean standard deviation of 0.93 lbf. Peak load is the amount of weight it took to tear the material.

4.5 Grab Test Results

Table 8 shows mean peak load and mean Elongation at Peak Load for the grab test. The grab test was run to evaluate the tensile strength of the treated and untreated hemp fabric, cotton woven, and Tyvek. This test is not suggested for knits due to their high level of elongation. Therefore, the Burst Strength Test was run to evaluate the tensile strength of knits. Table 8 results report the mean peak load and the mean peak elongation. The mean peak load reveals the average amount of weight, or force, it takes to create a tear, or break, in the fabric. The higher the peak load, the more force it can handle before breaking. The mean elongation reveals the average distance the fabric was pulled before the grab test mechanism detected fiber breakage. The higher the mean elongation, the further it can be stretched before breaking. The standard deviation reported for mean peak load and mean elongation tells the researcher the amount of variation between each measurement for the specific fabric sample group. The grab test results of each fabric are discussed in the following sections.

Table 8. Mean Grab Test Results

Fabric	Material Direction	Peak Load (lbf) Mean	Peak Load (lbf) Std. Dev.	Elong @ Pk Ld (mm) Mean	Elong @ Pk Ld (mm) Std. Dev.
PAA Hemp Woven	Warp	125.68	8.03	6.2	0
PAA Hemp Woven	Fill	109.07	6.31	23.9	1.4
Untreated Hemp Woven	Warp	127.43	6.59	7.7	1.4
Untreated Hemp Woven	Fill	116.29	3.63	23	0.7
Tyvek	Warp	21.74	1.82	20	1.5
Tyvek	Fill	17.87	1.66	13.8	2.6
Cotton Woven	Warp	45.5	4.21	13.3	1.3
Cotton Woven	Fill	39.78	11.74	13.6	2.7

4.5.1 PAA Treated Hemp Woven Fabric

Peak load of the PAA Hemp Summercloth was 125 lbf for the warp direction and 109. lbf for the fill direction. The standard deviation for peak load in the warp direction was 8.03 and 6.31 lbf for the fill direction. The mean elongation at peak load was 6.2mm for the warp direction and 23.9mm for the fill direction. The standard deviation of elongation at peak load was 0mm for the warp direction and 1.4mm for the fill direction.

4.5.2 Untreated Hemp Woven Fabric

The untreated hemp resulted in a mean peak load of 127.43 lbf for the warp direction with a standard deviation of 6.59 lbf and 116.29 lbf for the fill direction with a standard deviation of 3.63 lbf. The mean elongation at peak load was 7.7mm for the warp and 23mm for the fill direction. The standard deviation for elongation at peak load was 1.4mm for the warp direction and 0.7mm for the fill direction.

4.5.3 Tyvek

The mean peak load of Tyvek in the machine direction, also known as the warp direction, was 21.74 lbf with a standard deviation of 1.82 lbf. In the fill direction, also known as the cross direction, the mean peak load was 17.87 lbf with a standard deviation of 1.66 lbf. The elongation of peak load was 20mm for the warp direction and 13.8mm for the fill direction. The warp direction for elongation of peak load had a standard deviation of 1.5mm and 2.6mm for the fill direction.

4.5.4 Cotton Woven

The cotton woven resulted in a mean peak load of 45.5 lbf in the warp direction and 39.78 lbf in the fill direction. The standard deviation for peak load was 4.21 lbf for the warp direction and 11.74 lbf in the fill direction. The mean elongation at peak load was 13.3mm for the warp direction with a standard deviation of 1.3mm and 23mm for the fill direction with a standard deviation of 2.7mm.

4.6 Burst Test

Table 9 shows results for the burst test on cotton jersey knit. This test was run to determine the tensile strength of the cotton knit. The mean peak load was reported at 49.7 lbf and had a standard deviation of 2.8 lbf.

Table 9. Burst Test Results for Cotton Jersey Knit

Fabric Type	Mean Peak Load (lbf)	Standard Deviation of Peak Load (lbf)
Cotton Jersey Knit	49.7	2.8

4.7 Martindale Abrasion Test

The Martindale Abrasion Test was run in two stages. The first stage was to understand the material durability against abrasion at 1000, 3000, and 5000 abrasion cycles. The untreated hemp, PAA treated hemp, cotton woven, cotton knit, and Tyvek were all run to understand how the abrasion strength of each fabric ranked against each other when evaluating the fabric samples. The second stage of the Martindale Abrasion Test was performed to understand the PAA finish's durability after being grafted onto hemp at 1000, 3000, and 5000 abrasion cycles. These samples were a separate set of samples ran from stage 1 of the Martindale Abrasion Test. Once the PAA treated samples were run on the Martindale apparatus, the samples were assayed to evaluate how much PAA loss had occurred from the abrasion.

4.7.1 Material Durability

Each fabric sample was run on the Martindale Abrasion Tester in groups of two at 1000, 3000, and 5000 cycles. The samples were checked at every 1000 to 2000 cycles.

The Tyvek showed no signs of abrasion when removed from the test apparatus after each set of cycles.

The cotton woven showed very minimal abrasion with no signs of pilling or fiber loss. The samples at each set of cycles appeared to look the same.

The cotton knit appeared to have heavy pilling and fiber loss. The samples for the cotton jersey knit at 1000 cycles showed signs of pilling. The samples at 3000 cycles showed some pilling and fiber loss. The samples at 5000 cycles showed heavy pilling and fiber loss with holes.

Figure 19. Hemp samples after 5000 abrasion cycles

The untreated hemp woven samples showed minimal signs of abrasion with some appearing to be eroded with no holes being created from the abrasion action. There were no signs of fiber loss or pilling on the samples for 1000, 3000, and 5000 cycles.

The PAA treated hemp woven samples showed various signs of pilling and fiber loss. At 1000 and 3000 cycles, the samples showed minimal fiber and finish loss. When the samples were removed from the foam backing, it was apparent that some of the finish had been abraded off onto the foam. The surface finish of the samples appeared to have been eroded. The samples run at 5000 abrasion cycles resulted in various results. Because of this, more than two samples were run at 5000 cycles. Contradicting results were still given. Some samples were completely obliterated, some showed some fiber loss with holes, and others only showed surface finish erosion.

4.7.2 PAA Finish Durability

Table 10 shows assay results for the abrasion testing conducted to determine the durability of the PAA finish. Samples were run at 1000, 3000, and 5000 cycles in groups of two. The mean concentration of the TBO dye for the samples ran with 1000 abrasion cycles was 0.0174. Samples run with 3000 abrasion cycles resulted in a mean concentration of 0.0159. The mean concentration for samples ran with 5000 abrasion cycles was 0.0165. The concentration of TBO dye represents the concentration of PAA present on the samples.

Table 10. Assay of PAA on Martindale Abraded PAA Treated Hemp

Sample #	Number of Abrasion Cycles	Wavelength	Concentration (g/L) (scaled)
Control Sample	0	634	0.0159
Mean	1000	634	0.0174
Mean	3000	634	0.0159
Mean	5000	634	0.0165

4.8 Air Permeability

The air permeability test was conducted to determine the average level of air flow that could pass through each fabric. Table 11 shows the mean cfm (cubic feet per minute per square feet of fabric) recorded during the air permeability test for each fabric. The higher the air flow reported, the more breathable the fabric. The cotton jersey knit reported the highest level of air flow per cubic feet per minute per square feet of fabric. An 11mm orifice was used to read the air permeability of the cotton jersey knit material; the average reading was 276.2 cfm. The air permeability of untreated hemp had the second highest average air flow which averaged at 210.4

cfm; an 11mm orifice size was used. The average reading for air permeability of the PAA treated hemp was 182.6 cfm. It used an 11mm orifice size as the material is a more open weave structure. The Cotton woven material was read with a 6mm orifice and resulted in an average air permeability reading of 52.98 cfm. Air permeability was unable to be read for Tyvek as its air permeability was out of the machines scope. None of the orifice sizes were about to get a pressure reading on the material's air permeability, suggesting little to no air is able to flow through the material.

Table 11. Air Permeability Results

Material Type	Orifice Size	Mean Cfm (Cubic feet per minute per square feet of fabric)
PAA Treated Hemp Woven	11mm	182.6
Untreated Hemp Woven	11mm	210.4
Cotton Woven	6mm	52.98
Tyvek	N/A	N/A
Cotton Jersey Knit	11mm	276.2

4.9 Focus Group

A focus group was held with tobacco growers to understand their initial value perceptions of the protective ensemble. The focus group data was transcribed manually from the audio recording into a word document (Appendix D). Discussion results were analyzed, hand coded, and then broken out into themes. Coding was carried out through color coding where each color represented a different topic group. While reading through the transcript, the researcher highlighted each comment made by the participants with a color depending on the topic of the comment. There was a total of 9 color codes. Once the data was coded, the codes were organized and turned into themes. The following themes emerged from analyzing the focus group data:

- Toxin Exposure

- Current Protective Wearable Systems
- Recommendations for Future Development of Protective Wearable Systems
- Laundering and Care for Protective Wearable Systems
- Economic Impact of Protective Wearable Systems

4.9.1 Toxin Exposure

Tobacco Growers mentioned that pesticide exposure and green tobacco sickness (GTS) were common health issues faced by migrant workers on their tobacco farms. Growers' opinions during the focus group were that Pesticide was not be as big of an issue compared to GTS. The researcher would like to note that this assertion has not been researched for supporting data as it is outside the scope of the current study.

4.9.1.1 Pesticide Exposure Challenges for Workers

The focus group participants reported that pesticide exposure is not as big of an issue on their farms. One of the focus group participants stated, "There usually isn't a problem, some farmers have never had an issue with pesticide exposure". According the participants, exposure to pesticides is not as much of a problem because pesticide training is given to the farmworkers and Restricted Entry Intervals (REI) are in place. The REI is where workers are not able to enter the field after spraying pesticides for a certain amount of time. The growers perceive that if the REI is followed and workers clean up themselves after spraying the chemical pesticide, then there is not an issue. However, according to the growers, when there is an issue, it's not a case of pesticide poisoning, but rather just "a little bit of a burn". The growers mentioned that after pesticide exposure, the pesticide is not always washed off the skin in a timely manner which leaves the exposed worker with a burning feeling on the exposed area of the skin. The growers also discussed that exposure to pesticide also occurs when farmworkers choose not to wear spray suits. No major issue with pesticide poisoning was mentioned by the participants in the discussion.

4.9.1.2 Green Tobacco Sickness (GTS)

The growers reported GTS as an issue with which they (the growers) are more concerned. They report that GTS is a case by case issue. As one grower mentioned "Not everyone gets it. It's not widespread…it's like an allergy so to speak". Some people are affected by the nicotine exposure and some are not. Another grower mentioned that "people who come year after year don't have as much of an issue with it because they've been exposed to the nicotine and have built up a higher tolerance compared to new workers".

Other various factors can increase the risk of contracting GTS. One respondent commented:

> There's a couple factors… you got weather conditions like yesterday, very hot and humid and your pores are open, you know, nothing's evaporating probably dehydrated, little heat stroke.

The growers stated that all these conditions tied together can cause some serious health effects and increase the risk of contracting GTS as the nicotine travels through the pores much quicker and the body cannot defend itself.

All respondents agreed that GTS, due to nicotine dermal exposure, is a bigger factor than pesticide poisoning for the migrant workers on their farms. According to the growers, they need a protective barrier that can combat the absorption of nicotine.

4.9.2 Current Protective Systems

When asked what type of protective wearable systems were currently used on the growers' farms to combat pesticide poisoning, all respondents mentioned that migrant farmworkers were offered an education process and training session on how to properly handle pesticides, what type of equipment to wear, and best practices to reduce the risk of exposure to pesticides and the risk of tracking it into their dwellings. These practices included washing hands and showering immediately after work.

Through the Worker Protection Standard (WPS), the EPA mandates that tobacco growers must provide personal protective equipment (PPE) to employees for specific tasks, such as applying pesticides. Growers are required by the EPA to provide training to farmworkers on a yearly basis to educate them about pesticide hazards, farm safety, and how to protect themselves from being exposed or harmed through the WPS. According to the WPS, anyone handling pesticides should follow the pesticide label and wear protective gear as outlined on the label. The growers must provide the protective gear for handling pesticides. Protective gear for certain tasks includes gear such as gloves, masks, Tyvek coverall suits, rubber boots, and slip on boots.

The Tyvek coverall suit was agreed upon by all growers to be one of the main protective systems that are currently used on their farms by the farmworkers when handling pesticides or harvesting the tobacco. These suits are typically used once by the farmworkers and then thrown away at the end of the day. They are protective, but not durable or breathable.

4.9.2.1 Current Protective System Challenges

Participants discussed challenges that the growers and their farmworkers face with current protective systems. The main challenges mentioned were heat, breathability, durability, size of garment, and disposal.

The growers discussed how the protective garments, worn by the growers and their farmworkers, are not breathable, particularly with Tyvek coverall suits. Their body heat is unable to escape from the garment and protective gloves they are also wearing. This was mentioned as a major issue for the growers and farmworkers as majority of harvesting is during the peak of summer. As referenced in section 4.8.2, the growers stated that Tyvek coverall suits are one of the main types of protective gear the growers and farmworkers wear out in the field. The suits were mentioned to be suffocating as they trap in heat and barely allow for any airflow to travel through. The suits are also not durable as they only last for a day. According to the growers, cleaning the suits the end of the day is typically not an option because so much physical force is put on the suits throughout the workday that it weakens the suits. The suits become completely soiled from pesticides, dirt, and nicotine sap at the end of a workday which leaves them in a non-reusable condition. The growers mentioned that the suits are disposed of in the trash can after using it one time which creates a disposal and durability issue. One respondent mentioned that “cumbersomeness and heat” were issues they faced when using their current protective systems. When asked to expand on that, the respondent said:

> Just the durability and other things with the Tyvek suits, the zippers seem to fail from time to time, but putting them on and putting them off, they don’t last very long. And then the heat, the body heat is just kinda encapsulated in it. I mean they’re breathable but at the end of the day they’re still another layer of heat. A barrier that doesn’t allow the heat to escape the body.

Due to current systems not being customized, the growers discussed sizing as another issue with current protective systems. The growers were concerned that there doesn’t seem to be a proper sizing standard for the protective garments they currently use. The suits were mentioned to be either too long or too loose, for most growers and farmworkers. All growers agreed that many of them (the growers) will have to constantly roll up the legs on the suits or pull them up throughout the day as they work which can slow down the growers and farmworkers productivity.

4.9.3 Recommendations for Future Development of Protective Wearable Systems

When discussing the current prototype and the value the participants saw in the protective suit, many suggestions were made. Moisture management was among the top suggestions as workers need to be able to stay dry in the field. As mentioned by the participants, current protective garments are not breathable while working in the field which cause the farmworkers to sweat and overheat. Moisture is the main entryway for nicotine and pesticides to enter the workers' bodies. In the growers' perspectives, a waterproof barrier would be ideal for the protective suit, potentially where workers are exposed to the leaves which carry the nicotine and pesticides. One participant gave an example of when farmworkers harvest leaves, they typically pick and tuck them under their arm. Having a waterproof barrier under the arm and along the side of the body would potentially stop the nicotine and pesticides from getting through the garment. Where exposure is not as high, ventilation systems could be put in place. Participants suggested something similar to the vent design on the back of the Columbia Sportswear Performance Fishing Gear shirts.

Respondents offered many different suggestions about garment details, add-ons, and concerns which could be addressed to benefit farmworkers out in the field. A detachable hood was one suggestion made by a participant in which all participants nodded their head to in agreement. Swapping out the current snaps for more durable snaps than what is currently on the prototype, was suggested. Participants even mentioned using Velcro for closures. When determining the final closure type, researchers will need to be careful of closures, like the snaps, falling off the garment and ending up in the tobacco processing procedure. It was suggested by the focus group respondents that having a conversation with purchasers of tobacco about how to avoid non-tobacco material ending up in the tobacco would be worthwhile. Non-tobacco material is any substance, particle, or object that does not belong in the tobacco when processing. These materials are sorted out through a conveyor belt system with a computer that identifies non-tobacco material and removes it as it is passing through. However, these objects are not always caught by the system. Respondents mentioned possibly making the closures a color that would stand out in a pile of tobacco, like a neon pink or purple. This would help machinery spot a non-tobacco material much easier than a closure that blends in with the tobacco.

Another suggestion from the growers would be to design pants with length options which would be helpful as the exposure to the lower body is not as big of a concern. The growers mentioned that farmworkers get hot in the field, so they tend to roll up their pants to allow their body to cool. One respondent mentioned “making the jacket longer, like three quarter length as long pants may not be worn so a longer jacket would be good for harvesting and priming”. It should be noted here that a design with pant length options would be a concern in terms of the WPS as the standard requires farmworkers to wear long pants as a proper protective barrier. Therefore, future research should be aware that this suggestion does not follow WPS protocol.

Standardization of sizes is a concern for the respondents. They mentioned that the garment should be able to fit a range of sizes. Respondents suggested adding elastic details or drawstrings, which could allow the garment to fit a broader size range. Even adding overall straps to the pants could give some flexibility on the size. Oftentimes, the pants get baggy throughout the day due to sweat weighing the garment down and stretching due to worker repetitive movements; therefore, respondents suggested that drawstrings and overall straps could help with this issue.

Aside from waterproof properties, other material properties were mentioned that were considered crucial for future design needs. The garment should be made with the lightest color possible as one participant mentioned “the lighter the color the better because you’re working in a hot field”. The thinnest fabric possible without it losing its durability properties would be ideal for a tobacco protective garment, according to the growers. They mentioned the fabric should be thin, but still functional, and have high tear resistance. A material with high tear resistance was important to the growers as there are many sharp corners around the farm.

The growers also mentioned the material should be breathable as it is one of the major challenges they mentioned when asked about current challenges with protective clothing. It was also suggested that a less porous material should be used so “nicotine gum does not get intertwined into the fiber”. Respondents suggested creating multiple iterations with different features and fabric variations to test on the field with farmworkers to determine the best design options.

4.9.4 Laundering and Care for Protective Wearable Systems

According to the participants, farmworkers currently launder their clothing using a domestic washing machine. The participants explained that the protective gear that farmworkers wear currently is made of plastic or vinyl material (Tyvek Coverall Suits). The suits are usually just rinsed off with a hose or thrown away after having been exposed to nicotine and pesticides. “Rinsing is not done on a daily basis; it’s really just done to clean up a little bit from where they’ve been wearing it.”

From a grower's perspective, there would not be any concern from the growers to use special equipment to launder the clothing with nicotine exposure. "The only thing I would question is if once this thing gums up real bad, that's going to be a mess. You can stand up in a corner and pressure wash it, but it'd be like getting a wad of chewing gum stuck to this to some degree." The nicotine exposed garment would need to be washed in hot water. A less porous material may make it easier for the nicotine gum to be washed off as it would be less likely to "intermingle" with the fibers.

Clothing with pesticide exposure on it may require a separate laundering system. Respondents are unsure if they would need a separate washer, but if they did it would be costly for the growers to install a washer.

4.9.5 Economic Impact of Protective Wearable Systems

Many concerns were raised about cost for the garment throughout the focus group. Determining the customer is crucial as growers cannot afford to eat up another cost and farmworkers make too little to purchase a high-priced garment. Currently, Tyvek Coverall suits are purchased from U-Line in bulk which costs between $7 and $9 dollars each. For one respondent, the cost of using a garment that is washable and durable would be worth it, but the cost would still need to stay in the low to medium cost point, approximately a maximum of $25-$30. As explained by one respondent:

> Me personally, yes. If I can take it home and clean it for my purposes…that's just less waste I am generating and less money down the drain. but again, that goes back to how durable is durable? You know, can I wash it 10 times or can I wash it 50 times. I mean, I think $50 is probably stretching it, but $25…?

For others, the cost may be too much to incur. As explained by one respondent:

> Regardless of the fact...it's another cost that's passed onto the farmer that we're not able to recoup at any level. But if it's a dollar a piece or 120$ a piece...it's still a cost not to mention the fact that even if you have to launder it...that we're not gonna get reimbursed for. So not to kinda shoot ourselves in the foot with this thing...if you don't have a market, there's no market for it, you can't sell it. And you can eat up a certain amount, but you can't eat 'em all. And that's the biggest thing moving forward. We've already hit on the fact that pesticide issue is not a big problem, at all, on our farms. We're already regulated and in a good way. Our employees are part of our family. We don't want them to get sick. We've got a lot of money invested. We're doing everything already to keep them from getting exposed. But there is an avenue to the Green Tobacco Sickness that this could come in, but at the end of the day this is cost that the farmers got to incur that we don't get paid for.

The respondents all mentioned that there was value potential for this garment, but the cost would need to stay as low as possible. They stated that growers are the ones who typically eat up the cost and there is currently no funding for protective garments. Farmworkers, especially migrant farmworkers, make low living wages so incurring this cost could stretch them or the growers very thin.

CHAPTER 5

DISCUSSION & RECOMMENDATIONS

5.1 Research Question 1 (RQ1)

RQ1: What is the effectiveness of the combination of 100% hemp woven fabric and a Poly (acrylic acid) finish on garments for protective garments?

RQ1A: What is the effectiveness of the adsorption of the pesticide flumetralin by the PAA?

RQ1B: What is the durability of the hemp after applying the PAA finish?

Research question one and sub-questions 1A and 1B were answered through a series of assays and physical testing on PAA finished hemp. The flumetralin assay showed that there was a 22% decrease in TBO dye reacting with PAA sites. TBO dye was used as the indicator for PAA sites as PAA cannot be visually seen. Assuming the decrease was due to the flumetralin reacting to the PAA and occupying the -COOH groups, therefore, adsorbing less TBO dye, suggests that the PAA was successful in adsorbing the flumetralin. In addition to the assay, there was an observation that the flumetralin did soak through to the back of the PAA treated hemp. This contradicts the results claiming that the garment is effective in adsorbing the flumetralin and holding it on the surface of the front side of the material to keep the flumetralin from soaking through to the back side of the material and exposing the farmworker's skin.

The assay showed that the PAA can prevent around 25% exposure to flumetralin when the concentration is 1%. The amount of flumetralin farmworkers are exposed to will vary depending on the acreage of the farm and there may be different concentrations used on each farm. The amount of flumetralin the farmworkers are exposed to may also vary depending on the work task they are performing. For example, flumetralin applicators maybe more exposed compared to a farmworker who is carrying out priming of the tobacco leaves. The level of exposure may also depend on how much of their skin is exposed. For instance, if farmworkers decide to roll up their sleeves, they may be more exposed to the chemicals compared to a farmworker who does not roll up their sleeves.

The durability of the PAA finish when applied to woven hemp fabric appears to be able to withstand abrasion and laundering. However, because of discrepancies in the testing process, the claim that it is durable against laundering and abrasion cannot be fully proven. The control sample concentration, for the Martindale Abrasion Test, was reported at 0.0159 g/L. The average concentration for 1000 abrasion cycles was 0.0174 g/L, for 3000 abrasion cycles it was 0.0159 g/L, and for 5000 cycles it was reported at 0.0165 g/L. Compared to the benchmark sample, the average concentration for each cycle stayed the same or had a higher concentration. Because of the discrepancy in results, the researcher is unable to conclude the abrasion resistance of the PAA finish on the hemp woven fabric.

There are various variables that could have attributed to the discrepancy of the results. The higher concentration in some samples compared to others may be due to samples being cut from different areas of the PAA treated fabric. The different areas of the fabric may vary in PAA concentration. The assumption was made that the PAA was grafted onto the hemp material evenly, however, this is showing to not be true due to discrepancies in concentrations. The higher concentration may also be due to human error when pipetting the extracted solution into the cuvette to be read by the UV-vis spectrophotometer. If the solution was not well shaken before transferring it into the cuvette, the dye molecules may have not been evenly distributed causing more dye molecules in solution to be pipetted into the cuvette than intended.

While the durability of the PAA finish through laundering and abrading cannot be fully reported due to discrepancies in comparing the results to the benchmark, the performance of the various fabrics tested for tensile strength, and air permeability can be compared. A cotton jersey knit t-shirt, a cotton woven button-down, and Tyvek coveralls were tested as they are typical protective barriers that migrant farmworkers wear in the field. The tensile strength of each was tested through tongue tear tests, burst test, and grab tests. The durability against abrasion was tested with the Martindale Abrasion tester, and the breathability of each fabric was tested with the air permeability test.

When comparing the durability of fabrics' tensile strength, untreated hemp performed better than other fabrics tested. For the tongue tear test, the average peak load of the PAA treated hemp reported at 26.25 lbf and 33.79 lbf for the warp and fill direction. The untreated hemp had a mean peak load of 33.31 lbf and 40.51 lbf in the warp and fill direction. Comparing the treated hemp against the untreated hemp, the untreated hemp performed better by approximately 20%. However, the better performance with the untreated hemp was anticipated because the treated hemp was processed with high heat, which can weaken the fiber while giving the material functional properties for its specific end use (S. Michielsen, personal communication, 2019). When comparing it to the cotton woven (mean peak load 3.34 & 3.66lbf) and Tyvek (mean peak load 2.91 & 2.62 lbf), the hemp could handle approximately 50% more than the peak load of cotton woven and Tyvek material. The cotton knit could not be tested through the tongue tear test because knits are too stretchy to gather accurate information about its tear strength through this standard.

Hemp also outperformed the cotton woven and Tyvek in the grab test. In the grab test, the finished hemp had a mean peak load of 125.68 and 109.07lbf in the warp and fill direction. The unfinished hemp had a mean peak load barely higher than the treated hemp at 127.43 and 116.29 lbf in the warp and fill direction. The cotton woven and Tyvek had significantly lower mean peak loads as shown in Table 7. The grab test is not suitable for knits, so the burst test was carried out to determine peak load of breaking strength. The cotton knit had a peak load of 49.7lbf which was also significantly lower than the hemp. While the untreated hemp did outperform the PAA treated hemp fabric, the PAA treated hemp was only outperformed by approximately 5% of its peak load. The PAA treated hemp did outperform the cotton woven, Tyvek, and cotton jersey knit material significantly, therefore, is still a viable fabric to use for the protective suit in terms of strength.

Samples were tested to understand the abrasion resistance of the PAA finished hemp woven fabric compared to the unfinished hemp, cotton woven, cotton knit, and Tyvek. The abrasion resistance was tested, and it was found that at 1000 and 3000 cycles, no alteration in appearance was observed. The PAA hemp was durable enough to withstand the 1000 and 3000 cycles, however, results for the 5000 abrasion cycles were contradictory. Multiple samples were run at 5000 abrasion cycles, checking it at 1000, 3000, and 5000 abrasions. However, while some withstood the 5000 abrasion cycles with minimal evidence of the fabric weakening, half of the samples completely obliterated (Figure 20). The low abrasion resistance in this samples may be due to the chemical finish accelerating the degradation of the hemp fabric when applied. This makes the abrasion resistance of the PAA finished hemp inconclusive. The unfinished hemp showed little wear after 1000, 3000, and 5000 abrasions. The cotton woven and Tyvek showed no fiber breakage from the abrasions confirming that the Tyvek and cotton woven has high resistance to abrasion. The cotton knit had completely pilled and begun to show signs of fiber breakage.

There could be errors that cause the discrepancy in the hemp material, including that the pressure applied by the machine was uneven. The material may have not been placed into the holder tightly enough causing it to slip and abrade with a different pressure. Abrasion is difficult to accurately represent with lab tests as abrasion pressure occurs differently when it is actually worn by a human. Due to these difficulties, the Martindale abrasion test is not accepted for commercial use and only used to compare different fabrics in a lab setting. To gain a more accurate representation of how the PAA treated hemp will perform in the field, it is best to perform tests on a human subject.

Air permeability of the fabrics were compared. As seen on Table 10, the untreated hemp, PAA treated hemp, and cotton jersey knit had the highest air permeability reading. The cotton jersey knit ranked higher than both treated and untreated hemp, however, considering the tensile and abrasion strength of the cotton to hemp, hemp is still the better performing fabric. Cotton woven had a very low air permeability reading at 52.98cfm and the Tyvek was not able to be read with the air permeability apparatus. This means that the Tyvek's air permeability is out of the standards scope or the Tyvek does not have any breathability. These results confirm that Tyvek has a very low breathability rate.

The dimensional stability of the PAA treated hemp showed positive results as the samples tested only showed 1.6% shrinkage in the warp direction for the PAA treated hemp. The untreated hemp showed 4.7% shrinkage in the warp direction and 1.6% shrinkage in the fill direction. Overall, the untreated hemp fabric resulted in 6% shrinkage and the PAA treated hemp fabric resulted in 2% shrinkage. The minimal shrinkage was expected as the supplier of the hemp specified that approximately 17% of shrinkage in the warp and 1% of shrinkage in the weft of would occur. The PAA treated hemp appeared to have better dimensional stability than the untreated hemp, suggesting that the PAA strengthens the dimensional stability of the hemp fabric.

Overall, hemp outperformed the cotton jersey knit, cotton woven, and Tyvek in terms of tensile strength and tear strength, suggesting that it is a valid choice for materials sourcing when further developing the protective garments for use against pesticides and other tobacco farming hazards.

5.2 Research Question 2 (RQ2)

RQ2: What is the tobacco growers' acceptance, or value perception, of the protective suit design?

Based on focus group feedback from the growers, the garment does have potential to be valuable, but would be even more valuable if it could protect against Green Tobacco Sickness (GTS) at a low cost. Questions about the cost, who the purchaser is, and other protective properties were raised during the discussion. Future research will need to address these questions. In addition, the price of the garment will need to be further explored. The protective suit will either need to be sold at a very low cost, or the garment will need to be donated to migrant farmworkers.

Focus group data suggest that growers perceive pesticide poisoning to be less of an issue than Green Tobacco Sickness (GTS). However, the growers only represent one aspect of the consumers of this suit as conversations with the farmworkers could have different results. Therefore, more research needs to be done to determine the most important elements against which the suit should protect the workers.

The growers suggested incorporating waterproof materials into the suit design. The waterproof material would need to be breathable to allow the wearer to perform work duties in the heat. The growers mentioned in the discussion that heat and breathability were some of their biggest challenges with their current protective systems they use on the farm. Size variations and a standard for fit would also need to be explored when designing the garment as. Design variations should be created and presented to future focus groups, particularly with the migrant farmworkers and non-migrant farmworkers, for feedback. It is important to gain the insights of the migrant farmworkers and non-migrant farmworkers as they are the ones who would be wearing the protective suit in the field. These design variations should also be tested by human subjects for feedback on design and material features.

Discussing the issue and garment development with tobacco companies and tobacco partners to get their buy-in was suggested by the focus group participants. This would help researchers further understand the issue of GTS and pesticide poisoning and potentially gain support from these companies to provide all farmworkers with the garment. It would also help researchers understand the tobacco supply chain and the key partners that contribute to it. In addition to tobacco companies and partners, gaining the buy-in of social ventures would also be beneficial such as Episcopal Ministries of Newton Grove, NC. Jerry Hartsell, who is a member of the episcopal ministries group, and his team recently assisted in funding and deploying a water bottle to help migrant tobacco farmworkers stay better hydrated out in the fields.

5.3 Future Research Recommendations

This research continued proof of concept testing of a protective migrant farmworker suit, by evaluating the combination of a PAA finish and 100% hemp woven fabric together with grower evaluation of the suit's effectiveness and usefulness. There are several suggestions for the next phases of future work on this project, including lab wear testing, field testing, development of alternative finishes, larger scale testing, and further material testing.

5.3.1 Protective Chemical Finishes Alternatives and Improvements

Future research should determine alternative finishes to protect tobacco farmworkers from pesticides and GTS. This research was limited to PAA protecting against flumetralin under the assumption that the PAA would adsorb the flumetralin through a chemical reaction. However, future development of a finish that could protect from multiple pesticides, especially more toxic pesticides, and GTS would be ideal. As discovered from the focus group discussion, the growers perceive GTS as a bigger issue in tobacco farming than pesticide poisoning. A protective finish and/or material that could successfully protect from GTS, while also protecting from pesticides, would add more value to the growers. Flumetralin is still an important pesticide to continue research on as a large number of farmworkers are exposed to flumetralin during the tobacco growing and harvesting season; it takes multiple farmworkers to apply the pesticide to the entire field compared to more toxic chemicals.

Waterproof finishes should be investigated to aid in protecting the farmworkers from pesticide and nicotine exposure. The finish would need to be waterproof but also breathable to allow moisture and heat to evaporate from the garment as farmworkers work in hot conditions.

5.3.2 Focus Group Interviews

Further investigation on the value perception of the protective suit should be explored through conducting more focus group interviews. This research focused on exploring initial perceptions of the garment by tobacco growers to determine their support of a protective suit among their farmworkers. The tobacco growers mentioned that they believe GTS is a much bigger issue in the tobacco agriculture industry, compared to pesticide poisoning, and suggested that protection from nicotine exposure would give the protective suit higher value compared to a suit that only protected from pesticides. This is only the perception of one party within the tobacco supply chain, therefore, interviews should focus on holding a discussion with the migrant farmworkers, who would be the main user of the protective suit. This would allow the researcher to gain a true perception of the garments value to the farmworkers and the challenges they face with current protective systems; thereby, allowing the researcher to better cater the garments to the wearers' needs. It would also allow the researcher to understand the farmworkers level of concern for nicotine poisoning versus pesticide poisoning.

5.3.3 Further Fabric Testing

Various hemp structures should be tested with the PAA protective finish to determine if a lightweight hemp could hold up the same durability and protection standards as the 100% hemp woven fabric that was used as the suitable fabric of choice in this research. While the hemp fabric is a viable fabric choice, respondents in the focus group mentioned their bias for lighter fabrics. Lighter weight fabrics, compared to the hemp woven used in this study, need to be explored to provide the lightest fabric possible with the beneficial element of protection. A comparison study of each fabric could be conducted with PAA as well as alternative finishes.

5.3.4 Lab Wear Tests

Wear testing in a lab setting should be the next step in proving the effectiveness of the protective suit. Through Textile Protection and Comfort Center (TPACC), the following tests could be carried out on prototype suits:

- Sweating Manikin Test
- Hollies Protocol Wear Test

The sweating mannikin can detail further information about the thermal comfort of the garment. Once the thermal comfort is determined to be at an acceptable level, a human subject wear test should be carried out based on Hollies Protocol. Hollies Protocol allows for a more realistic simulation of actual wear as organized tasks are carried out in a lab setting under specific conditions. These conditions and tasks can be a combination of common tobacco harvesting movements and temperatures in which tobacco farmworkers typically work. While Hollies protocol is focused mainly on gaining comfort feedback, it also can allow the researcher to determine the durability of the treated fabric over a certain amount of time and movements through evaluating the garment at the end of the wear trial.

5.3.5 Field Testing

Field testing on NC State's research farm would allow for the garment to be fully tested on human subjects in the tobacco harvesting environment. This would allow researchers to observe how the garment is used in the field and determine the durability of the garment after a certain number of uses by the farmworkers. Abrasion testing in the lab is not accurate or suitable to represent how the garment would be used out in the field because different points of abrasion are observed when being worn by a human versus being abraded by a machine. Field testing would give a more accurate representation of how the garment can withstand against abrasion during the rigorous tasks farmworkers have to carry-out in harvesting season.

Field testing would also allow researchers to collect the exposed and used garment to carry out assay tests in professional testing facilities to determine the effectiveness in protection against pesticides after a set amount of uses. Professional lab facilities would be able to conduct tests with more advanced equipment which would allow for researchers to determine the amount of flumetralin adsorbed by the protective suit. Professional lab facilities could also detect other chemicals farmworkers are exposed to, such as nicotine. Field testing the garment would give a much more accurate representation of flumetralin exposure, versus a heavily concentrated spray action carried out in a small lab setting. Professional lab facilities should also be able to determine how much PAA still exists on the garment after being exposed to abrasion from farmworkers using the garments in the field.

Field testing can also allow future researchers to gain feedback about the garment from the human subjects wear testing the garment. This would allow for further development in the design and construction of the garment. When conducting research, field workers should be cautious about the vulnerability of the farmworker population. There may be language barriers involved as majority of migrant and seasonal farmworkers are of Hispanic backgrounds, have little education, and speak little English (NAWS, 2018). Researchers will need to determine if a translator is required to interact with the farmworkers and the measures that need to be taken to conduct a human subject study on a population that is considered vulnerable.

5.3.6 Larger Scale Testing

Lager scale testing at professional testing facilities should be utilized to determine the effectiveness of the PAA finish and the durability of the material after wear testing for a period of time. The TBO dye/stain test used in this research is not sufficient for this as it is only meant for small scale testing in a lab. In the flumetralin assay, there may have been unknown errors that occurred, such as evaporation. The assay confirmed that the flumetralin was adsorbed by the PAA. However, further research would be required to determine the exact amount of flumetralin that was bonded to the PAA. Professional testing facilities, such as Global Laboratory Services, located in Winston, NC, would be able to provide the flumetralin levels. This testing facility has a method to analyze flumetralin and can analyze about 200 grams per fabric sample. Each sample would cost about $80 to test. Testing at professional facilities would allow for a more accurate representation of the PAA concentration on the hemp and the amount of flumetralin it can adsorb as these professional facilities specialize in testing whole garments and finishes.

Larger scale testing should also be performed to determine the level of nicotine exposure farmworkers face. Once a proper barrier is designed to combat against nicotine poisoning, utilizing a large scale lab test would allow the researchers to accurately determine the amount of nicotine exposure on the protective suit.

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APPENDICES

Appendix A: Creating the Standard Calibration Curve Procedure

Before conducting the assays, a standard calibration curve was created to verify that the molar concentration of the Toluidine Blue O (TBO) was accurately represented through the Beer-Lambert Law. A standard curve was created with the Toluidine Blue O (TBO) dye solution. A 100mL, stock solution with a 100Micromol concentration was created through dissolving .03g of TBO dye in a 50/50% volume of acetic acid and pH 10 deionized (Di) water solvent. The stock solution was then used to create the concentration solutions for the standard curve through dilution.

The concentrations of the solutions used for the standard curve consisted of 5 micromol, 10 micromol, 15 micromol, and 20 micromol. Each concentration was created through a dilution method. The 5 micromol concentration solution was created through diluting 1mL of the TBO stock solution with 199mL of the 50/50% volume acetic acid and Di water solvent in a 200mL Erlenmeyer flask. The amount of concentration solution was measured through using a 1000microL pipette. The 10, 15, and 20 Micromol solutions were mixed and stored in 100mL Erlenmeyer flasks. The 10micromol concentration was created with 1 mL of TBO stock solution and 99mL of solvent. The 15micromol concentration was mixed with 1.5mL of TBO stock solution and 98.5mL of the solvent, and the 20micromol concentration was created through mixing 2mL of TBO stock solution and diluted with 98mL of the solvent.

Once the TBO concentrations were created, they were taken to the Analytical Testing Lab, located in the Wilson College of Textiles, to be read in the Agilent Technologies Cary Series UV-Vis Spectrophotometer (Figure 20).

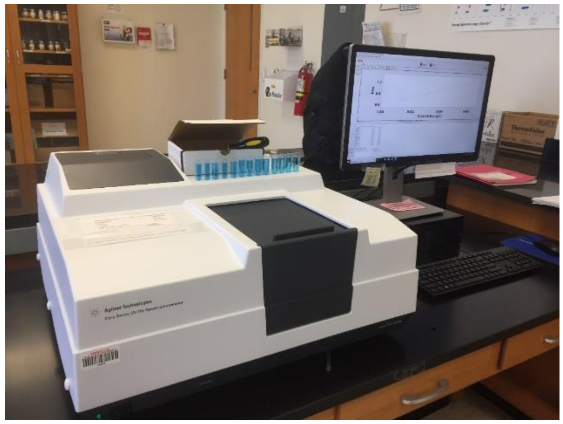

Figure 20. Agilent Technologies Series UV-Vis Spectrophotometer

Before being able to read each concentration, a baseline needed to be established. The baseline is the solvent, which in this experiment was the 50/50% volume acetic acid and Di water solution. A disposable cuvette was filled 2/3 of the way with the clear solvent, inserted into the machine, and read. The baseline zeros out the curve to create a starting point, or reference point, for the curve. Once the baseline was established, the highest concentration level was read to determine the lambda max, which is the wavelength at which a substance shows maximum absorbance. The lambda max is important because it ensures highest sensitivity and minimizes deviations from the Beer-Lambert Law (Loudon, 2009).

After the baseline and the lambda max were read, disposable cuvettes were filled with each concentration, placed into the UV-Vis Spectrophotometer and were read and plotted electronically through the UV-Vis Spectrophotometer program. The reading settings were set to visible light and linear plotting. The standard curve R^2 value was collected to show that the absorbance used to generate the curve is linear. Creating the standard curve ensures that there is an accurate linear representation of the molar concentration to absorbency of the TBO dye, in accordance to the Beer-Lambert Law.

Appendix B: eIRB Focus Group Supporting Documents

Email Communication Requesting Participation

Hello (Insert Name Here),

My name is Victoria Luong Vu and I am a graduate student at NC State University's Wilson College of Textiles. As part of my master's studies in Textile Technology Management, I am conducting a research study about developing a protective garment for farm workers on tobacco farms and the value perception of the garment. Specifically, the garment is designed to reduce the exposure to pesticides and nicotine during the growing and harvesting seasons. During the month of May, I am looking for growers of tobacco farms to take part in my focus group, which will be conducted at (Insert location here). As you are a tobacco grower, I am looking for your input in this study. The entire process will take about one hour in which you will participate in an open discussion about tobacco farming and opinions about the protective garment currently being developed.

If you are interested in participating or have any questions, please contact me via email at vqluongv@ncsu.edu. I will be following up with an email with more details about the process of the focus group study. Thank you for your time and I look forward to hearing from you soon!

Sincerely,
Victoria Luong Vu

Follow-Up Email Communication

SUBJECT: TOBACCO PROTECTIVE GARMENT FOCUS GROUP

Hello (Insert Name Here),

Thank you for your interest in participating in the study: Grower Perception of Protective Garments for Migrant Farmworkers on Tobacco Farms

You are scheduled for May _, 2019 at (Insert Time) in Raleigh, NC at the Wilson College of Textiles Room (Insert Number Here).

Parking Location: (Insert parking location and link to map here)

This is the introductory email with the study information, please read the below information carefully and let me know if you have any questions:

Hello, my name is Victoria Luong Vu and I am a masters student at NC State University's Wilson College of Textiles. Thank you for taking the time to participate in this focus group. I am looking forward to our discussion. As you may know, I am researching and developing a protective garment for migrant farmworkers on tobacco farms to protect them from chemical pesticide exposure and nicotine exposure. Your participation is invaluable to this process and I, again, thank you for the time and willingness to engage with me on this topic.

I expect the interview will take approximately 60 minutes and will take place in a conference room located at the Wilson College of Textiles. If we begin to go over 60 minutes I will give you a warning at which point you may decide whether you would like to end the discussion or continue until the end. During the discussion please feel comfortable to move around if necessary and express yourself in a way that is comfortable for you. During this time we will briefly discuss current practices on your tobacco farm to protect farmworkers from pesticide and nicotine exposure and any challenges you may face with this topic. We will then move into discussing the current development of the protective garment and review a sample of the physical garment.

Important things to note is that there are no right or wrong answers and you have the right to end this interview at any time as well as the ability to decline to answer any question. As this is an audio-recorded interview, you also have the right to decline audio recording while also declining to participate in the study.

Additionally, before we begin the interview I will have you give me a pseudonym in which I may refer to you throughout the duration of the interview. You will also be referred by this name within any future research. It is best to choose a name, which is different from your own and does not align with any nicknames or characteristics that may identify you. To further protect your identity I will not link this pseudonym with you in any email or phone communication. Additional privacy measures, in addition to providing you with an alias, includes protecting notes and audio records created as a result of your interview by storing them on an encrypted computer within a password-protected file to which only the primary researcher has access.

At anytime, if you feel uncomfortable or wish to refrain from answering a question, please let me know and we will move on. Again, you have the right to drop out of this study at any time, including prior to, during, and after the interview.

Lastly, prior to beginning the interview I will offer you a form, entitled "Informed Consent," which will outline the procedures of this study and my duty to ensure your privacy. You will find that a lot of this information will be repeated on this form. The informed consent ensures that you understand the purpose of the interview and the research, that you understand how your information and identity will be protected within the research, and any risks and/or benefits of the study.

To ensure I appropriately represent you and our conversation I will present to you a transcription of the interview for checking. My goal is to ensure, I accurately represent your thoughts and ideas throughout the study and I cannot do this without you.

You do not have to do anything until we meet for our interview. You will receive a separate email that will have the subject line "Your Focus Group Participation" which will confirm the date, time, and location for the interview. To maintain confidentiality regarding your participation there will not be any identifying information about the study in this email.

If you have any questions, please email me at vqluongv@ncsu.edu. Looking forward to meeting with you!

Sincerely,
Victoria Luong Vu

Appendix C: Focus Group Consent Form

North Carolina State University

INFORMED CONSENT FORM for RESEARCH

Title of Study/Repository: Grower Perception of Protective Garments for Migrant Farmworkers on Tobacco Farms
Principal Investigator: Victoria Luong Vu, (919) 349-1972, vqluongv@ncsu.edu

Faculty Point of Contact: Katherine Emma Annett-Hitchcock, kate_annetthitch@ncsu.edu

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What are some general things you should know about research studies?
You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate and to stop participating at any time without penalty. The purpose of this research study is to gain a better understanding of the growers and farmworkers perception of value of a protective garment for migrant farmworkers on tobacco farms.

You are not guaranteed any personal benefits from being in this study. Research studies also may pose risks to those who participate. You may want to participate in this research because the development of this protective garment could prevent farmworkers from being exposed to hazardous chemicals in the field and increase productivity on tobacco farms.

In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above or the NC State IRB office (contact information is noted below).

What is the purpose of this study?
The purpose of the study is to determine the growers, farm owners, and farmworkers' perception of value of a protective garment for migrant farmworkers' on tobacco farms.

Am I eligible to be a participant in this study?
In order to be a participant in this study you must be at least 18 years old and associated with tobacco farming.
You cannot participate in this study if you are under the age of 18.

What will happen if you take part in the study?
If you agree to participate in this study, you will be asked to do all of the following:

(a) Participate in a focus group discussion about safety practices on tobacco farms and the perceived value of the protective garment.

The total amount of time that you will be participating in this study is approximately 1 hour. The survey should take about 20 minutes and the focus group will be held for about 40 minutes. The study will take place at the Wilson College of Textiles. Audio recording will take place. No one will be identified; everyone will stay anonymous.

Photos and video
If you want to participate in this research, you must agree to being audio recorded. If you do not agree to being audio recorded, you cannot participate in this research.

As a part of this research, we would like your consent to audio record your conversation during the focus group.
____ I consent to be audio recorded
____ I do not consent to be audio recorded

Risks and benefits
There are minimal risks associated with participation in this research. Should the participant decide to end the survey or focus group discussion prior to completion, all identifying information will be destroyed and their answers will not be included in the study. There are no direct benefits to your participation in the research. The indirect benefits are contributing to ongoing research to understand the value perception of the protective garment for migrant farmworkers on tobacco farms. Participants may gain a better understanding of hazards migrant farmworkers face from chemical exposure in tobacco farming through the focus group discussion.

Confidentiality
The information in the study records will be kept confidential to the full extent allowed by law. Data will be stored securely on a password protected NC State computer and will not exist on a cloud or third-party application. Only the researcher, Victoria Luong Vu, and Faculty Advisor, Dr. Kate Annett-Hitchcock, will have access to the information. No reference will be made in oral or written reports which could link you to the study unless you give explicit permission to the contrary.

Compensation
You will not receive anything for participating.

What if you are an NCSU student?
Participation in this study is not a course requirement and your participation or lack thereof, will not affect your class standing or grades at NC State.

What if you are an NCSU employee?
Participation in this study is not a requirement of your employment at NCSU, and your participation or lack thereof, will not affect your job.

What if you have questions about this study?
If you have questions at any time about the study itself or the procedures implemented in this study, you may contact the researcher, Victoria Luong Vu, 1020 Main Campus Dr, Raleigh, NC 27606, vqluongv@ncsu.edu, (919)349-1972

<u>What if you have questions about your rights as a research participant?</u>

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the NC State IRB (institutional Review Board) Office via email at irb-director@ncsu.edu or via phone at 1.919.515.8754. You can also find out more information about research, why you would or would not want to be a research participant, questions to ask as a research participant, and more information about your rights by going to this website: http://go.ncsu.edu/research-participant

Consent To Participate

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled."

Participant's printed name ____________________________________

Participant's signature _______________________________________ **Date** ____________

Investigator's signature ______________________________________ **Date** ____________

Appendix D: Focus Group Script

[greet and direct everyone where to be seated]

Hello everyone, welcome…

Thank you for taking time out of your day today to participate in my study around developing a protective garment for farmworkers on tobacco farms. There are refreshments (insert direction it is located), please help yourself. Please feel free to move around as needed during this focus group session.

As a reminder, my name is Victoria Luong Vu and I am a graduate student at North Carolina State University Wilson College of Textiles. I am conducting research in developing a protective garment for migrant farmworkers on tobacco farms to help reduce the exposure to chemical pesticides as part of my graduate studies. With my studies, I have so far been able to determine the effectiveness of the protective finish on the garment and am now in the stage where I am looking for initial reactions and interest in a garment which is why your participation is so important. I am happy to be able to offer you a $25 gift certificate for your time (pass around).

Before we begin our discussion, I will go over the rules of the group interaction and discussion.

Rules:

- Please refrain from using your real names during the discussion. No one should expose anyone's true identities as all the reporting and data will be done anonymously.
- All opinions are respected, there are no right or wrong answers in this discussion.
- You are being audio recorded. Please speak one at a time and speak clearly so the audio recorder can pick up the details. The audio will be transcribed, and all data will be password protected so that your identity is also protected. All the data will be destroyed once we have made transcriptions and used the transcriptions to advance the design and use of the garment.
- We will start with the left side and go around the room. Please be sure to speak clearly one at a time and make sure you do not speak over anyone else. You will each get your opportunity to contribute because we will be going around the room one at a time.
- If you could limit your responses to the questions to 3 minutes per question

Additional privacy measures include protecting notes and audio records created as a result of your interview by storing them on an encrypted computer within a password-protected file to which only the primary researcher has access.

At anytime, if you feel uncomfortable or wish to refrain from answering a question, please let me know and we will move on. Again, you have the right to drop out of this study at any time, including prior to, during, and after the interview.

We will now move into the discussion about current challenges and protective barriers used in tobacco farming. Before we move into the discussion does anyone have any questions?

[Question 1 is asked to understand current practices and protective barriers that are currently used on the tobacco farms and the challenges that the growers and farmworkers run into with implementing the protective practices, as well as health issues.]

I am now going to ask a series of questions. The first set will be to find out more about the current state of the problem and the second will be to find out more about what you all think of the garment.

Question 1: What are current protective practices or protective systems that are used on your farm by the tobacco harvesters? (ie. Education, provided personal protective gear)

> **Question 1A:** What challenges do you and the farmworkers face with using these protective systems? (ie. are there any drawbacks to using this gear?)

***Say as a backup before we move onto the next questions -- are there any other challenges that you all see before we move onto the next questions

> **Question 1B:** Is pesticide exposure a problem for your workers and how do you deal with it currently?

**Before we move on is there anything anyone else would like to comment on pesticide exposure issues you experience on your farm that you haven't discussed?

[Questions 2-3 are asked to understand the value perception of the protective garment that has been developed for this study. The participants will have a chance to see and feel the garment. A description of the protective garments' properties will be verbally provided]

I am now going to show you all a prototype of the protective garment that has been developed for my research and will pass it around for you all to see and feel. This garment is made of Summercloth Hemp, which is durable, but still comfortable and breathable. It is finished with a protective finish to keep chemical pesticides from seeping through the garment while farmworkers are harvesting the tobacco crops. Along with the protective finish, the garment design features closures that are protected with different fabric flaps to keep the workers skin from coming in contact with pesticides.

[Pass around the garment to the participants.]

Please feel free to pass around the garment to examine the different closures and feel the fabric.

Question 2: What are your initial thoughts about the garment? (will want to go around in order, so pick a side to start on)

Question 3: Do you see any benefits to having a protective garment like this versus what is being currently used as personal protective equipment? (this may already be covered

Question 4: Do you foresee any issues in laundering this protective garment?

We are now at the 60 minute mark if anyone needs to go, would you all like to continue talking, or if you have to leave that is fine as well.

[END OF FOCUS GROUP DISCUSSION]
END: Congratulations! You have reached the end of the focus group. Thank you so much for your participation. As a reminder your identity will not be reviewed at any point through the reporting process. I hope you all have a great rest of your day. The exit is right this way.

I would just like to remind everyone that we are discussing **__________.

Appendix E: Focus Group Transcript

Focus Group to discuss current protective practices from pesticides on tobacco farms and to determine the initial value perception of the Protégete protective garment.
Date: Tuesday June 11, 2019
Location: State Club on Centennial Campus at the TGA Board Meeting
Participants: 5 total participants from the Tobacco Growers Association
Prompters: Victoria Luong Vu and Dr. Kate Annett Hitchcock
Spectator: Nikolas Mahlik (SIF)

PROMPTER: Just to reintroduce myself my name is Victoria Luong Vu. Thank you so much for taking time out of your day. I know it has probably been a long day for you guys, but this is going to be very beneficial to us in developing our garment to help tobacco farmworkers.

So, before we begin, I will go over the rules of the group interaction and discussion. Just please make sure you refrain from using anyone's real names when you guys are talking and answering questions. No one should expose anyone's true identities as all the reporting will be done anonymously.

All opinions here are respected so there are no right or wrong answers in this discussion. You will be audio recorded. This right here is the audio recorder so please make sure to speak one at a time and clearly so that the recorder can pick it up because we will have to transcribe it once we are done.

Once we have transcribed the data, have used it and stored it, we will be destroying it once all the recording has been done in our research

When I ask a question, we will start on my left side and go around the room one at a time so each one of you will have a chance to talk. Please make sure you do not speak over anyone else as each one of you will have a chance to speak.

We ask that you limit your response to three minutes because we do want to get you guys out of here and on time so try not to go over if you can, but we know it happens

So just some additional privacy measures.it will include protecting notes and audio records on an encrypted computer. This will be on NC State's campus and only Dr. Kate and I will have access to that on google.

So, at any time, as Dr. Kate has mentioned, if at any time you guys feel uncomfortable or wish to refrain from answering a question, just let me know and we can move on to the next question or respondent.

You have the right to drop out of this study at any time including prior to, during, or after to.

So, we will now move into the discussion about the current challenges, and the protective barriers used in the tobacco farming, but before we do, does anyone have any questions?

I am now going to ask you guys a series of questions. The first set will be to find about the current state of the challenges that you guys face on the farms and the second will be to find out more about what you guys think about the initial garment made.

PROMPTER: Starting with question 1, what are current protective practices, or protective systems, that are used on your farm by the tobacco harvesters? So, for example, do you guys educate your workers and what type of protective gear do you provide, if there is any.

RESPONDENT: We run an education process or training session when our guys come on the farm and we provide them with what is required by us from gloves to depending on their job specific task that they do. So, some tasks have gloves, some tasks have masks, some have the Tyvek coverall and stuff and rubber boots and slip-on boots, and we provide those. Now it's up to them. I'm not gonna tell you that they always use it, but it is there for them to use.

PROMPTER: Thank you.

RESPONDENT: So, we do the same in my research program. We provide anywhere from a 3-5 mil rubber glove, Tyvek spray suits. If we are spraying things fairly close to the ground you know, maybe soil applied, we may have Tyvek spray pants and maybe rubber boots and face masks/face shields for when we start spraying things that are head high or above when there is potential for dermal exposure in the face. In general, we don't typically work with things that need respirators, but we do have those in case they are needed, but again, pretty standard stuff.

RESPONDENT: I do the same thing. We train our workers when they come to the farm and we provide rain suits and whatever kind of gloves and whatever needs for them to stay dry.

RESPONDENT: We do the same thing also. Workers are trained when they arrive on the farm. Whatever type of protective clothing they need for whatever specific task they do is provided. Usually it's a waterproof type of material.

PROMPTER: Thank you. Is there anything else anyone would like to add before we move onto the next question?

Okay, so next question:

Do you or your farmworkers face any challenges when using these protective systems? For example, what are the drawbacks to using the gear that you currently use?

RESPONDENT: Cumbersomeness, heat.

PROMPTER: Can you expand on that?

RESPONDENT: Just the durability and other things with the Tyvek suits, the zippers seem to fail from time to time, but putting them on and putting them off, they just don't last very long. And then the heat, just the body heat is kinda encapsulated in it. I mean they're breathable but at the end of the day they're still another layer of heat. A barrier that doesn't allow the heat to escape the body.

RESPONDENT: I agree. For us, we use a Tyvek suit one time and then we throw it away. Just because the aspect of pulling it on and off, a lot of times it gets ripped. Um, you know for me, I'm not very tall, but I'm fairly stout so I have to have a large or an extra-large and then a lot of times it's too long so I have to roll the bottom of the pants up and then it starts to fall down and then it rips and tears and it's muddy and nasty. I just feel like disposing of that after a single use is a lot better than constantly reusing it especially when you have certain pesticides on it that you are getting re-exposed to. For the gloves you know the thicker the better but those also come with challenges because if they're too thin they rip but if they're too thick then they're also fairly hot and can be a little bit cumbersome to deal with.

RESPONDENT: Same problems. Either the rain suit sometimes gets real hot and you end up sweating so much on the inside can't get to that like he's done with the barrier. And same issues.

RESPONDENT: It's the same with my operation. It's awful. 90% of the problem is just with the body heat not being able to escape from the garment they're wearing and the protective gloves. And durability to a certain extent. The protective clothing will not hold up because it's used a lot and in not the easiest conditions that it's held in

PROMPTER 2: Can I ask a follow up question. You in the blue shirt, when you're talking about Tyvek. Do you mean the same material they insulate houses with?

RESPONDENT: Yes.

PROMPTER 2: If you are disposing after each use, how do they get disposed of?

RESPONDENT: In the trash can, yeah. Which creates a whole 'nother issue in of it with itself.

PROMPTER: Are there any other challenges before we move on to the next question?

So, follow up question to that: Is pesticide exposure a problem for your workers and how do you deal with it currently?

RESPONDENT: I would say for us it's not a massive problem just because we're trying to use proper PPE and proper procedures. But in my opinion we have had instances and I'll say that myself I've sprayed certain products without the spray suit because it was so hot and didn't clean the material off of my arms in a timely fashion and you know felt a little bit of a burn because I didn't clean up properly, but again that was because that was my own fault but it was ultimately because the spray suit was too hot for this particular time of the day

RESPONDENT: We usually don't have any issues mostly because when we do spray, we'll do the reheat REI waiting proper time to go back into the field, so we usually don't have a problem.

RESPONDENT: I've never had a worker have an issue with pesticide exposure. I think as long as we flow the REI and don't let the workers go back into the field it is not a problem.

RESPONDENT: We're the same, we don't have any issues.

PROMPTER: If pesticide isn't an issue on the field with the workers, do you guys have another challenge that you're more worried about?

RESPONDENT: I don't want to answer for him, but I would say that from my perspective, probably Green Tobacco Sickness.

RESPONDENT: Yep. It's just the thing that they need to be able to stay dry while they are in the field.

RESPONDENT: and that green tobacco sickness is not necessarily widespread because I've never had it, never bothered me from the time I grew up, but you might have, the guy in the black shirt, it might affect him every day. It's like an allergy so to speak...

PROMPTER 2: Like Poison Ivy of some kind

RESPONDENT: Exactly, some people it effects and some people it doesn't and you just kind of learn to work around it.

RESPONDENT: Most of the guys who come here year after year, they don't really have a problem with it. You might have a young guy come, he might have a little issue with it, but most of them don't have a problem.

RESPONDENT: Usually if a worker is a tobacco product consumer, they typically don't have an issue because they have a higher level of tolerance for the nicotine. As opposed to someone who doesn't. For example, my mother grew up on a tobacco farm and she would tell me that when they got done cropping tobacco if she got home and didn't immediately wash her hands and her arms she would get sick, whereas somebody like my father who was a product consumer never had a problem with it and myself included.

PROMPTER: Is there anything else anyone would like to contribute before we move onto the next section? Questions?

So now were going to talk about questions on the prototype and just to show you all again what the prototype looks like, this is the prototype that's been developed. Again, this is made of 100% hemp summercloth, it features a poly acrylic acid finish which were testing against the flumetralin pesticide right now. It has multiple design features where there's this closure here covering the zipper to stop any pesticides from coming through the closures and then also when they're removing there clothing this is just an extra set of fabric that will keep their hands off from like touching their bare skin. And there's the high neck collar to protect the neck area. And then this placket here to keep anything from coming through and tighter cuffs to hopefully keep their skin from being exposed so it doesn't move up and down as much as a loose cuff would.

And we can pass this around again so you guys can touch and feel it.

So, while that's coming around, I'll just start with the first question for this part of the focus group. What are your initial thoughts about this garment?

RESPONDENT: I think that it would work pretty good, but our main concern is the water proof...like used for a rain suit. If it won't let flumetralin come in, why wouldn't it do the same thing with water and dew? That's my question.

RESPONDENT: So, one thing I would think about is, particularly if you have a harvest crew that is hand harvesting the tobacco, they typically, as they harvest, they put the leaves under their arm. So, if you have the core of it that might be breathable and maybe the arm or one side of the underarm be more waterproof or waxy to repel, then that might be another option to keep the breathability…

RESPONDENT: and off the back kinda like the shirts with the flutes in the back. The PFG with the little vents.

RESPONDENT: Obviously the reason I said wax is the tobacco companies, and I assume the reason its hemp, is because if it ends up in the product, it's still all natural and it actually would be a combustible, you know like, the fiber as opposed to a plastic rain suit.

How much interaction are you having in terms of this having application, is this only for tobacco?

PROMPTER: As of right now, yes, but we are hoping to expand in the future.

RESPONDENT: And how much have you spoken with Philip Morris, Altrea, Reynolds, or any of those people.

PROMPTER: Not very much.

RESPONDENT: Also, just going back to the tobacco, the plastic snaps…and that's what I was trying to say, that if they pop up and they get into the tobacco that is an issue.

RESPONDENT: So, you may want to think about Velcro, but I do think it's worth having a conversation with the purchaser because they will always…they always use the term farm material…non-tobacco material and TRN non-tobacco related. So that's a constant educational process, particularly with drink cans, or coolers, or cell phones or anything that's loose that can end up at the field in a trailer that might automatically dump at the barn or when you're taking out dry tobacco, which I realize you wouldn't use the suit there necessarily, around the baling system.

So pieces of rubber from rain suits, Philip-Morris years ago issued those and garbage bags, they don't like that fiber, that material that getting into...cause when it goes into the manufacturing facilities...the machines…that creates a problem...they've got magnets that pick-up metal, screwdrivers, nails, things like that but it's harder on the inanimate things

RESPONDENT: I think that if you could find some way, whatever coating, well just the fasteners for one thing, to make those durable

PROMPTER: Yeah these actually aren't the final closures, because it's just a prototype...so were hoping for something more durable. We were looking at metal and were thinking that wouldn't work cause they're in the heat all day so some so it might get too hot or someone might be allergic to the metal in it. So, any suggestions would be great.

RESPONDENT: Anyway, like I was saying, if you could put some type of coating on the arms and just down the sides where the arms against the rib cage of the individual, I don't think so much the lower garment would be a problem.

RESPONDENT: Have you been to a field and actually...cause we're all trending towards harvest when we talk about that and I know you're talking about like maybe some hand applied succulent control product. There wouldn't be any other pesticide that should be in the field. We've got No Entry Rule and all that. But have you actually been out and observed? How new are you in this...?

PROMPTER: Not yet, we want to go and observe around august time so we're waiting for that right time to go.

RESPONDENT: So, one of the proposals we just often discuss is once we start to apply sucker control with our backpacks that would be a good time for them to see some of that and then also some machinery doing that and then after that will be harvesting.

RESPONDENT: But it needs to be something that deals with the absorption of the nicotine...is a bigger factor than the pesticide...that's our number one challenge from some of the critics of the industry...is about these health concerns...

PROMPTER: Is there anything else that anyone would like to add?

RESPONDENT: I mean it has a space age appearance to it like it's off star trek or something.

RESPONDENT: I mean it's close enough looking to linen that I think they'll be wearing it to Walmart on Sundays instead of in the field...

RESPONDENT: He's talking about himself wearing it...haha...

RESPONDENT: What would be the options for a detachable hood...that way if we needed to include that you could put it on there?

PROMPTER: What about color...or would you just use the natural hemp?

RESPONDENT: You're in a hot field...the lighter the better...

RESPONDENT: One of the things with the plastic caps or the plastic snaps...which you said this is not the final product...but if it was to get into the manufacturing if it was...with the color sorter...if it was a purple or something where the computer or eyes could see it…it would blow it out. Does not need to be green, yellow, red, or brown...or even black. It's gotta be really flashy...purple, blue, neon green, pink, etc...

You know what we are describing is the thrasher... a high-speed conveyor…

I would say that maybe your next focus group needs to be the purchasing side of the industry with regard to…?

You know there's plenty of sharp corners on a tobacco trailer or wherever around the farm. This things gonna get caught and ripped and wherever. So that's the next question...what's the strength on it? How rip or tear resistant is it?

PROMPTER: So, I tested it and it's a lot more tear resistant than I thought. I don't have the exact number off the top of my head ...

RESPONDENT: You say better than cotton?

PROMPTER: Yeah, way better than cotton. It basically...so when I did the tear test on it, it tore in the opposite direction that it was supposed to so it's very strong, it was resisting the tear a lot.

PROMPTER: What do you guys think of the weight of the fabric?

RESPONDENT: The thinner the better. The thinnest you can get it and still function. It does look a little bit heavy but it's not as...its heavier than it looks, but at the end of the day....

RESPONDENT: It'd be real heavy when its wet.

RESPONDENT: Yeah that's true, I hadn't thought about that.

RESPONDENT: You know, that pant may need to have a draw string in it because if it gets wet it's gonna try to travel down or as you go through the course of the day you might lose a couple of pounds out there on a hot day and all of a sudden your clothes are ..you know what I mean....you start off in the mornings snug and they end up loose, but I think that's the other thing too is you got to think about the umm...you need something, whether its elastic...idk if you make hemp and elastic on the sides...it's gonna need to be where it can fit a range of sizes...

RESPONDENT: Overall straps

RESPONDENT: Yeah, that might be pretty good...I don't know, I never worn many overalls and had those straps but....

RESPONDENT: They're comfy.

RESPONDENT: Yeah, well that might give you some flexibility on the size and all and you don't have to have just specific pants.

RESPONDENT: And you could actually if you did that and I'm just thinking outside the box/brainstorming...if you did that you could do away with the zipper.

RESPONDENT: Well I'll give you another too...on this jacket, you may want to think about making it a three-quarter length so ...is this waist length?

PROMPTER: It's hip length

RESPONDENT: What about the wash ability of it?

PROMPTER: Yeah, that's what we're testing next to determine how durable the finish and material is and how the water quality.

RESPONDENT: So, what I'm describing to you is...let's say were using it in harvest...and you hand prime and you're getting the bottom leaves...I might would wear one that came to here and may not wear the pants. So that's why I'm saying like a three-quarter rain jacket

PROMPTER: Oh, you're saying with a longer rain jacket

RESPONDENT: Yes. So, I might even wear it with short pants and hiking boots, work boot style...very red neck-ish but it's the way I roll. But I think try one of those models because it might provide options.

RESPONDENT: So, the dermal exposure from nicotine absorption is not really in the legs. Particularly, late season...it's in the forearms and I would argue probably right here in the rib cage region and armpit area.

RESPONDENT: There's a couple factors you got weather conditions like yesterday, very hot and humid and your pores are open, you know, nothings evaporating, probably dehydrated, little heat stroke...all tied in there together. You know those are all factors...when you move into the fall of the year that is what I always suffered chronically from green tobacco sickness...bothered me terribly...but I think it was as much as about 102 degrees and your hot, but you get to labor day...humidity breaks, temperature drops, you're standing upright priming tobacco...never get sick and the nicotine is highest in the top of the plant. Early in the stage…the nicotine percent is much lower and its very much less in the lower leaves so the theory that you're putting that leaf under your arm...now, do you build up tolerance?...but my personal theory belief is that it is as much to do with cooler temperature and being upright. Less humidity and you're not as wet. It's just not as hot.

RESPONDENT: I will share with you while you're looking at your next question...this concept is interesting because we've had discussions about this with industry critics for a number of years...developing a fabric that would repel and help....there's even been discussions about if you're left handed or right handed, it might be a smock that might have and opening on one side like an apron or welding apparatus type thing. Your back might be open to allow airflow.

RESPONDENT: Maybe put one on the top because you don't really have exposure in your shoulder. Get a little air…that might also give you a broader range of fit.

RESPONDENT: What's this going to cost? Did you say that yet?

PROMPTER: Not yet. So right now, without wholesale costing and getting it in bulk, it's about $120-150, but we predict that once we get it into mass production it will be about 50-60% less.

PROMPTER 2: We haven't even thought about distribution. Is this going to be purchased by the workers or is this going to be purchased by someone else? Is there a possible leasing or lending program? Is there a way of getting it all laundered together?

RESPONDENT: Your washable study in July will tell you a lot about that.

RESPONDENT: There are uniform companies out there where the truck comes by and drops off at the you know, so that might be the avenue that economizes it.

PROMPTER: Yep. So, we can go ahead and move on to the next question: So, if this were something that were worn and laundered on your farm, do you guys see any issues in laundering the protective garment? So, if it wasn't through a third party laundering system and you guys had to launder it based on what your current laundering system is right now?

RESPONDENT: They can just wash it like they wash the clothes, I guess.

RESPONDENT: I'd be willing to…I don't know…I don't know if that would need to be laundered as something separate. If it's that pesticide exposure on it. It could be a cost issue if you had to install a washer.

RESPONDENT: Yeah.

RESPONDENT: Mmhmm.

RESPONDENT: I wouldn't say that it'd be prohibited but it would be another cost.

RESPONDENT: Regardless of the fact...it's another cost that's passed onto the farmer that we're not able to re-coop at any level. But if it's a dollar a piece or 120$ a piece...it's still a cost not to mention the fact that even if you have to launder it...that we're not gonna get reimbursed for. So not to kinda shoot ourselves in the foot with this thing...if you don't have a market, there's no market for it, you can't sell it. And you can eat up a certain amount, but you can't eat 'em all. And that's the biggest thing moving forward. We've already hit on the fact that pesticide issue is not a big problem, at all, on our farms. We're already regulated and in a good way. Our employees are part of our family. We don't want them to get sick. We've got a lot of money invested. We're doing everything already to keep them from getting exposed. But there is an avenue to the Green Tobacco Sickness that this could come in, but at the end of the day this is cost that the farmers got to incur that we don't get paid for.

RESPONDENT: Is there CBD in this like you get a benefit after you wear it?

PROMPTER: Ha, unfortunately industrial hemp does not have that property.

PROMPTER: I guess how are your farmers laundering their clothing now? Do you have a wastewater treatment that you guys have to do or anything like that?

RESPONDENT: They launder their clothes now with just a traditional washing machine. They don't have pesticide exposure on those clothes. The protective gear they wear now is more or less vinyl plastic...I'm not exactly sure what...they may take a water hose and rinse it off occasionally but not on a daily basis. And a lot of times some of them not at all, but they're not doing it to remove pesticides to begin with. They're just trying to clean it up a little bit from where they've been wearing it...for several days in a row a lot of times.

RESPONDENT: So, from a nicotine standpoint...If you were to wash this thing…I don't think there would be any kind of special equipment need or any kind of concern. The only thing that I would question is once this thing gums up real bad that's going to be a mess. You can stand up in a corner and pressure wash it. It'd be like getting a wad of chewing gum stuck to this to some degree. I mean not that extreme, but you know once it gets on there, I don't know how you get it off. And that's why I think...

RESPONDENT: Hot water would be the only thing

RESPONDENT: Yeah, some kind of maybe less porous material, here, in that exposure area it might come off a little easier then where it can get intermingled with the fiber.

RESPONDENT: Yeah cause once that thing got gum on it…the breathability would be gone, more or less.

RESPONDENT: You just gotta field test it. Yep.

RESPONDENT: And you may want to bring a couple of different models. I don't know if you have time to do modifications in the next 6 weeks.

PROMPTER: Yeah, I think field testing would likely take place next season if we can get it...

RESPONDENT: Yeah, I've seen some employees feelin hot...like I asked you about the 3 quarters...they may cut the legs off at the knees and make shorts out of them.

PROMPTER: Do you think it would be beneficial to have a zipper option where they can remove the bottom part?

RESPONDENT: I think that's an expense.

PROMPTER: True.

RESPONDENT: Whether they're gonna make a capri out of it, I don't know...I think the range in size is gonna be a challenge. You know, you're gonna have a short, medium and tall and you're gonna have a small, medium, and large in each dimension. That's gonna be challenging. But I applaud the effort, we need it.

PROMPTER: So, I guess, that was the last question of this...is there anything else anyone would like to add that we didn't cover?

RESPONDENT: I think you need to have different variations. Use the same material although with the added protection for the arms and down aside the rib cage. Something like this with pants and jacket, but also something like the guy in the blue shirt was talking about...something three quarter length, just a jacket with no pants...because some workers prefer it one way and some prefer another. And some...if the only option they had was the pant and the jacket, they would just not wear the pants and just wear the short jacket which is not going to afford much protection from the waist to the knees.

RESPONDENT: Cost is the big issue...put a lot of effort into the cost.

PROMPTER: I guess, if you were to set a price for something like this, how much would you pay?

RESPONDENT: So, we buy our stuff from U-Line, which is a bulk producer of cardboard boxes and stuff, somewhere between 7 and 9 dollars is what I can buy suits for work.

RESPONDENT: Now that's considered disposable, right?

RESPONDENT: Exactly.

RESPONDENT: Like the White coveralls you see somebody wear down the utility lines and sometimes painters use it and they just throw it away when they're finished.

PROMPTER: Do you think that whoever we would market this to they would be willing to pay a little bit more that's a little bit more durable and reusable versus something you just throw away after using it once and not having to keep on buying a new one every time?

RESPONDENT: Me personally, yes. If I can take it home and clean it for my purposes…that's just less waste I am generating and less money down the drain, but again that goes back to how durable is durable? You know, can I wash it 10 times or can I wash it 50 times. I mean, I think 50 is probably stretching it, but 25...

RESPONDENT: If it can last a season all season long.

RESPONDENT: If it's 25-30$ you might as well have it, but if it's gonna be $100...people have 20 workers, you know, that adds up.

PROMPTER: And how many days would the season be?

RESPONDENT: Oh gosh, anywhere from the middle of June to October. It'd be a good four months, yeah.

PROMPTER: If no one has anything else to add that is the end. Thank you so much for your time. We really appreciate you giving us feedback.