THE POTENTIAL IMPACT OF IMPROVED PEANUT VARIETIES AND FUNGICIDE APPLICATIONS ON PEANUT PRODUCTIVITY AND PROFITABILITY IN HAITI

by

JOHN MCKENZIE NORTH

(Under the Direction of Genti Kostandini)

ABSTRACT

Peanuts are a valued cash crop for the majority of rural Haitian subsistence farmers, and they are also important for their protein content. Local peanut varieties and antiquated farm management dominate the Haitian peanut sector, leading to vast inefficiencies throughout the value chain. Non-governmental organizations such as Meds and Foods for Kids (MFK) and Acceso have embarked on a training and education mission, backed by researchers from the University of Georgia (UGA), to provide Haitian peanut farmers with some modern-day tools to increase peanut yields as well as raise household incomes. This thesis provides a description of the peanut value chain in Haiti, analyses the effect of fungicide applications on peanut yield, and economic profits using trials conducted in two major peanut producing regions in Haiti. A varying price scheme is also applied to peanut yield results to provide additional insight into potential revenues that would be realized by Haitian farmers. The results showed overwhelmingly that net farm-level incomes increase significantly given a small up-front investment in disease management.

INDEX WORDS: Value Chain, Production Optimization, Disease Management

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

Haiti is one of the most under-developed countries in the Western Hemisphere according to the United Nations' Food and Agriculture Organization (FAO), the second most populated country in the Caribbean at 10.7 million people (FAO 2017) and the only success story of a slave rebellion that overthrew its colonial rulers. Political instability has raged in Haiti since independence in 1804 while dependence on foreign aid has created a society and economy mired in stagnation. In spite of rapid urbanization and concentration of the population in the Haitian capital of Port-au-Prince, approximately 4.4 million Haitians remain in the rural areas whose economies are primarily dependent on small scale agriculture (FAO 2017). The primary agricultural commodities produced by Haitian farmers include corn, cassava, sweet potatoes, and peanuts generally at a subsistence level. Protein in the form of animal meat is a rare treat, a luxury good reserved only for special occasions. Therefore, the majority of dietary protein must be derived from other sources such as peanuts, which are a crucial consumption and cash crop to Haitian farmers. In addition, peanuts provide important disposable income to families that largely live on the equivalent of $1.50 USD per day (FAO 2017).

It is well known in the development economics literature that the adoption of improved inputs and more technologically-advanced practices will result in higher output (e.g. Liu 2013, Suri 2011). In the context of the Haitian peanut farmer, higher output translates to more disposable income and a higher standard of living. However, the adoption of these new technologies is often met with great indifference, even reluctance bordering on skepticism from

Haitian farmers. One explanation is that the risk preferences produce a different set of incentives that can discourage labor and capital investment in technological progress, even if the investment requirement for both are minimal (Liu 2013). Suri (2011) suggests that returns to technology are heterogenous and farmers who are likely to see a low net return do not adopt new technologies. A second explanation is known as the status quo bias, which indicates an individual's aversion to changing from an established behavior and is found to be an implication of loss aversion (Liu 2013). Despite empirical evidence that supports the efficiency of new technologies, rural farmers are often resistant to change because the outcome of taking such risk is unknown (Dercon & Christiaensen 2005). A tried and true process that yields a known outcome is usually preferable. A third explanation is purely cultural; neo-colonialism can be alarming to a nation such as Haiti. Not wanting to repeat history, foreigners and foreign farming practices are potentially viewed as suspicious and disingenuous by the indigenous population.

Stemming from a resistance to change at the farm-level, technological inefficiencies exist throughout the Haitian peanut value chain. Value chains are an important economic development tool; globalization figuratively dissolves political borders and economies become more specialized based on their individual strengths; education levels, geography and other cultural factors. Value chain analysis and optimization allows developing countries to play an increasingly key role in the global economy, leveraging their comparative advantage and raising the standard of living. Despite Haiti's staggeringly high unemployment, a low Human Development Index, and vast income inequality, significant development and improved quality of life can be brought to the Haitian people when agricultural productivity increases, the agricultural value chain improves, and the barriers to market entry are dissolved (FAO 2017). However, the agricultural value chain is inherently different than a standard product value chain in that the production process is constrained by many external factors; including weather, soil conditions, and crop disease. For example, foliar diseases are a significant problem in Haiti that further reduce farm-level productivity. The year-round warm and humid climate exacerbates diseases such as peanut rust[1] and late leafspot[2], both of which dramatically reduce peanut quality and overall yield if not outright result in total crop loss. A 2012 study by Technoserve (TNS), an international non-profit organization in Haiti, noted that a sizable percentage of Haitian farmers are not even aware of the dangers these diseases present to their crops and their presence was noted on almost every farm observed. These diseases drastically decrease peanut productivity and peanut value chain efficiency. They result in higher price volatility, thus heightened risk and uncertainty which decreases market participation. Moreover, input constraints, imperfect or even no information flow, and seasonal demand and supply shifts make the peanut value chain unpredictable. As a result, researching and understanding where inefficiencies lie within the peanut value chain as well as understanding the impact of technologies that increase peanut productivity is important for improving the farmers' welfare in Haiti.

This thesis has two objectives. The first is to provide an analysis of the peanut value chain in Haiti. The second is to examine the impact of fungicide treatments on peanut productivity and profitability by using data from controlled variety trials in Haiti. The remainder of this thesis is organized as follows. Chapter 2 provides a discussion of the Haitian peanut value chain; the process of peanut farming and harvest in Haiti is explained. In Chapter 3, an explanation of the theoretical model we use to examine the impact of managed fungicide use on improved peanut varieties to increase farm-level output/yield and profitability. Furthermore, the

[1] *Puccinia arachidis.*
[2] *Cercosporidium personatum.*

chapter discusses the trial data collected and a comprehensive explanation of our econometric approach. Chapter 4 discusses results with respect to productivity and fungicide applications as well as profitability. Chapter 5 concludes the study and provides suggestions for future research.

CHAPTER 2

VALUE CHAIN

2.1 Current State of Peanut Value Chain in Haiti

There has been little formal research into the Haitian peanut value chain, apart from the study mentioned earlier by Technoserve (TNS) in 2012. TNS is an international non-profit development organization that outlined in detail the full spectrum of the peanut value chain from seed to processor and finally the consumer. The TNS study highlighted the diminishing amount of land under cultivation, the pervasive crop diseases, and the lack of profitable markets where farmers can sell their peanuts. However, peanuts still play a very important role in the life of Haitians, both as a significant source of protein and income, and thus peanut cultivation and propagation will remain an important development tool. This thesis complements previous research by focusing on increasing farm-level production, through fungicide use, in an effort to increase efficiency at the beginning node of the value chain.

The peanut is often the sole cash crop for the small-holder farmer who operates less than a two-hectare plot and realize significantly less than global average yields. For example, in 2012 the average peanut yield from the neighboring country, the Dominican Republic was 1519 kg/ha compared to that of Haiti, 870 kg/ha, just over half (57.3%) of the Dominican Republic's production (FAO 2012). Methods of peanut cultivation and harvesting in Haiti are outdated and laborious which contribute to plant diseases such as a prevalent fungal infection known as aflatoxin. Aflatoxins are toxic metabolites produced by fungi in peanuts and they are associated with various serious diseases in humans, livestock and animals (Schwartzbord et al. 2014).

Aflatoxin presence in Haitian peanuts is very common and thus if not controlled at the farm level can be transmitted through the production process and into the final product. The lack of government oversight or institutional control within the food and fiber sector of the Haitian economy also contributes to the prevalence of this fungus throughout the value chain. For example, nearly all peanut butter samples collected from Haitian grocery stores during 2009 and 2010 were contaminated with aflatoxin; the levels ranged from 7.9 to 799.8 parts per billion (ppb), compared to the 25ppb in the United States as mandated the US Food and Drug Administration (FDA Compliance Policy Guide Sec. 570.375).

Efforts to improve input practices have been underway through many non-governmental development organizations (NGO), such as Accesso and Meds and Food for Kids (MFK), mainly through training and education programs. Some of these organizations also structure credit packages that are aimed to reduce risk and uncertainty, increase profits for farmers, and to incentivize them to adopt new technologies. Demand for peanuts is highly elastic as price swings are often dramatic due to supply being highly seasonal and inelastic. Because of high price volatility, farmers often store peanuts for sale in the future when supply is low and price is high, which further contributes to aflatoxin persistence and potential health risks to consumers.

When economists refer to the market in developed countries, generally they're referring to the formal market, which is officially regulated, taxed, and monitored by its respective government. Prices and locations of participants are advertised and goods are openly exchanged and formal contracts exist between employer and employee. However, in the majority of the developing world because of poor governance and weak institutions there are also informal markets where often cash is king and there's no regulatory oversight except that of Adam Smith's invisible hand. This market is rife with negative externalities such as a lack of food safety standards. These markets in Haiti rely primarily on middle-men purchasers or “Madan Saras” as they are referred to in Haiti (the same phenomenon exists in West Africa, known as “Market Mammy”). “Madan Saras” are usually Haitian women with low levels of formal education who focus on the informal trade in rural markets (Okonjo 1975). These women have influence over a group of farmers within a certain geographical region from whom they purchase peanuts. For a small profit margin, they then accept cost of carry and transport risk to a local market where the peanuts are sold to individual consumers or to larger Haitian peanut aggregators and roasting companies. These companies are part of the value-added stage which includes roasting peanuts for school snacks, Ready-to-Use Therapeutic Food (RUTF)[3] processing, or producing peanut butter (TNS 2012).

Because there is no formal structure, the “Madan Sara” are not employees of more official aggregators nor do they have capital assets of their own such as transportation; instead they rely on cash transactions, public transport and just-in-time delivery to avoid the expense of cost of storage. Thus, the farm marks the beginning of a disjointed value chain along which there is a dearth of information flow, various buyers, sellers and aggregators, minimal value-added activity and even less government oversight. This less-than-optimal value chain operation transfers unnecessary costs that are borne by both the farmer in terms of less revenue from peanuts and then by the consumer in terms of the health risks associated with low quality and high aflatoxin contamination.

[3] Ready-to-Use Therapeutic Foods (RUTF) are high-energy, lipid-based spreads used in any cultural setting for the treatment of severe acute malnutrition (SAM).

2.2 Haitian Peanut Value Chain Under the Scope of Value Chain Literature

Prominent academic work on value chains includes Kaplinsky and Morris' 2001 Value Chain Analysis handbook developed for the International Development Research Centre (IDRC) which provides a general overview of value chain structure, external value chain actors, and potential research methods for value chain analysis. According to Kaplinsky and Morris, a value chain describes the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use (Kaplinsky and Morris 2001). The analysis also provides three key elements; barrier to entry and rent, governance, and systemic efficiency. This section seeks to use the Kaplinsky and Morris handbook's techniques to provide insights on the Haitian peanut value chain to establish a baseline for future research into full-spectrum optimization.

The first element of Kaplinsky and Morris' analysis, barriers to entry, highlights the need to diversify product offerings as a catalyst for increased competition within the peanut market. Peanut oil, flavored peanuts, feedstock for chickens, cooking briquettes made from aflatoxin-infested peanuts are all examples of diversified bi-products using peanuts as an input. Entrepreneurial surplus allocates scare resources more efficiently, allowing for specialization and optimization, which creates competitive advantage. However, entrepreneurship activity requires education and there is little investment in education by the Haitian government; participation even in the current education system is not compulsory. Private education exists for those who can afford it. However, given a very low household income, the investment in education is often not made. Weir and Knight (2000) underscore education level as the main driver for technological adoption. As Liu (2013) and Suri (2011) point out, rural farmers are often risk adverse and negative outcomes impacts their standard of living more significantly than higher incomes do. The same might be true of Haitian farmers and like investments in education, investments in product diversity and technology are rarely made.

A very simple case in which comparative advantage could be gained from product diversification along the Haitian peanut value chain is that of peanut oil. Peanut oil is a relatively simple derivation from the peanut, has known health advantages such as naturally trans-fat free and cholesterol free. The process by which the oil is extracted from peanuts also eliminates any aflatoxin[4] presence, thus giving the farmer a market outlet for his peanuts that are unsafe for human consumption. Additionally, peanut butter, which is widely consumed by Haitians, is increasingly being imported due to high aflatoxin levels in domestically grown peanuts as the fungus is not eradicated in the peanut butter production process.

Unfortunately, there is a disincentive to control aflatoxins within the value chain; food safety is often a function of government and seemingly falls very low on the priority list of Ministry of Agriculture officials in Port-au-Prince. This lack of external governance has given rise to these inefficiencies as well as increased concerns about food safety present in the peanut value chain.

The second element to value chain analysis, governance, can be divided into two simpler forms (Kaplinsky and Morris 2001). The internal governance of the value chain, which manages the labor force or the "interfirm division of labor" and the external governance which ensures compliance with the rule of law, food safety standards, and trade policies. These distinctions are significant because of the coordination required between both forms of governance when it comes to policy design, quality standards, and trade restrictions. For example, if Haitian grown

[4] Aflatoxins are toxic metabolites produced by fungi in foods and feeds which are harmful if consumed by humans.

peanuts were destined for export markets, they must meet the food safety standards of their receiving markets. For this to be possible, a high level of coordination between internal management and government regulators would be required to ensure international standards are met. However, the Ministry of Agriculture is seemingly powerless to enforce even simple and domestic regulation, which effectively eliminates Haitian peanuts from inclusion in the international market since food quality standards, especially in potential export markets such as the European Union, are higher and cannot currently be met by Haiti.

Even the domestic market is negatively impacted by a misaligned incentive structure. For example, Meds and Food for Kids (MFK), an NGO operating in the Northern Province near Cap-Haitian, is a Ready-to-Use Therapeutic Food (RUTF) producer based almost entirely on peanuts. However due to high aflatoxin levels in Haitian peanuts, MFK is forced to import 80% of the peanuts it uses in the production process. If either the Haitian government developed and implemented an aflatoxin control policy or if the altruistic farmer took measures to do the same, the demand for peanuts from MFK could be fulfilled primarily by domestic supply. Additionally, a futures or forward contract system could be implemented resulting in increased up front income for the farmer. Which not only would decrease their risk while affording them capital to consume or make investments, but it also would increase domestic supply for MFK and other purchasers of peanuts, and ultimately lead to increased overall quality and decreased price volatility.

The third element of value chain analysis is targeting systemic efficiencies (Kaplinsky and Morris 2001). In a value chain defined by inefficiencies, there are many links and nodes that can be improved upon. As the TNS study points out, improved seed quality and adoption of best practices can dramatically increase farmers' yields. Two main peanut varieties are grown in

Haiti; a local Valencia and a local Runner variety. However, there exists no government or private organization for seed production, multiplication, or genetic engineering. The study also noted that farmers rarely retain the best seed for use in the next year's crop. Typically, poorer quality seed is retained from the harvest and then replanted the next season generating a geometric decay in yield and quality over time. MFK has established research plots for improved seed trials and has found success with improved varieties from the United States. However, a cure-all seed, that is one that is high yielding and disease resistant, has not been developed. Runner and Valencia varieties that have been developed in the US by crop scientists at the University of Georgia and the University of New Mexico have been bred and selected for resistance to standard diseases such as Tomato Spotted Wilt Virus and White Mold. Specifically, the Georgia-06G (GA06G) and the New Mexico Valencia have both proven to be both high yielding of high quality peanuts and resistant to disease. Partnerships between US research universities and Haiti-based NGOs or the Haitian Ministry of Agriculture could prove to be mutually beneficial relationships in the seed sector.

Furthermore, Porter and Millar (1985) work on the information flow along the value chain is relevant for the current state of the Haitian peanut value chain as there is minimal information available. Farmers are likely not aware of prices in the markets, demand signals are transmitted slowly through outdated information architecture, and limited information on weather forecasts hinder a farmer's ability to plan his planting and harvest. If information flowed faster and more freely, each agent in the value chain could make the best decision possible given their current information. The authors suggest that free information sharing optimizes the supply chain from start to finish and realized return is spread across all involved. Firms tend to become more integrated and work towards a common goal, though they must first be educated on best practices in order to gain equity in the process (Porter and Millar 1985).

The Madan-Sera style distribution breeds inefficiencies, in addition to aflatoxin infestation. While their highly-decentralized distribution provides market outlets for a larger number of farmers spread across the country, their operation is extremely limited in scope and scale. Thus, they only earn a few Gourdes (HTG)[5] for transporting small quantities of peanuts only a short distance. This inefficient distribution system necessitates an ever-constant changing of hands, decreased margins, and increased likelihood of fungal contamination. Thus, there are efficiency gains to be realized in both policy and distribution; additionally, implementation of the former will force productivity in the latter, improving the overall value chain.

[5] $1 USD = 63 Haitian Gourdes

CHAPTER 3

EFFECT OF FUNGICIDE USE ON YIELD AND PROFITABILITY

3.1 Data and Methodology

The data used in this research were collected from controlled variety trials conducted by a group of plant pathologists from the University of Georgia, in conjunction with several agronomists from Meds and Food for Kids (MFK), based in Cap-Haitien, Haiti. The purpose of these trials was to determine the number and interval of fungicide applications necessary for minimizing the severity of foliar diseases, such as late leaf spot and peanut rust, in addition to comparing the yield performance between two improved peanut varieties and two Haitian varieties. The trials took place over a two-year period, spanning the course of 2015 and 2016 and in two different locations, 22 different fungicide applications, 4 peanut varieties that included both runner and Valencia varieties as well as local and improved varieties. Test plots available at the MFK compound in Cap-Haitien provided one location for the trial, while the second location is situated further south in country in the Central Plateau region near the town of Mirebalais, which is thought to be a highly fertile and productive region of Haiti.

Trials at MFK were conducted under what is considered “ideal” conditions, such as advanced land preparation methods, calculated seed spacing methods, more frequent weeding schedule and contemporary sprinkler irrigation. The trials in Central Plateau were also conducted under controlled conditions, but better reflected techniques used by the majority of Haitian farmers, such as manual land preparation and flood irrigation. Due to the nature of Haiti’s tropical climate, which consists of an alternating dry season and rainy season pattern, two planting and harvesting periods can be completed throughout the year. To account for seasonal effects, planting periods are interspersed across both years and in both locations, though climatic differences between the two locations are minimal and are not expected to affect the yield significantly.

While Haitian local runner and Valencia seed varieties are well adapted to the Haitian climate, as well as traditional Haitian farming methods, the improved varieties from the United States have been bred specifically for their high yield potential; most notably in intensively managed agroecosystems. These specific varieties may include more resistance to the predominant foliar diseases in Haiti, late leaf spot and peanut rust as examples. All the varieties used in these studies are susceptible to these diseases, but it is not known to what degree they may differ. Late leaf spot and rust are prevalent in warm, humid climates and can result in total crop failure if not carefully managed. Both leafspot and rust can be controlled with fungicide applications, however these inputs are costly and it is often the case that Haitian farmers forgo this treatment because of the associated opportunity and economic costs.

The runner varieties tested were the local Haitian variety and the improved variety from the United States, 'Georgia-06G' (GA06G). The GA06G is a high-yielding, large seeded, runner-type variety, developed at the UGA Coastal Plain Experiment Station located in Tifton, Georgia (Branch 2006). This variety has an intermediate or decumbent runner growth habit, dark green foliage and medium maturity. The GA06G combines high resistance to the virus Tomato spotted wilt (TSWV) and moderate levels of leaf spot resistance with medium maturity and excellent yield, grade, and dollar value return per acre in the US (Branch, 2006). Both the local runner variety and the GA06G were tested at the MFK test plots in Cap-Haitian with extensive ground preparation completed prior to planting.

Seeds were planted in one of two ways to control for spacing; either 3 seeds per foot or 6 seeds per foot, along two 15-foot rows set apart by two feet. The total duration of the trial was approximately 130 days, a standard gestation period for these varieties under these conditions. Weeding was done manually starting at week 4 after planting and again at 6 and 8 weeks while fertilizer and irrigation treatments were applied as needed. Visual inspections of common diseases such as leafspot and rust were measured and recorded at various intervals during the growth stage. Twelve different combinations of fungicide applications were sprayed throughout the growth process and compared to the untreated control plot to determine the optimal number and frequency of fungicide treatments. The fungicide used was Muscle ADV, an evolution of two proven and powerful fungicides, Tebuconazole and Chlorothalonil. Muscle ADV has been proven to be effective against early and late leaf spot, rust, southern blight[6], rhizoctonia, as well as other diseases (Sipcam Agro). Fungicide is available to Haitian farmers from purchase in the market or as part of the credit package offered by firms like MFK and Acesso. Table 1 illustrates the specifics of the fungicide applications at MFK:

[6] *Sclerotium rolfsi*

Table 1: MFK Fungicide Application

Fungicide Treatment Indicator	**Total Applications**	**First Application**	**Spray Interval**
0	Untreated	NA	NA
1	1 Spray	45 DAP[7]	NA
2	2 Spray	45 DAP	21 days
3	2 Spray	45 DAP	28 days
4	2 Spray	60 DAP	28 days
5	3 Spray	30 DAP	21 days
6	3 Spray	37 DAP	28 days
7	3 Spray	45 DAP	14 days
8	3 Spray	45 DAP	28 days
9	4 Spray	30 DAP	14 days
10	4 Spray	37 DAP	21 days
11	4 Spray	45 DAP	21 days
12	6 Spray	30 DAP	14 days

Harvest occurred approximately 18 weeks after planting, during which the plants were pulled up manually and yield measurements were taken. During harvesting some peanuts remain in the ground once the initial mass has been removed, however it is standard practice for Haitian farmers to dig up the remaining peanuts. Yield was assessed with two different methods, the US-style of harvesting and the Haitian style.

First, after manually pulling the plants from the ground, pods that were on the surface of the ground or still attached to the plant were bagged and labeled separately. Because US harvesting is fully mechanized, this is where the process ends. Whereas the Haitian method is fully manual, the harvesters will dig up the top 6 inches of the soil in each plot and sift through to uncover all pods. These additional pods that were found were placed in a separate sack and labeled. The final yield estimate is a combination of the peanuts from the initial pull that have

[7] Days After Planting (DAP)

been picked off the plant combined with the mass of those that have been dug up from the soil. A 10% moisture downward adjustment is made to final calculation, and yield is measured in kilograms per hectare.

The Valencia varieties trials were conducted just outside of Mirebalais in the Central Plateau region of Haiti. A local Valencia and improved Valencia, New Mexico Valencia A, were tested under slightly different conditions than trials in Cap-Haitien. The New Mexico Valencia A was released by New Mexico State University (NMSU) Agricultural Experiment Station in 1971 (NMSU 1971). It is a selection made from an older Tennessee Red variety, has a bunch growth habit and a maturity range of 130-135 days. However, preliminary results indicate that these varieties mature approximately 20 days earlier in Haiti.

Due to economic and opportunity cost of inputs such as precise planting, weeding and sprinkler irrigation on the average small holder Haitian farm, they are often omitted completely. The Central Plateau Trial mimicked indigenous conditions by reducing management and financially intensive inputs and both varieties went through the same treatments. Land preparation was limited to simple tillage and a less frequent weeding schedule. Over the course of the growth cycle, weeding took place only twice, once at 4 weeks after planting and then 6 weeks. Flood irrigation was used in lieu of sprinkler irrigation; as the former method is the more commonly used in Haiti. This irrigation technique simply diverts water from its source via a ditch or pipe, over the land. However, depending on the slope of the land this method does not evenly distribute water across the crop and is prone to runoff, thus its efficiency and efficacy are reduced. Visual inspections were made and measurements taken of disease presence, leafspot and rust, beginning 30 days after planting and were continued until the end of the trial. As in the Cap-Haitian trials, eight combinations of fungicide application were sprayed at various times after planting and then at varying intervals to determine application optimality. The same Muscle ADV fungicide was used as in the previous trials to control for differences in types of fungicides. Table 2 specifies the timing and frequency of fungicide applications for the Central Plateau trials.

Table 2: Central Plateau Fungicide Application

Fungicide Treatment Indicator	**Total Applications**	**First Application**	**Spray Interval**
0	Untreated	NA	NA
1	1 Spray	45 DAP	NA
2	2 Spray	45 DAP	28 days
3	2 Spray	45 DAP	21 days
4	3 Spray	45 DAP	21 days
5	3 Spray	30 DAP	21 days
6	3 Spray	37 DAP	14 days
7	3 Spray	37 DAP	21 days
8	4 Spray	30 DAP	14 days

Though there are an infinite number of explanatory variables that pertinently explain yield, a combination of management inputs and environmental inputs (Gotsch and Regev 1996) have been shown to be the best predictors. Management input variables include seed spacing, irrigation method and disease mitigation; while environmental inputs are those such as location and year. During the trials at MFK and Central Plateau, several measurements of explanatory variables were taken of throughout the growing cycle to capture all relevant information that could best explains peanut yield. Table 3 gives a breakdown of the variables used in the study.

Table 3: Variable Descriptions

Variables	**Definition**	**Variable type**	**Model Notation**	**MFK**	**Central Plateau**
Yield (Dependent Variable)	Measured in Kilograms per Hectare (kg/ha)	Continuous	yield	Same in both locations	
Variety	Four (4) Varieties; Local Runner, Local Valencia, GA06G, and New Mexico Valencia	Binary	lrun lval ga06g nmval	Local Runner, Local Valencia, GA06G, and New Mexico Valencia	Local Valencia and New Mexico Valencia
Seed Spacing	Three or Six Feet Space Between Seed Plots	Binary	threeft sixft	Three Feet or Six Feet	Three Feet
Fungicide Treatment	Twenty-two (22) Different Combinations of Fungicide Treatments to Include Untreated Plants.	Factor Quadratic	trt trt^2	Thirteen (13) Treatments	Nine (9) Treatments
Leafspot and Rust	Visual Inspection of Disease Presence. Severity Scale, 1-10 (10 defined as most severe)	Continuous	leafspot rust	Same in both locations	

Because the trial procedures in each location were very different the empirical model is broken into two different models by location. Using a dummy variable to differentiate between locations only appeared to confound the results and create collinearity, resulting in some parameters not being estimated, thus two separate models for each location are used. The total sample is 458 observations which is split by location; 129 in the Central Plateau and 329 at MFK. The summary statistics of variables for both Central Plateau and MFK are presented in Tables 4 and 5, respectively. Figures 1 and 2 display a visual reference of yield variability at both sites.

Table 4: Summary Statistics, Central Plateau

Variable	**Mean**	**Standard Deviation**	**Minimum Value**	**Maximum Value**
2015	.43	.49	0	1
2016	.56	.49	0	1
Local Valencia	.51	.50	0	1
New Mexico Valencia	.48	.50	0	1
Fungicide Treatment	3.81	2.68	0	8
Leafspot	2.85	1.08	1.5	7
Rust	3.34	1.44	1.5	7.5
Overall Yield	2162.86	876.01	566.89	4160.1
Local Valencia Yield	2412.14	864.75	949.01	4160.1
NM Valencia Yield	1897.23	813.65	566.89	3480.92

The Central Plateau trials had 126 observations of yield with the mean of the local valencia variety being much higher than the New Mexico Valencia, indicating that even an improved variety does not always adapt well in a new environment. The means of both rust and leafspot were reltiviely low given the persistence of the diseases in Haiti.

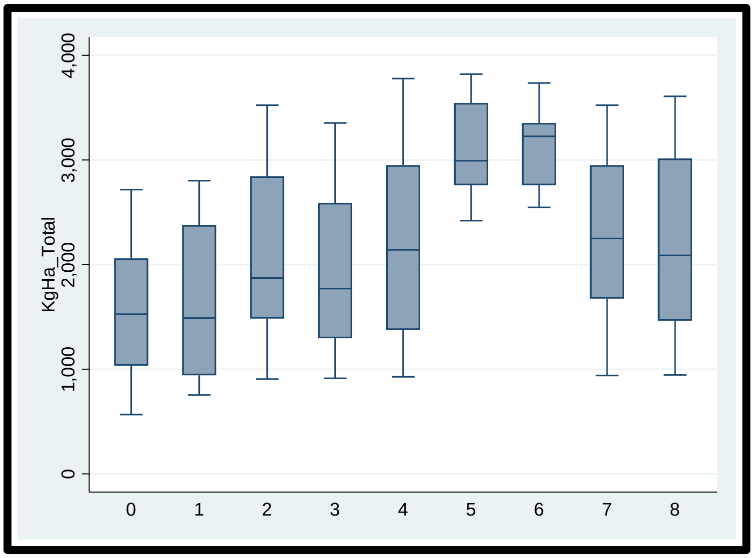

Figure 1: Yield Varability, Central Plateau

Figure 1 is Tukey's box graph of yield and its variation across the range of fungicide treatments. The shape across the median values is parabolic, indicating a diminishing marginal returns effect on yield as funcigide treatments increase. In spite of some treatments having high varability, there are no outlier observations and only Treatment 1 performed worse than the control, Treatment 0 or Untreated. Treatments 5 and 6 appear to be yield-maximizing, Treatment 6 having the higher median while Treatment 5 has the higher maximum value, in addition to having the least varaibilty.

Table 5: Summary Statistics, MFK

Variable	**Mean**	**Standard Deviation**	**Minimum Value**	**Maximum Value**
2015	.33	.47	0	1
2016	.66	.47	0	1
Local Valencia	.25	.43	0	1
New Mexico Valencia	.24	.43	0	1
Local Runner	.24	.43	0	1
GA06G	.24	.43	0	1
3 Feet Spacing	.41	.49	0	1
6 Feet Spacing	.58	.49	0	1
Fungicide Treatment	5.55	3.93	0	12
Leafspot	4.13	2.10	1.5	10
Rust	4.82	2.06	1.25	9
Yield	3898.02	1291.82	1001.4	8945.97
Local Runner Yield	3555.71	1108.68	1405.3	7827.72
GA06G Yield	4681.13	1811.11	1788.6	8945.97
Local Valencia Yield	3628.48	779.53	1335.3	4981.6
NM Valencia Yield	3729.96	888.35	1001.4	5232.8

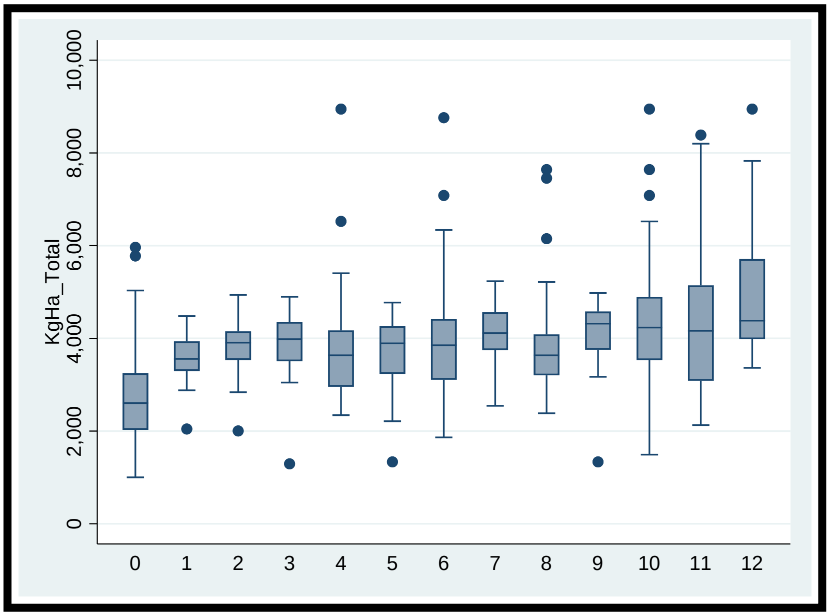

Figure 2: Yield Varability, MFK

Comparing the summary statistics shows systematic differences between the two locations in terms of yield; mean values and maximum values, the higher of both being at MFK. The GA06G variety produced nearly 1000kg/ha more than the two local varieties at MFK and also the varieties in the Central Plateau. This is likely attributed to the more intensely-managed inputs used at MFK such as seed spacing and increased fungicide treatments. Contrarily however, Figure 2 shows significant variability as well as many outliers both on the low and high ends of the MFK trials. There does not appear to be a pattern of diminishing marginal productivity in the MFK yield data, as the median yield generally increases with each treatment. Additionally, though a subjective measure, both leafspot and rust were, on average, lower in Central Plateau than at MFK.

3.2 Empirical Analysis

To analyze the effect and the magnitude of fungicide treatments on peanut yield, we estimate an unrestricted linear model by Ordinary Least Squares (OLS). Gotsch and Regev (1996) suggest that a linear relationship between inputs and output best fit agricultural data. Model flexibility, computational ease, and coefficient interpretation of an OLS are also essential to examine the individual effects of fungicide application on yield. As mentioned earlier, we use two separate specification for each location because the trials were quite different and some covariates held significant explanatory power in one location, but not in another. For example, in the Central Plateau trials, it was determined that the yield differed systematically between 2015 and 2016, and this was not the case at MFK. Following Gotsch and Regev (1996) the specifications for each location are presented below.

Central Plateau Regression Equation:

(1) $Yield_i = \alpha_0 + \alpha_1 2015_i + \alpha_2 LVal_i + \alpha_3 Leafspot_i + \alpha_4 Rust_i + \alpha_k \sum_{i=0}^{8} FungTrt_i + \varepsilon_i$

(2) $Yield_i = \alpha_0 + \alpha_1 2015_i + \alpha_2 LVal_i + \alpha_3 Leafspot_i + \alpha_4 Rust_i + \alpha_5 FungTrt_i + \alpha_6 FungTrt_i^2 + \varepsilon_i$

MFK Regression Equation:

(3) $Yield_j = \beta_0 + \beta_1 LVal_j + \beta_2 LRun_j + \beta_3 GA06G_j + \beta_4 ThreeFt_j + \beta_5 Leafspot_j + \beta_6 Rust_j + \beta_j \sum_{i=0}^{12} FungTrt_j + \varepsilon_j$

(4) $Yield_j = \beta_0 + \beta_1 LVal_j + \beta_2 LRun_j + \beta_3 GA06G_j + \beta_4 ThreeFt_j + \beta_5 Leafspot_j + \beta_6 Rust_j + \beta_7 FungTrt_j + \beta_8 FungTrt_j^2 + +\varepsilon_j$

Where the variables are defined in Table 3, $FungTrt_i^2$ is Fungicide Treatments squared, and ε_i is the error term.

The model uses the level values of the continuous variables in lieu of logarithmic values, binary variables were used for peanut varieties, while factor variables quantify the fungicide treatments. We expect the increase in fungicide applications and frequency to increase yield and ultimately, as explained below, increase net income with respect to additional cost of fungicide.

Standard OLS assumptions are tested and verified in the model. We assume the residuals are distributed normally and sum to zero, a normal probability plot confirms this conclusion. Second, we assume there is no perfect multicollinearity. A visual inspection of the residuals indicates no presence of serial correlation. However there appears to be heteroskedasticity in the residuals and the Breusch-Pagan test for heteroskedasticity supported this. As a result, the inflated standard errors are corrected by specifying heteroskedastic-robust standard errors. In addition, a post estimation Variance Inflation Factor (VIF) test indicates this correction is appropriate and thus the significance of parameters is not biased in the results. Throughout the estimation process, as a robustness check, we specified various econometric models. However, The Ramsey Regression Equation Specification Error Test (RESET) suggests the specification estimated is appropriate and does not suffer from omitted variable bias.

Following Gotsch and Regev (1996), the unrestricted linear regression allows us to observe the marginal productivity of each fungicide application through the partial derivative of the yield with respect to a specific input and is given by a linear combination of the parameter vector. The marginal product of each fungicide treatment (MPF) can be determined by:

$$MPF = \frac{\partial Yield_i}{\partial FungTrt_i} = \alpha_k$$

Given a quadratic variable the MPF is determined using the equation below:

$$MPF = \frac{\partial Yield_i}{\partial FungTrt_i^2} = \beta_j + 2 * \beta_k$$

where the α_k is the ceteris paribus effect of fungicide on yield compared to the base group of no treatment while all other explanatory variables are held constant. The quadratic interpretation is a bit different as the marginal effect of $\beta_j + 2 * \beta_k$ implies an exponential increase in yield as fungicide treatments also increase.

3.3 Supplementary Regression Specification

In addition to the primary regression models specified in Section 3.2, we want to provide variety-specific analysis by estimating supplementary regressions. Similar to the previous analysis we use yield as the dependent variable which is stratified by variety. The independent variables include seasons, seeds per hole, and the number of fungicide treatments. Irrigation was not controlled for at either location since all the trials were under well irrigated conditions. These variables differ slightly in notation and a more detailed description is provided in Appendix A. The specifications for variety-specific yield at both locations are:

(5) $LValYield_i = \alpha_0 + \alpha_1 \sum_{i=0}^{2} Season_i + \alpha_2 Rust_i + \alpha_3 Leafspot_i + \sum_{i=0}^{9} \alpha_k FungTrt_i + \alpha_j \sum_{i=0}^{9} FungTrt_i * \sum_{i=0}^{2} Season_i + \varepsilon_i$

(6) $NMValYield_i = \alpha_0 + \alpha_1 \sum_{i=0}^{2} Season_i + \alpha_2 Rust_i + \alpha_3 Leafspot_i + \sum_{i=0}^{9} \alpha_k FungTrt_i + \alpha_j \sum_{i=0}^{9} FungTrt_i * \sum_{i=0}^{2} Season_i + \varepsilon_i$

$$(7)\ LValYield_j = \beta_0 + \beta_1 \sum_{i=0}^{2} Season_j + \beta_2 Seeds_j + \beta_3 Leafspot_j + \beta_4 Rust_j + \beta_k \sum_{i=0}^{9} FungTrt_j + \beta_j \sum_{i=0}^{9} FungTrt_j * \sum_{i=0}^{2} Season_j + \varepsilon_j$$

$$(8)\ NMValYield_j = \beta_0 + \beta_1 \sum_{i=0}^{2} Season_j + \beta_2 Seeds_j + \beta_3 Leafspot_j + \beta_4 Rust_j + \beta_k \sum_{i=0}^{9} FungTrt_j + \beta_j \sum_{i=0}^{9} FungTrt_j * \sum_{i=0}^{2} Season_i + \varepsilon_j$$

$$(9)\ LRunYield_j = \beta_0 + \beta_1 \sum_{i=0}^{2} Season_j + \beta_2 Seeds_j + \beta_3 Leafspot_j + \beta_4 Rust_j + \beta_k \sum_{i=0}^{6} FungTrt_j + \beta_j \sum_{i=0}^{6} FungTrt_j * \sum_{i=0}^{2} Season_j + \varepsilon_j$$

$$(10)\ GA06GYield_j = \beta_0 + \beta_1 \sum_{i=0}^{2} Season_j + \beta_2 Seeds_j + \beta_3 Leafspot_j + \beta_4 Rust_j + \beta_k \sum_{i=0}^{6} FungTrt_j + \beta_j \sum_{i=0}^{6} FungTrt_j * \sum_{i=0}^{2} Season_j + \varepsilon_j$$

Equations 5 and 6 are for each variety tested in the Central Plateau and equations 7 through 10 are for each variety tested at MFK in Cap-Haitian.

3.4 Return on Investment Methodology

Agriculture is, at its core, an entrepreneurial enterprise. Often a sole proprietorship whereby the farmer employs his or her human capital, financial capital, and other inputs into production of a good to be sold for greater than the sum total cost of the inputs. There are however risk and uncertainty present in an entrepreneurial venture but if the former are well-managed, profit is an attainable outcome. Thus, the regression results provide insights into whether and how the fungicide applications increase productivity and therefore profits. Another important question is what is the optimal use of fungicides given increased yields but also accounting for costs to maximize profits.

The results of the empirical models show a consistent increase in yield given an increase in fungicide applications and frequencies, even when taking into account the diminishing marginal returns observed in the Central Plateau data. However, given the development context it must be noted that the initial capital investment in fungicide, not to mention the later investment in additional labor can constitute a significant portion of the farmer's income and leaves the farmer with a difficult decision with imperfect information and an unknown outcome. Thus, we will employ a simple Return on Investment (ROI) approach to comparing the income impacts of capital investment in different amounts of fungicide balanced by the cost of the fungicide.

ROI is in its basic form below:

$$ROI = \frac{(P * Q) - C(K, L)}{C(K, L)}$$

Where revenue is the product of current peanut prices (*P*) and yield (*Q*). Where the cost function (*C*) is the total sum of capital (*K*) and labor (*L*) inputs the farmer invests throughout the planting and harvesting period. ROI is expressed as a percentage.

It must be noted that estimates provided here are for in-shell peanuts, as shelling incurs additional costs which are difficult to estimate because they vary greatly from sheller to sheller. Additionally, there are loss rates associated with shelling that may vary substantially upon the sheller and the machine employed to shell peanuts. Costs for inputs, such as fungicide and labor are estimated from NGO workers with years of experience in Haiti and provide a framework for comparing potential revenues from improved practices and varieties. Itemized costs are detailed in Table 6.

Table 6: Estimated Input Costs

Input	**HTG**	**USD**
Muscle ADV fungicide (2.5gal)	9275	$147.22
Labor/ha	774	$12.28
Total Cost	10049	$159.50

There are quite a few assumptions that must be made when estimating farmers' cost for fungicide. Firstly, if the fungicide is purchase on the open market then the entire container must be purchased, not only what is needed for the application. However, MFK personnel have calculated that roughly only 1/3 of the container is used per hectare and since the average farm size is around one hectare, the remaining fungicide can be used for future planting seasons. It also must be noted that labor costs are highly variable by region and farmers often participate in a system called *konbit*, which is a communal approach to labor sharing where there is often no money exchanged. Nevertheless, we estimate that the average laborer can spray one hectare in approximately 2 hours, thus our labor cost planning factor in Table 6. It is likely that we are overestimating the cost of fungicide, however we are not considering other labor costs like weeding and harvest. Additionally, we omit factors such as discount rates, interest rates, and taxes because the budget is only a snapshot in time and we do not want to confound the results with unnecessary or contextually non-existent variables that would shift focus away from the goal of isolating the effect of fungicide on yield and household income.

In the last step of the ROI analysis, we do not use yields from the trial data as they were a lot higher than the average farmer peanut yields and restrict yield to reflect those more commonly found on Haitian farms. Specifically, we employ the same cost structure from Table 6 but limit yield to 250, 500, and 750 kilograms per hectare (kg/ha). This exercise will provide more insight into whether it is profitable for Haitian peanut farmers to use fungicide treatments

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Central Plateau Regression Results

The regression results from Equation (1) for the Central Plateau are presented in Table 7. The estimation results explain 87% of the variation in peanut yield, indicating the model fits the data relatively well. 10 of 13 coefficients, including the constant, are strongly statistically significant, the exceptions being Treatment 1, Leafspot, and Rust which are still moderately significant at the 5% level of significance. The binary year variable is interpreted relative to the base year, 2016, thus the 2015 trials yielded systematically less than those in 2016. Similarly, Treatment 0 or "Untreated" is dropped to avoid perfect multicollinearity and the remaining treatment variables are compared to the untreated group.

Most input variables are consistent with plant management theory and quantitative studies which purport that the managed inputs and improved varieties have a positive effect on peanut yield. The quadratic treatment variable has a negative coefficient which implies that it has a negative effect on yield after a certain point on the parabola. Based on the results of equation 1, this maximum point is treatment 5. Treatment 5, which corresponds to 3 Sprays at 45 days after planting and a spraying frequency of 14 days, provides the highest positive effect on yield with 867 kilograms per hectare more than the untreated group. Though the standard error for treatment 5 is significantly higher than the other treatments, the 95% upper-bound is over 125kg higher on average than the next highest yielding treatment. However, we do witness diminishing marginal returns present in the yield data. Once the optimal treatment is surpassed, as more treatments are added, we observe a slightly negatively sloped trend in output, which is consistent with production economic theory.

Table 7: OLS Regression Results, Central Plateau

Central Plateau	Equation 1	Equation 2
Variables	Coefficient (Robust SE)	Coefficient (Robust SE)
2015	-1284.1*** (109.26)	-1248.29*** (97.25)
Local Valencia	482.03*** (61.09)	485.00*** (63.819)
Leafspot	129.61** (60.90)	92.83 (65.28)
Rust	-109.90** (54.87)	-118.35** (55.73)
Treatment 1	201.14** (102.61)	
Treatment 2	610.81*** (127.30)	
Treatment 3	348.94*** (122.38)	
Treatment 4	717.76*** (135.58)	
Treatment 5	868.52*** (194.48)	
Treatment 6	855.38*** (138.92)	
Treatment 7	724.78*** (135.36)	
Treatment 8	784.36*** (141.51)	
Treatment		220.57*** (47.18)
$Treatment^2$		-16.92*** (5.46)
Constant	1938.51*** (166.73)	2103.49*** (149.09)

n = 126
Equation 1 - R-squared = 0.8732
Equation 2 – R-squared = 0.8575
Statistically significant at the *10%, **5%, and ***1% confidence levels

Results also indicate that the New Mexico Valencia performed worse at improving overall yields than the local Valencia variety. This could be a negative outcome related to the climatic differences between New Mexico and Haiti. Specifically, the conditions under which the New Mexico Valencia variety was developed does not perfectly mimic the weather patterns, soil composition, input management techniques, etc. of the adopted environment and thus cannot guarantee equivalent results.

The late leafspot coefficient in Table 6 is confounding because it is positive but weakly significant, indicating that an increase in leafspot results in an increase in yield which is contrary to plant disease management theory, whereas the effect of rust is negative and significant. Rust contributed to a reduction in yield of over 100kg on average. According to the plant pathologists conducting the trials, rust was monitored closely as its spread can result in total crop failure. The association between rust and yield by treatment is further quantified in Table 7 using Pearson's correlation coefficient (ρ) which indicates a highly inverse relationship, adding evidence to the importance of disease management.

Table 8: Peanut Rust and Yield Correlation, Central Plateau

Treatment	Average Rust	Average Yield (kg/ha)
0	4.7	1,558.74
1	4.0	1,728.54
2	3.3	2,121.51
3	3.7	1,919.63
4	3.2	2,227.67
5	1.9	3,104.17
6	2.4	3,120.09
7	2.7	2,252.32
8	2.9	2,368.00
Correlation Coefficient (ρ)		-0.93

Figure 3 below visually depicts the yield-maximizing treatment, treatment 5, and also the diminishing marginal returns phenomenon which occurs after the optimal point. Corresponding to the regression results, treatment 5 appears to be the optimal treatment in terms of highest yielding, however this does not take into consideration the cost of each treatment which will be discussed in Section 3 of this Chapter. On average, it yielded only 13kg/ha higher than treatment 6, however the maximum value of treatment 5 is over 125kg/ha higher at 2829kg/ha.

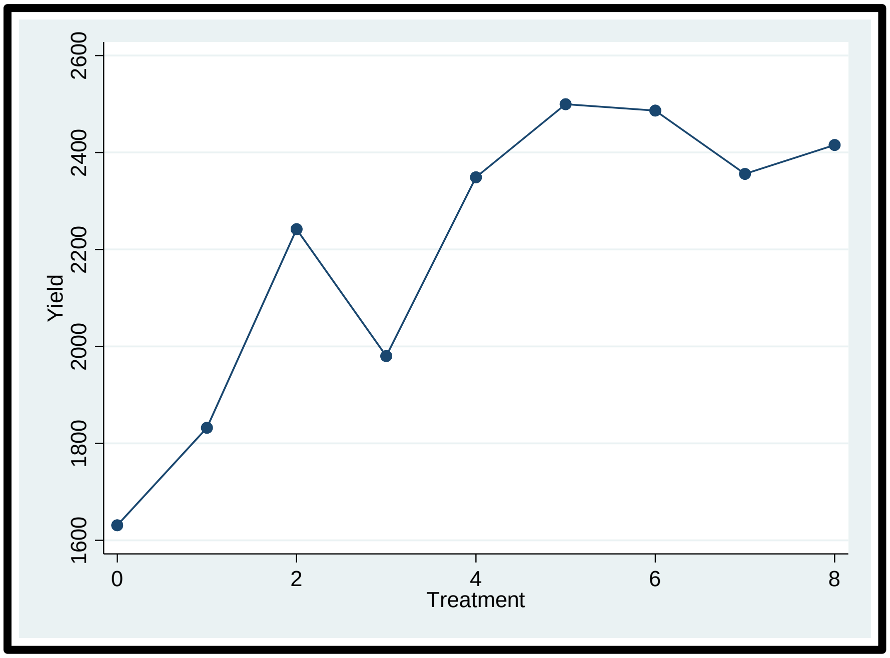

Figure 3: Average Yield by Treatment, Central Plateau

The results in Table 9 are derived from the Marginal Product of Fungicide (MPF) equations where a partial derivative of the regression equation is calculated with respect to each fungicide treatment, all other variables being held constant. This allows for a ceteris paribus comparison which isolates the individual treatment effect. The marginal products are equal to the regression coefficients except for the quadratic term which requires the use of the power rule for differentiating equations. The diminishing marginal productivity is evident in the results and, like the regressions, suggest that treatment 5 is optimal from a productivity and yield-maximizing perspective.

Table 9: Marginal Productivity per Treatment, Central Plateau

Variable	Margin	SE	Lower 95%	Upper 95%
Treatment 1	201.13**	102.61	-2.15	404.42
Treatment 2	610.80***	127.30	358.59	863.01
Treatment 3	348.93***	122.38	106.46	591.41
Treatment 4	717.76***	135.58	449.15	986.37
Treatment 5	868.51***	194.48	483.21	1253.82
Treatment 6	855.37***	138.92	580.14	1130.61
Treatment 7	724.77***	135.36	456.58	992.96
Treatment 8	784.36***	141.51	504.01	1064.73
Treatment	220.57***	47.18	127.13	314.01
Treatment^2	186.73***			

Statistically significant at the *10%, **5%, and ***1% confidence levels

The upper and lower 95% confidence intervals allow us to make a simple inference about potential revenue realizations from fungicide-use. To do this we remove the seasonal trend and take a yearly average and use Valencia in-shell prices per kilogram, which calculates to 60.60 HTG/kilogram after the conversion of the local weight measurement of marmites to kilograms. Then applying those prices to the confidence intervals produces potential revenues for each treatment. For comparison, conversion of Haitian Gourdes to US Dollars is provided. The results are highlighted below in Table 10:

Table 10: Revenue by Treatment, Central Plateau

Treatment	Lower Revenue Bound (HTG)	Upper Revenue Bound (HTG)	Lower Revenue Bound (USD)	Upper Revenue Bound (USD)
0	87,878	109,802	1,395	1,743
1	102,064	119,994	1,620	1,905
2	126,416	145,294	2,007	2,306
3	109,706	130,266	1,741	2,068
4	132,258	152,415	2,099	2,419
5	131,465	171,480	2,087	2,722
6	137,530	163,822	2,183	2,600
7	132,547	152,977	2,104	2,428
8	134,605	158,141	2,137	2,510

Without taking cost into account, it is evident that the investment in fungicide significantly increases revenue potential. Compared to Untreated (Treatment 0), Treatment 1's the lower bound revenue potential increases 16%. Moreover, the optimal treatment's (Treatment 8) lower bound revenue when compared to Untreated increases 53%.

4.2 MFK Regression Results

Table 11 presents regression results of equations (3) and (4) for the trials at MFK. The regression results from the MFK trials differ from those in the Central Plateau in two aspects. Firstly, there are no diminishing marginal returns observed in the treatment effects from either equation and while the coefficient on the quadratic term is negative as would be expected, it's not statistically different from zero. Secondly, the improved varieties offered no better results as compared to their local counterparts. In fact, only the local runner variety produced statistically significant results even though its performance was weak as compared to the New Mexico Valencia variety which is the base group. Additionally, seed spacing seemed to play a role in increasing yield; the coefficient of the 3 feet spacing variable is positive and significant relative to the base group of 6 feet spacing. There is a generally increasing magnitude of effect on yield given each treatment culminating with treatment 12[8] which is the optimal fungicide application; on average, contributing to a 1759kg/ha increase in yield compared to the untreated group. The leafspot coefficient is not statistically different than zero which is likely due to the increased amount and concentration of fungicide applications from which this trial benefited.

[8] Treatment 12 (6 Sprays,30 Days After Planting, 14 Day Intervals)

Table 11: OLS Regression Results, MFK

MFK	Equation 3	Equation 4
Variable	Coefficient (Robust SE)	Coefficient (Robust SE)
3 Feet Spacing	611.51*** (165.44)	620.38*** (163.75)
Local Runner	-1122.24*** (444.12)	-1272.16*** (278.62)
GA06G	222.03 (335.58)	84.7 (186.22)
Local Valencia	-54.60 (114.48)	-24.83 (116.37)
Leafspot	35.66 (46.77)	19.11 (44.21)
Rust	-121.82* (63.39)	-147.95*** (57.71)
Treatment 1	836.38*** (220.62)	
Treatment 2	990.90*** (281.03)	
Treatment 3	962.89*** (292.49)	
Treatment 4	859.71** (388.90)	
Treatment 5	838.82*** (301.91)	
Treatment 6	907.77** (397.84)	
Treatment 7	1104.23*** (335.43)	
Treatment 8	938.46*** (334.93)	
Treatment 9	1060.06*** (369.36)	
Treatment 10	1371.10*** (410.39)	
Treatment 11	1235.77*** (450.42)	
Treatment 12	1759.91*** (432.46)	
Treatment		91.97 (62.32)

Table 11: OLS Regression Results, MFK (Continued)

Treatment^2		-.518 (5.47)
Constant	3397.23*** (491.89)	4091.60*** (356.31)

n = 329
Equation 3 - R-squared = 0.3158
Equation 4 - R-squared = 0.2859
Statistically significant at the *10%, **5%, and ***1% confidence levels

Rust has a significantly adverse effect on the viability of the plant, not to mention seed and oil quality. During the trials, the plant pathologists were very concerned about its presence since its proliferation can result in absolute crop failure. Fortuitously, Table 12 shows a negative relationship in disease occurrence given an increase in fungicide treatments. Pearson's correlation coefficient highlights this relationship.

Table 12: Peanut Rust and Yield Correlation, MFK

Treatment	Average Rust	Average Yield (kg/ha)
0	7.6	2,766.19
1	6.7	3,587.04
2	5.3	3,826.72
3	5.3	3,849.82
4	4.8	3,902.45
5	5.2	3,701.01
6	3.7	4,071.00
7	3.9	4,078.57
8	4.5	4,011.84
9	3.4	4,090.74
10	3.3	4,543.42
11	3.5	4,392.55
12	2.3	5,027.20
Correlation Coefficient (ρ)		-0.94

Figure 4 shows the drastic increase in yield using treatment 12, a 42% improvement over treatment 11. Also noteworthy is the change in yield between treatment 0 or the untreated option and treatment 1; underscoring the importance of employing even minimal disease management and its positive effects on yield.

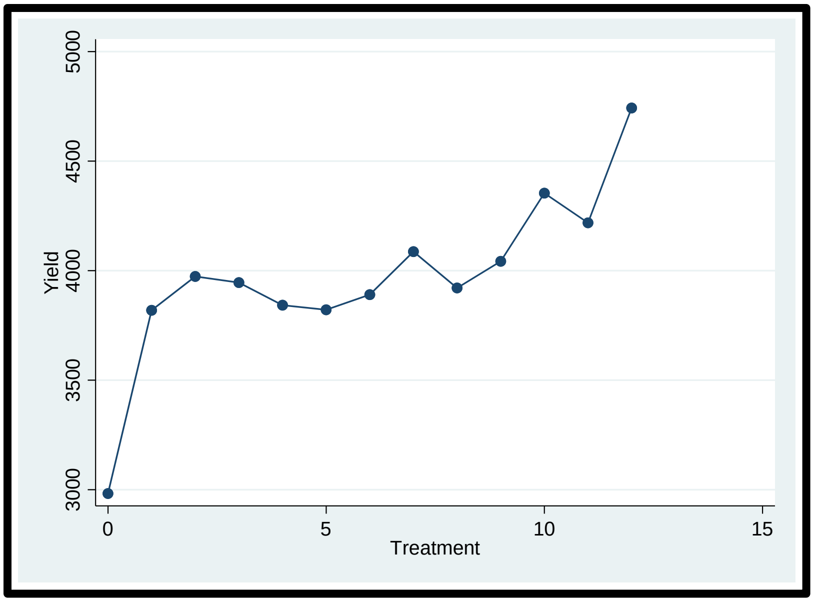

Figure 4: Average Yield by Treatment, MFK

Table 13 highlights the marginal effects of each individual treatment along with the 95% confidence interval. In fact, the yield range varies widely throughout the treatments with many outliers, though the average does generally increase with increased treatments. The most frequent and concentrated treatment resulted in the highest yield by over 4000 kg/ha, both having similar standard errors. Like the results from Table 9, the margins are equal to the regression coefficients, with the exception of the quadratic term, which in this case is not statistically significant. In fact, the quadratic term is used to capture increasing marginal effects, specifically yield that is increasing at an increasing rate (exponentially) with each additional treatment, but given the term's insignificance we can infer that this is not the case with the MFK trials. The 95% confidence interval of treatment 12 in Table 14 covers a wide range of potential revenues for in-shell peanuts.

Table 13: Marginal Productivity per Treatment, MFK.

Variable	Margin	SE	Lower 95%	Upper 95%
Treatment 1	836.38**	220.62	402.26	1270.50
Treatment 2	990.90***	281.03	437.923	1543.88
Treatment 3	962.89***	292.499	387.35	1538.42
Treatment 4	859.71**	388.90	94.478	1624.94
Treatment 5	838.82***	301.91	244.76	1432.88
Treatment 6	907.77**	397.84	124.94	1690.59
Treatment 7	1104.23***	335.49	444.21	1764.25
Treatment 8	938.46***	334.935	279.42	1597.49
Treatment 9	1060.06***	369.31	333.28	1786.84
Treatment 10	1371.10***	410.39	563.58	2178.62
Treatment 11	1235.77***	450.42	349.50	2122.05
Treatment 12	1759.91***	432.46	908.97	2610.85
Treatment	91.97	62.32	-30.63	214.58
$Treatment^2$	90.93			

Statistically significant at the *10%, **5%, and ***1% confidence levels

Using the same methodology from the Central Plateau analysis, the upper bound of the highest yielding treatment results in an increase of 121,173 HTG or $1800 in revenue as compared to treatment 0, the untreated option. The result for each treatment is highlighted in Table 14.

Table 14: Revenue Analysis by Treatment, MFK

Treatment	Lower Revenue Bounds (HTG)	Upper Revenue Bounds (HTG)	Lower Revenue Bounds (USD)	Upper Revenue Bounds (USD)
0	155,962	205,519	2,476	3,262
1	209,999	252,851	3,333	4,014
2	218,520	263,058	3,469	4,176
3	213,765	264,419	3,393	4,197
4	193,733	271,945	3,075	4,317
5	205,335	257,811	3,259	4,092
6	195,344	276,159	3,101	4,383
7	221,511	273,804	3,516	4,346
8	204,051	271,171	3,239	4,304
9	214,962	274,998	3,412	4,365
10	224,294	303,365	3,560	4,815
11	212,662	298,595	3,376	4,740
12	248,091	326,692	3,938	5,186

This rudimentary analysis is simply more evidence of the positive effects of fungicide use on yield and thus revenue. The increase between treatment 0 (untreated) and treatment 1 a 23% increase in the upper revenue bound, underscoring even minimal disease management's positive impacts on yield and revenue. The optimal treatment, treatment 12, nearly triples the increase (59%) in potential income as compared to untreated yield however treatment costs should be considered. The Return on Investment Analysis section, which is discussed next, considers costs searches further into the net financial benefits of disease management.

4.3 Supplementary Regression Results

The results of all supplementary regressions are detailed in Appendix B. Table 22 in Appendix B presents the results for the Local Valencia, New Mexico Valencia at Central Plateau. In fact, only a few treatments terms were significant at the 1% level; the highest magnitude of effect on yield for the Local Valencia was Treatment 7[9] and Treatment 5[10] for the New Mexico Valencia We need to mention that specific variety regressions have a small number of observations which may affect the significance of the coefficients. The season dummy was highly significant which in the Central Plateau context indicates that the yield from the Spring 2016 were higher than the yields of the Spring/Summer 2015 trial.

Results from all four varieties at MFK were similar to those from the Central Plateau in that in spite of relatively high R-squared values, few of the terms were statistically significant; the majority of the variation in yield is captured by just a few variables including the constant term. For the Valencia varieties the treatment with the largest magnitude of effect on yield was Treatment 8[11]. Other treatments were statistically significant at the 5% and 10% levels; however the effect of Treatment 8 was 17% higher for the Local Valencia and 31% higher for the New Mexico Valencia than the next most significant treatment. The results also indicate no systematic difference in yield between seasons or seeds planted per hole.

The results for the runner varieties are presented in Table 24. The Local Runner and GA06G performed significantly worse in the Spring and Winter trials compared to the base season; both variables have large and negative magnitudes of effect in addition to being highly significant, the 5% and 1% levels, respectively. The seed variable was weakly significant; three seeds in each hole performed better than six per hole, this could indicate 6 seeds crowd each other out and constrained soil nutrients decreased germination rates. The runner varieties both benefited from a treatment that included 4 sprays of fungicide, though it is unclear why the GA06G, an improved variety, was not more inherently resistant. While Treatment 6 has the largest magnitude of effect

[9] Treatment 7 (3 Sprays, 45 Days After Planting, 14 Day Intervals)
[10] Treatment 5 (3 Sprays, 37 Days After Planting, 14 Day Intervals)
[11] Treatment 8 (3 Sprays, 45 Days After Planting, 28 Day Intervals)

on both the Local Runner and the GA06G, the treatment is only significant at the 10% level and highly variable. Thus, the Local Runner benefited most from Treatment 5[12], significant at the 1% level and with a much lower standard error. The GA06G had a similar result, Treatment 6 is only weakly significant while Treatment 4[13] was 107 kg/ha lower but is significant at the 1% level and has much lower yield variation.

These results are roughly similar to the primary regressions in that we can see diminishing marginal returns to fungicide. More clearly, the treatments that used more than 3 sprays for the Valencias and more and 4 for the Runners had no statistically significant effect on yield.

4.4 Return on Investment Analysis Results

The average yearly income of the Haitian farmer is approximately 40500 HTG or $642 USD (Kostandini et al. 2015). Some assumptions must be made regarding the cost of additional labor, time required to spray a tract of land with fungicide, and size of farm. For ease of comparison in addition to modeling a typical Haitian peanut farm, we assume a plot size of 1 hectare, the average is .96 hectares (Kostandini et al. 2015), and use yield data from the Central Plateau trials which more closely reflect local conditions. Based on the regression results in Table 6, the optimal fungicide application is Treatment 5[14] based on its magnitude of effect on yield. A range of peanut prices by variety were obtained from historical data kept by MFK and provide the information needed to estimate the spectrum of potential revenues. The standard size of a container of fungicide is 9.5 liters (2.5 gallons). Given the high cost of fungicide in Haiti, farmers tend to lower the concentration of fungicide by diluting it with water from the

[12] Treatment 5 (4 Sprays, 45 Days After Planting, 21 Day Intervals)
[13] Treatment 4 (4 Sprays, 37 Days After Planting, 21 Day Intervals)
[14] Treatment 5 (3 Sprays, 37 Days After Planting, 14 Day Intervals)

recommended mixture of 45ml of fungicide to 3.8l of water to 35ml to 3.8l of water. However, this dilution at this level does not seem to impact the fungicide's efficacy and lasts the duration of the growing season per MFK personnel and UGA Plant Pathologists. Given a properly calibrated sprayer, it is estimated that 1 hectare can be adequately sprayed in 2 hours. Table 15 gives planning factor costs, prices, and yields for both untreated and optimal treatments of fungicide in Haitian Gourdes and US Dollars:

Table 15: ROI Planning Factors, Central Plateau.

Central Plateau Trials	**HTG**	**USD**
Average Yearly Farmer Income	40500 HTG	$642
Plot Size	1 hectare	2.47 acres
Average Labor Cost/hectare	930	$14.76
Untreated Total Cost	0 HTG	$0
Untreated Average Yield	1631	3588.2
Optimal Treatment Total Cost	10049 HTG	$159.50
Optimal Treatment Average Yield	2499	5497.8
Low Price - Valencia	33.33 HTG/kg	$0.24
Average Price - Valencia	66.67 HTG/kg	$0.48
High Price - Valencia	100 HTG/kg	$0.72

Table 16: Profit Comparison, Central Plateau.

Price Scheme	**Low Price - Valencia**	**Average Price - Valencia**	**High Price - Valencia**
Untreated Profit - HTG	54,361.23	108,738.77	163,100
Treated Profit - HTG	73,242.67	154,543.33	239,851
Difference - HTG	18,881.44	45,804.56	76,751
Difference - USD	299.71	727.06	1218.27
Percent Change	35%	42%	47%

The Central Plateau ROI results highlight the complex decision faced by small scale Haitian peanut farmers, especially when faced with imperfect information. The initial investment of over 10000 HTG for fungicide and labor is met with an immediate return of 35% even with prices being at the lowest levels. The returns increase dramatically in bull markets when prices are at a moderate level, up to a 42% return. If the analysis included an even larger range of yields, costs and prices, it is possible that variety and price combinations would also result in lower return. However, the results overwhelmingly suggest the modest investment yields high returns. The yield-maximizing treatment (Treatment 5) combined with a high price environment can produce an ROI of 47%.

ROI analysis for the MFK trials follow the same structure as those from the Central Plateau analysis and are detailed in Table 17.

Table 17: ROI Planning Factors, MFK.

MFK Trials	**HTG**	**USD**
Average Yearly Farmer Income	40500 HTG	$642
Plot Size	1 hectare	2.47 acres
Average Labor Cost/hectare	930	$14.76
Untreated Total Cost	0 HTG	$0
Untreated Average Yield	2982 kg/ha	6560.4
Optimal Treatment Total Cost	10049 HTG	$159.50
Optimal Treatment Average Yield[15]	4742 kg/ha	10432.4
Low Price - Runner	27.27 HTG/kg	$0.20
Low Price - Valencia	33.33 HTG/kg	$0.24
Average Price - Runner	54.54 HTG/kg	$0.39
Average Price - Valencia	66.67 HTG/kg	$0.48
High Price - Runner	81.81 HTG/kg	$0.59
High Price - Valencia	100 HTG/kg	$0.72

[15] Treatment 12 (6 Sprays, 37 Days After Planting, 14 Day Intervals)

Like the Central Plateau ROI analysis, the results in Table 18 highlight a very discernable incentive to invest in disease management. Returns even when prices are low are well over 70%, and during periods of high demand for both runner and Valencia peanuts, a farmer can potentially see a return on investment of 92% and 94%, respectively. These results also highlight the effect of better management practices as MFK trials were more closely managed compared to those at the Central Plateau which more closely mimicked the typical Haitian farmer's practices.

Table 18: Profit Comparison, MFK.

Price Scheme	**Low Price - Runner**	**Low Price - Valencia**	**Average Price - Runner**	**Average Price - Valencia**	**High Price - Runner**	**High Price - Valencia**
Untreated Profit - HTG	81,319.14	99,390.06	162,638.28	198,809.94	243,957.42	298,200
Treated Profit - HTG	119,265.34	148,001.86	248,579.68	306,100.14	377,894.02	464,151
Difference - HTG	37,946.2	48,611.8	85,941.4	107,290.2	133,936.6	165,951
Difference - USD	602.32	771.62	1364.15	1703.02	2125.98	2634.14
Percent Change	47%	49%	53%	54%	55%	56%

Both ROI analyses present situations where farmers do not appear to be acting rationally when data clearly show high revenue potential from fungicide use. However, this is likely the result of imperfect information, liquidity constraints, and risk preferences. The decision to adopt or not adopt a new technology, such as the use of fungicide, is inherently risky. A farmer who is classified as risk neutral or risk seeking, might be more apt to adopt fungicide into his farm management given the Central Plateau ROI results above all scenarios resulted in a significant

(>50%) returns on investment. Additionally, the price variability could be controlled through policies and market initiatives, such as forward contracts, in order to ensure a more constant revenue stream which could allow farmers to take those risks and invest in technologies. Intertemporal choice also presents the farmer with problematic financial questions given budgetary constraints that farmers face in Haiti. For example, if school fees are due during the planting season and the household must make a choice between education and fungicide, it is likely the latter that is eschewed and thus no initial investment is made. Furthermore, these hurdles manifest themselves in farmer non-adoption and the status quo remains the prevalent crop management technique.

4.5 Restricted Yield Profit and Return on Investment Results

Peanut yields among Haitian farmers tend to be lower, on average, than the trial data which were irrigated and subject to superior management techniques and treatments. By restricting yields to those found among farmers in Haiti and analyzing ROI, we can see more clearly that the choice to adopt new varieties is not so simple.

Results are detailed in Appendix C and indicate that a low yielding farm (<250 kg/ha) will experience a negative return on investment in technology assuming prices for runner and Valencia varieties are low; which is typically the case at harvest time as supply floods the market. However, for a farm producing >500 kg/ha, the ROI is significantly better even given post-harvest low prices, 36% for runner and 66% for Valencia. Beyond 500 kg/ha and average to high prices for each variety, the ROI soars over 100%, which is evidence that returns to technology are high and adoption rates should follow. Farmers in Haiti need to see higher yields in order to increase adoption of new varieties and improved management techniques.

CHAPTER 5

CONCLUSION

This thesis' goal was twofold. The first was to provide a short discussion of the Haitian peanut value chain, giving some insight into some current problems and provide potential improvements. Second was to examine the marginal impact of fungicide treatments on peanut yield and quality in order to maximize farmer profit and compare the productivity of improved and local varieties. This research also sought to quantify the tangible benefits of more highly managed peanut cultivation practices in the context of a developing economy. While training events put on by NGOs such as Acceso and MFK are sometimes met with skepticism, the results of the trials validate the training efforts of those organizations and should encourage further studies that will further develop and specify farmer education and training. Ultimately, the mutual success of Haitian peanut farmers and firms such as Acceso and MFK is incumbent upon a relationship based in trust and understanding. The most data-driven, optimized training and robust credit packages will never serve the farmer any benefit if, on a human-level, he does not trust the provider.

A case could be made that the trials done at MFK were conducted under ideal conditions, sprinkler irrigation, seed spacing, etc. However, despite those differences, it was evident that, on average, the use of fungicide significantly reduced disease severity while increasing yield and quality. As a first step, these results should be propagated throughout the Haitian peanut farmer community in order to establish confidence and promote improved technological adoption. Moving forward, observing the performance of farmers who choose to adopt fungicide and improved seedlings could be used to compare with those who opt not to adopt one or both, as a case study to provide more robust findings about the efficacy and efficiency of technological adoption.

Yield differences between varieties were not generally statistically significant though the results of local varieties do indicate that they, on average, performed worse than their improved counterparts. In addition, the performance of an improved runner variety of peanut, the GA06G, overshadowed its local competitor. A partnership between Acceso, MFK and the GA06G creator, the University of Georgia with USAID funding already exists and thus a “quick win” for all stake-holders is the inclusion of this variety within the credit packages offered. While there was no discernable difference in the productivity of the Valencia varieties tested, more trails may need to be conducted to test the GA06G in a variety of locations in Haiti under a variety of conditions and input management practices to ensure its reliability as a productive replacement for the local runner peanut variety.

Additionally, the data were used in a Return on Investment Analysis and showed how household incomes can increase given the initial investment in disease management techniques given different scenarios. The average return across the price spectrum was approximately 47% for runners and 62% for Valencia. As firms like Acceso and MFK continue to grow their customer base and develop training and credit packages, inclusion of the optimal fungicide application as well as training events on its implementation will be crucial in maintaining program loyalty as well as, in Acceso’s case, becoming profitable.

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APPENDIX A

VARIABLE DESCRIPTIONS FOR SUPPLIMENTARY REGRESSIONS

Table 19: Variable Descriptions

Variable	Model Abbreviation	Type	Details
Seeds Per Hole	seeds	Dummy	3 seeds per foot is base group
Season	season	Factor	Spring_Sum=0 (Base Group) Spring = 1 Winter = 2 (Runner Only) Fall =2 (Valencia Only)
Fungicide Treatment	trt	Factor	See Below
Leafspot	leafspot	Continuous	0-10 severity scale
Rust	rust	Continuous	0-10 severity scale

Table 20: Valencia Variety Treatments

NM Valencia & Local Valencia			
Code	Total Applications	First Application	Spray Interval
0	Untreated	NA	NA
1	1 Spray	45 DAP	NA
2	2 Spray	45 DAP	21 days
3	2 Spray	45 DAP	28 days
4	3 Spray	30 DAP	21 days
5	3 Spray	37 DAP	14 days
6	3 Spray	37 DAP	21 days
7	3 Spray	45 DAP	14 days
8	3 Spray	45 DAP	28 days
9	4 Spray	30 DAP	14 days

Table 21: Runner Variety Treatments

GA06G & Local Runner			
Code	Total Applications	First Application	Spray Interval
0	Untreated	NA	NA
1	2 Spray	60 DAP	28 days
2	3 Spray	37 DAP	28 days
3	3 Spray	45 DAP	28 days
4	4 Spray	37 DAP	21 days
5	4 Spray	45 DAP	21 days
6	7 Spray	30 DAP	14 days

APPENDIX B

SUPPLIMENATRY REGRESSION RESULTS

Table 22: OLS Regression Results by Variety, Central Plateau

Central Plateau	Local Valencia	New Mexico Valencia
Spring	1030.71*** (321.86)	1010.95 (382.34)
Treatment 1	186.19 (137.89)	80.43 (274.49)
Treatment 2	390.92 (237.49)	260.95 (333.44)
Treatment 3	502.91* (283.50)	166.25 (284.01)
Treatment 4	712.81** (359.43)	291.65 (346.82)
Treatment 5	608.05** (303.69)	888.63*** (247.67)
Treatment 6	888.63** (375.51)	809.65*** (250.76)
Treatment 7	974.38*** (262.86)	
Treatment 8	485.06 (352.82)	452.19 (411.56)
Treatment 9		315.88 (355.08)
Treatment 1*Spring	1.47 (293.16)	86.67 (330.78)
Treatment 2*Spring	-2.60 (346.45)	207.89 (361.39)
Treatment 3*Spring	383.15 (315.69)	101.37 (364.47)
Treatment 4*Spring	266.88 (367.80)	433.57 (362.60)
Treatment 5*Spring	280.11 (419.83)	
Treatment 8*Spring	669.24 (422.34)	-90.94 (411.01)

Treatment 9*Spring		453.17 (408.48)
Leafspot	68.3 (125.56)	99.30 (113.95)
Rust	-101.02 (82.61)	-133.15 (93.77)
Constant	1374.40*** (560.72)	1110.59* (643.22)
Observations	65	61
R-Squared	.8767	.8879

Table 23: OLS Regression Results by Variety, MFK

Variable	Local Valencia	New Mexico Valencia
Spring	428.97 (484.19)	-462.49 (749.06)
Fall		
Seeds Per Foot		
Treatment 1	1062.90*** (315.51)	615.35 (411.97)
Treatment 2	1002.10** (442.61)	913.79** (463.11)
Treatment 3	1283.10*** (415.78)	991.94** (456.48)
Treatment 4		832.56** (423.43)
Treatment 5	1252.86*** (437.43)	
Treatment 6		
Treatment 7	1035.32** (504.36)	823.74* (484.43)
Treatment 8	1524.04*** (504.39)	1335.94*** (494.29)
Treatment 9	1299.81** (576.55)	1013.01** (477.70)
Treatment 1*Fall	-463.92 (347.99)	99.87 (706.65)
Treatment 2*Fall	-908.67 (530.05)	-164.84 (799.00)
Treatment 3*Fall	-714.98 (418.80)	-624.45 (766.84)
Treatment 5*Fall	-1784.3 (561.05)	-429.74 (838.33)

Treatment 8*Fall	-1565.60 (543.18)	-753.85 (759.24)
Treatment 9*Fall	-1054.12 (605.12)	-877.16 (922.52)
Leafspot	-120.74 (93.23)	-77.80 (89.49)
Rust	-58.78 (96.02)	-46.13 (86.08)
Constant	3601.50*** (919.34)	3745.20*** (607.83)
Observations	80	81
R-Squared	.7152	.6319

Table 24: OLS Regression Results by Variety, MFK

MFK	Local Runner	GA06G
Spring	428.66 (796.43)	-1880.35*** (587.45)
Winter	-890.67** (386.17)	-3432.09*** (536.77)
Seeds Per Foot	-580.13** (246.89)	-487.83* (286.64)
Treatment 1	1308.17** (617.53)	1276.20 (1008.12)
Treatment 2	433.26 (864.43)	1017.68 (1367.17)
Treatment 3	1357.65** (585.11)	1363.43 (1039.50)
Treatment 4	1269.55 (973.25)	2608.89*** (907.46)
Treatment 5	2376.32*** (640.60)	1490.64 (1225.93)
Treatment 6	3080.41* (1160.34)	2745.70** (1274.02)
Treatment 1*Spring	-699.53 (703.58)	-442.42 (1208.67)
Treatment 2*Spring	879.93 (957.93)	1032.92 (1848.18)
Treatment 3*Spring	-889.25 (728.17)	-813.15 (1082.10)
Treatment 4*Spring	-65.49 (1095.75)	-864.83 (817.93)

Treatment 5*Spring	-1081.84 (797.40)	563.08 (1569.04)
Treatment 6*Spring	-1407.92 (1285.19)	-441.43 (942.42)
Treatment 1*Winter	-203.03 (624.87)	255.73 (1257.85)
Treatment 2*Winter	1016.39 (830.10)	1052.44 (1764.70)
Treatment 3*Winter	56.07 (647.15)	850.60 (1101.99)
Treatment 4*Winter	452.53 (951.61)	86.90 (996.29)
Treatment 5*Winter	-1074.23* (617.18)	222.31 (1467.31)
Treatment 6*Winter	-977.78 (1008.26)	114.21 (751.81)
Leafspot	-9.05 (98.10)	71.50 (130.87)
Rust	8.28 (154.80)	106.77 (179.88)
Constant	2621.32*** (967.72)	4192.87*** (1553.93)
Observations	82	83
R-Squared	.6193	.6980

APPENDIX C

RESTRICTED YIELD PROFIT AND ROI RESULTS

Table 25: Restricted Yield Profit

Restricted Yield	Low Price - Runner	Low Price - Valencia	Average Price - Runner	Average Price - Valencia	High Price - Runner	High Price - Valencia
250	-3231	-1716	3586	6618	10403	14951
500	3586	6616	17221	23286	30856	39951
750	10403	14948	30856	39953	51308	64951

Table 26: Restricted Yield ROI

Restricted Yield	Low Price - Runner	Low Price - Valencia	Average Price - Runner	Average Price - Valencia	High Price - Runner	High Price - Valencia
250	-32%	-17%	36%	66%	104%	149%
500	36%	66%	171%	232%	307%	398%
750	104%	149%	307%	398%	511%	646%