THE ROLE OF QUALITY SEED IN RICE PRODUCTION - A CASE STUDY OF THE DAWHENYA IRRIGATION SCHEME

BY

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THIS THESIS/DISSERTATION IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY IN SEED SCIENCE AND TECHNOLOGY DEGREE.

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DECLARATION

I, Amihere Kwame Blay Nwaleh, do hereby declare that except for the references to work of other researchers which have been duly cited, this thesis consists entirely of my original work produced from research undertaken under supervision and that no part of it has been presented for another degree in this university or elsewhere.

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ABSTRACT

Rice, which is considered as one of the most agriculturally significant crops in the world, responsible for providing two thirds of the total calorie intake of more than 3 billion people in Asia and one third of the total calorie intake of mainly 1.5 billion people in Africa and Latin America is plagued by many difficulties in production particularly in developing countries. Though its consumption is on the rise in Ghana, domestic production has been reported to be disproportionate to consumption demands. The low domestic production figures are linked to the fact that many Ghanaian farmers use seeds of low quality. Since the rehabilitation of the Dawhenya irrigation scheme, by the Korean International Development Agency (KOICA) between 2011 and 2013 which cost US$ 3.6 million, the site has been facing declining yields in rice production with the project average yield falling from 6.7 t/ha to 5.2 t/ha within 3 cropping seasons. The dip in yield figures was attributed to many factors such as bad agronomic practices, high irrigation charges, the quality of water used in the cultivation of the crop and the unavailability of quality seeds. This study therefore aimed at examining the role that quality seeds used by farmers at the Dawhenya irrigation scheme play in the yield decline by weighing the quality of the seeds physically, conducting germination percentage tests, moisture content test and seed health status with that of the criteria recommended by International bodies. The mindset of the farmers was first evaluated to know their perception on what the actual cause of declining yield at the site is. Samples of the seeds of 30 randomly selected farmers were then taken to the National Seed Testing Laboratory at the Ghana Seed Inspectorate Division (GSID), Pokuase for the quality tests of the seeds. The analysis showed that the seeds used by the farmers (Farmer saved seeds) at the site was up to the required standards and in some cases above the standards in most areas of quality. It was therefore concluded that the quality of the seeds used in the cultivation of rice at the site was not a factor
that contributed to the perceived decline at the site and that the perception of the farmers which was largely attributed to the high cost of production of the commodity may be the cause of the yield decline in their respective fields at the Dawhenya Irrigation Scheme. Implications of this study may be that when steps are taken to reduce the cost of production of rice at this site, production of the commodity would increase and consequently improve rice production in the country.
DEDICATION

This piece is dedicated to my entire family, my loving parents who may not have understood in detail the entirety of the work but have been supportive and encouraging throughout. To my siblings who have helped in no small way and have motivated me to get this far I say thank you. To my aunties and cousins and everyone I call family, am truly blessed to have you all in my life.
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<tbody>
<tr>
<td>°C</td>
<td>Degree Celsius</td>
</tr>
<tr>
<td>AGRA</td>
<td>Alliance for Green Revolution Africa</td>
</tr>
<tr>
<td>BC</td>
<td>Before Christ</td>
</tr>
<tr>
<td>cm</td>
<td>Centimeters</td>
</tr>
<tr>
<td>CRI</td>
<td>Crop Research Institute</td>
</tr>
<tr>
<td>DNA</td>
<td>Deoxyribonucleic Acid</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agricultural Organization of the United Nations</td>
</tr>
<tr>
<td>GRiSP</td>
<td>Global Rice Science Partnership</td>
</tr>
<tr>
<td>hrs</td>
<td>Hours</td>
</tr>
<tr>
<td>ICC</td>
<td>International Chamber of Commerce</td>
</tr>
<tr>
<td>IRRI</td>
<td>International Rice Research Institute</td>
</tr>
<tr>
<td>ISHI</td>
<td>International Seed Health Initiative</td>
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<tr>
<td>ISO</td>
<td>International Standards Organization</td>
</tr>
<tr>
<td>ISTA</td>
<td>International Seed Testing Association</td>
</tr>
<tr>
<td>JICA</td>
<td>Japan International Cooperation Agency</td>
</tr>
</tbody>
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kg  Kilogram
km  Kilometer
m   Meter
Mb  Million base pairs
mm  Millimeter
MOFA Ministry of Food and Agriculture
MT  Metric Tonnes
NERICA New Rice for Africa
NGO Non-Governmental Organizations
NSHS National Seed Health System
t/ha Tonnes per hectare
US United States
USDA United States Department of Agriculture
1. CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Rice is the most economically relevant food crop in a lot of developing countries making up two thirds of the total caloric intake of more than 3 billion people in Asia, and for approximately 1.5 billion people in Africa and Latin America, providing one third of the total caloric intake (FAO, 1995). Brar and Khush (2002) noted that the crop contributes about 23% of the world’s supply of calories. Almost 90% of the world's rice is cultivated and consumed in Asia with over 70% relying on the economic efficiency of the irrigated rice ecosystems for their supply of nourishment. Sub-Saharan Africa is said to account for a third of global rice imports at an alarming cost of more than US$4.3 billion per year, an amount which otherwise could be used in other areas of development (Nakano et al, 2011).

In 2014, approximately 163 million hectares was harvested worldwide out of which 740 million tonnes of paddy rice was produced. Eleven million hectares of the total harvested area was from Africa contributing 31 million tonnes of paddy rice production to the global figures. Ghana’s contribution to these figures was only 604,000 tonnes (FAO STAT, 2016). Seventy-five percent of the world’s rice supply is produced using irrigated rice. This constitutes about half of the world’s rice fields (about 135 million hectares). This system of cultivating rice consequently makes it one of the most important agricultural ecosystem in the Asian provinces as it produces the most food to feed its vast population.
The irrigated ecology is recorded to have the highest rice yields because of the levels of technology utilization (improved land preparation, improved varieties, fertilizer application and weed control through water management) which are higher than found in cultural practices in both rain fed lowland and upland ecologies.

A swift shift in dietary preference to rice was experienced in Ghana, especially in the urban centers, starting in 1957 during the early post-independence period. The change to rice diets was associated with an increased income, favorable government pricing policies, good storage properties of rice and ease of cooking (Nyanteng, 1987). As indicated by the Food and Agriculture Organization, 444 million tons of rice was consumed worldwide in 2008, by 2050, this figure is expected to rise by 50%. In Ghana, annual per capita rice consumption on the average increased from 17.5 kg during 1999-2001 to 22.6 kg during 2002-2004 (MOFA-NRDS, 2009).

Tran (1997) noted that, the chief challenge for rice research and its development in the world, as well as the improvement of the standards of living and welfare of smallholder farmers and economically sustainable rural employment, is how to device means of producing adequate amounts for the ever-increasing population with limited land for cultivation, little or no labor, less water and above all, little or no use of chemical inputs.

Despite recent efforts at encouraging the increase in rice production, such as development of the varieties of New Rice for Africa (NERICA) (WARDA, 2004), which could withstand varied biotic stresses, grain yields are still very low in the Guinea and Sudan savannah zones of Ghana (JICA/CSIR, 2001). Recent decline in rice yields, land degradation and environmental pollution in some irrigated rice areas have raised concerns regarding the long-term sustainability of such production and productivity. Pertinent factors militating against enhanced rice production could
be attributed to weed interference, poor water management, the inability of farmers to use seeds of good quality and declining soil fertility (Dogbe et al., 2015).

1.2 Problem Statement

The Dawhenya Irrigation Scheme in the Accra-Tema metropolitan area of the Greater Accra region, first established in 1959 appeared to have been abandoned for more than a decade until an integrated rehabilitation work was carried out by the Korean International Development Agency (KOICA) between 2011 and 2013. Rehabilitation work which was done through a US$ 3.6 million Korean Government grant to Ghana helped to rejuvenate the Integrated Community Development Project.

Since the rehabilitation however, production of rice at the site appears to be declining with the project average yield falling from 6.7 t/ha to 5.2 t/ha in 3 consecutive cropping seasons. The dip in yield has been attributed to many factors such as salinity, bad agronomic practices and high irrigation charges among others coupled with the unavailability of quality seeds for planting. Planting is done at the site using farmer saved seeds which tend to lose their seed quality after continuous use.

1.3 Justification

Though rice consumption is increasing, domestic production is disproportionate to consumption demands. There is therefore the need to improve its production in terms of quantity and quality in order to make up for the deficit in supply (Agbanyo, 2012). According to the USDA (2016), Ghana
is currently ranked 46th in the production of milled rice at 300,000 MT behind Nigeria and Côte D’Ivoire which rank 18th and 22nd respectively. Domestic consumption however is 980,000 MT leaving a huge production gap which is then filled by the importation of about 650,000MT (USDA, 2016). Current output of the country’s rice production sector is unable to meet this increasing local demand. Estimates vary, but it will not be an exaggeration to assume that more than 70% of the rice consumed in Ghana is imported (estimated cost of US$ 450 m each year). The decline in yield on farmers’ fields has not yet been thoroughly studied and documented.

Many Ghanaian farmers in general cultivate with seeds that are of low quality, thus leading to low yields and compounding their poverty levels (Gyesi, 2016). Ghana has a long and distinguished history of crop variety development and registration, and yet the use of improved seed by farmers remains low. Part of the reason for low farmer uptake of improved varieties is the lack of knowledge of the availability and characteristics of improved varieties (Dockrey, 2015). Farmers seed management practices studies show that farmers in most cases do not purchase certified seeds. Seeds used by farmers in cultivation are usually grown by the farmers themselves or are exchanged with seeds of the available varieties with other farmers (Diaz et al., 1994). Farmers tend to select fields that appear to have healthy plots with no off-types and look to be free of weeds, as a source of planting material for the following season. Farmers also consider seeds obtained from the second cropping season to have better quality and use them for planting in the next season (Escalada et al., 1996). With all these practices, farmers are often found to use seeds that have impurities and contaminants, including pathogen infected seeds. (Fujisaka et al., 1993).

Sowing high quality seeds lead to lower seed rate, better emergence (i.e. greater than 70%), more field uniformity, less replanting, and vigorous early growth which helps to increase resistance to
insects and diseases and decrease weeds. As a result, yield can increase from between 5−20% (IRRI, 2015).

1.4 Objective

The objective of this study was to investigate the role that quality rice seed plays in the decline of rice yields at the Dawhenya Irrigation Scheme in relation to the other factors that influence yield.

Specific Objectives were to:

- evaluate farmers’ perceptions on the causes of yield decline in their various fields,
- ascertain the role of quality seeds in the perceived yield decline, and
- identify other crop production practices in use at the project site, which may be contributing to declining yields.
2.0 LITERATURE REVIEW

2.1 Description and Morphology of Rice

Rice, which is a monocotyledonous angiosperm, is usually grown as an annual plant. In tropical areas, it can also survive as a perennial and can produce a ratoon crop for up to 30 years (IRRI, 2009). It belongs to the grass family *Poacea* and is one of the leading food crops in the world. As such, it is a staple of over a half of the world’s population, mostly in Asia. After wheat, rice is the second most cultivated cereal. It provided 19% of global human per capita energy and 13% of per capita protein in 2009 (GRiSP, 2013).

It was reiterated by Smith (1998) that, as large portions of maize and other crops are not only used for human consumption but for other purposes, rice becomes the most significant food crop when it comes to human nutrition as it provides more than one-fifth the amount of calories consumed by humans around the world.

The genus it belongs to, *Oryza*, is known to possess more than 20 species, only two of which are referred to as cultivated rice: *O. glaberrima* which is cultivated in West Africa and *O. sativa*, grown in South-east Asian countries and Japan (Watanabe, 1997). The crop was originally cultivated in tropical Asia, the oldest record dating 5000 years BC, but then extended also to temperate regions (Watanabe, 1997).

The two most cultivated rice species, *Oryza sativa* L. and *Oryza glaberrima* Steud., both belong to the species group *Oryza sativa* complex with the five wild taxa, *Oryza rufipogon* (sensu lato),
Oryza longistaminata Chev. et Roehr., Oryza barthii A. Chev., Oryza glumaepatula Steud., and Oryza meridionalis Ng. This species complex was initially defined as the diploid species sharing a common genome A. It was not until later that, the similarities among these species genetically were confirmed using isozymes (Second, 1991), Amplified Fragment Length Polymorphism (AFLP) (Aggarwal et al., 1999), Restriction Fragment Length Polymorphisms (RFLPs) of nuclear DNA (Wang et al., 1992) and chloroplast DNA (Dally and Second, 1990) and mitochondrial DNA (Second and Wang, 1992). This might have indicated that nuclear and organellar genomes that were thought to undergo different evolutionary rates evolved concertedly at this level.

Among these taxa, fertile F1 hybrids were only produced by Oryza rufipogon with Oryza sativa and these two species were therefore considered to belong to one biological species.

Oryza sativa is known to constitute two main subspecies namely: japonica or sinica variety; the short grained, sticky type and indica variety; the non-sticky, long grained type. Japonica varieties are mostly cultivated in dry fields, in temperate conditions in East Asia, upland regions of Southeast Asia and high elevations in South Asia, while indica varieties are predominantly lowland rice, which are usually cultivated submerged, throughout tropical Asia (Molina et al., 2011).

Another subspecies, a third, known to have broad-grains and can survive under tropical conditions, based on its morphology was identified and initially called javanica, but is now called tropical japonica.

Rice cultivation is tailored to countries and areas with low cost of labor and high amount of rainfall, as its production is labor-intensive and requires a lot of water (IRRI, 2009). With the use of water-controlling systems however, rice can be virtually grown anywhere, even in a mountainous area.
or on a steep hill (IRRI, 2009). Its parent species, although native to Asia and certain parts of Africa, the crop has been commonly cultivated in many cultures worldwide, through centuries of trade and exportation (IRRI, 2009).

Other than its significance economically, *Oryza* has become a very important crop for genetic and genomic studies. The crop is a diploid with twenty-four (24) chromosomes which can be recognized individually using cytogenetic techniques (Fukui and Lijima, 1991). The rice genome is small (about 430 Mb) as compared to other cereal crops such as wheat which has 16,000 Mb, barley and maize with 4,900 Mb and 2,400 Mb respectively, and contains an estimated 32,000 to 62,000 genes (Bennetzen, 2002; Sasaki and Sedoroff, 2003). Its small genome size has made it to become the prominent model system for cereal genomics as well as a model for monocotyledonous plants.

The commonly cultivated rice crop is an annual which can grow to a height of about half a meter (0.5 m) to about two meters (2 m). Certain varieties however, can grow much taller to between six meters (6 m) to nine meters (9 m). Certain deep-water varieties grow with the gradual rise of the flood water level. A rice plant can mainly be divided into two parts namely root system and shoot system.

The plant, depending on the variety and soil fertility can grow to up to 1 to 1.8 m tall, or more. Rice possesses long, slender leaves with a length and breadth of between 50 to 100 cm and 2 to 2.5 cm respectively. The small flowers are produced in a branched arching to the pendulous inflorescence 30-50 cm long. The caryopsis measuring 5 to 12 mm in length and with a 2 to 3 mm thickness is known to be the edible part of the rice plant and is made up of endosperm, embryo, and glumes (Boumas, 1985). Certain varieties even possess awns at the tips of the grain. The awn
is sometimes very long on some varieties, so long that special machines are needed to pry away
the awns before the paddy is de-husked (Belsnio, 1980).

Li (2003) described the grain of rice as paddy or rough rice, made up of brown rice (or caryopsis)
and the hull. The endosperm, embryo and several thin layers of well differentiated tissues, the
pericarp (the ovary wall), the seed coat and the nucleolus make the brown rice (or caryopsis). Li
(2003) noted further that the seed coat consisted of six layers of cells, with the aleurone layer,
being the innermost. The embryo comprises the embryonic leaves (plumule), bounded by a sheath
(coleoptiles), embryonic primary root (radical) unsheathed by the coleorhizae, and the joining part
(mesocotyl). Rice endosperm is made up mostly of starch granules in a proteinaceous matrix,
together with sugar, fats, crude fibre and organic matter. The hull weight is about 20% of the total
grain weight. The hull of some rice grains has the palea, lemmas, and richilla, while others have
rudimentary glumes and perhaps a portion of the pedicel. The lemma is usually tough, archmen-
like, sometimes awned, and bigger than the palea. Grain ripening stage (15-65 days) can be
subdivided into milky, dough, yellow-ripe, and maturity stages based on the texture and color of
the growing grains.

African rice is known to have small grains that are in the shape of a pear and also have a red bran
and an olive-to-black seed coat, simply branched straight panicles, and short, rounded ligules.
Some Asian rice types however, also possess these pear-shaped grains with a red bran, with some
African types having pointed ligules (Richards, 1996). Other ecological traits of the two species
may be more significant when the point of view is switched to human selection potential. African
rice (O. glaberrima) varieties seem to possess some negative traits when it is compared to the
Asian Oryza sativa in that, it comes with brittle grain which is difficult to mill, the seed easily
shatters and most important of all, it doesn’t yield as much as the O. sativa. The O. glaberrima
species however offers some distinct advantages over *O. sativa* in that, the plant offers luxurious broad leaves that are perfect for shading out weeds and also, the species has been found to be more resistant to a host of diseases and pests. Moreover, African rice tolerates fluctuations in depth of water, iron toxicity, infertile soils, harsher climates and human neglect better than the species grown in Asia. Some *O. glaberrima* species also reach maturity quicker than the Asian types, which makes them ideal as emergency food crop (National Research Council, 1996).

The new varieties, named “New Rice for Africa” (hence NERICA), are a result from crosses between *O. sativa* and *O. glaberrima*. The genetic cross between these two species brings together the productivity of *O. sativa* of rice and the resilience of *O. glaberrima*. Scientists working with these two varieties at the West African Rice Development Association (WARDA) successfully crossed the two species by using a technique known as the embryo rescue techniques which enables the crosses to be fertile and mature successfully (Manners, 2002). NERICA varieties have been developed to be pest resistant and drought tolerant, shade out weeds by using their wide leaf characteristics, be able to grow in poor soils, and mature within 30 to 50 days quicker than the traditional varieties (Linares, 2002). Moreover, they have also been developed to produce about four hundred (400) grains per plant (as opposed to the seventy-five (75) to one hundred (100) grains per plant produced in previous varieties) (Linares, 2002). They are also known to possess 2% more proteins and as a bonus, are said to have the African rice taste. Its Asian parent’s high productivity which is transferred to the NERICA strains could cause the variety’s yields to increase from one 1 ton per hectare to about 1.5 tons per hectare without the aid of inputs. This indicates that, with the addition of fertilizers and proper care for the crop, yields can be doubled or even tripled. The new rice hence, holds great promise for the future in a region desperate to decrease hunger and increase food security (Linares, 2002).
2.2 History of rice in Africa

In sub-Saharan Africa, the crop (*Oryza barthii* formerly known as *Oryza brevilugata* which is a wild ancestor to *Oryza glaberrima*) is thought to have been grown for at least three thousand years (Portères, 1962). It was noted by Strabo that the crop was bred in the Fezzan which is now modern-day Libya by the Garamantes. African rice was perhaps common in the Sahara during the rainy periods. Despite the fact that this is well outside the area of production today (Chevalier, 1932). African rice, scientifically known as *Oryza glaberrima* is a recognizably different species from its cousin *Oryza sativa* - the Asian species and is unable to interbreed with it. Leo Africanus made the first reference to the crop in West Africa when he noticed the prominence of rice cultivation ‘on the waters’ in the region of current day Sokoto in northwest Nigeria during his travels through the region in 1560’s (Chevalier, 1932). Till today, the technique is still in full use in several places around the world. In as much as it is important, native African rice is among the lesser known major cereals (Portères, 1955; 1976).

Local to sub-Saharan Africa, *O. glaberrima* is thought to have been domesticated from the wild progenitor *O. barthii* (in the past known as *O. brevilugata*) by groups living in the floodplains at the curve of the Niger River somewhere 2,000–3,000 years ago (Portères, 1962; 1976).

In the absence of substantial archaeological evidence, it is hard to determine if Portères (1962; 1976) was right in proposing that *O. glaberrima* was primarily domesticated in the inland Delta of the Upper Niger River (somewhere in modern day Mali, approximately 2,000 or 3,000 years ago). Portères (1976) however, continued to state that the species dispersed to two secondary centers of diversification, one in the coast of Gambia, Casamance, and Guinea Bissau, the other in the Guinea forest between Sierra Leone and the western Ivory Coast.
The early colonial history of one of the most cultivated rice species, *O. glaberrima*, started with the advent of the first Portuguese in the West African coast. They first observed the growing of the crop in the floodplains and marshes of the Upper Guinea Coast (Linares, 2002). They noted in their narrative, covering the 2nd half of the 15th century and all of the 16th century, of large portions of land planted with rice by the indigenes emphasizing on the significant role that the cereal played in the diet of the native people. In 1446, Gomes Eanes de Azurara became the pioneer chronicler from Portugal to acknowledge that rice was being grown in the Upper Guinea Coast (Linares, 2002).

Currently, the native *O. glaberrima* has been succeeded everywhere in West Africa by *O. sativa*, the Asian species, popularized by the Portuguese into the continent as early as the mid-16th century (Portères, 1962).

### 2.3 Production of rice

Rainfall patterns, elevation, depth of flooding and drainage are some of the things that describe rice ecosystems. Generally, four cultivation practices are known in rice production namely upland, rainfall low land, flood-prone and irrigated cultivated rice.

Worldwide rice production dramatically rose between the years of 1961 and 2010, with a compound development rate of 2.24% every year (2.21% in rice-producing Asia). This rise was marginally more prominent than that for wheat (2.02% every year), but considerably less than that for maize, which rose at 2.71% every year. The majority of the growth in rice production was as a result of increased yields, which rose at an annual rate of 1.74%, compared with an annual average growth rate of 0.49% for area harvested (GRiSP, 2013).
The global rice industry according to FAO Stats (2017) has seen an increase in production in the last 25 years from 3.66 t/ha to 4.56 t/ha. The Asian region alone accounts for over 90 percent of that number. As shown in Appendix IV Figure 1, there has been a steady rise in production figures in the last 6 years from 2009 to 2014.

2.3.1 Production in Ghana

Rice cultivation in Ghana was smallholder-driven in specific environments under indigenous production system. This system became subject to change and transformation resulting from state interventions over time which have as their agricultural modernization policy focus, the promotion of large-scale commercial rice farms (Agbanyo, 2012).

Production of the crop in Ghana can be grouped into three main ecologies. These ecologies include: the lowland rain-fed ecology also known as valley-bottom, which is made up of rice planted in the receding waters of the Volta and other rivers making up 78 percent of the total harvested area of the crop in the country; upland rain-fed ecology which makes up 6 percent of the total harvested area and the irrigated ecology which makes up the remaining 16 percent (Kranjac-Berisavljevic, 2000; JICA, 2007).

Valley-bottom and Upland rice production might be viewed as the usual rice production technique and employ the use of species of African rice, *O. glaberrima*. Albeit primary cultivation is on a small scale, it is likewise to a great degree far reaching, particularly in remote regions and there is a specific market for the purported ‘red rice’ created accordingly. All through the greater part of the district north of the forest areas, rice is grown in little amounts in valley bottoms.
In Ghana, rain-fed upland rice is chiefly cultivated in the rocky territories of the Volta Region, between the Volta lake and the Togolese fringe. The rice territory extends amongst Ho and Nkwanta. Rice is viewed as the focal staple and the agrarian timeline rotates around its production. All the "conventional" rice is *O. glaberrima* albeit some early assortments of *Oryza sativa* are likewise present. Lately, the presentation of new frameworks of rice production has changed this trend. Valley-bottom cultivation has been embraced, especially by female farmers and is presently produced generally in lowland areas, ordinarily without additional water systems ("Rice production in Ghana", n.d.).

2.3.2 History of rice production in Ghana

The Ghana Irrigation Development Authority was set up in 1977 and started making various large-scale rice projects that relied on pumps, dams, intricate water-diverting and mechanical harvesting, and in addition concentrating on high-input rice varieties. A significant number of the irrigation projects set up within this period have been criticized for their approach, for failing to provide new advancements with adequate comprehension of local cultivating frameworks to empower a fruitful move to an alternative cultivating technique. These schemes have been a focus of numerous damaging reviews (Goody 1980; Konings 1981; Shepherd 1981). As in other areas, seeds, tillage and fertilizer were considerably subsidized and numerous growers extended their assets to a hundred plus hectares. Associations of affluent producers were created and for a period the scheme seemed fruitful. But, immediately the subventions declined, so did the associations and presently, only a small number of the growers are producing any rice at all.
The specialized training required by local growers to enhance their rice crop yields through irrigation is utterly necessary. Where agriculturists have a current vocation, they have been hesitant to try different things that involve new and more convoluted strategies for cultivation. One clear example is the Bolgatanga Irrigation Authority. For this situation, growers were invited from Bawku right around 250 km away to cultivate on the irrigation project on the grounds that the nearby Dagomba growers did not have any desire to embrace the new procedures required by the Irrigation Authority. This represents the issues that expansive scale irrigation projects have had in presenting new advancements for rice cultivation in Ghana and the approach was in this way, expected to change to incorporate more prominent cooperation with local growers to build up the procedure of progress from old cultivation techniques to new advances.

Rice production in Ghana has been fairly inconsistent in recent years with an average increase of 0.36 t/ha between the 2004 and 2005 production years. Production then saw a decrease in 2006 to 2 t/ha and a further decline to 1.70 t/ha in 2007. Production has since increased from 2007 to 2010 with a production difference of 1.01 t/ha between these years.

From 2011 through to 2014, production of paddy rice has experienced steady increase from 2.35 in 2011 to 2.69 t/ha in 2014 (Appendix IV Figure 2).

2.4 Seed Quality Characteristics

Seed quality is a relative term and can be characterized by the level of perfection when contrasted with an adequate standard seed. Seeds that fulfill the mandatory standard of genetic purity, good health and physiological purity (viability and vigor) and other characteristics are alluded to as quality seed (IRRI, 2003). The quality of seeds is considered as an imperative factor in expanding
yield. The utilization of high value seeds helps extraordinarily in higher production per unit area in order to achieve sustenance security in different parts of the world. Quality seeds have the capacity for effective use of the inputs such as fertilizers and irrigation (Hasanuzzaman, 2015).

Seeds of good quality is one that is unadulterated (of the chosen variety), full and uniform in size, viable (over 80% germination with great seedling vigor), and is without weed seeds, seed-borne diseases, pathogens, insects or other matter (IRRI, 2003). A blend of higher crop emergence, vivacious early crop development, and increased crop imperviousness to diseases and insects could result to a 20% rise in yield (IRRI, 2003).

Seed quality starts with choosing a proper rice variety to suite ecological conditions, management practices, and the end utilization of the crop (IRRI, 2009). The distinctive rice assortments have diverse physical and chemical qualities. It is critical to consider every variety's positive and negative attributes before settling on a choice of rice that will suite specific conditions.

Mbora et al. (2009) reported that seeds of the best quality will result in crops of the best quality in the field which will result to yields of the highest value. Richman et al. (2006) reported that the quality of the seed was very important to farmers as it measures the potential performance of the seed under optimal conditions.

2.4.1 Seed Quality Attributes

In the early beginnings of seed testing, purity and germination capacity were the main properties of seed which were considered while evaluating seed quality. Today, seed quality alludes to a
group of seed components thought to be of significance for the estimation of seed quality for propagating purposes (Esbo, 1980).

Thompson (1979) delineated 10 seed quality attributes with varying degrees of practical significance to agriculture viz analytical purity, species purity, freedom from weeds, cultivar purity, germination capacity, vigor, size, uniformity, health and moisture content.

Procedures of seed quality assessment which are internationally acceptable are occasionally published by the International Seed Testing Association (ISTA, 1985).

Seed Quality can be grouped into four main categories as follows:

- Physical qualities of the seed in the specific seed lot
- Physiological qualities which refers to aspects of performance of the seed
- Genetic quality which relates to specific genetic characteristics of seed variety
- Pathological quality which refers to the presence of diseases and pests within a seed lot

At the point where the seed possesses great physical, physiological genetic and health qualities, farmers have more noteworthy prospects of delivering a decent product. Excellent seed is key in getting a good yield stand and quick plant advancement even under unfavorable conditions albeit different factors, for instance, precipitation, agronomic practices, good soil quality, and disease and pest control are likewise critical.

2.4.1.1 Physical Quality

Physical seed quality refers to the percentage pure seed of the desirable crop in a seed lot. Size of the seed is sometimes taken into consideration in pure seed definitions. It is measured by certain
components such as Analytical purity, Moisture content, Size, Appearance, Colour, Insect infestation and Presence of other undesirable materials (Hasanuzzaman, 2015).

Analytical purity, also referred to as physical purity, is an indication of the seeds of the species under test in the sample and also the amount of foreign materials contained in the sample in the form of other seeds. The purity attributes are mostly expressed as a percentage by weight of the seed sample analyzed (Scott, 1980).

The pure seed component of physical purity appertains to the species specified by the source or the species predominantly discovered in the test. This pertains to all botanical varieties of that species. Other seed component indicates the seeds and seed-like structures of any plant species other than the pure seed (Hasanuzzaman, 2015).

Certain species of weed seeds which are not universally present on all farms and which once established are difficult to eradicate are known in Analytical purity terms as “Noxious” weeds. Materials such as straw, chaff, stones, broken pieces or physically injured seeds that are less than half of the original size, dust, gall, etc. are separated as the inert matter portions (Thomson, 1971 and ISTA, 1985).

The moisture content of a sample is the weight loss of the sample after drying or the amount of water amassed after it is distilled. This is calculated and expressed in percentage of the weight of the original sample. Seeds are regarded as structures made up of complex substances like cellulose, starch and proteins and also, water (Thomson, 1979). It is generally assumed that the high respiration at high temperature is in some way related to rapid loss in germination (Harrington, 1972).
2.4.1.2 Physiological Quality

Seed germination and seed vigor are attributes that are characteristics of physiological quality. The vivacity of a seed is known as viability. The degree of enthusiasm for production of decent seedlings or the capacity of seed for production of seedling with standard root and shoot under benign conditions is referred to as germinability (Vikaspedia, 2017).

According to Hasanuzzaman (2015), the ability of a seed to germinate includes factors such as germination capacity, viability, vigor, and other characteristics related to seed dormancy.

The significance of physiological quality can’t be over highlighted. Seed can only satisfy its natural role on the off chance that it is viable. Accordingly, physically uniform seed of an adapted variety will be useless if it is low in germination and vigor or in the event that it does not germinate when sown.

Greatest potential for germination and seed vigor happens amid physiological maturity. In any case, seeds have high water content at this stage, which upsets automated harvesting (Marcos-Filho, 2005). After physiological maturity, seed quality starts to diminish through the normal procedure of decay (Krzyzanowski et al., 2008), particularly when reaping is postponed, and furthermore under adverse climatic conditions.

Germination in laboratory tests is the emergence and development of essential structures from the embryo of the seeds being tested providing an indication of the ability for the structures to mature into a normal plant under favorable conditions in the soil (ISTA, 1985). The germination capacity of a seed lot is the percentage by number of pure seeds which produce seedlings in laboratory tests (Thomson, 1979).
Seed germination is reliant on conditions which are both internal and external. The most vital external factors include; air or oxygen, water, optimum temperature and in certain instances, darkness or light (Raven et al., 2005). For a few seeds, their future germination reaction is influenced by natural conditions amid seed development; as a general rule, these seed reactions are sorts of seed torpidity or seed dormancy.

The germination rate depicts what number of seeds of a specific plant species, i.e. variety or seed lot, are most expected to sprout or grow over a specified time frame. It is a measure of germination time and is usually communicated as a percentage, e.g., an 85% germination demonstrates that around 85 out of 100 seeds will most likely grow under appropriate conditions over the given germination time-frame.

The germination rate is helpful in the estimation of seed prerequisites for a given area or the required number of plants on the field. To seed physiologists and seed researchers, "germination rate" is the corresponding estimation of time taken for the procedure of plant germination to occur and end starting with time of sowing. Then again, the quantity of seeds ready to complete germination in a populace (i.e. seed lot) is alluded to as the germination capacity of the populace.

Historically, seed quality has been synonymous with germination; the main purpose of germination testing being to bring forth knowledge about the planting worth of the seed lot.

Many rice varieties have an inactive period instantly after harvest which is between the range of 0-12 weeks (ISTA, 2007; Mahadevappa and Nandisha 1987, Richman et al., 2006). It was reported in IRRI (2009) that by storing rice under traditional open systems, their germination rate will begin to deteriorate. ISTA (2007) considered germination test as the only test farmers can make on seeds to determine whether it is appropriate for sowing. By getting to know the germination rate, farmers
have the option to alter their sowing rates to achieve the desired plant population in the field (ISTA, 2007).

It was reported by Ocran et al. (1998) that for certified rice seed in Ghana, the minimum acceptable standard for germination percentage is 80%.

According to Rickman et al. (2006), normal and abnormal seedlings are counted on the tenth day after planting to determine the germination percentage. Normal seedlings were defined by Schenidt (2000) as the seedlings which develops with all essential structures and abnormal seedlings as those that sprouted during the assessment period but lacked the important structures such as cotyledons or were discolored or infected by seed-borne pathogens.

Viability is the term given to seeds which possess the ability to sprout and give rise to normal seedlings. This reference is used synonymously with germination capacity. In this sense, a given seed is either given the tag of being viable or non-viable relying upon whether or not it is able to germinate and create seedlings of normal attributes, accordingly, just viable seed lots representative of the populations of seeds which are of good quality may display high degrees of viability (Hasanuzzaman, 2015).

Germination requirement and dormancy features of this particular species are often presumed to be adaptations to the particular habitats in which it occurs successfully (Angevine and Chabot, 1979; Meyer et al., 1990). Germination at the right time and in the right place is very essential to deduct and determine the probability of a seedling surviving to maturity (Thompson, 1979). Studies and researches previously made have indicated that temperature (Hartleb et al., 1993; Ke and Li, 2006; Hay et al., 2008; Jarvis and Moore, 2008) and light (Coble and Vance, 1987; Lal and Gopal, 1993) are important ecological triggers in the seed germination of submerged species.
Seed vigor is defined as the characteristics of an active good health and natural robustness in a seed which upon planting permits germination to proceed rapidly under a wide range of growing conditions (Woodstock, 1969). Also, Ching (1973) defined seed vigor as the potential for rapid uniform germination and fast seedling growth under general field conditions.

Seed vigor is described as the capacity of seed to emerge from the soil and survive under potentially stressful field conditions and to grow rapidly under favorable conditions.

Certain theoretical parameters which has surfaced that make clear the meaning of vigor in terms of seeds, seedlings and plant performance include; Speed of germination, uniformity of germination and plant development under non-uniform conditions, wet and pathogen-infected soil, normal morphological development, germination and seedling emergence from cold, and storability under optimum or adverse conditions.

Among the many components of vigor, speed of germination is recognized as an extremely important aspect of vigor (Boyd et al., 1971). Seshu et al. (1988) used the rate of germination as a measure of seedling vigor in rice.

Seed vigor provides a very good estimate of the potential field performance, and subsequently, the field planting value of a seed (Willan, 1987). Rickman et al. (2006) also reported that though the speed of germination varies across varieties, the seed is considered to have germinated if the seeds absorb moisture and produce roots and the first leaf within 5 days.

By knowing the seed vigor of a seed lot, farmers can then decide whether a seed lot is suitable for continued storage or for immediate planting (Tokpah, 2010).
It was explained by Pollock and Roos (1972) that the causes of variations in seedling vigor are associated with maturity when harvested, how the yield is handled after harvest and the growth habit of the plant.

It was also stated by Perry (1981) that the determination of seed vigor is dependent on the seed and may be influenced by various environmental conditions during seed maturity, handling of crop products both before and after harvest and storage.

Maguire (1962) brought to light the existence of a positive relationship between seedling vigor and germination rate. Wanjura et al. (1969) also showed that the early emergence of cotton is in correlation with both greater survival of seedlings and higher yield.

The loss of a seed’s ability to germinate is the last step (not the first step) in a long process of deterioration (gradual loss of viability). Decrease in seed vigor and other physiological changes happen before loss of germination. Therefore, seed with acceptable germination can be low in vigor.

2.4.1.3 Genetic Quality

Genetic purity refers to the percentage of contamination by seeds or genetic material of other varieties or species. The genetic purity of any commercial agricultural product propagated by seed begins with the purity of the seed planted (Seedquest, 2015).

Crops developed by seeds of a variety offer the same features and these characteristics are reproducible from one generation to another. Seed of varied varieties of the same crop are often difficult or not so easily distinguishable once it is harvested. A mixture of different varieties of the
same crop or species can occur when the grain/seed is sold and it enters into the formal and informal marketing systems.

A blend of varieties can be an issue in light of the fact that: mixed varieties may develop at various circumstances which bring about issues in harvesting, post-harvest handling, and brings about reduced yields.

Moreover, each seed of an undesired variety in a mixture will create seed when it is sown and those seeds will give rise to more seed and consequently, every year the extent of the undesired variety ends up plainly more prominent.

It should however be called to attention that conventional varieties or landraces especially of cross pollinated varieties utilized by subsistence farmers are frequently populaces of plants that are not extremely uniform. This heterogeneous character can be advantageous in a few conditions of low precipitation, low fertility and pest and disease pressure.

High yielding capacity is connected to a scope of plant attributes including plant engineering, supplement utilization proficiency and variables specified above i.e. adaptation to local conditions, resilience to pest and disease attacks and so forth. Increased yields mean more nourishment and income for farmers.

Resistance to pests and diseases (biotic factors) implies that a plant can survive with these organisms without any notable loss to yield and quality. Clearly, resilience to vital diseases and pest is critical and a major goal of plant breeders. Disease and pest resistance is viewed as outright imperviousness to harm by the organisms.
Maintenance of cultivar purity is the significant purpose behind the presence of the seed accreditation scheme (Scott and Hampton, 1985), and the smooth operation of the scheme depends on seed producers and seed traders adhering strictly to the right strategies.

2.4.1.4 Pathological Quality

Pathological quality sometimes referred to as seed health quality is said to be the presence or absence of disease in or on the seed.

The disease-causing organisms come in various forms such as fungi, bacteria and viruses, and animal pests, including nematodes and insects on or in the seed although conditions such as trace element deficiencies may also be involved (ISTA, 1985).

ISTA (1985) grouped the organisms that are commonly associated with causing diseases to seeds, seedlings and crops into 5 categories, although some other diseases may result from inefficiencies of plant nutrients. Mechanical damage has also been found to impair seed quality.

The five groups of organisms include:

- Fungi,
- Bacteria,
- Viruses,
- Nematodes, and,
- Insects.

Fungi may assume an imperative part in affecting the nature of seeds. Right around 150 species have been discovered related with grain seeds of different sorts. Fungi relationship in seeds will
most likely be on the higher side in regions where wet season prevails at the time of harvest or atmospheric humidity stays high amid the development of the seed. (Dharamvir, 1974).

Henderson and Christensen (1961) also stated that improper store management and crop husbandry can increase the incidence of fungi infection.

Bacterial diseases happen most often in areas where high dampness or wet climate prevails amid the time heads are developed (Kreitlow et al., 1961). Numerous microscopic organisms that cause diseases in grains are seed-borne.

Kreitlow et al. (1961) also noted that viral infections resulted in yield reductions of about 75 percent in wheat and 64 percent in barley.

Most grain nematodes diseases are related with soil infections yet a few are seed-borne. Some of which incorporate the white tip infection of rice (Kreitlow et al, 1961).

Insects cause quantitative and qualitative losses to seeds placed in storage. Commonly found insects in storages include weevils, grain borers, grain moths, and beetles among others (Henderson and Christensen, 1961).

2.5 Seed Testing

Seed testing is the science of evaluating the quality of seeds to determine their value for planting. Seed testing is essential for the assurance of the quality of seeds based on various seed quality characteristics, giving a premise to cost and purchaser discrimination among seed lots and seed sources, deciding the source of seed problems, in this manner encouraging any restorative measure(s) that might be required and satisfying the legal and administrative requirements for
certified seed classes and take into consideration the movement of seeds across international boundaries.

Strategies and benchmarks for performing seed testing for most crops are established by the International Seed Testing Association (ISTA). The methodology and measures are intermittently updated in light of new scientific proof.

According to the FAO four assessments are ordinarily conducted in seed testing laboratories. These include;

- Tests on purity,
- Incidence of noxious weed seed,
- Germination test, and,
- Moisture content.

Other seed tests carried out also include,

- Varietal purity, and
- Seed borne diseases/Seed Health Test.

2.5.1 Physical purity test

This physical purity test which is also recognized and alluded to as analytical purity is the total percentage of the seed that is of an identical crop but not necessarily the same crop variety.
The purpose of these seed tests is to determine the physical composition of a seed lot by going through a detailed and precise separation on a small representative working sample (Elias et al, 2012).

To perform this test, the sample is isolated into their various segments. At the point when purity assessment is done, it is the principal test to be conducted in light of the fact that ensuing tests are done using the pure seed component.

Pure seeds are alluded to as the species being considered and notwithstanding mature, undamaged seeds which also comprises: small shriveled, undeveloped and sprouted seeds, if they can be recognized as the desired species; and pieces coming about because of breakages which are more than one-half of their original size (ISTA, 1976).

Distinctive segments of the specimen might be comprised of different seeds of all species beside that which is under test and Inert matter. Inert material involves bits of broken or damaged seeds not as much as a large segment of the principal size (not less than half of the original size), wings of coniferous species, coniferous and leguminous seeds with the seed coat altogether discarded and other matter, for instance, parts of leaves, twigs, stones and soil. In Coniferae (with the exception of Chamaecyparis, Cupressus and Thuja) any residual seed wings not officially expelled in cleaning ought to be isolates and classed as inert material.
2.5.2 **Incidence of noxious weed seed**

As selected by decree or by official guidelines, this is an extension of purity test (analytical test) to show the degree of incidence of certain weed seed which is considered dangerous to productivity.

2.5.3 **Germination test**

Germination is a general term characterized by the rise and advancement from the seed embryo of fundamental structures which are demonstrative of the seed's ability to deliver an ordinary plant under positive or reasonable conditions (Justice, 1972; ISTA, 1976).

This is to quantify the capacity of the seeds to sprout and create ordinary seedling. Abnormal seedlings do not have a shoot, root or have different deformities. An essential component among all the quality estimations of a seed lot is the likely germination of the seeds (Bonner, 1974).

As indicated by Elias *et al.* (2012), germination tests are performed on seeds to arbitrate how they will perform when sown in the field, the garden or in a seedling nursery. This usefulness of the data received from this test is demonstrated with regards to labeling or marketing purposes or in deciding whether a seed lot has been legitimately labeled when sold or offered available to be purchased.

Germination is conveyed as the level of pure seeds which produces normal seedlings or as the amount of seeds growing per unit weight of the specimen.

In some special cases, all germination tests ought to be performed with pure seeds which are isolated from the seed lot by the purity test. The exemptions are species with minute seeds in which
it is impractical (a few species of Eucalyptus) or extremely cumbersome (Alnus, Betula, Populus, Salix) to isolate the seeds from the accompanying inert material or chaff. In cases such as this, the assessment is made with the same number of replicates however the replicates possess identical weight as opposed to an equivalent number of seeds (Bonner, 1974).

The perfect conditions for the different periods of germination and seedling advancement are not tantamount and may even be distinctive for different sorts of seeds inside a similar seed lot. The purpose of this seed testing study has along these lines been to choose the correct blend of conditions which will give the most standard, fast and wholistic germination for most of similar species.

Rarely is soil utilized as a substrate for seed germination evaluations on the grounds that each sample will be significantly different in physical, chemical and biological properties. While the germination results may be more equivalent with field conditions, the problem of reproducibility and trouble in comparing tests of contrasting seed lots render it inadmissible. Artificial media are a great deal more effortlessly standardized.

Most research center tests on species with minute seeds are conducted using paper. Different materials used incorporate sand, granulated peat moss and extended mica (Vermiculite and Terralite). Justice (1972) expressed that the fundamental requirements for the substrate include;

- non-toxic to the germinating seedlings,
- free of fungi and other micro-organisms, and,
- of porous texture to enable adequate aeration and moisture for the germinating seeds.
The selection of media on which the seeds are put for germination is reliant on the sort of equipment, the species of seeds, the working conditions and the experience of the person conducting the test (Bonner 1974).

Abnormal seedlings are excluded in the germination evaluation since they seldom endure long enough to produce plants.

Four categories of standards were perceived by the International Seed Testing Association (ISTA 1976) for seedlings which were deemed abnormal. These were, (a) damaged seedlings, (b) deformed seedlings, (c) decayed seedlings, (d) seedlings with unusual hypocotyl formation. These categories and their attributes are characterized in detail in the ISTA rules. In a laboratory test, most of the normal seedlings are generally expelled at the interim counts, yet the evaluation of the numerous unsure and abnormal seedlings must be left until the point that the test is concluded, to ensure that passively developing yet otherwise normal seedlings are not inaccurately characterized.

2.5.4 Moisture content

The moisture content of a seed is the value of weight loss in the seed sample when it is dried. Moisture is expressed as a percentage of the mass of the genuine sample. It is one of the most significant factors in the aim of maintaining quality of seeds.

There is an immediate relationship between deterioration rates and moisture content, fungal attack, insect infestation level, susceptibility to mechanical damage, and storability. Be that as it may, this is not a compulsory test with a standard seed testing.
There are a few factors which are more essential to the quality and function of seed than moisture content. Moisture content is in connection with almost every aspect of seeds and their function, including their maturity, timing of the harvest, susceptibility to mechanical injury during threshing or handling, longevity in storage and injury due to heat, frost fumigation, insects and pathogens. Due to this, moisture content is perhaps the most significant factor in the determination of when seed is harvested, how it is handled after harvest and how long this seed can maintain its quality (Elias et al, 2012).

With a specific end goal to quantify the moisture content of seeds, strategies can be extensively categorized in two classes: Direct technique and Indirect technique.

**Direct technique**

Under this group, the seed moisture content is calculated directly by fall or rise in seed weight. These are:

- Desiccation method,
- Phosphorus pentaoxide method,
- Oven-drying method,
- Vacuum drying method,
- Distillation method,
- Karl Fisher's method,
- Direct weighing balance, and,
- Microwave oven method.
**Indirect technique**

The indirect method is quite inaccurate; estimation is approximate but convenient and quick to use. They are, much of the time utilized at seed processing plants. This strategy can be utilized to test other physical parameters like electrical conductivity or electrical resistance of the moisture present in the seed. Qualities are measured with the assistance of seed moisture meters and these values are changed into seed moisture content with the assistance of calibration charts, for every species, against standard air-oven strategy or basic reference technique.

Most importantly, Karl-Fisher’s technique has been regarded as the most accurate and the essential reference technique for standardizing different strategies for seed moisture determination. The constant temperature oven drying technique is the main useful technique, affirmed by International Seed Testing Association (ISTA) and other associations to be used for routine seed moisture determination in a seed-testing research facility (Seed Moisture Testing, n.d.).

The constant temperature oven drying method is broadly grouped into two categories:

- Low Constant Temperature Oven Method and
- High Constant Temperature Oven Method.

The suggested technique for seeds of the species rich in oil content or unstable substances is known as the low constant temperature oven technique. In this technique, the measured weights of moisture bottles alongside seed material are set in an oven upholding a temperature of 103°C. Drying seeds in the temperature stated above are kept in the oven for about 17 hours ±1 hour. The relative humidity of the surrounding air in the research facility must be under 70 percent when the moisture content determination is being assessed.
High constant temperature oven technique is similar to the low constant temperature method except that the temperature of the oven is kept at a temperature of 130°C-133°C. If the sample is *Zea Mays*, then it is dried for a period of approximately four hours. In the case of other cereals, drying takes two hours and for other species, it takes one hour of drying. In this method, no distinct prerequisite is involved relating to the relative humidity of the surrounding air in the facility during the determination of moisture in seed moisture testing.

### 2.5.5 Varietal purity

This is the percentage of the pure seed that will bring about plants which display the attributes of that particular crop variety. The most ideal approach to decide the varietal purity is during field review when the seed is being produced.

If a variety authentication trial is demanded, then samples of the seed is grown in plots alongside the plots of the known crop varieties. Observations are conducted from early seeding growth through pollination and seed development to confirm if the seed is the specific crop variety.

### 2.5.6 Seed Health

Standard principles and methodology are employed by mycologist and Phyto pathologists to figure out the presence of seed borne diseases.

A large number of high yielding varieties have shown weakness to various diseases and a several of these infections are seedborne. The developing seeds, also known as the seed primordium, may contract contamination either directly from the tainted plant through the flower or fruit stalk and the seed stalk or directly from the surface of the seed or the disease might be presented from the
outside through the stigma or ovary wall or pericarp and the flower or fruit stalk and later through
the testa or seed coat.

The several parts mentioned may be penetrated by a pathogen and may end up being infected.
Harvesting, threshing and processing are certain instances in which the infestation or
contamination of the seed may occur (Agarwal and Gaur, n.d).

To guarantee that seed health tests are standardized and give solid and reproducible outcomes as
per the given specifications of the test techniques, strategies ought to go through a peer review
system and additionally, cooperative investigation among laboratories. Three essential
associations publish standardized seed health tests: The International Seed Testing Association
(ISTA), the International Seed Health Initiative (ISHI), and the U.S. National Seed Health System
(NSHS) (Gullino and Munkvold, 2014).

Hiltner in the 1010’s talked about strategies for evaluating the health of seeds in germination tests
(Mathur and Jørgensen, 2002). In any case, as indicated by Agarwal and Sinclair (1987), the
primary seed health testing research center on the planet was established in 1918 at the
Government Seed Testing Station, Wageningen, in Netherlands.

ISTA technique approval basically inspects a seed quality test to guarantee that the depiction of
the strategy is clear and complete and that the method gives exact, reproducible and repeatable
outcomes (Hampton, 2007).

In spite of the fact that the worldwide seed industry requires that the number of regulated seed
health tests be exponentially expanded, bodies involved in the regulation of new techniques need
to guarantee that the techniques are approved and hence reproducible and repeatable by research
facilities from everywhere throughout the world. This is vital for the general harmonization of
phytosanitary regulations which involves the movement of seed in global seed exchange (Munkvold, 2009).

2.6 Use of certified seeds in crop production

Certified seed is developed from seed of known genetic origin and genetic purity, developed in a controlled and tried way, handled and declared as per the Law on Seeds (Bogdanović et al., 2015). Seed certification is a quality assurance framework whereby seed purposed for marketing is liable to official control and assessment (Aidoo et al., 2014). Seed quality is guaranteed through a protracted development process that starts by building up the seed crop varietal seeds, crop support and expert testing of crops, and finishes in the wake of harvesting, processing, quality control and labelling. Thus, every nation strives to guarantee great organization of seed production regulations that govern all phases in the seed production process (Milošević et al. 1996).

The immediate target of seed accreditation is to supply high quality seed to growers and different producers, which is consistent with the type of crop desired, high in purity and germination capacity and free from diseases and pests (Kojo et al., 2015). Seed quality is most critical in crop cultivation, as top-notch seed is fundamental for good product yields and great returns and limits the probability of failure of the crop.

There are just a few nations in the world making full use of certified seed. The Republic of Croatia is a case of a nation where the utilization of certified seed was 100% preceding its EU accession. Around the world, the level of certified seed utilized ranges from 20% (in developing nations) to 80% (in developed nations) (Bogdanović et al., 2015).
In Africa, smallholder farmers are confronted with several issues when the time comes to set up new crops. These include a constrained access to quality seeds. Be that as it may, where seed is accessible, its quality is low. Moreover, the supply of seed is much more restricted or totally absent with regards to indigenous or local crops, which, once in a while, assume a vital part in food security. Furthermore, national seed production and dissemination frameworks inadequately take care of seed demand and growers need to a great extent depend on their own saved seeds (Guei et al., 2010). More often than not, for varieties grown locally, fundamental seed vital for delivering certified seed is accessible in constrained amounts and consequently seed ventures cannot create vast amounts of certified seed (Jones and Rakotoarisaona, 2007).

Research has demonstrated that certified seed varieties reliably beat saved seed in yield, quality and test weight. In an investigation led by the Georgia Crop Improvement Association (2015) on little grain penetrate box review, certified seed brought about a US$ 6.75 per acre return over the cost of the seed (Syngenta, 2016).

The utilization of quality seed by growers has prompted improved yields in north Cameroon. Data assembled from rice growers and extension officers shows that ordinarily rice farmers acquire a yield of 2–3 t/ha with farmer saved seed, however with the utilization of certified seed and great cultivating practices, up to 6.0–8.0 t/ha can be accomplished (Guei et al., 2010). Agriculturists who utilize certified seed get higher quality seeds as an essential for accomplishing higher yields. The utilization of certified seed checks the spread of weed species by means of seed, in this manner lessening the quantity of treatments required with herbicides while decreasing expenses. Numerous infections of cultivated crops are transferred by seed, which is the reason it is vital to utilize seeds with the required health and specific purity (Bogdanović et al., 2015).
Seed processed at registered centers possesses extensively more elevated amount as far as consistency of seed size and seed quality than the seed saved by farmers from their own cultivation. By treating seed at processing centers with fungicides and insecticides, thereby shielding the seeds from diseases and infections, a higher quality disbursement of molecule arrangements on the seed itself is guaranteed (Bogdanović et al., 2015).

The limitations of this traditional source of seed are low yield and absence of guaranteed seed quality; after a brief time of production, a mixture of varieties of seed occurs, prompting loss of desirable attributes. In spite of these impediments, growers keep on using a greater amount of the farmer saved seeds and restricted amounts of certified seeds (GRAIN, 2007).
3.0 MATERIALS AND METHODS

3.1 Site Background Information

The Dawhenya Irrigation Project was developed by the State Farms Corporation in 1959 with the aim of producing vegetables for the Accra-Tema Metropolitan area. Construction work on the dam began and was completed during 1975 to 1978, with a total irrigable area of 450 hectares. About 200 hectares of this irrigable land so far is being used.

The Dawhenya reservoir, with a capacity of 5.8 mm³, receives its water from the Dechidaw River, which is ephemeral and has a catchment area of 500 km² at the dam site (MOFA, 2015).

Rice is the main crop produced at the site. Other crops grown aside rice are maize and vegetables. The various varieties of rice produced at the site are Marshall, Aromatic short, Jasmine 85 and CRI-AgraRice. Private entities also use the services of the site with one company producing flowers solely for export.

This research was divided into two parts, a survey which employed both qualitative and quantitative approaches and a lab analysis.
3.2 Experiment 1: Evaluation of the use of quality rice seed for production and factors which may influence yield decline

A questionnaire was developed and pretested at the Ashaiman irrigation Scheme using twenty (20) respondents. The feedback was then used in revising the questionnaire for use at the Dawhenya irrigation scheme.

The research site had 237 rice farmers at the time of study out of which 109 were randomly selected to participate in the study.

The questionnaire administered to the randomly selected respondents was a ten-page document (Appendix I) comprising of 4 sections ascertaining their perception about the causes of yield decline in their various fields and the role seeds play.

Section One of the questionnaire asked of the demography of each respondent. Questions on age, sex, religion, number of dependents, etc. were asked in this section.

The Second Section was on farming experience and the respondents’ familiarity with certified seeds. Farming experience in general as well as experience in rice farming was also asked. The size of their land used for cultivating rice, the variety grown by the respondent, and how long they have grown them was asked as well in this section. This section also included questions on whether or not the respondents grow other crops aside rice or have ever grown other crops aside rice.

Section Three was meant to find out the methods of production employed at the site by each respondent. Stages of production such as seed selection, land preparation, through to post harvest processes were sub sectioned under this section and questions were asked about each stage of production. Questions such as the origin of the planting materials in seed selection, method of land preparation (whether manual labor using hand held tools or mechanical method using tractors and
other machinery) were asked in the land preparation subsection and also the type of crop establishment method each respondent applies on their field (whether direct seeding or nursery and transplantation or if there is any other method employed).

Section Four, the final section of the questionnaire, inquired about the perception of the respondents on the causes of yield decline in their fields. In this section, subsections on the stages of production process were again employed and various questions were asked pertaining to the respondents’ perception of factors in each stage of production and its relationship to yield. In this section, respondents were required to rate on a scale of 1 to 3 with 1 indicating that the factor of production at that stage directly affects yield either positively or negatively; 2 indicating indirect effect and three indicating no effect. The final part of this section was dedicated to finding the opinion of each respondent on the one process or factor of production which contributes the most to yield loss on their field.

The questionnaire was administered using the interview approach where the randomly selected respondents were personally interviewed on their fields and in their homes and their responses collected and analyzed using the SPSS and Tableau 10.2 software.

3.3 Seed Quality Evaluation

3.3.1 Experiment 2: Seed Sampling

Thirty (30) out of the 109 respondents were identified for the evaluation of the quality of seeds used for production at the site.
Seed samples (1 kg in weight) were collected from the farmers prior to planting and after harvest. Samples used for planting (Sample A) and (Sample B) from the harvested material earmarked for farmer saved seed were used for the seed quality evaluation.

The seeds were sampled using hand sampling to obtain the primary sample. The primary samples were then mixed and put together to form the composite sample, which was then taken to the lab.

The samples were collected in moisture-proof Ziplock bags (33cm x 25cm). A smaller moisture-proof Ziplock bag (26cm x 20cm) was also used to separate the samples to be used for the moisture test from the bulk samples. The smaller moisture proof Ziplock bags were then placed into the bulk samples each corresponding to their own variety and the samples were labelled.

In labelling the samples, paper tapes and markers were used. The inscriptions on the labels contained the name of the variety, the number of the farmer and the type of sample (Sample A or Sample B).

### 3.3.2 Laboratory Evaluation of sampled rice seeds

The seed analysis was conducted at the National Seed Testing laboratory of the Ghana Seed Inspection Division (GSID) at Pokuase using standard procedures.

The GSID is a division under the Plant Protection and Regulatory Services Directorate PPRSD and is responsible for the registration of the seed growers, monitoring of seed and planting material production of crop species, certification of foundation and certified seeds and also primary and secondary planting materials, training of major stakeholders (seed inspectors, registered seed growers, dealers, extension staff of the MOFA and NGOs, etc.) and also the facilitation of promotional activities in the seed industry.
They obtain their mandate from the part two of the Plants and Fertilizer Act, 2010 (Act 803). The National Seed Testing laboratory operates with the current International Seed Testing Association (ISTA) rules (2017).

3.3.2.1 Moisture Content of rice seed

Moisture content of the submitted samples was the first test to be conducted. This was done using the small moisture-proof Ziplock bags which were placed inside the bulk submitted samples. In conducting the moisture test, the 2017 ISTA rules were used as the guideline.

The constant temperature oven method was used to determine the moisture content of the submitted samples. This is well known in many labs and it is used by many international organizations like ISO, ICC, EU. The principle behind the constant temperature oven method is that the Moisture Content in a seed is determined by the loss in weight after the working sample has been dried for a specific time in a drying oven set at a specific temperature. The temperature and amount of time used is species dependent (in this case 133°C for 2 hrs). For certain seeds grinding or cutting is required before oven drying. The equipment (Appendix V) used for this analysis included:

- An oven with a stable and a high capacity capable of providing a uniform temperature.  
  (Appendix V, Figure 7)
- A well calibrated grinder/mill (Appendix V, Figure 3)
- A sensitive balance capable of weighing at least up to 3 decimal places (Appendix V, Figure 4)
Containers made of a non-corrosive metal (stainless steel), with random numbers inscribed on their lids (Appendix V, Figure 5)

Desiccators with plates at the bottom capable of holding samples after drying during cooling (Appendix V, Figure 8)

The desiccants are usually placed in the desiccator to absorb the moisture removed from the environment of the removed from the environment of the desiccator. This ensures samples cooled in a desiccator do not reabsorb moisture.

Before the process was started, the oven was turned on so as to build heat to the required temperature before the samples were placed in.

With the oven building up heat, the grinder was cleaned and calibrated to a fine texture and the sample were mixed and ground. Three spoons full were fetched into the feeder into a separate grinder reception container with lids.

The numbers on the non-corrosive containers were recorded on a moisture form. Two containers were used for each sample of the 60 samples representing two replicates for each sample. The empty containers were weighed with their lids placed under the containers on the balance. The weights were recorded and the value on the scale zeroed.

The ground samples were then mixed with a spoon and three scoops were fetched into the metal containers whose weights have been zeroed on the balance giving now the weight of just the scooped sample. This weight recorded was tallied on a moisture form.

This procedure was repeated for all sixty samples, cleaning the grinder thoroughly each time after grinding before grinding another batch to prevent introduction of fragments from one sample into another.
The samples were then placed into the oven after grinding and weighing for two (2) hours and afterwards, the samples were taken from the oven and allowed to cool in the desiccator for forty-five (45) minutes after which the final weights were recorded.

Each replicate was calculated separately using the formula:

\[
\frac{(\text{container weight + sample weight before drying}) - (\text{Weight of container and sample after drying})}{\text{sample weight before drying}} \times 100
\]

The maximum tolerance between replicants should not be greater than 0.2%.

### 3.3.2.2 Working Sample Determination

Working samples were taken from the bulk composite samples and submitted for the analysis of other quality characteristics of seed. In taking the working samples, care was taken to ensure that the sample taken was a representation of the submitted sample.

According to the ISTA rules (2017), a submitted sample must at least be the size specified in the International rules of ISTA (2017) for a submitted sample may comprise either the whole or sub-sample of the composite sample (In this case the whole composite samples for the sixty samples were submitted).

The working samples which can be obtained either by the use of mechanical dividers or manually (by hand) was taken manually using the hand halving method. Neergaard (1979) stated that there is an important disadvantage of using mechanical dividers in connection with seed health testing; in that contamination may occur from one sample to subsequent ones and the safe cleaning of the divider after each sampling is too cumbersome to be practical.
The seeds were evenly poured onto a smooth clean surface, mixed thoroughly and mounded in a heap.

The mound was divided into two (2) halves and each half was halved again giving four portions. Each of the four portions was halved again giving eight portions as arranged in Figure 3.1.

![Figure 3.1: Arrangement of working sample in eight (8) portions](image)

Alternate portions were combined and retained and four portions were taken from the eight (Figure 3.2). The four portions taken out were poured back in the original bags of the submitted sample.
Figure 3.2: Arrangement of working sample in four (4) portions

The division process was repeated until a very small portion remained on the division table. That small portion was again divided into eight portions using the same method and four portions collected but this time, the portions were weighed on a balance (Appendix VI, Figure 9) to obtain the recommended working sample of 70 g (maximum of +0.5 g) for rice.

3.3.2.3 Purity Analysis

The purity analysis for each of the sixty samples was done with the aid of the current ISTA (2017) rules and 3rd Edition (2010) ISTA handbook on pure seed definitions.
The purity and other seed determination form was filled with the information required before the analysis began.

In this analysis, a diphanoscope (Appendix VI, Figure 10) was used to separate the pure seed from the inert materials and other seeds.

The pure seed definition for rice is that a pure rice seed should have; spikelet with glumes, lemma and palea enclosing a caryopsis, including the awn irrespective of its size or a piece of caryopsis larger than one half the original size (ISTA, 2010).

Once separated, the pure seed portions were weighed using a balance (Appendix VI, Figure 9) and recorded, and so were the other seed portions and inert matter portions. The weights were tallied and the total also recorded.

Their percentage were calculated using the formula: $\text{Fraction} \% = \frac{\text{Fraction}}{\text{Total}} \times 100$

The percentage weight loss was also calculated using the formula:

$\text{Weight loss} = \frac{\text{Working sample} - \text{Total Working sample}}{\text{Working sample}} \times 100$

The type of inert matter found during the analysis was listed on the form and the species name and number of other seeds found other than the pure seeds were also recorded.

3.3.2.4 Germination and Vigor

Seed germination and vigor analysis was the next test done on the samples. The pure seed fraction from the purity analysis of each of the sixty samples was used in determining the germination and vigor of the lots. The germination test was done using ISTA (2017) rules and the ISTA (2009) handbook on seedling evaluation 3rd edition with amendments.
The rolled paper towel method was used in the analysis.

One hundred seeds of each sample were spread evenly on a double moistened blotter paper (Figure 3.4) with wax paper underneath with the help of a seed counting board (Figure 3.3). Another sheet of moistened blotter paper was placed on top of the seeds (Figure 3.5) and the entire apparatus wrapped and tied at the end with rubber bands to prevent the seeds from slipping out. The wrapped sheets were then labelled with the sample number and the date of planting (Figure 3.6). This procedure was repeated 3 more times, giving four replicates for each sample. The samples were then evaluated 5 days after planting for the first count and then 14 days after planting (9 days after first count) for the final count.

The first count was considered as the vigor in accordance with ISTA rules (2007). The seedlings were evaluated using the ISTA (2009) handbook on seedling evaluations. Normal, abnormal, fresh seeds and dead seeds and their counts were recorded on the germination forms and expressed in percentages. The final germination percentage for each sample was obtained by finding the average of the replicate.
Figure 3.3: Seed counting board with one hundred (100) seeds in holes

Figure 3.4: Evenly spread seeds on double moistened blotter paper

Figure 3.5: Sheet of moistened blotter paper placed on planted seeds

Figure 3.6: Rolled up labelled planted seeds
3.3.2.5 Seed Health Analysis

The pure seed fraction from the purity analysis was also used in the seed health test. The test was done using the current (2017) ISTA rules, the International Rules for Seed Testing Edition 2013 with annex to seed health testing and a handbook on seed mycology First Edition (1994) by Mathur and Kongsdal.

The blotter method which is one of the incubation methods was used to carry out the health analysis for the submitted samples. In the method, twenty-five seeds of a sample were plated on a well water-soaked blotter in Petri dishes replicated seven times giving eight replicates and two hundred plated seeds per sample in all, as shown in Figure 11 of Appendix VII.

The plated samples were then incubated for seven days at 20°C ± 1-2°C under 12 hours alternating cycles of light and darkness. Ultra violet light was used to assist the incubation. (Appendix VII, Figure 12)

After seven days, the incubated seeds were evaluated with a stereo microscope under different magnifications of up to sixty times (Appendix VII, Figure 13). The evaluation was done by thoroughly examining each of the two hundred seeds and the identification of fungi was based on their habit characters which is the way individual fungi developed on seeds and on the morphological characters of their fruiting bodies. Further identification of the species was done by preparing slides of the species formed on the evaluated seeds and examining their spores and conidia under a compound microscope which can magnify up to four hundred times (Appendix VII, Figure 14).
The identified species were recorded on a worksheet in rows. Each row had columns numbering 1-8 which represented each replicate per infection per sample where the infection counts of the identified species were recorded.

3.3.2.6 Other Tests Carried Out

Aside the tests carried out at the National Seed Testing Lab, Pokuase, another test was carried out on the submitted samples using the pure seed fraction.

One thousand seeds were counted for each sample and weighed in grams. This was replicated twice and the average was found. This test was used to find out if there was a relationship between the weight of the seeds and its vigor.

3.4 Analysis of Data from Lab Tests

The data obtained from the tests conducted on moisture content, purity, germination and seed health along with other tests conducted on the thousand-seed count was analyzed using excel and Genstat statistical package to generate cross tables, chi-square analysis and t-test analysis.
4.0 RESULTS

4.1 Evaluation of Respondents perceptions at the Dawhenya Irrigation Scheme

Results from the survey of the questionnaires issued at the Dawhenya Irrigation Scheme are reported in the figures below using charts and graphs.

4.1.1 Influence of Sex and Number of years of farming on rice production

Results from the survey conducted indicates that of the total number of respondents interviewed (109 respondents), 61 of them translating to 56% of the total population had over 20 years’ experience in farming in general. Majority of that (95%) were male (Figure 4.1).

However, these numbers changed when the element “Rice Farming” is introduced into the equation. From the 109-respondent interviewed, 54 of them (50%) have been involved in rice farming for twenty years or more. This shows that some of the respondents have been farming other crops in general but were not into rice farming from the time they began their farming venture. Twenty-four (24) of the respondents responded to being into farming for between 10 and 20 years 71% of whom were male. Again, this number was different for rice farming as 21 of them responded to have been in the venture for between 10 and 20 years with 95% of them being male.

The rest of the results for farming experience showed that the respondent with farming experience of between 5 and 10 years and less than 5 years in raw numbers were 17 and 47 respectively. These numbers however increased with rice farming experience from 17 to 20 respondents for those who
have been in the venture between 5 and 10 years and from 7 to 14 respondents for those who have been in the rice farming venture for less than 5 years. 94% of the 17 in the general farming section for those between 5 and 10 years were male while all 7 (of 100%) of the respondents for those with less than 5 years’ experience were male in the same section.

Figure 4.1: Graph of farming experience with respect to gender
4.1.2 Rice varieties cultivated and other crops grown by farmers at the site

Three main rice varieties are cultivated at the site. These varieties are CRI-AgraRice, Aromatic Short and Jasmine 85 (Figure 4.3).

Of the Sixty (60) samples collected, twenty-four (24) of them was Aromatic Short, twenty (20) was CRI-AgraRice and sixteen (16), Jasmine 85.
Of the 3 varieties cultivated at the site, the combination of Jasmine 85 and Aromatic Short were the most dominant varieties adopted by a large number of the respondents (Figure 4.3). The newly introduced Agra variety was still under close examination and trials by some of the farmers at the site although concerns have been raised during interaction with them about the sagging nature of the crop which makes it difficult to harvest. All of the respondents however, cultivate more than one of the three main varieties with some even opting to cultivate all three interchangeably at different cropping seasons.

55% of the respondents have grown other crops aside rice (Figure 4.4). Of this group, only 27% still grow other crops alongside the rice they cultivate (Figure 4.5). Some of the crops they stated to have grown or still grow include maize, cassava, vegetables such as okro, pepper, tomatoes and onion.
Figure 4.4: Percentage of respondents that have grown other crops aside rice

Figure 4.5: Percentage of respondents that still grow other crops aside rice
4.1.3 Class of seed cultivated at the site

The type of seed (Class of seed) used by the respondents were grouped based on their farming experience (Table 4.1). Here, it was observed that the respondents with the most experience (20 or more years) opted to use farmer saved seeds more than the certified seeds. This trend was also observed with the other categories of farming experiences with farmer saved seeds being the preferred choice for most of the respondents. A chi-square test to show the relationship between type of seed used with respect to farming experience showed no statistical relationship between the type or class of seed used and farming experience (p=0.070).

62% of the respondents were aware of certified seeds on the market (Figure 4.7) and out of this figure, 36% of them have used certified seeds at least once in their rice cropping venture (Figure 4.8). Of the 36% who have used certified seeds, 4 (10%) responded to be still using certified planting materials, 10 (26%) of them say the last time they used certified seed was last cropping season while 16 (41%) of them say it has been more than two cropping seasons since they last used certified seeds (Figure 4.9).

The respondents also weighed in their opinions on the reason why they have stopped using certified seeds (for those who say they are no longer using certified seeds in the cultivation of their rice crop) or why they have never used certified seeds in the cultivation of their rice crop. Thirteen (13) of the respondents said that the certified seeds were not readily available to them for purchase, 10 of them said that the certified seeds on the market was too expensive, 5 of them said they have actually used it before but they did not get good yields, 16 of them said they either heard from a fellow farmer or fellow farmers that the material doesn’t give good yields or the material’s yields
outputs and strengths were no different from that of farmer saved seeds. 15 of the respondents said the certified seeds was not necessary (Figure 4.10).

Figure 4.6: Type of seed used by respondents
Table 4.1: Type of seed used by respondents with respect to farming experience

<table>
<thead>
<tr>
<th>Seed class</th>
<th>Farming experience Crosstabulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>20 years or more</td>
</tr>
<tr>
<td>Certified seeds</td>
<td>7</td>
</tr>
<tr>
<td>Farmer saved seeds</td>
<td>51</td>
</tr>
<tr>
<td>Other seeds</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>61</td>
</tr>
</tbody>
</table>

Table 4.2: Chi-Square Test of seed used by respondents with respect to farming experience

<table>
<thead>
<tr>
<th>Chi-Square Tests</th>
<th>Value</th>
<th>df</th>
<th>Asymp. Sig. (2-sided)</th>
<th>Monte Carlo Sig. (2-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>10.577a</td>
<td>6</td>
<td>.102</td>
<td>.097b</td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>9.071</td>
<td>6</td>
<td>.170</td>
<td>.236b</td>
</tr>
<tr>
<td>Fisher's Exact Test</td>
<td>10.264</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N of Valid Cases</td>
<td>109</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. 6 cells (50.0%) have expected count less than 5. The minimum expected count is .58.
b. Based on 10000 sampled tables with starting seed 1993510611.
Figure 4.7: Respondents awareness of certified seeds

Figure 4.8: Use of certified seeds by respondents
Figure 4.9: Certified seed user’s recollection of the use of certified seeds

- Still in use
- Last Cropping Season
- Last Two Cropping Seasons
- More than Two Cropping Seasons

Figure 4.10: Respondents reasons for stopping the use of certified seeds or not using at all

Factors:
- Not Applicable
- Heard from others that it doesn’t give good yield or yields are no different from farmer saved seeds
- Not necessary
- Not readily available
- Too expensive
- Used before but didn’t get good yields
4.1.4 Effect of factors of production and farmer’s perception on yield

Figure 4.11: Origin of planting material used by respondents
In the section of farmers perception, 33% (36 of the respondents) indicated that the cost of the production was the most important factor of production that affected yield negatively. 17% (19) of them chose weather conditions as the most important factor, 16% (18) chose water management, 11% (12) of the respondents chose both seed selection and nutrient management as the most important factor and 3% (3) each chose soil conditions, land preparation, harvesting techniques and crop health as the most important factor (Figure 4.13).
Figure 4.13: Respondents perception about yield loss on their various fields
4.2 Lab Evaluation of selected rice varieties used by farmers at the Dawhenya Irrigation Scheme

4.2.1 Moisture Content

Mean moisture content of Samples A and B for each variety are presented in the table below along with the mean difference between each sample (Table 4.3). Calculations from the statistical analysis of both samples (Table 4.4) indicates that there is no statistical significant difference between the means for moisture contents of Sample A and Sample B (p=0.531335257).

Table 4.3: Mean moisture content analysis of Samples A and B grouped by various varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Sample A Moisture Content (%)</th>
<th>Sample B Moisture Content (%)</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aromatic short</td>
<td>11.823</td>
<td>11.967</td>
<td>-0.144</td>
</tr>
<tr>
<td>CRI-AgraRice</td>
<td>12.33</td>
<td>12.07</td>
<td>0.26</td>
</tr>
<tr>
<td>Jasmine 85</td>
<td>11.613</td>
<td>12.450</td>
<td>-0.837</td>
</tr>
</tbody>
</table>

Table 4.4: Statistical analysis of moisture content of Sample A and Sample B

<table>
<thead>
<tr>
<th></th>
<th>Sample A Moisture Content (%)</th>
<th>Sample B Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>11.922</td>
<td>12.16233333</td>
</tr>
<tr>
<td>Variance</td>
<td>0.135873</td>
<td>0.064716333</td>
</tr>
<tr>
<td>Observations</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>-0.571721369</td>
<td></td>
</tr>
<tr>
<td>Hypothesized Mean Difference</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>df</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>t Stat</td>
<td>-0.750294268</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) one-tail</td>
<td>0.265667629</td>
<td></td>
</tr>
<tr>
<td>t Critical one-tail</td>
<td>2.91998558</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) two-tail</td>
<td>0.531335257</td>
<td></td>
</tr>
<tr>
<td>t Critical two-tail</td>
<td>4.30265273</td>
<td></td>
</tr>
</tbody>
</table>
4.2.2 Percentage Purity

Mean purity percentages of Samples A and B for each variety are presented in the table below along with the mean difference between each sample (Table 4.5). Calculations from the statistical analysis of both samples (Table 4.6) indicates that there is no statistical significant difference between the means for percentage purity of Sample A and Sample B (p=0.214963748).

Table 4.5: Mean percentage purity analysis of Samples A and B grouped by various varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Sample A Purity (%)</th>
<th>Sample B Purity (%)</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aromatic short</td>
<td>98.4916</td>
<td>98.483</td>
<td>0.0086</td>
</tr>
<tr>
<td>CRI-AgraRice</td>
<td>98.83</td>
<td>96.62</td>
<td>2.21</td>
</tr>
<tr>
<td>Jasmine 85</td>
<td>98.7875</td>
<td>94.7625</td>
<td>4.025</td>
</tr>
</tbody>
</table>

Table 4.6: Statistical analysis of percentage purity of Sample A and Sample B

<table>
<thead>
<tr>
<th></th>
<th>Sample A Purity (%)</th>
<th>Sample B Purity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>98.70303333</td>
<td>96.62183333</td>
</tr>
<tr>
<td>Variance</td>
<td>0.033979603</td>
<td>3.460532583</td>
</tr>
<tr>
<td>Observations</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>-0.803121129</td>
<td></td>
</tr>
<tr>
<td>Hypothesized Mean Difference</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>df</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>t Stat</td>
<td>1.79224995</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) one-tail</td>
<td>0.107481874</td>
<td></td>
</tr>
<tr>
<td>t Critical one-tail</td>
<td>2.91998558</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) two-tail</td>
<td>0.214963748</td>
<td></td>
</tr>
<tr>
<td>t Critical two-tail</td>
<td>4.30265273</td>
<td></td>
</tr>
</tbody>
</table>
4.2.3 Germination Percentage and Seed Vigour Test

The standard set by Ocran et al (1998) and replicated by Tokpah (2010) was used to group the samples in descending order according to varieties into two groups as; ≥80% and ≤79.9% (Table 4.7a and Table 4.7b). As stated earlier, the first count (5 days after planting) was used in determining the seed vigor of the lot as postulated by the ISTA rules (2007). This was also grouped into two as ≥70% and ≤69.9% (Table 4.8a and Table 4.8b) in descending order according to varieties.

4.2.3.1 Germination Analysis

≥80%

Table 4.7a: Germination percentage of submitted samples greater than or equal to 80 percent grouped by various varieties

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Germination Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer 2- CRI-AgraRice: B</td>
<td>99</td>
</tr>
<tr>
<td>Farmer 8- CRI-AgraRice: B</td>
<td>98</td>
</tr>
<tr>
<td>Farmer 12- CRI-AgraRice: A</td>
<td>94</td>
</tr>
<tr>
<td>Farmer 21- CRI-AgraRice: A</td>
<td>93</td>
</tr>
<tr>
<td>Farmer 8- CRI-AgraRice: A</td>
<td>92</td>
</tr>
<tr>
<td>Farmer 15- CRI-AgraRice: B</td>
<td>92</td>
</tr>
<tr>
<td>Farmer 20- CRI-AgraRice: B</td>
<td>92</td>
</tr>
<tr>
<td>Farmer 27- CRI-AgraRice: A</td>
<td>92</td>
</tr>
<tr>
<td>Farmer 2- CRI-AgraRice: A</td>
<td>91</td>
</tr>
<tr>
<td>Farmer 20- CRI-AgraRice: A</td>
<td>91</td>
</tr>
<tr>
<td>Farmer 21- CRI-AgraRice: B</td>
<td>91</td>
</tr>
<tr>
<td>Farmer 22- CRI-AgraRice: B</td>
<td>91</td>
</tr>
<tr>
<td>Farmer 26- CRI-AgraRice: B</td>
<td>91</td>
</tr>
<tr>
<td>Farmer 15- CRI-AgraRice: A</td>
<td>90</td>
</tr>
<tr>
<td>Farmer 22- CRI-AgraRice: A</td>
<td>90</td>
</tr>
<tr>
<td>Farmer 26- CRI-AgraRice: A</td>
<td>90</td>
</tr>
<tr>
<td>Farmer 27- CRI-AgraRice: B</td>
<td>90</td>
</tr>
<tr>
<td>Farmer 12- CRI-AgraRice: B</td>
<td>89</td>
</tr>
<tr>
<td>Sample Number</td>
<td>Germination Percentage</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Farmer 14- CRI-AgraRice: A</td>
<td>89</td>
</tr>
<tr>
<td>Farmer 14- CRI-AgraRice: B</td>
<td>80</td>
</tr>
<tr>
<td>Farmer 6- Jasmine 85: B</td>
<td>98</td>
</tr>
<tr>
<td>Farmer 17- Jasmine 85: A</td>
<td>97</td>
</tr>
<tr>
<td>Farmer 6- Jasmine 85: A</td>
<td>95</td>
</tr>
<tr>
<td>Farmer 5- Jasmine 85: B</td>
<td>94</td>
</tr>
<tr>
<td>Farmer 13- Jasmine 85: A</td>
<td>94</td>
</tr>
<tr>
<td>Farmer 13- Jasmine 85: B</td>
<td>94</td>
</tr>
<tr>
<td>Farmer 18- Jasmine 85: A</td>
<td>94</td>
</tr>
<tr>
<td>Farmer 29- Jasmine 85: A</td>
<td>94</td>
</tr>
<tr>
<td>Farmer 24- Jasmine 85: B</td>
<td>93</td>
</tr>
<tr>
<td>Farmer 5- Jasmine 85: A</td>
<td>92</td>
</tr>
<tr>
<td>Farmer 23- Jasmine 85: B</td>
<td>92</td>
</tr>
<tr>
<td>Farmer 24- Jasmine 85: A</td>
<td>91</td>
</tr>
<tr>
<td>Farmer 17- Jasmine 85: B</td>
<td>89</td>
</tr>
<tr>
<td>Farmer 23- Jasmine 85: A</td>
<td>88</td>
</tr>
<tr>
<td>Farmer 29- Jasmine 85: B</td>
<td>87</td>
</tr>
<tr>
<td>Farmer 18- Jasmine 85: B</td>
<td>82</td>
</tr>
<tr>
<td>Farmer 19- Aromatic Short: B</td>
<td>97</td>
</tr>
<tr>
<td>Farmer 1- Aromatic Short: B</td>
<td>96</td>
</tr>
<tr>
<td>Farmer 28- Aromatic Short: A</td>
<td>96</td>
</tr>
<tr>
<td>Farmer 3- Aromatic Short: B</td>
<td>95</td>
</tr>
<tr>
<td>Farmer 7- Aromatic Short: A</td>
<td>95</td>
</tr>
<tr>
<td>Farmer 10- Aromatic Short: B</td>
<td>95</td>
</tr>
<tr>
<td>Farmer 16- Aromatic Short: B</td>
<td>94</td>
</tr>
<tr>
<td>Farmer 30- Aromatic Short: A</td>
<td>93</td>
</tr>
<tr>
<td>Farmer 4- Aromatic Short: B</td>
<td>92</td>
</tr>
<tr>
<td>Farmer 10- Aromatic Short: A</td>
<td>86</td>
</tr>
<tr>
<td>Farmer 11- Aromatic Short: A</td>
<td>85</td>
</tr>
<tr>
<td>Farmer 4- Aromatic Short: A</td>
<td>84</td>
</tr>
<tr>
<td>Farmer 25- Aromatic Short: A</td>
<td>84</td>
</tr>
<tr>
<td>Farmer 1- Aromatic Short: A</td>
<td>81</td>
</tr>
<tr>
<td>Farmer 9- Aromatic Short: A</td>
<td>81</td>
</tr>
<tr>
<td>Farmer 19- Aromatic Short: A</td>
<td>81</td>
</tr>
</tbody>
</table>
Table 4.7b: Germination percentage of submitted samples less than or equal to 79.9 percent grouped by various varieties

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Germination Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer 28- Aromatic Short: B</td>
<td>79</td>
</tr>
<tr>
<td>Farmer 25- Aromatic Short: B</td>
<td>77</td>
</tr>
<tr>
<td>Farmer 30- Aromatic Short: B</td>
<td>77</td>
</tr>
<tr>
<td>Farmer 7- Aromatic Short: B</td>
<td>76</td>
</tr>
<tr>
<td>Farmer 3- Aromatic Short: A</td>
<td>75</td>
</tr>
<tr>
<td>Farmer 11- Aromatic Short: B</td>
<td>75</td>
</tr>
<tr>
<td>Farmer 16- Aromatic Short: A</td>
<td>71</td>
</tr>
<tr>
<td>Farmer 9- Aromatic Short: B</td>
<td>45</td>
</tr>
</tbody>
</table>

4.2.3.2 Seed Vigor analysis

≥70%

Table 4.8a: Percentage vigor of submitted samples greater than or equal to 70 percent grouped by various varieties

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Percentage Vigor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer 3- Aromatic Short: B</td>
<td>90</td>
</tr>
<tr>
<td>Farmer 28- Aromatic Short: A</td>
<td>88</td>
</tr>
<tr>
<td>Farmer 19- Aromatic Short: B</td>
<td>87</td>
</tr>
<tr>
<td>Farmer 4- Aromatic Short: B</td>
<td>85</td>
</tr>
<tr>
<td>Farmer 16- Aromatic Short: B</td>
<td>83</td>
</tr>
<tr>
<td>Farmer 25- Aromatic Short: A</td>
<td>81</td>
</tr>
<tr>
<td>Farmer 10- Aromatic Short: A</td>
<td>80</td>
</tr>
<tr>
<td>Farmer 7- Aromatic Short: A</td>
<td>78</td>
</tr>
<tr>
<td>Farmer 30- Aromatic Short: A</td>
<td>76</td>
</tr>
<tr>
<td>Farmer 9- Aromatic Short: A</td>
<td>75</td>
</tr>
<tr>
<td>Farmer 10- Aromatic Short: B</td>
<td>75</td>
</tr>
<tr>
<td>Farmer 28- Aromatic Short: B</td>
<td>75</td>
</tr>
<tr>
<td>Farmer 1- Aromatic Short: B</td>
<td>71</td>
</tr>
<tr>
<td>Farmer 3- Aromatic Short: A</td>
<td>71</td>
</tr>
<tr>
<td>Farmer 19- Aromatic Short: A</td>
<td>71</td>
</tr>
<tr>
<td>Farmer 17- Jasmine 85: A</td>
<td>90</td>
</tr>
<tr>
<td>Farmer 24- Jasmine 85: B</td>
<td>90</td>
</tr>
<tr>
<td>Sample Number</td>
<td>Percentage Vigor</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Farmer 24- Jasmine 85: A</td>
<td>89</td>
</tr>
<tr>
<td>Farmer 23- Jasmine 85: B</td>
<td>84</td>
</tr>
<tr>
<td>Farmer 5- Jasmine 85: A</td>
<td>83</td>
</tr>
<tr>
<td>Farmer 29- Jasmine 85: A</td>
<td>82</td>
</tr>
<tr>
<td>Farmer 23- Jasmine 85: A</td>
<td>80</td>
</tr>
<tr>
<td>Farmer 6- Jasmine 85: B</td>
<td>79</td>
</tr>
<tr>
<td>Farmer 6- Jasmine 85: A</td>
<td>77</td>
</tr>
<tr>
<td>Farmer 17- Jasmine 85: B</td>
<td>75</td>
</tr>
<tr>
<td>Farmer 18- Jasmine 85: A</td>
<td>75</td>
</tr>
<tr>
<td>Farmer 13- Jasmine 85: A</td>
<td>74</td>
</tr>
<tr>
<td>Farmer 13- Jasmine 85: B</td>
<td>71</td>
</tr>
<tr>
<td>Farmer 29- Jasmine 85: B</td>
<td>71</td>
</tr>
<tr>
<td>Farmer 15- CRI-AgraRice: A</td>
<td>88</td>
</tr>
<tr>
<td>Farmer 8- CRI-AgraRice: A</td>
<td>85</td>
</tr>
<tr>
<td>Farmer 22- CRI-AgraRice: A</td>
<td>85</td>
</tr>
<tr>
<td>Farmer 15- CRI-AgraRice: B</td>
<td>83</td>
</tr>
<tr>
<td>Farmer 20- CRI-AgraRice: B</td>
<td>83</td>
</tr>
<tr>
<td>Farmer 8- CRI-AgraRice: B</td>
<td>80</td>
</tr>
<tr>
<td>Farmer 14- CRI-AgraRice: A</td>
<td>80</td>
</tr>
<tr>
<td>Farmer 20- CRI-AgraRice: A</td>
<td>80</td>
</tr>
<tr>
<td>Farmer 22- CRI-AgraRice: B</td>
<td>79</td>
</tr>
<tr>
<td>Farmer 27- CRI-AgraRice: A</td>
<td>79</td>
</tr>
<tr>
<td>Farmer 2- CRI-AgraRice: B</td>
<td>78</td>
</tr>
<tr>
<td>Farmer 26- CRI-AgraRice: A</td>
<td>77</td>
</tr>
<tr>
<td>Farmer 27- CRI-AgraRice: B</td>
<td>75</td>
</tr>
<tr>
<td>Farmer 21- CRI-AgraRice: A</td>
<td>72</td>
</tr>
<tr>
<td>Farmer 12- CRI-AgraRice: A</td>
<td>71</td>
</tr>
<tr>
<td>Farmer 14- CRI-AgraRice: B</td>
<td>71</td>
</tr>
<tr>
<td>Farmer 12- CRI-AgraRice: B</td>
<td>70</td>
</tr>
<tr>
<td>Farmer 16- Aromatic Short: A</td>
<td>67</td>
</tr>
</tbody>
</table>

Table 4.8b: Percentage vigor of submitted samples less than or equal to 69.9 percent grouped by various varieties
<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Percentage Vigor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer 11- Aromatic Short: A</td>
<td>65</td>
</tr>
<tr>
<td>Farmer 1- Aromatic Short: A</td>
<td>63</td>
</tr>
<tr>
<td>Farmer 11- Aromatic Short: B</td>
<td>63</td>
</tr>
<tr>
<td>Farmer 4- Aromatic Short: A</td>
<td>62</td>
</tr>
<tr>
<td>Farmer 25- Aromatic Short: B</td>
<td>62</td>
</tr>
<tr>
<td>Farmer 7- Aromatic Short: B</td>
<td>53</td>
</tr>
<tr>
<td>Farmer 30- Aromatic Short: B</td>
<td>51</td>
</tr>
<tr>
<td>Farmer 9- Aromatic Short: B</td>
<td>41</td>
</tr>
<tr>
<td>Farmer 5- Jasmine 85: B</td>
<td>62</td>
</tr>
<tr>
<td>Farmer 18- Jasmine 85: B</td>
<td>55</td>
</tr>
</tbody>
</table>

**4.2.4 Seed Health Analysis**

From the seed health analysis, it was found that ten (10) fungal species were the source of infection for the seeds. The identified species are;

*Alteneria tenuis, Alteneria longissima, Alteneria padwickii, Bipolaris oryzae, Curvularia lunata, Fusarium moniliforme, Fusarium oxysporium, Nigrospora oryzae, Sarocladium oryzae, Verticilium cinnabarium*

Again, the mean infection percentages of Samples A and B for each variety are presented in the table below along with the mean difference between each sample (Table 4.9). Calculations from the statistical analysis of both samples (Table 4.10) indicates that with the seed health analysis also, there was no statistical significant difference between the means of Sample A and Sample B (p=0.358211286).

*Bipolaris oryzae* was the most prevalent fungal species in sample A with 457 incidences (Figure 4.14). This is followed by *Curvularia lunata* with 332 incidences. There was no incidence of *Verticillium cinnabarium* but *Alteneria longissima* and *Fusarium oxysporium* held the lowest incidence with 6 each.
In sample B, *Curvularia lunata* held the highest incidence with 601 infections followed by *Bipolaris oryzae* with 472 infection cases. Here, *Verticilium cinnabarium* and *Fusarium oxysporium* held the lowest infection incidence with 1 and 2 cases respectively. *Alteneria longissima* however recorded no cases for sample B (Figure 4.15).

Overall, the total fungal species incidence recorded was 2262. Out of this, *Curvularia lunata* and *Bipolaris oryzae* held the highest numbers with *Curvularia lunata* having 933 infections and *Bipolaris oryzae* 929. The lowest incidence was *Verticilium cinnabarium* which recorded one (1) infection in all (Figure 4.16).

To put these numbers into better perspective, for each of the samples tested, 200 seeds were plated. 25 seeds per petri dish of 8 replicates. Of the 60 samples tested 12,000 seeds were plated for the test and examined. For each infection case recorded, the incidence is from the total 12,000 seeds analysed. Hence, the total fungal species incidence of 2262 accounts for 18.85% of the total plated and analysed seeds of this 18.85%, *Curvularia lunata* and *Bipolaris oryzae* alone made up 82.32% of the total fungal incidence recorded.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Sample A Percentage Infection (%)</th>
<th>Sample B Percentage Infection (%)</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aromatic short</td>
<td>17.0833</td>
<td>19.7083</td>
<td>-2.625</td>
</tr>
<tr>
<td>CRI-AgraRice</td>
<td>17.2</td>
<td>16.25</td>
<td>0.95</td>
</tr>
<tr>
<td>Jasmine 85</td>
<td>16.8125</td>
<td>28.5625</td>
<td>-11.75</td>
</tr>
</tbody>
</table>

Table 4.9: Average percentage infection values of Samples A and B grouped by various varieties
Table 4.10: Statistical analysis of percentage infection of Sample A and Sample B

<table>
<thead>
<tr>
<th></th>
<th>Sample A Percentage Infection (%)</th>
<th>Sample B Percentage Infection (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>17.03193333</td>
<td>21.50693333</td>
</tr>
<tr>
<td>Variance</td>
<td>0.039517963</td>
<td>40.32572546</td>
</tr>
<tr>
<td>Observations</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>-0.999755086</td>
<td></td>
</tr>
<tr>
<td>Hypothesized Mean Difference</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>df</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>t Stat</td>
<td>-1.183528739</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) one-tail</td>
<td>0.179105643</td>
<td></td>
</tr>
<tr>
<td>t Critical one-tail</td>
<td>2.91998558</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) two-tail</td>
<td>0.358211286</td>
<td></td>
</tr>
<tr>
<td>t Critical two-tail</td>
<td>4.30265273</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.14: Fungal species incidence for Sample A
Figure 4.15: Total fungal incidence

Figure 4.16: Fungal species incidence for Sample B
4.2.5 1000 Seed Weight Analysis

Results from the 1000 seed weight test is presented below. The mean trends of the weight of each seedlot is presented in the chart below (Figure 4.18). Descriptive statistics of the weights of seeds indicating the mean seed weight, standard deviation and variance are presented in Table 4.11. The chi-square analysis of the mean weights and seed vigor shows that there is no statistical relationship between the weight of seeds and the vigor of the seed (p=0.891) (Table 4.12).

Figure 4.17: Mean trend of Sample weights
Table 4.11: Descriptive Statistics of weight of seeds

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>60</td>
<td>25.0</td>
<td>30.0</td>
<td>26.353</td>
<td>.8386</td>
<td>.703</td>
</tr>
</tbody>
</table>

Table 4.12: Chi-square analysis of the relationship between seed weight and seed vigor

<table>
<thead>
<tr>
<th>Chi-Square Tests</th>
<th>Value</th>
<th>df</th>
<th>Asymp. Sig. (2-sided)</th>
<th>Monte Carlo Sig. (2-sided)</th>
<th>Monte Carlo Sig. (1-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>375.229</td>
<td>392</td>
<td>.720</td>
<td>.692&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.683</td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>160.414</td>
<td>392</td>
<td>1.000</td>
<td>.884&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.878</td>
</tr>
<tr>
<td>Fisher's Exact Test</td>
<td>656.195</td>
<td>1</td>
<td>.891&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.885</td>
<td>.897</td>
</tr>
<tr>
<td>Linear-by-Linear Association</td>
<td>.013&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1</td>
<td>.910</td>
<td>.910&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.905</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>N of Valid Cases</th>
<th>60</th>
<th>95% Confidence Interval</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower Bound</td>
<td>.446&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.436</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upper Bound</td>
<td>.455</td>
<td></td>
</tr>
</tbody>
</table>

a. 435 cells (100.0%) have expected count less than 5. The minimum expected count is .02.
b. Based on 10000 sampled tables with starting seed 2000000.
c. The standardized statistic is -.113.
5. CHAPTER FIVE

5.0 DISCUSSION

5.1 Respondents perception to yield loss and the cultivation practices at the Dawhenya Irrigation Scheme as influenced by sex and farming experience

Study results at the Dawhenya irrigation scheme showed a majority of the total respondents belonging to the male gender (89.9%) as opposed to the female gender (10.1%). Male and female farmers have distinct obligations in agrarian production systems, including rice cultivation. These distinctions in gender orientation roles are not generally self-evident but need to be recognized if rice production is to be expanded, particularly among small scale farmers (FAO, 2004). Although females represent essential assets in agriculture and the rural economy through the parts they play as producers, workers and business visionaries, they are however confronted with extreme requirements than their male counterparts in terms of access to beneficial resources. Despite the fact that in most developing nations, both male and female farmers are not afforded satisfactory resources; female's access is considerably more constrained because of social, customary and sociological elements (FAO, 2003). This can be hence linked to the low number of female respondents who grow rice at the Dawhenya irrigation scheme.

Regardless of whether farming experience improves or dampens agricultural innovation acceptance is still not clear in present studies (Knowler and Bradshaw, 2007). In any case, distinct answers are vital for policy-makers, particularly those advancing the adoption of agricultural technologies and involvement in farmer field schools (Duveskog et al., 2011). As producers gather experience as time passes, they dynamically change from customary agrarian innovations to
enhanced advancements on the premise of experiential performance and learning by doing (Arrow, 1962; Dosi, 1982; Feder et al., 1985).

The crops at the site were established by broadcasting. Farmers at the site were observed to prefer the broadcasting method as their planting method rather than to nurse and transplant them. Other than production cost and labour requirement, the planting techniques affect the development and yield of rice (Sanjitha and Jayakiran, 2010). While customarily rice may be transplanted, steady increase in labour cost, have called for other planting techniques. No farmer was observed to nurse and transplant rice in the study area. This observation was similar to reports by Dawe, (2003) and Naklang et al., (1996) which show planting systems being slowly supplanted by direct sowing in many third world nations due to expanded labour cost. Although most of the respondents were aware of the benefits of the nursing and transplanting and were also aware of some down sides associated with the method of crop establishment they employed such as the uneven distribution of seeds on the field and also the incidence of birds feeing on the broadcasted seeds, they attributed their adoption of broadcasting to lack of labour and where available, costly.

Eighty-four (84) of the respondents indicated that they obtained their seeds from fellow farmers, eleven (11) of them noted that they used their recently saved stock from the previous season, and nine (9) purchased their seeds from input dealers. Aromatic short and Jasmine 85 were the largest varieties being cultivated in spite of availability of different varieties of rice released for cultivation in the country. The newly introduced CRI-AgraRice was not being planted by a large number of the farmers at the site in spite of it being recommended for planting. In a research led by Ainembabazi and Mugisha (2014) it was proposed that farming experience is to a great extent helpful in the beginning periods of adoption of a given innovation for a few crops, when agriculturists are still in the process of testing its potential advantages. A need for the setup of
demonstration plots for new varieties being introduced would facilitate the adoption of innovations where the benefits of the innovation can be clearly envisaged by the farmers. The farmers also complained about the high cost of seeds and associated inputs that often accompany new varieties contributing to their unwillingness to adopt these new innovations. These observations agree with a report by Langyintuo et al. (2008) who noted that seed suppliers attribute the low selection rate to various elements including high cost of certified seeds, high cost of inputs such as fertilizer, inaccessibility of certified seeds in cultivating communities, illiteracy and lack of awareness among producers. Others include, absence of access to credit, distance to source of certified seeds, absence of association with local associations and poor extension coverage because of restricted financial resources and human resources.

Results of the respondent’s awareness of certified seeds showed 62.4% of the farmers at the Dawhenya irrigation scheme having knowledge of certified seeds with only 36.1% using it. This observation confirms earlier reports by other researchers where a large number of farmers interviewed knew about certified seeds but only a small proportion utilized it. In the case of Aidoo et al. (2014) where 95% of farmers indicated awareness of certified but only 27% of them who were aware of it actually utilized certified seeds. The reasons for the non-use was found to be the unavailability of certified seeds in farming communities and the high cost of certified seeds. At the Dawhenya irrigation scheme however, these two constraints were only the fourth and fifth in terms of priority affecting their use of certified seeds.

The general cost of production of the commodity was the major constraint indicated by farmers at the Dawhenya irrigation scheme to be the most important factor contributing to yield loss at the site. In a study undertaken by Abdul-Gafar et al. (2016), it was discovered that the socioeconomic constraint made up of the high cost and unavailability or difficulties in accessing critical resources
for production such as credit, land, labour, seed, fertiliser and mechanisation in rice production was higher in Niger state in Nigeria as compared to that of Hainan in China. This was followed by weather conditions which was closely followed by water management with seed selection and nutrient management both having the same number of response from the interviewed respondents. Soil conditions, land preparation, harvesting techniques and crop health were all tied as having the least impact on yield in the opinion of the interviewed farmers.

The respondents had the understanding that aside the weather conditions which they had no control over, the cost of production influences and is influenced by all the other factors and processes of production.

5.1.1 Other rice cultivation practices at the site.

Water has been a major challenge to rice production in Ghana even at irrigation schemes. Unlike schemes like the Ashaiman irrigation scheme which uses gravity as a means of conveying water from the dam to the fields, sites like the Dawhenya irrigation scheme requires electricity in order to pump water from the dam to supply to the various fields at the sites. With these challenges farmers are therefore more comfortable growing varieties which use minimal resources but still produce some yield to enable them even out their cost of production.

Land preparation at the Dawhenya irrigation scheme was usually done mechanically with the use of tractors and other machinery. All the respondents prepare their land by tilling, crossing and levelling the land every cropping season before planting. Tilling and crossing is an important practice as some of the farmers explained that if these practices were not done yields would be affected. Levelling of the land is also equally as important as other land preparation practices as a
level land would ensure the even distribution of water to the crops which may result in an even or in some cases very good crop performance.

Fertilizer is applied by all the respondents at the scheme. With a wide range of fertilizers on the market the notable ones in use by the respondent however vary from farmer to farmer depending on the variety of rice cropped, the experience of the farmer and nature of the fields. Some farmers also practice incorporation.

Most of the respondents indicated in the survey that they do not face any major pest, bacteria or fungi problems mainly due to the preventive measures taken by the farmers with the exception of birds that they scare at the maturity stage of the crop’s development. This was however not observed during the analysis of the samples submitted, with some of the seeds expressing fungal infections when they were plated and observed. Some of the samples, particularly the samples taken before planting (Sample A), contained a variety of storage pests namely, *Corcyra cephalonica* and *Sitophilus oryzae*. These storage pests are known to cause various economical and physical damages to stored rice seeds.

Weeds however was something they were often challenged with and they usually control it by using weedicides and at certain stages of the crops development hand weeding is employed.

Harvesting at the site is mainly done with the use of a combine harvester. The produce is then threshed, winnowed, gathered and collected from the field, dried and weighed.
5.2 Laboratory evaluation of submitted seed samples

5.2.1 Impact of Moisture content on rice seed quality

With the reference to Appendix II (seed quality standards for emergency activities Based on FAO Quality Declared Seed QDS), and Appendix III (seed storage life and moisture content) the maximum percentage moisture content based on the FAO Quality Declared Seed for rice crops is 13% moisture content and the storage period for rice seeds at 13% or less moisture content is 8 to 12 months. Individually, the various samples possessed varied moisture content percentages. Collectively, the samples collected before planting (Sample A) had a lower moisture content as compared to the samples collected after harvest (Sample B) with average moisture content values of 11.922% and 12.1623% respectively. These results are both lower and in line with Appendix III which indicates rice seeds attaining a maximum percentage moisture content of 13%. This suggests that the samples can be stored for up to 12 months.

Farmer 21-Agra: B recorded a moisture content higher than the maximum percentage moisture content recorded in Appendix II which suggests that the seed can be stored for only 2 to 3 weeks (Appendix III). Farmer 15-Agra: B recorded the lowest percentage moisture content which was lower than the criteria set by FAO in Appendix II and Appendix III which indicates that rice seeds with moisture content of 9% or less could be stored for more than a year.

5.2.2 Impact of Purity of submitted rice samples on rice seed quality

The purity analysis showed that the samples purity was relatively higher although the numbers varied among the samples. It was observed that the samples collected before planting (Sample A)’s
was higher in purity as compared to that of samples collected after harvest (Sample B). Agra rice and Jasmine seeds were observed to have lower purities which could be attributed to challenges in harvester calibrations and post-harvest operations. Rice samples collected showed a higher rice seed analytical purity than minimum rice analytical purity (98%) as was recorded in Appendix II. The study's results showed rice seed sample A with the highest percentage purity as compared to B. study's outcome are in line FAO standards for Quality Declared Seeds (QDS). The highest and lowest percentages however both came from the Agra variety of the samples collected after harvest.

Although the seed lots were relatively pure analytically, other seeds were found in most of the sample tested. *Oryza longistaminata* popularly known as ‘red rice’ was the major other seed fraction found in majority of the tested samples. According to Khush (1997) *Oryza longistaminata* evolved in west Africa and is restricted to the African continent. IER (1989) also reported that yield losses have been estimated to be in the order of 85% in fields severely infested with *Oryza longistaminata* in Mali. It was observed by Parker and Dean (1976) that commercial rice grown contaminated with wild rice seeds such as *Oryza longistaminata* reduces the grains quality as additional polishing may be required to remove the red pericarp of wild rice grains.

John *et al.* (1984) and Buddenhagen (1982) stated that, in addition to the competitive effect on the crop, *Oryza longistaminata* is an alternative host to some important pests and pathogens in the rice crop including rice yellow mottle sobemovirus and rice bacterial blight (*Xanthomonas oryzae* pv.*oryzae*).
5.2.3 Impact of Germination Percentage and Seed Vigour on submitted samples

Results showed that 86.67% of sample collected recorded a % germination greater than or equal to the minimum certification standard (80%) as reported by Ocran et al. (1998). In contracts, Farmer 16-Short Aroma: B and Farmer 9-Short Aroma: B recorded a lower % germination than the FAO (QDS) standards. Only Farmer 16-Short Aroma: B and Farmer 9-Short Aroma: B with the lowest recorded germination percentage did not meet this standard. Similarly, a large number of the tested samples (46 of the 60 samples which translates to 76.7% of the total) recorded high percentages of germination (greater than or equal to 70%) in the first count which was used as the seed vigour parameter. 14 of the 60 samples recorded percentages lower than or equal to 69.9%. Farmer 9-Short Aroma: B again recorded the lowest percentage in this group. A positive correlation was found between the seed vigour analysis and germination for most of the samples in this test similar to reports by Tokpah (2010) meaning the highest vigour percentages resulted in a higher germination with the exception of Farmer 28-Short Aroma: B and Farmer 3-Short Aroma: A which according to the groupings had a lower germination percentage and also a high vigour percentage according to the vigour groupings. This can be associated with the high range of the system used in categorising the tested samples. IRRI (2009) stated that seeds high in vigour are known to have early and uniform stands which affords the developing seedlings a good resilience to various abiotic stresses.

Study outcome revealed differences in seedling germination and seedling vigor as Perry (1981), and Pollock and Roos (1972) reported variation in seedling vigor and germination as a result of genetic characters or environmental factors. This further indicates loss of seed vigor in storage conditions are Mahadevappa and Nandisha (1987) and Black and Halmer (2006) reported.
Perry (1981) and Pollock and Roos (1972) both reported that variations in seedling vigour and germination could be as a result of inherent characters or surrounding conditions acting on the crop all through its development.

Mahadevappa and Nandisha (1987) and Black and Halmer (2006) had previously stated that seeds possessing low vigour had the tendency to lose their viability faster as compared with those with a much higher vigour when kept under the same conditions.

5.2.4 Impact of Seed Health on rice

*Bipolaris oryzae* and *Curvularia lunata* were found to have the highest rate of incidence during the seed health analysis. These were followed by *Alteneria padwickii*, *Sarocladium oryzae* and *Fusarium moniliforme* although the magnitude of these infections was not as high as the *Bipolaris oryzae* and *Curvularia lunata*.

Rice is subject to many diseases such as *Pyricularia oryzae*, *Thanatephorus cucumeris*, *Bipolaris spicifera*, *Helminthosporium oryzae*, *Nigrospora oryzae* (teleomorph is known as *Khuskia oryzae*), *Exserohilum rostratum*, *Curvularia lunata*, *Alternaria spp.* and *Fusarium spp.* (Vidhyasekaran et al., 1991; Khan and Sinha, 2005; Sami, 2006; Shabana et al., 2008; Khosravi et al., 2011; Nur Ain Izzati et al., 2011; Schwarz et al., 2012; Kamaluddeen and Abhilasha, 2013).

These fungi are considered economically important pathogenic fungi as they have a broad range of hosts and distribution around the world (Brecht et al., 2007; Aye and Matsumoto, 2010; Ali and Alwan, 2012). Because of their wide host range and higher survival capacity, these are difficult to manage (Shamoun et al., 1991; Schill et al., 1994). They have been held accountable for extreme
economic losses by reducing harvest yields to at least 80% of all crops which are related with at least one disease triggered by these pathogens (Leslie and Summerell, 2006; Nadia and El Shamy, 2014), and also decrease the quality of staple foods (Laurids et al., 2013).

Moreover, these pathogens cause a variety of disease symptoms causing a high degree of devastation in rice yield and wide range of plant species such as leaf spots, crown rot, foliar diseases, leaf spots, blights, ear rot and root rot. These symptoms are also spread among different plants such as grasses, cotton, cane, sorghum, cereals and corn (Najeeb et al., 2008; Zhang et al., 2012). Alternaria alternata and Alternaria tenuissima strongly associated with root rot fungus as is Fusarium spp. (Morgavi and Riley, 2007; Gargouri-Kammoun et al., 2014). Also, Bipolaris, Curvularia, Drechslera and Exserohilum species, as fungi which cause lesions on the leaves of Lolium multiflorum (L.) and Cynodon dactylon (L.) were evaluated (Pratt, 2006). Curvularia leaf spot caused by the fungal pathogen Curvularia lunata (Wakker) Boed greatly impacts corn production and development worldwide (Dai et al., 1995; Dai et al., 1998; Li et al., 2006; Gao et al., 2014).

Pathogens of C. lunata, Exserohilum rostratum, Alternaria spp. and Bipolaris spicifera have been identified by the presence of melanin pigment in their cell walls (Iram and Ahmad, 2005; Gao et al., 2015).

Understanding the disease cycles of B. spicifera (H. oryzae), E. rostratum, C. lunata, Fusarium spp., N. oryzae, T.cucumeris and Alternaria spp. are imperative in developing a sustainable integrated pest pathogen management programme (Harman et al., 2004).

In spite of the adverse effects it has on crops, Curvularia spp. as facultative parasites are part of the microorganisms which are being used for weed control (de Luna et al., 2002). In South
American countries, *Curvularia lunata* and *Phyllachora sp.* have been identified as leaf spot-causing factors in *Hymenachne amplexicaulis* (Rudge) (Monterio et al., 2003).

### 5.2.5 1000 Seed Weight Analysis

In theory, heavier seeds are thought to produce more vigorous seedlings which are responsible for higher grains as reported by Mahadevappa and Nandisha (1987). This however, was not entirely realized in the analysis as Farmer 14-Agra: B, although having the highest 1000 seed weight of 29.5g did not have the highest seed vigour (Figure 4.19). Also, the chi-square analysis showed that there was no statistical relationship between the weight of the seeds and its vigor. This means that the vigor of the seeds are not dependent on its weight and hence other factors could be responsible for the seed vigor. It was according to the groupings in the seed vigour category however, among the samples with a high vigour. Sample Farmer 29-Jasmine 85: A with the lowest seed weight of the lot (25g) recorded a high seed vigour of 82%.
6. CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

From the study conducted, the following conclusions can be made,

I. Although a fair number of the farmers at the Dawhenya Irrigation Scheme know of certified seeds, only a small percentage of that number have used it in cultivating their rice crop.

II. The farmers at the site’s response to their perception on yield loss varies greatly although a large number of them believe that the cost of production is the most important factor that dictates their production patterns and yield. The influence of seeds was not greatly considered by the farmers as a factor that influences crop yields.

III. From the lab analysis, it can be concluded that the samples taken from the farmers were not of an inferior quality. The figures from the moisture content tests show the seeds possessed the right moisture content with the exception of a few samples whose moisture content was on the higher side. These samples can however be further dried to the required moisture content.

IV. The purity analysis also showed that the seeds analysed possessed a high percentage of analytical purity. Results from the purity analysis also show that the Agra variety (F14-AG: B) was the purest of the entire lot although it was the least preferred variety of the three major varieties cultivated at the site. The sample with the lowest purity was also from the Agra variety (F02-AG: B) providing two contrasting remarks of the variety. The high
and low purity can be chalked down to post harvest processing and handling which is usually done with machinery which when not properly calibrated can give undesirable results. Also, with the purity analysis, the sample taken before planting (Sample A) was seen to possess a higher mean purity than that of the sample taken after harvest (Sample B).

V. The Agra variety was also seen to have the highest germination percentage with 99%. The groupings presented a good picture of each samples performance. Of 60 samples, the samples taken before planting (Sample A) had 28 of its 30 samples in the greater than or equal to 80% category. Only the samples Farmer 3-Short Aroma: A and Farmer 16-Short Aroma: A with percentages of 75% and 71% respectively were found in the less than or equal to 79.9% range. The samples taken after harvest (Sample B) however had 24 of its 30 sample in the greater than or equal to 80% range. There was correlation between germination and seed vigour but no correlation between seed vigour and 1000 seed weight.

VI. Although farmers at the site’s response to the health section of the survey was that they don’t face any notable health problems, the seeds health status after careful examination was found to contain an 18.85% fungal infection incidence of the total seeds tested and this number was largely made up of Curvularia lunata and Bipolaris oryzae. These fungi species pose a major hindrance to rice production but their numbers may not be in the alarming range to cause an emergency although steps could be taken to curb their incidence and efficacy.

VII. Based on all these findings, it can therefore be stated that the farmers’ saved seeds at the Dawhenya Irrigation Scheme is of a high quality. Hence the seeds are not a factor in the
perceived decline at the site. The decline may however be as a result of the recent rise in the cost of production of the crop as reported by a majority of the farmers at the site.

6.2 RECOMMENDATIONS

I. Further studies can be carried out to ascertain the actual cause of yield decline at the site.

II. A more reliable way of conducting vigour tests on rice should be researched into rather than the use of the first germination count.

III. This study can be replicated at the other irrigation schemes to have a wholistic view of the state of farmer saved seeds around the country.

IV. Government interventions to help in reduction of the cost of production particularly through the irrigation charges and other input subsidies would go a long way in improving the profitability of producing the crop and hence encourage more farmer to pursue rice production and in the process, meeting the consumption demands of an ever-growing population in Ghana and Africa as a whole.
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cultivation started along the banks of the Yangtze River in southern China and subsequently moved northward."


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APPENDICES

APPENDIX I: QUESTIONNAIRE ISSUED TO FARMERS AT DAWHENYA IRRIGATION SCHEME

The series of questions in this questionnaire are designed to obtain the farmers perception on the causes of yield decline on their various fields and also to identify crop production practices in use at the site which may contribute to the declining yields.

Please answer the questions that follow by ticking the appropriate options (if provided) or writing unrestrictedly for open-ended questions. Please answer all questions freely but objectively.

The information is for academic purposes only and will be treated with the strictest confidentiality.

Section 1: Demography

i. Age........................................................................................................................................................................

ii. Sex

  Male □  Female □

iii. Ethnicity...............................................................................................................................................................

iv. Religious background

  Christian □  Muslim □  Other □

v. Marital Status

  Single □  Married □  Divorced □  Separated □

vi. Number of dependents........................................................................................................................................

Section 2: Farming Experience
i. How many years have you been farming?
   - Less than 5 years [ ]
   - Between 5 and 10 years [ ]
   - Between 10 and 20 years [ ]
   - 20 years or more [ ]

ii. How many years have you been into rice farming?
   - Less than 5 years [ ]
   - Between 5 and 10 years [ ]
   - Between 10 and 20 years [ ]
   - 20 years or more [ ]

iii. Have you grown any other crops aside rice?
   - Yes [ ]
   - No [ ]

iv. If yes, how many crops have you grown aside rice? (State the number and type of crop)
   ……………………………………………………………………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………………………………………………………………

v. Do you still grow other crops aside rice?
   - Yes [ ]
   - No [ ]

vi. If yes, please state them
   ……………………………………………………………………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………………………………………………………………

vii. What variety or varieties of rice do you grow?
   ……………………………………………………………………………………………………………………………………………………………………

viii. How long have you been growing this or these varieties?
   ……………………………………………………………………………………………………………………………………………………………………

ix. What type of seed do you use in cultivating your rice crop?
   - Farmer saved seeds [ ]
   - Certified seeds [ ]
   - Other [ ]
   Others? Please state………………………………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………………………………………………………………

x. Where do you obtain the seeds you use in cultivating your rice crop?
xi. Are you familiar with Certified Rice Seeds available on the Ghanaian Market?
   Yes [ ] No [ ]

xii. Have you ever used certified planting material?
    Yes [ ] No [ ]

xiii. If Yes, when was the last time you used certified planting material?
      Still in use [ ] Last Cropping Season [ ] Last Two Cropping Seasons [ ]
      More than Two Cropping Seasons Ago [ ]

xiv. If you have ever used certified planting material but have stopped or have never used at all before, why did you stop using it or why have you never used it before?
    Too expensive [ ] Not readily available [ ] Used before but didn’t get good yield [ ]
    Heard from other users that it doesn’t give good yields or the yields aren’t different from farmer saved seeds [ ] Not Necessary [ ] Not Applicable [ ]

xv. What is the area of the plot you cultivate your rice crop on?

xvi. What was your yield last season?

xvii. What was your yield last two seasons?

Section 3: Production Practices Undertaken at the Site

The following are a set of production practices which are employed in rice cultivation. Please indicate by ticking the techniques you use in the production of your rice crop and write unrestrictedly any other information required. A comment section is also provided for additional information where needed.

i. Seed Selection

Purchased from input dealers [ ] Recently saved stock (Last Season’s harvest) [ ]
Stock from harvested produce (Two or more season’s harvest) [ ]
Obtained from fellow farmer

None of the above? Please state…………………………………………………………………………………………………………………

…………………………………………………………………………………………………………………………………………………………………..

Comment…………………………………………………………………………………………………………………………………………………

…………………………………………………………………………………………………………………………………………………………………..

ii. Land Preparation

Manual Labor (Using hand held tools) □ Mechanical Preparation (Use of tractors and other machinery) □

Tilling □ Crossing □ Leveling □

How often do you undertake land preparation?

…………………………………………………………………………………………………………………………………………………………………..

…………………………………………………………………………………………………………………………………………………………………..

Comment…………………………………………………………………………………………………………………………………………………

…………………………………………………………………………………………………………………………………………………………………..

iii. Crop Establishment

Direct Seeding □ Nursery and Transplanting □ Other □

Comment…………………………………………………………………………………………………………………………………………………

…………………………………………………………………………………………………………………………………………………………………..

iv. Water Management

Irrigation only □ Rain fed only □ Both Irrigation and Rain fed □

How often do you irrigate your crop?

…………………………………………………………………………………………………………………………………………………………………..

…………………………………………………………………………………………………………………………………………………………………..

Do you get enough water to irrigate your crop?

Yes □ No □

Do you get the water when you need it?

Yes □ No □
Comment………………………………………………………………………………………………………………………………………………….

………………………………………………………………………………………………………………………………………………………………

v.  Nutrient Management

Do you apply fertilizer to your crop?

Yes ☐   No ☐

If yes, what type of fertilizer(s) do you apply?

……………………………………………………………………………………………………………………………………………………………..

……………………………………………………………………………………………………………………………………………………………..

When do you apply the fertilizer to the crop? (At what stage of crop development)

……………………………………………………………………………………………………………………………………………………………..

……………………………………………………………………………………………………………………………………………………………..

Where do you get the fertilizer you use from?

……………………………………………………………………………………………………………………………………………………………..

……………………………………………………………………………………………………………………………………………………………..

Comment………………………………………………………………………………………………………………………………………………….

………………………………………………………………………………………………………………………………………………………………

vi.  Crop Health

Do you face any pest problems at your site?

Yes ☐   No ☐

If yes, which of the methods below do you use in curbing the pest problem?

Chemical method ☐   Non-chemical method ☐

Others? Please state……………………………………………………………………………………………………………………………..

………………………………………………………………………………………………………………………………………………………………

If the chemical method is used what chemical do you use and how often do you use it?

………………………………………………………………………………………………………………………………………………………………

………………………………………………………………………………………………………………………………………………………………

If the Non-chemical method is used what method do you use and how often do you use it?

………………………………………………………………………………………………………………………………………………………………
If any other method is used please state how often it is used.

Do you face any bacterial, fungal or viral problems?

Yes to all □ No to all □ Yes to Bacterial and Fungal only □
Yes to Bacterial and Viral only □ Yes to Fungal and Viral only □ Yes to Bacterial only □
Yes to Fungal only □ Yes to Viral only □

What method do you use to control bacterial, fungal and viral problems if you face any of them at your site?

Do you face any weed problems at your site?

Yes □ No □

If yes, what method do you use to control this problem and how often do you undertake weed control?

Comments

vii. Harvesting

How do you harvest your crops?

Mechanical harvesting □ Manual harvesting □

What tools do you use in harvesting your crop?

Comment
viii.  **Post-Harvesting**

Which of the following post-harvest processes do you undertake?

- Threshing  
- Drying  
- Winnowing  
- Milling  
- Gathering and Collection  
- Weighing  
- Storing

If you thresh, what equipment do you use to thresh?

If you dry, where, how and for how long do you dry your harvested crop?

If you winnow what equipment do you use to winnow?

What tool do you use to gather and collect the grain from the field and how is it done?

If you mill, where and how do you mill your harvested crop?

If you store, where, how and for how long do you store your harvested crop?

Comment

ix.  **Are there any other production processes that you undertake which have not been captured above?**
Section 4: Perception of farmers on the causes of yield decline on their fields

In this section, your perception of yield loss will be taken. On a scale of 1 to 3 with 1 being directly affecting, 2 being indirectly affecting and 3 being not affecting at all, rate the following factors in the production processes on their likelihood of affecting yield either positively or negatively.

Scale: 1=directly affecting  2=indirectly affecting  3=does not affect at all

Seed Selection
- i. To what extent do you think the Variety of seeds grown affects yield?  
- ii. To what extent do you think the Origin of seeds used affects yield?  
- iii. To what extent do you think the Class of seed used with respect to farmer saved and certified seeds affects yield?  
- iv. To what extent do you think the Cost of seed acquisition affects yield?  

Land Preparation
- i. To what extent do you think Tilling affects yield?  
- ii. To what extent do you think Crossing affects yield?  
- iii. To what extent do you think Leveling affects yield?  
- iv. To what extent do you think the Type of machine used in land preparation affects yield?  
- v. To what extent do you think the Cost of land preparation affects yield?  

Crop establishment
- i. To what extent do you think Direct seeding (Broadcasting) affects yield?  
- ii. To what extent do you think Nursing and transplanting affects yield?  
- iii. To what extent do you think Cost of crop establishment affects yield?  

Water Management
- i. To what extent do you think using artificial irrigation only affects yield?  
- ii. To what extent do you think using rain fed irrigation only affects yield?  
- iii. To what extent do you think using both artificial and rain fed irrigation affects yield?  
- iv. To what extent do you think the Quality of water used (pH, salinity, acidity etc.) affects the yield?  
- v. To what extent do you think cost of irrigation (irrigation charges) affects yield?
Nutrient Management

i. To what extent do you think the type of fertilizer applied affects yield?

ii. To what extent do you think the frequency of fertilizer application affects yield?

iii. To what extent do you think the timing of fertilizer application affects yield?

iv. To what extent do you think the cost of nutrient management affects yield?

Crop Health

i. To what extent do you think the type of pesticide used affects the yield?

ii. To what extent do you think the frequency of pesticide application affects the yield?

iii. To what extent do you think the timing of pesticide application affects the yield?

iv. To what extent do you think the type of fungicide used affects the yield?

v. To what extent do you think the frequency of fungicide application affects the yield?

vi. To what extent do you think the timing of fungicide application affects the yield?

vii. To what extent do you think the type of weed control used affects the yield?

viii. To what extent do you think the frequency of weed control affects the yield?

ix. To what extent do you think the timing of weed control affects the yield?

x. To what extent do you think the type of weed control used affects the yield?

Harvesting

i. To what extent do you think the mechanism of harvesting (whether mechanical or manual) affects the yield?

ii. To what extent do you think the timing of harvest affects the yield?

iii. To what extent do you think the tool used for harvesting affects the yield?

iv. To what extent do you think the cost of harvesting affects the yield?

Post-Harvesting

i. To what extent do you think threshing affects yield?

ii. To what extent do you think the tool used for threshing affects yield?

iii. To what extent do you think the timing of the Threshing affects yield?

iv. To what extent do you think Drying affects the yield?

v. To what extent do you think the timing of Drying affects the yield?

vi. To what extent do you think the mechanism of Drying (whether artificial or natural) affects the yield?

vii. To what extent do you think the tool used for winnowing affects the yield?

viii. To what extent do you think the time for winnowing affects the yield?

ix. To what extent do you think the tool used for gathering and collection affects the yield?

x. To what extent do you think the time of gathering and collection affects yield?

xi. To what extent do you think milling of harvested produce affects the yield?

xii. To what extent do you think the tools used in milling affects the yield?

xiii. To what extent do you think storing of harvest affects the yield?
xv. To what extent do you think the storage duration affects the yield?

If there are any other factors not listed above please state them and their respective likelihood of affecting yield.

In your opinion, which of the following processes and factors of production do you think contributes the most to yield loss on your field? (Select one by ticking)

- Seed Selection
- Land Preparation
- Crop Establishment
- Water Management
- Nutrient Management
- Crop Health
- Harvesting techniques
- Post-harvest techniques
- Weather conditions (Drought, Floods, etc)
- Soil Conditions (pH, Salinity, Acidity, etc)
- Cost of production operations
APPENDIX II: SEED QUALITY STANDARD FOR EMERGENCY ACTIVITIES
- BASED ON FAO QUALITY DECLARED SEEDS (QDS)

Seed Quality Standards for Emergency Activities
Based on FAO Quality Declared Seed (QDS)

<table>
<thead>
<tr>
<th>CEREALS</th>
<th>Varietal purity(^1) (min. %)</th>
<th>Analytical purity(^2) (min. %)</th>
<th>Germination (^3) (min. %)</th>
<th>Moisture content (^4) (max. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>98</td>
<td>98</td>
<td>80</td>
<td>13</td>
</tr>
<tr>
<td>Pearl Millet</td>
<td>98</td>
<td>98</td>
<td>70</td>
<td>13</td>
</tr>
<tr>
<td>Rice</td>
<td>98</td>
<td>98</td>
<td>75</td>
<td>13</td>
</tr>
<tr>
<td>Sorghum</td>
<td>98</td>
<td>98</td>
<td>70</td>
<td>13</td>
</tr>
<tr>
<td>Wheat</td>
<td>98</td>
<td>98</td>
<td>80</td>
<td>13</td>
</tr>
<tr>
<td>FOOD LEGUMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beans</td>
<td>98</td>
<td>98</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>Broad beans</td>
<td>98</td>
<td>98</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>Chickpeas</td>
<td>98</td>
<td>98</td>
<td>75</td>
<td>10</td>
</tr>
<tr>
<td>Cowpeas</td>
<td>98</td>
<td>98</td>
<td>75</td>
<td>10</td>
</tr>
<tr>
<td>Dry Peas</td>
<td>98</td>
<td>98</td>
<td>75</td>
<td>10</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>98</td>
<td>98</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>Lentils</td>
<td>98</td>
<td>98</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>Mungbeans</td>
<td>98</td>
<td>98</td>
<td>75</td>
<td>10</td>
</tr>
<tr>
<td>Soyabeans</td>
<td>98</td>
<td>98</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>OIL CROPS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sesame</td>
<td>98</td>
<td>98</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>Sunflower</td>
<td>98</td>
<td>98</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>INDUSTRIAL CROPS</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotton</td>
<td>98</td>
<td>98</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>Castor Bean</td>
<td>98</td>
<td>98</td>
<td>70</td>
<td>10</td>
</tr>
</tbody>
</table>

In determining seed quality the working seed sample is separated into 3 fractions, pure seed, seed of other crops (includes weed seed), and inert matter. In the QDS specifications, seed of other crops, weed seed and inert matter should be at an acceptable maximum level.

\(^1\) Varietal purity: the percentage of the pure seed that will produce plants that exhibit the characteristics of that specific crop variety. This can only be determined through DNA fingerprinting and/or field inspection of seed crop plots.

\(^2\) Analytical purity: the percentage of the seed that is of the same crop species but not necessarily the same crop variety. The balance can include inert matter, weed seed, damaged seed. While regular seed testing procedures may not, in all cases, distinguish between different varieties of the same species, the seeds of different crop (species) can be identified in the seed laboratory by close examination of the seed.

\(^3\) Germination: the percentage of the seed with the ability to germinate and that can develop into plants under appropriate field conditions of optimum moisture, aeration and temperature.

\(^4\) Maximum moisture content recommended for safe storage and good germination. Values may vary with crop types (starchy vs. oil/high protein content seeds) and according to local conditions, in particular with environmental relative humidity and temperature.
### APPENDIX III: SEED STORAGE LIFE AND MOISTURE CONTENT

**Table 5: Seed storage life and moisture content**

<table>
<thead>
<tr>
<th>Storage period</th>
<th>Required MC for safe storage</th>
<th>Potential problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 3 weeks</td>
<td>14 – 18 %</td>
<td>Molds, discoloration, respiration loss</td>
</tr>
<tr>
<td>8 to 12 months</td>
<td>13 % or less</td>
<td>Insect damage</td>
</tr>
<tr>
<td>More than 1 year</td>
<td>9 % or less</td>
<td>Loss of viability</td>
</tr>
</tbody>
</table>
APPENDIX IV: RICE PRODUCTION TRENDS

Figure 1: World Rice Production figures from 2009 to 2014
(Source: FAOSTAT 2017)

Figure 2: Ghana Rice Production Figures from 2004 to 2014
(Source: FAOSTAT 2017)
APPENDIX V: EQUIPMENTS USED FOR MOISTURE CONTENT EVALUATION

Figure 3: Grinder/Mill
Figure 4: Sensitive balance measuring up to four decimal places
Figure 5: Non-corrosive metal Containers

Figure 6: Plastic containers for grinder
Figure 7: High Capacity Electric Oven
Figure 8: Desiccator
APPENDIX VI: EQUIPMENTS USED FOR WORKING SAMPLE DETERMINATION AND PURITY ANALYSIS

Figure 9: One decimal place Balance

Figure 10: Diphanoscope
APPENDIX VII: EQUIPMENT USED FOR SEED HEALTH TESTS

Figure 11: Eight (8) replicates of Twenty-five (25) plated seeds for seed health test

Figure 12: Plated seeds arranged under Ultraviolet Light

Figure 13: Stereo Microscope

Figure 14: Compound Microscope
APPENDIX VIII: DATA ON THE MOISTURE CONTENTS OF SUBMITTED SAMPLES BEFORE PLANTING AND AFTER HARVESTING

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Sample A Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer 1- Aromatic Short</td>
<td>11.5</td>
</tr>
<tr>
<td>Farmer 3- Aromatic Short</td>
<td>11.98</td>
</tr>
<tr>
<td>Farmer 4- Aromatic Short</td>
<td>11.8</td>
</tr>
<tr>
<td>Farmer 7- Aromatic Short</td>
<td>12</td>
</tr>
<tr>
<td>Farmer 9- Aromatic Short</td>
<td>11.7</td>
</tr>
<tr>
<td>Farmer 10- Aromatic Short</td>
<td>11.9</td>
</tr>
<tr>
<td>Farmer 11- Aromatic Short</td>
<td>11.8</td>
</tr>
<tr>
<td>Farmer 16- Aromatic Short</td>
<td>11.8</td>
</tr>
<tr>
<td>Farmer 19- Aromatic Short</td>
<td>12.3</td>
</tr>
<tr>
<td>Farmer 25- Aromatic Short</td>
<td>12.4</td>
</tr>
<tr>
<td>Farmer 28- Aromatic Short</td>
<td>11.2</td>
</tr>
<tr>
<td>Farmer 30- Aromatic Short</td>
<td>11.5</td>
</tr>
</tbody>
</table>

Range (Min-Max) 11.2 – 12.4

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Sample A Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer 2- CRI-AgraRice</td>
<td>11</td>
</tr>
<tr>
<td>Farmer 8- CRI-AgraRice</td>
<td>10.5</td>
</tr>
<tr>
<td>Farmer 12- CRI-AgraRice</td>
<td>18.2</td>
</tr>
<tr>
<td>Farmer 14- CRI-AgraRice</td>
<td>11</td>
</tr>
<tr>
<td>Farmer 15- CRI-AgraRice</td>
<td>18.5</td>
</tr>
<tr>
<td>Farmer 20- CRI-AgraRice</td>
<td>11.4</td>
</tr>
<tr>
<td>Farmer 21- CRI-AgraRice</td>
<td>11</td>
</tr>
<tr>
<td>Farmer 22- CRI-AgraRice</td>
<td>10.1</td>
</tr>
<tr>
<td>Farmer 26- CRI-AgraRice</td>
<td>11.4</td>
</tr>
<tr>
<td>Farmer 27- CRI-AgraRice</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Range (Min-Max) 10.1 – 18.5

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Sample A Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer 5- Jasmine 85</td>
<td>10.9</td>
</tr>
<tr>
<td>Farmer 6- Jasmine 85</td>
<td>11.1</td>
</tr>
<tr>
<td>Farmer 13- Jasmine 85</td>
<td>10.9</td>
</tr>
<tr>
<td>Farmer 17- Jasmine 85</td>
<td>11.8</td>
</tr>
<tr>
<td>Farmer 18- Jasmine 85</td>
<td>10.8</td>
</tr>
<tr>
<td>Farmer 23- Jasmine 85</td>
<td>12.5</td>
</tr>
<tr>
<td>Farmer 24- Jasmine 85</td>
<td>12.4</td>
</tr>
<tr>
<td>Farmer 29- Jasmine 85</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Range (Min-Max) 10.8 – 12.5
<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Sample B Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer 1- Aromatic Short</td>
<td>11.8</td>
</tr>
<tr>
<td>Farmer 3- Aromatic Short</td>
<td>14.7</td>
</tr>
<tr>
<td>Farmer 4- Aromatic Short</td>
<td>11.1</td>
</tr>
<tr>
<td>Farmer 7- Aromatic Short</td>
<td>10.7</td>
</tr>
<tr>
<td>Farmer 9- Aromatic Short</td>
<td>12.3</td>
</tr>
<tr>
<td>Farmer 10- Aromatic Short</td>
<td>11.1</td>
</tr>
<tr>
<td>Farmer 11- Aromatic Short</td>
<td>11.9</td>
</tr>
<tr>
<td>Farmer 16- Aromatic Short</td>
<td>12.3</td>
</tr>
<tr>
<td>Farmer 19- Aromatic Short</td>
<td>11.7</td>
</tr>
<tr>
<td>Farmer 25- Aromatic Short</td>
<td>11.9</td>
</tr>
<tr>
<td>Farmer 28- Aromatic Short</td>
<td>11.7</td>
</tr>
<tr>
<td>Farmer 30- Aromatic Short</td>
<td>12.4</td>
</tr>
<tr>
<td><strong>Range (Min-Max)</strong></td>
<td><strong>10.7 – 14.7</strong></td>
</tr>
</tbody>
</table>

| Farmer 2- CRI-AgraRice | 11 |
| Farmer 8- CRI-AgraRice | 11.5 |
| Farmer 12- CRI-AgraRice | 11 |
| Farmer 14- CRI-AgraRice | 12.7 |
| Farmer 15- CRI-AgraRice | 8.9 |
| Farmer 20- CRI-AgraRice | 15.3 |
| Farmer 21- CRI-AgraRice | 19.7 |
| Farmer 22- CRI-AgraRice | 9.8 |
| Farmer 26- CRI-AgraRice | 10.6 |
| Farmer 27- CRI-AgraRice | 10.2 |
| **Range (Min-Max)** | **8.9 – 19.7** |

| Farmer 5- Jasmine 85 | 12.4 |
| Farmer 6- Jasmine 85 | 11.8 |
| Farmer 13- Jasmine 85 | 13 |
| Farmer 17- Jasmine 85 | 13 |
| Farmer 18- Jasmine 85 | 12.8 |
| Farmer 23- Jasmine 85 | 12.3 |
| Farmer 24- Jasmine 85 | 12.1 |
| Farmer 29- Jasmine 85 | 12.2 |
| **Range (Min-Max)** | **11.8 – 12.8** |
APPENDIX IX: DATA ON THE PERCENTAGE PURITY OF SUBMITTED SAMPLES BEFORE PLANTING AND AFTER HARVESTING

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Sample A Purity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer 1- Aromatic Short</td>
<td>98.4</td>
</tr>
<tr>
<td>Farmer 3- Aromatic Short</td>
<td>98.1</td>
</tr>
<tr>
<td>Farmer 4- Aromatic Short</td>
<td>98.9</td>
</tr>
<tr>
<td>Farmer 7- Aromatic Short</td>
<td>99.2</td>
</tr>
<tr>
<td>Farmer 9- Aromatic Short</td>
<td>99.1</td>
</tr>
<tr>
<td>Farmer 10- Aromatic Short</td>
<td>97.8</td>
</tr>
<tr>
<td>Farmer 11- Aromatic Short</td>
<td>97</td>
</tr>
<tr>
<td>Farmer 16- Aromatic Short</td>
<td>99.1</td>
</tr>
<tr>
<td>Farmer 19- Aromatic Short</td>
<td>98.1</td>
</tr>
<tr>
<td>Farmer 25- Aromatic Short</td>
<td>98.2</td>
</tr>
<tr>
<td>Farmer 28- Aromatic Short</td>
<td>98.9</td>
</tr>
<tr>
<td>Farmer 30- Aromatic Short</td>
<td>99.1</td>
</tr>
<tr>
<td>Range (Min-Max)</td>
<td>97 – 99.2</td>
</tr>
<tr>
<td>Farmer 2- CRI-AgraRice</td>
<td>98.7</td>
</tr>
<tr>
<td>Farmer 8- CRI-AgraRice</td>
<td>98.5</td>
</tr>
<tr>
<td>Farmer 12- CRI-AgraRice</td>
<td>98.9</td>
</tr>
<tr>
<td>Farmer 14- CRI-AgraRice</td>
<td>98.9</td>
</tr>
<tr>
<td>Farmer 15- CRI-AgraRice</td>
<td>98.9</td>
</tr>
<tr>
<td>Farmer 20- CRI-AgraRice</td>
<td>98.9</td>
</tr>
<tr>
<td>Farmer 21- CRI-AgraRice</td>
<td>98.4</td>
</tr>
<tr>
<td>Farmer 22- CRI-AgraRice</td>
<td>99.1</td>
</tr>
<tr>
<td>Farmer 26- CRI-AgraRice</td>
<td>99.1</td>
</tr>
<tr>
<td>Farmer 27- CRI-AgraRice</td>
<td>98.9</td>
</tr>
<tr>
<td>Range (Min-Max)</td>
<td>98.4 – 99.1</td>
</tr>
<tr>
<td>Farmer 5- Jasmine 85</td>
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<tr>
<td>Farmer 6- Jasmine 85</td>
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<td>Farmer 13- Jasmine 85</td>
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<td>Farmer 17- Jasmine 85</td>
<td>99.8</td>
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<td>Farmer 18- Jasmine 85</td>
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<tr>
<td>Farmer 23- Jasmine 85</td>
<td>99.2</td>
</tr>
<tr>
<td>Farmer 24- Jasmine 85</td>
<td>99</td>
</tr>
<tr>
<td>Farmer 29- Jasmine 85</td>
<td>96.2</td>
</tr>
<tr>
<td>Range (Min-Max)</td>
<td>96.2 – 99.8</td>
</tr>
<tr>
<td>Sample Number</td>
<td>Sample B Purity (%)</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------</td>
</tr>
<tr>
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<td>Farmer 21- CRI-AgraRice</td>
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<td>Farmer 22- CRI-AgraRice</td>
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<td>Farmer 24- Jasmine 85</td>
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<tr>
<td>Farmer 29- Jasmine 85</td>
<td>95.3</td>
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<tr>
<td><strong>Range (Min-Max)</strong></td>
<td><strong>90.1 – 97.2</strong></td>
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APPENDIX X: DATA ON THE PERCENTAGE INFECTION OF SUBMITTED SAMPLES BEFORE PLANTING AND AFTER HARVESTING

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<thead>
<tr>
<th>Sample Number</th>
<th>Sample A Percentage Infection</th>
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<tr>
<td>Farmer 11 - Aromatic Short</td>
<td>23</td>
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<tr>
<td>Farmer 16 - Aromatic Short</td>
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<td>Farmer 19 - Aromatic Short</td>
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<tr>
<td>Farmer 28 - Aromatic Short</td>
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<tr>
<td>Farmer 30 - Aromatic Short</td>
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<td>Range (Min-Max)</td>
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<tr>
<td>Farmer 12 - CRI-AgraRice</td>
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<tr>
<td>Farmer 14 - CRI-AgraRice</td>
<td>14.5</td>
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<tr>
<td>Farmer 15 - CRI-AgraRice</td>
<td>29</td>
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<tr>
<td>Farmer 20 - CRI-AgraRice</td>
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<tr>
<td>Farmer 21 - CRI-AgraRice</td>
<td>13</td>
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<tr>
<td>Farmer 22 - CRI-AgraRice</td>
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<td>Farmer 26 - CRI-AgraRice</td>
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Range (Min-Max) 4.5 – 37

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<td>Farmer 12- CRI-AgraRice</td>
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<td>Farmer 14- CRI-AgraRice</td>
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<tr>
<td>Farmer 21- CRI-AgraRice</td>
<td>19</td>
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Range (Min-Max) 2.5 – 25

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<tr>
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Range (Min-Max) 19 – 37.5