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Project Title: Melon Cover Cropping: Retailer Acceptance and Microbial Quality of Non-Washed Fruit

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Problem Outline:

The cantaloupe industry has faced several high profile human pathogen outbreaks traced to production practices, handling and packinghouse environments. Modifying in-field production practices to reduce or eliminate water during eastern melon handling is a critical need. The need for washing has been justified due to the potential for soil splashing onto fruit during rainfall events. The inability of sanitizers used within the melon wash line to eliminate surface microorganisms and to stop cross-contamination with pathogens like *Listeria monocytogenes* and *Salmonella spp.* coupled with the added costs of monitoring and maintaining these systems (water pH, disinfectant concentration, water turbidity (< 20 FAU) within the tank) have all contributed to increases in the risk of human pathogen outbreaks and illnesses. Eliminating the need to wash fruit could increase profit margins within the industry without increasing the risk to consumers. This study modified current melon preharvest production practices in eastern melon production by introducing a simple, cost-effective strategy to reduce soil splashing onto melon fruit during rain events. Cover crops (sunn hemp, buckwheat, and mustard) were grown beneath melon fruit and tested to see whether this simple practice can reduce the microbial load and potential presence of human pathogens from the surface of melons while impacted by these rain events. This practice may provide a new approach to grow melons in this region with reduced soil contamination and eliminate the need for washing lines within postharvest environments. Retailer perceptions of this new technique were measured and evaluated in addition to postharvest and economic analysis of these new practices.

Approach:

Background:

Melons, including cantaloupe, honeydew, and other mixed specialty melons are a major horticultural crop in the United States. Eastern melon production accounts to roughly 30% of the total national production of this fruit while California (60%) and fruit imports (10%) control the remaining 70% (NASS, 2011). Over the past decade, melons have been implicated on numerous outbreaks of foodborne illness and recalls due to *Salmonella enterica* and *Listeria monocytogenes.* Most of these events have been linked to cantaloupes where the netting structure of the fruit surface and several industry practices and/or scenarios (washing, soil amendments and animal intrusion) have been linked to contamination (CDC 2002b; Munnoch et al, 2009). As a result, the U.S. Food and Drug Administration (FDA) have classified cantaloupes as risky for microbiological food contamination.

Commodity Specific Food Safety Guidelines for the Melon Supply Chain (PMA and United Fresh, 2005), FDA Guide to Minimize Food Safety Hazards of Melons (FDA 2009) and the Guidance on Environmental Monitoring and Control of Listeria for the Fresh Produce Industry

(United Fresh 2013) describe the hazard analysis and practice-based risk reduction procedures identified as key components within melon production systems. One clear knowledge gap within these guidelines is specifically linked to Eastern production practices where the development of practical and sustainable agronomic practices to reduce melon fruit contamination with soil, plant and other debris caused by splashing during short but intense rain events is needed. Current melon processing conditions in the East Coast involve washing and disinfection steps that rely on proper management oversight of water quality, packinghouse cleanliness and disinfectant efficiency during fruit washing. Reducing or eliminating this step within the melon production system not only could reduce costs of melon production and reduce postharvest water use but also increase the safety by reducing cross-contamination events during handling, washing and drying of the fruit.

Melon production, packinghouse environments and risks for Listeria

Listeria monocytogenes (LM) is a foodborne bacterial pathogen associated with severe disease (listeriosis) in individuals at risk (pregnant women, the elderly, and those undergoing immunosuppressive treatments or otherwise in immunocompromised states). Listeriosis is accompanied with a severe symptoms (stillbirths or abortions, meningitis, septicemia) and a high fatality rate of 16-22%, even with appropriate antibiotic treatment (Scallan et al., 2011; CDC, 2013). In 2011, the largest outbreak of listeriosis in the United States involved contaminated whole cantaloupe (McCollum et al., 2013). FDA's environmental assessment following the outbreak revealed that contamination of the equipment and environment in the packing house was responsible for the contamination of the fruit. Several equipment and environmental samples were positive for the outbreak strains, whereas samples from the field (e.g. soil) and the melons preharvest were negative (FDA, 2011).

LM is well known for its remarkable ability to colonize food processing environments and equipment and to persist there, sometimes for decades (Kathariou, 2001; Gandhi and Chikindas, 2007; Kornacki and Gurtler 2007; Carpentier and Cerf, 2011). Outbreaks of listeriosis typically involve food products that become contaminated postharvest though exposure to contaminated processing environments and equipment. This attribute of the pathogen clearly highlights the key role of adequate cleaning, sanitation and microbiological monitoring of the postharvest environment and equipment. However, it also highlights opportunities to avoid contamination by strategically minimizing exposures of ready-to-eat commodities to potential sources of LM in the processing environment.

In the case of whole melons, the water used for washing the fruit in the packing house represents a potential vehicle for LM cells that may have colonized the postharvest environment or that may come from preharvest operations. Washing used to remove soil and other debris and to thus enhance market appeal of the melons also has the potential to mobilize LM from various harbor sites in the equipment and the environment which in turn provide pathogen access the surface of the fruit. It has been well established the limitations of commercial disinfectants to effectively reduce the population of many human pathogens including LM due to many factors including access to protected site, inappropriate levels of disinfectant, insufficient contact time or innate resistance of the pathogens that allows them to remain viable within the surface of the fruit and later replicate under permissive storage temperatures or

handling practices. Once on the surface of the fruit LM or any other pathogen can be transferred from the surface to the edible portion of the fruit during cutting. Predictive modeling data suggest a significant potential for growth of LM on cut melon (Danyluk et al., 2014). Based on such evidence, we hypothesize that avoiding postharvest washes of the melons may reduce risk for contamination by LM. We propose to assess the potential of several preharvest practices to obviate the need for postharvest washes without increasing the risk of farm-level contamination of the melons with *Listeria*.

The use of cover crops in melon production systems

Cover cropping practices within organic or conventional farming systems aim to increase soil organic matter through the addition of plant biomass while reducing erosion and water runoff by increasing soil stability via aggregate formation (Langdale et al., 1991; Kuo et al., 1995; Wyland et al. 1996, Lu et al., 2000;). The use of cover crops in melon production systems has been explored extensively to improve soil health, N content and decrease the need for synthetic fertilizer applications (Bhardway, 2006 and Singogo et al. 1996). Cover crops like Buckwheat, Sunn hemp, Lupin, and hairy vetch have proven to successfully improve growing conditions and yields of melons and watermelons grown under intense agronomic practices (Rangappa et al. 2002 and Bhardway, 2006). Buckwheat and Sunn hemp have also been used to control cucurbit fruit fly and cucumber beetle infestation and to reduce root rot nematode pressure in melon cropping systems (Kuo et al. 1996; Cline et al. 2008; Jacquemart et al. 2008; Hinds and Hooks, 2013). Root rot nematode control; mainly associated with sunn hemp, has been correlated with the liberation of Pyrrolizide alkaloids through root exudates or from decaying leaves and stems after mowing the cover crop (Wang et al., 2002; Marahatta et al. 2010 and Marahatta et al., 2012). All these beneficial properties attributed to the cover crops listed before have been observed prior to melon or cucurbit production, but none of them have been used concomitantly along the melon cropping cycle.

Rainfall events during the East coast melon production season are common and periodically splash the fruit with soil and other debris. This situation has been cited by West Coast melon producers as both reducing fruit quality and increasing risk. This anecdotal marketing strategy has negatively impacted eastern melon marketability and given rise to need to wash melons after harvest. Numerous studies have shown an increase in the risk of pathogen contamination and in the populations of background microflora on melon fruit surfaces after washing (Gagliardi et al. 2003, Johnston et al., 2005 and Akins et al. 2008). Recently Dr. Gutierrez had the opportunity to collaborate with the Suslow Lab at UC-Davis, CA looking at the distribution of generic *E. coli* on melon fruit surfaces and in soil (See section (9) Appendix Figures: Figures 2 and 3) in close proximity to the fruit. From his evaluations he was able to determine a significant gradient in the populations of generic *E. coli* present in soil (populations varied between Log # and 5 CFU/g soil) within a 60m gradient within the field. However populations of this same microorganism within the melon surface remain stable across the gradient at around Log 4 CFU/g melon peel (Figure 1, appendix) suggesting that exposure to arid conditions and dust was influencing the populations of generic *E. coli* instead of the actual population of this microorganism in soil in close proximity to the fruit. Under our experimental conditions we look to grow melons concomitantly with Buckwheat, Sunn hemp and mustard. By following these practices we mainly look to provide ample field coverage to allow the fruit to rest under a

green cover crop blanket instead of resting on bare soil. These conditions will provide protection against soil and plant debris splashing on top of melon fruit surfaces eliminating the need to wash the fruit.

Objectives:

This project looked to determine and establish an alternative method for melon production in NC that is both applicable to other production regions within the southeast United States and capable of reducing soil/plant residues, total microbial load and the potential presence of LM that originates during rain splashing.

Objectives List:

1. Preharvest Practices in Field:

   1.A - Describe the preharvest (soil, water, fruit) and postharvest (shelf life studies) microbiome of cantaloupe melons grown in cropping systems with and without the presence of row cover crops (buckwheat, sunn hemp and mustard).

   1.B - Survey melon microbiome, fecal indicators, and the prevalence of *Listeria spp* and *L. monocytogenes* during the cropping cycle within the proposed cropping systems.

   1.C - Evaluate the postharvest shelf life of melons grown in these systems to determine any impact on shelf life and holding times.

2. Retail Acceptance: Evaluate retailer risk perceptions and acceptability of non-washed melons in the retail environment, the gatekeepers of the consumer world.

3. Economic evaluation: Assess the economic viability of netted and smooth skin melons that have not be washed prior to delivery to the point of sale through the use of cover cropping methods in the preharvest environment.

Rationale and Significance

The increased presence and prevalence of human pathogens in fruits and vegetables is undermining industry and federal efforts to promote healthy eating habits in our country. Numerous foodborne outbreaks linked to melon fruit contamination with various *Salmonella enterica* serotypes and with LM have reduced the confidence of consumers and federal agencies in the ability of the agricultural industry to provide safe melons to consumers. Such events highlight the need to identify intervention strategies at the preharvest or postharvest level that can reduce pathogen contamination. Melon production, handling and packing practices vary between Western and Eastern producers; field-packing (West) vs packinghouse (East) practices and field humidity drive the major operational differences between regions. These inherent differences between regions create varying microbial (human pathogen) risk hazards within each location that have pushed the industry to adopt different handling and processing practices based on unknown hazards. In Eastern melon production, washing, sanitizing and sizing of melon fruit within the packinghouse represents the greatest risk of cross-contamination due to the high volume of fruit and water used during these operations. The rationale behind the use of packinghouse facilities (washing and disinfecting fruit) is linked to humid growing conditions and sporadic but intense rain events that may splash the fruit with soil, plant and other debris.

Consequently, modifying current Eastern melon production practices to conditions that can reduce rain/humidity related contamination events may eliminate or reduce the need to use water within the packinghouse or even yield melons that lend themselves to field packing.

Our research efforts focused on determining the background microbial load and composition, the presence of fecal indicator microorganisms and the potential presence of *Listeria spp.* and LM on melon fruit grown with and without the presence of row cover crops within the preharvest environment. Melons were harvested and their microbial safety and quality were determined during standard postharvest storage conditions. The retailer's risk perception and acceptability of the fruit and the economic viability of this new practice were assessed along the preharvest to postharvest continuum of the fruit. Our extension efforts (presentations, research updates, and workshops) were driven by our research goals and were crafted based on industry needs and concerns.

Cantaloupe melons were grown on a commercial field and a research station farm with and without the presence of three independently grown cover crops: buckwheat, sunn hemp and mustard. Each cover crop was grown for a period of 35 days. The cover crop was mowed and sections of the field were minimally tilled and prepared following standard commercial melon practices (bed formation, drip irrigation and bed plastic coverage). A portion of the field remained without cover crop and used as our control. Melons were harvested and followed along the preharvest to postharvest continuum to determine the microbiological characteristics of the fruit and the packing-line.

Approach and Experimental Setup

This project focused on growing cantaloupe melons following commercial agronomic practices (drip irrigation and plastic covered beds) with one simple but important modification. We included, along the cropping cycle, the presence of 3 different cover crops (buckwheat, sunn hemp and mustard). Each cover crop was grown for a period of approximately 35 days. The cover crop was mowed and sections of the field were minimally tilled and prepared following standard commercial melon practices (bed formation, drip irrigation and bed plastic coverage). In addition to providing a physical barrier to soil-to-fruit contact, these cover crops possess unique soil health benefits and may attract pollinators and beneficial insects within a short but robust growing season. A portion of the selected fields followed standard growing procedures and not receive any cover crops. It served as the grower control standard. Once melons were harvested the microbial diversity and composition on melon fruit surfaces as well as, the presence of fecal indicator microorganisms and the presence of *Listeria* spp. and LM was determined. Two locations (Salisbury Research Station and a commercial farm) were selected to test our experimental approach. These locations were located within two of the major growing regions for melon production within the state of NC.

Results and Discussion:

Objective 1.A: Preharvest Practices in Field and Objective 1.B: Melon Microbiome

A total of 6 experimental plots were established at three different locations (Kinston, NC, Raleigh, NC and Salisbury, NC). Between each experimental plot there was a 40 day window from sowing seed within each growing season. Each sampling plot was between 0.7 and 1.5

acres; all of them following a complete randomized design with 3-4 replicates per treatment. Treatments consisted on the presence or absence of a specific cover crop (Buckwheat, Sunn Hemp or Mustard) all with the same cantaloupe cultivar (Athena) and in Raleigh and Salisbury Honeydew melons were also grown. Soil samples were collected before bed preparation, 10 days after sowing and right before harvest to determine the presence of indicator microorganisms, STEC, *Salmonella* spp. and *Listeria monocytogenes*. Cover crops were sown either prior bed forming or 10-15 days before planting. Due to adverse weather conditions (extreme heat and no rainfall) sprinkler irrigation was used on all experimental plots before, during and after cantaloupe sowing for a period of 30-45 days to allow cover crop establishment. Despite these efforts in some experimental plots only marginal row coverage was possible. The best coverage was found in the mustard cover crops. An alternative approach was established to compensate for these difficulties experience with this cover crop and included the following procedure: 1- Field preparation (fertilizer and insecticide control), 2- Bed formation and placement of plastic cover (month of October), 3- Broadcast winter ryegrass in between beds with sprinkler irrigation for up to 1 week, 4- Allow winter ryegrass to grow and reach an maximum altitude of 1.2m (early April), 5- Herbicide applications followed by vegetation rolling (April) and 6- Cantaloupe planting (Late April/early May).

Fruit from all 6 experimental plots was harvested at full physiological maturity and at the half to full slip stage. Melon fruit resting on the plastic bed was separated from fruit resting on top of the cover crop. In general, over 75% of the fruit was found to be on top of the plastic row cover when in-row spacing was 46cm while over 62% were resting on top of the plastic row cover with in-row spacing of 61cm. These differences were specific to in-row spacing and consistent across commercial practices and varied between growers depending on plot size and the desired planting density they could vary between 3500 and 5500 plants per 0.4 hectares. Under our experimental conditions over 70% of the fruit was resting on top of the plastic row cover, 15-20% was hanging/resting on the edge of the plastic bed and soil and the remaining fruit was resting on soil or cover crop (Obj. 1A&B. Figure 1).

At harvest, each fruit was hand harvested using sterile gloves and placed inside a 4G whirl-pack bag, labeled as needed (cover, no-cover, plot location, time) and each bag was placed inside a cooler with ice-packs and transported back to the laboratory facilities for further processing. At the laboratory, cantaloupes were stored inside refrigerated units (5-11 °C) for a period of 24-48h before processing. One portion of the fruit (around 120-165 fruit) were used to enumerate background microflora and the presence of *Salmonella*, STEC and *Listeria monocytogenes* while another portion was stored under refrigeration for 7 or 15 days. After each storage time point around 60 to 80 fruit were removed from cold storage and bacteria enumeration and pathogen detection was performed as described below.

Sterile gloves were used to harvest each fruit to avoid cross contamination during harvest. Fruit were field packed into clean, new, cardboard, commercial melon packing boxes. These boxes (totaling 192 melons) were transported and held at 4 °C. Cantaloupe melon peels were separated from the fruit using a knife disinfected with Oxivir® TB (Diverse Care, WI) and transferred to a sterile bag containing 100 mL of potassium phosphate supplemented with 0.05% Tween 20. Samples were vigorously massaged and shaken by hand for one minute followed by a 20 min sonication step to detach bacteria. A 10ml aliquot was transferred into a 15 ml sterile centrifuge tube for quantification of coliforms, generic *Escherichia coli*, *Enterococcus* and aerobic plate

counts (APCs) using Chrom-ECC agar, M-*Enteroccocus* and Trypticase soy agar (TSA), respectively, and incubated at 42 and 37 °C for 24h. The remaining wash suspension was centrifuge and the pellet was used for DNA extraction using the PowerLyzer ®Soil DNA isolation kit (Mobio, Carlsbad, CA). Quantification of *Enterococcus* for peel, soil, water and packing line surfaces was performed by qRT-PCR as previously described by Haugland et al. (2005).

For *Listeria* spp. detection, the FDA Bacteriological Analytical Manual (BAM) protocol was employed using 25 ml of the buffer-Tween 20 rinsate, as described (Azizoglu et al., 2014). Putative *Listeria* spp. colonies from the selective agar plates Modified Oxford Agar (MOX) were sub-cultured on blood agar media and several hemolytic colonies (putative LM) were characterized via PCR to determine serotype designations (Lee et al., 2012).

Soil samples were collected in and around the location where cantaloupe and honeydew melon fruit were harvested. A total of 12 locations within each plot were sampled following a Z patterned (Gutierrez-Rodriguez et al., 2011). The sampled locations were pooled, mixed and sieved through a 4 mm mesh. A total of 32 pooled soil samples each year were collected per 2-acre plot at harvest (16) and after planting (16). From the sieved material, 150g of soil were mixed with 0.2 M of sodium phosphate supplemented with 0.05% of Tween 20 at a 1:2 ratio (v/w) to create a bacterial suspension after hand homogenization for one minute. The entire supernatant was transferred to a new sterile bag and used to quantify total coliforms, *E. coli* and *Enterococcus* spp as described previously. From the same sieved soil 0.35g of soil will be used to extract DNA. Bacteria quantification and DNA extraction will follow the same procedures described before. For *Listeria* spp. detection, the FDA BAM protocol was employed as described above using 25g of soil from the sieved material. Identification of putative LM colonies and serotype determinations was done as described above.

The Kinston, NC farm was located within one the major cantaloupe growing regions in North Carolina. Soils in this area tend to be Wagram loamy sand, with over 80% of sand within the first 50cm of the soil profile. The population density and distribution of *enterococci* and *coliforms* after cantaloupe bed forming was similar between all locations. The average population of *enterococci* was 2.9 Log CFU/ 150g of soil while for *coliforms* it was 4.2 Log CFU/150g. Significant variability in the population of both indicator microorganisms was observed between samples as described by standard deviations in the range of 1.2 Log CFU/150g of soil (Obj. 1A&B Figure 2). No generic *E. coli* was recovered from soil after bed formation.

The population of these same indicator microorganisms increased by 1.7-fold after 90 days of cantaloupe cultivation (Obj. 1A&B Figure 3). During this period of time water was applied via sprinkler irrigation during the first 35 days of the cropping cycle to allow cover crop establishment. During the remaining 55 days water was only applied via drip irrigation to cantaloupe plants. During this other sampling event, generic *E. coli* was recovered from two locations where no cover crop was present between beds. At these two locations bare soil or a combination of bare soil with a small number of dry weeds was the only cover present between beds. This cantaloupe season had atypical weather conditions. Less than 0.5 inches of rain fell throughout the entire season. The lack of rain, coupled with the intrinsic soil properties of the

region made growing conditions suboptimal for the selected cover crops. Despite these limitations soil coverage was present between beds although not all came from the sown cover crops, due to a combination of weeds and the planted covers.

Within this experimental location a total of 300 fruit were harvested from the field at full to half-slip maturity. This fruit corresponded to roughly 50% of the total fruit available in the field. The remaining fruit was left in the field for the grower to use for commercialization purposes. The population of indicator microorganisms was determined 36h after harvest. The overall population of aerobic bacteria was identical between cantaloupes grown with and withinout any of the selected covers crops. *Enterococci* and *coliforms* were found in all fruit samples irrespective of the presence or absence of cover crops with average populations of 4.9 and 5.9 Log CFU/fruit respectively (Obj. 1A&B Figure 4). Generic *E. coli* was also recovered from all sampled fruit with an average population of 2.5 Log CFU/fruit. The distribution of generic *E. coli* was similar among all cantaloupe fruit collected from locations with and without cover crops (Obj. 1A&B Figure 4).

The Raleigh, NC farm is located within one of the NC State research stations. Soils in this area tend to be Cecil gravelly sand, with 65% of sand within the first 50cm of the soil profile. The population density and distribution of *enterococci* and *coliforms* after cantaloupe bed forming was similar between all locations. The average population of *enterococci* was 1.7 Log CFU/ 150g of soil while for *coliforms* it was 3.5 Log CFU/150g. Generic *E. coli* populations were on average 1.3 CFU/150g of soil across all locations. The distribution and overall population of these indicator microorganisms did not increase significantly during the cropping cycle where populations of both indicator microorganisms remained at 2.1 Log CFU/150g and 3.9 Log CFU/150g of soil.

There were also no differences in the populations of aerobic bacteria, *enterococci, coliforms* and generic *E. coli* from fruit grown with and without the presence of a cover crop. At this location there were less issues with seed germination and cover crop establishment due to higher water holding capacity of the Cecil soil type as compared to the Wagram soil type. At this location, there was a small significant difference between the population of *enterococci, coliforms* and generic *E. coli* recovered from fruit grown with the presence of a cover crop when compare to those with bare soil (Obj. 1A&B Figure 5). At this location there was also less the 0.3 inches of rain throughout the entire growing season making impossible the comparison between the microbial population of fruit before and after rain events in the presence and absence of cover crops. Despite these limitations an important difference in the population of indicator microorganisms was observed within our first trial.

The postharvest quality of cantaloupe was also evaluated from a small number of fruit collected from this experimental plot. Cantaloupe fruit were harvested at half to full slip maturity. A total number of 20 fruit were evaluated at harvest and 7 days after harvest stored at 25 and 11 °C. No significant differences were observed in the sugar content of the fruit stored at these two temperatures and coming from fruit grown with or without the presence of a cover crop (Obj. 1A&B Table 1). The acidity/alkalinity (pH) of melons was also determined during storage. No

significant differences were observed in the acidity of the fruit stored at these two temperatures and coming from fruit grown with or without the presence of a cover crop (Obj. 1A&B Table 2).

The microbial quality of cantaloupe fruit was also evaluated during storage (Obj. 1A&B Table 3). Melon fruit were stored at 25 and 11°C inside secondary containers with a lid to avoid moisture loss. Inside each container moist sterile paper towel was placed at the bottom of the containers while the melons rested on top of a mesh-stand that allowed separation between the fruit and the moist paper towels. Overall there was an increase in the APC and *enterococci* populations during 7 days of storage while the population of *coliforms* and generic *E. coli* remained similar to harvest conditions. All fruit had an overall visual quality score greater than 3 (scale: 1-poor, 3-marketable 5- excellent).

The Salisbury, NC farm is located within a major vegetable and row crop growing region in North Carolina. Soils in this area tend to be Dorian fine sandy with 75% sand, 10% clay and 15% Silt within the first 50cm of the soil profile. The population density and distribution of *enterococci* and *coliforms* after cantaloupe bed forming was identical between all locations and corresponded to Log 4.6 and 4.7 CFU/150g; while the average population for generic *E. coli* was Log 3.1 CFU/ 150g. At this location variability in the population of soil indicator microorganisms was small and in the range of 0.5 Log CFU/150g of soil.

The microbial quality of cantaloupe fruit was also evaluated during storage (Obj. 1A&B Table 4). Melon fruit were stored at the same refrigeration temperatures as other fruit coming from the Raleigh or Kinston experimental plots for up to a period of 7days. Overall there was a decrease in the APC and *enterococci* populations during 7 days of storage while the population of *coliforms* and generic *E. coli* remained similar to those estimated at harvest. Average populations for coliforms and generic *E. coli Log 6.4 CFU/fruit (+/- 0.2) and Log 0.7 CFU/fruit (+/- 0.14) respectively*. All fruit after 7 days of storage had an overall visual quality score greater than 3.5 (scale: 1-poor, 3-marketable 5- Excellent).

The presence of *Salmonella spp., STEC and Listeria monocytogenes* was also determined from fruit collected at this location. In general, none of the fruit and soil tested positive for *Listeria monocytogenes* while a small but significant number of fruit at harvest and during storage had presumptive positive samples for *Salmonella spp. and STEC* (Obj. 1A&B Table 5 and 6). When testing the interactions between treatments it was determined that there was a significant effect of cover crop and storage temperature on the population of STEC in cantaloupe fruit, while for *Salmonella spp.* the only significant effect was the presence or absence of a cover crop. Prob > Chi Square was equal to <0.03. p value for cover crop effect was 0.01. No significant differences were found for time (0.28) and fruit type (0.53). N= 38 for no-cover crop and sunhemp and N=42 for buckwheat and mustard cover crop

For *Salmonella spp.* the highest number of presumptive positive samples were attributed to mustard and sunn hemp cover crops. Both of these crops had marginal plant set and greater vegetation decay when compared to the no-cover control and buckwheat plots (Obj. 1A&B Table 5). Contrary to *Salmonella spp.* the number of presumptive STEC positive samples was similar between no-cover control and mustard and significantly lower than buckwheat and sunn

hemp; both of them with similar percentages of positive samples for this pathogen at harvest. During storage, the number of presumptive STEC positive samples significantly increased from harvest and in some instances this increase was 3 to 6-fold higher when compared to initial assessments (Obj. 1A&B Table 6). This increase in the population of pathogenic microorganisms during refrigerated storage was not observed for *Salmonella spp.*

Overall this set of experiments suggest the following overall conclusions for Objective 1A&B: 1- There are few significant differences in the culturable microbiota between fruit grown with and without cover crops; 2- The presence and persistence of pathogens in soil and on the fruit is site specific; 3- *Listeria monocytogenes* was not isolated from any fruit or soil samples collected at any of the selected sites; 4- High or low levels of generic *E. coli* were not associated with the presence or absence of a human pathogen; 5- Successful use of the selected cover crops had important weather related challenges that prevented full cover crop establishment during the growing season.

Objective 1.C: Postharvest shelf life studies

Cantaloupe were collected from three production areas in 2016 and were grown with cover crops of control (C), buckwheat (B), sunhemp (S) or mustard (M). Most fruit were ripe to very ripe and measured, but not further stored. Those from the commercial grower field location were sorted and fruit that were not very ripe, which could be stored, were held for a week at 4 C and 80% relative humidity. Regardless of storage all fruit were weighed individually and length (blossom to stem end) and diameter were determined. Melons were cut through the ground spot and color readings taken at stem and blossom end and at the points half-way between them. A Konica-Minolta CR 400 colorimeter using C color space was used to collect color data in L*a*b* Hunter values. Firmness (resistance to penetration) readings were taken on the opposite melon half at the same locations as color readings. A Wagner force gauge (FDIX) equipped with a 3/8 inch probe and 25 lb module was used to collect maximum force (N). A sample of melon flesh was then cut from the fruit and frozen for soluble solids content (SSC), pH and beta carotene content. A digital refractometer (Atago Pal-1) was used to determine % soluble solids content and pH determined with a Hach pH meter with a stainless steel probe electrode on the thawed and pureed flesh samples. Beta carotene was extracted with acetone:hexane:ethanol and absorbance determined at 450 nm using a spectrophotometer (Shimazdu UV 2120).

When averaged across all locations, n cover crop (treatment) differences were found among the variables measured for the cantaloupes postharvest (Obj. 1C Table 1). Melons from the mustard treatment were heaviest. This treatment also produced the longest average melon length. The melons from the buckwheat treated plots had the most beta carotene, when averaged across study locations.

Cantaloupes from the Kinston, NC growing location were stored for one week at 4C. Following storage, quality of these melons was also evaluated as above (Obj. 1C Table 2). Cantaloupes

stored for one week were lighter (L), and had lower soluble solids content (SSC). In addition, the phytochemical content also dropped during storage. This was shown in the lower beta carotene values following storage, compared to those evaluated prior to storage.

Melons were evaluated by their individual growing location, though few treatment differences were detected (Obj. 1.C Table 3). Melons from the Piedmont Research station and Kinston, NC growing locations were firmer than those grown at the Raleigh, NC Field Lab location. This was true for all cover crop treatments. Melons from those two locations were also somewhat higher in soluble solids content across cover crops, with the exception of the sunn hemp cover, which resulted in slightly higher soluble solids than the piedmont location.

Melons were also evaluated for their color and phytochemical (beta carotene) content within each production location (Obj. 1C Table 4). Locational differences were detected in these phytochemical parameters. For example, melons from the Piedmont Research Station production location were consistently highest in beta carotene, regardless of cover crop treatment. Chroma was also highest in Piedmont melons, reflecting the deeper orange yellow color that is associated with more beta carotene.

Objective 2: Retail Acceptance

Concurrently with evaluating different strategies to explore whether eliminating the requirement for washing Eastern cantaloupes is possible, an investigation of retailer perceptions towards these steps was carried out. It was important to measure the acceptability of non-washed melons in the retail environment as this group is the gatekeeper to market and represent the hurdle to potentially reducing risk. Significantly, and the driver for this project, retailers have expressed that there currently is a tradeoff between managing excess soil in the retail store and requiring producers to conduct an activity (washing) that introduces additional risk into the product.

When communicating to retailers about food safety risks, targeting a specific audience and providing information in context for individuals, have both been shown to be an effective strategy, and have resulted in actual, observable behavior changes (Chapman et al., 2010). Leventhal and colleagues (1965) demonstrated the importance of providing context in a study of risk communication materials. Schein (1993), found that creating dialogue and generating discussion between a team is a necessary condition for teamwork and working towards shared values. Generating dialogue has also been shown to promote collective learning and impact collective intentions within a group, which can be precursors to changing behavior (Ajzen, 1991; Bohm et al., 1993; Dignum et al., 2001). In the food safety context, Pragle and colleagues (2007) found that a lack of knowledge of consequences of not practicing specific food safety practices was a barrier to self-reported behavior change.

Evaluating market acceptance to gain an understanding of how retailers measure risk versus the additional cleaning and sanitation at the store level. Targeted messaging to retail decision-makers through a telephone survey was administered to food safety program decision makers and category buyers within the retail environment. Data generated from Objective 1 were used

helpful in identifying with list of risk ranking questions which were administered through a semi-structured mixed-methods survey. A cohort of 40 national and regional chains was identified and this group made up the sample population. Support letters from two progressive national retail chains, Delhaize America and Publix were obtained for this proposal and each company volunteered to help the evaluation portion of the project.

Participants for the survey were chosen based on their employment and involvement with the International Association for Food Protection (IAFP). Recruitment began by identifying the largest retail and wholesale chains by total sales. Retail and wholesale chains were chosen based on three criteria: they sold products directly to the public at retail or wholesale, had a significant number of stores in the United States, and were likely to sell fresh produce. IAFP members employed by these companies were then identified using the IAFP membership directory. Twenty individuals were chosen based on their employer and familiarity with the company's produce handling procedures. Individuals were then emailed with requests to take the survey over the phone or online through SurveyMonkey, with all participants choosing to take the survey online. Results were analyzed using the built-in analysis tools provided by SurveyMonkey as well as Microsoft Excel. In total, 8 individuals participated in the survey.

The survey results indicate that cantaloupes are seen as a moderate to high risk product (Obj. 2 Figure 1). Participants were asked to rank the safety of various products on a 5-point scale, with 1 being low risk and 5 being high risk. Cantaloupes, rated as a 3.875, have recently been implicated in fatal outbreaks of foodborne pathogens, as have tomatoes, rated as 3.375, which likely explains the higher risk perception. Cabbage, rated at 2.875 has recently been linked to several outbreaks of pathogenic *E. coli* but these outbreaks did not reach the scale of the outbreaks of cantaloupes or tomatoes. Similarly, sweet potatoes, rated a 2, are rarely linked to foodborne illness, which likely explains the perception of lower risk. Eastern and western cantaloupes were seen to have a similar risk, being rated 3.875 and 3.5 respectively. This follows the geographic distribution of many of the outbreaks of foodborne illness. Western cantaloupes are largely considered to be grown in California, Texas, and southern Arizona (Shellie & Lester, 1996) while eastern cantaloupes are grown outside of these areas.

The two largest cantaloupe related outbreaks, the 2013 Chamberlain Farms *Salmonella* outbreak and the 2011 Jensen Farms *Listeria* outbreak took place in Indiana and Colorado, both involved eastern cantaloupes. Investigations into both of these outbreaks were linked to improper washing techniques and a lack of sanitizer used in wash water. Washing had significant effect on the perceived safety of cantaloupes, with unwashed cantaloupes given a risk of 4.25 compared to unwashed cantaloupes rated as a 3.125 (Obj. 2. Figure 2). While washing can reduce pathogen levels in some fresh produce, the netted rind of cantaloupe makes conventional washing techniques largely ineffective (Walsh, Bennett, Mahovic, & Gould, 2014). In addition to a lack of reduction, pathogens located on the rind of the cantaloupe are capable of transferring in rinse water if not properly chlorinated (Parnell, Harris, & Suslow, 2005).

Eastern cantaloupes are more likely to be washed due to the higher amounts of field dirt on the rind compared to western cantaloupe. All eight (100%) participants stated that washing may increase the risk of foodborne pathogen contamination if done improperly (Obj. 2 Figure 3).

However, six (75%) claimed that their employers required cantaloupe suppliers to provide washed product (Obj. 2 Figure 4). Five of the eight (62.5%) said that they have changed cantaloupe washing guidelines after recent outbreaks. Retailers were found to follow different guidelines for washing, some following 3rd party standards such as GFSI, while others followed the FDA guidelines for cut melon or simply requiring sanitizer use (Obj. 2 Figure 5. Five (75%) required the use of sanitizers in the rinse water (Obj. 2 Figure 6).

When asked if the retailer had different washing specifications for whole cantaloupe sold versus cutting in the store, six (75%) stated they would wash before fresh cutting (Obj. 2 Figure 7). Interestingly, when asked about where in the distribution chain cantaloupes should be washed, while the majority said by the supplier (5 respondents), the packing house and "ideally the consumer" were also mentioned (Obj. 2 Figure 8).

These results show that washed cantaloupe is perceived to be a safer product than unwashed cantaloupe. The majority of participants require that suppliers provide washed product despite the belief that improper washing can increase the risk of foodborne pathogen contamination. This indicates a need to better educate retail food safety specialists on the risks of washing cantaloupes and post-harvest handling practices. This could include education on appropriate sanitizer use as well as alternative methods to deal with field soil.

Objective 3: Economic impact of cover crop use in field production system.

A baseline of economic costs was established for the test plots using industry standard production and harvesting practices. This figure was used as a point of reference to establish the gain or loss of income associated with the proposed mitigation strategies. Both pre and postharvest activities were evaluated in order to determine if the proposed strategies are financially feasible for the producer. For example, utilizing a cover crop may make it possible to eliminate the need for water during postharvest but may potentially increase preharvest water use that exceeds the industry standard of one inch per week during growth (Mossler, 2012). A net increase/decrease in water consumption can be identified as one variable in deciding if this mitigation strategy is cost-effective for producers. Other variables to consider include the cost of seed, labor, materials, and equipment. A cost-benefit analysis incorporating each of these variables allows us to evaluate the overall impact of the mitigation strategies on the producer's bottom line (Gittinger, 1982).

Three production areas were used in the layout of the study. Out of the three, The Piedmont Research Station was the only area to collect, and provide complete production costs for the study. From one location only partial costs were available, the commercial farm was unable to provide costs. Total yields not provided for any of the production area individual locations.

In order to compare each cover crop against the industry standard, data from each production area was corrected to a standard of 0.75 acres. Using this baseline, the break-even yield as well as break-even price per CWT assuming everything else held constant (Obj. 3 Table 1). Based on the information provided from the post-harvest results in conjunction with information provided by the Piedmont Research Station, using a cover crop of either mustard, sun hemp, or buckwheat

did not result in significant economic increases compared to the industry standard of not using a cover crop. If assumed yield data values are adjusted up or down, these results may change. Variability in yield is dependent on variety, environmental factors and production expertise. These variables can be expected to change from location to location and seasonally. While the use of cover crops to decrease soil splash onto the cantaloupe surface resulted in an increased total cost price, this increase was not significant and the benefits of using this method to decrease surface soil and increase food safety may outweigh these increased costs (Obj. 3 Table 1).

Tables and Figures:

Obj. 1A&B Table 1: Sugar content (Brix) of Cantaloupe fruit at harvest and after 7 days of storage at 25 and 11 °C.

Storage Temperature	Cover Crop	Storage Time	
		0 time	Day 7
25 °C	Present	9.4 ±0.7	8.1 ±0.6
	Absent	10.6 ±0.3	8.8 ±0.5
11 °C	Present	8.5 ±0.1	9.2 ±0.2
	Absent	8.8 ±0.1	8.8 ±0.1

Data represent averages of 10 fruit per time point and storage temperature.

Obj. 1A&B Table 2: Acidity (pH) of Cantaloupe fruit at harvest and after 7 days of storage at 25 and 11 °C.

Storage Temperature	Cover Crop	Storage Time	
		0 time	Day 7
25 °C	Present	6.8 ±0.4	5.8 ±0.5
	Absent	6.9 ±0.3	6.6 ±0.4
11 °C	Present	6.0 ±0.1	6.5 ±0.2
	Absent	5.9 ±0.3	5.6 ±0.3

Data represent averages of 10 fruit per time point and storage temperature.

Obj. 1A&B Table 3: Microbial quality of cantaloupe fruit at harvest and after 7 days of storage at 25 and 11 °C.

Storage Temp.	Cover Crop	APC (Log CFU/Fruit)		Enterococci (Log CFU/Fruit)		Coliforms (Log CFU/Fruit)		E. coli (Log CFU/Fruit)	
		0t	7D	0t	7D	0t	7D	0t	7D
25 °C	Present	7.0±0.2	8.0±0.2	5.4±0.6	7.3±0.4	5.0±0.6	4.6±0.9	3.4±0.6	2.7±0.4
	Absent	6.9±0.9	8.2±0.1	5.1±0.8	6.1±0.1	5.6±0.4	5.4±0.2	4.3±0.4	4.3±0.4
11 °C	Present	7.0±0.2	8.1±0.2	5.4±0.6	7.4±0.6	5.0±0.6	5.0±0.6	3.4±0.6	3.4±0.6
	Absent	6.9 ±0.9	8.3±0.1	5.1±0.8	7.0±0.7	5.6±0.4	6.2±0.5	4.3±0.4	0.0±0

Obj. 1A&B Table 4: Microbial quality of cantaloupe fruit at harvest and after 7 days of storage at 25 and 11 °C grown with and without the presence of a cover crop.

Storage Temperature	Storage Time	APC Log CFU/Fruit	Enterococci Log CFU/Fruit
25 °C	0 Day	9.6 ± 0.05 a	7.1 ± 0.1 a
11 °C	7 Day	9.1 ± 0.09 b	6.1 ± 0.3 b

Values are means (SEM, ± standard error of the mean). Values in columns followed by different letters (a,b) indicate significant differences between storage temperature. No significant differences were found for yeast and molds, generic *E. coli* and coliforms.

Obj. 1A&B Table 5: Effect of cover crop on the presence of Salmonella at harvest in cantaloupe.

Cover Crop	Salmonella (% Presumptive Positive)
Control (No –Cover crop)	6.9
Buckwheat	6.3
Mustard	13.8
Sunhemp	10.6

Obj. 1A&B Table 6: Effect of Cover Crop and Storage temperature on the presence and persistence of STEC in cantaloupe.

Storage temperature	Cover Crop	STEC (% Presumptive Positive)
21◦ C (Total N=128)	No cover	2
	Buckwheat	10
	Mustard	5
	Sunhemp	8
11◦ C (Total N=64)	No cover	13
	Buckwheat	19
	Mustard	16
	Sunhemp	16

Obj. 1.C Table 1: Postharvest variables averaged across across all locations prior to postharvest storage.

	Cover Crop Treatment			
Variable	C	B	M	S
Weight (g)	2234.59	2169.80	2415.96	2354.09
Length (cm)	18.31	18.31	19.30	18.85
Diameter (cm)	16.17	15.82	16.28	16.32
Firmness (N)	9.60	10.52	10.02	9.47
pH	6.57	6.54	6.56	6.61
SSC (%)	9.03	9.04	9.14	9.89
l	64.07	64.67	64.03	65.34
a	9.67	9.74	9.14	9.17
b	31.10	30.95	29.93	30.42
chroma	32.58	32.46	31.32	31.78
hue (°)	72.85	72.61	73.19	73.28
Beta carotene (mg/100 g fwt)	1.72	1.79	1.59	1.65

*Treatment refers to cover crop where, C=Control (no cover), B=Buckwheat, M=Mustard, and S=Sunn Hemp.

Obj. 1.C Table 2: Postharvest quality variables showing differences between weeks 0 and 1 of melons from Kinston stored at 4 C, averaged across all treatments and locations.

	Week	
Variable	0	1
pH	6.59	6.51*
%SSC	8.9	8.1*
L (light/dark value)	65.21	63.57*
Beta carotene (mg/100 g fwt)	1.25	0.83*

*Indicates significant difference in mean from week 0 to week 1, means separated by Student's t-test, $P<0.05$.

Obj. 1.C Table 3: Postharvest physical and quality variables measured following harvest by location.

Cover Crop Treatment	Location	Fruit Weight (g)	Length (cm)	Diameter (cm)	Average Firmness (N)	pH	SSC (%)
C	Kinston	1889	17.4	15.6	10.2a	6.53	8.7
	Raleigh	2415	18.7	16.2	6.6b	6.60	7.7
	Piedmont	2577	19.3	19.9	10.4a	6.60	10.1
B	Kinston	2206	18.3	15.9	11.83a	6.54	8.6
	Raleigh	2068	17.9	15.6	6.87b	6.51	8.5
	Piedmont	2213	18.7	15.9	12.63a	6.55	10.1
M	Kinston	1814b	17.1b	15.1b	10.74a	6.60	8.1b
	Raleigh	2774a	21.0a	16.9a	6.47b	6.58	8.8b
	Piedmont	2856a	20.6a	17.2a	12.23a	6.48	10.8a
S	Kinston	2198	18.1	16.0	10.2	6.69	10.4
	Raleigh	2508	16.5	16.6	7.7	6.61	9.9
	Piedmont	2452	19.4	16.6	9.7	6.53	9.2

*Means separated within column and location by Tukey's, $P<0.05$. Mean values without letters indicate no significant differences. Cover crop treatment refers to cover crop where, C=Control (no cover), B=Buckwheat, M=Mustard, and S=Sunn Hemp.

Obj. 1.C Table 4: Postharvest color and phytochemical variables measured following harvest by location.

Cover Crop Treatment	Location	l	a	b	Chroma	Hue (°)	bcarotene (mg/100 g fwt)
B	Kinston	64.66ab	8.32c	29.39b	30.55b	74.22a	1.26a
	Raleigh	62.21b	9.97b	29.66b	31.31b	71.41b	1.76b
	Piedmont	66.83a	11.29a	34.03a	35.86a	71.65b	2.47b
C	Kinston	65.39a	8.12b	29.22b	30.33b	74.55a	1.30b
	Raleigh	60.08b	10.2a	26.62b	31.33b	71.01b	1.66ab
	Piedmont	64.4a	11.34a	34.19a	36.02a	71.64b	2.24a
M	Kinston	65.13a	7.52b	28.31b	29.31b	75.23a	1.02b
	Raleigh	61.05b	9.45a	28.11b	29.66b	71.49b	1.45b
	Piedmont	65.26a	10.89a	33.56a	35.3a	72.12b	2.22a
S	Kinston	65.67ab	8.09b	28.76b	29.88b	74.32a	1.42
	Raleigh	62.30b	9.18ab	28.39b	29.84b	72.08b	1.72
	Piedmont	66.83a	10.52a	33.76a	35.37a	72.73b	1.89

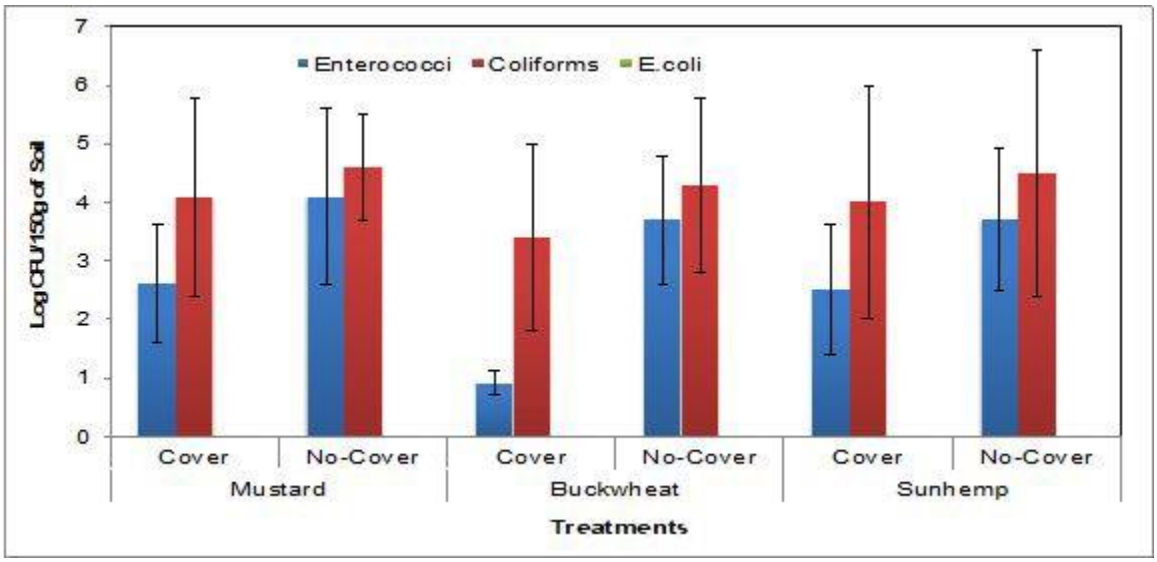
*Means separated within column and location by Tukey's, P<0.05. Mean values without letters indicate no significant differences. Cover crop treatment refers to cover crop where, C=Control (no cover), B=Buckwheat, M=Mustard, and S=Sunn Hemp.

Obj. 3 Table 1: Break-even yield and break-even price per hundredweight (cwt) of melons.

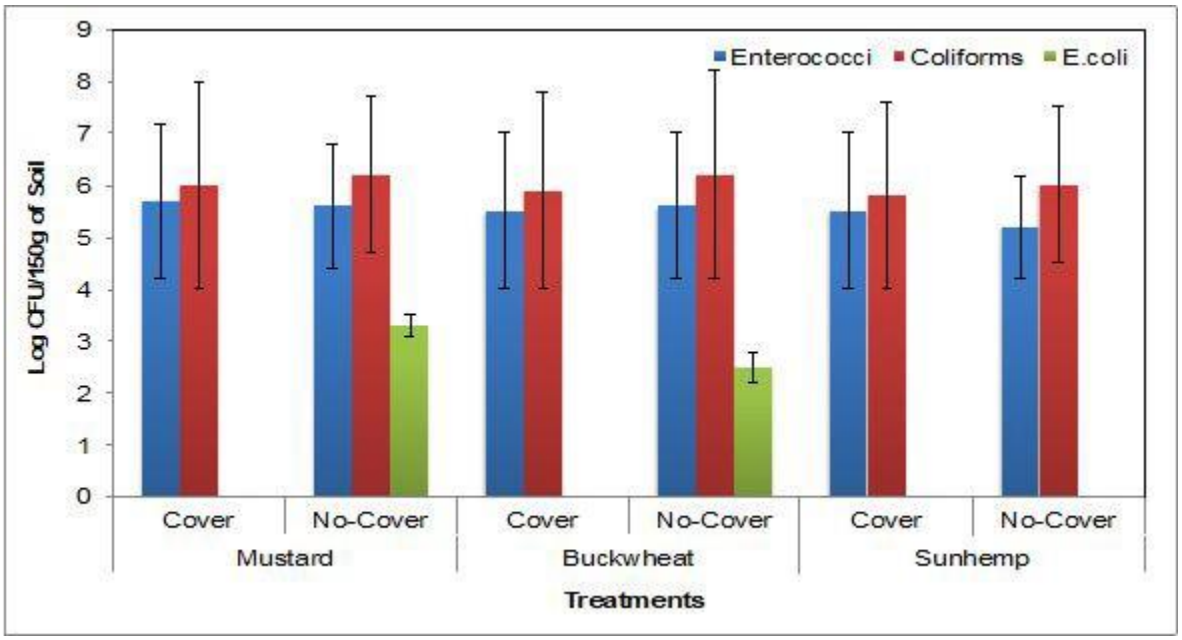
Variables	Industry Standard	Mustard	Sun Hemp	Buckwheat
Variable Cost Yield	272	362	362	338
Total Cost Yield	317	416	416	390
Variable Cost Price	$18.38	$22.87	$22.86	$21.68
Total Cost Price	$20.50	$25.30	$25.29	$24.03

Obj. 1A&B Figure 1: Layout of melon plots depicting the overall distribution of winter ryegrass in Salisbury NC (A), other cover crops (B and C) and the location of melon fruit away from plastic row covers and resting on top of the cover crop instead of soil (D).

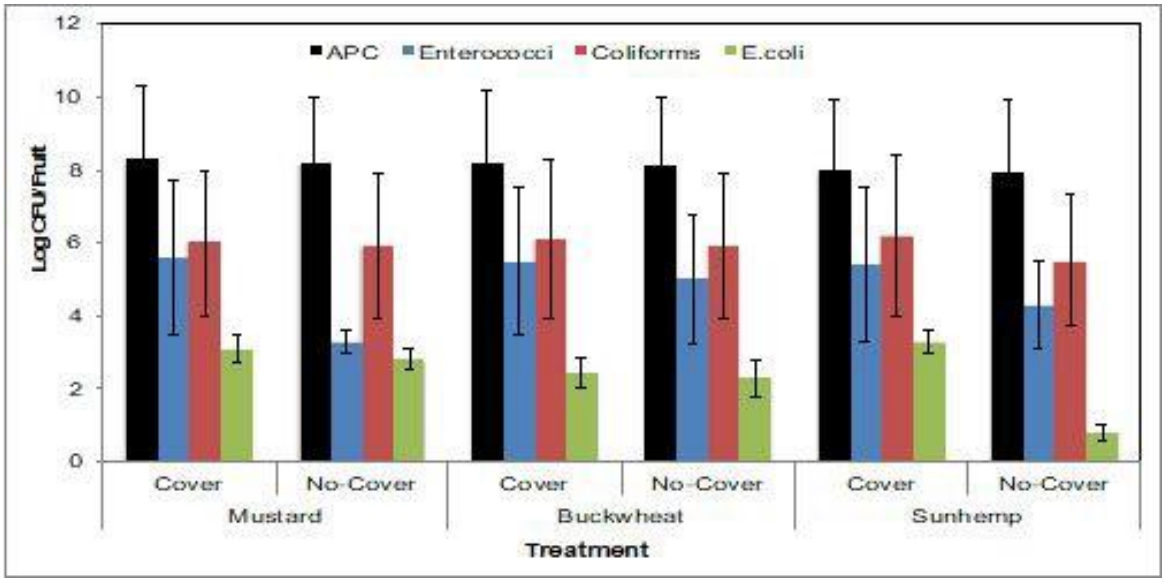
Obj. 1A&B Figure 2**:** Population of indicator microorganisms recovered from soil after cantaloupe bed forming. Data represents the average of 10 repetitions per treatment each of 150g.



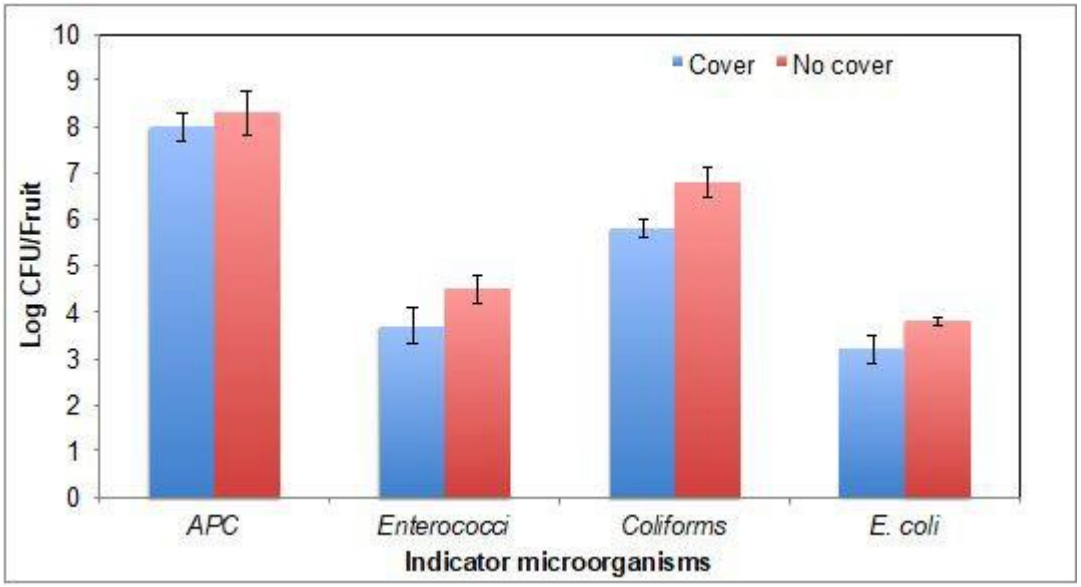
Obj. 1A&B Figure 3**:** Population of indicator microorganisms recovered from soil before harvest. Data represents the average of 10 repetitions per treatment each of 150g.



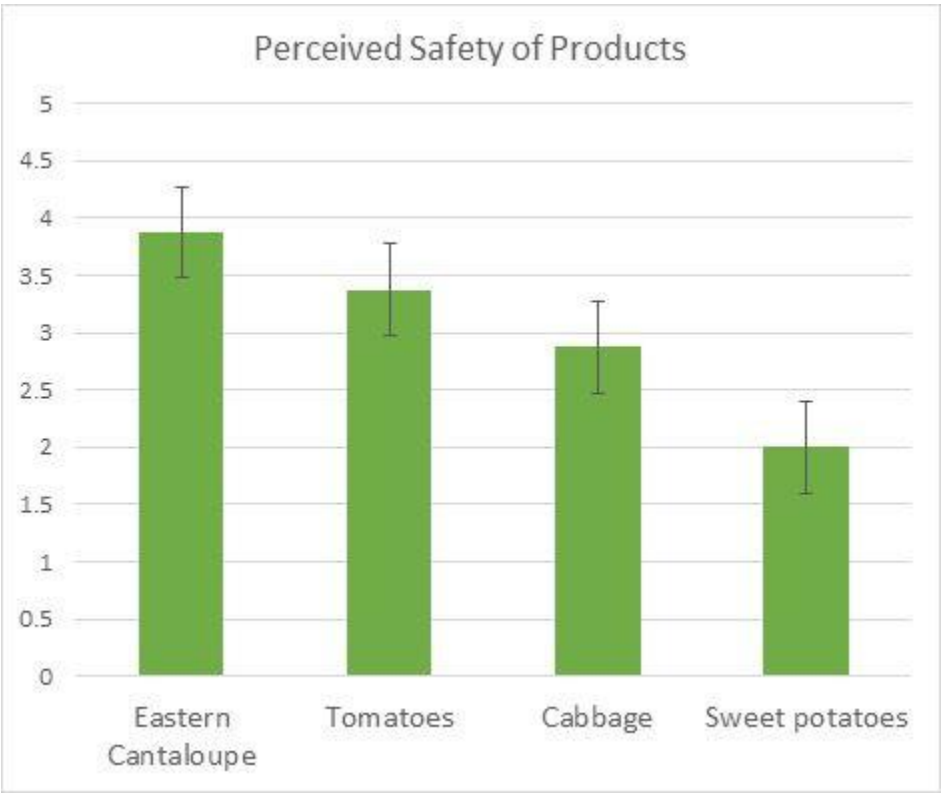
Obj. 1A&B Figure 4**:** Population of indicator microorganisms recovered from the surface of cantaloupe fruit grown with and without the presence of cover crops between field beds. Data represents the average population from 20 fruit per treatment.



Obj. 1A&B Figure 5**:** Population of indicator microorganisms recovered from the surface of cantaloupe fruit grown with and without the presence of cover crops between field beds. Data represents the average population from 20 fruit per treatment.

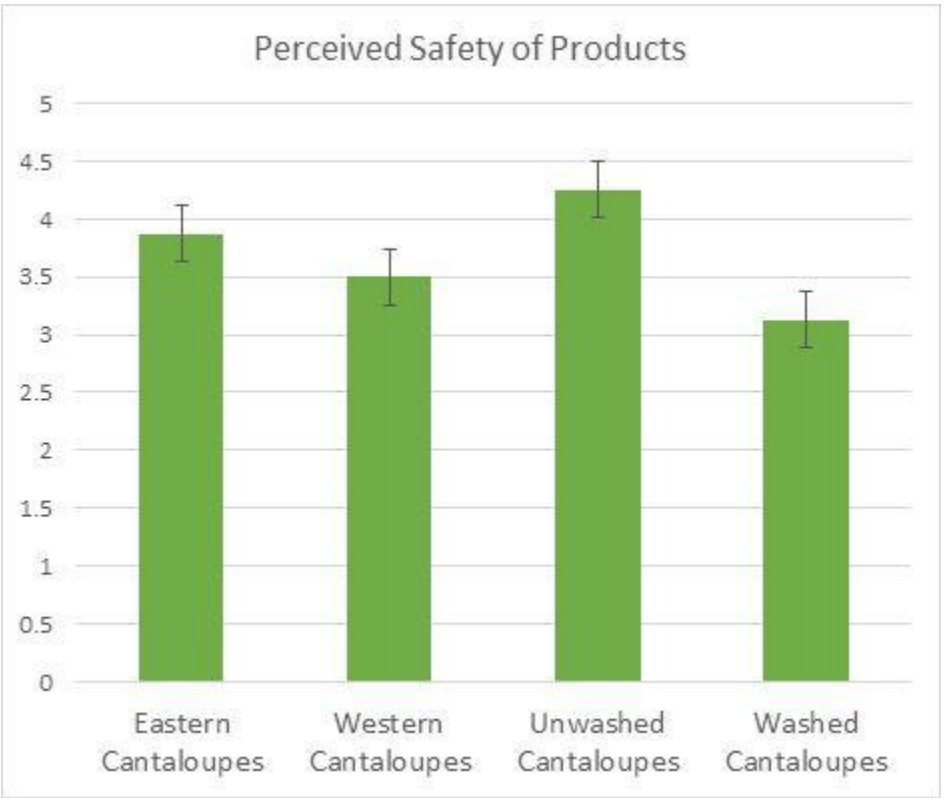


Obj. 2 Figure 1: Perceived food safety risks of specific surveyed items of fresh produce by retail buyers.



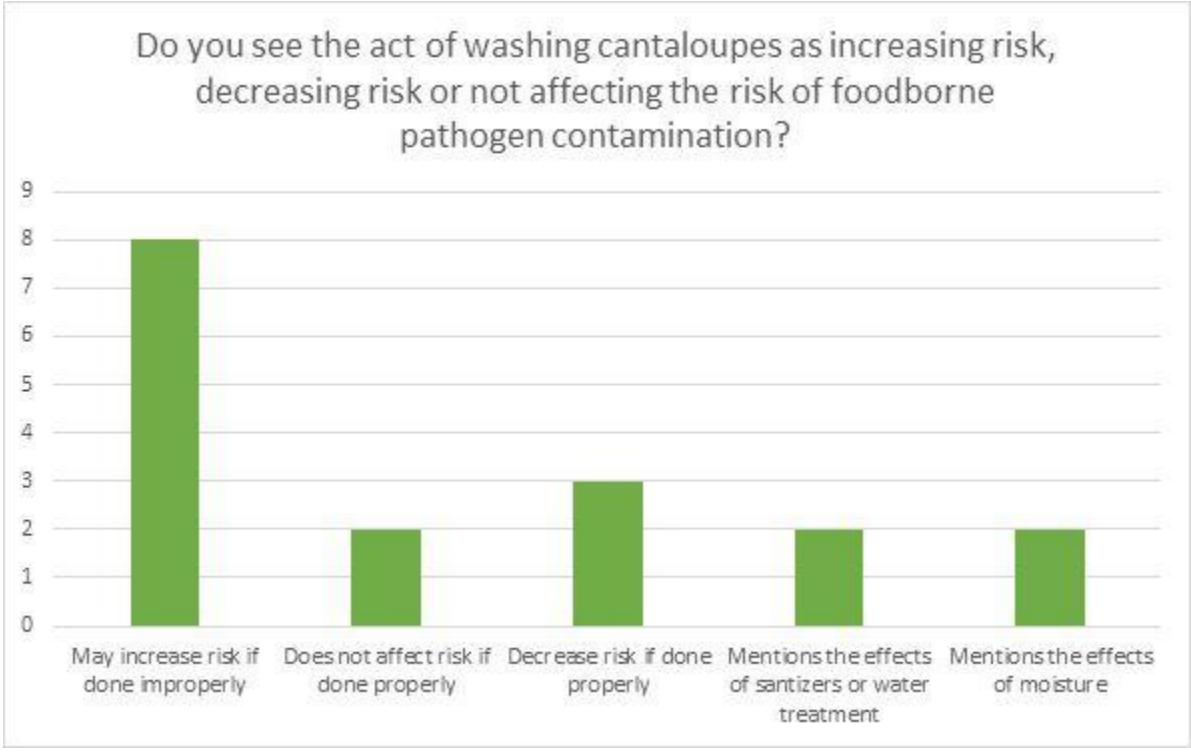
*n=8 for this question. Scale is 1=Low risk, to 5=High risk.

Obj. 2. Figure: 2: Perceived food safety risk of eastern and western cantaloupes both washed and unwashed melons by retail buyers.

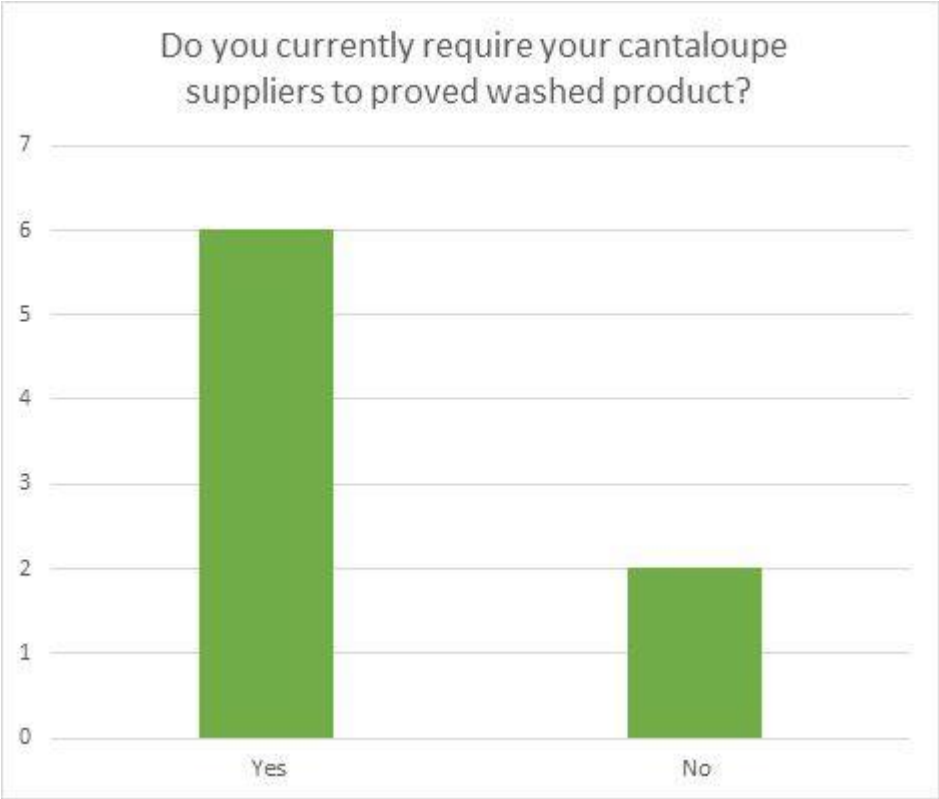


*n=8 for this question. Scale is 1=Low risk, to 5=High risk.

Obj. 2 Figure 3: Retail buyers perception of risk associated with the act of washing.

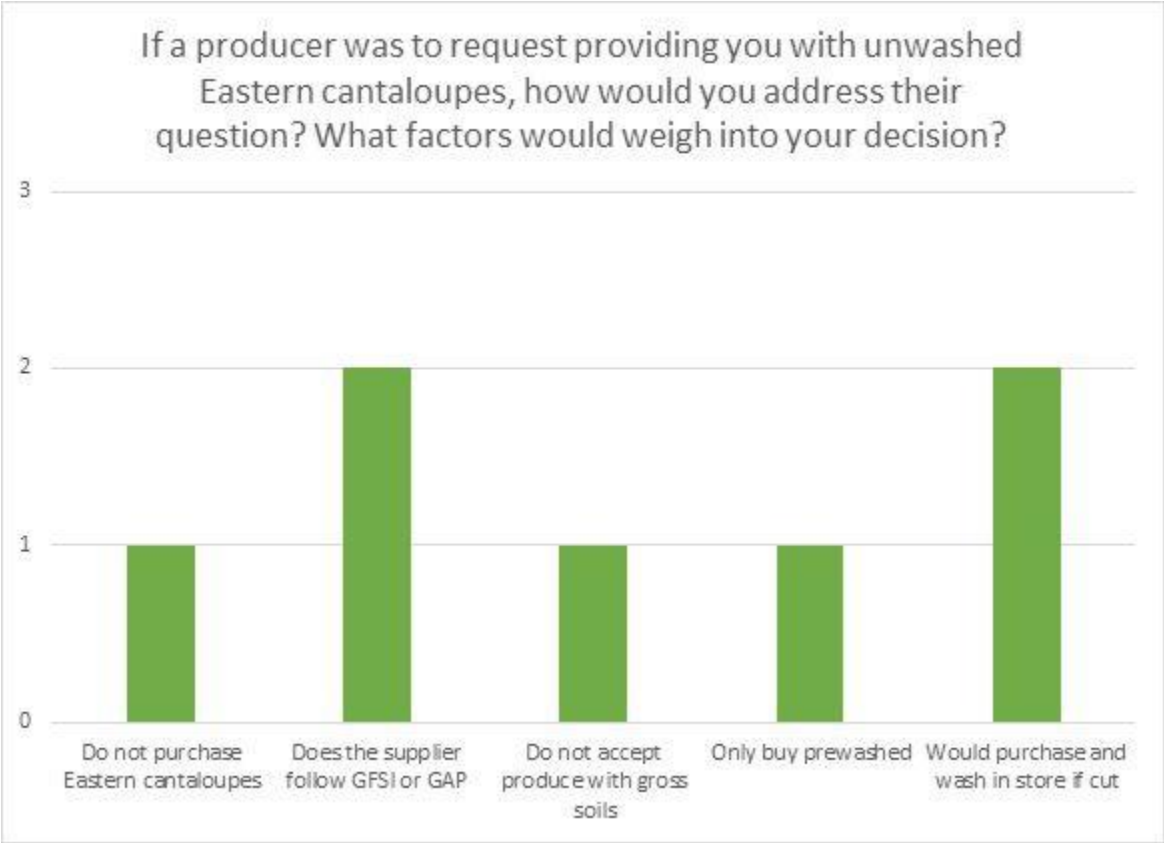


Obj. 2 Figure 4: Responses to the question of suppliers about requiring producers to wash cantaloupes prior to purchasing.



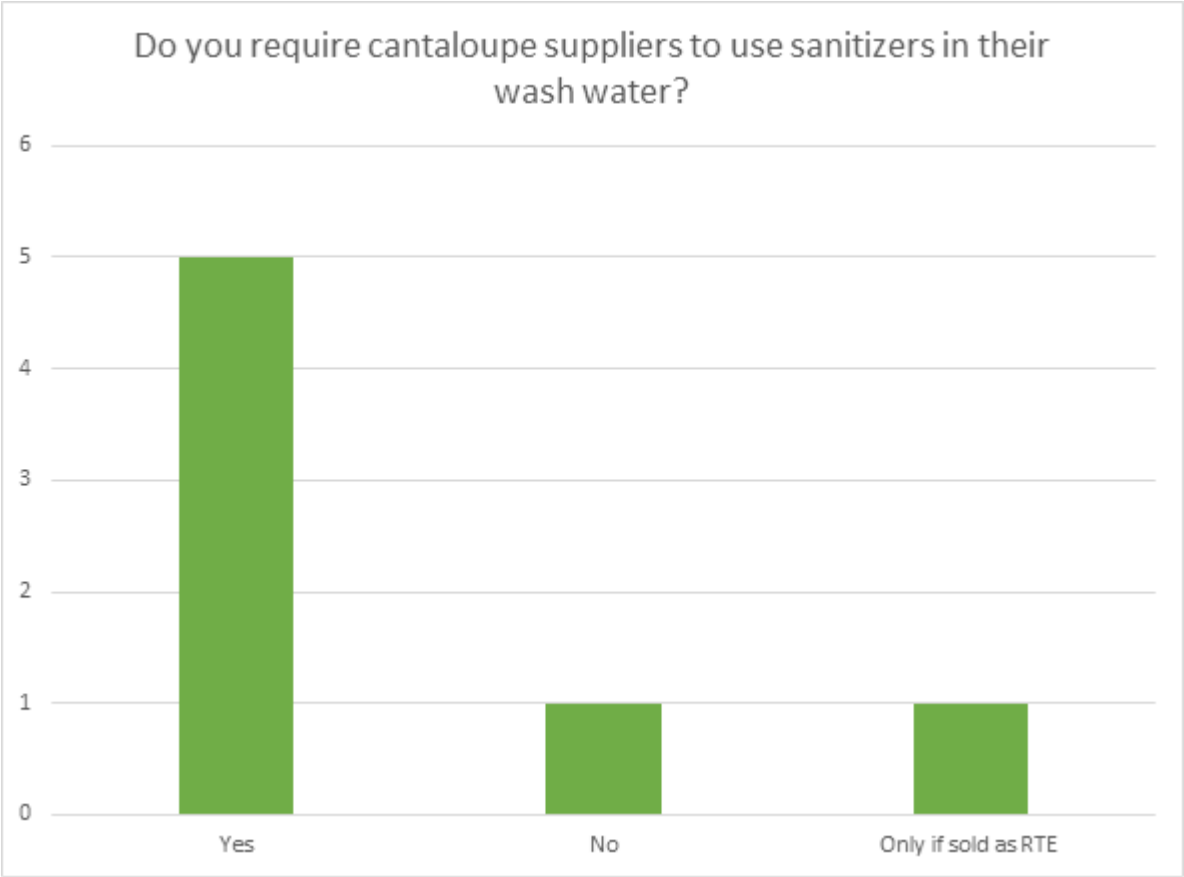
*n=8 for this question.

Obj. 2 Figure 5: Retail buyers response to grower request to supply unwashed Eastern cantaloupe.



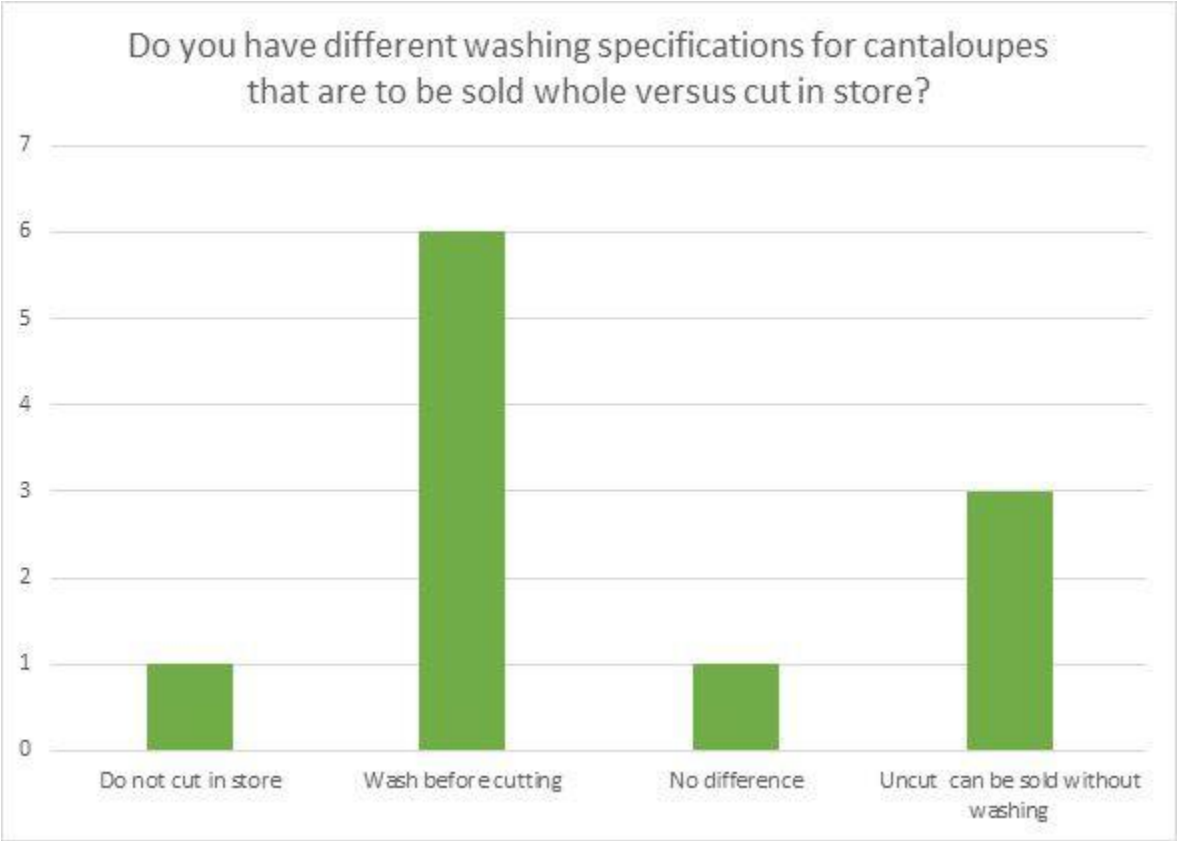
*n=8 for this question.

Obj. 2 Figure 6: Buyers requirements for sanitizers in on-farm wash water.



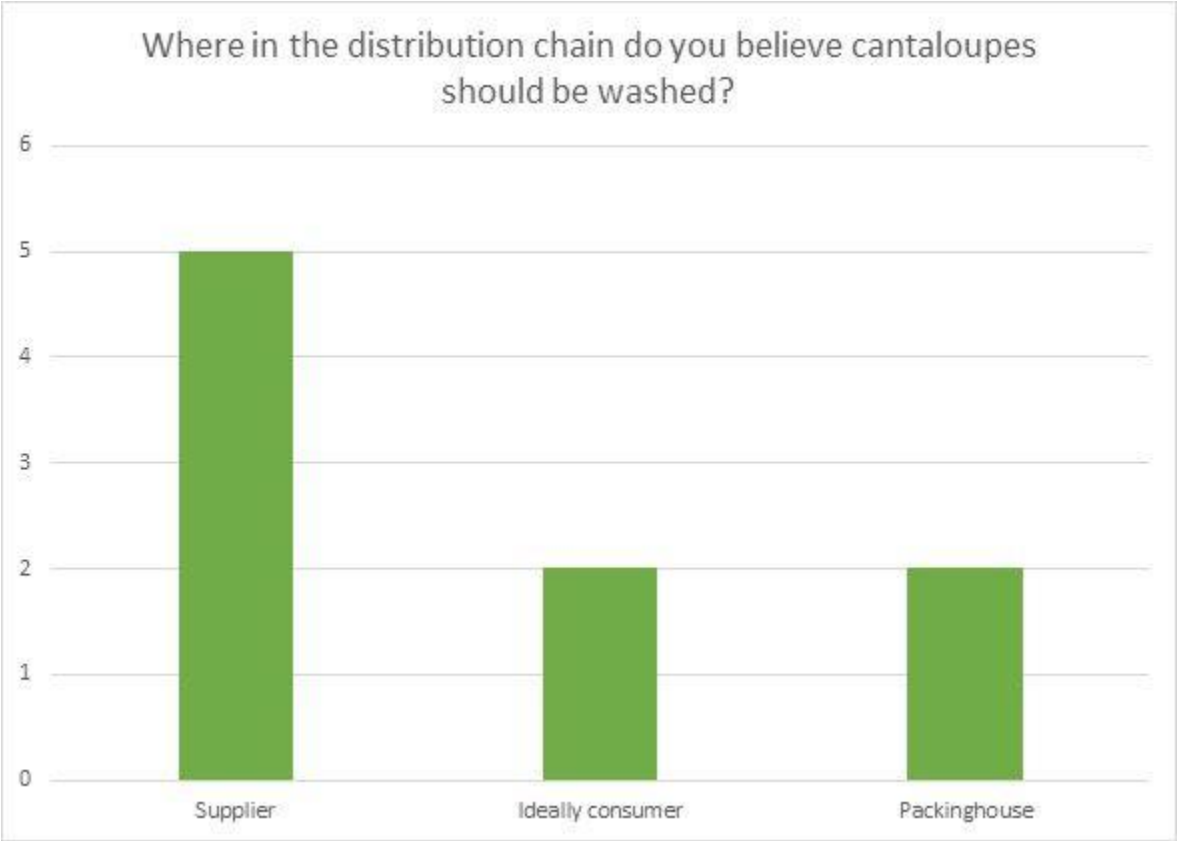
*n=7 for this question. RTE refers to Ready to Eat.

Obj. 2. Figure 7: Retail buyers differences in washing specifications for cantaloupes sold whole or cut.



*n=8 for this question.

Obj. 2. Figure 8: Retail buyers perception of when in the supply chain cantaloupes should be washed.



*n=8 for this question.

Project Evaluation, Outputs and Outcomes:

The melon industry was over 12,000 acres in 2007 and more recently reported 14.2 million value at the farmgate. Our project outcomes are of interest to all of these producers whose product enters into wholesale commerce. We attempted, as a part of the economic impact of this project, to ask participants to quantify real costs of water use and sanitizers in their current system. Each of these producers currently does some type of postharvest washing treatment which, while potentially resulting in cleaner fruit, may be unnecessary if those fruit are delivered to the packing facility in a cleaner state or are even field packed. The new production methods tried here, could result in new guidelines and alternative strategies for melon packing and grading. At the end of the study we quantified the real savings for producers employing these new methods, in terms of actual dollars saved. No differences in those economic factors were significantly different between the control and the use of supplemental cover crops in terms of economics.

Project Deliverables:

A comprehensive delivery strategy of the results was used to present to stakeholder audiences at all levels. This project was discussed with producers and stakeholder groups at association meetings. We plan to make them available online through extension websites, following publication of the results in scientific journal publications. Production practices were introduced to interested growers via these presentations, and will be developed into extension pamphlets and videos to growers and industry professionals and made available online.

Outreach Plan:

Outreach to interested stakeholders has been made at all levels. We have made presentations at grower educational conferences and and are planning both scientific journal publications and extension bulletins for producers. The results discovered in objective 2 are providing a framework to present the wash vs. no wash analysis to retailers through traditional extension activities and are being used to develop a trade publication (planned for Food Safety Magazine and/or Supermarket News). Additionally, the food safety scientific audience will be informed through presentations at the Food Marketing Institute's Food Safety group's education sessions. Results will be also made available through online venues and advertised on industry websites. Hands on demonstrations of these methods through field days and grower walk-throughs may also be conducted.

Partner Agencies and Cooperators:

This project had strong support from public and private agency cooperators and growers. Project cooperators worked closely with the North Carolina Department of Agriculture staff at the Piedmont Research station located near Salisbury, NC to conduct a portion of the field based research data collection. The project gained support from the Easter Cantaloupe Growers association for the outreach portion of the project. PI's delivered a presentation to their

membership at the annual research update forum held by that organization. This allowed for updating both retail buyers and growers present at the meeting. This information was also shared with grower groups in North Carolina at educational meetings for growers in the state. This project also partnered with a number of retail grocery chains, most notably Delhaize America and Publix. Both of these retailers participated in the retailer acceptance survey and in the development of the project objectives.

Lessons Learned:

This project involved a diverse set of objectives encompassing field practices, postharvest evaluation, retailer acceptance and economic analysis. In projects involving highly diverse objectives, in which one objective's success depends upon another, difficulties can arise. This was evident to the PI team when cover crop establishment in the initial year of the project became difficult. This was primarily due to water availability and environmental conditions, but resulted in limited availability of fruit for the postharvest sampling and evaluation. On the positive side, the retailer acceptance portion, which did not depend substantially on field level success, was performed and data collection and analysis proved to be efficient. The PI team was able to communicate effectively with stakeholder groups and deliver these results. Growers have expressed increasing interest in using cover crops for the benefit of soil and water conservation and are very interested in the potential additional benefits that may be gained in the area of fresh produce safety.

Current and Future Benefits:

The team of PI's on the project are planning to continue working in the area of fresh produce safety and melon retailer acceptance. The practice of requiring growers to wash melons opens up a host of management complexity, which increases the risk that a failure may occur and food borne pathogen introduction may result. The use of water in the postharvest environment is challenging for growers for number of reasons. A sanitation agent needs to be incorporated into the water handling process for the farm. This translates to a need for accurately measuring and monitoring the sanitizer throughout the use period. Additionally, disposal of this sanitized water may pose some environmental concerns and, depending upon local state laws, may require additional permitting and/or containment. It is thought that work like this, both in the field at direct contact with buyers, can improve the marketability of unwashed melons. If producers can reduce the amount of soil clinging to the fruit surface and retailers can acceptance melons that are free of excessive soil, but are unwashed, the results will be increased product safety, increased environmental quality, and ultimately more dollars returning to the farm.

Future Research:

In the future, it would be advisable to search for cover crops that fulfill multiple objectives in the production cycle. For example, cover crops can be chosen for their ability to fix nitrogen, or to loosen compacted soils. Choosing cover crops that have these additional benefits while at the same time, reducing soil splash onto the crop will be beneficial.

Project Beneficiaries:

This project will be of benefit to eastern cantaloupe growers, producing in humid climates that may experience seasonal rainfall during the growing and harvesting season. In terms of impact of this research there are at least seven leading states in these production environments (FL, GA, IL, IN, NC, SC, PA) that would benefit from these findings. Those states represent 10,100 acres of harvested eastern cantaloupe. There is an average yield across those states of 194 cwt/Acre and an average price of $22.92/cwt. This equates to an industry value in these states of $44.8 million dollars. Increasing marketability and product safety in this industry would benefit both consumers, retailers, and cantaloupe growers.

Additional Information Generated:

International Association for Food Protection Annual Meeting. M.A. Albarracin, C. Gunter, P. Perkins-Veazie, B. Chapman, J. Baros, S. Kathariou, and E. Gutierrez-Rodriguez. Cantaloupe Fruit Microbiome: Responses to Field Location, Cover Crop, and Cold Storage. Tampa, FL. July 2017.

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