

DISSERTATION

CHALLENGES IN THE SUSTAINABILITY OF LIBYAN AGRICULTURE:
OPPORTUNITIES FOR THE LIBYAN SEED SYSTEM

Submitted by

Neama Lariel

Graduate Degree Program in Ecology

In partial fulfillment of the requirements

For the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Summer 2015

Doctoral Committee:

Advisor: Gregory D. Graff

Co-Advisor: Stephen Davies

James Stanelle

Dennis Ojima

Copyright by Neama Lariel 2015

All Rights Reserved

ABSTRACT

CHALLENGES IN THE SUSTAINABILITY OF LIBYAN AGRICULTURE: OPPORTUNITIES FOR THE LIBYAN SEED SYSTEM

Globally, agriculture has met the needs of a growing population remarkably well (Agriculture and Natural Resources Team of the UK DFID, 2004). However, this success has been at the expense of our natural resources. A sustainable approach must lead future agricultural decision-making processes. According to Tilman, Cassman, Matson, and Polasky (2002), the global population is expected to increase by 50% in 2050; this increase in production will affect the environment adversely. There are numerous global challenges associated with creating a sustainable agriculture model.

As one of the most arid countries on Earth and one that is just emerging from decades of authoritarian rule, Libya faces several big challenges in order for its agriculture to meet demand in a sustainable manner. Specifically, improvements in Libya's seed system may be needed to help close the yield gap, reduce negative externalities associated with agricultural production, and facilitate the adaptation of Libyan agriculture to climate change.

While there are many factors that contribute to Libya's apparent current yield gap in wheat and barley, one of its most important agricultural sectors, the lack of availability of appropriate genotypes for each environment serves as the primary factor focused on in this study. The objectives to this research are to understand what varieties farmers currently grow, why they grow those varieties, and how they access the seed for those varieties as well as understanding what constrains farmers' adoption of new varieties in order to recommend mechanisms of

improvement to the seed system in Libya. To achieve sustainability in agriculture, higher yields must be maintained while minimizing environmental impacts, making it increasingly important to understand the Libyan seed system and its users and their access.

This research has two primary hypotheses in regards to closing the yield gap: One focuses on the demand side and why farmers are not adopting improved varieties. The other concerns the supply side and questions of who provides wheat and barley seed to farmers, under what arrangements, and where the genetic varieties originate. The preliminary assumption is that Libyan wheat and barley farmers are more likely to use imported seeds than domestic seeds due to the lack of availability of improved local varieties due to the lack of breeding programs in Libya.

ACKNOWLEDGEMENTS

First of all, I would like to gratefully and thankfully acknowledge Allah, that he helped me to keep doing my dissertation despite all the difficulties. I also have the support from my family and encouragement from friends. I would like to express my deepest gratitude to my advisor, Dr. Gregory D. Graff, for his excellent guidance, enthusiasm, patience, and immense knowledge and providing an excellent atmosphere for doing research. He told me one day that “people will look to your study and say ‘wow this is the first systematic study’, studies will come after and they were all inspired by you, Neama!” Also, I would like to thank my committee: Stephen Davies, Jim Stanelle, and Dennis Ojima.

I would like to thank Dr. Ali Arhama, who helped me to manage and distribute my survey in Libya. His experience of research in this field, as well financial support for the study were invaluable, without him, this dissertation could have been completed. Also, thanks go to Dr. Naser El-Msalati, who helped me distribute surveys in the eastern area and he gave many resources to support my dissertation.

I would also like to thank my parents, five sisters, and five brothers. They have always supported me and encouraged me with their best wishes. Also, I dedicate this dissertation to all my 29 nieces and nephews, with the intent that my work will inspire them in their future work. Last but not least, I would like to thank all of my friends Tiffany, Patricia, Laura, Jared, Amanda, Majeda, Wijdan, and Rehab which are great friends and have always been willing to help and support since my family is far away. They are always cheering me up and have stood by me through the good times and bad. It would not have been possible to complete my education without their support.

TABLE OF CONTENTS

ABSTRACT.....	ii
ACKNOWLEDGEMENTS.....	iv
LIST OF TABLES.....	ix
LIST OF FIGURES.....	xi
1 Challenges to the Sustainability of Agriculture: Worldwide and in Libya.....	1
1.1 Sustainability in Agriculture and Economic Development.....	1
1.1.1 Closing the Yield Gap.....	3
1.1.2 Increasing Production Limits.....	4
1.1.3 Reducing Waste.....	5
1.1.4 Changing Diets.....	5
1.1.5 Expanding Aquaculture.....	6
1.1.6 Using Water Efficiently.....	7
1.1.7 Maintaining Soil Fertility.....	8
1.1.8 Controlling Pests.....	9
1.1.9 Producing Livestock Sustainably.....	9
1.1.10 Stopping Expansion of Agricultural Lands.....	10
1.1.11 Adapting to Climate Change.....	10
1.2 Overview of Libya’s Economy and Agriculture.....	12
1.2.1 Libya’s Land Resources.....	13
1.2.2 The Libyan Economy.....	17
1.2.3 Impact of Trade Sanctions.....	19
1.2.4 Libyan Agriculture.....	21
1.2.5 The Structure of Libya’s Agriculture Sector.....	22
1.2.6 Government Support of Agriculture in Libya.....	26
1.2.7 Agricultural Marketing in Libya.....	28
1.2.8 The Current State of Libyan Agriculture and the Continuing Importance of Cereal Grains Production.....	28
1.3 Sustainability Challenges in Libyan Agriculture.....	30

1.3.1	Water Management.....	30
1.3.2	Marginalization of Agriculture Due to Land Use Change.....	32
1.3.3	Low Primary Productivity, Due to Low Quality of Farm Inputs, Including Seeds 32	
1.3.4	Efficiency and Environmental Safety of Agricultural Chemicals	33
1.3.5	Adaptation to Climate Change.....	33
1.4	Summary and Conclusions.....	34
2	The Yield Gap in Grains Production in Libya.....	36
2.1	Introduction	36
2.1.1	Why Closing the Yield Gap is Important to Sustainability	36
2.1.2	Yield as Just One Measure of Sustainability	37
2.1.3	Defining the Yield Gap.....	38
2.1.4	Actual and Potential Yields	39
2.1.5	How Yield Gap is Measured.....	40
2.2	Current Status of Wheat and Barley in Libya: Is There a Yield Gap?.....	44
2.3	Measuring the Yield Gap in Libya.....	51
2.3.1	Comparison with Yields in Neighboring Countries.....	51
2.3.2	Yields on Experimental Fields in Libya	52
2.3.3	Estimated Yields Based on Global Climate Models.....	53
2.4	Impacts of Seed Quality on Yields in Libya	53
2.5	Discussion and Conclusions: Farmers' Choices of Crop Variety in Closing the Yield Gap	54
3	Availability and Adoption of Improved Wheat and Barley Varieties: A Survey of Grain Farmers in Libya.....	57
3.1	Introduction	57
3.2	Survey Design and Administration	58
3.3	Farmer and Farm Characteristics	61
3.3.1	Farmers' Socio-Demographic Characteristics	61
3.3.2	Farm Land.....	66
3.3.3	Farm Labor.....	67

3.3.4	Mechanical Technology.....	69
3.3.5	Irrigation	70
3.3.6	Fertilizer Use.....	72
3.3.7	Pesticide Use.....	73
3.3.8	Government Support.....	75
3.3.9	Marketing.....	76
3.4	Identified Wheat and Barley Varieties Grown in Libya	80
3.4.1	Varieties of Wheat Grown in Libya.....	81
3.4.2	Varieties of Barley Grown in Libya.....	84
3.4.3	Definition and description of local or mahale varieties of wheat and barley grown in Libya	86
3.5	Farmer Decisions Regarding Wheat and Barley Varieties.....	87
3.5.1	Farmers' Sources of Wheat and Barley Seeds	87
3.5.2	Intentions for Saving Seed and Purchasing Certified Seed	91
3.5.3	Purchased Versus Saved Seed for Wheat and Barley Varieties	92
3.5.4	Farmers' Stated Preferences for Growing Wheat and Barley over Other Crops	96
3.5.5	Farmers Stated Preferences for Growing Local (mahale") Varieties versus Imported Varieties	97
3.5.6	Farmers Stated Preferences for Growing Specific Wheat and Barley Varieties	99
3.5.7	Seeding Rates of Wheat and Barley Varieties	103
3.6	Logit Analysis of Adoption of Improved Varieties	104
3.6.1	Methods and Data for Logit Regression Analysis	105
3.6.2	Description of Variables Used	105
3.6.3	The First Model: Decision of Farmers to Grow Any Improved Variety ..	110
3.6.4	The Second Model: Decisions of Farmers to Grow Only Improved Varieties	113
3.7	Conclusions	115
4	The Role of an Improved Seed System in Closing the Yield Gap in Libyan Agriculture	117
4.1	Introduction	117

4.1.1	The fundamental importance of a well-functioning seed system	117
4.1.2	National Seed Systems: Formal and Informal Sectors	119
4.2	The Seed System in Libya.....	120
4.2.1	The Public Sector’s Dominant Role in the Seed System in Libya	121
4.2.2	International Organizations Working with the Libyan Seed System.....	123
4.2.3	The Private Sector’s Uncertain Role in the Libyan Seed System.....	125
4.3	General Recommendations for Improving Seed Systems in Developing Countries 127	
4.3.1	Variety Registration, Testing, Certification, and Labeling.....	128
4.3.2	Farmer Engagement and Education	129
4.3.3	Plant Breeders’ Rights (PBRs) as Private Sector Incentives	130
4.3.4	Better Coordination of the Roles of the Public and Private Sectors	130
4.4	A Path Forward for the Libyan Seed System: Conclusions and Recommendations from the Current Study	131
5	Summary and Conclusions	135
5.1	Summary of Chapter 1	135
5.2	Summary of Chapter 2	135
5.3	Summary of Chapter 3	136
5.4	Summary of Chapter 4	136
5.5	Limitations of this Study.....	136
5.6	Recommendations for Future Studies	137
5.7	Final Conclusions.....	138
	References.....	140
	APPENDIX 1. Survey Cover Letter (English version)	150
	APPENDIX 2. Survey Cover Letter (Arabic version).....	152
	APPENDIX 3. Survey (English version).....	153
	APPENDIX 4. Survey (Arabic version)	170
	APPENDIX 5. Institutional Review Board (IRB) Exemption Letter	183

LIST OF TABLES

Table 1.1 Land Use in Libya.....	15
Table 1.2 Gross Domestic Product Composition, by Sector	19
Table 1.3 Main Crop Production in Libya, Ranked by Production Volume in 2010, in Tonnes	26
Table 2.2 Barley and Wheat Import Dependency Ratio (IDR), 1990 to 2012	49
Table 3.1 Numbers of Wheat and Barley Farmers Surveyed, by Region.....	60
Table 3.2 Numbers of Wheat and Barley Farmers Responding, by Crop and Region	60
Table 3.3 Income Sources	63
Table 3.4 Other Crops Grown on Farm, As Indicator of Degree of Specialization or Diversification.....	64
Table 3.5 Off-Farm Income	64
Table 3.6 Sources of Off-Farm Income	65
Table 3.7 Farm Size	66
Table 3.8 Ownership of Land	67
Table 3.9 Area of Land Planted to Wheat or Barley.....	67
Table 3.10 Additional Workers on Farms.....	68
Table 3.11 Difficulty in Finding or Hiring Farm Workers	68
Table 3.12 Reasons for Difficulty in Finding or Hiring Farm Workers	69
Table 3.13 Use of Irrigation.....	70
Table 3.14 Cross Relationship between Rainfall and Irrigation	71
Table 3.15 Fertilizer Use.....	72
Table 3.16 Factors that Influence Fertilizer Use.....	73
Table 3.17 Experience with Fertilizer Use	73
Table 3.18 Pesticide Use.....	74
Table 3.19 Factors Influencing Pesticide Use.....	74
Table 3.20 Experience Using Pesticides	75
Table 3.21 Government Subsidies for Growing Wheat/Barley	75
Table 3.22 Type of Subsidies Provided by Government	76
Table 3.23 What Farmers Do with Their Grain Harvests	77
Table 3.24 Difficulty in Selling Harvest.....	77
Table 3.25 Reasons for Difficulty in Selling Harvest.....	78
Table 3.26 Price Received for Wheat in 2013	79
Table 3.27 Price Received for Barley in 2013	79
Table 3.28 Wheat Varieties Identified in the Survey as Being Grown in Libya: Including Number of Farmers and Reported Area.....	80
Table 3.30 Farmers' Sources of Seeds for Wheat Varieties Grown	87

Table 3.31 Farmers' Sources of Seed for Barley Varieties Grown	89
Table 3.32 Expectation of Saved Seed	91
Table 3.33 Certified Seed Purchasing.....	92
Table 3.34 Share of Wheat Varieties Planted with Newly Purchased or Saved Seed	92
Table 3.35 Share of Barley Varieties Planted with Newly Purchased Seed or Saved Seed.....	94
Table 3.36 Preference for Local ("mahale") Varieties	98
Table 3.37 Farmers' Stated Reasons for Choice of Wheat Varieties	100
Table 3.39 Seeding Rate of wheat Varieties Planted.....	103
Table 3.40 Seeding Rate of Barley Varieties Planted.....	104
Table 3.41 Descriptive Statistics of the Primary Explanatory Variables.....	109
Table 3.42 Correlation Matrix for Primary Explanatory Variables	109
Table 3.43 "Any Improved" Varieties Model Predication, without Explanatory Factors.....	111
Table 3.44 "Any Improved" Varieties Model Prediction, with Explanatory Factors.....	111
Table 3.45 Results of Logistic Regression for Any Improved, Using Six Explanatory Variables	112
Table 3.46 "Only improved" Varieties Model Predication, without Explanatory Factors.....	113
Table 3.47 "Only Improved" Varieties Model Prediction, with Explanatory Factors.....	114
Table 3.48 Results of Logistic Regression for Only Improved, Using Six Explanatory Variables	115

LIST OF FIGURES

Figure 1.1 Timeline of Trade Sanctions in Libya	20
Figure 2.1 Barley and Wheat Area Harvested in Libya, 1990-2013	48
Figure 2.2 Barley and Wheat Production in Libya, 1990-2013	48
Figure 2.3 Barley and Wheat Yields in Libya, 1990-2013	48
Figure 2.4 Wheat and Barley Cultivation, by Region of Libya, 2007-2008	50
Figure 2.5 Annual Wheat Yields of Northern African Countries and the Region as a Whole, 1961-2011	52
Figure 3.1 Wheat and Barley Farms Responding to the Survey (by percentage that grow wheat, barley, and both within each major region)	61
Figure 3.2 Frequency Distribution of Rainfall on Farms of Survey Respondents.....	71
Figure 3.3 Farmers’ Source of Seeds for Improved Wheat Varieties	88
Figure 3.4 Farmers’ Source of Seeds for Improved versus Local (“mahale”) Wheat Varieties	88
Figure 3.5 Farmers’ Sources of Seeds for Improved Barley Varieties	90
Figure 3.6 Farmers’ Source of Seeds for Improved versus Local (“mahale”) Barley Varieties	90
Figure 3.7 Areas of Improved Wheat Varieties Planted with Purchased or Saved Seed in 2013	93
Figure 3.8 Areas of Improved Versus Local (“mahale”) Wheat Varieties Planted with Purchased or Saved Seed in 2013.....	93
Figure 3.9 Areas of Improved Barley Varieties Planted with Purchased or Saved Seed in 2013	95
Figure 3.10 Hectares of Improved and Local (“mahale”) Barley Varieties Planted in 2013	95
Figure 3.12 Reasons Stated for Growing Improved Barley Varieties, by Variety	102

1 Challenges to the Sustainability of Agriculture: Worldwide and in Libya

1.1 Sustainability in Agriculture and Economic Development

Globally, agriculture has met the needs of a growing population remarkably well (Agriculture and Natural Resources Team of the UK DFID, 2004). However, this success has been at the expense of natural resources. Sustainable approaches must lead future agricultural decision-making processes if agriculture is to continue providing for a growing population. In 1987, the World Commission on Environment and Development (WCED) report provided a definition of sustainable development: “Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their needs” (WCED, 1987, p. 16). Many scientists have similar definitions of sustainability. For example, Dawe and Ryan (2003) define sustainability as preserving economic prosperity, environmental integrity, and social welfare. The Scottish Environment Protection Agency (as cited in Dawe and Ryan, 2003) talks about the same three aspects of sustainability:

“A simple way of picturing sustainable development is to think of it as a stool with three legs, representing the environment, the economy and society, if any leg is more or less important (i.e., shorter or longer) than the others, the stool will be unstable (but perhaps still usable—at least for a while). If any leg is missing, the stool simply will not work. But if all three legs are the same length (i.e., environmental, economic and social considerations have been given equal weight), the result will be a well-balanced stool which will serve its purpose indefinitely—a sustainable stool.”

However, these definitions do have differences as well. Tilman et al. (2002) focus on two of the three aspects when they state that sustainability is the maintenance of high yields in conjunction with acceptable environmental impact. Krysiak and Krysiak (2006) give a more

generalized definition of sustainability when they write that it could be defined as the requirement to maintain well-being over a long period of time without economic decline.

From these definitions of sustainability, we can understand the essential notion of agricultural sustainability to mean an increase of production while simultaneously protecting the environment and social welfare. According to the United Nations Population Division (United Nations, 2013), the global population is expected to increase by about 50% by 2050. Pardey, Beddow, Hurley, Beatty, and Eidman (2013) estimates that 70 % more food production will be needed to meet the demand of this increased population; and by most accounts, this increase in production will affect the environment adversely. A balance is needed between the two aspects.

Despite rapid technological advances and dramatic yield improvements over the past half-century (Godfray et al., 2010), today, more than one in seven people still do not have access to adequate protein and energy from their diet (FAO, 2009). A larger number of people also suffer from micronutrient deficits and undernourishment (FAO, 2009). Sustainable agriculture must maintain high yields while minimizing environmental impact. As the global population continues to climb toward nine billion (Godfray et al., 2010), net benefits that society receives from agricultural systems and from ecosystem services must be maximized (Tilman et al., 2002).

The challenges that must be addressed globally in order for agriculture to be sustainable are significant. Several factors directly influence the development of sustainable agriculture. Not only is population growth a driver of consumption growth, but as a population's per capita income increases, their consumption habits change to demand more food diversity and consumable goods. Recent analyses suggest that the world will need seventy to one hundred percent more food than agriculture is supplying today (Godfray et al., 2010; Pardey et al., 2013).

Some solutions for more sustainable agriculture practices in agricultural and food systems are already well known.

1.1.1 Closing the Yield Gap

In order to meet the growing demand for food, agricultural systems must close the yield gap (Foley, Ramankutty & Brauman, 2011; Godfray et al., 2010) while minimizing environmental impacts. This means production must increase in underperforming lands. Closing gaps to approximately 95% of their yield potential for sixteen staple food and feed crops could add 2.3 billion tons of additional production without using more land (Foley et al., 2011). The kinds of developments that could close yield gaps include the following: improved seed varieties, water conservation and irrigation, precision agricultural practices, soil nutrients, pest management, biodiversity conservation, integrating organic agricultural practices, as well as reforming conventional input rates and timing (Foley et al., 2011; Godfray et al., 2010). In Africa, the yield gap is greatest. In the mid 1970's, Africa's per capita production began to decrease and recently has reached the equivalent of 1961 per capita production (Godfray et al., 2010).

Ecological costs from closing the yield gap are inevitable and may not be reflected in consumer food prices. Specifically, increased agricultural production can be expected to increase greenhouse emissions and pesticide and nutrient pollution in runoff. Over-extraction of water may lead to aquifer depletion and water shortages. Soil degradation and biodiversity loss as a result of land conversion and poor management are likely consequences of increased production and may also affect capacity for future food production. Overall, ecosystem destruction due to

over harvesting of aquatic systems may also be a consequence of production increases (Godfray et al., 2010).

Another challenge in attempting to close yield gaps is determining where to most efficiently make scarce financial investments. For example, investment is necessary in regional and national infrastructure, such as roads and ports, while investing in social and economic capital is equally necessary (Godfray et al., 2010). High costs of inputs increase farming costs, while less-developed marketing opportunities often do not provide a fair return on investment. Maximum production remains unattainable with this barrier in place for farmers (Godfray et al., 2010). Low yields also occur because of technical insufficiencies that prevent local food producers from increasing productivity (Godfray et al., 2010). For example, in many countries, policy is currently ineffective or absent that regulates and educates on the most efficient use of fertilizers and pesticides (Foley et al., 2011).

1.1.2 Increasing Production Limits

Improving feasible yields on existing farmland in order to minimize further conversion of natural areas to farmed ground is necessary (Barnett, Payne, & Steiner, 1995; Ruttan, 1999, in press). Most of the world's best quality farmable land is already in production, leaving mostly marginal lands available for further expansion. Thus, expansion may result in low yields and further land degradation (Cassman, 1999; Young, 1999). Already, limited amounts of water are available for human consumption and this water is often utilized for non-agricultural purposes, especially if low yields are the result of the water diversion (Cassman, 1999). Evidence suggests that genetic improvements in corn and rice have reached their yield ceiling; however, wheat breeding continues to increase yield potentials via breeding programs (Reynolds, Rajaram, & Sayre, 1999). Availability of, and knowledge about, biotechnology is limited (Godfray et al.,

2010), but this may be an important technology for closing the yield gap. International gene banks are also valuable, yet it is necessary to ensure that regionally adapted crop and livestock germplasm is not lost in the process of replacement by modern varieties and breeds (Godfray et al., 2010). However, there is also an issue with public trust and acceptance of biotechnology (Godfray et al., 2010). It will be necessary to address these issues in order for this technology to become part of the sustainable agriculture model. In addition, there is a virtual monopoly on genetically modified traits, which limits innovation and investment in the technology (Godfray et al., 2010). Judicious use of existing technologies, both chemicals and biotechnology, could go a long way in closing the yield gap.

1.1.3 Reducing Waste

Reduction of waste could significantly increase sustainability. Between thirty and forty percent of all food produced is lost as waste as a result of the lacking food chain infrastructure for storage, transportation, pest exclusion, or spoilage (Godfray et al., 2010). Also, as the population increases and consumption increases, directly and indirectly produced volumes of waste will increase in developing countries and in industrialized countries at the consumer level (Foley et al., 2011). Since the overall waste challenge is immense Foley et al. (2011) suggest focusing initially on reducing waste in the most resource intensive foods, such as meat and dairy.

1.1.4 Changing Diets

History has shown that as wealth increases, people shift from a diet primarily of vegetables to one including larger quantities of meat and protein (Godfray et al., 2010). Producing meat requires more energy than producing a calorie-equivalent plant-based food

(Foley et al., 2011). Decreasing the amount of meat consumed is challenging. Trends in the last fifty years illustrate an increase in demand for meat and dairy due to increased wealth.

There are pros and cons associated with this worldwide change in eating habits (Godfray et al., 2010). Negative consequences include substantial variation in production efficiency for different food sources and a variation in environmental impact of different types of meat eaten by people, such as the methane gas produced from livestock production. On the other hand, non-arable land may be used for grazing to provide much needed protein for developing countries. Livestock is also used as a source of income in poor communities and often plays an important cultural role. However, there is the possibility that better animal husbandry and genetic improvement of animal breeds may improve production (Godfray et al., 2010).

Balancing reduction in consumption of meat with increase in consumption of more efficient types of protein is necessary. The production of one kilogram of meat may necessitate between three and ten kilograms of grain (Tilman et al., 2002). Shifting diets to include pork, poultry, or pasture-fed beef and away from grain-fed beef can help increase the energy efficiency of a protein rich diet (Foley et al., 2011). Well-balanced diets of grain, vegetables and meat must become a norm for all cultures (Godfray et al., 2010).

1.1.5 Expanding Aquaculture

Aquatic products provide nearly three billion people with at least 15% of their animal-based protein supply (Godfray et al., 2010). The potential for expansion of aquaculture systems are greater than the potential for expansion of terrestrial agricultural systems and may be able to support the sustainable agriculture goal. However, it is important to strategically develop fishery and coastal zone management in order not to deplete or displace natural fisheries (Whitmarsh & Palmieri, 2008). Fish growth rates and the length of time required before harvest require a

financing arrangement that provides working capital as well as risk management for farmers (Godfray et al., 2010). Environmental impact from aquaculture inputs, such as disease treatment chemicals, fish food, fish waste, and genetic contamination of wild species are challenges associated with expanding aquaculture systems (Godfray et al., 2010).

1.1.6 Using Water Efficiently

As population increases, competition for water and arable land also rises, leading to increasing food security issues (Godfray et al., 2010). In the past fifty years, world irrigated cropland has doubled, and now 70% of freshwater withdrawals are used in irrigation (Foley et al., 2011). According to Gleik (1993) and Postel, Daily, and Ehrlich (1996), it is estimated that 40% of crop yields come from the 16% of arable land that is irrigated.

To meet the growing demand for food while saving water, it is imperative to increase irrigation efficiency. Since 1978, the global rate of irrigated acres has decreased by five percent and new dam constructions may only offer a 10% increase in irrigation water supplies over the next thirty years (Dynesius & Nilsson, 1994; Postel et al., 1996). Many regions, including China, India, Pakistan, North Africa and the Middle East will soon fall short of an adequate water supply to sustain per capita food production from irrigated ground (Seckler, Barker, & Amarasinghe, 1999). Without irrigation, global cereal production would decrease by approximately 20%, which would require more land to produce equal yields (Foley et al., 2011).

Additionally, agricultural runoff tends to carry more salts, nutrients, minerals and pesticides into the surface and ground water; this affects downstream agriculture productivity, natural ecosystems and drinking water (Tilman et al., 2002). Several suggested approaches may address these challenges, including: utilizing more efficient irrigation technologies, such as drip

and pivot irrigation, adding manure to the soil to aid in water retention, reducing tillage, and breeding more drought resistant crops (Tilman et al., 2002).

1.1.7 Maintaining Soil Fertility

Fertile soil is necessary to support a sustainable agriculture system. However, since 1945, approximately 17% of arable land has suffered human-induced soil degradation and decreased productivity, often from poor fertilizer management, soil erosion and shortened fallow periods (Tilman et al., 2002). Continuous cropping and insufficient nutrient and organic matter replacement deplete fertility and causes organic soil matter to decline, often to half or less of original levels (Matson, Naylor, & Ortiz-Monasterio, 1998). Tillage increases the rate of decomposition of organic matter and the release of mineral nutrients, and erosion may be severe on slopes that are mismanaged (Tilman et al., 2002). Crop rotation, reduced tillage, cover cropping, increased fallow periods, manuring, and balanced fertilizer application can all help maintain and restore soil fertility (Tilman et al., 2002).

Fertilizers are a key component in sustainable agriculture; however, mismanagement of them has negative impacts. Widespread nutrient pollution and the degradation of surface water bodies are already prevalent in the world (Godfray et al., 2010). In addition, the release of nitrous oxide from fertilized fields exasperates climate change. Excess nutrients also have energy costs associated with the processes that converts atmospheric nitrogen and mined phosphorus into a plant, an available form of fertilizer.

Although negative environmental consequences occur from over-use of fertilizers, it is equally a problem that insufficient nutrients are available in worldwide agronomic production. Many yield gaps are due to incorrect amounts of necessary plant nutrients (Cassman, Doermann,

& Walters, 2002). A survey of world agriculture illustrates that there are “hotspots” of both low nutrient use efficiency and large volumes of excess nutrients. 10% of the world’s croplands account for 32% of the global nitrogen surplus and 40% of the phosphorus surplus. Policy and better management strategies could improve the balance between the environment and yields (Foley et al., 2011)

1.1.8 Controlling Pests

Corn, rice, and wheat are the dominant crop species planted for human consumption. These three crops make up 60% of human food needs (Tilman et al., 2002). As the acreage for each of these crops continues to increase, research suggests that the pest pressure will increase proportionally to the host crop’s abundance (Tilman et al., 2002). Improvement in pest control can increase yields. Tilman et al. suggested a three-fold approach to addressing pest and pesticides that includes breeding for new disease resistance, discovering new pesticides and planting different crops with greater spatial and temporal diversity. Zhu et al. (2000) suggested that an important and costly rice pathogen was controlled in a large region of China by sowing two rice varieties in alternating rows. This management strategy increased profitability and reduced the use of pesticides.

1.1.9 Producing Livestock Sustainably

Since 1970, global per capita meat production has grown more than 60%. This trend is correlated to global per capita income increases (Tilman et al., 2002). In response to this trend, livestock production evolved into an industry. In livestock production, large-scale operations are economically competitive because of economies of scale; however, this scale of production has health and environmental costs (Martin, 2000). Management practices that may minimize the health and environmental costs include composting animal wastes to create a crop fertilizer that

no longer harbors pathogens (Tilman et al., 2002). Alternatively, pasture-based grazing systems make widespread use of ecosystem services and minimize negative environmental externalities associated with protein production (Tilman et al., 2002).

1.1.10 Stopping Expansion of Agricultural Lands

Currently, arable land covers approximately 38% of the earth's surface (Foley et al., 2011). The growth in agricultural land development is moving toward tropical ecosystems. In addition, expanding agriculture into sensitive ecosystems has negative effects on biodiversity, stored carbon, and important ecosystem services (Foley et al., 2011). Annual estimates show that five to ten million hectares of forest are still being cleared annually for agricultural expansion (Foley et al., 2011). Maintaining ecosystem services is imperative for global sustainability. For example, preserving forests to purify water through soil filtration serves humanity as a whole. However, it is understood that agricultural practices decrease the ability of an ecosystem to perform these services (Tilman et al., 2002).

1.1.11 Adapting to Climate Change

Climate change (Godfray et al., 2010) will also affect the global efforts to produce a sustainable food supply. There are two critical areas of climate change to consider when discussing sustainable agriculture. They are the impact of agriculture on climate change and the impact of climate change on agriculture.

Worldwide, agriculture is responsible for thirty to 35% of greenhouse gas emissions, primarily from tropical deforestation, emissions from livestock, rice cultivation and overly fertilized soils (Foley et al., 2011). There are many agricultural factors that affect the climate directly or indirectly, such as: quantity and type of land cover, type of materials used to create a windbreak, type of irrigation system, and tillage techniques. These factors alter the climate by

changing transpiration, adding particles to the air, and modifying both precipitation and wind (Desjardins, 2009). Approximately 13% of the radiative force from greenhouse gases is produced by agricultural activity.

In the United States and Canada, carbon dioxide (CO₂) produced by agriculture accounts for six to eight percent. However, greenhouse gases produced from agricultural activities are mostly in the form of methane (CH₄) and nitrous oxide (N₂O) (IPCC, 2007). Until the 1970's, agricultural activities created more atmospheric CO₂ than fossil-fuel burning (Lal, Kimble, Follett, & Cole, 1998). Agriculture is an important factor in climate change, mostly because rapid changes in the way land is used causes related environmental changes (Goldewijk, 2004). From about 1981 to 2001, approximately 75% of the CO₂ emissions could be credited to the burning of fossil-fuel and the remaining 25% could be attributed to land-use changes (IPCC, 2001). Currently, agricultural intensification and development are major contributors to global climate change (Foley et al., 2011).

Global climate change can affect agriculture in several ways, such as: shifting temperatures, precipitation, quality of soil, growth patterns for each season, and pest management. "Resilient agriculture systems" are more likely to maintain economic, ecological and social benefits when external forces such as climate change and price fluctuations occur. In order to be sustainable in an unpredictable environment, food production systems should be developed that are diverse and flexible, with incorporation and management of livestock and crop production (National Sustainable Agriculture Coalition, 2009).

Global climate change also impacts livestock. For example, the increased temperature may cause more livestock deaths. Increased temperature may also increase disease, parasites, and pathogens. Livestock will also need additional water if the temperature increases "Horticultural

crops are likely to be more sensitive to climate change than grains and oilseeds” (National Sustainable Agriculture Coalition, 2009). Increasing temperatures will require a new management strategy for global agriculture: Crops will require greater water-use efficiency (Foley et al., 2011), more efficient management of other inputs, and increased use of stress-tolerant crop varieties.

In conclusion, the global challenges associated with creating a sustainable agriculture model are numerous. However, by understanding each challenge thoroughly, scientists and economists can work toward addressing each issue individually and develop solutions with an interdisciplinary approach. This study focuses on three big challenges in Libya that must be addressed in order for agriculture to be sustainable: closing the yield gap, negative externalities associated with closing this yield gap, and agricultural adaptation to climate change by considering the relationship between sustainability, agriculture, and economic development. Specifically, the study investigates to what extent an improved seed system and improved custom management serve to close the yield gap, assist with diminishing negative externalities, and adapt to climate change.

1.2 Overview of Libya’s Economy and Agriculture

Libya is located in North Africa. It is bordered by Algeria and Tunisia on the west; Sudan, Chad and Niger on the south; and Egypt and Sudan to the east. Libya’s northern border has about 2,000 km of Mediterranean coastline. Its total land area is 1.8 million km², which is approximately the size of Alaska (Laytimi, 2006).

The population of Libya is increasing 3.1% every year (Government of the Libyan Arab Jamahiriya, 2006). It was one million in 1955, and is predicted to be more than 12 million by 2025 (Nasid, 2006, as cited in Zidan, 2007). The current population is about six million people.

Approximately 85% of the total population lives in or around the capital city of Tripoli or nearby in Benghazi, both of which are on the Mediterranean Coast. These two urbanizing areas also account for more than 80% of the country's agricultural production. In 2001, it was estimated that one-third of the population in urban areas resided in slums and were below the poverty level (WFP & FAO, 2011). However, Libya has the highest literacy and education rates in North Africa. The literacy rate is about 86% for the population over fifteen years old. This includes 91% of the males and 81% of the females (Eastern Mediterranean Regional Health Systems Observatory, 2007). The average per capita income for the Libyan population is estimated at US \$18,720 per year (Asylum Research Consultancy, 2013).

1.2.1 Libya's Land Resources

Only two percent of Libya's total land area is considered suitable for agriculture, all of which is near the Mediterranean coast. Approximately 95% of Libya's total land area is desert, while four percent is grassland, suitable for grazing animals, and one percent is forest (FAO, 2012; Laytimi, 2006). Libya has predominantly dry and semi-dry areas, and the soil is sandy with low fertility (FAO, 2012). According to Mahdoa (1998), the location of Libya's semi-desert areas (characterized by regular drought due to low and intermittent rainfall) are influenced by the Mediterranean climate in the north. In the desert climate, covering more than 90% of the country, the temperature varies according to the location and the seasons of the year. There are four main terrains in Libya: the coastal plains (wet winters and dry summers), the northern mountains, known as Jabal al-Khaddar and al-Jabal Natusah (which are more humid and have higher rainfall), the internal depressions (with some oases), and the southern and western mountains (desert climate, zero rainfall) (FAO, 2005).

The usual precipitation in Libya is only 28 mm/year. The annual rainfall amounts are low; 95% of the total land area receives less than 100 mm/year (FAO, 2005; Goodland, 2013). The coastal zone, with about 150-400 mm of rain every year, is near the Mediterranean Sea. According to FAO (2005), this zone has fish resources that are not being utilized to their potential. The mountain zone, with Jabal al-Khaddar and al-Jabal al-Natusah, receives about 300-450 mm of rain every year, has cold winter temperatures, and shallow soils. The wadis and oases receive little or no rain, but water is available from the upper aquifers.

However, the most important agricultural zone is the coastal zone and includes about 70% of the agricultural activity in the country. The second most important agricultural area is the mountain zone and the third area is the oases zone. Approximately 220,000 hectares of agricultural area gets more than 300 mm of rain every year. Also, approximately 3.2 million hectares of agricultural area gets 200 mm to 250 mm of rain every year. Irrigated agriculture was 175,000 hectares in 1970, and increased to 350,000 hectares in 2000 (Government of the Libyan Arab Jamahiriya, 2006). El-Msalati (2012) estimated that Libya had about 871.3 thousand hectares of arable land in the northwestern regions, 52.34% of that region; and about 416.9 thousand hectares in the northeastern regions, 29.26% of the total area of the region. However, the total amount of non-arable land in the northwestern areas is about 793.3 thousand hectares, 47.65%, and total non-viable areas for agriculture in the northeastern regions are nearly one million hectares, which is 70.73% of that region's total area. Also, this does not count land that is under-utilized because of seasonal agriculture. Lower annual growth rates for agricultural land results from decreasing arable land (about 0.5% per year) because of population infringement and climate change leading to reduced rainfall. However, the area of agricultural

land reserved by the government for sustainable agriculture in Libya during the same period has increased annually, estimated at 7.2% of total land in the country (El-Msalati, 2012).

Table 1.1 Land Use in Libya

Year	Arable land (hectares)	Agriculture land (hectares)	Land under cereal grains production
1961	1,700,000	1,117,000	489,000
1970	1,725,000	1,302,500	375,537
1980	1,753,000	1,508,000	555,230
1990	1,805,000	1,545,500	404,060
2000	1,815,000	1,545,000	344,493
2010	1,716,000	1,535,100	357,445

Source: FAOSTAT, 2013

The total area of agricultural holdings in Libya, according to results of a survey of agriculture for the year 1995, was about 2.176 million hectares, compared to 1.626 million hectares in 1974, but the percentage of irrigated area relative to total land in 1995 was only about 23% compared to 31% in 1974 (El-Msalati, 2012). This is the result of increased consumption of water and limited availability (General Planning Council Committee in Libya, 2003).

Water resources are divided into traditional and non-traditional water resources (El-Msalati, 2012). Traditional water resources are divided into groundwater and surface water (Salem, 2005, as cited in Zidan, 2007). Groundwater is the main source of water used for all purposes in Libya and the increasing demand for groundwater on an ongoing basis corresponds with the rapid growth of all sectors and services. Libya depends on ground water for its water supply (Abu Fayed & El-Ghuel, 2001, as cited in Zidan, 2007). The availability of groundwater is dependent on the amount of local rainfall and the geological structure and topography of the land (General People's Committee for Agriculture and Ministry of Agriculture, 1978).

Groundwater provides more than 95% of the total water currently used, and recharges directly from rainfall and floods.

Surface water includes rainwater reserved behind dams and natural springs, and is considered an important water resource, especially in the northern regions of Libya's territory. The total surface water resources are estimated at 170 million cubic meters and contribute about five percent of the total water resources in Libya (Arab Organization for Agriculture Development, 1994). Although surface water is less than three percent of the total water in the country, it is used for residential as well as agricultural activities.

The non-traditional water resources include water reclaimed by desalination, wastewater treatment, and the Great Manmade River (GMR) project extracting deep aquifer water from beneath the Sahara desert. Water desalination is important for many countries that have low-rainfall and coasts as large as Libya. Libyan users represent 69% of those using desalination in North Africa (Shalluf & Fares, 2003). Goodland (2013) said, "Libya is ranked fifth in the world in the use of desalination technologies, even though less than two percent of its annual water demand is satisfied by desalinated water." He further said that the State of the Environment report in 2002 discussed seventeen desalination plants in Libya, which have reached their design capacity of approximately 100 million cubic meters/year. Sewage or wastewater treatment is also an area of interest to be used in agricultural projects. There are about forty treatment plants, many in major cities, and the total capacity design has about 175 million cubic meters annually (El-Msalati, 2012; Goodland, 2013).

The third non-traditional water resource is the Great Manmade River (GMR) project. In 1984, Libya started creating the GMR. The water is brought from its source in the desert to the coast, and it is predicted that the resource will last for 50 years (Loucks, 2004). The implementation of this project came after many studies of its economic feasibility. It was decided to exploit the aquifers of fresh water in the southern areas for consumption in the urban and

agricultural areas of the coastal North. The goal of this project was stimulating investment in agriculture and providing drinking water to areas where the population density is concentrated. The GMR moves over six million cubic meters of water daily. This project is one of the largest systems for the transfer of water in the world (General People's Committee for Planning Economic and Ministry of Economics, 1991). It supplies about 200,000 hectares used for agriculture. The GMR was expected to provide about 67% of the water needed for agriculture in 1993. However, The GMR now provides more than 70% of the water that is planned for agricultural use (Goodland, 2013; Government of the Libyan Arab Jamahiriya, 2006). The cost of his project is estimated at about 25 billion US dollars (Loucks, 2004).

While the GMR has increased irrigated crop production, it is neither sufficient nor sustainable. Libya grows enough vegetables and fruits to satisfy its food demands within the country; however, only about 25% of the demand for wheat and barley is supplied from within the country. These grain crops are grown on different sized farms with greatly varying degrees of efficiency (Government of the Libyan Arab Jamahiriya, 2006). Only 2.2 million hectares are arable in Libya. The irrigated arable land is approximately 309,000 hectares and is primarily from groundwater extraction. Along the coastline, this extraction is depleting the underground water supply and is causing saline intrusion (Heemskerk & Koopmanschap, 2012).

1.2.2 The Libyan Economy

Agriculture is the second largest sector in the Libyan economy, yet it contributes in most years an average of less than 10% of the country's Gross Domestic Product (GDP) (Government of the Libyan Arab Jamahiriya, 2006). Oil production is the primary sector in the Libyan economy, to the extent that oil contributes an average of more than 45% of GDP and over 90% of the country's export earnings (FAO, 2005; Government of the Libyan Arab Jamahiriya, 2006)

and about five percent of the GDP is from the agriculture sector (FAO, 2011). The oil income and political changes implemented by the longtime Libyan leader, Moammar Gadhafi, were both factors that have strongly affected the development of Libya (Russo, 2004).

Since the discovery of large amounts of oil, Libya has suffered from what is known as Dutch Disease. This economic phenomenon occurs as a result of developing one industry or sector while neglecting others. Two major results most often occur as a result: the appreciation of its currency, and then a decline in international competitiveness of the other under-developed sectors. There is a diversion of resources (labor and investment) away from efforts to produce goods in the other non-export sectors, and into the sector engaged in production of exports. The major consequences of Dutch Disease are: a decline in exports of traditional goods, an increase in food commodity prices, and an increase in the number of foreign laborers hired (FAO, 2013).

The source of Libya's Dutch Disease is its overdependence on the oil sector. Meanwhile, many other sectors have not been able to compete effectively in world trade (Government of the Libyan Arab Jamahiriya, 2006). The lack of diversification has limited economic growth and government investment in program development. In 1970, the Libyan government started exploring alternative sources and ways to increase the country's income in order to no longer rely solely on income from oil. Agriculture and manufacturing were the two main alternatives (Government of the Libyan Arab Jamahiriya, 2006).

To reduce the effect of Dutch Disease, the Libyan government can be proactive and take some basic steps. First, they must create an oil revenue savings fund to stabilize the economy when oil prices decrease (Chouikhi, Jbir, & Boujelbene, 2011). Second, they must utilize some of the oil revenue to fund non-oil products, such as agriculture, by providing money for infrastructure and technology sectors (Chouikhi et al., 2011).

Table 1.2 Gross Domestic Product Composition, by Sector

Sector	2002	2005	2008
Agriculture	5.2%	2.3%	1.9%
Industry (primarily oil)	66.1%	75.5%	78.2%
Services	28.7%	22.2%	19.9%

Source: World Bank, 2013

As can be seen from Table 1.2, rather than diversifying and reducing reliance on the oil industry, Libya's dependence on oil has gone up in recent years. The oil and gas sector contributed about 74% of GDP in 2006 (African Economic Outlook, 2008). When the price of oil in the global market fluctuates, the economy in Libya is affected and also fluctuates (Government of the Libyan Arab Jamahiriya, 2006). Higher oil prices from 2004-2007 eased the effects of sanctions and increased foreign trade. Libyan oil production is approximately 1.6 million barrels/day and equals roughly two percent of global trade in oil (WFP & FAO, 2011), but oil production decreased from the 1980's until 2003 because of a lack of investment in oil exploration. Despite this, Libya's economy grew very well helped by the gas and oil industry and strong oil prices, but after the 2011 civil war it has been disrupted (African Economic Outlook, 2012). During the 2011 civil war, Libya's assets were frozen. This impacted the economy by cutting oil production and exports. The conflict has also caused destruction of infrastructure and flight of human capital as well as reduced exports and oil production representing about 70% of Libya's GDP (African Economic Outlook, 2012).

1.2.3 Impact of Trade Sanctions

In 1986, Gadhafi restructured the government in an attempt to diminish the impact of the United States' sanctions on Libya. The sanctions created short-term food and consumer shortages and negatively affected the growth of the economy when the price of oil declined. Oil was not being sold to the United States, but exports were still occurring through European companies. The

sanctions had little long-term impact, except that the international community saw Gadhafi as a “red flag,” as a danger to companies considering working with him. After 2004, and the lifting of sanctions, oil prices and foreign trade increased because Libyan oil could then be sold on the open market again (Government of the Libyan Arab Jamahiriya, 2006). Libya has had a history of economic challenges: currency devaluation, oil price fluctuations, and sanctions. Trade sanctions were in place from 1986 to 2006 by the United States and from 1992 to 1999 by the U.N.

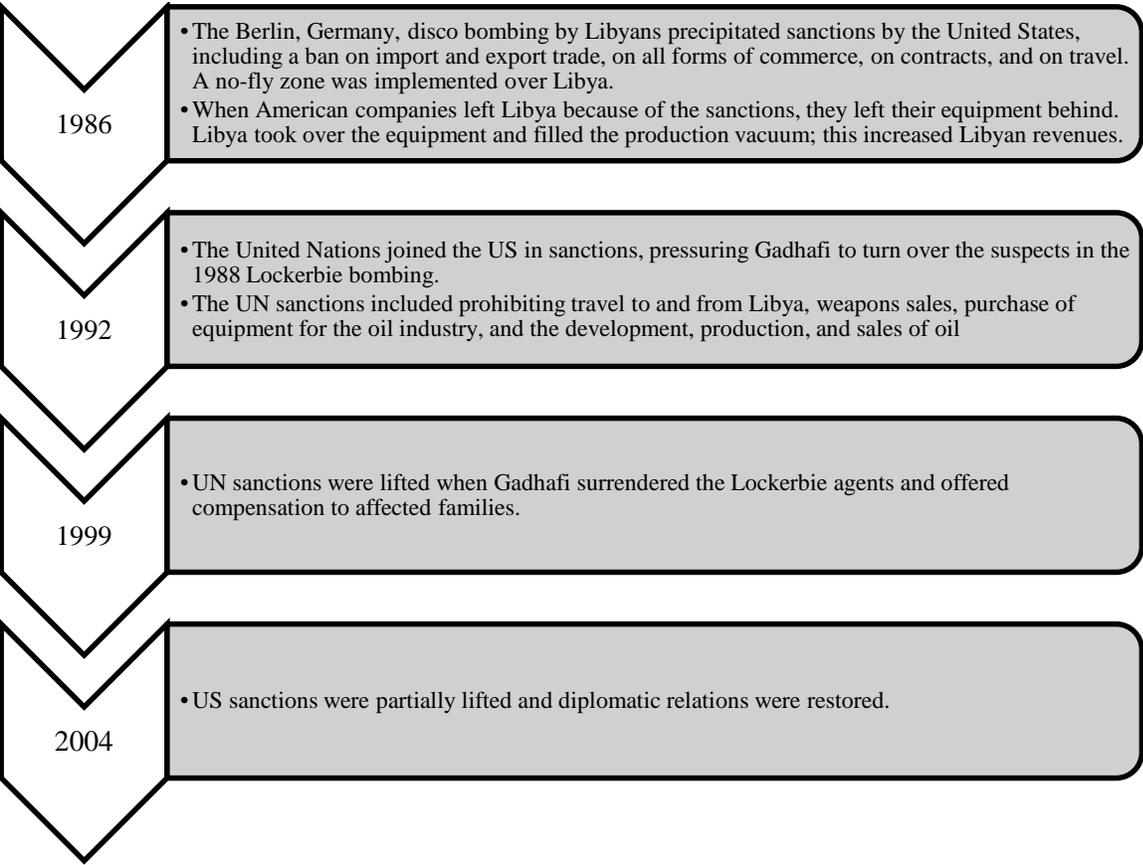


Figure 1.1 Timeline of Trade Sanctions in Libya

Information Source: Hufbauer et al., 2008

This had an effect of slowing the growth of the economy. Weak institutions and legal systems further slowed down economic reforms and growth (African Economy Outlook, 2008).

Following the ousting of Gadhafi in 2011, after he had spent over forty years in power, significant political, economic, and social changes have been underway. Economic production declined after 2011 due to the civil war, and by 2014 the industry and services sectors had an almost identical percentage, while the agriculture sector has been fairly stable (Combaz, 2014). Also, after the end of the Gadhafi regime in 2011, declining oil production has destabilized the economy. The economy shrank by nearly 42% in 2011 when the country temporarily stopped oil production and exports. Meanwhile, the international community froze Libya's assets, essentially freezing the economy as well (African Economic Outlook, 2012).

1.2.4 Libyan Agriculture

Agriculture is considered the second most important economic sector in Libya after oil. Important agricultural products include wheat, barley, olives, dates, citrus, vegetables, peanuts, soybeans, and cattle (Margo, Bonning, & Neighbor, 2012). However, Libya still imports about 75% of its food (Margo et al., 2012). Libya imports corn oil, milk, and wheat flour, with these three products representing about 40% of all agricultural imports. According to the Agricultural Research Center (ARC) Libya-ICARDA Collaborative Program (2010b), there has been an increased quantity of wheat imports, increasing from 380,000 tons in 1990 to 880,000 tons in 2009. Libya does export groundnuts (peanuts) which comprise about 50% of all agriculture exports (FAO, 2011). Prior to 1958, prior to development of the oil industry, agriculture made up a significant share of Libya's GDP, at 30% of the total. However, its contribution has been decreasing since 1958, when oil was discovered. In 2003, only five percent of GDP was from Libyan agricultural products (Laytimi, 2006).

Libyan farms can be divided into three types: 90% are considered small (less than twenty hectares), nine percent are medium sized (20-100 hectares), and one percent are large farms (greater than 100 hectares). In the last 25 years, the number of small farms has grown while the number of medium and large farms decreased (Government of the Libyan Arab Jamahiriya, 2006). About six percent of the Libyan people make a living from agriculture (Laytimi, 2006). The largest agricultural areas are in the Gefara Plains near Tripoli and Al-Jabal al Khaddar in the North East (WFP & FAO, 2011). These two areas account for more than 80% of the country's agricultural production. Fruits and vegetables (including potatoes) form the bulk of the output. Libyan agricultural production only meets 20% of domestic demand for barley and wheat (WFP & FAO, 2011).

Libya's ratio of food exports to food imports is low at 11.1%; similar to Tunisia, but higher than Egypt at 6.9 percent. Meanwhile, export bans and other export restrictions, along with banking challenges that prevent imports, continue Libya's food insecurity (WFP & FAO, 2011).

1.2.5 The Structure of Libya's Agriculture Sector

The agriculture sector in Libya depends heavily on rain-fed cultivation. The land area that is rain-fed is about 1.5 million hectares or 73% of the total arable land estimated at 2.1 million hectares. Irrigated agriculture is about 400,000 hectares and constitutes 16% of the total cultivable land (Lafi, 2004). In 1994, Libya developed plans for the agricultural sector to achieve food security and the maximum food production. The Libyan government estimated how much food Libya would need in the future, based on an efficient use of resources, such as proper use of the most important water sources (Arab Organization for Agriculture Development, 1994).

The percentage of wheat varies because it can only be grown during certain seasons and is dependent on the amount of rainfall. The proportion of wheat has decreased in recent years. Farmers have begun to increase their plantings of barley—at the expense of wheat—because barley is easier to dispose of. Also, farmers do not receive subsidies from the government for the production of wheat. The most important policy of the government’s production plan is the cultivation of wheat on irrigated land in the desert projects and growing rain-fed wheat on the areas that have a relatively high rainfall, such as the Green Mountains region of the northeast, which has more than 250 mm per year. The cultivation of barley in irrigated projects run by the government and the private cultivation of rain fed barley is done in the areas that have prevailing rainfall between 150 to 300 mm per year in the northern areas of Libya. The role of the private sector in increasing the production of wheat and barley is due to a combination of agricultural policies and price incentives (Arab Organization for Agriculture Development, 1994).

Libya’s statistics on agriculture indicate that the area of planted grain crops during the period 1990 to 2009 was declining, from 404 thousand hectares to 364 thousand hectares, which is 9.86 percent of planted area. Also, productivity of grain crops decreased from 0.65 tons/ha to 0.57 tons/ha, a decline of 15%. In 2009, wheat productivity was 0.65 t/ha compared to barley productivity, which was 0.49 t/ha (FAOSTAT, 2010).

Libya has seen a decline and fluctuation of productivity, higher costs and a change in planting area due to inefficient use of agricultural resources (El-Msalati, 2012). The consequent insufficiency in domestic production of grain, while having increasing demand rates, increases dependence on imports of grain. These consequences negatively affect Libya’s economy. According to Government of the Libyan Arab Jamahiriya (2006), the productivity and production of cereal declined in 1996 to 2006 due to mismanagement of irrigated public land, not

enough profit for the farmers, little current technology with no improved seeds, fertilizers, and a lack of agricultural policies that would favor farmers who grow cereal grains.

El-Msalati (2012) reviewed a number of relevant past studies about wheat and barley in Libya; the following are some examples from El-Msalati. Daba (1991, as cited in El-Msalati, 2012) found that the most important factors affecting the production of rain fed wheat were rainfall, harvest, and time. The study showed that in each of the harvested areas, the average productivity per hectare, and total production of rain fed wheat was unstable. The fluctuation can be traced to weather factors and technical changes in production. Al Sgayna (1993, as cited in El-Msalati, 2012) found the productivity of wheat and barley crops was lower and varied significantly from year to year due to climatic, technical and economic factors. Mohammed (2004, as cited in El-Msalati, 2012) reported that Libya has a greater degree of self-sufficiency in its production of maize and rapeseed oil than it does with wheat and barley. The average self-sufficiency for wheat is 35%, while barley's average self-sufficiency is approximately 21%.

Abdul Hamid (2005, as cited in El-Msalati, 2012) found a general increase in the trend of consumption in wheat, rice, barley, maize, sugar, potatoes, oils, and fats. The study pointed out that the average per capita Libyan annual food consumption is greater than what the World Health Organization recommends. Aldaikh's (2005, as cited in El-Msalati, 2012) study showed that the most important determinants for the production of wheat are the amount of wheat that Libyans consume, the quantity of imported wheat, the quantity of barley that is produced, the amount of barley that Libyans consume, the acreage of barley, and the quantity of imported barley. Al Jade (2006, as cited in El-Msalati, 2012) pointed out there was an increase in the area planted with wheat during the 1980s due to the government encouraging farmers to cultivate more wheat; however, in the 1990s the amount of area under wheat cultivation began to decline.

The study found the most important factors affecting the production of wheat were the size of the harvested area; for example, increasing the area of cultivation by 10% would increase production by an estimated 12.7%. Because of the weakness of the price policy for wheat, there is a weakness in the domestic supply response of wheat to the variables of price.

Azwam (2007, as cited in El-Msalati, 2012) confirmed earlier studies that found the most important variables specific to wheat production in Libyan agriculture were represented in the amount of cultivated area, the amounts of rainfall, and the cost per hectare. Osman (2007, as cited in El-Msalati, 2012) evaluated the main problems faced by the Libyan wheat sector related to irrigation, fertilization, marketing, and seeds, as well as problems related to harvesting, machinery, and agricultural labor.

Mohammed (2009, as cited in El-Msalati, 2012) analyzed how the areas of production of wheat and barley fluctuate year by year in relation to fluctuations in crop prices. The study found that increasing the price farmers receive for the wheat crop by one dinar leads to an increase in the area of land planted in wheat crops by 3,300 hectares, and concurrently increasing the price farmers receive for barley by one dinar leads to a decrease in the area planted in wheat by about 3,300 hectares. While an increase in the price of wheat by one dinar leads to the increased production of wheat, estimated at 4.84 tonnes, increasing the price of barley by one dinar leads to a decrease in wheat production by about 2.39 tonnes. Therefore, the barley crop is a competitor of the wheat crop.

Saad (2009, as cited in El-Msalati, 2012) compared the cultivation of wheat and barley crops in agricultural projects, both public and private sector, in Shabha. The study found that the most important economic inputs affecting the production of wheat and barley were: the amount of phosphate fertilizer, the amount of nitrogen from manure, the amount of compound fertilizer,

the amount of seeds, the number of hours of human labor, the number of hours of automated work, and the amount of water used. The study showed that lacking a proper irrigation system resulted in about 3.6 percent losses to the wheat crop, and about 2.33 percent to the barley crop.

1.2.6 Government Support of Agriculture in Libya

The Libyan government maintains a number of programs and policies to support investments in the agricultural sector, largely by giving subsidies for public sector

Table 1.3 Main Crop Production in Libya, Ranked by Production Volume in 2010, in Tonnes

Year	Potatoes	Dates	Wheat	Barley	Oranges	Grapes	Water-melon	Maize
1961	14,000	29,100	29,992	72,000	17,522	7,100	21,000	2,000
1970	9,982	49,111	27,189	52,807	16,972	6,500	21,000	1,262
1980	102,857	86,523	140,500	71,000	51,740	14,152	17,092	931
1990	145,000	74,000	128,760	141,476	91,000	36,565	20,000	400
2000	190,000	120,000	125,000	85,000	42,500	50,000	21,400	5,780
2010	290,000	161,000	106,000	102,000	46,400	35,000	24,500	2,900

Source: FAOStat, 2014

projects such as poultry and sheep farms, as well as wheat production in the desert areas (FAO, 2011). Such agricultural policies must be understood in light of the fact that food import subsidies are greater than two percent of Libyan GDP. Because of its harsh climate, Libya is importing 75% of its food. For example, flour import subsidies are almost equal to the combined administrative budgets of the Ministries of Justice and Foreign Affairs (Heemskerk & Koopmanschap, 2012).

From the 1970s until the mid-1980s, the government's Price Stabilization Fund provided subsidies for both the inputs--including fertilizers, animal feed, machinery, and seed--as well as

the outputs of agricultural production, for example, barley, olive oil, wheat, and milk. (Government of the Libyan Arab Jamahiriya, 2006). Although the Libyan government planned to phase out the general agricultural subsidies, special case subsidies have remained in place; for example, the subsidy for sheep feed that mitigated damages from two years of drought from 2010 to 2011. Moreover, there is little indication that the special input subsidies supposedly paid to cooperatives and farmers' associations were actively paid (Heemskerk & Koopmanschap, 2012).

Libya's National Center for Improved Seed Production (NCISP) subsidizes the farmers by providing low priced foundation seed. The farmers grow certified seed, and then NCISP purchases the certified seed from the farmers at a high price. The subsidies encourage more farmers to enroll in the program and also encourages farmers to buy new pivot irrigation technology to increase their production. Additionally, the Agricultural Bank subsidizes cereal prices to encourage the purchase and use of improved seeds produced by NCISP and the SPS farmers (Al-Shreidi & Sbith, 2009) The national seed system currently gives price premium incentives to private farmers to produce and market improved seed locally (Heemskerk & Koopmanschap, 2012). This system reduces the need throughout Libya for NCISP to give farmers seed and makes certain that seeds are available in a timely manner to the majority of farmers.

The Great Manmade River (GMR) project provides a subsidized supply of water for agriculture While the government pays USD \$0.90/m³ in costs for irrigation water through the GMR project, it only charges the public farms a very low price of USD \$0.03/m³ for that same supply of water, making this a serious investment on the part of the government.

1.2.7 Agricultural Marketing in Libya

In the late 1970s, the National Agricultural Marketing Company (NAMC) was created to manage the export and import of agricultural products. In the late 1980s, when sanctions were lifted, private distributors and farmers were allowed to sell their produce in private local markets (Government of the Libyan Arab Jamahiriya, 2006). Two public companies were originally responsible for marketing inputs. The National Company for Light Supplies (NCLS) marketed such things as seeds, fertilizers, and pesticides, while the National Company for Heavy Equipment (NCHE) marketed harvesters, pumps, tractors, ploughs, and irrigation equipment. By 2002, the two companies had been dissolved and the marketing of agricultural inputs was taken over by the private sector (Government of the Libyan Arab Jamahiriya, 2006).

1.2.8 The Current State of Libyan Agriculture and the Continuing Importance of Cereal Grains Production

Despite the change in power after the end of the Ghaddafi regime in 2011, the agricultural sector has not changed significantly and still faces many of the same challenges. Cereal crops are still of great importance in the food sector of the economy in Libya, and they occupy the greatest amount of area of all crops grown in Libya.

Cereal crops are associated with the concept of food security, because they supply a high percentage of calories in the human diet. The cereal crops in Libya include barley, wheat, oats, millet, and corn. The estimated daily need of an individual human is about 3,611 calories, of which grain provides about 37%. Grain provides only about 14% of the daily needs for livestock (Qasem, 1988). One reason why cereal crops are grown in such abundance is because of the absence of other economic crops competing with them, such as rice, cotton, and sugar cane (El-Msalati, 2012).

Throughout history, wheat and barley grain crops have been the main crops traditionally associated with the lives of Libyan farm families. To a lesser extent, farm families have raised corn and millet. Barley is considered one of the most important traditional crops in Libya and has been ever since ancient times. Originally, it was the only source of grain for bread and meals. Today in Libya, barley is used in certain popular dishes, but most of the barley crop is used as feed and fodder for animals—in the forms of the green plant, the grain, or the straw. Wheat is the second most important field crop after barley, while the oat, millet, and corn crops are planted on a smaller scale.

The Deputy Minister of Agriculture, Animal and Marine Wealth stated in an interview that the post-Gaddafi regime in Libya acknowledges and emphasizes the need to recognize and strengthen the role of the private economic sector and to aid entrepreneurs and the development of both small and medium enterprises. The Deputy Minister also stated that in order to accomplish these goals for private sector development, the government will need to bolster the institutional and regulatory framework. The principles of value chain development will be incorporated into the agricultural development strategies. For instance, instead of focusing only on production, there will also be focus on other functions in the chain, such as market orientation and processing. Also, post-harvest storage losses are currently very high at 25% and need to be reduced to improve the value of the harvest (Heemskerk & Koopmanschap, 2012).

In conclusion, Libyan agriculture has many reasons to make progress toward sustainability and has many ways in which to improve. Under the Gadhafi regime, Libya had many goals for agricultural development. Those goals included:

- increased production with increased efficiency, to ensure food security;
- better management of natural resources, such as water and soil conservation;

- increased contribution by agriculture to GDP, for diversification of the economy;
- creation of jobs in the farming sector;
- provision of good infrastructure in the unpopulated areas of the country to encourage people to live there and create a better rural-urban balance;
- find good sources of industrial materials and inputs, such as seed genetics, agrochemicals, and other agricultural technologies; and
- Improved management of infrastructure, including the water supply, roads, and electricity, to minimize agricultural production interruptions (Government of the Libyan Arab Jamahiriya, 2006).

All of these goals are still necessary to address after Gadhafi in order to serve the population sustainably.

1.3 Sustainability Challenges in Libyan Agriculture

Despite the change in government regime, Libya still faces the same agricultural challenges in terms of food security and sustainability. According to a number of researchers (El-Msalati, 2012), the following six agricultural sustainability challenges are the most important for Libya: (1) water management; (2) marginalization of agriculture from land use changes, particularly from urbanization pressures; (3) low primary agricultural productivity, especially due to poor seed management and lack of improved varieties; (4) efficiency and environmental safety of agricultural chemical use; (5) adapting to climate change.

1.3.1 Water Management

Because Libya is an arid country receiving limited and erratic rainfall (Wheida & Verhoeven, 2007), water management is perhaps the most important challenge. Libya's water

resources are limited; about 90% come from aquifers, and about 80% of aquifer use is for agriculture but is limited in infrastructure (Arab Organization for Agriculture Development, 1994; FAO, 2008). Wasteful water practices are common because no costs are associated with usage (Zidan, 2007). The demand on water continues to increase as the population grows (Wheida & Verhoeven, 2007). The water exploitation index, which is the total water extracted per year as a percentage of long-term fresh water resources, is already over 90% (NIC, 2009). All of these problems are made worse because the country lacks water policy and regulation (Zidan, 2007).

The water supply and usage are major challenges. In 2013, the total population of Libya was six million and is expected to rise to twelve million by 2050 (Wheida & Verhoeven, 2007). Water usage is predicted to also increase in the future with population. Total water withdrawal for agricultural, domestic and industrial use was estimated at 3,843 million m³ in 1998, with a water deficit of approximately 1,154 million m³ in 1998. By 2025, the estimated water requirement for the Libyan population is expected to be between 8,200 and 8,840 million m³, with a deficit of 4,339 million m³ if water usage patterns continue (Wheida & Verhoeven, 2007). This is simply unsustainable when rainfall for the country varies between 100-500 mm/yr. in the north and as little as 10 mm/yr. in the south.

One of the “solutions” the past regime created was the Great Manmade River (GMR). However, this also created problems. When the river was built, there was a massive loss of natural habitats. “New” agricultural land requires increased quantities of fertilizers and pesticides to maximize production in an irrigated system, which means an increased cost to farmers and increased environmental impacts. The large supply of water without any real regulations has also resulted in wasteful usage (Zidan, 2007).

1.3.2 Marginalization of Agriculture Due to Land Use Change

Urbanization trends have also adversely affected the environment, particularly through encroachment on agricultural and forest lands, along with pollution of air and water (Goueli, 2004). These factors are increasing desertification in those small areas of Libya that are not already desert. 25% of prime farmland has been lost to urbanization, while agricultural activities are pushed on to marginal land. In 1950, 19% of the population lived in urban areas. That increased, by 2010, to 88%, and by 2030 it is predicted to be 92%. People in the urban areas have a higher standard of living than in the rural areas and also have a larger energy footprint.

1.3.3 Low Primary Productivity, Due to Low Quality of Farm Inputs, Including Seeds

There is low primary productivity for many crops grown in Libya. One of the main steps required to raise productivity is to improve the genetic quality of seed, which in turn requires improvements in the seed production system and in the available propagation material (FAO, 2011). There are specific requirements for the seed genetics needed. Agriculture in Libya is highly constrained by scarce fresh water resources (Laytimi, 2006; Zidan, 2007) as well as poor soil fertility, structure, salinity, and drainage (Laytimi, 2006). Climatic conditions also limit yield due to high temperatures, winds, and temperature fluctuations (Laytimi, 2006). An additional challenge is the fact that farmers have limited money to invest in farmland and inputs. These conditions mean that, while farmers need quality seed stock of advanced varieties appropriate for Libyan conditions, many cannot afford them.

Libya faces seed production quality and supply limitations. Due to limited technical capacities and quarantine measures, new strains of plant and animal pests and diseases have entered the country and found their way to the farming sector. Minimal research on genetic improvement for pest resistance (both public and private) has been conducted, in part, because

the country lacks technical expertise in seed genetics. This has led to relative monopoly of technology in the industry by some public institutions and international companies.

Another major problem is the limitations of seed storage. Minimal infrastructure means there is little to no temperature or climate control to keep local seeds and tubers viable for the following season. Also, pest control is limited, and imported seed quality decreases in poor storage conditions.

1.3.4 Efficiency and Environmental Safety of Agricultural Chemicals

Libya imports nearly all of its agricultural inputs, including seed and animal feed, fertilizers, pesticides, and agricultural machinery (Government of the Libyan Arab Jamahiriya, 2006; Laytimi, 2006). As a result of limited domestic capacity, there is a lack of understanding about the dangers associated, in particular, with fertilizer and pesticide use. This has led to too much chemical being used which has had a negative effects on the soils and waters of Libya (Laytimi, 2006). Coordinated programs developed to combat agricultural pests are very weak. Until 2002, two large public companies (NCLS and NCHE) marketed all agricultural inputs (Government of the Libyan Arab Jamahiriya, 2006). In 2002, the two companies were dissolved and the private sector began marketing agricultural inputs. No regulations require testing for input quality at this time (Government of the Libyan Arab Jamahieriya, 2006).

1.3.5 Adaptation to Climate Change

Seasonal precipitation variability in Libya is more evident from 1976-2000, indicating the growing extent of climate change. The primary anticipated impacts of climate change on Libya include reduced crop production and food security, reduced available water resources, and reduced biodiversity (FAO, 2008). Harsh climatic conditions and poor soil already severely limit

yield and arable land hectares (WFP & FAO, 2011). Libya is already dry, but has an increasing drought problem causing decreases in agricultural production (El-Tantawi, 2005). Crop production is affected by variable temperatures, uneven rainfall, longer periods of drought, and increases in pests and diseases. Clearly, Libya faces many daunting challenges in the agricultural sector due to climate change.

1.4 Summary and Conclusions

The regime change in 2011 has brought many changes to Libya, but the agricultural challenges that have persisted for decades remain. These problems will not wait for the political situation to resolve itself and yet are interconnected. Strategies must be developed between the private and public sectors. The driving motives for the Libyan government to invest large amounts of money and subsidies in agricultural production are social and political, and are not because of economic principles or for profitability. A new approach is needed that requires cooperation and supportive institutions. This will require time and the building of trust between farmers, the private sector, and whatever new government develops. In the future, the objectives will probably mix social and economic principles, requiring that the economy not be based solely on the oil industry (Heemskerk & Koopmanschap, 2012).

The challenges facing Libyan agriculture today are evidenced in a large yield gap. While many parts of the world realize lower yields relative to their potential, the margin is wider in North Africa and particularly in Libya. The next chapter will define what the yield gap is, how it is measured, and how Libya compares to other North African countries and the world. The chapter will also go into more details about the factors contributing to this large yield gap for Libya. While water resources are likely the most important factor, seed quality and genetics are also key factors.

The overall objectives of this research are to investigate how to achieve greater food security and sustainability in Libya's agriculture, which requires higher yields be reached while minimizing environmental impacts. This makes it increasingly important to understand the Libyan seed system and its users and their access. What varieties do farmers currently grow? Why do they grow those particular varieties? How do they access the seed for those varieties? What constrains farmers' adoption of new varieties? Investigating these factors will lead to recommendations for improving the seed system in Libya.

2 The Yield Gap in Grains Production in Libya

2.1 Introduction

2.1.1 *Why Closing the Yield Gap is Important to Sustainability*

Yield is one of the most common measures of crop productivity. It is defined as the output of a crop per unit of land used to produce metric tons per hectare, according to Beddow, Hurley, Pardey, and Alston (2013). A yield gap is important because it reveals how efficiently land and other resources are utilized. In terms of environmental sustainability, according to Lobell, Cassman, and Field (2009), a yield gap helps bring forth estimates/projections of crop yields in the future. Closing a yield gap could thus improve agriculture sustainability. Foley et al. calculate that bringing 16 important feed and food crops to within 95% of their potential yield worldwide would improve production by about 2.3 billion tones. According to Mueller et al. (2012), “Yield gaps are caused by deficiencies in the biophysical crop growth environment that are not addressed by agricultural management practices” (p. 254).

Knowledge of what factors are contributing to a yield gap can help build awareness of how to develop a sustainable agricultural system. The major factors that could negatively affect environmental sustainability if not properly managed include genetic varieties, fertilizers, pesticides, and irrigation. Technology transfer and access issues, such as farmer resistance to new skills or new technologies, often contribute to yield gap. Additional causes include socio-economic conditions such as farmers’ income and access to credit, knowledge, and policy/institutional constraints.

Understanding causes of the yield gap is therefore an important component when trying to achieve environmental sustainability. Godfray et al. (2010) and Foley et al. both emphasize

the importance of closing the yield gap in order to meet the growing global population's food demand and to minimize environmental impacts of production. These researchers discussed that in order to close the yield gap, focus should be put on improved seed varieties, water, agricultural practices, nutrients, etc.

Crucially, according to Job (2006), closing the yield gap improves more than productivity, as it can improve the efficiency of production, optimizing the return on inputs of pesticides, fertilizers, and water. According to Singh et al. (2006), "The yield gap needs to be bridged by adopting improved soil and water management and fertility management practices and by alleviation of various production constraints described earlier" (p. 32).

2.1.2 Yield as Just One Measure of Sustainability

Jacobs (1995) and Rigby, Woodhouse, Young, and Burton (2001) claimed there are about 386 definitions of sustainable agriculture, due to the different meanings associated with different places, time periods, and individuals. Indicators help researchers answer scientific questions and make scientific measurements in regards to economic and political decision-making, as well as social and environmental aspects of sustainability. As such, indicators or measures of sustainable agriculture have value in understanding, developing, and encouraging sustainable practices.

The study by Rigby et al. (2001) framed the dilemma of how to define and measure sustainable agriculture, taking into account the social, economic, and physical dimensions of agricultural practices. It used five indicators of sustainable agriculture: seed source, weed control, crop management, pest control, and soil fertility maintenance. The study's empirical analysis focused on physical environmental factors, particularly fertilizers and pesticides, and analyze agrochemicals in terms of types and magnitudes of effects on the environment.

Fertilizers are a key component in sustainable agriculture; however, mismanagement of them has

negative impacts. For example, widespread nutrient pollution and the degradation of surface water bodies are already prevalent in the world (Godfray et al., 2010). In addition, the release of nitrous oxide from fertilized fields exacerbates climate change. Although negative environmental consequences occur from over-use of fertilizers, it is equally a problem that insufficient nutrients are available in worldwide agronomic production. Many yield gaps are due to incorrect amounts of necessary plant nutrients (Cassman et al., 2002). Policy and better management strategies could improve the balance between the environment and yields (Foley et al., 2011).

2.1.3 Defining the Yield Gap

Singh et al. (2006) defined yield gap as “the difference in experimental yield and on-farm yields” Page #. Hence, yield gap is the difference between the yield potential of perfect conditions--such as water, temperature, and fertilizer--and actual yield in term of what farmers really harvest given their resources of limited water, seed, and weather. According to Foley et al., yield gap is “the difference between crop yields observed at any given location and the crop’s potential yields at the same location given current agriculture practices and technologies” (p. 339). Similarly, Nirmala, Deshmanya, Muthuraman, Meera, and Sain (2009) and many other researchers define yield gap as, “the difference between the maximum attainable yield and the farm level yield” (238). Pratt-Nin et al. (2010) explained the concept of yield gap as the “...technical agronomic analysis of production as a measure of performance because it implies a comparison between yields actually obtained under particular agroecological conditions on commercial farms and the maximum or potential yield in that region” (p. 66). Licker et al. (2010) defined yield gap technical as “climatic potential yield – actual yield,” with the yield gap fraction defined as “ $1 - (\text{actual yield} / \text{climatic potential yield})$.”

Yield gap has, furthermore, been described as being made up of two primary components: ‘transferable’ and ‘non-transferable’ (Nirmala et al., 2009). Transferable components are controlled by management practices such as water use, fertilizer use, pesticide use, etc. to increase efficiency. The non-transferable components are environmental conditions that cannot be controlled, such as the climate, amount of light, soil quality, water quality, air quality, and microorganisms. Hence, these definitions bring forth the importance of analyzing practices and performances of crops to understand the crop’s current level and the attainable level it could reach.

2.1.4 Actual and Potential Yields

More specifically, actual yield is known as the ‘average farmer yield’ by farmers within a particular space and time. Van Ittersum et al. (2013) defined actual yield as average yield (Y_a) produced in a farmer’s field. Rabbinge (1993) discussed the fact that farmer yield or actual yield depends upon control of factors such as pests, weeds, pollutants, and diseases. Potential yield, however, is defined as the maximum yield achieved by a crop cultivar with adapted nutrients, complete pest management, and non-limited water use to grow crops efficiently (Evans & Fischer, 1999). Evans’ (1993, as cited in Lobell et al., 2009) description of potential yield as determined by factors such as water, temperature, and solar radiation, which are grown under favorable conditions absent of limitations. According to Pathak et al. (2003), potential yield was defined “as the maximum yield of a variety restricted only by the season-specific climatic conditions” (p. 225).

Also, Singh et al. (2006) defined potential yield as “the maximum yield obtained in research station field experiments conducted under optimal management” (p. 31). According to Pratt-Nin et al. (2010), “The potential yield is determined by producing the crop without

constraints that are normally found at the farmer level” (p. 66). The FAO (2004) in the International Year of Rice, expanded on this definition by further explaining maximum attainable yield as “...yield of experimental/on-farm plots with no physical, biological or economic constraints...” and farm level yield as, “the average farmer’s yield in a given target area at a given time at a given ecology” (p. 1). Agronomists define theoretical yield or potential yield as "the maximum yield that can be achieved in a given agroecological zone with a given cultivar,” additionally, “production is determined solely by CO₂, temperature, solar radiation, and crop characteristics" (Fermont & Bonson, 2011, p. 3). According to Wolf and Vandiepen (1995), potential yield can be found through determining solar radiation, temperature, and crop characteristics, which can be recognized in locations where the crop management, plant nutrients and the water supply are ideal.

2.1.5 How Yield Gap is Measured

Yield gap is measured through examination of location, average yield or actual yield, and potential or maximum yield. In the study by Nirmala et al. (2009), yield gap is measured in terms of *yield gap 1* and *yield gap 2* at three different locations. Yield gap 1 was inferred based on the difference between the research station’s reported potential yield and the demonstration plot’s reported yield. Yield gap 2 was measured by the difference between potential yield and farmer’s yield. The author also took into account the major constraints to rice production in order to infer yield gap, such as institutional, bio physical, technical, soil problems, machinery, and socio-economics (Nirmala et al., 2009).

The FAO (2004) in their International Year of Rice publication and later Schneider and Anderson (2010) break down yield gap analysis into three components. The first yield gap is the “gap between theoretical potential yield and experimental station yield” (p. 1), which includes

breeding new varieties. The second yield gap is measured “between the experiment station yield and the potential farm yield” (p. 1), which is caused by transferable factors. The third yield gap is determined “between the potential farm yield and the actual farm yield” (p. 1), which is caused by the lack of improved seed and low input use, ultimately referring to poor management practices that are not cost-effective.

According to Lansigan (1998), analysis of yield gap in crop production may be accomplished by using three sets of elements: growth and yield limiters, including nutrients and water; growth and yield determinants, including solar radiation and temperature; and finally, growth and reducing factors including pests, weeds, and diseases. Also, he estimated yield gaps by using good quality inputs and crop models. Evaluation of such analyses could result in changes in controllable variable factors such as water and fertilizer.

According to Beddow et al. (2013), yield gap is explained by three concepts. The first is that yield gap is different between yields accomplished by farmers in countries with high income, and farmers in countries with low income; thus, by closing the yield gap poverty can be reduced and solutions found for food security challenges. The second concept of yield gap is the difference between the experimental yield accomplished by researchers and the commercial yield accomplished by farmers; therefore, yield gap depends on the location and crop. Finally, the third concept of yield gap is the difference between some concept of a biological maximum potential yield and experimental yields.

Licker et al. (2010), estimated yield gap using climatic potential yield, defined as “the 90th percentile yield achieved for a given crop in a given climate zone....As defined by a comparative statistical analysis of other regions with similar climatic conditions” (p. 776). They found in regions with high inputs or in developed countries, the yield gap is low.

Actual yield is often measured by a farmer's crop over a particular time and space. Also, Beddow et al. discussed actual yield (YA) as “the measured yield at a particular location and point in time” (p. 11).

Maximum potential yield, in general, is estimated with the results from experimental and on-station growing areas that use characteristics of the most modern varieties (Fischer, Byerlee, & Edmeades, 2009). Schneider and Anderson (2010) referred to the three common methods, also discussed by Lobell et al., to calculate yield potential:

- 1) To calculate a specific region, controlled field experiments with sanctioned yield is used.
- 2) To simulate yield under specified parameters, crop models can be used.
- 3) Yield potential can be estimated on the basis of the farmer's maximum yield.

Also, there are several methods to measure potential yields, such as the crop simulation model. This model estimates potential yields with an understanding of the diversity of weather, pests, agronomic management, frost, soil and flooding (Aggarwal et al., 2008). Lobell et al. further discussed how to estimate potential yield by “crop models that assume perfect management and lack all yield-reducing factors” (5), which could include disease control, pest management, fertilizer control, and sufficient water use.

Potential yield is also referred to as location specific because it is more dependent on the climate than on soil properties (van Ittersum et al., 2013). Since it is difficult to understand the existing management practices in a particular time and space, surveys are often used to measure yield potential (Lobell et al., 2009). In the study by Aggarwal and Kalra (1994) for example, a survey was used called the ‘WTGROWS crop model’ of simulated potential yield to develop an

understanding of optimal sowing date, in which they found late sowing harvest caused reduced wheat yields. Potential yield is often gathered from data already collected from institutions that have determined experimental yields when attempting to improve agronomic practices via research stations (Pala et al. 2011). According to Martin, Shroyer, Shoup, Olson, and Duncan (2011), yield potential was defined as “the yield of a crop under ideal conditions. In this context, yield potential is the yield at the time of the estimation assuming favorable conditions after evaluation takes place” (p. 1).

As this review shows, actual yield and potential yield are important concepts for measuring yield gaps. They also have several different definitions and measurements to find their results. However, the various definitions are similar, with minor differences based on academic backgrounds and physical factors. While actual yield can be found as a concrete number, what the farmer produced, potential yield is an estimate or projection based on experimentation. Potential yield can be hard to estimate if proper experimentation has not been conducted. This also complicates measurements of yield gaps. However, finding the yield gap is an important step in closing this gap.

With limited breeding programs and the increasing concerns of climate change, it is becoming more important to focus on future yield gaps, to understand how to measure yield gap, and to practice closing yield gaps to develop food stability. By closing yield gaps, efficiency of environmental quality and food production will follow. It is important to balance the costs to the environment when growing wheat and barley in particular, in order to use the land and resources to its full potential while being mindful of pollutant affects that result.

2.2 Current Status of Wheat and Barley in Libya: Is There a Yield Gap?

Wheat and barley grain crops have been the main crops traditionally associated with the lives of Libyan farm families, with corn and millet being raised to a lesser extent. Barley is considered one of the most important traditional crops in Libya and has been ever since ancient times. Originally, it was the only source of grain for bread and meals. Today in Libya, barley is used in certain popular diets for people, but most barley is used for animal fodder—in the forms of the green plant, the grain, or the straw. Barley is mostly grown in Libya under rain-fed environments. Wheat (soft and durum) is the second most important field crop after barley, while oats and corn crops are planted on a smaller scale. Wheat grows under both rain-fed and irrigated environments. According to Al-Shreidi and Sbith (2009) wheat supplies 1,311 kilocalories (kcal) of the needs of an individual in Libya per day. Given that an individual needs 3,330 kcal, this accounts for nearly 40% of caloric intake for the average Libyan.

Libya is one of the largest wheat importing countries in the world. Quantities imported ranged from 380,000 tonnes in 1990 to 1,623,390 tonnes in 2012. The total area harvested for wheat during 1990 was 104,538 hectares and increased to 160,000 hectares in 2013 (FAOSTAT, 2015). See Table 2.1 and Table 2.2 below.

For barley, imported quantities ranged from 832,238 tonnes in 1990 to 179,413 tonnes in 2012. In addition, the total area harvested for barley during 1990 was 296,742 hectares to 200,000 hectares in 2013 (FAOSTAT, 2015). See Table 2.1 and Table 2.2 below.

The Libyan government has established numerous agricultural projects to encourage the production of wheat and barley in areas where permanent irrigation is used, particularly in the southwestern and southeastern Sahara desert regions supplied by water from the Great Man-Made River (GMR) irrigation project. As a result, there has been some gain in production and

productivity. Government plans have included increasing the area allocated to growing grain crops, financial allocations to farmers, securing sources of irrigation to new areas of production, including diverting water from the Great Man-Made River to the Northern areas. Despite these efforts, the production of crops still has not reached the goals and productivity was low.

According to Al-Shreidi and Sbith (2009), there has been little success with growing wheat and barley crops efficiently for the following reasons:

1. Lack of availability of appropriate genotypes for each environment throughout different areas of agricultural production.
2. Lack of identification of appropriate agricultural operations of the production process throughout different production conditions.
3. Management service operations are not efficient.
4. There is a low level of fertility in most agricultural soils.
5. There are impacts of weeds, diseases, and pests.
6. Lack of humidity level presents the need for irrigation
7. Spreading the seeds of improved varieties did not reach the required level.
8. Technology for agricultural mechanisms was not available especially for the private sector.
9. High wastage through harvesting and threshing.
10. Climate change affects the environment for the grain production in different areas.

More than 90% of the wheat area in Libya is grown with systems of either permanent or supplementary irrigation. The Morziq (Murzuq) region, in the southwest, has the most agricultural projects, and produces 49% of total wheat in the country. Marge

(Marj), on the northern coast near Benghazi, is the second most productive area, with 16% of wheat and 80% of barley produced in the area, grown under rainfed conditions, ranging between 50 to 350 mm of rainfall annually (Commission on Public Information Libya Tripoli, 2007).

Table 1.2 Production Statistics for Small Grains in Libya, 1990-2013

Year	Barely				Wheat			
	Barley area harvested (Ha)	Barley yield (Hg/Ha)	Barley production (tonnes)	Seed *(tonnes)	Wheat area harvested (Ha)	Wheat yield (Hg/Ha)	Wheat production (tonnes)	Seed *(tonnes)
1990	296,742	4,767.64	141,476	33,800	104,538	12,317.05	128,760	7,875
1991	260,000	4,807.69	125,000	27,750	105,000	12,380.95	130,000	8,479
1992	185,000	4,864.86	90,000	15,750	99,748	12,531.58	125,000	12,750
1993	105,000	4,761.90	50,000	12,750	150,000	8,400.00	126,000	13,175
1994	85,000	4,705.88	40,000	7,500	155,000	7,741.94	120,000	13,600
1995	50,000	4,600.00	23,000	8,850	160,000	7,312.50	117,000	14,450
1996	59,000	4,779.66	28,200	12,750	170,000	7,294.12	124,000	13,175
1997	85,000	4,952.94	42,100	20,250	155,000	10,090.32	156,400	13,600
1998	135,000	4,814.81	65,000	24,000	160,000	8,750.00	140,000	14,025
1999	155,000	4,838.71	75,000	27,750	165,000	7,878.79	130,000	13,370
2000	180,000	4,722.22	85,000	27,750	157,293	7,946.95	125,000	14,366
2001	180,500	4,709.14	85,000	27,750	169,012	7,395.92	125,000	14,050
2002	173,697	4,893.58	85,000	27,750	165,294	7,562.28	125,000	16,798
2003	180,000	4,722.22	85,000	28,500	197,624	6,325.14	125,000	16,847
2004	184,000	4,619.57	85,000	32,250	198,197	6,306.86	125,000	14,025
2005	204,080	4,900.04	100,000	32,250	165,000	7,575.76	125,000	11,220
2006	204,080	4,900.04	100,000	32,250	132,000	7,878.79	104,000	11,220
2007	204,080	4,900.04	100,000	32,250	132,000	7,878.79	104,000	11,220
2008	204,080	4,900.04	100,000	30,750	132,000	7,878.79	104,000	11,305
2009	200,000	5,050.00	101,000	28,200	133,000	7,894.74	105,000	11,475
2010	186,500	5,469.17	102,000	31,500	135,000	7,851.85	106,000	12,750
2011	207,000	4,740.58	98,130	31,500	150,000	11,066.67	166,000	14,025
2012	210,000	4,666.67	98,000	31,500	165,000	12,121.21	200,000	13,600
2013	200,000	4,850.00	97,000	31,500	160,000	12,500.00	200,000	12,000

Source: FAOSTat, 2015

*Seed data include the amounts of the commodity in question set aside for sowing or planting (or generally for reproduction purposes, e.g. sugar cane planted, potatoes for seed, eggs for hatching and fish for bait, whether domestically produced or imported) during the reference period. Account is taken of double or successive sowing or planting whenever it occurs. The data of seed include also, when it is the case, the quantities necessary for sowing or planting the area relating to crops harvested green for fodder or for food. (e.g. green peas, green beans, maize for forage) Data for seed element are stored in tonnes (t). Whenever official data were not available, seed figures have been estimated either as a percentage of supply (e.g. eggs for hatching) or by multiplying a seed rate with the area under the crop of the subsequent year (FAOSTAT, 2015).

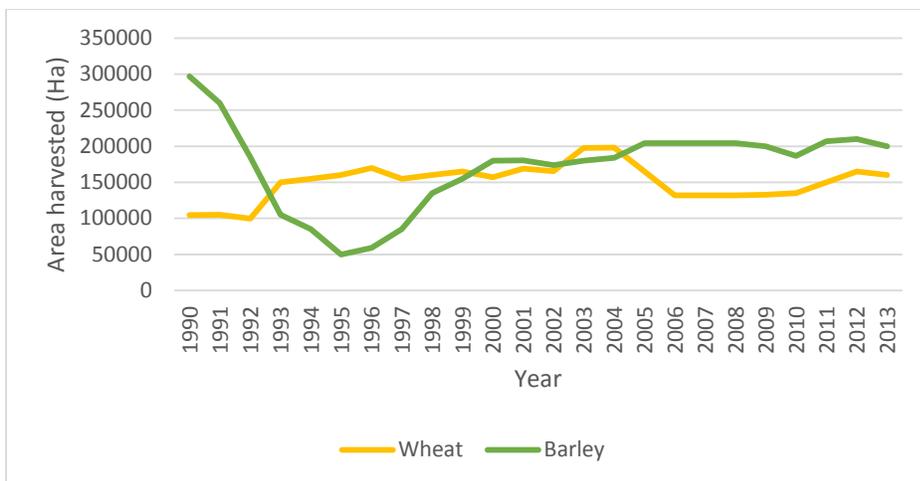


Figure 2.1 Barley and Wheat Area Harvested in Libya, 1990-2013

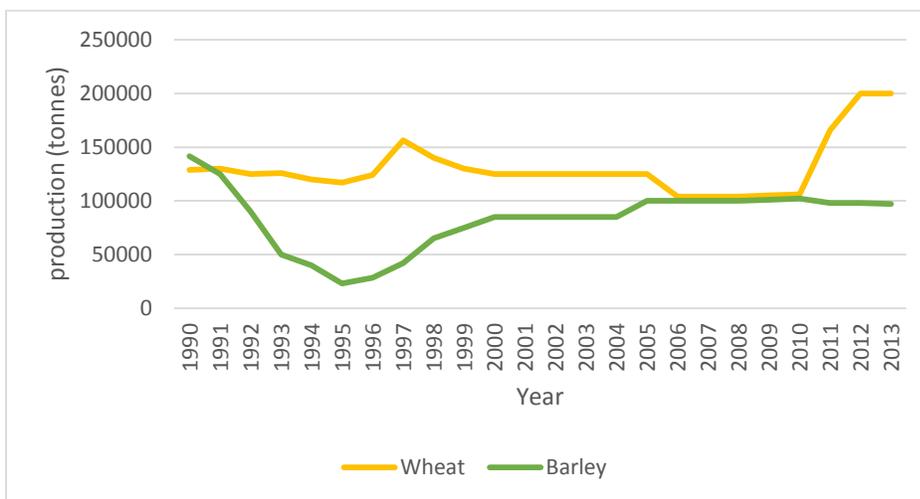


Figure 2.2 Barley and Wheat Production in Libya, 1990-2013

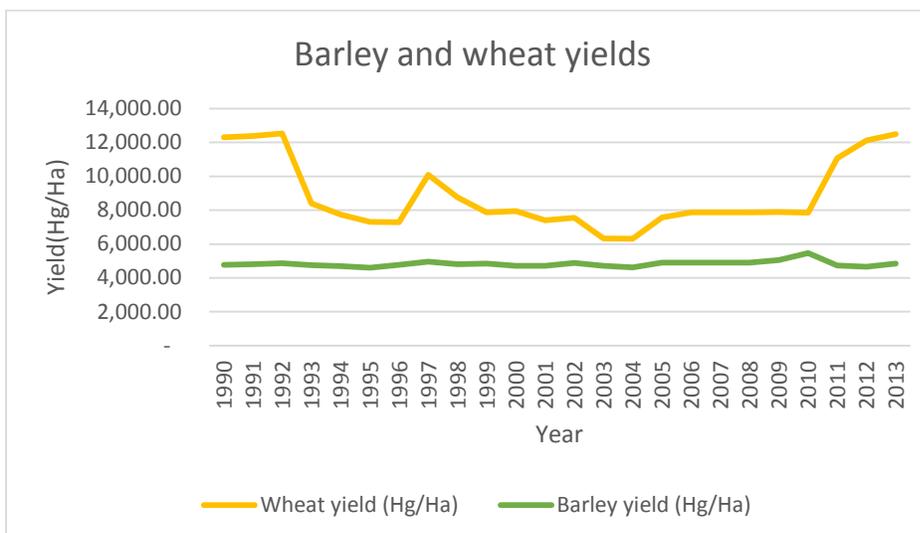


Figure 2.3 Barley and Wheat Yields in Libya, 1990-2013

Table 2.1 Barley and Wheat Import Dependency Ratio (IDR), 1990 to 2012

Year	Barley				Wheat			
	Barley production (tonnes)	Barley imports (tonnes)	Total barley (tonnes)	IDR	Wheat production (tonnes)	Wheat Imports (tonnes)	Total Wheat (tonnes)	IDR
1990	141,476	832,238	973,714	85%	128,760	380,000	508,760	75%
1991	125,000	478,792	603,792	79%	130,000	614,000	744,000	83%
1992	90,000	280,000	370,000	76%	125,000	480,000	605,000	79%
1993	50,000	930,000	980,000	95%	126,000	715,000	841,000	85%
1994	40,000	450,000	490,000	92%	120,000	300,000	420,000	71%
1995	23,000	217,823	240,823	90%	117,000	351,952	468,952	75%
1996	28,200	130,950	159,150	82%	124,000	315,000	439,000	72%
1997	42,100	638,000	680,100	94%	156,400	352,000	508,400	69%
1998	65,000	215,004	280,004	77%	140,000	285,000	425,000	67%
1999	75,000	300,000	375,000	80%	130,000	298,000	428,000	70%
2000	85,000	37,822	122,822	31%	125,000	427,333	552,333	77%
2001	85,000	141,486	226,486	62%	125,000	266,550	391,550	68%
2002	85,000	205,377	290,377	71%	125,000	490,005	615,005	80%
2003	85,000	87,968	172,968	51%	125,000	214,843	339,843	63%
2004	85,000	266,698	351,698	76%	125,000	410,325	535,325	77%
2005	100,000	159,344	259,344	61%	125,000	580,307	705,307	82%
2006	100,000	242,705	342,705	71%	104,000	522,197	626,197	83%
2007	100,000	48,806	148,806	33%	104,000	853,091	957,091	89%
2008	100,000	177,131	277,131	64%	104,000	809,962	913,962	89%
2009	101,000	410,000	511,000	80%	105,000	1,854,814	1,959,814	95%
2010	102,000	472,244	574,244	82%	106,000	1,713,190	1,819,190	94%
2011	98,130	152,889	251,019	61%	166,000	832,051	998,051	83%
2012	98,000	179,413	277,413	65%	200,000	1,623,390	1,823,390	89%

Source: FAOStat, 2015

* Import dependency ratio (IDR) is defined as $\text{imports} \times 100 / (\text{production} + \text{imports} - \text{exports})$. The complement of this ratio to 100 would represent that part of the domestic food supply that has been produced in the country itself. However, there is a caveat to be kept in mind: these ratios hold only if imports are mainly used for domestic utilization and are not re-exported (FAOStat, 2015).

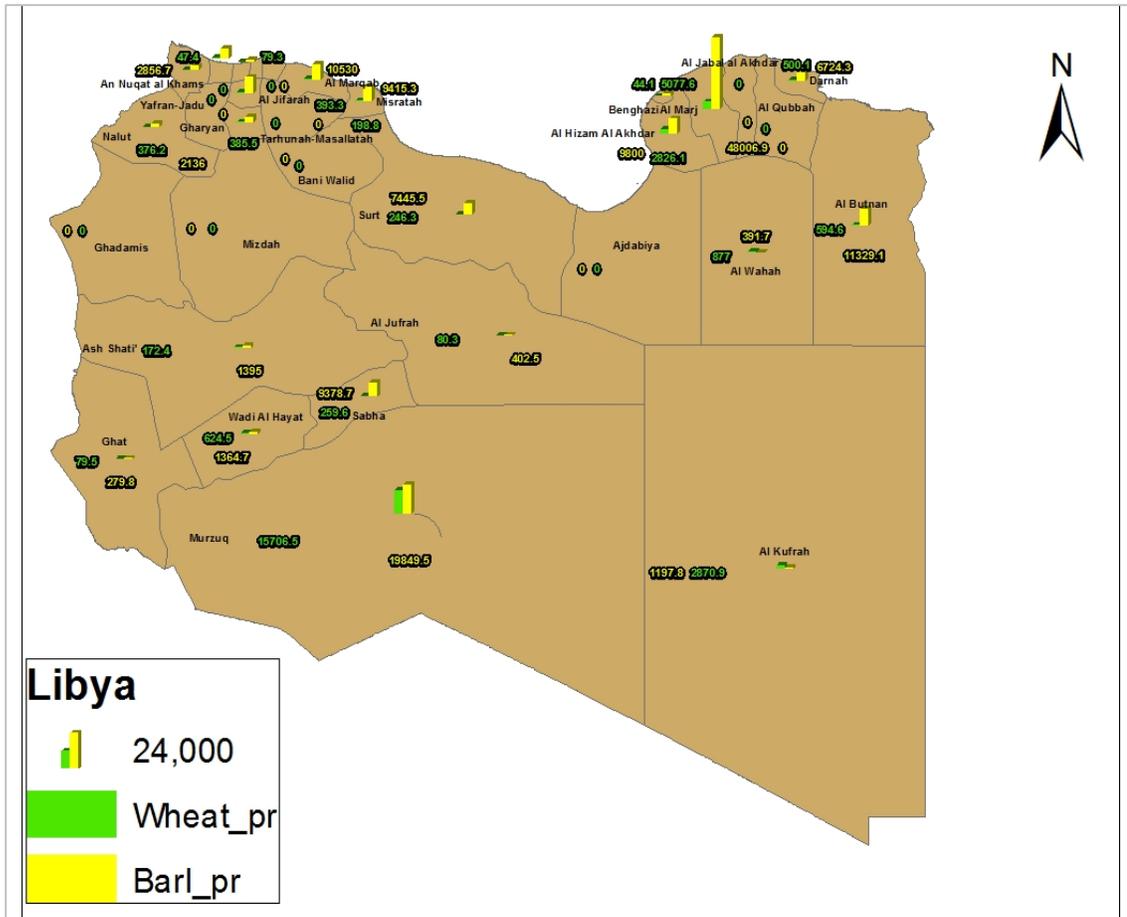


Figure 2.4 Wheat and Barley Cultivation, by Region of Libya, 2007-2008

Globally, due to the Green Revolution varieties, wheat has become a primary crop with remarkable benefits. According to Aggarwal et al. (2008), “Over the last 50 years, area under wheat cultivation has increased from 10 million to 26 million hectares.” Page # Crop yields and irrigation areas (30% to 85% of the total irrigation area) have increased due to increasing irrigation facilities, supporting farmer’s socio-economics, improving seed varieties, and the application of fertilizers (Aggarwal et al., 2008). Even in the more challenging environments of North Africa and the Middle East, wheat productivity has grown.

2.3 Measuring the Yield Gap in Libya

Measurement of yield gap in Libya is found by subtracting or taking the fraction of the actual yield from the potential yield. Actual yield is often measured by a farmer's crop over a particular time and space. Actual yield is the economic yield attained at harvest under standard production conditions. Such data is readily available.

However, potential yield of Libya's grain crops is more elusive. Such measures can be found by three possible means. The first is data from neighboring countries such as Morocco, because of its similar geographic conditions. The second is experimental field data from Libya. . The third option are estimates or simulated yields from global models associating crop productivity with climactic data worldwide.

2.3.1 Comparison with Yields in Neighboring Countries

Libyan yields have been among the lowest in the region (Figure 2.5). Moreover, Libya has apparently not even kept up with the general increase in yields experienced across the region since the late 1990s. Libyan wheat yields have held constant over the last decade and a gap has emerged between Libyan wheat yields and wheat yields of even its closest comparison countries. Today, neighbors such as Tunisia, Algeria, and Morocco have wheat yields that are almost double those in Libya. Comparing Libya to its neighbors generally, it is clear that the other countries benefit from a more stable governmental system, they have not had decades of economic sanctions, they have a more open international trading system, and they also have more usable water. All of these factors contribute to Libya lagging behind.

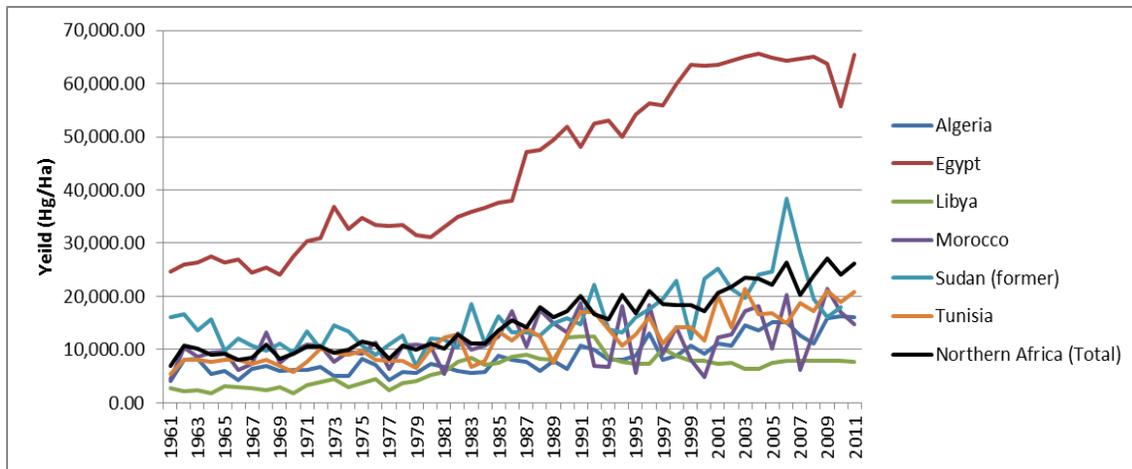


Figure 2.5 Annual Wheat Yields of Northern African Countries and the Region as a Whole, 1961-2011

Data source: FAOSTAT, 2013

2.3.2 Yields on Experimental Fields in Libya

Starting in 2008, a collaborative project was begun between International Center for Agricultural Research in Dry Areas (ICARDA) and ARC to study three important agricultural aspects. The relevant project for this study looked at improved varieties of wheat and barley in rainfall and irrigated system in Libya. They tested several hundred types of wheat and barley under drought conditions and by using saline water in order to find high-yielding strains under these harsh conditions. The project did find a number of strains that yielded under these conditions, but these strains were also potentially susceptible to diseases and may not grow well in wet conditions. The project had three recommendations to strengthen the seed supply system in Libya: Establish a variety foundation seed under ARC, Develop a national variety catalogue, and develop cereal seed growers' schemes in cooperation with NCIS and pilot farmers. Their study indicated that providing financial incentives to private farmers willing to grow and market the seed enhances seed availability to most farmers and eases the pressure on national organizations to provide seed to farmers over the entire country. Yields ranged from a mean of 4.8 to 5 tonnes/Ha for wheat and 3.7tonnes/Ha for barley (ARC Libya-ICARDA Collaborative Program, 2010a).

2.3.3 *Estimated Yields Based on Global Climate Models*

Traditional methods of estimating potential yield are problematic for Libya based on a lack of data. One way that potential yields are estimated is by global climate models based on nonlinear regression analyses within each climate zone in the world (Mueller, Gerber, Johnston, Ray, Ramankutty, & Johnson, 2012). This seems to be the closest way to find potential yields for Libya in order find yield gap. An analysis by Licker (2010) using the same methodology as Mueller et al. shows that if the farmers could reach their climatic potential yield, there would be, for example, 60% more wheat by managing all of the production factors. However, from this analysis it is still not clear if all the farmers could achieve the climatic potential yield by changing their management practices. In some areas, there are massive problems—such social-economic and political obstacles—to achieve the climatic potential yields. Both studies found that areas with the lowest yield gaps were in developed countries or areas with high-input agriculture.

2.4 *Impacts of Seed Quality on Yields in Libya*

Seed is, in a fundamental sense, the primary agricultural input. Seed provides the producing organism, which affects all other inputs such as irrigation, fertilizers, insecticides, etc. With poor seed quality or poor seed genetics, the impact of all other inputs are limited. This means good quality seed is necessary. Physical purity, germinability, genetic purity and seed health are the four components of quality seed (Verma, 2011).

From the literature, we know that low quality seed is a major contributing factor to the low productivity of most agricultural crops in Libya, and a major reason for observed yield gaps. One of the sector priorities is to use highly productive seeds adapted to the local environment. Currently, Libya does not have a well-functioning seed system, and therefore, does not have

assured access to high quality seed. Additionally, most seeds of improved varieties are imported and not bred with Libyan conditions in mind, which may also have an impact. All of Libyan society would directly benefit from a breeding program to select or adapt varieties to Libyan conditions for increased productivity.

Seed certification is another significant agronomic practice that could improve yields, by assuring high quality seeds. Seed certification involves processes of seed quality control by overseeing seed production and multiplication as well as whether the seed reaches certain standards (Verma, 2011). Lack of quality seed certification is another problem in Libya.

It is expected that better seeds would make a significant contribution to decrease the yield gap in Libya. However, specific studies about Libyan seed quality and impacts of crop variety choice on yield are unavailable.

2.5 Discussion and Conclusions: Farmers' Choices of Crop Variety in Closing the Yield Gap

Providing a technology with potential to increase yield is one question, but whether or not the farmer will use that technology is another matter. The farmer's acceptance of the technology is vital for its successful implementation.

Griliches (1960) discussed the factors around the rate at which a hybrid corn seed was accepted and used in U.S agriculture. He observed that adoption timing depends on when the technology becomes available (date of availability), which is dependent on the activities of seed producers (market density and cost of entry), which in turn base their activities on the expected profits and contributions of experimental stations (rates of acceptance). In addition, Griliches (1960) argued that adoption of a hybrid seed also depends on farmers' expected profit, in terms of both the profitability per farm and per acre. Higher yielding hybrid corn was found to be more

profitable in *good* areas than in *poor* areas, largely because the *good* areas had better land and water resources, enabling yield gains and thus returns to be more readily realized. Griliches (1960) reasoned that the introduction of innovations may lead to an increased gap between the good regions and poor regions since the good regions have greater incentives to be early adopters of new technology.

This highlights the importance of the concept of *cost of entry* and how it differs among regions. Cost of entry is specifically important to the cost of research, development, marketing, distribution, and other factors into the cost of introducing a new crop variety. As hybrid corn was expected to spread more quickly in the *good areas* with high productivity and growth, breeders were more likely to focus on developing varieties for these regions. Smale, Hartell, Heisey, and Senauer (1998) also looked at the genealogical dissimilarity of wheat varieties and highlighted the pattern that farmers often choose varieties with high economic values, which allows the researchers to understand the unobservable genetic characteristics.

Heisey, Smale, Byerlee, and Souza (1997) found that when a trade-off is presented between resistance to disease and yield, some farmers will opt to under-produce in order to maintain resistance to disease and minimize losses. However, the benefit of higher yield, is leads most farmers to grow the more susceptible strain. Farmers may continue to grow higher yielding varieties that are not recommended despite their greater susceptibility to disease due to the perceived individual cost of switching to a more diverse field of recommended varieties. Farmers chose to grow only the highest yielding variety over those that would be more resistant to disease. Farmers also ignored what varieties the farmers around them were using in their fields. This ignoring of fellow farmer choices as well as recommended strains caused overall

lower genetic diversity in the region at the expense of optimizing protection against new strains of rust.

Smale (2000) discusses collaborative plant breeding (CPB), which uses skills and experience of both farmers-breeders and professional plant breeders to improve crop varieties for a given region. How much the farmer and professional breeders engage in the plant breeding effort depends on many factors, such as the types of characteristics that need improvement, existing choice of varieties, and 'intra-population' selection practices (to pick which types of seeds to use to improve the crop). The long term goals of CPB depend on who participates. Some have proposed to support on-farm conservation by linking agricultural subsidies with the diversity of crop genetic resources.

There are arguments for the approach that participatory breeding can support the maintenance of more diverse, locally-adapted plant populations. The biological truth of this proposition still needs to be tested. For economists, a fundamental question surrounding the issue is whether the efforts will be cost effective for farmers. Examining this question requires the investigation of issues such as the effectiveness of farmers' methods of seed selection and management, the nature of the seed supply systems to help the benefits of improved varieties spread among farmers, and farmer's own perceptions of what goals can be attained through choice of variety. A better understanding of what farmers know and what they base their decisions on is critical.

3 Availability and Adoption of Improved Wheat and Barley Varieties: A Survey of Grain Farmers in Libya

3.1 Introduction

Despite regime change in Libya in 2011, continued demand from a growing urban population is posing greater challenges to agriculture. Small grains farming makes up the largest share of Libya's agricultural sector, and yet more than three quarters of grain consumed by the population must be imported. Improved yield and drought tolerance are essential for Libyan grain farming to remain viable and sustainable. Central to such improvements are the varieties of wheat being grown by Libyan farmers. Under the previous government little attention was given to improvement of the seed system in Libya. Little is known about the crop variety decisions being made by grain farmers in Libya.

To understand what varieties are being grown in Libya and set a benchmark against which future analyses can be measured, a survey was conducted of a random sample of Libyan small grain farmers to determine the following questions: What factors influence and/or are associated with farmers' adoption of improved wheat and barley varieties? Why do farmers grow wheat and barley instead of growing other crops? By description of the wheat and barley varieties, which wheat and barley varieties? Where do farmers get these varieties? Why do they grow those varieties? Why do farmers' prefer those varieties? Do farmers save seed? If so, which farmers save seed? What are the characteristics of these farmers?

This survey of Libyan grain farmers was conducted to investigate farmers' decisions involving seed quality, improved variety adoption, and their relationship to other farming practices. Collectively, the results help to determine productivity and yield gap, and contribute to

the objectives of this study, which are to examine the factors that influence farmers' adoption of improved wheat and barley varieties. This chapter includes three main sections: first, a description of the design and administration of a survey of Libyan small grain farmers; second, a descriptive summary of the survey results; and third analysis of which factors are associated with adoption of improved wheat and barley seed varieties by Libyan small grain farmers.

3.2 Survey Design and Administration

The purpose of this survey was to develop a better understanding of the wheat and barley seed system in Libya, including how farmers choose their wheat and barley seed varieties, and in turn, how those seed varieties perform in Libyan agriculture. The results of this survey can be utilized in informing future efforts to improve the seeds system in Libya and to recommend ways to provide better crop genetics to Libyan farmers.

This survey was prepared by the research team overseen by Dr. Gregory Graff at Colorado State University. It was reviewed and approved by the Institutional Review Board (IRB) at Colorado State University before being sent to Dr. Ali Arhama, professor of Agricultural Economics at the University of Tripoli, Libya. The survey included an informational cover letter and survey questions in both Arabic and English. The survey questions were organized into ten sections: socio-demographics, land, farm labor, marketing, seed, mechanical use, irrigation, fertilizer, pesticide, and government support. The survey was administered in Libya by Dr. Ali Arhama, of the University of Tripoli, who is also Director of the General Authority for Cereal Production at the Ministry of Agriculture in Tripoli. The target sample size, covering both barley and wheat growers, was 181. The sampling distribution was determined from the 2007 Agricultural Census (Commission on Public Information Libya, 2007) and the Commission on Public Information regarding where wheat and barley is grown across Libya.

Dr. Arhama distributed the survey to the western, southern, and eastern parts of Libya in May 2014. He also sent the survey to Dr. Naser El-Msalati, professor of Agricultural Economics at the Omar Al-Mukhtar University, in Bayda, Libya, who helped Dr. Arhama distribute surveys across the eastern regions of Libya. Dr. El-Msalati asked his students to interview farmers growing wheat and/or barley. Furthermore, Dr. Arhama sent agronomists to meet farmers in the southern and western regions.

The administration of the survey took longer than expected due to the heightened national security situation in Libya in 2014. In June, he concluded the survey in the east and the south, but it was very difficult to collect surveys from the western regions around Tripoli, due to ongoing civil war violence. Therefore, the total responses collected were from 136 farmers from eastern and southern Libya. Returning the surveys to the United States was also a significant challenge due to the siege of the Tripoli international airport in summer of 2014. They were received in September 2014. Once received, the data was entered into Excel and transferred to SPSS for analysis.

The surveys were sent to twelve different regions in Libya. Results came from: 46 farmers in Al Marj (33.8%), 45 farmers in Marzuq (33.1%), 12 farmers in Sabha (8.8 percent), 12 farmers in Jabail Akhdar (8.8 percent), 11 farmers in Tubruq (8.1 percent), and 10 farmers in Derna (7.4 percent). Surveys were also sent to 45 farmers in the western regions of Libya (including Zawiya, Sirte, Misurata, and Murgub); however, no surveys were collected from the western regions because it was too dangerous to ask anyone to travel there because of continued instability and violence following the ousting of Gadhafi (Table 3.1).

Table 3.1 Numbers of Wheat and Barley Farmers Surveyed, by Region

Location of Farmers	Number of farmers targeted for survey	Number of farmers responding	Percentage of total farmers responding
Marzuq (South)	45	45	33.1
Sabha (South)	12	12	8.8
Derna (East)	10	10	7.4
Al Marj (East)	46	46	33.8
Jabail Akhdar (East)	12	12	8.8
Tubruq (East)	11	11	8.1
Zawiya (West)	10	0	0
Sirte (West)	10	0	0
Misurata (West)	12	0	0
Murgub (West)	13	0	0
Total	181	136	100

Table 3.2 Numbers of Wheat and Barley Farmers Responding, by Crop and Region

Location of Farmers	Total farmers responding	Number that grow wheat	Number that grow barley	Number of farmers that grow both
Marzuq (South)	45	29	25	9
Sabha (South)	12	0	12	0
Derna (East)	10	3	7	0
Al Marj (East)	46	0	46	0
Jabail Akhdar (East)	12	3	9	0
Tubruq (East)	11	0	11	0
Total	136	35	110	9

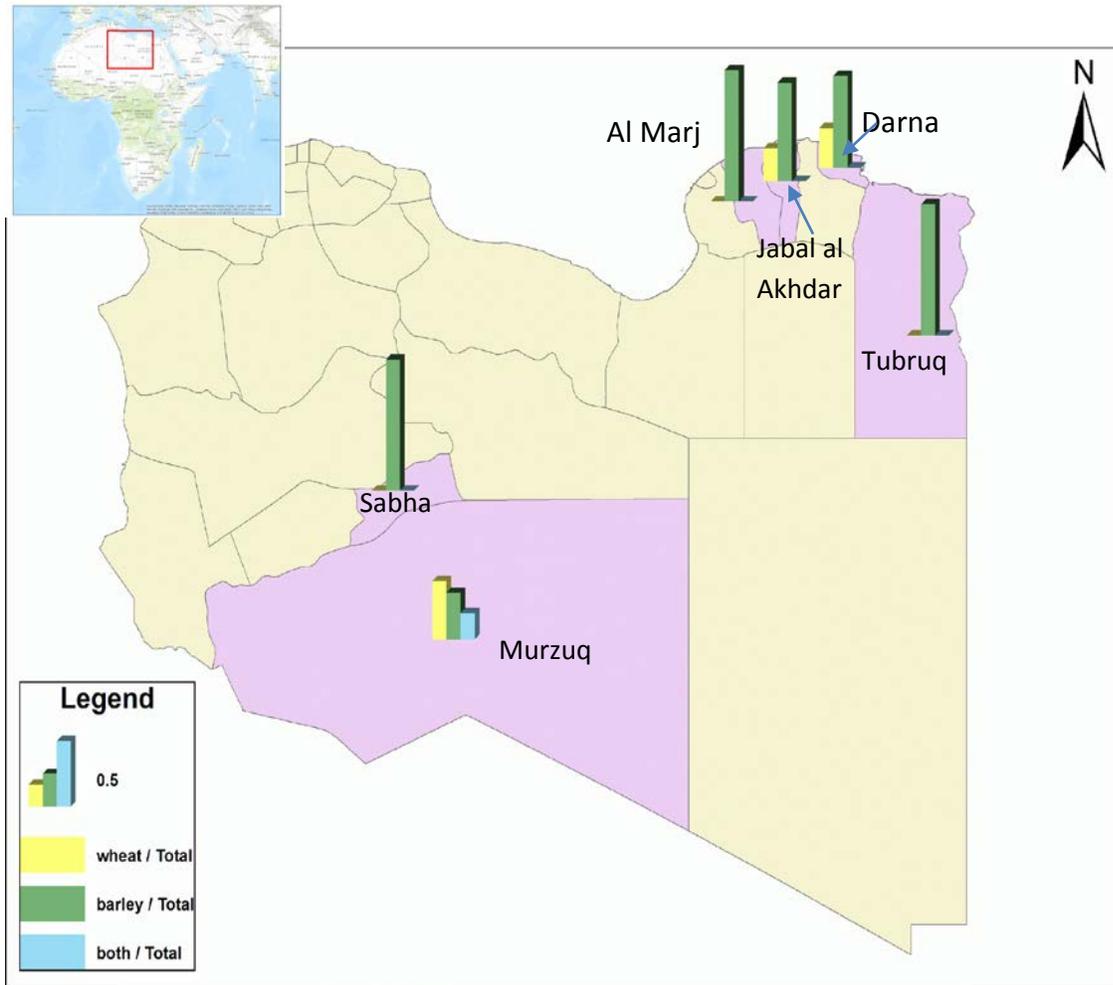


Figure 3.1 Wheat and Barley Farms Responding to the Survey (by percentage that grow wheat, barley, and both within each major region)

3.3 Farmer and Farm Characteristics

3.3.1 Farmers' Socio-Demographic Characteristics

Farmers' characteristics included: gender, household size, age, education, income and experience. Discovering these characteristics helped to better understand the farmers who were growing wheat and/or barley in Libya, to learn how farmers choose their wheat and barley seed varieties and how those seed varieties perform in Libyan agriculture. The survey respondents

totaled 136 and all farmers were male. While there is no law that women cannot be farmers in Libya, traditional cultural and religious gender norms prevent women from farming.

Farmers were asked how many people live in their household. Over half of the respondents (n = 73; 54%) said that the highest number of people who live together in their household was six to eight. Thirty-eight farmers (28%) said there were nine or more living in their household. Seventeen farmers (13%) had four to five people living together. While only eight farmers (six percent) had from one to three people living in the household. These results show that typical farming households are large, with 82% of responding households containing at least six people. A majority of the large households grew barley instead of wheat (65%).

Farmers were asked about the age of the primary farm operator. The highest group percentage was between 51 and 60 years of age; 55 farmers were in this category (40%). The next largest group was aged 61 or older (n = 44; 32%). Farmers between 41 and 50 years old had 24 respondents (18%). Eight of the farmers (four percent) were under 30 years old. The smallest group was between 31 and 40 years old (n = 7; 5 percent). These results show that 72.1% of farmers were over 50 years old; these demographics are considerably different from the country as a whole, which is predominantly younger. Older farmers (more than 40 years old) predominately grew barley rather than wheat (91%).

Farmers were asked about their years of farming experience. As might be expected based on the previous question of age, 104 (76%) of the respondents reported over ten years of farming experience. While 25 farmers (18%) said their experience was between five and ten years. Only seven farmers (five percent) stated their farming experience was less than five years. These results further show that older and experienced people farm in Libya, while there are few

young farmers, particularly compared to the general demographics of the country. Most (81%) farmers with more than ten years of experience grew barley instead of wheat.

Farmers were asked about their highest education level. The largest group consisted of 50 farmers (37%) who were college graduates. Three farmers (two percent) stated they held a post-graduate degree. However, about 67% of the farmers had a high school diploma or less. Forty-one farmers (30%) had some high school education, while 27 farmers (20%) graduated high school, and 15 farmers had no formal education (11%). None of the farmers stated they have some college or university education (0 percent).

Based on these results, it becomes clear that farming is predominately done by large households, with the primary farmer being over age 50, and with limited education. These results also indicate that barley is more popular to grow than wheat for these farmers.

Farmers were asked if any of their income came from other crops or livestock other than wheat or barley. About 90% (n = 123) said they had other income, while the rest said they did not have additional income sources. Table 3.3 shows these results.

Table 3.3 Income Sources

Do you have income from production and sales of any other crops or livestock besides wheat and/or barley?	Yes	No
Number of Farmers Responding	123	13
Percentage of Farmers Responding	90.4%	9.6%

This question was broken down further to explore these other income sources. Of the farmers with additional income, 107 farmers (78.7%) reported that they sold cattle. The remaining farmers sold some other types of crops. Table 3.4 shows the breakdown of these other crops.

Nearly 90% of respondents had off-farm income in their households, while only 10% reported no other income (Table 3.5).

Table 3.4 Other Crops Grown on Farm, As Indicator of Degree of Specialization or Diversification

Other Crops grown on Farm	Farmers with this Crop	Percentage of Farmers Responding
Cattle	107	78.7%
Grapes	28	20.6%
Tomatoes	19	14.0%
Dates	18	13.2%
Oranges	12	8.8%
Apples	11	8.1%
Potatoes	8	5.9%
Olives	7	5.1%
Maize	3	2.2%
No other crops grown	13	9.6%

Table 3.5 Off-Farm Income

Do you and/or any other member of your household have sources of <i>off-farm</i> income?	Yes	No
Number of Farmers Responding	122	14
Percentage of Farmers Responding	89.7%	10.3%

Among the farmers with off-farm income in their households, 80 (58.8%) reported that the source of income was from working in government services. Twenty-six farmers' households (19.1%) earned income as teachers. Eight farmers' had members of the household that were employees in a company (5.9 percent). Four farmers (2.9 percent) were drivers or equipment operators. Two farmers (1.5 percent) stated their off-farm income was from a family member working in a bank. Another two farmers (1.5 percent) had a family member working as a mechanic, carpenter, electrician, plumber, or other skilled trade. No farmers worked for neighbor's farms. Table 3.6 shows the results for this question.

Table 3.6 Sources of Off-Farm Income

Source of Off-Farm Income	Number of Farmers Responding	Percentage of Farmers Responding
Government service	80	58.8%
Teacher	26	19.1%
Employee in company	8	5.9%
Driver or equipment operator	4	2.9%
Employee in bank or financial	2	1.5%
Trades (mechanic, electrician, etc.)	2	1.5%
Service to neighboring farms	0	0%

3.3.2 Farm Land

Farmers were asked about the size of their farms. The most common farm size was five to twenty hectares (ha), with 65 farmers reporting this size (47.8%). The next most frequent was the smallest size, between one and five ha, with 25 farmers (18.4%). 34 farmers reported their farm was between twenty and 100 ha (25%), while twelve farmers reported they planted grain in a farm size of more than 100 hectares (8.8 percent) (Table 3.7).

Table 3.7 Farm Size

Farm size in hectares	1-5 Ha	5-20 Ha	20-100 Ha	More than 100 Ha
Number of Farmers Responding	25	65	34	12
Percentage of Farmers Responding	18.4%	47.8%	25.0%	8.8%

Farmers were asked about the ownership of the land that they farmed. Nearly 90% (122 farmers) reported that they owned the land they farm. An additional thirteen respondents farmed on land that they both owned and either leased or rented (9.6 percent). Only one farmer reported that he leased or rented all the land he farms (0.37 percent). These results are shown in Table 3.8.

Farmers were asked about how much of their land was planted in either wheat or barley. Twenty-one farmers (15.4%) reported that they planted from one to five ha in wheat; Twelve farmers planted five to 20 ha (8.8 percent) and 2 farmers planted twenty to 100 ha (1.5 percent). For barley, 51 farmers reported that they planted from one to five ha

(37.5%); 37 farmers planted five to twenty ha (27.2%); 21 farmers planted twenty to 100 ha (15.4%); and one farmer stated that he planted more than 100 ha in barley (0.7 percent). Table 3.9 shows these results.

Table 3.8 Ownership of Land

Ownership of the land that you farm?	I farm only land that I own.	I farm only land that I lease or rent.	I farm both land that I own and land that I lease or rent.
Number of Farmers Responding	122	1	13
Percentage of Farmers Responding	89.7%	0.4%	9.6%

Table 3.9 Area of Land Planted to Wheat or Barley

Area planted in wheat or barley	Land in Wheat (Ha)				Land in Barley (Ha)			
	1-5	5-20	20-100	More than 100	1-5	5-20	20-100	More than 100
Number of Farmers Responding	21	12	2	0	51	37	21	1
Percentage of Farmers Responding	15.4%	8.8%	1.5%	0%	37.5%	27.2%	15.4%	0.7%

3.3.3 Farm Labor

Farmers were asked about how many other people work on their farms. Of the respondents, 53 (39%) reported that they have one to three farm operators or farm workers, including paid family members, who are full-time or permanently employed on the farm. Meanwhile, nine farmers (6.6 percent) said they employ more than three workers, while eleven

farmers (8.1 percent) said they had no full-time or permanent workers. Regarding part-time or seasonal workers, 48 farmers employ one to three workers (35.3%), 26 farmers have more than three seasonal workers (19.1%), and twelve farmers reported they have no part-time workers (8.8 percent). These results are shown in Table 3.10.

Table 3.10 Additional Workers on Farms

How many farm operators of farm workers, including paid family members?	Full Time or Permanent Workers			Part Time or Seasonal Workers		
	None	1-3	More than 3	None	1-3	More than 3
Number of Farmers Responding	11	53	9	12	48	26
Percentage of Farmers Responding	8.1%	39.0%	6.6%	8.8%	35.3%	19.1%

Farmers were asked if they felt it was difficult to find labor for their farms. The majority (101 farmers; 74.3%) stated they had problems finding or hiring sufficient workers for their farms, while 35 farmers (25.7%) did not have any problems finding or hiring sufficient workers.

Table 3.11 shows these results.

Table 3.11 Difficulty in Finding or Hiring Farm Workers

Do you have any problems finding or hiring sufficient workers for your farm?	Yes	No
Number of Farmers Responding	101	35
Percentage of Farmers Responding	74.3%	25.7%

Among the farmers who had difficulty in finding workers, 65 stated the problem was their dependence on expatriate or foreign labor (47.8%), which is unstable. Another 46 farmers said there is a lack of experienced operators or laborers in their area (33.8%). High wages were blamed by another 35 farmers (25.7%). Results are shown in Table 3.12.

Table 3.12 Reasons for Difficulty in Finding or Hiring Farm Workers

What are the reasons for difficulty finding or hiring sufficient workers for your farm?	Lack of experienced operators or laborers in my area	High wages	Dependence on foreign labor, which is unstable
Number of Farmers Responding	46	35	65
Percentage of Farmers Responding	33.8%	25.7%	47.8%

3.3.4 Mechanical Technology

Farmers were asked about the number and size of machinery used on their farms. The majority (88 farmers; 64.7%) reported that they use one tractor or piece of farm equipment. One farmer reported that he uses five tractors or pieces of farm equipment (0.74 percent) and one other farmer reported using six (0.74 percent). However, it appears that not all of the respondents understood this question, as 18 farmers seemed to think the survey was asking if they owned the equipment. They reported that they do not use any tractors or pieces of farm equipment because they rent the equipment, which was not the interpretation intended by the question. There are 48

farmers reported that the horsepower (HP) of the largest tractor engine they owned was 50-99 HP and just 8 farmers stated 200-299 HP.

3.3.5 Irrigation

Farmers were asked about rainfall levels on their farms. The average annual rainfall for the individual farms for 136 farmers was 3,498mm, which includes the farmers who reported zero rainfall for their farms in the southern part of Libya. A majority (88 farmers; 64.7%) said they use irrigation for growing their wheat and/or barley, while 48 farmers said they do not use irrigation because they rely solely on rainfall (35.3%). This is shown in Table 3.13.

Of the 88 farmers who reported using irrigation, all of them used a sprinkler system (64.7% of total *n*). All 88 of these farmers used underground well water as the source of their irrigation water (64.7%). Seventy-nine of these farmers (58.1%) used on-farm (private) pumped wells as their well water source, while seven farmers (5.1 percent)

Table 3.13 Use of Irrigation

Do you use irrigation for growing your wheat and or barley?	Yes	No
Number of Farmers Responding	88	48
Percentage of Farmers Responding	64.7%	35.3%

used local community pumped wells as their well water source. Table 3.14 below shows that 48 farmers have rainfall and 57 farmers use irrigation in their farms, likewise, 31 farmers have rainfall and irrigation to grow their crops.

Table 3.14 Cross Relationship between Rainfall and Irrigation

		Use Irrigation		Total
		No	Yes	
Rain	No	0	57	57
	Yes	48	31	79
Total		48	88	136

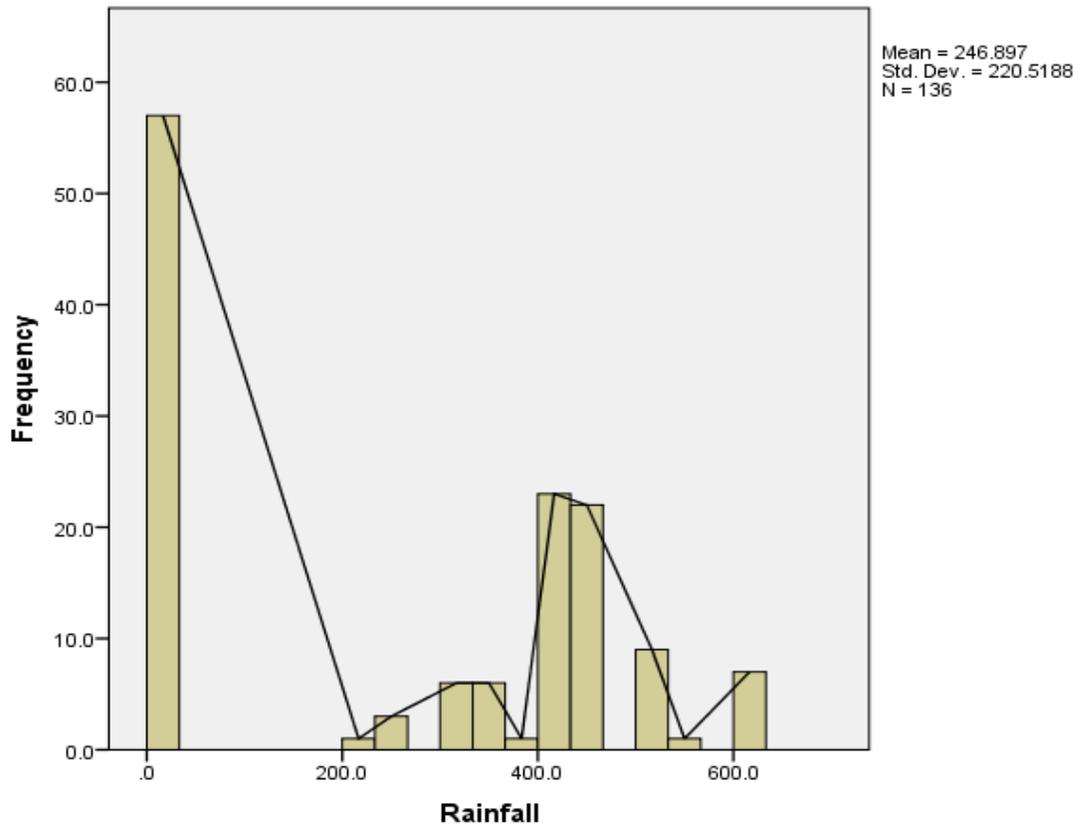


Figure 3.2 Frequency Distribution of Rainfall on Farms of Survey Respondents

3.3.6 Fertilizer Use

Farmers were asked about how much fertilizer they use on their farms. The most common answer, by 43 farmers (31.6%), was that they do not use any fertilizer on their wheat and/or barley crops. Forty farmers said they use more than 100 kg/ha (29.4%). Twenty-nine farmers used 50-100 kg/ha (21.3%). Twenty-four farmers stated that they use 0-50 kg/ha fertilizer on their wheat and/or barley crops (17.7%). These results are shown in Table 3.15.

Table 3.15 Fertilizer Use

Total fertilizer applied during growing season (kg/ha)	Number of Farmers Responding	Percentage of Farmers Responding
None	43	31.6%
0-50	24	17.7%
50-100	29	21.3%
Over 100	40	29.4%

Of the 93 farmers who use fertilizer, 91 stated that cost is the greatest factor influencing how much fertilizer they use (97.8). Forty-four farmers said that their past experiences with productivity/yield gains influenced their use (47.3%). Twenty-nine farmers stated that they followed the recommended fertilizer application rates or regulations for soil type and needs (31.2%). Table 3.16 shows these results.

Table 3.16 Factors that Influence Fertilizer Use

Factors influence Fertilizer use	Number of Farmers Responding	Percentage of Farmers Responding
Cost	91	97.8%
Past experiences	44	47.3%
Regulations	29	31.2%

The vast majority (123 farmers; 90.4%) reported that they had a positive experience with fertilizer use, as it helped production. Only seven farmers remained neutral or said that they did not know (5.2%), while six farmers said they had a negative experience with fertilizer use, as it had impacts on the water or soil quality or the farmer’s health (4.4 percent). These results are shown in Table 3.17.

Table 3.17 Experience with Fertilizer Use

Describe experience with fertilizer use?	Number of Farmers Responding	Percentage of Farmers Responding
Positive	123	90.4%
Don't know/neutral	7	5.2%
Negative	6	4.4%

3.3.7 Pesticide Use

The farmers were asked about their pesticide use. A majority (85 farmers; 62.5%) reported that they do not use any form of pesticide for growing wheat and/or barley, while 51 farmers stated they use some form of pesticide (37.5%). This result is shown in Table 3.18.

Table 3.18 Pesticide Use

Do you use any form of pesticide for growing wheat and/or barley?	Yes	No
Number of Farmers Responding	85	51
Percentage of Farmers Responding	51.0%	37.5%

The influencing factors for why these farmers did not use pesticides were: costs (57 farmers; 41.9%) and past experiences with productivity/yield gains (29 farmers; 21.3%). The other 51 farmers stated they use some form of pesticide, such as insecticide, fungicide, and/or herbicide (37.5%). (See Table 3.19.)

Table 3.19 Factors Influencing Pesticide Use

Factors influence fertilizer use	Number of Farmers Responding	Percentage of Farmers Responding
Cost	57	67.1%
Past experiences	29	34.1%
Regulations	51	60.0%

Farmers were asked about their experiences using pesticides. Even though a majority reported that they did not use them, still, a majority (88 farmers; 64.7%) reported a positive experience with pesticides and said that pesticides helped production. Meanwhile, 52 farmers stated they had a negative experience, because of the pesticide's impacts on soil and water quality or on the farmer's health (38.2 %). Three farmers did not know or were neutral about their experiences with pesticides (2.2 percent). These results are shown in Table 3.20.

Table 3.20 Experience Using Pesticides

Describes experience with fertilizer use?	Number of Farmers Responding	Percentage of Farmers Responding
Positive	88	64.7%
Don't know/neutral	3	2.2%
Negative	52	38.2%

3.3.8 Government Support

The vast majority (123 farmers; 90.4%) reported that they do not receive subsidies from the government related to growing wheat or barley. (See Table 3.21.)

Table 3.21 Government Subsidies for Growing Wheat/Barley

Do you receive subsidies from government related to growing wheat or and barley?	Yes	No
Number of Farmers Responding	13	123
Percentage of Farmers Responding	9.6%	90.4%

The 13 farmers (9.6 percent) who stated they receive subsidies from the government such as free or subsidized (lower) price of inputs were asked about this subsidy. Twelve of these farmers (8.8 percent of total) said they have free or subsidized (lower) price of seed. Two of these thirteen farmers (1.5 percent) receive free or subsidized (lower) price of fertilizer. One of these thirteen farmers (0.74 percent) receives free or subsidized (lower) cost of irrigation water. Note that one farmer gave two answers to this question. These results are shown in Table 3.22.

Table 3.22 Type of Subsidies Provided by Government

Type of subsidies from the government related to growing wheat and or barley?	Number of Farmers Responding	Percentage of Farmers Responding
(Lower) price of seed	12	9.8%
(Lower) price of fertilizer	2	1.6%
(Lower) Cost of irrigation	1	0.8%
Guaranteed (higher) prices	0	0%
Purchase of equipment	0	0%
Direct subsidies to farmers	0	0%

3.3.9 Marketing

Farmers were asked about how they use their crops and how they earn money for their crops if they are sold. The majority (117 farmers; 86.0%) reported that they sell their wheat and/or barley harvests at local or regional farmer sikh wages were blamed by a farmers; 59.6%) save some as seed for the next year or keep seed for their own household consumption (55 farmers; 40.4%). Meanwhile, 35 farmers (25.7%) sell to a private (non-government) grain merchant or Food Company. Four farmers (2.9 percent) exchange with other farmers for goods, services, or labor. Only one farmer stated that he sells his harvest to The Seed Center (0.7 percent). Table 3.23 shows these results.

Table 3.23 What Farmers Do with Their Grain Harvests

What do you do with your wheat and/or barley harvests?	Keep for our own household use	Save some as seed	Sell at farmers' market	Exchange with other farmers	Sell to the Seed Center	Sell to a private broker
Number of Farmers Responding	55	81	117	4	1	35
Percentage of Farmers Responding	40.4%	59.6%	86.0%	2.9%	0.7%	25.7%

Farmers were asked about how easy it is to sell their crops in the past year. A majority (82 farmers; 60.1%) reported that they have problems in trying to sell or were unable to sell some of their wheat and/or barley crops. Another 54 farmers (39.7%) stated they did not have problems selling their crops. (See Table 3.24.)

Table 3.24 Difficulty in Selling Harvest

Did you have problems in trying to sell wheat/barley?	Yes	No
Number of Farmers Responding	82	54
Percentage of Farmers Responding	60.1%	39.7%

Farmers that did report problems were asked what those problems were. The most common reason cited, by 55 farmers (40.4%), was low market prices or competition with grain imports from abroad. Thirty-nine farmers (28.7%) said it was from high costs of transporting the grain, and 18 farmers reported losses during transport or storage (13.2%). Meanwhile, eight farmers stated a lack of a truck or necessary equipment to transport the grain (5.9 percent), and six farmers (4.4 percent) stated the problem for them was a lack of a formal market within a reasonable distance. These results are shown in Table 3.25.

Table 3.25 Reasons for Difficulty in Selling Harvest

Reason for problems selling wheat/barley?	Number of Farmers Responding	Percentage of Total Farmers
High costs of transporting grain	39	28.7%
Lacking truck or necessary equipment to transport grain	8	5.9%
Losses during transport or storage	18	13.2%
Low market prices or competition with grain imports from abroad	55	40.4%
Lack of formal market nearby	6	4.4%

The farmers sold their wheat for an average price of 528.27 Libyan Dinar (about US\$400) per ton for the 2013 season. Table 3.26 shows the further breakdown of this question according to responses.

Table 3.26 Price Received for Wheat in 2013

Selling Price of Wheat for 2013 Season (in Dinar per ton)	Number of Farmers Responding	Percentage of Farmers Responding
Less than 200	7	5.1
200-300	3	2.2
300-400	4	2.9
400-500	16	11.7
500-600	9	6.6
Over 600	11	8.1

Meanwhile, the farmers sold their barley for an average price of 382.15 Libyan Dinar (about US\$290) per ton for the 2013 season. Table 3.27 shows the further breakdown of this question according to responses.

Table 3.27 Price Received for Barley in 2013

Selling Price of Barley for 2013 Season (in Dinar per ton)	Number of Farmers Responding	Percentage of Farmers Responding
Less than 200	13	9.6
200-300	20	14.7
300-400	22	16.2
400-500	35	25.7
500-600	15	11
Over 600	1	0.74

3.4 Identified Wheat and Barley Varieties Grown in Libya

According to the farmer survey responses, there are a number of different varieties of wheat and barley grown in Libya today. The most commonly grown varieties of hard or Durum wheat in Libya, identified in this survey, are Karim, Marjawi, and Fazan. The most commonly grown variety of soft or bread type wheat grown in Libya is Salambo. The most common varieties of barley grown in Libya, identified in this survey, are Barjoui, Rihan, as well as a variety of local (in Arabic “*mahale*”) varieties.

Table 3.28 Wheat Varieties Identified in the Survey as Being Grown in Libya: Including Number of Farmers and Reported Area

Variety of Wheat	Number of Farmers	Reported Number of Hectares (not all farmers answered this question)
Karim	11	53 Ha
Salambo	15	117 Ha
Marjawi	5	45 Ha
Fazan	4	3 Ha
Khurais	1	1 Ha
Sedi Al mussri	1	1 Ha
Total Improved	37	220 Ha
Total Local (<i>mahale</i>)	5	15 Ha

Table 3.29 Barley Varieties Identified in the Survey as Being Grown in Libya, Including Number of Farmers and Reported Area

Variety of Barley	Number of Farmers	Reported Number of Hectares (not all farmers answered this question)
Barjouj	31	341 Ha
Rihan	37	146 Ha
Other varieties	15	57 Ha
Total Improved	83	544 Ha
Total Local (<i>mahale</i>)	64	478 Ha

3.4.1 Varieties of Wheat Grown in Libya

Durum wheat (*Triticum turgidum* L. var. durum). Per Al-Jibouri (1966,) “The durum wheat, *Triticum durum*, is predominantly cultivated in the heavy clayey soils of the plateau where the growing season is longer” (p. 1).

3.4.1.1 Karim

Karim is a variety of durum (hard) wheat that was bred and first released in Tunisia in 1985, according to Genetic Resources Information System for Wheat and Triticale (GRIS). Due to its adaptability and high productivity, Karim was released in Libya five years later (1990) where the climate and environment are similar to Tunisia, according to the CIMMYT (International Maize and Wheat Improvement Center) (Wheat Atlas, 2015. (<http://wheatatlas.org/country/varieties>).

Karim has a light-colored, medium-sized grain. One thousand seeds weigh 49 grams. The variety has average branching and a hypocotyl that is strong enough to withstand high wind velocities. Karim resists lodging and powdery mildew and shows average resistance to black and

yellow leaf rusts in addition to septoria. This seed variety is best used in areas where permanent irrigation, supplemental irrigation, or rainfall is consistent. In Libya, it is planted in November during the rainy season and matures in the spring for harvest when soil moisture and the climate best support it. On average, it takes 135 days to reach maturity. Yield is high, averaging, 5,000 kg/Ha in areas that are irrigated or have consistent rainfall. In areas where irrigation or rainfall is inconsistent productivity falls dramatically to an average of 600 kg/Ha. (Arhama, 2015a).(General Authority for cereal production, Committee for seed registration, Tripoli Libya, 2015). It is mostly grown in southwest Libya by farms in the major irrigated projects (Arhama, 2013)

3.4.1.2 Marjawi

Marjawi is a variety of durum (hard) wheat developed by CIMMYT. The overall focus of CIMMYT's durum section is to increase yields in developing countries, ultimately supporting food security. Their objective is to increase durum wheat productivity by developing germplasm that is resistant to disease, high quality, and easily adopted by farmers. The Marjawi variety was released in 1983 in Libya by a breeding program in the Ministry of Agriculture's Agricultural Research Center (ARC) at Tripoli (CIMMYT), followed by its release in Syria in 1985 by (Genetic Resources Information System for Wheat and Triticale (GRIS). Marjawi resists such diseases as Rust (Arhama, 2015aGeneral Authority for cereal production, Committee for seed registration, Tripoli Libya, 2015).

3.4.1.3 Fazan:

Fazan is another variety of durum (hard) wheat developed by CIMMYT. It was released in 1985 in Libya by the breeding program in the Agricultural Research Center (ARC) at Tripoli

(CIMMYT). Fazan resists rust (Arhama, 2015a General Authority for Cereal Production, Committee for Seed Registration, Tripoli, Libya, 2015)

Bread wheat (*Triticum aestivum*) “*Triticum aestivum*, is grown mostly in the coastal plains, semi-desert areas and oases” (Al-Jibouri, 1966, p. 1)

3.4.1.4 *Salambo*

Salambo is a variety of bread (soft) wheat that was bred and first released in Tunisia in 1980 (CIMMYT). Due to its adaptability and high productivity, later it was released in Libya where the climate and environment are similar to Tunisia (Wheat Atlas, 2015 <http://wheatatlas.org/country/varieties>).

Salambo is a white-colored, medium-sized grain and spring-based class of wheat. One thousand seeds weigh 39 grams. It is a variety that has average branching and a hypocotyl that is strong enough to withstand high wind velocities. *Salambo* resists lodging and powdery mildew and shows average resistance to black and yellow leaf rusts, in addition to septoria. This seed variety is best used in areas where permanent irrigation, supplemental irrigation, or rainfall is consistent. It is planted in November during the rainy season and matures in the spring for harvest when soil moisture and the climate best support it. On average, it takes 130 days to reach maturity. Yield is high, averaging 5,000 kg/ha within the areas that have irrigated systems or consistent sources of water. In areas where irrigation is inconsistent with a reliance on rain fed irrigation, productivity falls to an average of 900 to 1,000 kg/ha (Arhama, 2015a). The success of this variety is best seen in areas that are semi-arid. It is mostly available in the east and south of Libya (Arhama, 2013).

3.4.1.5 *Local or mahale varieties of wheat*

CIMMYT database reports local (*mahale*) wheat varieties in Libya, with release dates prior to 1900.

3.4.2 *Varieties of Barley Grown in Libya*

3.4.2.1 *3.4.2.1 Barjoui*

Barjoui is a variety of barley that was developed by the ICARDA. It was registered in Libya in 1990 by the breeding program of the ARC at Tripoli. The ARC-Libya and ICARDA have partnered to improve cereal production in Libya. Due to this partnership, beneficial genetic determinants and variety characteristics were developed, resulting in diversification of barley.

The type of spike in Barjoui has six rows (*Hordum vulgare L*). Barjoui is resistant to rust diseases (Arhama, 2015a).

3.4.2.2 *Rihan*

Rihan is a variety of barley that was bred and first registered in Tunisia in 1987 (Arhama, 2015a). Due to its adaptability and high productivity, it was released in Libya where the climate and environment are similar to Tunisia. The type of spike in Rihan has six rows (*Hordum vulgare L*). Rihan is a yellow-colored, medium-sized grain and spring-based class. One thousand seeds weigh 42 grams. It is a variety that has average branching and resists grain sprouting and lodging, which means it is strong enough to withstand high wind velocities. However, it is not resistant to diseases such as rust. This seed variety is best used in areas where permanent irrigation, supplemental irrigation, or rainfall is consistent. It is planted from mid-November to mid-December during the rainy season and matures in the spring for harvest when soil moisture and the climate best support it. On average, it takes 133 days to reach maturity. Yield is high,

averaging, 4,500 kg/ha within areas that have irrigation systems or consistent rainfall. In areas where irrigation is inconsistent or where there is a reliance on rainfall, productivity falls to an average of 1,000 to 3,000 kg/ha (Arhama, 2015a).

3.4.2.3 *Local or “mahale” 6-row barley*

Mahale is a general term for varieties of barley that were present in Libya before 1900. There are two general types of *mahale* barley, six-row and two-row.

The *mahale* six-row barley is a yellow-colored, medium-sized grain and is a spring-based class. Mahale's spike has six rows (*Hordum vulgare L*). One thousand seeds weigh 29 grams. It is a variety that has average branching and resists grain sprouting and lodging phenomenon that means it is strong enough to withstand high wind velocities. Mahale is resistant to rust disease. It is planted from mid-November to mid-December during the rainy season and matures in the spring for harvest when soil moisture and the climate best support it. On average, it takes 150 days to reach maturity. Yield is high, averaging 5,000 to 6,000 kg/ha within the areas that have irrigated systems or consistent sources of water (Arhama, 2015a).

3.4.2.4 *Local or “mahale” 2-row barley*

The *mahale* 2-row variety is a local variety of barley present in Libya since prior to 1900. Mahale 2-row is a yellow-colored, medium-sized grain and is a spring-based class. The variety's spike has two rows (*Hordum distichumi*). One thousand seeds weigh 35 to 40 grams. It is a variety that has average branching and resists grain sprouting and lodging phenomenon that means it is strong enough to withstand high wind velocities. Mahale 2-row is resistant to rust disease. This seed variety is supported in the permanent irrigation areas. It is planted from mid-November to mid-December during the rainy season and matures in the spring for harvest when soil moisture and the climate best support it. On average, it takes 150 days to reach maturity.

Yield is high, averaging 5,000 to 6,000 kg/ha within the areas that have irrigated systems or consistent sources of water (Arhama, 2015a).

3.4.3 Definition and description of local or mahale varieties of wheat and barley grown in Libya

A local or *mahale* variety designation means that it has a local origin within Libya and is fairly uniform throughout all of Libya (Arhama, 2015b). The *mahale* varieties of seed have been used for over one hundred years because of their resistance to conditions such as water stress, high temperature, or certain insects. The productivity for these varieties is not as high as certain imported improved varieties from other countries. Unlike some improved varieties of barley and wheat, the history of the *mahale* varieties of barley and wheat are difficult to trace through time, but historians are convinced that the local varieties go back to the Italian farmers' presence in Libya prior to 1900. Exactly when these varieties of barley and wheat were first used is difficult to trace because most of them have no records. They pre-date the adoption of improved varieties. Usually, farmers will opt for the local or *mahale* variety when they cannot get improved seeds.

The definition of *mahale* varieties are landraces that are old traditional seed grown for many generations and only exist because farmers continue to save the seed and grow them each year. These Local varieties do not come from a breeding program. "Local varieties of wheat and barley in Libya are well adapted to the prevailing ecological and environmental conditions" (Forward by Jose Vallage, as cited in Al-jibouri, 1966, Front matter).

3.5 Farmer Decisions Regarding Wheat and Barley Varieties

3.5.1 Farmers' Sources of Wheat and Barley Seeds

In the survey, after revealing which varieties of wheat or barley they grow, farmers were asked “Where did you originally get this variety (of wheat)?” Of the respondents, 14 of the 15 total farmers who grow Salambo said they acquire their variety from their own saved seed, and 13 of the 15 farmers also obtain seed from the Ministry of Agriculture’s Seed Center. Of the 37 farmers who grow improved seed, 30 of them (81%) acquired at least some of their seed for this season by saving from previous harvests and 24 (65%) of them also obtained new seed from the Seed Center. Four of five farmers growing local varieties of wheat (80%) use their own saved seed. These results are shown in Table 3.30. Figures 3.3, 3.4 show Origin of improved varieties of wheat and Origin of wheat varieties.

Table 3.29 Farmers’ Sources of Seeds for Wheat Varieties Grown

Variety (number of farmers)	Saved seed	Neighbor purchase	Ag supply	Seed Center	Other
Karim (11)	8	0	0	5	0
Salambo (15)	14	1	0	13	0
Marjawi (5)	4	0	0	2	0
Fazan (4)	2	1	0	2	0
Other varieties (2)	1	0	0	2	0
Total Improved (37)	30	2	0	24	0
Total Local (<i>mahale</i>) (5)	4	1	0	1	0

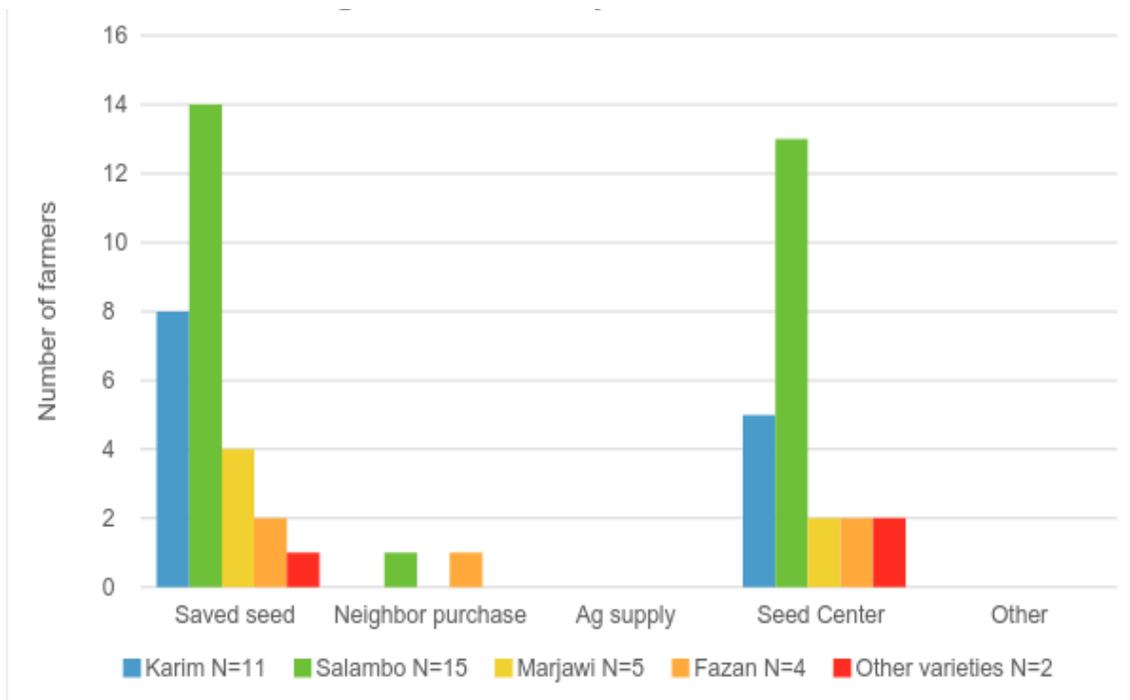


Figure 3.3 Farmers’ Source of Seeds for Improved Wheat Varieties

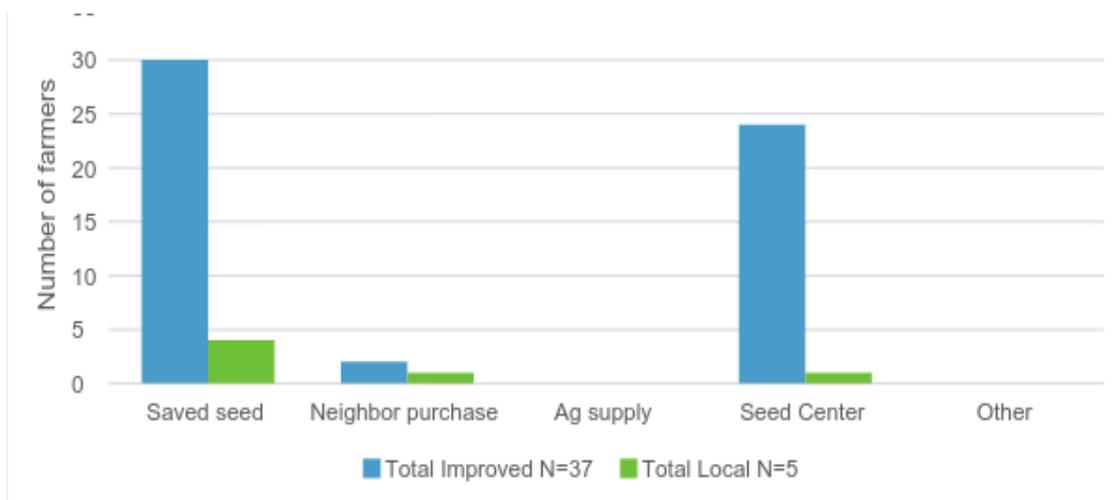


Figure 3.4 Farmers’ Source of Seeds for Improved versus Local (“mahale”) Wheat Varieties

Farmers were asked, “Where did you originally get this variety (of barley)?” 24 of 37 total farmers who grew Rihan said they acquire their seed from their own saved seed while 24 of 37 total farmers obtain their seed from the Seed Center. 54 of 83 total farmers who grew improved seed acquire their seed from their own saved seed and 42 farmers obtain their seed from the Seed Center. Fifty nine farmers out of 64 in total said they acquire their seed from their own seed savings. These results are shown in Table 3.31.

Table 3.30 Farmers’ Sources of Seed for Barley Varieties Grown

Variety (number of farmers)	Saved seed	Neighbor purchase	Ag supply	Seed Center	Other
Barjouj (31)	23	3	5	11	0
Rihan (37)	24	1	1	24	0
Other varieties (15)	7	1	0	7	0
Total Improved (83)	54	5	6	42	0
Total Local (<i>mahale</i>) (64)	59	9	21	6	0

Figures 3.5, 3.6 show Origin of improved varieties of barley and Origin of barley varieties.

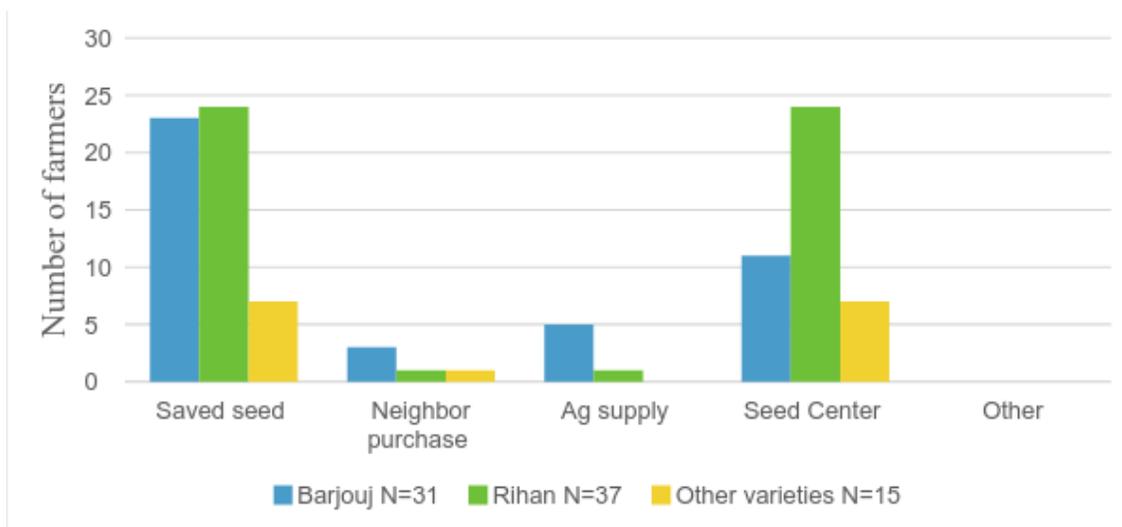


Figure 3.5 Farmers’ Sources of Seeds for Improved Barley Varieties

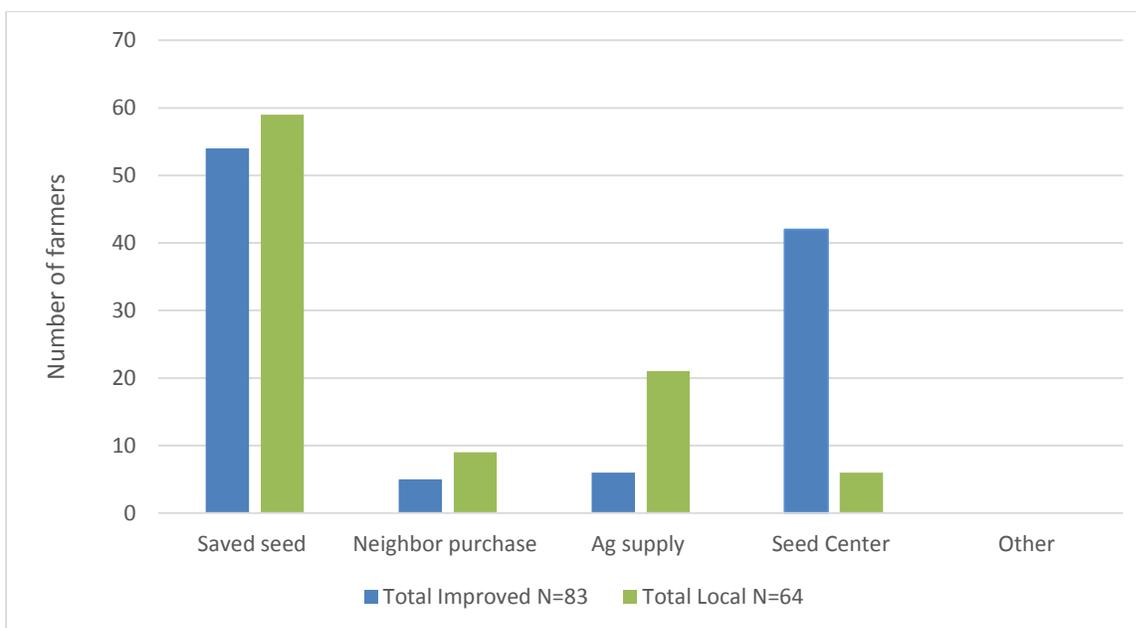


Figure 3.6 Farmers’ Source of Seeds for Improved versus Local (“mahale”) Barley Varieties

3.5.2 *Intentions for Saving Seed and Purchasing Certified Seed*

Farmers were asked whether they anticipated their home-saved seed levels would increase or decrease in the future. The majority (87 farmers; 64%) reported that they anticipate their share of home-saved seed decreasing because of the lack of transportation, poor storage, disease, and lack of equipment to clean and treat seed. Another 39 farmers reported that their share of home-saved seed will remain the same (28.7%), with one of these farmers explaining that he will continue to use home-saved seed because his variety keeps its genetic traits. Only eight farmers expected an increase in home-saved seed (5.9 percent). These results are shown in Table 3.32.

Table 3.31 Expectation of Saved Seed

Do you anticipate your share of home-saved seed to...	Increase?	Decrease?	Stay the same?
Number of Farmers Responding	8	87	39
Percentage of Farmers Responding	5.9%	64.0%	28.7%

Farmers were asked about whether they buy certified seed or not. The majority (113 farmers; 83.1%) reported that when they buy new seed, they buy certified seed. Only 23 farmers did not buy certified seed (16.9%). These results are shown in Table 3.33.

Table 3.32 Certified Seed Purchasing

When you buy new seed, do you buy certified seed?	Yes	No
Number of Farmers Responding	113	23
Percentage of Farmers Responding	83.1	16.9

3.5.3 Purchased Versus Saved Seed for Wheat and Barley Varieties

The farmers were asked what share of their wheat varieties was planted with newly purchased seed and what share of their wheat varieties was planted with own saved seed. A majority of farmers who responded (12 out of 15 responded, 83 Ha, 71%) grow Salambo and reported that they plant purchased seed. However, they plant saved seed (34 Ha, 29%). Twenty-six farmers out of 37 who grow improved varieties plant purchased seed (164 Ha, 66%) and (74 Ha, 34%) plant saved seed. On the other hand, 5 Ha, 33% of the 3 out of 5 farmers who reported growing Local varieties said they share purchased Local seed, and (10 Ha, 67%) they share saved seed. Results are shown in Table 3.34, and Figures 3.7, 3.8.

Table 3.33 Share of Wheat Varieties Planted with Newly Purchased or Saved Seed

Varieties (numbers of farmers reporting areas planted of the variety)	Reported Area Planted to Purchased Seed	Reported Area Planted to Saved Seed	Total Reported Area
Karim (6 out of 11)	40 Ha (75%)	13 Ha (25%)	53 Ha
Salambo (12 out of 15)	83 Ha (71%)	34 Ha (29%)	117 Ha
Marjawi (4 out of 5)	29 Ha (65%)	16 Ha (35%)	45 Ha
Fazan (2 out of 4)	1 Ha (40%)	2 Ha (60%)	3 Ha
Other varieties (2 out of 2)	1 Ha (40%)	1 Ha (60%)	2 Ha
Total Improved (26 out of 37)	146 Ha (66%)	74 Ha (34%)	220 Ha
Total Local (mahale) (3 out of 5)	5 Ha (33%)	10 Ha (67%)	15 Ha

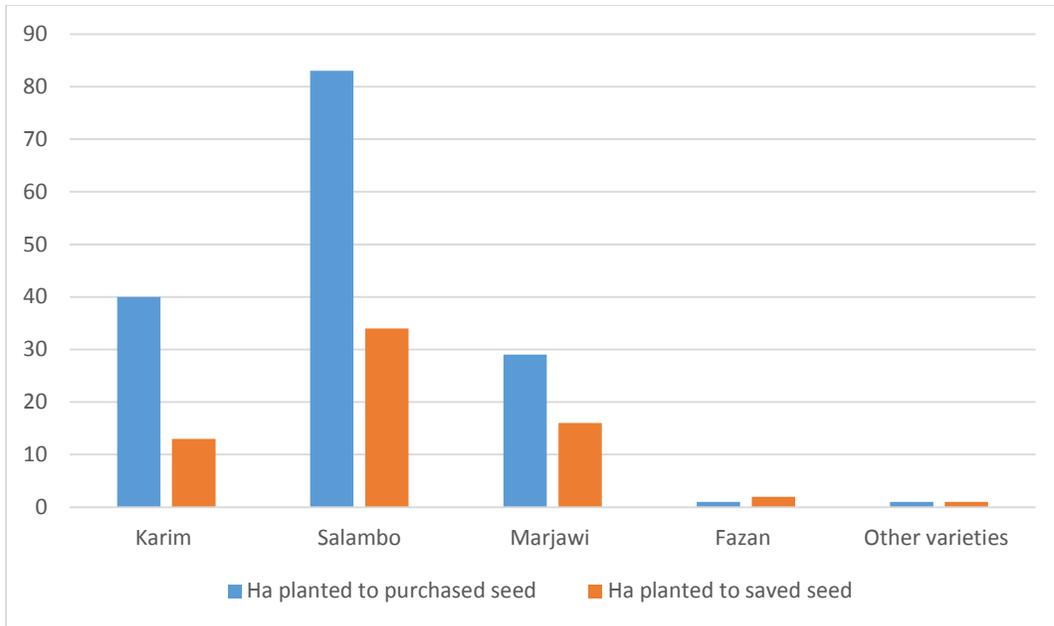


Figure 3.7 Areas of Improved Wheat Varieties Planted with Purchased or Saved Seed in 2013

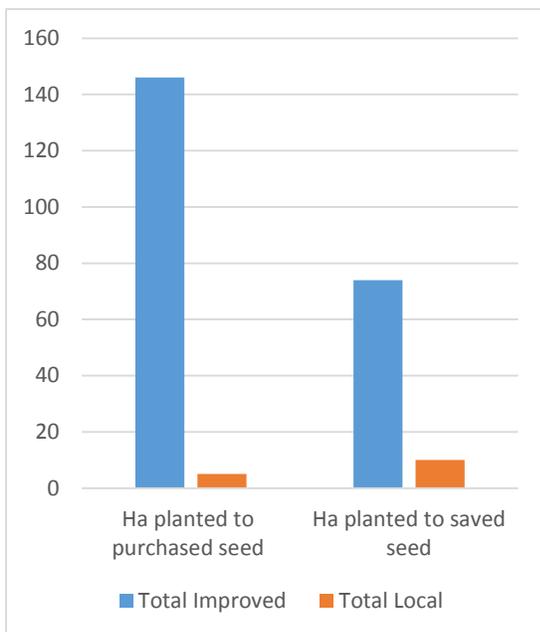


Figure 3.8 Areas of Improved Versus Local (“mahale”) Wheat Varieties Planted with Purchased or Saved Seed in 2013

The farmers were also asked about barley. A majority of farmers who responded (26 out of 31) who grow Barjouj reported that they planted purchased seed on 280 Ha (82% of the reported Barjouj planted area). They reported planting saved seed on 61 Ha (18% of reported Barjouj planted area). Overall, 52 of 83 farmers who grow improved varieties share purchased seed (419 Ha, 77%), and 125 Ha, 23% share saved seed. On the other hand, 237 Ha, 50% of the 43 out of 64 responding farmers who reported growing Local varieties said they share purchased seed, and about 241 Ha, 50% they share saved seed. These results are shown in Table 3.35 and Figure 3.9. 3.10

Table 3.34 Share of Barley Varieties Planted with Newly Purchased Seed or Saved Seed

Varieties (number of farmers reporting areas planted to the variety)	Reported Area Planted to Purchased Seed	Reported Area Planted to Saved Seed	Total Reported Area
Barjouj (26 out of 31)	280 Ha (82%)	61 Ha (18%)	341 Ha
Rihan (19 out of 37)	91 Ha (63%)	55 Ha (37%)	146 Ha
Other varieties (7 out of 15)	55 Ha (96%)	2 Ha (4%)	57 Ha
Total Improved (52 out of 83)	419 Ha (77%)	125 Ha (23%)	544 Ha
Total Local (43 out of 64)	237 Ha (50%)	241 Ha (50%)	478 Ha

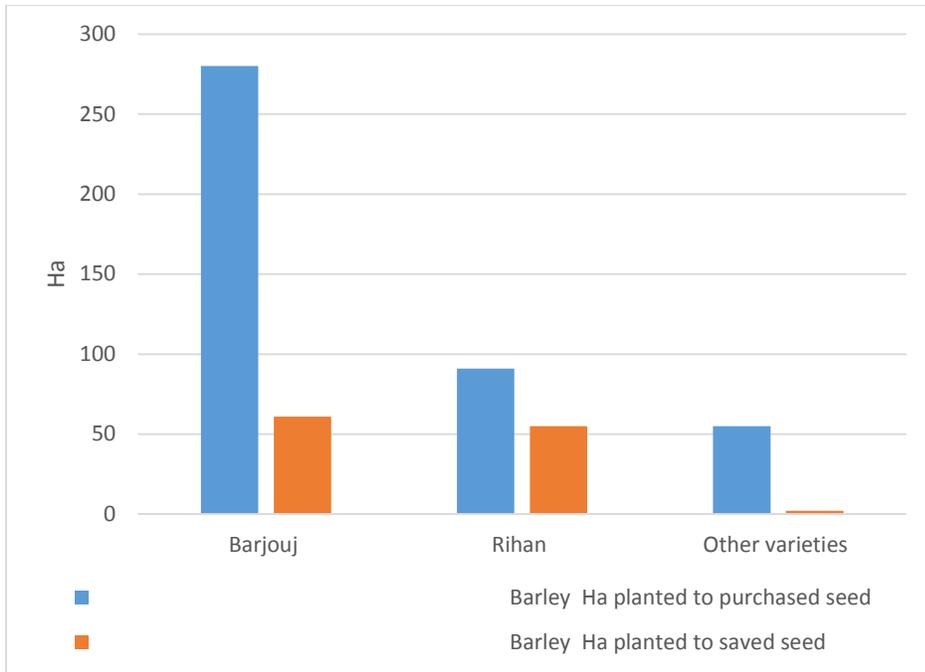


Figure 3.9 Areas of Improved Barley Varieties Planted with Purchased or Saved Seed in 2013

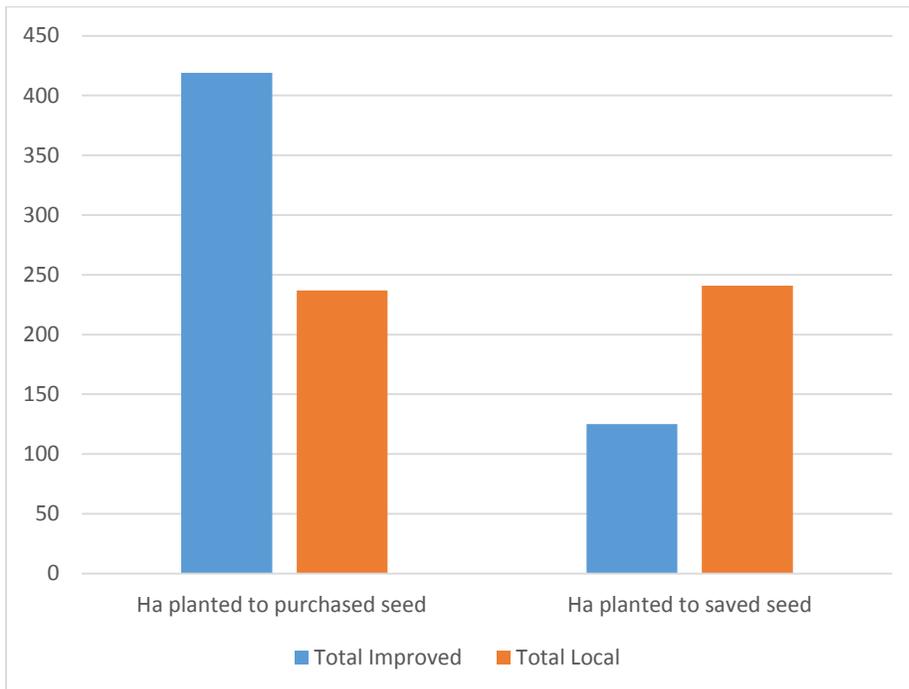


Figure 3.10 Hectares of Improved and Local (“mahale”) Barley Varieties Planted in 2013

3.5.4 Farmers' Stated Preferences for Growing Wheat and Barley over Other Crops

The survey included 136 wheat and/or barley farmers. Farmers were asked, “Why do you believe growing wheat or barley is better than other crops?” The most frequently reported factor for growing wheat and/or barley compared to other crops was the lower water requirement; 57 out of 136 (41.9%) farmers reported this. 48 (35.3%) farmers reported that reduced risk of low yields and reduction of input costs was the second most-reported factor; that is, wheat and barley are more tolerant to local conditions and less likely to fail than other crops. The third most frequently reported factor by 37 (27.2%) of the surveyed farmers was their greater familiarity with wheat and barley than with other crops. Twenty-four (17.6%) farmers reported that family history was the fourth most frequently reported factor; growing wheat and barley was a tradition that runs in their family. Finally, 22 (16.2%) farmers believed that wheat and/or barley are less impacted by diseases than other crops.

Based on the data summarized above, farmers preferred to grow wheat and barley over other crops that could be grown in the area. Perhaps the fact that barley is grown in the east where there is plentiful rainfall and wheat is grown in the south where an irrigation project is already established contributes to why farmers chose water requirements as the number one most reported factor in planting wheat and barley. The second reason that wheat and barley production prevails over other crops is that they possess a lower risk than other crops. Lower risk crops tend to have a higher yield, on average, because switching to other crops can incite many additional input costs such as fertilizer, pesticides, and irrigation systems. If those crops fail, all of the new input costs would eat into profits and production. Therefore, wheat and barley have a higher chance of the farmer making a steady income from production. Another reason that wheat and barley are grown more is that they are familiar crops. Familiarity means that the farmers know

exactly what they need to grow the crops and they also have knowledge of expected production. Therefore, they don't have to take the time to learn about other crops.

The fourth most frequently reported reason that wheat and barley are grown from generation to generation is that it is a family tradition. It is a custom which is well known to farming families in Libya. The farmers are like a family, many are literally related, and the farming community remains close to one another. Many farmers have a set exchange of crops with neighboring farmers. The farmer's choice to grow wheat and barley is very influenced by what they saw grown when they were young. By growing the same crops year after year, they are also able to save their seed to sow next year's crop. Additionally, in the farmers' experience, they have seen less disease in wheat and barley crops; therefore, they see them as disease-resistant. They are not very willing to plant other crops that may not be as resistant and instead produce less when affected with unknown diseases. The farmer's choice to grow wheat and barley is dependent on many reasons, such as water usage, familiarity, lower risk, family tradition, and disease resistance.

3.5.5 Farmers Stated Preferences for Growing Local (mahale") Varieties versus Imported Varieties

Farmers were asked about their preference for their own landrace or local variety, 125 farmers believed that their own landrace/local/*mahale* variety was better (more cost effective) than newly bred improved or imported varieties (91.9%), while eleven farmers disagreed (8.1 percent). These results are shown in Table 3.36.

Table 3.35 Preference for Local (“mahale”) Varieties

Is your own landrace or local variety better than imported varieties?	Yes	No
Number of Farmers Responding	125	11
Percentage of Farmers Responding	91.9	8.1

Farmers were also asked, “Do you prefer imported seed and why?” Results showed that 65 farmers preferred imported seed (47.8%), while 71 farmers did not (52.2%). Among the farmers that preferred imported seed, they were asked to state why. Despite the fact that 65 preferred imported seed, 70 responses were given. This means that some farmers likely gave more than one answer. However, all of these answers were included in the results. The most frequent reason given was that the imported variety gave a higher yield (52 responses). The second most frequent reason given was that it produces a better quality wheat or barley, which sells at a higher market price (13 responses). Five responses stated the reason was because the imported seed is of a better quality, for instance higher germination rate or less weed contamination.

To summarize this question, it appears that preference for imported seed is nearly evenly split (65 farmers who prefer versus 71 farmers who do not). The vast majority of the 65 farmers who said they prefer imported seed was because it gave a better yield, while others believed they receive a higher market price because the product was of better quality and also had a higher germination rate.

Farmers were next asked, “Do you prefer seed varieties from Libya?” Nearly all of the respondents said yes (130 of 136). This means that even the farmers who just said they preferred imported seeds would rather use Libyan varieties, however they used imported seeds because of perceived superior quality in imported seeds as shown in the previous question. The most frequent reason given for preferring Libyan varieties was familiarity (70 responses). Forty-six responses indicated that they generally prefer seed from Libya, while 41 responses showed the preference was based on taste and fit for traditional foods.

Based on these two questions, it appears there is support or desire to use local or domestically developed varieties, however, actual usage is nearly split on using imported seeds. This indicates that if a Libyan seed program existed that produced high-quality, high-yield varieties, then many of the farmers currently using imported seeds would likely switch to local varieties. This bodes well for a potential Libyan seed program and its success if it can produce high quality varieties and develop a good reputation. This would also lower the risk to farmers using an imported seed that may not be well acclimated to Libya’s climate and growing conditions. Additionally, this indicates a likelihood of support from farmers in experimenting with local varieties to strengthen their quality and insure that stable local varieties will exist for the future.

3.5.6 Farmers Stated Preferences for Growing Specific Wheat and Barley Varieties

Farmers were asked, “Why did you choose to grow this wheat variety?” Results showed that farmers who prefer to grow Salambo wheat preferred it for its easy access (14 farmers, 93%). The second highest response preferred because of its easy access was Karim wheat variety (100% or 11 of 11 total farmers). The second reason they chose the Salambo variety was for a

better yield with 12 of 15 farmers or 80% responding with this reason. For Karim wheat, 5 farmers of 11 total (45%) stated that better yield was a factor.

Of the total number of 37 farmers who grew improved varieties of wheat, 32 farmers (86%) said that they chose the varieties because of easy access to the seed. The second most common reason for preferring these varieties was a better yield and was mentioned by 54% (20 of 37 farmers) of the improved wheat growers. Of the five farmers who used local seed, 100% of them said they had chosen local varieties due to easy access. The second reason was that they are more reliable, which means that they are better suited to the region and less likely to fail. These results are shown in Table 3.37. Figure 3.8 shows the reasons for growing improved wheat varieties.

Table 3.36 Farmers' Stated Reasons for Choice of Wheat Varieties

Variety (number of farmers)	Easy access	Good price	Better yield	More cost effective	Familiar	More reliable	No other varieties available
Karim (11)	11	0	5	0	1	4	0
Salambo (15)	14	0	12	0	1	6	0
Marjawi (5)	4	0	2	0	1	4	0
Fazan (4)	3	0	1	0	1	1	0
Other varieties (2)	0	1	0	0	1	0	0
Total Improved(37)	32	1	20	0	5	15	0
Total Local (5)	5	0	1	0	0	5	0

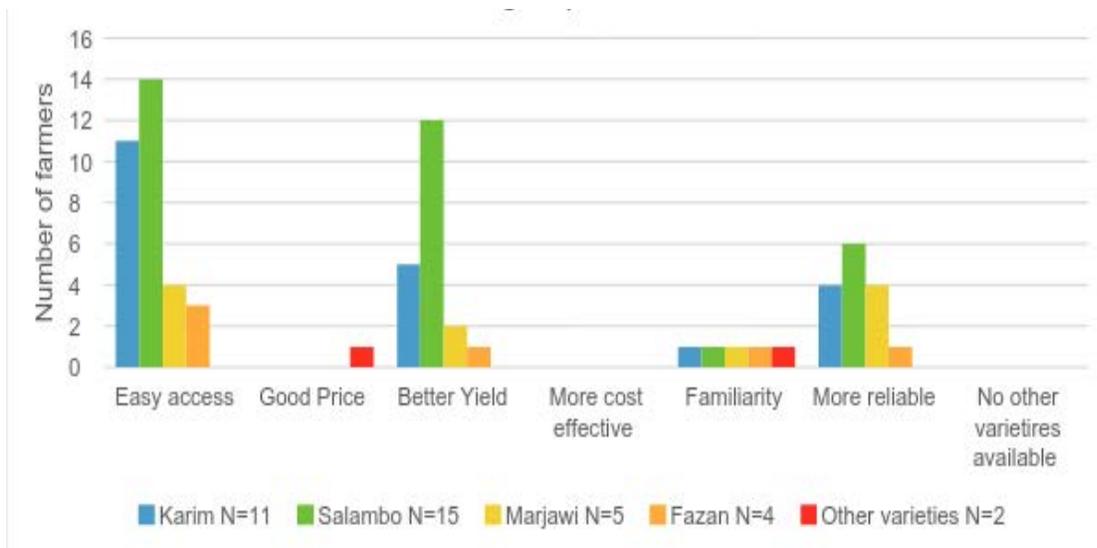


Figure 3.8: Reasons Stated for Choosing Improved Wheat Varieties, by Variety

Farmers were also asked, “Why did you choose to grow this barley variety?” The top reason given by farmers who prefer to grow the Rihan variety of barley was easy access (78% or 29 of 37 total farmers responding). The second highest reason they chose the Rihan variety was better yield, with 22 farmers of 37 responses (59%). For the Barjouj variety of barley (24 farmers of 31 total, 77%) was selected because of its reliability. For the Barjouj variety, the second highest reason it was preferred was because it is easy to access (68%, 21 of 31 total farmers).

The first reason improved seed was preferred over local was easy access (59 of 83 responses or 71.1%). The second reason improved seed was preferred over local was for reliability (53 of 83 responses or 64%). For local varieties, 56 of 64 total responses (88%) stated that easy access was the first reason. More reliable was the second reason with 53 of 64 responses or 83%. These results are shown in Table 3.38.

Table 3.38: Farmers' Stated Reasons Stated for Choice of Barley Varieties

Variety (number of farmers)	Easy access	Good price	Better yield	More cost effective	Familiar	More reliable	No other varieties available
Barjouj (31)	21	1	10	0	4	24	1
Rihan (37)	29	1	22	1	5	20	0
Other varieties (15)	9	1	8	1	3	9	0
Total Improved(83)	59	3	40	2	12	53	0
Total Local (64)	56	4	8	1	12	53	3

Figure 3.9, below, shows the reasons for growing improved barley varieties.

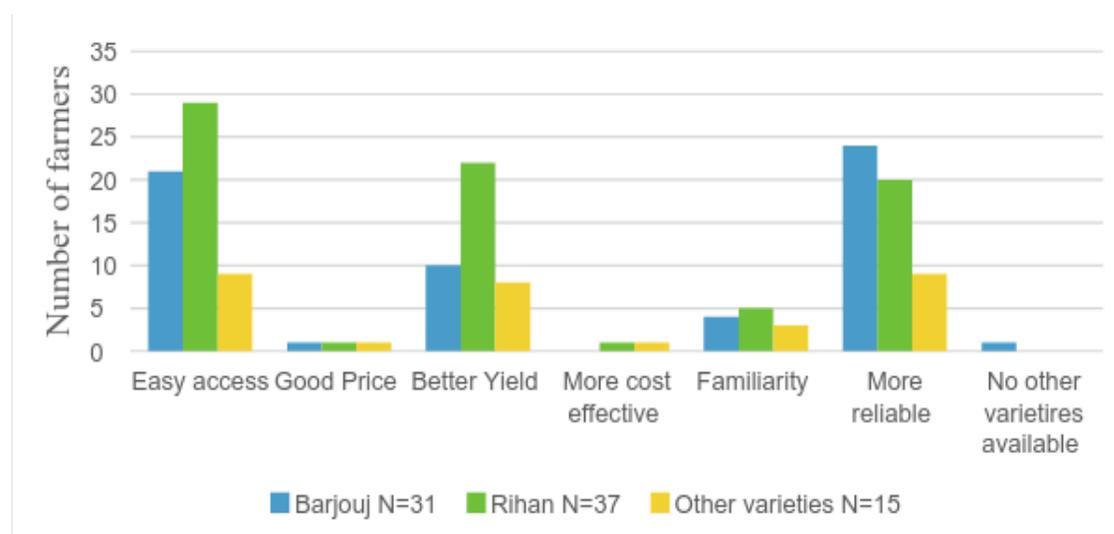


Figure 3.11 Reasons Stated for Growing Improved Barley Varieties, by Variety

3.5.7 Seeding Rates of Wheat and Barley Varieties

Farmers were asked, “What seeding rate of wheat varieties do you plant?” The majority (14 of 15 farmers, 93%) of farmers who planted the Salambo wheat variety stated they preferred to plant at a rate of 120 kg/ha. Observing the results for all the improved wheat varieties, 23 of 37 farmers who responded (62%) preferred planting at a rate of 120 kg/ha. The farmers who grew improved seed feel this seeding rate of 120kg/ha gives them a higher yield. In addition, Local varieties are planted at a rate of 120 kg/ha, with 3 of 5 responses or 60% of farmers selecting that rate of planting. These results are shown in Table 3.39.

Table 3.37 Seeding Rate of wheat Varieties Planted

Variety (number of farmers)	Wheat Seeding Rate: kg/ha						
	30	60	90	120	150	180	> 180
Karim (11)	0	0	1	5	0	0	0
Salambo (15)	0	0	0	14	0	0	0
Marjawi (5)	0	0	1	2	0	0	0
Fazan (4)	0	0	3	1	0	0	0
Other varieties (2)	0	0	0	1	0	0	0
Total Improved (37)	0	0	5	23	0	0	0
Total Local (5)	0	0	1	3	0	0	0

Farmers were asked, “What seeding rate of barley varieties do you plant?” The majority of farmers (23 of 37 farmers, 62%) who planted the Rihan variety stated they prefer to plant at a rate of 120 kg/ha. Observing the results for all the improved barley varieties, 42 of 83 farmers who responded (51%) preferred planting at a rate of 120 kg/ha. The farmers who grow improved seed feel this seeding rate of 120kg/ha gives them a higher yield. Moreover, Local varieties are planted at a rate of 120 kg/ha, with 32 of 64 responses or 50% of farmers selecting that rate of planting. These results are shown in Table 3.40.

Table 3.38 Seeding Rate of Barley Varieties Planted

Variety (number of farmers)	Barley seeding rate kg/ha						
	30	60	90	120	150	180	> 180
Barjouj (31)	0	0	4	12	0	0	0
Rihan (37)	0	1	5	23	0	0	0
Other varieties (15)	0	0	2	8	0	0	0
Total Improved (83)	0	1	11	42	0	0	0
Total Local (64)	0	0	28	32	0	0	0

3.6 Logit Analysis of Adoption of Improved Varieties

This section further explores some of the research questions presented at the beginning of this chapter by utilizing some of the survey data in an analysis of Libyan farmers’ adoption of improved varieties. This section is organized into the study area, methodology, logistic regression framework, description of variables and description of results.

3.6.1 Methods and Data for Logit Regression Analysis

As mentioned at the beginning of this chapter, the survey sought to collect detailed information from 181 wheat and barley farmers in Libya in 2014. Since there was civil war in Libya at the time of the survey administration, surveys could not be collected from all of the regions intended, particularly in the west of the country. However, 136 farmers from eastern and southern Libya responded to the survey, which was the primary data collection method. These farmers constitute a representative sampling of all small grain farmers in Libya.

Logistic regression was used to predict farmers' adoption of improved wheat or barley varieties. Particularly, binary logistic regression was used for this study because the outcome was dichotomous, (i.e. "yes" or "no") (Leech, Barrett, & Morgan, et al., 2005). The logistic model for this study is explained by Davidson and Mackinnon (1995). The model is

$$p_i = 1 / (1 + \exp(\beta X_i))$$

where p_i is the probability of farmer i adopting a new variety and X_i is a vector of farmer i 's characteristics.

This test was used to examine which factors impact farmers' adoption of improved wheat or barley varieties and analyzes by using three groups of explanatory variables--Farmers' Socio-Demography Characteristics, Farm Characteristics, and Farmer Preferences--to explain the decision to adopt.

3.6.2 Description of Variables Used

The dependent variable in the adoption of improved wheat or barley varieties model are 0,1 dummy variables (No, Yes). Two models were used, given the detailed information on

farmers planting decisions, reflecting a weaker and stronger interpretation of adoption of improved varieties:

- **“Any improved”** is defined to equal 0 for those farmers who did not grow any improved varieties of either wheat or barley and 1 for those farmers who grow *any* improved variety of either wheat or barley. In other words, a 0 designates a farmer who grows only local or *mahale* varieties on their farm.
- **“Only improved”** is defined to equal 0 for those farmer who grows some local or *mahale* variety of wheat or barley and 1 if for those farmers who grows *only* improved varieties on their farm.

These definitions therefore can account for the significant subset of farmers who exhibit partial adoption. A complete non adopter will be 0 for “any improved” as well as 0 for “only improved.” A partial adopter will be 1 for “any improved” but 0 for “only improved.” A full adopter will be 1 for “any improved” as well as 1 for “only improved.”

The independent variables included in the vector X_i : were drawn from 38 possible variables available from the survey, reduced to three groups with common characteristics:

- **Farmers’ Socio -Demographic Characteristics:** including age of farm operator, household size, education, operator experience.
- **Farm Characteristics:** including farm size, location of farm, irrigation and rainfall, farm income, crop income, fertilizer, and labor.
- **Farmer Preferences:** for informal marketing, formal marketing, and seed saving.

Each of the possible explanatory variables was analyzed separately in cross correlation tests with the adoption variables and those that appeared to be most correlated with the outcome were further analyzed. From group one (Farmers’ Socio-Demographic Characteristics), the factor

identified from cross-correlation tests was education level. From group two (Farm Characteristics), four factors appear related to the use of improved varieties: irrigation, fertilizer, farm labor, and farm size. In the third group (Farmer Preferences), the only factor that appeared to be correlated with improved varieties was seed saving. These six variables were used as regressors for both models (“any improved” varieties and “only improved” varieties):

- **Education:** measured by the level of education attained.

The education variable was defined as “0” value equaling high school or below education attainment, and “one” value equaling some collage attendance or more. The mean for Education was 0.39, which means that the education attainment level was closer to a high school average. Standard deviation for education was 0.489, which means that the data is spread out wider than a normal distribution.

- **Farm size:** measured by hectares of planted groups.

Farm Size was defined as “1” value equaling 1-5 ha, “2” value equaling 5-20 ha, “3” value equaling 20-100 ha, and “4” value equaling more than 100 ha. The mean for Farm size was 2.243, which means that the average farm size was between 5-20 ha and 20-100 ha. Standard deviation for farm size was 0.8563, which means that the data was very wide.

- **Labor:** measured by numbers of full and part time workers.

The labor variable was defined as “0” value equaling no employment, “1” value equaling part-time employment, “2” value equaling both part and full-time employment, and “3” value equaling full time employment. The mean for labor was 1.74, which means that the average farmer employs part-time and full-time employees. Standard deviation for labor was 1.054, which means that the data was widely distributed.

- **Irrigation:** measured by use of irrigation: yes or no.

The irrigation variable was defined as “0” value equaling no irrigation use, and “1” value equaling some irrigation use. The mean for irrigation was 0.647, which means that the average farmer uses irrigation. Standard deviation for irrigation was 0.4797, which means that the data is wider spread than normal.

- **Fertilizer:** measured by how much fertilizers kg /ha used in their farms.

The fertilizer variable was defined as “0” value equaling no fertilizer use, “1” value equaling some fertilizer use. The mean for fertilizers was 0.68, which means that the average farmer uses fertilizer. Standard deviation for fertilizer was 0.467, which means that the data is closer to a normal distribution.

- **Seed Saving Plans:** measured by whether they increase, decrease or stay the same amount of saved seed.

Seed saving variable was defined as “0” value if seed saving is expected to decrease next year, a “1” value if it is expected to stay the same, and “2” if it is expected to increase. The mean for seed saving was 0.411, which means that the famers were between stay the same or decreasing seed saving. The average famer is not planning on increasing his saved seed. Standard deviation for seed saving was 0.602, which means that the data was wider spread than normal.

Table 3.41 shows the mean and standard deviations for the primary explanatory variables used in the logit regressions. These descriptive statistics provide a picture of how the data is distributed. It gives summary of the data and an important way for visualizing patterns that might emerge from the data. All 136 famers are accounted for with these explanatory variables, and there are no missing data.

Table 3.39 Descriptive Statistics of the Primary Explanatory Variables

		Education	Farm Size	Labor	Fertilizer	Irrigation	Seed Saving
N	Valid	136	136	136	136	136	136
	Missing	0	0	0	0	0	0
Mean		0.390	2.243	1.740	0.680	0.647	0.411
Std. Dev.		0.489	0.856	1.054	0.467	0.479	0.602

Table 3.40 Correlation Matrix for Primary Explanatory Variables

	Education	Farm size	Labor	Fertilizer	Irrigation	Seed saving
Education	1.000					
Farm Size	0.126	1.000				
Labor	0.282	0.209	1.000			
Fertilizer	0.284	0.323	0.406	1.000		
Irrigation	0.243	0.210	0.405	0.524	1.000	
Seed saving	0.004	0.279	-0.124	0.045	0.199	1.000

It was determined that each of these six variables were independently correlated with a farmers' uses of improved seed. A correlation matrix of these factors is shown in Table 3.42. The correlation matrix shows that the relationships between independent variables are generally small in size. Additionally, the matrix gives no indication of multicollinearity problems as the values are not close to 1.

Two outcomes or dependent variables are modeled. The Any "Improved" model defined 0 = no improved varieties for both wheat and barley, 1= any improved variety for either wheat or barley. The second model was "Only Improved model" defined that 0 = grows any local, 1 = grows no local variety.

3.6.3 The First Model: Decision of Farmers to Grow Any Improved Variety

This study wanted to identify what factors are associated with farmers who decide not to grow improved varieties and those who take the step to at least partially adopt improved varieties. Table 3.43 summarizes the 44 farmers who do not grow any improved varieties (who grow *mahali* only) for both wheat and barley and the 92 farmers who grow at least one improved variety of either wheat or barley. The table shows that without considering the six independent variables, a random prediction rate of 67.6% was possible simply reflecting their proportions within the populations of farmers.

66% of those who grow only local varieties were predicted correctly using the six independent factors and 89% of those who grow any improved varieties were predicted correctly. Overall, the ability to predict increased from 68% to 82% when considering the six factors (Table 3.44).

Table 3.41 “Any Improved” Varieties Model Predication, without Explanatory Factors

Observed			Predicted		
			Any Improved model		Percentage Correct
			no improved varieties (<i>mahali</i> only) for both wheat and barley	any improved variety (any share >0) for either wheat or barley	
Step 0	Any Improved model	no improved varieties (<i>mahali</i> only) for both wheat and barley	0	44	.0
		any improved variety (any share >0) for either wheat or barley	0	92	100.0
	Overall Percentage				67.6

a. Constant is included in the model. b. The cut value is .500

Table 3.42 “Any Improved” Varieties Model Prediction, with Explanatory Factors

Observed			Predicted		
			Any Improved model		Percentage Correct
			no improved varieties (<i>mahali</i> only) for both wheat and barley	any improved variety (any share >0) for either wheat or barley	
Step 1	Any Improved model	no improved varieties (<i>mahali</i> only) for both wheat and barley	29	15	65.9
		any improved variety (any share >0) for either wheat or barley	10	82	89.1
	Overall Percentage				81.6

a. The cut value is .500

Logistic regression was conducted using the SPSS program to measure whether the six predictor variables labor, irrigation, fertilizer, and saving seed were significant in predicting whether or not farmers used improved any crops. Education and farm size were are not significant but they were significant factors when used alone. When all six predictor variables are considered together, the results were significant ($\chi^2 = 63.926$, $df = 6$, $N=136$, $p = 0.00$). Table 3.45 shows the results.

In the regression, exp(B) gives the odds ratio for each independent variable. It can be seen that education, labor, fertilizer, use irrigation and saving seed all improved our ability to predict farmers who use any improved seed.

Table 3.43 Results of Logistic Regression for Any Improved, Using Six Explanatory Variables

Variables	B	S.E.	Wald	df	Sig.	Exp(B)
Education	0.380	.544	.489	1	.485	1.463
Farm Size	0.082	.293	.077	1	.781	1.085
Labor	0.505*	.286	3.110	1	.078	1.657
Fertilizer	1.562***	.553	7.988	1	.005	4.769
Irrigation	2.043***	.613	11.117	1	.001	7.711
Seed saving	-1.576***	.484	10.586	1	.001	.207
Constant	-1.677	.686	5.982	1	.014	.187
Observations			136			
Log likelihood			107.298a			
Cox & Snell R Square			.375			
Nagelkerke R Square			.524			

a. Estimation terminated at iteration number 6 because parameter estimates changed by less than .001.

* significant at <10%, ** significant at <5%, ***significant at <1%

3.6.4 The Second Model: Decisions of Farmers to Grow Only Improved Varieties

This study wanted to be able to predict which farmers will grow improved only grain and which will not. The use of the six independent variables allow for improving predictions over chance. Table 3.46 shows that without considering the six independent variables identified, a prediction rate of only 50.7% is possible.

It is evident that without considering the six independent variables, prediction is only as good as flipping a coin. Considering the six independent variables identified, there is a clear improvement in predictability. Table 3.46 shows these results.

85% of those who did grow some local varieties were predicted correctly using the six independent variables and 83% of those who grew only improved varieties (i.e. did not grow any local varieties) were predicted correctly. The ability to predict increased from 50.7% to 83.8% when considering the six factors. (Table 3.47).

Table 3.44 “Only improved” Varieties Model Prediction, without Explanatory Factors

Observed			Predicted		
			Only Improved model		Percentage Correct
			Any local (=0)	Only improved (=1)	
Step 0	Only Improved model	Any local (=0)	0	67	.0
		Only improved (=1)	0	69	100.0
	Overall Percentage				50.7

a. Constant is included in the model.

b. The cut value is .500

Table 3.45 “Only Improved” Varieties Model Prediction, with Explanatory Factors

Observed			Predicted		
			Only Improved model		Percentage Correct
			Any local (=0)	Only improved (=1)	
Step 1	Only Improved model	Any local (=0)	57	10	85.1
		Only improved (=1)	12	57	82.6
	Overall Percentage				83.8

a. The cut value is .500

Logistic regression was conducted using the SPSS program to measure whether the six predictor variables labor, irrigation, fertilizer, and saving seed were significant in predicting whether or not farmers used improved any crops. Education and farm size were are not significant but they were significant factors when use alone. When all six predictor variables are considered together, it was significant ($\chi^2 = 93.284$, $df = 6$, $N=136$, $p = 0.00$). Table 3.48 shows the results.

In the regression, $\exp(B)$ gives the odds ratio for each variables . It can be seen that education, labor, fertilizer, use irrigation and saving seed all improved our ability to predict farmers who use only improved seed.

Table 3.46 Results of Logistic Regression for Only Improved, Using Six Explanatory Variables

Variables	B	S.E.	Wald	df	Sig.	Exp(B)
Education	0.201	.570	.125	1	.724	1.223
Farm Size	-0.499	.314	2.524	1	.112	.607
Labor	0.969***	.290	11.185	1	.001	2.636
Fertilizer	2.628***	.714	13.557	1	.000	13.843
Irrigation	1.973***	.631	9.774	1	.002	7.189
Seed saving	-1.295***	.478	7.355	1	.007	.274
Constant	-3.174***	.909	12.183	1	.000	.042
Observations			136			
Log likelihood			95.223^a			
Cox & Snell R Square			.496			
Nagelkerke R Square			.662			

a. Estimation terminated at iteration number 6 because parameter estimates changed by less than .001.

* significant at <10%, ** significant at <5%, ***significant at <1%

3.7 Conclusions

Results showed that the factors influencing or associated with farmers' adoption of improved wheat and barley varieties were: education, farm size, labor, irrigation, fertilizer, and saving seed. These factors affect the yield gap in Libya. Education positively affects a farmer's ability to choose improved seed varieties or local seed varieties because he is better prepared to locate, process, and utilize information about adopting improved seed varieties (Gamba, Ngugi, Verkuijl, Mwangi, & Kiriswa, 2003). Farm size should affect a farmer's decision of whether or not to adopt improved seed varieties because if a farm is large, then the farmer has greater opportunity to multiply his seed output and experiment with improved varieties. Whereas, if a farm is small, then it could be expected that there is less opportunity or leeway to experiment

with seed varieties (Gamba et al., 2003). Labor, including both paid household members and hired laborers, both part-time and full-time, helps farmers solve the problems associated with labor constraints. Improved seed varieties require timely performance of land preparation, as well as weeding and harvesting. Labor should have a positive effect on the adoption of improved seed varieties (Mussei et al, 2001). Irrigation should provide positive effects for the farmers who adopt improved seed varieties because the improved varieties are developed to make maximum use of water. Fertilizer can have a positive effect on a crop if it is used. Saving seed, the farmers who save and use local save will buy less other improved seed. The opposite effect is seen with farmers who purchase improved seed use less local seed. It is assumed that using improved seed will increase yield. Finally, farmers in Libya have limited money to invest in farmland and inputs. These conditions mean that farmers need the highest quality seed stock available from the most appropriate advanced varieties for Libyan conditions, but many cannot afford them.

4 The Role of an Improved Seed System in Closing the Yield Gap in Libyan Agriculture

4.1 Introduction

This chapter discusses the role of the national seed system in closing the yield gap and improving the sustainability of Libyan agriculture. The research questions for this chapter include: What is the current structure and state of the seed system? What is missing in the Libyan seed system? For wheat and barley seed, where is the genetic material originating that is proving to be the most effective in Libyan agriculture?

The chapter will start with a review of relevant literature on the Libyan seed system. It will discuss the background of the current structure and function of the Libyan seed system. Then it will review past recommendations for improvements in the Libyan seed sector. The chapter closes with new recommendations based on data and insights from the survey and analysis in the previous chapter.

4.1.1 The fundamental importance of a well-functioning seed system

Seeds provide humans with our most fundamental capacity for food production. According to FAO (2009), by 2050, the expected demand for cereals—for both animal feed and human food—may reach three billion tones. The current demand is about 2.1 billion tones. With seed being the primary agricultural input, which affects the efficiency of other inputs such as irrigation, fertilizers, and insecticides, there is a need for good genetic traits and good quality seed. Seed quality is understood by Verma, (2011) as having four main components: seed health, physical purity, genetic purity, and germinability, all of which can be improved by a well-functioning seed system in order to adapt to the environment and enhance production, regardless

of the genetic profile contained in the seed. Developing varieties that have superior genetic characteristics for the farmer's intended use, as well as making them available at a practical price at the time and in the location where there is the demand for seed is likewise important (Verma, 2011). Furthermore, since seeds in nature germinate based on time and location, these biological factors of reproduction and germination are among the most basic seed characteristics essential to the genetic package. Genetic characteristics are an essential part of seed selection and production, in order to have a high quality seed available to farmers while minimizing costs, either environmental or economic.

Improved seeds often benefit from purchased inputs such as fertilizer, herbicide, pesticide, and irrigation of water in order to maximize seed genetic potential. Fertilizer application could be used to maximize yield, and even help with enhancing the physical characters of the harvested product (Verma, 2011). Well managed irrigation and drainage serves as another important mechanism for improving seed performance because poor seed germination is often caused by the extremes of dry conditions or excess water. Irrigation management, of course, depends on soil type, weather conditions, and the timing of crop production. Pest control combats the effect of insect pests or diseases that may compromise seed quality and crop yields. Seed treatments can help improve quality and control infestation by providing the right fertilizer or pest control product directly at the locus of seed germination (Verma, 2011).

Even when a farmer uses a good quality seed with favorable characteristics and/or improvements, still the seeds might not increase yields or might not adapt to the desired conditions. Also, a good quality seed cannot overcome inadequate seed storage. It is necessary for seed to be stored at an ideal temperature range (21° C – 27° C) for instance, to protect seed from fungi and insect infection (Harrington and Douglas, 1970).

Seed certification is another significant agronomic principle that improves yields with high quality seeds. Seed certification involves various processes of seed quality control by overseeing seed production and multiplication, as well as determining whether the seed reaches certain seed standards (Verma, 2011).

4.1.2 National Seed Systems: Formal and Informal Sectors

A national seed system can be thought of as a set of organizations with, “an outline of measures to be implemented and activities to be carried out to secure timely production and supply of seeds of prescribed quality in the required quantity” for the nation’s farmers (Feistritzer and Kelly, 1978). A national seed system provides the interface between domestic and international seed development and management activities—including the conservation and collection of germplasm, breeding and improvement of varieties, and distribution of quality seed to farmers—incorporating international agreements into the practices of local seed industries.

According to van Amstel, Bottema, Sidik, and van Santen (1996), the seed system can be defined as “the sum of physical, organizational and institutional components, their actions and interactions that determine seed supply and use, in quantitative and qualitative terms.” Broadly speaking, there are two primary seed supply sectors, known as the formal and informal seed supply systems. The difference between formal and informal sectors can be seen in Bishaw’s (2004) example of a farmer who adopts improved seed varieties from a public sector seed program, while still saving his own seeds to harvest for next year, which is the informal sector.

The formal seed system encompasses the public seed system, in which there are seed certification and quality control public services, which are generally provided by the public sector, as well as the commercial production and sale of seeds, which are generally done by private enterprises. According to Almekinders and Louette (2000), the formal sector can also

include formal ‘farmers’ or ‘local’ seed organizations or associations. One specific service offered by the formal seed system includes seed processing and multiplication, which is described by Bishaw (2004) as those processes that provide clean, certified seeds of good quality to farmers. Almekinders and Louette (2000) discussed the achievements in developing countries in “high potential yield areas” creating formal sectors to diffuse and develop improved varieties, while having less success doing so in “low potential yield areas,” with complex soil and climate conditions.

The informal seed system is mainly comprised of farmers who save their own seeds, which are often locally adapted landrace varieties, and potentially selling or bartering a portion of that saved seed locally. According to Pionetti (2006), farmers maintain the actual yield of their crops by adopting farming practices that coincide with local conditions and their economic objectives as producers or households. Reasons why farmers save specific varieties of seeds include ensuring current and future diversity in crops and subsistence foods, gaining seed capital, and maintaining seed characteristics that meet specific needs (Pionetti, 2006). Human and environmental forces—specific to the farming system and the location—interact to shape the local seed supply and its specific characteristics. According to Almekinders and Louette (2000), the informal sector is based on farmer selection, in which seed is chosen for its full suite of characteristics and performance in planting, harvest, storage, and re-production of seed.

4.2 The Seed System in Libya

In Libya, the frequent use of low quality seed is a major contributing factor to the low productivity of some agricultural crops. In regards to trying to improve the productivity for both formal and informal sectors, one of the sector priorities is to use more productive seeds adapted to the local environment. All of Libyan society—including the agricultural sector as well as

consumers—would directly benefit from better resource management and increased productivity resulting from improved seeds and seed system. The seed system in Libya involves both the public and the private sectors, with input from international organizations.

4.2.1 The Public Sector's Dominant Role in the Seed System in Libya

As early as the 1950s, the Libyan government created plans to improve and increase crop seeds in the Tripolitania region. In 1958, the government started education for farmers, teaching them the importance of handling and growing seeds properly (Majbari, 2009). Also in 1958, a national committee was formed to improve seed production. The intent of the plan was for seeds to be produced in the Fezzan region of Libya. In the same period, experiments began to produce seed in the eastern region of Libya (Al-Shreidi and Sbith, 2009).

In 1960, the Ministry of Agriculture purchased high quality wheat and barley grain and distributed it as improved seed to farmers. Beginning in 1964, farmers were required to label their seed sacks with information about purity and germination percent (Majbari, 2009). In 1966, the government began inspecting private farms to verify seed quality (Majbari, 2009). In the 1970s, numerous government agricultural settlement projects were constructed to improve productivity and to grow seeds and seedlings, such as cereal and fodder crops, in areas of permanent irrigation in the eastern area and in the south desert area of Fezzan. These two projects covered an area of approximately 40 hectares. Projects also were started in supplementary irrigation areas and in the Green Mountain coastal areas that have above average precipitation rates. Public projects were responsible for seed breeding and seed production to provide for the needs of the private sector, which included farmers and feed breeders in each production area of the country (Al-Shreidi and Sbith, 2009).

The ARC is a national organization under the Ministry of Agriculture that was created in the mid-1970s to provide technical assistance for agricultural development and research. At the time of its creation, the public sector had failed to properly manage the agricultural sector, which created massive problems and became a source of debt for the government. The center encouraged the private sector to play a larger role in marketing and processing. The center also has attempted to open up the agricultural sector to international markets, to strengthen and establish quality control and health standards, and to enforce their implementation (Arhama, 2013). According to Al-Shreidi and Sbith (2009), ARC has more recently received very little encouragement from the Libyan government for agricultural research, and there is a lack of stability in the ARC interactions with international organizations.

By the late 1990s, Libya was importing seed at a cost of about 15 million dinar annually. In 1998, a law was passed prohibiting the import of seed, which created a shortage of seed as well as increased illegal purchase of seed. In 1998, the National Center for Improved Seed Production (NCISP) was established, as part of a government formulated strategy to reduce seed imports and increase domestic seed production. NCISP began operations in 1999 with three farms for seed production (WANA Seed Network, 2007).

During the agricultural season of 1999/2000, NCISP started to improve seed production activity for major winter cereal crops of soft and hard wheat and barley, as well as summer crops, such as forage crop grasses, oats, and corn (Al-Shreidi and Sbith, 2009). In 2005, a National Committee for Variety Registration and Seed Certification was established to compile a catalog of all cereal and vegetable varieties marketed in Libya (Al-Shreidi, 2010). In 2007, the Seed Producers Society (SPS) was established. Its members are farmers in major seed production areas of the country who have contractual agreements with the NCISP (Al-Shreidi, 2010). In 2007,

NCISP explored alternative seed production arrangements to meet growing demand within Libya (Al-Shreidi, 2010). In 2009, Libya needed 25,000 tons of seed. NCISP provided more than 80% of Libya's need for improved wheat, oat, and barley seed (Al-Shreidi and Sbith, 2009).

The government has imported varieties of seeds for various reasons: the results of research, the recommendations of expert technical committees, the experiences of countries that have similar conditions, or the results of experiments carried out by foreign companies implementing agricultural projects. One result of importing seeds, however, has been deterioration of the seed varieties within Libya because of the effective absence of a responsible government agency to monitor the propagation methods and because of the lack of scientific verification of specific varieties. Given that purity of Libyan seed stock has deteriorated, it became imperative to continue the import of seed (Al-Shreidi and Sbith, 2009).

4.2.2 International Organizations Working with the Libyan Seed System

In the course of these domestic developments of the public sector, at least two major international organizations have been working with or within the Libyan national seed system. The most important organization working in Libya is the FAO, which has proposed plans to promote the development of a private seed industry. The FAO's first step in promoting the industry is to strengthen Libya's NCISP and the ARC. ICARDA also has a connections with Libya in their work to build better seed systems, largely with NCISP and ARC.

4.2.2.1 Food and Agricultural Organization (FAO)

As an organization within the United Nations, the FAO focuses on making agriculture more sustainable, reducing rural poverty, and helping create efficient food systems. In 1952, an agreement was made between the Libyan government and the FAO of the United Nations that started introducing seed technical assistance, increasing industry communication, and improving

seed production (Majbari, 2009). According to Al-Shreidi and Sbith (2009), the agreement was targeted especially for seeds for fodder (oats, sorghum, and alfalfa) and cereal (wheat and barley). In 1955, FAO created a plan to produce seed in different locations in the western region of Libya at farms belonging to the government.

But it was not until 2002 that an FAO office in Libya was established (FAO, 2011) and helps Libya with seed management by developing seed and breeding systems. FAO has set up infrastructure for germplasm information management, has established the foundation for a massive seed propagation program, has ensured sustainability of seed production activities, and has created seed quality control procedures.

In May 2005, FAO made excellent progress on their Technical Assistance Project in the following areas: plant genetic resources; plant breeding and nucleus seed production; variety release mechanism and seed certification; seed production and processing; and matching experts with farmers for training. As a result of this program, a system was created to collect and analyze farm data, develop efficient indicators, bring forth an electronic planning model for economic analysis, and help design future governmental policies, as well as allow the availability of electronic data for public use by projects and researchers.

Libya began a contract in 2010 with the FAO to improve wheat and barley grain in Libya, with the understanding that FAO would begin work in 2011 and complete the work in 2014. However, this work was never even begun because of conflict in Libya. Despite important plans, FAO has been unable to work in a stable manner with the Libyan Agricultural Ministry because of the the civil war started in 2011 with the overthrow of Ghaddafi, the NATO-led bombing with several no-fly zones created over Libya, and the political and civil conflict that continues to the present.

4.2.2.2 International Center for Agricultural Research in Dry Areas (ICARDA)

The International Center for Agricultural Research in Dry Areas (ICARDA) was established in 1977 becoming one of fifteen research centers around the world supported by the Consultative Group on International Agricultural Research (CGIAR). ICARDA works on improving land management, diversifying production systems, and creating better crop and livestock products.

ICARDA has worked closely with the ARC of the Libyan Ministry of Agriculture, since the early 1980s. This partnership has resulted in improved germplasm of cereal and legume crops, training of Libyan researchers, and coordination of donor-supported regional projects. Currently, three major projects are underway to further their objectives. The projects were started in 2010 and are intended to last five years. These projects are geared to the three different agricultural regions in Libya and have a total budget of about nine million U.S. dollars. The four stated objectives for these projects are: 1) determine the types and extent of different agro-ecologies of wheat and barley-based systems; 2) determine the productivity constraints for wheat and barley including physical, biological, managerial and socio-economic factors; 3) use a participatory approach with farmers and other stakeholders to devise, develop and test potential options to alleviate those constraints and improve crop productivity and profitability while conserving natural resources; and 4) build and improve the technical and organizational capacities of researchers and farmers in the target areas (ARC Libya-ICARDA Collaborative Program, 2010b).

4.2.3 The Private Sector's Uncertain Role in the Libyan Seed System

Today, the Libyan private seed business—as with private businesses in general—are in their infancy. For much of the Gadhafi regime, private businesses were actively discouraged. The

economy was almost entirely dependent on oil revenues and public sector institutions. In 2006 for instance, about 90% of Libyan export income was derived from oil. When seed production was ramped up in 1999, this was done through government organizations rather than private industry. Given that the seed system has been dominated by the government and has been the main point of contact with international organizations as well, the role of the private sector has been small and unstable, despite a couple of attempts to develop a private seed industry.

In 1975, the Libyan Romanian Company (LRC) was established for the purposes of starting a seed industry, transferring seed technology, and creating seed breeding farms in the western area (Al-Shreidi and Sbith, 2009). The LRC was terminated in 1991 when sanctions were imposed on Libya. At that time, the Libyan authorities contracted with Morocco to produce seed and to train Libyans in agricultural practices. The Saujet Company of Morocco raised varieties of barley, as well as hard and soft wheat for evaluation and breeding (Al-Shreidi and Sbith). The contract lasted only three years. Although farmers used their own seed, especially wheat and barley, production yields were far too little to meet the country's demand.

The dominant local seed company in place before the 2011 revolution was Zabtia, which had been working with Dutch seed companies. When Gadhafi was killed in 2011 during the NATO-led bombing of the country, the entire national political structure was shaken to its core and many aspects of society began to change. The process of change is still very active in Libya, and the end results are unknown. The lack of control and regulation has opened up opportunities for private businesses to operate freely. However, due to decades of government control, very few national businesses are capable of taking the lead. Under these conditions, international businesses have moved in and dominated some sectors. Due to the political upheaval, it is extremely difficult to get accurate and up-to-date information about Libya. Even though the

revolution has ended, it has been impossible to determine Zabtia's current situation because of the ongoing civil war.

4.3 General Recommendations for Improving Seed Systems in Developing Countries

There are many common problems in seed systems that need to be addressed throughout all developing countries, such as: (1) the limited availability for private companies to obtain public breeding materials and varieties; (2) insufficient legislation to protect the rights of the plant breeders, which limits local seed company investment and involvement; (3) inefficient seed laws and regulations; and (4) a lack of complementary inputs, such as fertilizer and pesticides (Stanelle, 2013).

Seed systems in developing countries have both weaknesses and strengths. Weaknesses include the lack of seed technology, the lack of modern varieties of seeds, inequity of access and seed diffusion, and lack of knowledge of how to employ modern technology. Despite these weaknesses, the informal sector shows strengths in local adaptation of local varieties, with appropriate genetic combinations, as well as crucial knowledge of local conditions. The formal sector often has weaknesses of inadequate or untimely supplies of improved varieties, limited selection of locally adapted improved varieties, and a lack of diversity of varieties. However, under the right conditions the formal seed system can provide good seed technology, with modern varieties and advanced knowledge of modern technology (Almekinders, 2000).

After decades of strict government control and inconsistent policies, Libya's seed system is in need of a major overhaul. The country is not the first to experience decades of strict control followed rapidly by almost no control at all. Many of the former Soviet republics experienced something similar after the rapid fall of communism in those countries. For this reason, current

literature and recommendations for these countries is helpful for Libya, as well as recent work done in Pakistan, Cambodia, and Bangladesh, to the extent that these are also developing countries with comparable political, social, economic, and ecological conditions. What follows are a number of recommendations from the reviewed literature that directly relate to Libya.

These needs are organized into the following four sections: (1) Varieties Registration, Certification, and Labeling; (2) Farmer Engagement and Education; (3) Plant Breeders' Rights and other Private Sector Incentives; and (4) Better Coordination of the Roles of the Public and Private Sectors.

4.3.1 Variety Registration, Testing, Certification, and Labeling

First and most fundamentally, it is crucial for developing countries with an immature seed system to establish a variety registration, with testing and certification, and accurate labeling of seeds. A seed law and seed regulatory system should ultimately provide “truth in labeling” so farmers can read the seed bag labels and understand the quality of the genetic inputs that they are buying for their farming operation. The labels should be an accurate portrayal of the seed inside the bag. A variety registration list shows what is being used, and ultimately serves to maintain knowledge of variety characteristics to establish a baseline against which to analyze future changes. Seed law enforcement designed to protect farmers should require seed sellers to label appropriately and should randomly test their seeds for accuracy.

Testing is an important capacity for developing countries to establish. Developing countries should be able to analyze and assess the quality of varieties being imported and sold by the private sector. Developing countries should improve the inspection of certified seeds in order to improve the system's efficiency. Testing facilities should include capacity for conducting field trials, to see how a variety works in the field, to see how the seed performs under actual farming

conditions, to see if it makes positive contributions to production results (including yield levels). The germination of seed should also be tested, to establish seed quality. Overall, variety testing is a crucial part of understanding varieties' susceptibility to diseases, pests, and other problems that may result when growing those varieties within a country or region.

After testing, the next step in seed certification is to monitor and control seed varieties via a timely and rigorous certification system. Any certification program should reflect genetic improvements to enable the partners—such as the government, the seed producers, and in particular the farmer—to have knowledge or make recommendations of the most appropriate seeds for a particular farm. This overall program of quality and production monitoring, through test sampling and field inspections, combined with education, can encourage major improvements in a seed certification program in a country like Libya, that currently lacks some of the elements of a basic seed system due to high imports and years of political turmoil.

4.3.2 Farmer Engagement and Education

One of the most important and recurring recommendations in the literature is for better farmer engagement and education. Seed producers and suppliers should educate farmers on how to select the best quality seed for their needs and provide a transparent seed production program that will engage farmers, including advising on production techniques that will produce the highest yielding results. Past recommendations also include the need for qualification standards that would assist in maintaining certification experts, which is essential to developing a better seed system.

According to Stanelle (2013), recommendations for Pakistan included the following:

“Empowering the farmer and seed buyers with better information and enable the market chain to provide the seed products and services they need in order to produce high yields.

Use of demonstration plots and farmer field days to show the value of the seed, provide for extension training of the farmers, establish a communication between the farmers and the other members of the seed supply chain all the way up to the plant breeders so that seed products being developed met the local farmer needs.” (p. 4).

All of these recommendations are certainly relevant to Libya as well.

Stanelle’s (2000) recommendations for the Kosovo are also relevant to Libya. In Kosovo, work did not get started on time because directors and staff did not have enough knowledge about the activities they must perform as part of their jobs. Stanelle (2000) foresaw the need to look at how to train the employees and board members, tailoring the training to what was needed within that country. Since such associations were new to Kosovo, the people working there knew little about how such organizations must work to be successful, or how to delegate tasks to people in a manner that will allow the development of seed production to go smoothly.

4.3.3 Plant Breeders’ Rights (PBRs) as Private Sector Incentives

Plant breeders should also have rights to protect their varieties, as breeders may be reluctant to enter into business in a country that does not take a stand on this issue. Lack of breeder rights prevent the best and newest varieties from reaching the country (Stanelle & Solieng, 2010). Libya currently does not have any plant breeder rights laws. Providing these laws might encourage private sector investment in the Libyan seed system.

4.3.4 Better Coordination of the Roles of the Public and Private Sectors

Overall, with the right sorts of collaboration, support, and knowledge, both public and private sector players in the seed system could improve in their respective roles in developing and maintaining seeds for a more sustainable agriculture.

But this is often difficult to achieve. For example, as private seed companies in Pakistan were becoming increasingly accepted within the market, the attitudes and policies of the public

sector impeded those private companies and prevented them from receiving equal opportunity; policies and market regulations favored the public sector organizations (Stanelle, 2013).

Furthermore, in many developing countries, there are protective practices, involving political, social, and economic dimensions that may actively hinder international seed companies from entering those national markets. In such cases, when an international company attempts to enter a national seed variety registration program, the company may be met with strong resistance, sometimes in the name of cultural values, that can strongly influence the development of their market positions. Without understanding local values, cultures, and economics, outside companies can face difficulties in the importation and sale of new varieties of seeds (Stanelle, 2013).

Since the current seed system in many developing countries depends more on the public sector than the private sector, the public and private sectors need to actively work together for a better system. A better system can be achieved by bringing both public and private together to make progress with sales and distribution that enhances the farmer's ability to obtain the desired seeds, and more international community involvement (Stanelle, 2013). This requires a change in the attitudes and policies of both public sector and private sector partners.

4.4 A Path Forward for the Libyan Seed System: Conclusions and Recommendations from the Current Study

From the information compiled about the Libyan agricultural system as well as the survey conducted in the current study, the following observations can be made:

In Libya, barley is grown on more area but yields are significantly lower than wheat. This is consistent with the lower income of surveyed farmers growing barley, most commonly with minimal inputs for their own subsistence use, particularly to feed livestock. In fact, this study

finds minimal inputs are used by Libyan farmers on both wheat and barley, but especially in rainfed barley production systems. Those farmers who are highly dependent on irrigation are at risk of reductions in available water in coming years, especially those that use water from the Great Manmade River (GMR) project. Therefore, seed likely to be of interest to Libyan farmers will be drought tolerant or water-use efficient varieties with low input requirements, to maintain stable, albeit lower yields than global averages.

According to results of this survey, the Libyan government does not directly support private farmers through subsidies. Thus, the introduction of well-designed production or input subsidies might help farmers move away from their current input-cost-minimization strategies and begin using more improved varieties as well as complementary inputs. It may also help improve collaboration among farmers.

According to survey results, a substantial number of Libyan farmers with higher education were among those more likely to use improved seeds. This suggests that increasing agricultural education or increasing outreach designed to appeal to educated farmers will likely increase improved seed adoption. It also suggests that educated farmers could be relied upon to play a role in improving the seed system.

Increased availability of improved varieties may lead to declining farmer interest in saving local landrace (*mahale*) seeds, which could lead to the loss of these varieties in the future. Engaging farmers to save local varieties could be a reason for creating local seed organizations that can do this in addition to testing, certifying seed, and more.

Finally, since the uprising in 2011 and the NATO-led bombing, the entire national political and economic structure has been shaken and many aspects of society have changed,

with the end results still uncertain. The lack of effective regulation after decades of government control has created an extremely difficult environment in which to operate.

From these observations, several concluding recommendations and goals can be made for the Libyan seed system:

- The creation of farmer organizations in Libya can serve as a foundation and framework for plant breeding and seed dissemination activities, during the current time of political and social transition. Still, such farmer organizations should work with the Ministry of Agriculture as well as ARC and the Seed Centers of the Ministry of Agriculture. The Ministry of Agriculture should continue to serve as the point of contact with ICARDA and FAO and help support breeding programs for commodities and regions that private seed companies do not.
- The Libyan farmer organizations can cooperate directly with farmer organizations in neighboring countries, such as Tunisia, with similar environmental conditions and thus seed requirements as Libya. This networked structure could make it easier in some ways to improve and distribute seeds.
- Breeding goals for Libya's seed system should include: (1) Create an adaptive breeding program for ultra-hardiness of wheat and barley varieties; (2) Draw upon local landrace ('mahale') varieties for their genetic adaptation to the region, both to preserve crop biodiversity they embody and to improve them; (3) Not necessarily attain top yield, but develop varieties that that effectively produce under actual field conditions rather than idealized lab conditions.

In conclusion, Libya has been under strict control for almost half a century until very recently. In implementing any future changes in the agricultural sector, it is important to consider

the old agricultural system and seed system structure, in order to determine what works and what does not in the existing system. It is important to understand the positives and negatives within the Libyan seed system before transitioning into a new system. Change needs to come gradually and deliberately to establish trust between those who will be implementing the changes and those who will continue to follow the old ways, (i.e., traditional farmers). Starting with the old structure as a framework for change is a safe place to begin.

The political structure will be the first step in forming a successful seed system with support from the international communities. Within the Gadhafi regime, the Libyan government often created unpredictable policies toward the international companies that were doing business in Libya. The international sanctions from the United Nations and the United States were a large part of the reason Libya was not able to participate in more seed system programs. Since the sanctions have been lifted now, perhaps the new Libyan government will actively participate, giving the seed system a chance to develop and grow. The only hopeful opportunity for a productive seed system to overcome the instability that exists today is if the various segments of politics and society can settle their different ways of thinking.

5 Summary and Conclusions

This brief concluding section contains a review of what was learned in each chapter of this study. The chapter also contains a discussion of the limitations of the study as well as recommendations for future follow-up studies.

5.1 Summary of Chapter 1

Chapter one presented literature that reviewed challenges to the sustainability of agriculture in Libya. The chapter included challenges to sustainable agriculture both globally and in Libya, a literature review on sustainability in agriculture and economic development, and an overview of Libya and its economy. The last part reviewed Libyan agriculture and sustainability challenges in Libyan agriculture. It was learned from this chapter that Libya has many agriculture problems and issues that need to be addressed, such as: poor water management, negative impacts from the “Great Man-made River”, desertification from urbanization, high volume imports of food - wheat and barley especially, low agricultural productivity from low yields and poor seed management, lack of research transfer/education, and weak linkage between sectors. This lack of education was seen in agricultural inputs, lack of understanding about the dangers associated with fertilizer and pesticide use, and climate change impacts.

5.2 Summary of Chapter 2

Chapter 2 presented the meaning of yield gap, how it is measured, the fact that Libya has a larger yield gap than its neighbors, and the importance of closing this gap. Libya is one the most important wheat importing countries in the world. Additionally, the primary factor contributing to yield gap that was researched was found to be seed varieties, which is covered in Chapter 4. Better seed is the primary way to reduce yield gap but very little literature exists for Libya and farmers closing the yield gap by choices in technology, management, and seeds.

5.3 Summary of Chapter 3

Chapter 3 contained a discussion of the research methodology of this study as well as the results of surveying 136 Libyan farmers. Data provided details on farmer choices by asking them many questions such as: why farmers grow wheat and barley instead of grow other crops? Which wheat and barley varieties do farmers grow in Libya? Where did they originate, Do farmers save seed? If so, which farmers save seed? These results were analyzed to find the economic, environmental, and cultural /historical factors for these choices and then results were analyzed to look at farmer adoption of improved wheat and barley varieties in 2013. The farmers chose these varieties because they believe they make better yield in their famers. The statistically significant factors found to affect and/or were associated with farmers' adoption of improved wheat and barley varieties were: education, farm size, labor, irrigation, fertilizer, and saving seed.

5.4 Summary of Chapter 4

Chapter 4 reviewed the seed system literature, overviewed the current structure and function of the Libyan seed system, and looked at organizations working with Libyan seed systems. This chapter also included recommendations were specifically learned from this study, such as variety Registration, testing, certification, and Labeling, Farmer Engagement and Education, Plant Breeders' Rights (PBRs) and other private sector incentives which could substantially help to close the yield gap in the country.

5.5 Limitations of this Study

As with any study, this study had its limitations. The primary issue while conducting this study was the state of civil war in Libya at the time of data collection, making collection difficult and dangerous. This lead to issues of insufficient data. Additionally, government instability possibly created apprehension for farmer participation. Also, since there was not government at

the time, there was no government support forthcoming for this study in any way. Due to the civil war, data could not be obtained from the western half of the country. It was attempted but was simply too dangerous to risk. This additional data would have increased the participant count, which could have helped create more significant correlations and may have changed the results with western farmers' opinions. Some farmers did not answer all questions, or understand all questions, leading to possible unintended responses. Assistants collected data rather than the author herself; this could potentially have made a difference in farmer's responses. Lastly, the potential yield data was not available, therefore the original intent to measure yield gap in Libya was ultimately not possible.

5.6 Recommendations for Future Studies

Future follow-up studies may want to consider the following recommendations:

1. Reduce the number of questions to save time for farmers, which may lead to more participants.
2. Make sure units of measurement are clear so that farmers will have no misunderstandings.
3. Distribute to more farmers, particularly in the west, which may make more results statistically significant.
4. Some questions could be worded more clearly to avoid any confusion.
5. Future studies would benefit to work with some organization within the country (FAO, etc.), which may open up more access and data.

6. Another interesting area of pursuit would be to look at the laboratories testing seed quality.
7. If possible, giving farmers some type of compensation for answering surveys would likely encourage more of them to participate.
8. Lastly, local organizations could work to inform farmer members through channels such as the internet or phone by using SMS.

5.7 Final Conclusions

In conclusion, Libya has many reasons to make progress toward sustainable agriculture and many ways to improve. According to Gadhafi's disposed regime, Libya has many goals for agricultural development, these goals included: increase production with efficiency to create food security; better management of natural resources, such as water management and soil conservation and reclamation; increase agriculture's contribution to the GDP (diversification of economy); create jobs in the farming sector; provide a good infrastructure in the unpopulated areas of the country to encourage people to live there and create a better balance; find good sources of industrial materials and inputs, such as seeds, genetics, and other agricultural technologies, that are used by agriculture; and improve management of the water supply, roads, and electricity to minimize agricultural production interruptions (Government of the Libyan Arab Jamahiriya, 2006). All of these goals are still necessary to address after Gadhafi. Therefore, this research focused on developing a strategy for an organized seed breeding, distribution, storage and education system that functions with available resources such as pesticides, fertilizers, water, and technology. It focused on what Libya's seed system must look like in order to serve the population sustainably.

Libya faces seed production, quality and supply limitations. Due to limited technical capacities and relaxed quarantine measures, new strains of plant and animal pests and diseases have entered the country and have found their way to the farming sector. Minimal research on genetic improvement for pest resistance (public and private) has been conducted, in part, because the country lacks technical expertise in seed genetics. This has led to a monopoly of technology in the industry by some institutions and international companies.

Another major problem is the limitations of seed storage. Minimal infrastructure means there is little to no refrigeration or climate control to keep local seeds and tubers viable for the following season. Also, pest exclusion is limited, and imported seed quality decreases in poor storage conditions.

In Libya, the frequent use of low quality seed is a major contributing factor to the low productivity of most agricultural crops. In regards to trying to improve the productivity, one of the sector priorities is to use highly productive seeds adapted to the local environment. All of Libyan society would directly benefit from the program through better resource management and increased productivity. History in Libya has shown a lack of organized seed adoption to strengthen varieties that are best suited for the country's environment. As a result, the most commonly used varieties are not as effective as they could be, which has contributed to lower production and a significant yield gap relative to neighboring countries.

References

- African Economic Outlook. (2008). *Libya 2008*. Retrieved from <http://www.oecd.org/dev/emea/40578167.pdf>
- African Economic Outlook. (2012). *Libya 2012*. Retrieved from <http://www.africaneconomicoutlook.org/fileadmin/uploads/aeo/PDF/Libya%20Full%20PDF%20Country%20Note.pdf>
- Aggarwal, P. K., Hebbar, K. B., Venugopalan, M. V., Rani, S., Bala, A., Biswal, A., and Wani, S.P. (2008). Quantification of yield gaps in rain-fed rice, wheat, cotton and mustard in India. *Global Theme on Agroecosystems*, Report No. 43.
- Aggarwal, P. K., & Kalra, N. (1994). Analyzing the limitations set by climatic factors, genotype, and water and nitrogen availability on productivity of wheat. Climatically potential yields and management strategies. *Field Crops Resources*, 38, 93-103.
- Agriculture and Natural Resources Team of the UK DFID, & Pretty, J. (2004). *Agricultural sustainability*. Retrieved from <http://dfid-agriculture-consultation.nri.org/summaries/wp12.pdf>
- Al-Jibouri, H. A. (1966). *Description and distribution of wheat and barley varieties grown in Libya*. Rome, Italy: Food and Agriculture Organization of the United Nations.
- Almekinders C., & Louette, D. (2000). Almekinders, C., & de Boef, W. (Eds.). Examples of innovations in local seed systems in Mesamerica. *Encouraging diversity. Plant genetic resource conservation and crop development*. (pp. 219-222). London, UK: IT Publications.
- Al-Shreidi, A. & Sbith, A. (2009). *References study on the development and seed system in Libya*. The Research Center of Agriculture and Animals & ICARD. Personal communication.
- Al-Shreidi, A. S. (2010). Contributions from seed programs and projects. *Seed Info: Official Newsletter of the WANA Seed Network*, 38, 9-12. Aleppo, Syria: WANA Seed Network Secretariat.
- Arab Organization for Agriculture Development (AOAD). (1994). *Agricultural policies in the eighties held in Libya*. Personal communication in Arabic.
- ARC Libya-ICARDA Collaborative Program. (2010a). *Highlights on major achievements*. Personal communication.
- ARC Libya-ICARDA Collaborative Program. (2010c). *Integrated improvement of wheat and barley-based cropping systems in rainfed and irrigated areas of Libya*. Personal communication.

- Arhama, A. (2013). *National medium-term investment programme*. Unpublished presentation. Personal communication.
- Arhama, A. (2015a). *General authority for cereal production, committee for seed registration, Tripoli, Libya*. Unpublished in Arabic. Personal communication.
- Arhama, A. (2015b). Personal communication, 2015 April.
- Asylum Research Consultancy. (2013). *Libya Country Report*. Commissioned by the Office of the United Nations High Commissioner for Refugees (UNHCR), Division of International Protection. Retrieved from <http://www.refworld.org/pdfid/51de77c24.pdf>
- Barnett, V., Payne, R., & Steiner, R. (Eds.). (1995). *Agricultural sustainability: Economic, environmental and statistical considerations*. Chichester: Wiley.
- Beddow, J. M., Hurley, T. M., Pardey, P. G., & Alston, J. M. (2013). *Rethinking yield gaps*. Unpublished manuscript submitted for publication.
- Bishaw, Z. (2004). *Wheat and barley seed system in Ethiopia and Syria*. (Doctoral dissertation, Wageningen University, The Netherlands). ISBN: 90-8504-035-3.
- Cassman, K. G. (1999). Ecological intensification of cereal production systems: Yield potential, soil quality, and precision agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, 96, 5952–5959. Retrieved from <http://www.pnas.org/content/96/11/5952.full.pdf+html>
- Cassman, K. G., Doermann, A., & Walters, D. T. (2002). Agroecosystems, nitrogen-use efficiency, and nitrogen management. *Ambio*, 31, 132-140.
- Chouikhi, H., Jbir, R., & Boujelbene, Y. (2011). The role of oil price in an exporting country: An empirical study of the Libyan economy. *The Journal of Energy and Development*, 34, 1-186.
- Combaz, E. (2014). *Political economy of Libya after the Qadhafi regime*. GSDRC: Applied Knowledge Services. Retrieved from www.gsdr.org
- Commission on Public Information Libya Tripoli. (2007). *The final results of the agricultural census 2007*. Personal communication in Arabic.
- Davidson, R., & MacKinnon, J. G. (1995). Estimation and inference in econometrics. *Econometric Theory*, 11, 631- 635.
- Dawe, N. K., & Ryan, K. L. (2003). The faulty three-legged-stool model of sustainable development. *Conservation Biology*, 17(5), 1458-1460.
- Desjardins, R. L. (2009). *The impact of agriculture on climate change*. Agriculture and Agri-Food Canada , Ottawa , Ontario.

- Dynesius, M., & Nilsson, C. (1994). Fragmentation and flow regulation of river systems in the northern third of the world. *Science*, 266, 753-762.
- Eastern Mediterranean Regional Health Systems Observatory. (2007). *Health Systems Profile - Libya*. World Health Organization. Retrieved from <http://apps.who.int/medicinedocs/documents/s17302e/s17302e.pdf>
- El-Msalati, N. (2012). *An analytical study for efficiency of cereals crop production in EL-Cabal EL-Akhdar region, in Libyan Jamahiriya*. (Doctoral dissertation, Alexandria University). Personal communication.
- El-Tantawi, A. M. M. (2005). *Climate change in Libya and desertification of Jifara Plain: Using geographical information system and remote sensing techniques*. (Published Doctoral dissertation, Johannes Gutenberg-Universität, Mainz). Retrieved from <http://ubm.opus.hbz-nrw.de/volltexte/2005/794/pdf/diss.pdf>
- Evans, L. T., & Fischer, R. A. (1999). Yield potential: Its definition, measurement, and significance. *Crop Science Society of America*, 39(6),1544-1551.
- FAO. (2004). *Rice and narrowing the yield gap*. International Year of Rice 2004. Food and Agriculture Organization of the United Nations. Retrieved from <http://www.fao.org/rice2004/en/f-sheet/factsheet5.pdf>
- FAO. (2008). *Water for agriculture and energy in Africa: The challenges of climate change*. Retrieved from <http://www.fao.org/docrep/014/i2345e/i2345e.pdf>
- FAO. (2009). *Global agriculture towards 2050*. High level expert forum – How to Feed the World in 2050. Retrieved from http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf
- FAO. (2011). *FAO achievements in Libya*. Rome, Italy: Publishing Policy and Support Branch, FAO.
- FAO. (2012). *Libya production potential*. Retrieved from <http://www.fao.org/ag/agp/AGPC/doc/field/Wheat/africa/libya/libyaagec.htm>
- FAO. (2013). Dutch Disease. <ftp://ftp.fao.org/docrep/fao/009/ag089e/ag089e02.pdf>
- FAO, Food and Nutrition Division. (2005). *Libyan Arab Jamahiriya nutrition profile*. Retrieved from <ftp://ftp.fao.org/es/esn/nutrition/ncp/lby.pdf>
- FAOSTAT. (2010). Statistics from 2010. Retrieved from <http://faostat3.fao.org/home/index.html>
- FAOSTAT. (2013). Statistics from 2013. Retrieved from <http://faostat3.fao.org/home/index.html>

- FAOSTAT. (2014). Statistics from 2014. Retrieved from <http://faostat3.fao.org/home/index.html>
- FAOSTAT. (2015). Statistics from 2015. Retrieved from <http://faostat3.fao.org/home/index.html>
- Feistritzer, W. P., & Kelly, A. F. (1978). FAO Plant Production Protection Bulletin No.15.
- Fermont, A., & Bonson, T. (2011). *Estimating yield of food crops grown by smallholder farmers: A review in the Uganda context*. Development Strategy and Governance Division. International Food Policy Research Institute.
- Fischer, R. A., Byerlee, D., & Edmeades, G. O. (2009). Can technology deliver on the yield challenge to 2050? *Expert Meeting on How to feed the World in 2050 Food and Agriculture Organization of the United Nations Economic and Social Development Department*. Retrieved from <http://www.fao.org/3/a-ak977e.pdf>
- Foley, J., Ramankutty, N., & Brauman, K. (2011). Solutions for a cultivated planet. *Analysis, Nature*, 478, 337-342.
- Gamba, P., Ngugi, C., Verkuijl, H., Mwangi, W., Kiriswa, F. (2003). Wheat farmers' seed management and varietal adoption in Kenya. Retrieved from <http://repository.cimmyt.org:8080/xmlui/bitstream/handle/10883/913/448317.pdf>
- General People's Committee for Agriculture and Ministry of Agriculture. (1978). *Resources of water in Libya*. Geology conference in Tripoli, Libya. Personal communication in Arabic.
- General People's Committee for Planning Economic and Ministry of Economics. (1991). *Growth of social and economy in Libya (1970-1990)*. In Arabic.
- General Planning Council Committee in Libya. (2003). *Agricultural policy in Libya*. Libya Tripoli. In Arabic.
- Gleick, P. (1993). Water and conflict: Fresh water resources and international security. *International Security*, 18, 79-112.
- Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty, J., Robinson, S., Thomas, S. M., & Toulmin, C. (2010). Food security; The challenge of feeding 9 billion people. *Science*, 327, 812.
- Goldewijk, K. K. (2004). Footprint from the past: Blueprint for the future? In R. S. DeFries, G. P. Asner, & R. A. Houghton (Eds.), *Ecosystems and land use change*, part of the Geophysical Monograph Series, 153, 203-215. Washington, DC: American Geophysical Union.
- Goodland, R. (2013). *Libya: The urgent transition to environmental sustainability*. The Environment General Authority, Tripoli. Retrieved from www.goodlandrobert.com

- Goueli, A. A. (2004). *The agriculture food challenge for North Africa and the Middle East in the new millennium*. The Global Forum on Agricultural Research. Retrieved from [http://www.egfar.org/egfar/lfm/gphi_documents/02_Region_specific_documents/B_West_Asia_and_North_Africa_\(AARINENA\)/02_Background_Documents/01_General_issues/B-1-002-B2_agriculture_food_challenge_in_WANA.pdf](http://www.egfar.org/egfar/lfm/gphi_documents/02_Region_specific_documents/B_West_Asia_and_North_Africa_(AARINENA)/02_Background_Documents/01_General_issues/B-1-002-B2_agriculture_food_challenge_in_WANA.pdf)
- Government of the Libyan Arab Jamahiriya. (2006). *Food security scheme (wheat, dates & olives, seed production)*. Personal communication.
- Griliches, Z. (1960). Hybrid corn and the economics of innovation. *Science*, 275-280.
- Harrington, J. F., & Douglas, J. E. (1970). *Seed storage and packaging*. National Seeds Corporation and Rockefeller Foundation. New Delhi, India
- Heemskerk, W., & Koopmanschap, E. (2012). *Agribusiness Development in Libya: A fact-finding mission. Project Report*. Wageningen, UR: Centre for Development Innovation.
- Heisey, P. W., Smale, M., Byerlee, D., & Souza, E. (1997). Wheat rusts and the costs of genetic diversity in the Punjab of Pakistan. *American Agriculture Economics Association*, 726-737.
- Hufbauer, G. C., Schott, J. J., Kimberly, A. E., & Oegg, B. (2008). *Economic sanctions and terrorism*. Peterson Institute for International Economics. Retrieved from http://www.iie.com/publications/papers/sanctions-iran-84-1_2006-1.pdf
- IPCC. (2001). Climate change 2001: The scientific basis. *Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK and New York, USA: Cambridge University Press.
- IPCC. (2007). Climate change 2007: The physical science basis. *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK and New York, USA: Cambridge University Press.
- Jacobs, M. (1995). Sustainable development—From broad rhetoric to local reality. Conference Proceedings from Agenda 21 in Cheshire, 1 December 1994, Cheshire County Council, Document No. 49.
- Job, E. (2006). Yield gap of rice in Alppuzha district of Kerala. *Journal of Tropical Agriculture*, 44, 88-90.
- Krysiak, F., & Krysiak, D. (2006). Sustainability with uncertain future preferences. *Environmental and Resource Economics*, 33, 511-531.
- Lafi, K. A. (2004). *Flow of resources between agriculture and industry: Try to apply the product user model in production*. (Master's Thesis in Arabic, Academy of Graduate Studies, Tripoli, Libya.)

- Lal, R., Kimble, J. M., Follett, R. F., & Cole C. V. (1998). *The potential of U.S cropland to sequester carbon and mitigate the greenhouse effect*. Boca Raton: CRC Press.
- Lansigan, F. P. (1998). Minimum data and information requirements for estimating yield gaps in crop production systems. The Asian Federation for Information Technology in Agriculture. Retrieved from http://www.afita.org/files/web_structure/20110307102312_40199/20110307102312_40199_32.pdf
- Laytimi, A. (2006). Market and trade policies for Mediterranean agriculture: The case of fruit/vegetable and olive oil. *Agricultural Situation Report-Libya*. Retrieved from <http://medfrol.maich.gr/documentation/view/reports/wp1-asr/Libya.pdf>
- Leech, N. L., Barrett, K. C., & Morgan, G. A. (2005). *SPSS for intermediate statistics: Use and interpretation*. (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.
- Licker, R., Johnston, M., Foley, J. A., Barford, C., Kucharik, C. J., Monfreda, C., & Ramankutty, N. (2010). Mind the gap: How do climate and agricultural management explain the 'yield gap' of croplands around the world? *Global Ecology and Biogeography*, 19, 769–782.
- Lobell, B. D., Cassman, G. K., & Field, B. C. (2009). Crop yield gaps: Their importance, magnitudes, and causes. *Annual Review of Environment and Resources*, 34, 179-204.
- Loucks, D. P. (2004). *The Great Man Made River in Libya: Does it make sense?* Presented at the Third Annual D. R. F. Harleman Honorary Lecture in Environmental Fluid Mechanics. Retrieved from <http://www.engr.psu.edu/ce/Divisions/Hydro/seminars/Harleman04.pdf>
- Mahdoa, M. (1998). Geography of Libyan public. Libya: Garyounis University of Benghazi. Private communication in Arabic.
- Majbari, F. A. (2009). *Review study on seed production of forage crops and range plants*. Tripoli, Libya: Agriculture Research Center.
- Margo, G., Bonning, B., & Neighbor, T. W. (2012). *Special focus on Libya – Understanding the Arab spring from inside out*. World Affairs Council Resource Packet. Retrieved from <https://www.world-affairs.org/wp-content/uploads/2012/04/Libya-cover-and-packet-final-for-web-4.2.12.pdf>
- Martin, K., Shroyer, J., Shoup, D., Olson, B., & Duncan, S. (2011). *Estimating wheat yield*. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Department of Agronomy. Retrieved from http://www.ellis.k-state.edu/docs/ag-documents/Estimating_Wheat_Yeild.pdf
- Martin, L. (2000). Costs of production of market hogs. *Western Hog Journal*, Banff Pork Seminar, 2000 Special Edition, 24.

- Matson, P. A., Naylor, R., & Ortiz-Monasterio, I. (1998). Integration of environmental, agronomic, and economic aspects of fertilizer management. *Science*, 280, 112–115.
- Mueller, N., Gerber, J. S., Johnston, M., Ray, D. K., Ramankutty, N., & Foley, J. A. (2012). Closing yield gaps through nutrient and water management. *Nature*, 490, 254–257.
- Mussei, A., Mwangi, J., Mwangi, W., Verkuil, H., Mongi, R., & Elanga, A. (2001). *Adoption of improved wheat technologies by small-scale farmers in Mbeya District, Southern Highlands, Tanzania*. International Maize and Wheat Improvement Center (CIMMYT) and the United Republic of Tanzania. Retrieved from http://ageconsearch.umn.edu/bitstream/56190/2/Mbeya_Tanzania.pdf
- National Sustainable Agriculture Coalition. (2009). *Agriculture and climate change: Impacts and opportunities at the farm level: A policy position paper*. Retrieved from http://sustainableagriculture.net/wpcontent/uploads/2008/08/nsac_climatechangepolicyper_final_2009_07_161.pdf
- NIC. (2009). *North Africa: The impact of climate change to 2030 (Selected Countries)*. Retrieved from http://livebettermagazine.com/eng/reports_studies/pdf/nic-climate2030_north_africa.pdf
- Nirmala, B., Deshmanya, J., Muthuraman, P., Meera, S. N., & Sain, M. (2009). Yield gap analysis of rice in Raichur district of Karnataka. *Karnataka Journal of Agricultural Science*, 22(1), 238-239. Retrieved from <http://14.139.155.167/test5/index.php/kjas/article/view/1520>
- Pala, M., Owieis, T., Benli, B., De Pauw, E., El Mouird, M., Karrou, M., Jamal, M., & Zencirci, N. (2011). *Assessment of wheat yield gap in the Mediterranean: Case studies from Morocco, Syria, and Turkey*. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria. Retrieved from http://geoagro.icarda.org/downloads/publications/geo/Assessment_of_wheat.pdf
- Pardey, P. G., Beddow, J. M., Hurley, T. M., Beatty, T. K. M., & Eidman, V. R. (2013). A bounds analysis of world food futures: Global agriculture through to 2050. *Australian Journal of Agricultural and Resource Economics*, 58(4): 571-589.
- Pathak, H., Ladha, J. K., Aggarwal, P. K., Peng, S., Das, S., Singh, Y., Singh, B., Kamra, S. K., Mishra, B., Sastri, A. S. R. A. S., Aggarwal, H. P., Das, D. K., & Gupta, R. K. (2003). Trends of climatic potential and on-farm yields of rice and wheat in the Indo-Gangetic Plains. *Field Crops Research*, 80, 223-234. Retrieved from www.elsevier.com/locate/fcr
- Pionetti, C. (2006). *Seed diversity in the drylands: Women and farming in south India*. Gatekeeper series, 126, 1-26. International Institute for Environment and Development. Retrieved from <http://pubs.iied.org/pdfs/14520IIED.pdf>
- Postel, S. L., Daily, G. C., & Ehrlich, P. R. (1996). Human appropriation of renewable fresh water. *Science*, 271, 785-788.

- Pratt-Nin, A., Johson, M., Magalhaes, E., You, L., Dio, X., & Chamberlin, J. (2010). *Yield gaps and potential agricultural growth in West and Central Africa*. Washington, D.C.: International Food Policy Research Institute.
- Qasem, S. (Ed.). (1988). *Food security in the Muslim world: Proceedings of the seminar on food security in the Muslim world*. Amman, Jordan: Islamic Academy of Sciences. Retrieved from <http://www.philadelphia.edu.jo/newlibrary/pdf/filee7f6f98dfb244c2e93ab5172d45776d0.pdf>
- Rabbinge, R. (1993). *The ecological background in food production*. Proceedings of the Ciba Foundation Symposium 177 on Crop Protection and Sustainable Agriculture. pp. 2–29. Chichester, UK: Wiley.
- Reynolds, M. P., Rajaram, S., & Sayre, K. D. (1999). Physiological and genetic changes of irrigated wheat in the post-green revolution period and approaches for meeting projected global demand. *Crop Sciences*, 39, 1611-1621.
- Rigby, D., Woodhouse, P., Young, T., & Burton, M. (2001). Constructing a farm level indicator of sustainable agricultural practice. *Elsevier Science, Ecological Economics*, 463-478.
- Russo, P. (2004). Policies for business in the Mediterranean countries: Great Arab popular Socialist Libyan Jamahria. Center for Administrative Innovation in the Euro-Mediterranean Region. <http://www.innovations.harvard.edu/sites/default/files/8899.pdf>
- Ruttan, V. W. (1999). The transition to agriculture sustainability. *Proceedings of the National Academy of Sciences of the United States of America*, 96, 5960-5967. Retrieved from www.pnas.org/content/96/11/5960.full
- Schneider, K., & Anderson, L. (2010). *Yield gap and productivity potential in Ethiopian agriculture: Staple grains & pulses*. Evans School Policy Analysis and Research (EPAR) No 98.
- Seckler, D., Barker, R., & Amarasinghe, U. (1999). Water scarcity in the twenty-first century. *International Journal of Water Resources Development*, 15, 29-42.
- Shalluf, F., & Fares, A. (2003). *Food security between development of political and investigation of food security in Libya*. Garyounis University, Benghazi, Libya. Personal communication in Arabic.
- Singh, P., Vijaya, D., Chinh, N. T., Pongkanjana, A., Prasad, K. S., Srinivas, K., & Wani, S. P. (2006). Potential productivity and yield gap of selected crops in the rainfed regions of India, Thailand, and Vietnam. Natural Resource Management Program Report no. 5. International Crops Research Institute for the Semi-Arid Tropics. *SAT eJournal*, 2(1), 1-32. Retrieved from ejournal.icrisat.org
- Smale, M., Bellon, M. R., & Pirigali, P. L. (2000). Farmers, gene banks, and crop breeding: Introduction and overview. In M. Smale (Ed.), *Farmers, gene banks and crop breeding*:

- Economic analyses of diversity in wheat, maize, and rice* (pp. 3-18). Boston: Kluwer Academic Publishers.
- Smale, M., Hartell, J., Heisey, P. W., & Senauer, B. (1998). The contribution of genetic resources and diversity to wheat productivity: A case from the Punjab of Pakistan. In M. Smale (Ed.), *Farmers, gene banks and crop breeding: Economic analyses of diversity in wheat, maize, and rice* (pp. 145-158). Boston: Kluwer Academic Publishers.
- Stanelle, J. (2000). Report of the Consultancy for association training and development of the Kosovo Seed Production System. Prepared for *International Fertilizer Development Center (IFDC)* and *Kosovo Emergency Agri-Inputs Project (KEAP)*. Personal communication.
- Stanelle, J. (2013). Streamlining for a demand driven seed sector in Pakistan. Unpublished manuscript.
- Stanelle, J., & Solieng, M. (2010). Cambodia seed sector overview. Prepared for Mr. Pavvo Eliste for the *Development of the Community Based Agricultural Productivity Project* and *The World Bank*. Personal communication.
- Tilman, D. K. G., Cassman, P. A., Matson, R. N., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature*, *418*, 671-677.
- United Nations, Department of Economic and Social Affairs, Population Division. (2013). *World population prospects: The 2012 revision: Volume II: Demographic Profiles*. Retrieved from http://esa.un.org/wpp/Documentation/pdf/WPP2012_Volume-II-Demographic-Profiles.pdf
- van Amstel, H., Bottema, J.W.T., Sidik, M., & van Santen, C.E. (Eds.). (1996). *Integrating seed systems for annual food crops: Proceedings from a Workshop, 24- 27 Oct 1995, Malang, Indonesia*. Bogor, Indonesia: CGPRT Center.
- van Ittersum, M. K., Cassman, K. G., Grassini, P., Wolf, J., Tittonell, P., & Hochman, Z. (2013). Yield gap analysis with local to global relevance – A review. *Field Crops Research*, *143*, 4–17.
- Verma, O. P. (2011). *Seed production techniques of major crops*. Delhi: Data Publishing House.
- WANA Seed Network. (2007). *Role of NCISP in seed production in Libya*. Seed Info: Official Newsletter of the WANA Seed Network, 33. Retrieved from <http://www.icarda.org/News/Seed>
- WCED. (1987). *Report of the World Commission on Environment and Development: Our common future*. Retrieved from <http://www.un-documents.net/our-common-future.pdf>
- WFP, & FAO. (2011). *Food Security in Libya -An Overview*. Working paper from WFP and FAO. Retrieved from <http://documents.wfp.org/stellent/groups/public/documents/ena/wfp234964.pdf>

- Wheat Atlas. (2015). Released wheat varieties database. Retrieved from <http://wheatatlas.org/country/varieties>
- Wheida, E., & Verhoeven, R. (2007). An alternative solution of the water shortage problem in Libya. *Water Resources Management*, 21, 961-982. Retrieved from <http://link.springer.com/article/10.1007%2Fs11269-006-9067-6>
- Whitmarsh, D., & Palmieri, M. G. (2008). Aquaculture in the Coastal Zone: Pressures, Interactions and Externalities. In M. Holmer, K. Black, C. M. Duarte, N. Marba, I. Karakassis (Eds.) *Aquaculture in the ecosystem* (pp. 251-270). Berlin, Germany: Springer Science + Business Media B. V.
- Wolf, J., & Vandiepen, C. A. (1995). Effects of climate change on grain maize yield potential in the European Community. *Climatic Change*, 29, 299-331.
- World Bank. (2013). Database. Retrieved from <http://www.worldbank.org/>
- Young, A. (1999). Is there really spare land? A critique of estimates of available cultivable land in developing countries. *Environment, Development and Sustainability*, 1(1), 3-18.
- Zhu, Y., Chen, H., Fan, J., Wang, Y., Li, Y., Chen, J., Fan, J., Yang, S., Hu, L., Leung, H., Mew, T. W., Teng, P. S., Wang, Z., & Mundt, C. C. (2000). Genetic diversity and disease control in rice. *Nature*, 406, 718-722.
- Zidan, A. M. (2007). *The impact of the Great Man River Project on Libya's agricultural activities and the environment*. (Master's Thesis, University Teknologi, Malaysi). Retrieved from <http://eprints.utm.my/6377/>

APPENDIX 1. Survey Cover Letter (English version)

Date: 13 January 2014

Cover Letter

Dear Participant,

My name is Neama Lariel. I am from Libya, but I am currently a Ph.D. student in the Department of Agricultural & Resource Economics at Colorado State University in the United States. The purpose of this survey is to develop a better understanding of the wheat and barley seed system in Libya, including how local farmers choose their wheat and barley seed varieties and how those seed varieties perform in Libyan agriculture. The information collected in this survey will be analyzed to recommend ways that, in the future, better crop genetics can be made available to Libyan farmers.

This study is being overseen by Dr. Gregory Graff, professor at Colorado State University. The administration of the survey within Libya is being managed by Dr. Ali Ahmed Arhama, professor of Agricultural Economics at the University of Tripoli and Director, General Authority for Cereal Production, Ministry of Agriculture, Tripoli, Libya.

This survey is intended to be taken by the primary operator of a farm that grows wheat and/or barley. It is estimated to take about 15 minutes to complete. Your participation is voluntary and you may stop answering questions at any time. You may also skip any question that you would rather not answer. There is no direct benefit for your participation; however, by participating in the survey you will help to improve our research at Colorado State University and University of Tripoli, which may in turn be useful in informing future efforts to improve the seeds available to you in Libya. There are NO KNOWN RISKS in participating and your responses will be treated confidentially: no names will be collected and data will be reported in aggregate.

If you have any question regarding the specifics of this research project, I can be reached at nametr73@gmail.com or by phone at (001) 970-646-2386. You also can connect with Dr. Gregory Graff at gregory.graff@colostate.edu or at (001)970-491-4028. . If you have question about human research participants' rights, please contact Janell Barker, Senior IRB Coordinator for Colorado State University at janell.barker@colostate.edu or (001) 970-491-1655. You can also contact with Dr. Ali Arhama at the University of Tripoli by phone at (011) 218-21-3891608 or (011) 218-9121`09830.

Thank you for your cooperation,

Neama Lariel

APPENDIX 2. Survey Cover Letter (Arabic version)

التاريخ : 13 يناير 2014

معلومات حول الاستبيان للمزارع

عزيزي المزارع

أنا نعمة لريل من ليبيا، أحضر الدكتوراه حالياً في قسم الاقتصاد الزراعي في جامعة ولاية كولورادو في الولايات المتحدة الأمريكية. الغرض من هذه الدراسة هو تطوير وفهم نظام بذور القمح والشعير في ليبيا، بما في ذلك كيفية اختيار المزارعين المحليين لأصناف بذور القمح والشعير و كيفية أداء تلك الأصناف في قطاع الزراعة في ليبيا. وسوف يتم تحليل المعلومات التي سيتم جمعها من هذه الدراسة لتحسين زراعة محصولي القمح والشعير في المستقبل، وتوفير معلومات للمزارعين الليبيين حول زراعة هذين المحصوليين.

ويشرف على هذه الدراسة الدكتور جريجوري غراف ، أستاذ في جامعة ولاية كولورادو. ومن داخل ليبيا سيشرف الدكتور علي أحمدار حومه ، أستاذ الاقتصاد الزراعي في جامعة طرابلس ومدير الهيئة العامة لي إنتاج الحبوب ، وزارة الزراعة ، طرابلس، ليبيا على توزيع هذا الاستبيان.

ويهدف هذا الاستبيان إلى جمع البيانات من المزارعين الذين يزرعون محصول القمح أو / والشعير. ويقدر أن يستغرق حوالي 15 دقيقة لإكماله. مشاركتكم في هذا الاستبيان طوعية و تستطيع التوقف عن الإجابة على الأسئلة في أي وقت. وتستطيع أيضاً تخطي أي سؤال لا ترغب في الإجابة عليه. ليس هناك فائدة مباشرة على مشاركتكم ، ولكن من خلال مشاركتكم في هذا الاستبيان سوف تساعد على تحسين بحثنا في جامعة ولاية كولورادو و جامعة طرابلس ، والتي بدورها قد تكون معلومات مفيدة في بذل جهود مستقبلية لتحسين البذور المتوفرة لديكم في ليبيا. لا توجد أي خطورة مترتبة على مشاركتكم في هذا الاستبيان ، و سيتم التعامل بسرية مع ردودكم حيث أنه لن تُسئل عن اسمائكم، وسوف يتم جمع البيانات بشكل كلي وليس فردي.

إذا كان لديك أي سؤال حول تفاصيل هذا المشروع البحثي ، يمكنك الاتصال بي عبر البريد الإلكتروني nametr73@gmail.com أو عن طريق الهاتف 970-646-2386 (001). كما يمكنك أيضاً الاتصال مع الدكتور غريغوري غراف عبر بريده الإلكتروني gregory.graff@colostate.edu أو عن طريق الهاتف (001)970-491-4028 وإذا كان لديك سؤال حول حقوق الإنسان للمشاركين في البحوث ' ، يرجى الاتصال بجانييل باركر ، في جامعة ولاية كولورادو عبر البريد الإلكتروني janell.barker@colostate.edu أو عن طريق الهاتف (001) 970-16551-491 . كما يمكنك أيضاً الاتصال مع الدكتور علي ارحومه في جامعة طرابلس عن طريق الهاتف 218-21-3891608 (011) أو (011) 218-9121`09830

شكراً لتعاونكم ،

نعمة لريل

APPENDIX 3. Survey (English version)

Survey Recruitment Script

Instructions:

Step (1): This survey is intended to be taken by the primary operator of a farm that grows wheat or barley.

Step (2): Please read the following:

- *This survey was prepared by Neama Lariel, a Libyan who is currently a Ph.D. student in the Department of Agricultural & Resource Economics at **Colorado State University** in the United States. This research project is overseen by Dr. Gregory Graff, professor at Colorado State University. The administration of the survey is being managed by Dr. Ali Arhama, professor of Agricultural Economics at the **University of Tripoli** and Director, **General Authority for Cereal Production**, of the Ministry of Agriculture, Tripoli.*

- *The purpose of this survey is to develop a better understanding of the wheat and barley seed system in Libya, including how farmers choose wheat and barley seed varieties and how those seed varieties perform in Libyan agriculture.*

- *It is estimated to take about 15 minutes to complete.*

- *Would you be willing to take this survey?*
 - **If “Yes”:** a copy of the cover letter with information about this survey is provided for you to keep. Please, continue to Step 3.
 - **If “No”:** thank you for your time, there is no need to continue.

Step (3): If you agree to take this survey, please read the following:

- *Your participation in this survey is voluntary and you may stop answering questions at any time. You may also skip any question that you would rather not answer. There are **NO KNOWN RISKS** in participating and your responses will be treated confidentially: no names will be collected and all data will be reported in aggregate.*
- *Please indicate your answer to each question by checking the box (or boxes) below the question that best fits your choice or writing your response in the space provided.*
 - *If you prefer, the survey can be read aloud for you, and your responses can be entered for you by the survey administrator.*

Step (4): Please complete the survey on the following pages.

Thank you very much for your time!

Survey

Section (A) General Information

These questions will help us to better understand more about who the farmers are that grow wheat and barley in Libya.

(1) Sex of survey respondent?

- A.) Male
- B.) Female

(2) Which of the following best describes the number of people who live together in your household?

- A.) 1-3
- B.) 4-5
- C.) 6-8
- D.) 9 or more

(3) Which of the following describes the age of the primary operator of your farm?

- A.) Under 30 years old
- B.) 31-40 years old
- C.) 41-50 years old
- D.) 51-60 years old
- E.) 61 and older

(4) Which of the following best describes the number of years of farming experience of the primary operator of your farm?

- A.) Less than 5 years
- B.) 5-10 years
- C.) More than 10 years

(5) Please indicate the highest level of education attained by the primary operator of your farm:

- A.) No formal education
- B.) Some high school
- C.) High school graduate
- D.) Some college/university
- E.) College/university graduate
- F.) Post graduate work

(6) Does your farming operation have income from production and sales of any other crops or livestock besides wheat and/or barley?

- A.) Yes
- B.) No

(If Yes) Which ones?

- 1) Potato
- 2) Tomato
- 3) Maize
- 4) Olive
- 5) Date
- 6) Grapes
- 7) Orange
- 8) Cattle
- 9) Others.....

(7) Do you and/or any other member of your household have sources of off-farm income?

- A.) Yes
- B.) No

(If Yes) What sources? (Check all that apply)

- 1) Work for neighbors' farms
- 2) Mechanic, carpenter, electrician, plumber, or other skilled trade
- 3) Driver or equipment operator
- 4) Teacher
- 5) Government service
- 6) Employee in company
- 7) Employee in bank
- 8) Other.....

Section (B) Land

These questions will help us to understand the locations and sizes of farms that grow wheat and barley in Libya.

(8) In what region is your farm located?

- A.) Murzuq
- B.) Al Kufrah
- C.) Sabha
- D.) Darnah
- E.) Marg
- F.) Sirt
- G.) Misurata
- H.) Tripoli
- I.) Aljafarah
- J.) Nalut
- K.) Other (please specify).....

(9) What category best describes your planted grain farm size in hectares?

- A.) 1-5 ha
- B.) 5-20 ha
- C.) 20-100 ha
- D.) More than 100 ha

(10) Which of the following best describes the ownership of the land that you farm?

- A.) I only farm land that I own
- B.) I only farm land that I lease/rent
- A.) I farm both land that I own and land that I lease/rent

Section (C) Farm Labor

These questions will help us understand the extent to which farm labor may be affecting productivity of wheat and barley in Libya.

(11) How many farm operators or farm workers, including paid family members, do you employ on the farm over the course of a given cropping year?

Full time or permanent:

- A.) None
- B.) 1-3
- C.) More than 3

Part time or seasonal:

- A.) None
- B.) 1-3
- C.) More than 3

(12) Do you have any problems finding or hiring sufficient workers for your farm?

- A.) Yes
- B.) No

(If Yes) What are the reasons? (Check all that apply)

- 1) Lack of experienced operators or laborers in my area
- 2) High wages
- 3) Dependence on expatriate/foreign labor, which is unstable
- 4) Other (please explain).....

Section (D) Marketing of wheat and barley harvests

These questions will help us to understand how farmers earn their return from growing wheat and barley in Libya and will be kept confidential.

(13) What do you do with your wheat and/or barley harvests? (Mark all that apply)

- A.) Keep for our own household consumption
- B.) Save some as seed for next year
- C.) Sell at local or regional farmers' market
- D.) Exchange with other farmers for goods/services/labor
- E.) Sell to The Seed Center
- F.) Sell to a private (non-government) grain merchant or food company
- G.) Other.....

(14) Did you have problems in trying to sell or were you unable to sell some of your wheat and/or barley crop this last year?

- A.) Yes
- B.) No

(If Yes) Why? (Mark all that apply)

- 1) High costs of transporting the grain
- 2) Lack of truck/necessary equipment to transport the grain
- 3) Losses during transport or storage
- 4) Low market prices/ competition with grain imports from abroad
- 5) Lack of formal market (within reasonable distance)
- 6) Other (please be specific).....

(15) At what price did you sell your wheat in the 2013 season?

..... Dinar per ton

(Or, if you are more comfortable, in what price range did you sell your wheat in the 2013 season?)

- A.) Less than 200 dinar per ton
- B.) 200-300 dinar per ton
- C.) 300-400 dinar per ton
- D.) 400-500 dinar per ton
- E.) 500-600 dinar per ton
- F.) More than 600 dinar per ton

(16) At what price did you sell your Barely in the 2013 season?

..... Dinar per ton

(Or, if you are more comfortable, in what price range did you sell your wheat in the 2013 season?)

- A.) Less than 200 dinar per ton
- B.) 200-300 dinar per ton
- C.) 300-400 dinar per ton
- D.) 400-500 dinar per ton
- E.) 500-600 dinar per ton
- F.) More than 600 dinar per ton

Section (E) Seed

These questions will help us to understand farmers' choices of seed for growing wheat and barley in Libya.

(17) How much area do you plant to wheat and barley?

Land in wheat:

- A.) 1-5 ha
- B.) 5-20 ha
- C.) 20-100 ha
- D.) More than 100 ha

Land in barley:

- A.) 1-5 ha
- B.) 5-20 ha
- C.) 20-100 ha
- D.) More than 100 ha

(18) If you grow wheat, what varieties of wheat do you grow, and how many ha?

Variety name	Hectares planted this year	Share of this variety planted with newly purchased seed	Share of this variety planted with own saved seed.	Is this variety considered Local in your region?	
A.) Karim	.....ha.	.....%	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>
B.) Marjawi	.....ha.	.....%	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>
C.) Fazan	.....ha.	.....%	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>
D.) Salambo	.....ha.	.....%	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>
E.) Garma	.....ha.	.....%	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>
F.) Sedi mussri	.....ha.	.....%	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>
G.) Other.....	.....ha.	.....%	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>
H.) Other.....	.....ha.	..... %	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>

In the last column of the list above, please mark all varieties that are considered local for your region, even if you do not grow them.

Wheat:

For the variety of wheat that you grow the most, .....(insert variety name):	For the variety of wheat that you grow second most, .....(insert variety name):
What is an average yield you can expect in a good year? What is the average yield you can expect in a poor year?	What is an average yield you can expect in a good year? What is the average yield you can expect in a poor year?.....
At approximately what seeding rate do you plant this variety? <input type="checkbox"/> 30 kg/ha <input type="checkbox"/> 60 kg/ha <input type="checkbox"/> 90 kg/ha <input type="checkbox"/> 120 kg/ha <input type="checkbox"/> 150 kg/ha <input type="checkbox"/> 180 or more kg/ha	At approximately what seeding rate do you plant this variety? <input type="checkbox"/> 30 kg/ha <input type="checkbox"/> 60 kg/ha <input type="checkbox"/> 90 kg/ha <input type="checkbox"/> 120 kg/ha <input type="checkbox"/> 150 kg/ha <input type="checkbox"/> 180 or more kg/ha
Why did you choose to grow this variety? (Mark all that apply) <input type="checkbox"/> Easy access to seed for this variety <input type="checkbox"/> Good price/cheaper seed than other varieties <input type="checkbox"/> Better yield; higher productivity than others <input type="checkbox"/> More cost effective; lower costs to grow than others <input type="checkbox"/> Familiarity with the variety <input type="checkbox"/> More reliable; better suited to this region; less likely to fail <input type="checkbox"/> No other varieties available <input type="checkbox"/> Other reason.....	Why did you choose to grow this variety? (Mark all that apply) <input type="checkbox"/> Easy access to seed for that variety <input type="checkbox"/> Good price/cheaper seed than others <input type="checkbox"/> Better yield; higher productivity than others <input type="checkbox"/> More cost effective; lower costs to grow than others <input type="checkbox"/> Familiarity with the variety <input type="checkbox"/> More reliable; better suited to this region; less likely to fail <input type="checkbox"/> No other varieties available <input type="checkbox"/> Other reason.....
Where do you originally get this variety? (Mark all that apply) <input type="checkbox"/> Saved own seed for many years <input type="checkbox"/> Local farmer/neighbor purchase or exchange <input type="checkbox"/> Locally, from seed or agricultural supply merchant <input type="checkbox"/> Seed Center (Ministry of Agriculture) <input type="checkbox"/> Other.....	Where do you originally get this variety? (Mark all that apply) <input type="checkbox"/> Saved own seed for many years <input type="checkbox"/> Local farmer/neighbor purchase or exchange <input type="checkbox"/> Locally, from seed or agricultural supply merchant <input type="checkbox"/> Seed Center (Ministry of Agriculture) <input type="checkbox"/> Other.....

(19) If you grow *barley*, what varieties of *barley* do you grow and how many ha?

Variety name	Hectares planted this year	Share of this variety planted with newly purchased seed	Share of this variety planted with own saved seed	Is this variety considered Local in your region?	
A.) Rihan	.....ha.	..... %	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>
B.) Exhad 179	.....ha.	..... %	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>
C.) Aryl	.....ha.	..... %	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>
D.) Araha	.....ha.	..... %	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>
E.) Barjouj	.....ha.	..... %	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>
F.) Visited Valley	.....ha.	..... %	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>
G.) Other	.....ha.	..... %	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>
H.) Other	.....ha.	..... %	.....%	Yes <input type="checkbox"/>	No <input type="checkbox"/>

In the last column of the list above, please mark all varieties that are considered local for your region, even if you do not grow them.

Barley:

For the variety of barley that you grow the most, .....(insert variety name):	For the variety of barley that you grow second most, .....(insert variety name):
What is an average yield you can expect in a good year? What is the average yield you can expect in a poor year?	What is an average yield you can expect in a good year? What is the average yield you can expect in a poor year?.....
At approximately what seeding rate do you plant this variety? <input type="checkbox"/> 30 kg/ha <input type="checkbox"/> 60 kg/ha <input type="checkbox"/> 90 kg/ha <input type="checkbox"/> 120 kg/ha <input type="checkbox"/> 150 kg/ha <input type="checkbox"/> 180 or more kg/ha	At approximately what seeding rate do you plant this variety? <input type="checkbox"/> 30 kg/ha <input type="checkbox"/> 60 kg/ha <input type="checkbox"/> 90 kg/ha <input type="checkbox"/> 120 kg/ha <input type="checkbox"/> 150 kg/ha <input type="checkbox"/> 180 or more kg/ha
Why did you choose to grow this variety? (Mark all that apply) <input type="checkbox"/> Easy access to seed for this variety <input type="checkbox"/> Good price/cheaper seed than other varieties <input type="checkbox"/> Better yield; higher productivity than others <input type="checkbox"/> More cost effective; lower costs to grow than others <input type="checkbox"/> Familiarity with this variety <input type="checkbox"/> More reliable; better suited to this region; less likely to fail <input type="checkbox"/> No other varieties available <input type="checkbox"/> Other reason.....	Why did you choose to grow this variety? (Mark all that apply) <input type="checkbox"/> Easy access to seed for this variety <input type="checkbox"/> Good price/cheaper seed than other varieties <input type="checkbox"/> Better yield; higher productivity than others <input type="checkbox"/> More cost effective; lower costs to grow than others <input type="checkbox"/> Familiarity with this variety <input type="checkbox"/> More reliable; better suited to this region; less likely to fail <input type="checkbox"/> No other varieties available <input type="checkbox"/> Other reason.....
Where do you originally get this variety? (Mark all that apply) <input type="checkbox"/> Saved own seed for many years <input type="checkbox"/> Local farmer/neighbor purchase or exchange <input type="checkbox"/> Locally, from seed or agricultural supply merchant <input type="checkbox"/> Seed Center (Ministry of Agriculture) <input type="checkbox"/> Other.....	Where do you originally get this variety? (Mark all that apply) <input type="checkbox"/> Saved own seed for many years <input type="checkbox"/> Local farmer/neighbor purchase or exchange <input type="checkbox"/> Locally, from seed or agricultural supply merchant <input type="checkbox"/> Seed Center (Ministry of Agriculture) <input type="checkbox"/> Other.....

(20) Do you anticipate your share of home-saved seed to increase, decrease, or remain the same in the next 3 to 5 seasons?

- A.) Increase
- B.) Decrease
- C.) Stay the same

Why?.....

(21) When you buy new seed, do you buy certified seed?

- A.) Yes
- B.) No

(22) Do you prefer imported seed?

- A.) Yes
- B.) No

(If yes) Why? (Mark all apply)

- 1) Generally higher yielding
- 2) Better quality (higher germination rate, less weed contamination)
- 3) Produces a better quality wheat or barley , sells at a higher market price
- 4) Others.....

(23) Do you prefer seed varieties from Libya?

- A.) Yes
- B.) No

(If yes) Why? (Mark all apply)

- 1) Familiar with these varieties
- 2) Preference for the quality/taste, more familiar for traditional food
- 3) Generally prefer seed from Libya
- 4) Other.....

(24) In your opinion, is your own landrace/local variety better (more cost effective) than newly bred or imported varieties?

- A.) Yes
 B.) No

(25) Please rank the following choices from most important (=1) to least important (=5) for why you believe growing wheat or barley is better than growing other crops.

1	2	3	4	5
Most important				Least important

- _____ More familiar with wheat and barley than other crops
- _____ Family history;tradition;runs in the family
- _____ Lower risk; wheat and barley are more tolerant to local conditions;less likely to fail than other crops
- _____ Lower water requirement than other crops
- _____ Less impacted by disease than other crops
- _____ Cheaper seed costs than other crops
- _____ Easier to plant, cultivate, harvest (given available labor) than other crops
- _____ Lower input cost/ requirement (like fertilizer, pesticide) than other crops
- _____ High demand/ good price for harvest
- _____ Traditionally consumed in the region / Food more preferred than other crops
- _____ Government support for growing wheat/barley are better than for growing other crops

Section (F) Mechanical inputs

These questions will help us to understand how machine technology is used to grow wheat and barley in Libya.

(26) How many tractors (pieces of farm equipment) do you use for growing your wheat and barley?.....

What is the horsepower (HP) of the largest tractor engine among those you own?

- A.) Under 20 HP
- B.) 20-49 HP
- C.) 50-99 HP
- D.) 100-199 HP
- E.) 200-299 HP
- F.) More than 300 HP

Section (G) Irrigation

These questions will help us to understand the use of irrigation to grow wheat and barley in Libya.

(27) What is the average annual rainfall at your farm?

.....cm

(28) Do you use irrigation for growing your wheat and/or barley?

- A.) Yes
- B.) No

(If Yes) Which kind of irrigation system do you use to grow your wheat and/or barley crops?

- 1) Flood
- 2) Sprinkler
- 3) Other (please specify).....

(29) What is the irrigation water source you use for growing your wheat and/or barley?

- A.) Underground well water
- B.) Surface water

(If A) What is your well water source?

- 1) On-farm (private) pumped well
- 2) On-farm (private) natural source (spring, qanat, oasis, etc)
- 3) Local community pumped well
- 4) Local community natural source (spring, qanat, oasis, etc)
- 5) Manmade River project
- 6) Other larger regional (government) pumped water project
- 7) Other (Please specify).....

(If B) What is your surface water source?

- 1) On-farm (private) pond or reservoir collecting rain/runoff
- 2) Local community reservoir or irrigation ditch
- 3) Larger regional (government) irrigation system
- 4) Other (Please specify).....

Section (H) Fertilizer

These questions will help us to understand the extent to which fertilizer is utilized in growing wheat and barley in Libya.

(30) How much fertilizer kg/ha on average do you apply total per season in growing your wheat and barley crops?

- A.) None
- B.) 0- 50 kg/ha
- C.) 50-100 kg/ha
- D.) More than 100 kg/ha

Please indicate which factors influence how much fertilizer you use (please mark all that apply):

- A.) Costs
- B.) My past experiences with productivity/yield gains
- C.) Following recommended fertilizer application rates or regulations for soil type and needs
- D.) Other

(31) What kind of fertilizer do you use, and how much? (provide names and average application rates for all that you apply)

For wheat:	For barley:
<p>(N)..... , at kg/h Such as:</p> <ul style="list-style-type: none"> • Anhydrous ammonia—NH₃ • Urea—NH₂-CO-NH₂ • Ammonium nitrate—NH₄NO₃ • Nitrogen solutions (UAN)— • Ammonium sulfate—(NH₄)₂SO₄ 	<p>(N)..... , at kg/ha Such as:</p> <ul style="list-style-type: none"> • Anhydrous ammonia—NH₃ • Urea—NH₂-CO-NH₂ • Ammonium nitrate—NH₄NO₃ • Nitrogen solutions (UAN)— • Ammonium sulfate—(NH₄)₂SO₄
<p>(P)..... , at kg/ha Such as:</p> <ul style="list-style-type: none"> • Diammonium phosphate (DAP)—(NH₄)₂HPO₄ • Monoammonium phosphate (MAP)—NH₄H₂PO₄ • Ammonium polyphosphate • Triple superphosphate—Ca(H₂PO₄)₂ 	<p>(P)..... , at kg/ha Such as:</p> <ul style="list-style-type: none"> • Diammonium phosphate (DAP)—(NH₄)₂HPO₄ • Monoammonium phosphate (MAP)—NH₄H₂PO₄ • Ammonium polyphosphate • Triple superphosphate—Ca(H₂PO₄)₂
<p>(K)..... , at kg/ha Such as:</p> <ul style="list-style-type: none"> • Potash—KCl or Sul-Po-Mag or K-Mag • Potassium sulfate—K₂SO₄ • Potassium nitrate—KNO₃ • Potassium hydroxide—KOH 	<p>(K)..... , at kg/ha Such as:</p> <ul style="list-style-type: none"> • Potash—KCl or Sul-Po-Mag or K-Mag • Potassium sulfate—K₂SO₄ • Potassium nitrate—KNO₃ • Potassium hydroxide—KOH
<p>(lime) , at kg/ha</p>	<p>(lime) , at kg/ha</p>
<p>(other)..... , at kg/ha</p>	<p>(other)..... , at kg/ha</p>

(32) Which of the following best describes your experience with fertilizer use:

- A.) Positive, as it helps production
- B.) Don't know/neutral
- C.) Negative, as it has impacts on the water or soil quality or on farmer's health
- D.) Others.....

Section (I) Pesticides

These questions will help us to understand the extent to which pesticides are utilized in growing wheat and barley in Libya.

(33) Do you use any form of pesticide?

- A.) Yes
- B.) No

(If Yes) What kind of pesticide do you use? And how often do you apply?

	1-2 times	3-5 times	5 or more
1) Insecticide	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2) Fungicide	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3) Herbicide	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4) Soil sterilizers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5) All of the above	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6) Other			

(If No) Please indicate which factors influence how the pesticides you use (please mark all that apply):

- 1) Costs
- 2) My past experiences with productivity/yield gains
- 3) Following recommended pesticide application rates or regulations given my pest problems
- 4) Other.....

(34) Which factors best describes your experience with pesticide use:

- A.) Positive, as it has helped production
- B.) Don't know/neutral
- C.) Negative, as it impacts on soil and water quality and on farmer health
- D.) Other.....

Section (J) Subsidies and Government Support

These questions will help us to understand the extent to which government supports influence the growing of wheat and barley in Libya.

(35) Do you receive subsidies from the government related to growing wheat or barley?

- A.) Yes
- B.) No

(If yes) which type of subsidies do you receive?

- 1) free or subsidized (lower) price of seed
- 2) free or subsidized (lower) price of fertilizer
- 3) free or subsidized (lower) cost of irrigation water
- 4) guaranteed (higher) prices when harvest is sold to government
- 5) subsidies for purchase of equipment
- 6) direct subsidies to farmers
- 7) Other, please specify

Please write any additional comments or questions you may have:

Thank you,

On behalf of Neama Lariel and Dr. Graff of Colorado State University we appreciate your help and thank you for your time. By completing this survey you are assisting me with my Ph.D research at Colorado State University.

APPENDIX 4. Survey (Arabic version)

توزيع الاستبيان

تعليمات:

الخطوة (1): صُمم هذا الاستبيان لجمع بيانات من المزارعين الذين يزرعون محصول القمح أو الشعير.

الخطوة (2): الرجاء قراءة ما يلي :

- هذه الدراسة أعدت من قبل نعمة لريل وهي طالبة ليبية تحضر درجة الدكتوراة في قسم الاقتصاد الزراعي في جامعة ولاية كولورادو في الولايات المتحدة الأمريكية، بإشراف الدكتور جريجوري غراف ، أستاذ في جامعة ولاية كولورادو، وايضا تحت اشراف الدكتور علي ارحومه، أستاذ الاقتصاد الزراعي في جامعة طرابلس ومدير الهيئة العامة لإنتاج الحبوب ، وزارة الزراعة ، طرابلس.
- الغرض من هذه الدراسة هو لتحسين وتطوير وفهم نظام بذور القمح والشعير في ليبيا ، بما في ذلك كيفية اختيار المزارعين لاصناف بذور القمح والشعير و كيفية أداء تلك الأصناف في القطاع الزراعي في ليبيا.
- ويقدر أن يستغرق هذا الاستبيان حوالي 15 دقيقة لإكماله
- هل أنت على استعداد للمشاركة في هذه الدراسة وملئ هذا الاستبيان ؟
 - إذا كانت الاجابة " نعم " : يوجد نسخة من رسالة تشمل معلومات حول هذا الاستبيان يمكنك الاحتفاظ بها. من فضلك، انتقل الان إلى الخطوة الثالثة
 - إذا كانت الاجابة " لا " : شكرا لك على وقتك.

الخطوة (3) : إذا وافقت على ملئ هذا الاستبيان ، يرجى قراءة ما يلي:

- مشاركتكم في هذا الاستبيان طوعية و تستطيع التوقف عن الإجابة على الأسئلة في أي وقت. وتستطيع أيضاً تخطي أي سؤال لا ترغب في الإجابة عليه. لا توجد أي خطورة مترتبة على مشاركتك في هذا الاستبيان ، و سيتم التعامل بسرية مع ردودكم حيث أنه لن تُسأل عن اسمك، وسوف يتم جمع البيانات بشكل كلي وليس فردي.
- يرجى الإجابة على كل سؤال عن طريق وضع علامة (✓) في المربع أو المربعات حسب الإجابة الأمثل التي تتناسب مع اختيارك، أو كتابة إجابتك في المساحة الفارغة تحت كل سؤال.
 - إذا كنت تفضل أن أقرأ لك هذا الاستبيان وتخبرني بإجابتك ليتم اضافتها في الاستبيان.

الخطوة (4) : يُرجى استكمال الاستبيان في الصفحات التالية.

شكرا جزيلاً على وقتك

استمارة الاستبيان

اولا : معلومات عامة :

هذه الأسئلة سوف تساعد على معرفة المزارعين الذين يزرعون محصولي القمح أو الشعير في ليبيا.

1- جنس المزارع :

A. ذكر

B. انثي

2- كم عدد افراد الاسرة الذين يعيشون معك؟

A. 3-1

B. 4-5

C. 6-8

D. 9 او اكثر

3- العمر :

A. تحت 30 سنة

B. 31-40 سنة

C. 41-50 سنة

D. 51-60 سنة

E. 61 سنة فأكثر

4- كم عدد سنوات خبرتك الزراعية؟

A. أقل من 5 سنوات

B. 5-10 سنوات

C. أكثر من 10 سنوات

5- المستوى التعليمي :

A. أمي

B. ابتدائي

C. إعدادي

D. ثانوي

E. دبلوم/ جامعي

F. دراسات عليا

6- هل لديك مصدر دخل آخر بالإضافة إلى زراعة القمح و / أو الشعير؟ مثل زراعة وبيع محاصيل أخرى أو تربية الماشية؟

- نعم .A
 لا .B

إذا كانت الإجابة نعم، فالرجاء الاختيار من القائمة أدناه:

- .A البطاطس
 .B الطماطم
 .C الذرة
 .D الزيتون
 .E التمر
 .F العنب
 .G البرتقال
 .H الماشية
 .I أخرى.....

7- هل لديك أو لدى أحد من أفراد اسرتك مصدر دخل آخر خارج المزرعة؟

- نعم .A
 لا .B

إذا كانت الإجابة نعم، فالرجاء الاختيار من القائمة أدناه:

- .A العمل في مزرعة الجيران
 .B ميكانيكي، نجار، كهربائي، سباك، أو غيرها من المهن الأخرى
 .C سائق أو مشغل معدات
 .D معلم
 .E موظف حكومي
 .F موظف في شركة
 .G موظف في بنك
 .H أخرى.....

ثانيا : المعلومات الخاصة بأرض المزرعة:

هذه الأسئلة سوف تساعد على معرفة موقع ومساحة المزرعة التي يُزرع فيها القمح أو/ و الشعير.

8- في أي مدينة تقع مزرعتك؟

- A. مرزق
 B. الكفرة
 C. سيها
 D. درنة
 E. مرج
 F. سرت
 G. مصراته
 H. طرابلس
 I. الجفارة
 J. نالوت
 K. أخرى.....

9- كم مساحة الحبوب التي تزرعها في مزرعتك ؟

- A. 1-5 هكتار
 B. 5-20 هكتار
 C. 20-100 هكتار
 D. أكثر من 100 هكتار

10- أي من الخيارات التالية تصف ملكيتك للمزرعة؟

- A. أنت مالك المزرعة
 B. أنت مستأجر المزرعة
 C. مالك و مستأجر

ثالثاً: العمال في المزرعة:

هذه الأسئلة سوف تساعدنا على فهم مدى تأثير العمال في المزرعة على إنتاجية القمح و/أو الشعير في ليبيا .

11- كم عدد العمال في مزرعتك، بما في ذلك أفراد أسرتك العاملين لديك في زراعة المحصول على مدار السنة؟

- دوام كامل:
 A. لا يوجد عمال
 C. 1-3 عمال
 E. أكثر من 3 عمال
- دوام جزئي:
 B. لا يوجد عمال
 D. 1-3 عمال
 F. أكثر من 3 عمال

12- هل واجهت أي مشاكل في العثور أو توظيف عمال يعملون في مزرعتك؟

- A. نعم
 B. لا

إذا كانت الإجابة نعم، فالرجاء الاختيار من القائمة أدناه:

1. عدم وجود عمال ذوي خبرة أو عدم وجود عمال في منطقتي
2. الأجور عالية
3. الاعتماد على العمال الأجانب ويعيبها عدم الاستقرار
4. أخرى الرجاء التوضيح.....

رابعاً: تسويق محصولي القمح أو/ والشعير:

هذه الأسئلة سوف تساعدنا على فهم كيفية كسب المزارعين على إيرادات محصولي القمح أو/ والشعير في ليبيا، و سيتم الحفاظ على سرية هذه المعلومات.

13- ماهي الخطوة التالية بعد حصاد محصولي القمح أو/ والشعير؟ الرجاء اختيار جميع النقاط المناسبة:

- A. يستهلك المحصول داخل أسرته
- B. حفظ بعض البذور للسنة القادمة
- C. بيع المحصول في السوق المحلي
- D. تبادل المحصول مع مزارعين آخرين مقابل خدمات أو سلع أخرى
- E. بيع المحصول كبنور للمركز الوطني للبذور المحسنة
- F. بيع المحصول لقطاع خاص (كمتجار الحبوب أو شركات المواد الغذائية)
- G. أخرى.....

14- هل واجهتك أي مشاكل في محاولة بيع محصولي القمح و / أو الشعير ، أو أنك لم تستطع بيع بعض من المحصول في العام الماضي؟

- A. نعم
- B. لا

إذا كانت الإجابة نعم، فالرجاء اختيار السبب/ أو الأسباب من القائمة أدناه:

1. ارتفاع تكلفة نقل الحبوب
2. عدم توفر شاحنة أو المعدات اللازمة لنقل الحبوب
3. خسائر أثناء النقل والتخزين
4. أسعار السوق منخفضة أو المنافسة مع واردات الحبوب من الخارج
5. عدم وجود سوق ضمن مسافة معقولة
6. أخرى.....

15- ماهو السعر الذي بعته به القمح في موسم 2013؟
دينار/طن.....

أو إذا كنت تفضل قم باختيار السعر الذي بعته به القمح في موسم 2013 من القائمة أدناه:

- A. أقل من 200 دينار لكل طن
- B. 200-300 دينار لكل طن
- C. 300-400 دينار لكل طن
- D. 400-500 دينار لكل طن
- E. 500-600 دينار لكل طن
- F. أكثر من 600 دينار لكل طن

16- ماهو السعر الذي بعته الشعير في موسم 2013؟

دينار/طن.....

أو اذا كنت تفضل قم باختيار السعر الذي بعته الشعير في موسم 2013 من القائمة أدناه:

- A. أقل من 200 دينار لكل طن
 B. 200-300 دينار لكل طن
 C. 300-400 دينار لكل طن
 D. 400-500 دينار لكل طن
 E. 500-600 دينار لكل طن
 F. أكثر من 600 دينار لكل طن

خامساً: الحبوب:

هذه الأسئلة سوف تساعدنا على فهم اختيار المزارعين للبذور المستخدمة في زراعة القمح و/أو الشعير في ليبيا.

17- كم مساحة الأرض المستخدمة في زراعة القمح والشعير؟

- | | |
|--|---|
| <p>المساحة المزروعة من الشعير</p> <p><input type="checkbox"/> A. 1-5 هكتار</p> <p><input type="checkbox"/> B. 5-20 هكتار</p> <p><input type="checkbox"/> C. 20-10 هكتار</p> <p><input type="checkbox"/> D. أكثر من 100 هكتار</p> | <p>المساحة المزروعة من القمح</p> <p><input type="checkbox"/> A. 1-5 هكتار</p> <p><input type="checkbox"/> B. 5-20 هكتار</p> <p><input type="checkbox"/> C. 20-10 هكتار</p> <p><input type="checkbox"/> D. أكثر من 100 هكتار</p> |
|--|---|

18- إذا كنت تزرع القمح، ما هي أصناف القمح التي تزرعها، وكم هكتار؟

في العمود الأخير من القائمة أدناه، يرجى وضع علامة لجميع الأصناف التي تعتبر محلية في مدينتك، حتى لو كنت لا تزرعها

هل هذا الصنف يعتبر محلي في مدينتك؟	نسبة هذا الصنف المزروعة باستخدام بذور محفوظة من أعوام سابقة	نسبة هذا الصنف المزروعة باستخدام بذور اشتريتها حديثاً هذا العام	عدد الهكتارات المزروعة لهذا العام	اسم الصنف
<input type="checkbox"/> لا <input type="checkbox"/> نعم	%.....	%.....	هكتار.....	A. كريم
<input type="checkbox"/> لا <input type="checkbox"/> نعم	%.....	%.....	هكتار.....	B. مرجاوي
<input type="checkbox"/> لا <input type="checkbox"/> نعم	%.....	%.....	هكتار.....	C. فزان
<input type="checkbox"/> لا <input type="checkbox"/> نعم	%.....	%.....	هكتار.....	D. سلامبو
<input type="checkbox"/> لا <input type="checkbox"/> نعم	%.....	%.....	هكتار.....	E. جرمة
<input type="checkbox"/> لا <input type="checkbox"/> نعم	%.....	%.....	هكتار.....	F. سيدي المصري
<input type="checkbox"/> لا <input type="checkbox"/> نعم	%.....	%.....	هكتار.....	G. أخرى.....
<input type="checkbox"/> لا <input type="checkbox"/> نعم	%.....	%.....	هكتار.....	H. أخرى.....

القمح

ما هو اسم أكثر صنف من القمح تزرعه في مزرعتك.....	ما هو اسم أكثر صنف من القمح تزرعه في مزرعتك.....
ما هو متوسط العائد الذي تتوقعه في العام الجيد؟..... ما هو متوسط العائد الذي تتوقعه في العام السيء؟.....	ما هو متوسط العائد الذي تتوقعه في العام الجيد؟..... ما هو متوسط العائد الذي تتوقعه في العام السيء؟.....
ما هو معدل البذور المستخدمة لزراعة هذا الصنف؟ <input type="checkbox"/> 30 كم/هـ <input type="checkbox"/> 60 كم/هـ <input type="checkbox"/> 90 كم/هـ <input type="checkbox"/> 120 كم/هـ <input type="checkbox"/> 150 كم/هـ <input type="checkbox"/> 180 وأكثر كم/هـ	ما هو معدل البذور المستخدمة لزراعة هذا الصنف؟ <input type="checkbox"/> 30 كم/هـ <input type="checkbox"/> 60 كم/هـ <input type="checkbox"/> 90 كم/هـ <input type="checkbox"/> 120 كم/هـ <input type="checkbox"/> 150 كم/هـ <input type="checkbox"/> 180 وأكثر كم/هـ
لماذا اخترت أن تزرع هذا الصنف؟ (الرجاء اختيار جميع الخيارات المناسبة) <input type="checkbox"/> سهولة الحصول على بذور هذا الصنف <input type="checkbox"/> سعر هذا الصنف جيد أو أرخص من الأصناف الأخرى <input type="checkbox"/> معدل إنتاجية هذا الصنف أعلى من الأصناف الأخرى <input type="checkbox"/> الاعتياد على زراعة هذا الصنف <input type="checkbox"/> يتلائم أكثر مع ظروف مدينتك وأقل عرضة للهلاك <input type="checkbox"/> عد توفر أصناف أخرى <input type="checkbox"/> أسباب أخرى.....	لماذا اخترت أن تزرع هذا الصنف؟ (الرجاء اختيار جميع الخيارات المناسبة) <input type="checkbox"/> سهولة الحصول على بذور هذا الصنف <input type="checkbox"/> سعر هذا الصنف جيد أو أرخص من الأصناف الأخرى <input type="checkbox"/> معدل إنتاجية هذا الصنف أعلى من الأصناف الأخرى <input type="checkbox"/> الاعتياد على زراعة هذا الصنف <input type="checkbox"/> يتلائم أكثر مع ظروف مدينتك وأقل عرضة للهلاك <input type="checkbox"/> عد توفر أصناف أخرى <input type="checkbox"/> أسباب أخرى.....
من أين تحصل على هذا الصنف (الرجاء اختيار جميع الخيارات المناسبة) <input type="checkbox"/> من البذور المحفوظة من الأعوام الماضية <input type="checkbox"/> شراء البذور من أحد المزارعين أو تبادلها <input type="checkbox"/> من شركات المستلزمات الزراعية <input type="checkbox"/> من مركز البذور المحسنة (وزارة الزراعة) <input type="checkbox"/> أخرى.....	من أين تحصل على هذا الصنف (الرجاء اختيار جميع الخيارات المناسبة) <input type="checkbox"/> من البذور المحفوظة من الأعوام الماضية <input type="checkbox"/> شراء البذور من أحد المزارعين أو تبادلها <input type="checkbox"/> من شركات المستلزمات الزراعية <input type="checkbox"/> من مركز البذور المحسنة (وزارة الزراعة) <input type="checkbox"/> أخرى.....

19- إذا كنت تزرع الشعير، ما هي أصناف الشعير التي تزرعها، وكم هكتار؟

في العمود الأخير من القائمة أدناه، يرجى وضع علامة لجميع الأصناف التي تعتبر محلية في مدينتك، حتى لو كنت لا تزرعها

اسم الصنف	عدد الهكتارات المزروعة لهذا العام	نسبة هذا الصنف المزروعة باستخدام بذور اشتريتها حديثاً هذا العام	نسبة هذا الصنف المزروعة باستخدام بذور محفوظة من أعوام سابقة	هل هذا الصنف يعتبر محلي؟
A. ربحان	.....هكتار	%.....	%.....	لا <input type="checkbox"/> نعم <input type="checkbox"/>
B. اكساد 179	.....هكتار	%.....	%.....	لا <input type="checkbox"/> نعم <input type="checkbox"/>
C. الاريل	.....هكتار	%.....	%.....	لا <input type="checkbox"/> نعم <input type="checkbox"/>
D. اربح	.....هكتار	%.....	%.....	لا <input type="checkbox"/> نعم <input type="checkbox"/>
E. بروج	.....هكتار	%.....	%.....	لا <input type="checkbox"/> نعم <input type="checkbox"/>
F. وادي زارت	.....هكتار	%.....	%.....	لا <input type="checkbox"/> نعم <input type="checkbox"/>
G. أخرى.....	.....هكتار	%.....	%.....	لا <input type="checkbox"/> نعم <input type="checkbox"/>
H. أخرى.....	.....هكتار	%.....	%.....	لا <input type="checkbox"/> نعم <input type="checkbox"/>

الشعير

<p>ما هو اسم أكثر صنف من الشعير تزرعه في مزرعتك</p> <p>ما هو متوسط العائد الذي تتوقعه في العام الجيد؟</p> <p>ما هو متوسط العائد الذي تتوقعه في العام السيء؟</p> <p>ما هو معدل البذور المستخدمة لزراعة هذا الصنف؟</p> <p><input type="checkbox"/> 30 كم/هـ <input type="checkbox"/> 60 كم/هـ <input type="checkbox"/> 90 كم/هـ</p> <p><input type="checkbox"/> 120 كم/هـ <input type="checkbox"/> 150 كم/هـ <input type="checkbox"/> 180 وأكثر كم/هـ</p> <p>لماذا اخترت ان تزرع هذا الصنف؟ (الرجاء اختيار جميع الخيارات المناسبة)</p> <p><input type="checkbox"/> سهولة الحصول على بذور هذا الصنف</p> <p><input type="checkbox"/> سعر هذا الصنف جيد أو أرخص من الاصناف الأخرى</p> <p><input type="checkbox"/> معدل إنتاجية هذا الصنف أعلى من الاصناف الأخرى</p> <p><input type="checkbox"/> الاعتماد على زراعة هذا الصنف</p> <p><input type="checkbox"/> يتلائم أكثر مع ظروف مدينتك وأقل عرضة للهلاك</p> <p><input type="checkbox"/> عد توفر أصناف أخرى</p> <p><input type="checkbox"/> أسباب أخرى.....</p> <p>من أين تحصل على هذا الصنف (الرجاء اختيار جميع الخيارات المناسبة)</p> <p><input type="checkbox"/> من البذور المحفوظة من الأعوام الماضية</p> <p><input type="checkbox"/> شراء البذور من أحد المزارعين أو تبادلها</p> <p><input type="checkbox"/> من شركات المستلزمات الزراعية</p> <p><input type="checkbox"/> من مركز البذور (وزارة الزراعة)</p> <p><input type="checkbox"/> أخرى</p>	<p>ما هو اسم أكثر صنف من الشعير تزرعه في مزرعتك</p> <p>ما هو متوسط العائد الذي تتوقعه في العام الجيد؟</p> <p>ما هو متوسط العائد الذي تتوقعه في العام السيء؟</p> <p>ما هو معدل البذور المستخدمة لزراعة هذا الصنف؟</p> <p><input type="checkbox"/> 30 كم/هـ <input type="checkbox"/> 60 كم/هـ <input type="checkbox"/> 90 كم/هـ</p> <p><input type="checkbox"/> 120 كم/هـ <input type="checkbox"/> 150 كم/هـ <input type="checkbox"/> 180 وأكثر كم/هـ</p> <p>لماذا اخترت ان تزرع هذا الصنف؟ (الرجاء اختيار جميع الخيارات المناسبة)</p> <p><input type="checkbox"/> سهولة الحصول على بذور هذا الصنف</p> <p><input type="checkbox"/> سعر هذا الصنف جيد أو أرخص من الاصناف الأخرى</p> <p><input type="checkbox"/> معدل إنتاجية هذا الصنف أعلى من الاصناف الأخرى</p> <p><input type="checkbox"/> الاعتماد على زراعة هذا الصنف</p> <p><input type="checkbox"/> يتلائم أكثر مع ظروف مدينتك وأقل عرضة للهلاك</p> <p><input type="checkbox"/> عد توفر أصناف أخرى</p> <p><input type="checkbox"/> أسباب أخرى.....</p> <p>من أين تحصل على هذا الصنف (الرجاء اختيار جميع الخيارات المناسبة)</p> <p><input type="checkbox"/> من البذور المحفوظة من الأعوام الماضية</p> <p><input type="checkbox"/> شراء البذور من أحد المزارعين أو تبادلها</p> <p><input type="checkbox"/> من شركات المستلزمات الزراعية</p> <p><input type="checkbox"/> من مركز البذور (وزارة الزراعة)</p> <p><input type="checkbox"/> أخرى</p>
---	---

20- هل تتوقع أن البذور المحفوظة لديك ستزيد، أو ستتناقص، أو ستبقى كما هي خلال 3- 5 المواسم القادمة؟

- A. ستزيد
- B. ستتناقص
- C. ستبقى كما هي

ولماذا؟

21- عند شرائك بذور جديدة، هل تشتري البذور المعتمدة؟

- A. نعم
- B. لا

22- هل تفضل شراء البذور المستوردة؟

- A. نعم
- B. لا

إذا كانت الإجابة نعم، فلماذا؟ (الرجاء اختيار جميع الاختيارات المناسبة)

- A. أعلى العائد
- B. نوعيته أفضل (أعلى معدل إنبات، أقل تآثراً بالأعشاب الضارة)
- C. نوعية انتاجه أفضل وسعره أعلى في السوق
- D. أسباب أخرى

23- هل تفضل شراء البذور من ليبيا ؟

- A. نعم
- B. لا

إذا كانت الإجابة نعم، فلماذا؟ (الرجاء اختيار جميع الاختيارات المناسبة)

- A. اعتدت على هذه الأصناف
- B. جودة وطعم هذه الاصناف يتناسب أكثر مع الأطعمة التقليدية في البلد
- C. بصفة عامة تفضل شراء البذور الليبية
- D. أسباب أخرى

24- في رأيك، هل بذورك المحسنة أو المحلية أفضل من حيث التكلفة من البذور المستوردة؟

- A. نعم
- B. لا

25- رتب الخيارات التالية من أهم (= 1) إلى الأقل أهمية (= 5)

لماذا تعتقد زراعة القمح أو الشعير أفضل من زراعة محاصيل أخرى؟

أقل أهمية				أكثر أهمية
5	4	3	2	1

- متعود على زراعة القمح والشعير أكثر من المحاصيل الأخرى _____
- المهنة المتوارثة في العائلة أو أحد التقاليد _____
- زراعة القمح والشعير أكثر تحملاً للظروف المحلية، وأقل عرضة للهلاك من المحاصيل الأخرى _____
- الاحتياجات المائية لزراعة القمح والشعير أقل من المحاصيل الأخرى _____
- أقل تعرضاً للمرض من المحاصيل الأخرى _____
- تكاليف البذور أرخص من المحاصيل الأخرى _____
- أسهل زراعة وحصاد من المحاصيل الأخرى _____
- التكاليف المتغيرة (مثل الأسمدة والمبيدات) أرخص من المحاصيل الأخرى _____
- تزايد الطلب عليه / تكاليف حصاده منخفضة _____
- محصول استهلاكي محلياً (مستخدم في الأطعمة التقليدية أكثر من المحاصيل الأخرى) _____
- الدعم الحكومي لزراعة القمح والشعير أكثر من الدعم لزراعة المحاصيل الأخرى _____

سادسا: الآلات والمعدات الزراعية:

هذه الأسئلة سوف تساعدنا على فهم كيفية استخدام التكنولوجيا والآلات لزراعة القمح أو / والشعير في ليبيا.

26- كم عدد الجرارات التي تستخدمها لزراعة القمح أو/ والشعير؟.....

كم قوة الحصان لمحرك الجرار الذي تملكه؟

- A. أقل من 20 حصان
 B. 20-49 حصان
 C. 50-99 حصان
 D. 100-199 حصان
 E. 200-299 حصان
 F. أكثر من 300 حصان

سابعاً: الري:

هذه الأسئلة سوف تساعدنا على فهم عملية الري لزراعة القمح أو / والشعير في ليبيا.

27- ماهو متوسط هطول الأمطار السنوي على مزرعتك؟

سم.....

28- هل تستخدم مياه الري لزراعة القمح أو/ والشعير؟

- A. نعم
 B. لا

إذا كانت الإجابة نعم، فأي من أنظمة الري تستخدم لزراعة القمح أو/ والشعير في مزرعتك؟

- A. الري بالرش
 B. الري بالتنقيط
C. أخرى (الرجاء التوضيح).....

29- ما هو مصدر مياه الري المستخدمة لزراعة القمح أو/ والشعير؟

- A. مياه جوفية (الآبار)
 B. مياه سطحية (مياه الأمطار، مياه السدود، مياه العينون)

إذا كنت إجابتك (A) فما هو مصدر مياه الآبار التي تستخدمها في الري؟

1. لديك آبار في مزرعتك
 2. لديك في مزرعتك مصادر مياه طبيعية (كالينابيع أو القنوات)
 3. مضخة مياه مشتركة في منطقتك
 4. مصادر مياه طبيعية مشتركة في منطقتك
 5. مشروع النهر الصناعي
 6. مشاريع حكومية أخرى لضخ المياه
 7. أخرى (الرجاء التوضيح).....

إذا كانت إجابتك (B) فما هو مصدر المياه السطحية التي تستخدمها في الري؟

1. لديك بركة أو خزان لتجميع مياه الأمطار
2. يوجد خزان مشترك لمياه الأمطار في منطقتك
3. مشروع حكومي لتجميع مياه الأمطار
4. أخرى (الرجاء التوضيح).....

ثامنا: الأسمدة:

هذه الأسئلة سوف تساعدنا على فهم مدى استخدام الأسمدة في زراعة القمح أو / والشعير في ليبيا.

30 - ما هو متوسط الأسمدة المستخدمة في زراعة محاصيل القمح أو / والشعير بكجم لكل هكتار في الموسم الواحد؟

1. لا شيء
2. 50-0 كجم/هـ
3. 100-50 كجم/هـ
4. أكثر من 100 كجم/هـ

يرجى الإشارة إلى العوامل التي تؤثر على مدى استخدامك للأسمدة (يرجى وضع علامة على كل ما ينطبق)

1. التكاليف
2. خبراتي السابقة في تأثير الأسمدة على الإنتاجية
3. اتباع الإرشادات استخدام الأسمدة بناء على نوعية التربة أو احتياجاتها
4. أخرى.....

31- ما هو نوع وكمية الأسمدة التي تستخدمها؟ (الرجاء ذكر أسم السماد ومتوسط معدل الاستخدام لكل ما ينطبق)

القمح	الشعير
(نيتروجين)..... في كجم/هـ مثل : • الأمونيا NH ₃ • اليوريا -NH ₂ -CO-NH ₂ • نترات الأمونيوم -NH ₄ NO ₃ • UAN • كبريتات الأمونيوم (NH ₄) ₂ SO ₄	(نيتروجين)..... في كجم/هـ مثل : • الأمونيا NH ₃ • اليوريا -NH ₂ -CO-NH ₂ • نترات الأمونيوم -NH ₄ NO ₃ • UAN • كبريتات الأمونيوم (NH ₄) ₂ SO ₄
(فوسفور)..... في كجم/هـ مثل : • ثنائي فوسفات الأمونيوم (داب) (DAP) • أحادي الفوسفات (MAP)—NH ₄ H ₂ PO ₄ • متعدد الفوسفات الأمونيوم • الثلاثي السوبر فوسفات الكالسيوم-(H ₂ PO ₄ 2)	(فوسفور)..... في كجم/هـ مثل : • ثنائي فوسفات الأمونيوم (داب) (DAP) • أحادي الفوسفات (MAP)—NH ₄ H ₂ PO ₄ • متعدد الفوسفات الأمونيوم • الثلاثي السوبر فوسفات الكالسيوم-(H ₂ PO ₄ 2)
(بوتاسيوم)..... في كجم/هـ مثل : • كبريتات البوتاسيوم K ₂ SO ₄ • نترات البوتاسيوم -KNO ₃ • هيدروكسيد البوتاسيوم KOH	(بوتاسيوم)..... في كجم/هـ مثل : • كبريتات البوتاسيوم K ₂ SO ₄ • نترات البوتاسيوم -KNO ₃ • هيدروكسيد البوتاسيوم KOH
(الجزير)..... في كجم/هـ أخرى.....	(الجزير)..... في كجم/هـ أخرى.....

32- أي من النقاط التالية تصف رأيك في استخدام الأسمدة؟

1. ايجابية (الاسمدة تساعد على انتاج أفضل)
2. لا أعرف
3. سلبية (الاسمدة تؤثر سلبيا على المياه ونوعية التربة و صحة المزارع)
4. أخرى.....

تاسعاً: المبيدات:

هذه الأسئلة سوف تساعدنا على فهم إلى أي مدى تستخدم المبيدات الحشرية في زراعة القمح أو/ والشعير في ليبيا.

33- هل تستخدم أي شكل من أشكال المبيدات؟

- A. نعم
- B. لا

إذا كنت الاجابة نعم، فأني من نوع من المبيدات تستخدم؟ و كم عدد مرات استخدامك للمبيدات؟

- | | | | |
|--------------------------|--------------------------|--------------------------|------------------|
| 5 مرات أو أكثر | 3-5 مرات | 1-2 مرة | المبيدات الحشرية |
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | فطريات |
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | مبيدات أعشاب |
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | معقمات التربة |
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | كل ماسبق |
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | أخرى..... |

إذا كنت الاجابة لا، يرجى الإشارة إلى العوامل التي تؤثر على كيفية استخدامك للمبيدات (يرجى وضع علامة على كل ما ينطبق)

1. التكاليف
2. خبراتي السابقة في تأثير الأسمدة على الانتاجية
3. اتباع الارشادات استخدام الأسمدة بناء على نوعية التربة أو احتياجاتها
4. أخرى.....

34- أي من النقاط التالية تصف رأيك في استخدام المبيدات؟

1. ايجابية (المبيدات تساعد على انتاج أفضل)
2. لا أعرف
3. سلبية (المبيدات تؤثر سلبيا على المياه ونوعية التربة و صحة المزارع)
4. أخرى.....

عاشراً: الدعم والإعانات الحكومية:

هذه الأسئلة سوف تساعدنا على فهم مدى تأثير الدعم الحكومي على زراعة القمح أو/ والشعير في ليبيا.

35- هل تتلقي أي إعانات حكومية لزراعة القمح أو/ والشعير؟

- A. نعم
B. لا

إذا كانت الإجابة نعم فأي نوع من الإعانات تتلقي

1. بذور مجانية أو بسعر منخفض
 2. أسمدة مجانية أو بسعر منخفض
 3. مياه للري مجانية أو بتكاليف منخفضة
 4. ضمان شراء محصولك بسعر أعلى عند بيعه للحكومة
 5. دعم لشراء المعدات
 6. إعانات مالية مباشرة للمزارعين
 7. أخرى (الرجاء التوضيح).....

يرجى كتابة أي أسئلة أو تعليقات إضافية:

و شكرا على حسن تعاونكم

نيابة عن الطالبة نعمة لريل والدكتور غراف من جامعة ولاية كولورادو. هم مقدرين مساعدتكم و يشكرونكم على وقتكم في استكمال هذا الاستبيان. إجاباتكم ستساعدنا في استكمال بحث الدكتوراه في جامعة ولاية كولورادو.

APPENDIX 5. Institutional Review Board (IRB) Exemption Letter



Research Integrity & Compliance Review Office
Office of Vice President for Research
Fort Collins, CO 80523-2011
(970) 491-1553
FAX (970) 491-2293

Date: February 11, 2014

To: Gregory Graff, Ag & Resource Econ.
Neema Lariel, Ag & Resource Econ.



From: Janell Barker, IRB Coordinator

Re: Big Challenges in the Sustainability of Libyan Agriculture: Opportunities for the Libyan Seed System

IRB ID: 016-15H Review Date: February 11, 2014
This project is valid from three years from the review date.

The Institutional Review Board (IRB) Coordinator has reviewed this project and has declared the study exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b)(2): Research involving the use of educational tests,....survey procedures, interview procedures or observation of public behavior, unless: a) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects.

The IRB determination of exemption means that:

- **This project is valid for three years from the initial review.** After the three years, the file will be closed and no further research should be conducted. If the research needs to continue, please let the IRB Coordinator know before the end of the three years. You do not need to submit an application for annual continuing review.
- You must carry out the research as proposed in the Exempt application, including obtaining and documenting (signed) informed consent if stated in your application or if required by the IRB.
- Any modification of this research should be submitted to the IRB through an email to the IRB Coordinator, prior to implementing any changes, to determine if the project still meets the Federal criteria for exemption.
- Please notify the IRB Coordinator if any problems or complaints of the research occur.

Please note that you must submit all research involving human participants for review by the IRB. **Only the IRB or designee may make the determination of exemption**, even if you conduct a similar study in the future.