UNIVERSITY FOR DEVELOPMENT STUDIES

EVALUATION OF UREA DEEP PLACEMENT AND FARMER MANAGEMENT PRACTICES ON PERFORMANCE AND GRAIN YIELD OF RICE (*Oryza sativa* L) AT THE TONO IRRIGATION SITE

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UNIVERSITY FOR DEVELOPMENT STUDIES, FACULTY OF AGRICULTURE, TAMALE

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MARCH, 2021

DECLARATION

I hereby declare that this thesis is my original work and that no part of it has been presented for another degree in this university or elsewhere. Work of others which served as useful information has been duly acknowledged by references to the authors.

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We, hereby declare that the preparation and presentation of the thesis was supervised in accordance with guidelines on supervision of thesis laid down by the University for Development Studies.

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ABSTRACT

Agricultural technology Transfer (ATT) project embarked on a scaling up campaign of the 'Urea deep Placement' (UDP) nitrogen management system that was expected to transform rice production in the Tono Irrigation Scheme (TIS). The technology was expected to be adopted by rice farmers in the project area, after its introduction in 2015. However, certain farmers still remain apprehensive about using the technology for several reasons. This study combined farmer surveys and detailed rice phenological characterization to validate the efficiency of the UDP technology. Structured questionnaires were used to collect primary data from willing collaborating farmers to learn about farmer perceptions and management strategies with respect to UDP and any other N management practices. The field experiment consisted of five UDP and five non-UDP fields in each zone. Five 50 cm x 50 cm quadrats were randomly sited in each farmers field and phenological data (including plant number, tiller numbers and productive tiller numbers and grains per panicle) were collected and aggregated for each farmer. Grain yield data were collected from three 2 m x 2 m quadrats from each farmers field after harvesting. The study revealed that gender, education, farming experience and adoption of UDP influenced rice yield in the scheme. Yield components; tiller number, effective tiller number and grains per panicle except 1000 grain weight obtained with UDP were significantly higher than non-UDP. Rice grain yield obtained with UDP (7.05 MT/ha) was significantly higher than non-UDP (6.19 MT/ha). The study reinforces the assertion that using UDP technology results in significant increase in rice yields over traditional farmer management. The study recommends that farmers should use UDP technology to maximize grain yields in irrigated rice cropping system.

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DEDICATION

This thesis is sincerely dedicated to ALMIGHTY ALLAH for His care, greatness and love He has shown me throughout the challenging years of my life.

I also dedicate this project to my late father Mallam Issah, may his soul rest in peace.

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LIST OF ACRONYMS

AGRA	Alliance for a Green Revolution in Africa
ATT	Agriculture Technology Transfer
CARD	Coalition for African Rice Development
FAO	Food and Agricultural Organization
ICOUR	Irrigation Company of Upper Region
IFDC	International Fertilizer Development Center
IRRI	International Rice Research Institute
MoFA	Ministry of Food and Agriculture
GNRDS	Ghana National Rice Development Strategy
NUE	Nitrogen Use Efficiency
ODI	Overseas Development Institute
OECD	Organization for Economic Co-operation and Development
PU	Prilled urea
SRID/MoFA	Statistics, Research and Information Directorate of MoFA
SSA	Sub-Saharan Africa
TIS	Tono Irrigation Scheme
UDP	Urea deep placement
USG	Urea Super Granule
WARDA	West African Rice Development Association

CHAPTER ONE

1.1 Background

Rice (*Oryza sativa* L) is one of Sub- Saharan Africa's (SSA) the most common cereal crops. It is listed as the fourth most important crop after sorghum, maize and millet production (FAO, 2006). Rice covers 10% of the total area of land under cereal cultivation and provides 15% of the total cereal cultivation (FAO, 2006). Roughly, 20 million SSA farmers grow rice and about 100 million people rely on it for their livelihoods (Nwanze *et al*., 2006). Rice is an important staple food which supplies the increasing population of most African countries with a bulk of dietary calories. It is listed as the fifth most prominent energy source in diet, responsible for 9% calories (FAO, 2012), which provides about 715/cal/caput/day, 20% of nutritional protein, 27% of nutritional supply of energy and 3% of nutritional fat (Kassali *et al*., 2010).

Rice is important for the economy in Ghana and accounts for roughly 15% of gross domestic product (GDP) (Kranjac-Berisavljevic, 2000). After maize, rice is the country's second largest cereal consumed and its consumption continues to rise as a result of population growth, urbanization and changes in consumer habits (MoFA, 2009). Rice was the Ghana's tenth agricultural food crop in 2010 by value of production while it is ranked eighth in terms of production quantity for the 2005-2010 period (MoFA, 2010).

Production, consumption and land area under cultivation of rice have increased tremendously over the last two decades. Between 2002 and 2010, area of land under rice cultivation rose from 123,000 hectares to about 189,000 hectares (MoFA, 2013). This accounted for about 45% of total hectares of land grown to cereals and about 4% of total crops harvested over that period. Between 2008 and 2015, about 192,000 hectares was used in rice production yearly with an average annual paddy and milled production of 493,000 MT and 322,000 MT, respectively (MoFA, 2016).

Rice demand has increased exponentially in the last past decades. Increasing population growth, rapid urbanization and the convenience of cooking and storing it has contributed to its rise in consumption and this is estimated to increase further (kwofie *et al*., 2016).

The annual per capita intake of rice in Ghana increased from 17.5kg during 1999-2001 to 24kg during 2010-2011 (MoFA, 2011; Ragasa *et al*., 2014). The annual rice per capita consumption increased further to about 32kg in 2015 (MoFA, 2016), and it was expected to reach 63 kg per capita by the year 2018.

In spite of the increasing importance of rice, domestic production of rice in Ghana has not caught up with local consumption. Since 1980, rice import has been increasing continuously and as a result contributed to more than 60% of all rice consumed in Ghana (Bimpong, 1998). Rice imports between 2000 and 2011, increased from 187,256 MT to 543,465 MT, respectively, which marked a rise of around 190%.

In the same years, the import bill rose from US$65.03 million to US$391.17 million (MoFA, 2012). In both 2014 and 2015, the import bill shot up to about US$ 1.2 billion (MoFA, 2016). The economic cost of relying on rice import therefore puts a lot of pressure on Ghana's foreign exchange reserves.

Ghana's rice cultivation is categorized by agro-ecologies. These comprise irrigated, rain fed lowland and rain fed upland. Lowland rain-fed ecology accounts for roughly 78% of the country's rice cultivation. Irrigated and upland rain-fed ecologies on the other hand produces about 16% and 6%, respectively (MoFA, 2009). The majority of local rice are produced in Volta regions (15 per cent), Northern (37 per cent) and Upper East (27 per cent) (Ragasa *et al.*, 2013).

1.2 Problem statement and justification

Ghana's average rice yield is estimated to be 2.5 MT/ha while yield of 6.5 MT/ha is achievable (MoFA, 2013). The yield gap could be attributed to a cocktail of factors such as poor soil fertility management which includes low rates and inappropriate methods of fertilizer applications, use of bad quality seeds and low adoption of required inputs and improved technologies (Ragasa *et al.*, 2013). Empirical research proved that, significant yield potential could be achieved by improving agronomic practices and adopting innovative technologies.

Nitrogen is the key nutrient affecting rice yields in irrigated fields (Buresh *et al.*, 2008). Urea is the primary source of N used in rice cultivation, owing to its high N content and its relatively low cost per Kilogram of N. However, productive rice yields are also dependent on proper and effective management of N fertilizers. N losses through conventional broadcast method of urea application are almost 60 to 70% (Morales *et al*., 2000). It is projected that about 30 - 40% of N fertilizer applied by traditional broadcast method is available for plant growth; the rest is subjected to losses such as denitrification, ammonia volatilization, leaching and biological or chemical immobilization and runoff (Craswell *et al*., 1981; Ladha *et al*., 2005). The N use efficiency (NUE) is even lower under wetland production systems.

The nature and magnitude of N losses largely depend on nitrogenous fertilizer sources and its application method. Broadcasting N fertilizer at different growth stages of rice in split doses, is the common method recommended by extension agents. As mentioned earlier, this method has many limitations. However, more promising methods that enhance NUE in irrigated rice fields are now available in most rice producing countries. Urea supergranules (USG) or urea briquettes is a slow release fertilizer produced by compacting prilled urea fertilizer. The supergranule, 1-3 grams in weight, is placed below the surface of the soil at 7-10 cm soil depth and centralized between four plants. Through transformation processes, N is slowly released over the growing season of the rice crop. Also, the supergranules or briquettes are applied in a single dose during the entire cropping season unlike traditional broadcast urea application where 2-3 split applications are required. The total quantity of urea required for the whole season can be reduced, thus minimizing production cost of rice. Moreover, the use of the UDP system is environmentally friendly and its adoption has the potential to improve rice production in Ghana.

Several studies have reported UDP technology's potential for increased rice productivity. Tarfa and Kiger (2013) showed that the use of UDP technology increased rice productivity by 20-30%, with NUE increasing as much as 40% over conventional broadcasting methods in Nigeria. Pasandaran *et al*. (1998) reported that UDP showed a 25% savings in N fertilizer rates leading to an average 400 kg ha^{-1} increase in rice yield in Indonesia. Bulbule *et al.* (2002) also showed that USG briquette applied at a rate of 56 kg N ha^{-1} yielded 25% higher than the recommended dose of 100 kg N ha^{-1} using traditional urea in Indian rice crops.

In view of the enormous merits of the UDP system, the Integrated Soil Fertility Management (ISFM) group of Agricultural Technology Transfer (ATT) project has adopted the 'UDP N management system as a viable strategy to improve NUE in flooded rice production systems in Ghana. The ATT project has embarked on a scaling up campaign of the UDP technology that is expected to transform rice production and also promote climate resilience in the Northern, Upper East and Upper west regions of Northern Ghana. However, many farmers still remain hesitant about using the technology. This study combines farmer surveys and detailed on-farm rice phenological characterization to validate the efficiency of the UDP technology. This approach is important because most of the evaluation of UDP in Ghana has been based on researcher-managed, controlled experiments and understanding the results of UDP technology under total farmer management on-farm would facilitate adoption of this technology.

1.3 Objectives of the study

The general objective of this study was to determine the efficiency of the UDP technology under on-farm conditions. The specific objectives are to:

1. Conduct detailed socioeconomic, cultural and scientific surveys on the use of the UDP technology
2. Carry out extensive phenological characterization of rice crop in UDP and non-UDP systems to validate the effect of UDP technology on growth, performance and grain yield of rice compared to non-UDP systems.
3. Develop a short time-lapse video that compares growth and development of the rice crop under non-UDP and UDP over the growing season.

CHAPTER TWO

LITERATURE REVIEW

2.0 Origin and Ecology of rice

Rice (*Oryza sativa* L) is a plant belonging to the grass family, Gramineae (Poaceae). Rice was first grown in South - east Asia, India and China (Normile, 2004). According to historical record, the oldest rice cultivated was believed to have come from the basins of the Yangtze river of China (Wang *et al*., 1996). In another report, the foothills of Himalayas of India, northeastern India, upper Myanmar, Yunnan province of China and Thailand and are some of the primary places and origin of rice (Porteres,1956; OECD, 1999). The genus *Oryza* has 25 known species, of which 23 are wild and two of which are domesticated, *Oryza sativa* and *Oryza glaberrima* (Morishima, 1984; Brar and Khush, 2003). Four complexes make up the genus *Oryza*. These are *O. sativa*, *O. officialis*, *O. ridelyi and O. granulate* (Vaughan and Morishima, 2003). Grown species of *O. sativa* and *O. glaberrima* and their weedy/wild ancestors are involved in the the sativa complexes. *Oryza. sativa* and *O. glaberrima* are believed to have formed separately from two distinct progenitors, viz. *O. nivara* and *O. barthii* and they are thought to be domesticated in South and South-East Asia, as well as tropical West Africa. The most widely cultivated of the two rice species is *O. sativa*. It is grown worldwide including Asia, North and South America, European Union, middle Eastern and African countries. However, *O. glaberrima* is cultivated mostly in West Africa.

Rice is cultivated in different types of ecosystems, on different types of soils, and under various climatic conditions. Rice can be cultivated under a variety of water system. The International Rice Research Institute categorized rice agro-ecosystems into four (IRRI), (1993). These are irrigated rice ecosystem, rainfed lowland ecosystem, upland rice ecosystem and flood prone rice ecosystem. On the other hand, based on hydrology and topography, Balasubramanian *et al*. (2007) classified rice agro-ecosystems into five in sub-Saharan Africa. These are (1) rain-fed uplands and hydromorphic slopes (2) rain-fed lowlands in valley bottoms and flood-plains (3) irrigated lowlands (deltas and flood-plains) (4) deep-water basins along major rivers and (5) mangrove-swamps in lagoons and deltas. In Ghana, rice is cultivated in three different ecologies which include; upland rainfed ecology, lowland rainfed ecology and irrigated ecology (CARD, 2010).

In the upland rain-fed ecology, rice is cultivated on well drained soils where the water level is normally below the rice plant root zone. Rainfall is the only source of water for crops in this ecology and consequently, cultivation is possible only once in a year under mono-modal rainfall distribution pattern (Kranjac-Berisavljevic *et al.*, 2003). Soil conditions in this ecology are suitable for most weeds which results in high weeds-rice competition. Short duration and drought tolerant varieties are usually grown in this ecology. Varieties of *O. glaberrima* are predominantly grown due to their capability to compete effectively with weeds (Agbanyo, 2012). These varieties are well used to the hash environmental conditions, diseases, insect pests and the low soil fertility (MoFA, 2009).

Rain-fed lowland ecology is more suitable for rice cultivation than the upland rain-fed ecology even though they both depend on rainfall. In this ecology, soils are able to conserve more water due to their hydromorphic nature and the topography (Agbanyo, 2012). Water from rainfall and other water bodies is conserved through levelling and bunding. The major problem of this ecology includes; weed control, water availability, and unfavorable soil conditions (Oteng, 1997).

In irrigated rice ecology, fields are bunded and often, a layer of ponded water is maintained continuously and used as water for irrigation over the entire dry season or as supplementary water source during the wet season. As a result, this ecology produces higher yields than the other ecologies (MOFA, 2009). Crops can be grown two or more times in a year because of the possibility of irrigation. In this ecology, weed competition is rarely a constraint as fields are continuously submerged to control weeds.

2.1 Nutritional importance and uses of rice

Rice is one of the world’s most important foods that supplies as much as half of the world’s daily calories. About, 3.5 million people consume rice globally (IRRI, 2013). Rice alone accounts for 20- 70 % of the total caloric intake in Asia. It is a nutritional staple food which provides instant energy as carbohydrate in the form of starch. Kassali *et al*. (2010) reported that rice provides about 716 kcal/caput/day, 20% of nutritional protein, 27% of nutritional supply of energy and 3% of nutritional fat. According to Umadevi *et al*. (2012), 13.7 moisture (%), 6.8% protein 0.5% fat, 0.5% fiber 0.9% minerals, and 76.7% carbohydrates are contained in 100 g of raw milled rice. These authors also mentioned that raw milled rice supplies the following minerals and vitamins, calcium (Ca) (10 mg), phosphorus (P) (160 mg), iron (Fe) (3.1 mg), minute amounts of Vitamin E and B complex. The vitamin B-complex such as thiamin, riboflavin and niacin, contained in a natural brown rice, supply nourishment and energy to blood vessels and skin. According to the FAO (2004), the major amino acids contained in rice are glutamic and aspartic acids while lysine is present in small amount. Deepa and Naidu (2008), observed that the amount of thiamin in raw rice could help in supplying Vitamin B1 to prevent deficiencies such as muscle weakness and neuritis.

Parboiling and milling of rice influence the nutritional composition of rice. Brown rice contains two times more protein than white rice. For example, 100 g of brown rice contains 14.6 g of protein while white rice contains 7.3 g of protein in 100 g. The fat content, however, is as high as 24.8 g/100g for brown rice and 1.5 g/100g for white rice (Seki *et al.*, 2005). The germ and bran of rice contain high amount of minerals, protein and vitamins. Rice bran alone, contains about 12% crude protein, 15% fat, 7% fiber and 31.1%. Rice bran also contains 0.3 mg/g Ca, 5 mg/g magnesium (Mg), 9 mg/g phytin, 43 µg/g zinc, 12 µg/g thiamine, 1.8 µg/g riboflavin and 267 µg/g niacin. According to some researchers, eating of whole rice grain including rice bran is believed to reduce the risk of obesity and weight gain. Whole rice grain consumption was found to be indirectly proportional to body mass index (McKeown *et al.*, 2002; Slavin, 2005). Higher consumption of bran as whole, reduces weight gain compared to eating fewer whole grain foods (Liu *et al*., 2003). Higher consumption of bran as whole grain is believed to lower risk of hypertension. According to Slavin (2005), those consuming, at least, four daily servings of whole grain compared those consuming less than one-half daily serving are 23% less likely to contract hypertension. Therefore, milling off of bran and germ from brown rice to produce milled rice reduces its nutritional value (Roy *et al*., 2008).

Apart from cooking, rice can also be processed into puffed rice, rice flakes, parched rice and rice flour (Norman and Kebe, 2006). The flour contains high amount of starch and it can be processed into puddings, gel, custard powder, ice cream and alcoholic beverages. Apart from being used as food, rice has medicinal attribute. It is used in treating measles, prickly heat, small-pox and other inflammatory infections of the skin including burns and scalds (Umadevi *et al*., 2012).

After harvesting, the straw can be used as a feed for animals, fuel, mulching, composting, mushroom bed, mats, ropes, hats, raw material for paper production or for thatching roofs.

Rice bran can also be used to prepare confectionery products such as; bread, snacks, cookies and biscuits. Oil from rice bran is used for cooking, manufacturing soap and fatty acids (Umadevi *et al*., 2012).

2.2 Rice production in Ghana

Two rice species, *Oryza sativa* and *Oryza glaberrima* are grown in Ghana (Agbanyo, 2012). Overseas Development Institute (ODI) (2003) reported that rice is produced in every region of Ghana. The crop is cultivated across the main agro-ecological zones comprising the interior savannah, the high rain forest zone, the semi-deciduous rain forest and the coastal savannah. The Volta, Northern, and Upper East regions are the dominant rice producing regions in Ghana. Between 2014 and 2016, Volta region outdid Northern region as the best rice producing region in the country with an average rice production of 206, 908. 45 MT. Northern region and Upper East region placed 2nd and 3rd, respectively with average production of 177,464.50 MT and 118,250.26 respectively (MoFA, 2016) Rice is predominantly produced by peasant famers, most of them cultivating less than one hectare in size (Angelucci *et al*., 2013). Low standard seeds mixed with other varieties which affects quality of harvest is mostly used by smallholder farmers. This brings a clear contrast between quality of local and imported rice. Land preparation activities which involve land clearing, ploughing, harrowing and harvesting are predominantly carried out by men (Norman and Kebe, 2006).

Women also are engaged in the rice production value chain. They perform activities such as transplanting, manual weeding, fertilizer application and birds scaring. Women are also involved in post- harvest task such as piling, threshing, hauling, winnowing, drying, parboiling, milling, storage and marketing.

2.3 Rice consumption in Ghana

Rice, by all accounts, is an important crop in Ghanaian staple diet hence its availability is of great importance throughout the year. Per capita consumption of rice has been increasing over the last two decades. It increased from 17.5 kg during 1999-2001 to 24 kg during 2010-2011 (MoFA, 2013; Ragasa *et al*., 2014). In 2015, The per capita consumption increased further to about 32kg (MoFA, 2016). The demand for rice is expected to expand at 11.8% rate yearly in the medium term (MiDA, 2010; Ragasa *et al*., 2013). Urban areas consume 76% of total rice in Ghana (CARD, 2010). Rice is preferred in urban areas over other staples as it is easy and convenient to prepare and adapted to a wide range of dishes. Locally grown rice in Ghana is mainly consumed as food with less than 1 % processed. Rice is not used as animal feed in the country.

Local production of rice in Ghana has consistently not catch up consumption need. Local rice production in Ghana has failed to catch up with the ever-growing domestic demand, thereby resulting in increasing the gap between demand and production. To offset this deficit, Ghana has to either increase its local rice production or import rice into the country. Between 2007 and 2015 the nation's value rice imports bill rose from US$152 million in 2007 to a peak of US$1.2 billion in both 2014 and 2015 (MoFA, 2016). The over reliance on imports is a major concern to the government as it affects Ghana's foreign currency reserves and food security. To revamp local rice cultivation in Ghana, the government introduced in 2008 the National Fertilizer Subsidy Programme and in 2009 the

National Rice Development Strategy (NRDS) with the rationale of increasing domestic production by 2018.

2.4 Technology Adoption by rice farmers

The process of implementing agricultural technology depends primarily on obtaining information, and on farmers' willingness and ability to use information platforms available to them. It is important to acknowledge adoption at household level as well as the factors that affect adoption of rice production technology in Ghana. Effort to increase rice productivity over the years have not produced desired effect due to limiting factors such as: inadequate institutional support (access to credit, research and extension), inappropriate production system, inadequate basic infrastructures, ineffective post-harvest management technologies, inappropriate marketing strategies, production risk and inefficiency on the part of the farmers (Apori-Buabeng, 2009; Yiadom Boakye *et al*., 2013).

Over the years, many researchers and policy makers in Ghana have focused their attention on technology adoption impact on increasing farm productivity and income (Ragasa *et al*., 2013). According to Edward (2014), improved production technologies are resource saving or resource intensive, that enhance yield of rice production. Angelsen *et al*. (2001) explained that labour-intensive technologies increase labour input per-hectare, whereas labour saving technologies reduces labour. Therefore, a capital-intensive technology raises resource inputs per-hectare and a money-saving technology decreases them. Yield may rise or decline with resource saving technologies, but adoption is possible if it is in line with farmers' profit maximizing goal (Edward, 2014). New innovations can be labour intensive as well as capital-intensive. A key example is an improved rice variety that raises the use of inputs such as fertilizer as well as labour for other farm operations (Angelsen *et al*., 2001).

The work of Ndagi *et al*. (2016) reported that some practices like nursery establishment, land preparation, and transplanting and spacing were adopted on relatively high scale on rice production in Nigeria, because there were perceived as compatible innovations, while the medium level adopted practice was land preparation. In addition, household size, farm size, farming experience, extension contacts, training participation, distance from market and social capital significantly impacted adoption level of the production technologies. Ndagi *et al*. (2016) recommended that, production technologies adoption by lowland farmers could be sustained provided the constraints are overcome. For example, introducing farmers to money saving good irrigation schemes and soil conservation management practices.

In a study to evaluate rice cultivation technologies adoption and its impact on technical efficiency in Sagnarigu District of Ghana, Abdulai *et al*. (2018) reported that farmers' groups and accessibilty to agricultural extension service positively impacted adoption. Oweing to ready market incentive, farmers who had contracts with buyers implemented more of the rice production technologies than their counterparts who did not have contract. The authors added that, members of farmer groups also implemented more production technologies than those who did not. Likewise, household labour, use of weedicides, fertilizer and farm size positively impacted rice output.

2.4.1 Socio-economic characteristics of technology adoption

Technology plays a large role that brings about changes in many disciplines. According to Ugo Chukwu and Phillips (2017), the knowledge and use of the technology takes place over a long period of time. Empirical studies on technology adoption asserts that, the impact or intended purpose of a new technology will only be experienced untill the intended end users (e.g. individuals, firms, industries) embrace and use it. The level of the impact, however, is determined by adoption rate, following the diffusion and learning over time about the technology or innovation (Ugo Chukwu and Phillips, 2017).

Different model on technology diffusion from studies have examined factors affecting new technologies adoption and/or rejection. The model most commonly used is the Everett Rogers' model of diffusion of innovations. Rogers' model became more common and widespread as he used the concept of innovation, which he defined not only as technology but any idea, object, or practice (Ndagi *et al*., 2016). Again, Rogers (1983) expounded diffusion as the "process by which an innovation is communicated through certain channels over time among the members of the social system". Pannell *et al*. (2006) reported that a number of studies across many disciplines have identified several factors, including personal, cultural, social, and economic attributes, as well as technology characteristics that affect technology adoption. While Sunding and Zilberman

(2001) emphasized on personal characteristics such as human resource, age, or risk preferences of potential adopters, Miller and Tolley (1989) found that regulators' market intervention, could accelerate the adoption of new technologies through a price support programme for example. Several studies on adoption focus in the area of agricultural production on technology adoption as influenced by operation scale, have found extension services, social networks, specialization, education, peer group pressure, complexity, and the cost of acquiring the technology, among others, to affect technology adoption (Batz *et al*., 1999; Garforth *et al*., 2003; Sauer and Zilberman, 2010; Millar, 2010).

Feder *et al*. (1982) cited in Ndagi *et al*. (2016) classified adoption into three categories. These comprise individual, farm-level versus aggregate-level adoption, single (e.g. fertilizer) versus package (e.g. fertilizer + improved seed variety + good management practices) adoption and divisible (e.g. new crop cultivar) versus indivisible (e.g. harvester) adoption. A number of studies (Fugile and Kascak, 2001; Arellanes and Lee, 2003) examined adoption of agricultural technologies and identified common factors influencing adoption. These are farm size, land tenure security, access to credit and extension services, land and labour availability, human capital (education, gender, demographics), and farmer attitude towards risks and uncertainty. Again, Marra *et al*. (2002) highlighted the ability of improved agricultural technologies in increasing productivity, income, and overall economic growth. Ugo Chukwu and Phillips (2017) added that, the expected benefits of a new technology can only be realized when it is embraced and implemented; crucial analysis of the expected benefits and cost associated with the technology is involved in adoption decision. A greater understanding of the diffusion, adoption, and impact of enhanced technologies can guide producer groups, research institutions, and policy makers in making wise and informed decisions about allocating technology development resources (Uaiene, 2011).

2.4.2 The Adoption Process

The literature on economic decision suggests that four crucial factors influence the decision to implement a new technology or innovation. According to Chen (1996), these factors comprise the acknowledgement of competitive stance among existing technologies, knowledge of the existing alternative technology following market conditions, motivation and/or incentive to explore alternatives, and availability of resources to implement the decision.

According to Rogers (2003), cited in Ugo Chukwu and Phillips (2017) the decision for new technology to be adopted comprise five stages. These stages are knowledge (awareness); persuasion, obtaining adequate information on the characteristics, benefits, and new technology cost; decision; implementation; and confirmation. The process of adoption begins with getting knowledge about the new technology, whether through extension agents media advertisement or social networks. This is accompanied by a thorough analysis of the perceived characteristics of the technology and the potential advantages and costs of acquiring the technology (Ugo Chukwu and Phillips, 2017). The decision to either accept or reject the technology, the most critical stage, is made after analyzing the characteristics and assessing the benefits, costs, and trade-offs related to the new technology. The adoption of technology begins with the adopter interest in the new technology to practice. At this point, the technology could be continually tested to ensure it meets expectations (Briney, 2015; Ndagi *et al*., 2016). This might contribute to reinvention, the technology being modified to match individual needs. It should be acknowledge that the prospective adopter continuously seeks more information about the technology from the awareness to implementation stage therefore incurs transaction costs. After implementation and reinvention, the implementer searches for credible evidence to justify his/her adoption decision, taking into account technology attributes (objective judgement). If the implementer is pleased, he/she would objectively embrace the technology (Ugo Chukwu and Phillips, 2017).

2.5 Water management practices in irrigated rice cropping systems

The yield of rice is related to many factors which include; land preparation and levelling, irrigation, fertilization, weeding, pest and disease control**.** Rice yield of 5 to 7 tons/ha is achievable if farmers utilize optimum input management such as fertilizer, pesticide, seed, and appropriate water management in irrigated rice farming system (WARDA, 2004).

Water supply and control are very important for rice field productivity. In fields that have sufficient water, number of tillers, panicles and rice yields are greater than dry fields (Singh *et al*., 2011). Crops are produced throughout the year and yields obtained are high under adequate irrigation paddy field. Irrigated paddy fields are often 100 times more productive than dry fields, 12 times more productive than deep- water paddy fields and 5 times more productive than rainfed paddy fields (Dobermann and Fairhurst, 2000).

Limited availability of water supply in paddy field reduces dry matter production which consequently reduce rice yield and yield components due to water stress (Lu *et al*., 2000). When rice plants are subjected to water stress, photosynthetic rate and nutrients absorption are reduced (Kropff and Spitters, 1991). Tiller number, leaf surface, distribution of dry matter, grain numbers per panicle, and rice yield also reduce (Amiri *et al*., 2009). Bouman *et al*. (2007) observed that, water stress during extremely important growth stages like flowering reduce rice grain yield. Belder *et al*. (2007) observed that rice yield was not affected when water stress was within field capacity. Thus, water stress above field capacity will decrease grain yield. However, for optimum rice production, sufficient supply of good quality irrigation water is needed. Proper water management practices can be used to manage nutrient such as nitrogen and phosphorus, control diseases such as rice blast and control weed and insect pests (Dingkuhn and LeGal, 1996).

According to Amiri *et al*. (2009), grain yield does not increase when water is supplied beyond what is required by rice plant. Thus, each of rice development stage has its specific water need. The paddy field should not be submerged throughout the growth period of rice as more water is wasted. According to Dingkuhn and LeGal (1996), rice requires water during vegetative stage (from germination to panicle initiation). Rice fields can be kept moist during early vegetative growth without standing water (Dobermann and Fairhurst, 2000). Too much water during the vegetative stage hampers tillering as much as too little water leads to few tillers whereas the absence of water during this stage favours weed growth development and may lead to a significant decrease in yield (Dingkuhn and LeGal, 1996). During the reproductive stage and first half of the maturation stage, rice requires adequate amount water for optimum growth, nutrient uptake, and consequently grain yield. Rice requires very limited amount of water during last half of the maturity stage (from dough stage to maturity). During the reproductive stage, lack of adequate water supply may lead to spikelet grain sterility and consequently a reduction in grain yield. Paddy fields kept submerged beyond the dough stage will mature in a non- uniform manner and would delay harvesting (Dingkuhn and LeGal, 1996).

Proper water management is significant for nutrient management such as nitrogen. Under continuous submergences, soils become anaerobic which reduces nitrification and therefore allowing accumulation of NH_4–N which is essential for making N available in growing lowland rice (De Datta and Buresh, 1991).

Urea should be applied in a shallow water of 3-5 cm so as to increase its efficiency. Urea is converted to ammonium and eventually to nitrate, which may be lost quickly through denitrification when rice fields become saturated from excessive rainfall, irrigation or permanent flood (Dobermann and Fairhurst, 2000). N losses should be avoided immediately after fertilizer application through water runoff over bunds.

2.6 Nitrogen requirements of rice

Rice requires nitrogen in the greatest amount of any nutrient, making it the predominantly deficient nutrient in rice production. Nitrogen requirement is large at extremely important growth stages between early to mid-tillering and panicle initiation stages. Nitrogen is also needed at the reproductive and ripening stages to increase spikelets number per plant and the percentage of filled spikelets (De Datta and Patrick, 1986).

Different organs of rice plant have different nitrogen concentration at different growth stages. Among plant parts, leaf blade contains high concentration of N at panicle initiation stage and during maturity, the level of N is higher in panicles and grains. The estimated amount of N in plant tissue at tillering and panicle formation ranges from 2.9- 4.2 % N (Table 2.1) while at flowering and maturity N content ranges from 2.2- 3.0 % N and 0.6- 0.8 % N respectively (Dobermann and Fairhurst, 2000). This shows nitrogen levels in different plants parts, decline with age.

The efficiency of nitrogen absorption varies from 20 to 60% depending on the doses and modes of application (split or not), conditions (type of soil, pH, water temperature and water control), and varieties (CIRAD-GRET, 2002). Rice plants absorb ammonium and nitrate-N randomly from the soil solution. In an irrigated field, ammonium is preferable as the main N source for rice to nitrate (Wang *et al*., 2010), though nitrate-N absorption is also possible (Narteh and Sahrawat, 1999). Ammonium-N fertilizer sources are recommended because the NH_4^+ is stable under flooded soil conditions (Snyder and Slaton, 2002), and its assimilation is easy and require less energy compared to nitrate (Mehrer and Mohr, 1989).

When nitrogen supply is slightly below optimum requirement for rice growth, the first deficiency of nitrogen is seen in reduced tillering ability. Consequently, leaf area development is hampered and rate of dry matter production reduces. Inadequate N supply at later stages of growth decreases grain filling ability.

Table 2.1: Optimal ranges and critical N levels in tissue

Growth stage	Plant part	Optimal (%)	Critical level for deficiency (%)
Tillering to panicle initiation	Y leaf	2.9- 4.2	< 2.5
Flowering	flag leaf	2.2- 3.0	< 2.0
Maturity	straw	0.6- 0.8	

Source: Dobermann and Fairhurst (2000)

2.7 Dynamics of nitrogen under irrigated fields

Under flooded condition, aerobic micro-organisms present in the soil use oxygen in respiratory processes (Dobermann and Fairhurst, 2000). Anaerobic micro-organisms then multiply as oxygen become quickly exhausted, using decomposable organic material as energy source and oxidized soil components as electron acceptors**.** These compounds; nitrates, manganic oxides, ferric oxides, and hydroxides, sulphates, CO_2 and sometimes phosphates are reduced, following a thermodynamically determined sequence (Ponnamperuma, 1965).

Chemically, as oxygen in the soil system is depleted, flooded rice soils are differentiated into layers; a flooded zone, an oxidized surface layer zone and an underlying reduced zone due to continuous flooding of fields during rice growth (Reddy *et al*., 1984).

These distinct soil layers as a result of flooding contribute to N supply; flooded zone layer varies in depth between 1 and 15 cm which is dominated by bacteria and algae that assist in biological N fixation. Beneath the flooded zone is a thin superficial oxidized layer (0.1-1 cm) which is followed by a thick, reduced soil layer (10-20 cm). A narrow-oxidized rhizosphere layer (0.1-0.5 cm) lies within the reduced soil (Dobermann and Fairhurst, 2000). N hydrolysis and nitrification occur in the oxidized zone, when urea or ammonium sulphate is broadcasted into the floodwater (Mosier *et al*., 1990). As a result of hydrolysis, ammonium ions spread into the oxidized soil and are taken up by the rice plant either directly or after nitrification, or become immobilized into organic- N pool of the soil. NO_3^--N is either take up by rice root or leached into the reduced soil layer after nitrification of NH_4^+-N in the oxidized layer, where it is denitrified and eventually lost as NH_3 and N_2 gas through volatilization and denitrification respectively (Dobermann and Fairhurst, 2000).

Incorporation of fertilizer N into soil as basal N or topdressed into flooded water determines their transformation. Ammonium is fixed on soil colloids, immobilized for some time by soil mico-organisms or adsorb to organic matter following ammonium fertilizers application into the reduced soil layer before or after flooding. If urea is topdressed after flooding, urea hydrolysis occurs quickly and become easily lost through NH_3 volatilization due to floodwater pH changes as a result of biological activity (Dobermann and Fairhurst, 2000).

2.7.1 Urea hydrolysis

As urea is applied to the soil, it reacts chemically with water and the enzyme, urease catalyzes the process to produce ammonium carbonate, an unstable compound that can rapidly decompose to NH_3 gas. The common urea hydrolysis reaction is as follows (Tisdale *et al.*, 1993):

$$CO(NH_2)_2 + 2H_2O \rightarrow (NH_4)_2CO_3$$

$(NH_4)_2CO_3$ is not stable and easily decomposes into water, carbon dioxide and ammonia through the following reaction:

$$(NH_4)_2CO_3 \rightarrow H_2O + CO_{2\ (gas)} + 2NH_{3(gas)}$$

This eventually leads to the volatilisation of urea because the hydrolysis reaction causes the pH around the region of the urea to rise, and ammonia may be lost to the atmosphere by volatilization.

2.7.2 Factors influencing urea hydrolysis

Soil organic matter content, soil water content and temperature are among many factors that influence urea hydrolysis. At higher temperatures, rate of urea hydrolysis is high. Urea hydrolysis rates increase with increasing levels of soil organic matter and crop residue. This is because the enzyme urease is produced by microorganisms that are more active with the availability of soil organic material.

Urease enzyme activity is influenced by several factors in the soil. According to Singh and Yadev, (1981), Khakurai and Alva, (1995), and Yadev *et al*. (1987), based on application rate, soil characteristics, and environmental factors, the process of hydrolysis last for 1 to 14 days.

The nature of urease enzyme activity has been difficult to explain in different soils using soil physical condition, although low urease activity has been correlated with coarse texture and low organic C content (Zantua *et al*., 1977; Singh and Yadev, 1981; Yadev *et al*., 1987; Wali *et al.*, 2003). Pettit *et al*. (1976) found pH between 6 and 8 in a silt loam soil to be the optimum pH for urease activity, although no relationship has been found between pH and activity of urease in different soil types. Urease activity increase with age of plant and level of decomposition (Hasan, 2000), the addition of organic matter in the form of N, temperature rise to 35°C, and water potential rise to field capacity (Kumar and Wagenet, 1984; Yadev *et al*., 1987). Qin *et al*. (2010) found soil urease activity to be high under reduced tillage and no-till agriculture, compared to traditional moldboard ploughing. Yadev *et al*. (1987) found a positive correlation between soil urease and clay content, although this may be linked to higher organic matter content or cation exchange capacity associated with the clay. Although there is difference of opinions in the studies about optimum pH, temperature, and water content of the soil for activity of urease (Gould *et al*., 1986; Hasan, 2000), basically, warm, moist soils with near-neutral pH enhance high activity of urease enzyme.

2.8 Nitrogen loss in irrigated rice systems

Low N recovery from fertilizer by rice is largely associated to losses of nitrogen through ammonia volatilization, denitrification and nitrate leaching (Cameron, *et al*., 2013).

2.8.1 Ammonia loss

In flooded or saturated soils, ammonia volatilization has been acknowledged as a major pathway by which N fertilizer is lost from rice fields. Ammonia volatilization account for about 50% or more of losses of applied urea-N (Bouman *et al*., 2007). Ammonia losses are reported to be about 29% of applied N from urea broadcast on pastures (Eckard *et al*., 2003). Ammonia volatilization losses are significant for both agricultural and non-agricultural ecosystems because they deprive plants of available N (Asman *et al*., 1994). There are several factors that influence nitrogen volatilization. These are physical, chemical and biological processes in soil (Hutchinson *et al*., 1972).

The rate of volatilization of NH_3 is dependent on urea hydrolysis rate, weather conditions following application, and various soil characteristics (Jones *et al*., 2007). Within a week of application to flooded soils, urea is quickly hydrolyzed (Fillery *et al*., 1984), and a high level of ammoniacal N produced from hydrolyzed urea along with high pH, temperature and floodwater enhance loss of added fertilizer N by NH_3 volatilization (Vlek and Stumpe, 1978).

The amount of NH_3 loss from flooded soils is directly related to the water content at the interface with atmosphere of aqueous NH_3 or partial pressure of ammonia (ρNH_3). Water pH and temperature directly influence aqueous NH_3 as a percentage of total ammoniacal N. Levels of aqueous NH_3 at pH below 7.5 is negligible, but are increasing rising from pH 7.5 to 10. Roughly 50% of the ammoniacal N in water is available as NH_3 at pH 9.2 (Vlek and Craswell, 1981). Aqueous NH_3 increases directly with temperature at a constant ammoniacal N concentration and pH, which result in almost four times rise with a temperature change from 10 to 40°C (Vlek and Craswell, 1981).This is one reason why it is recommended to apply urea during periods with cool temperatures so as to reduce volatilization, especially on high pH soils. However,water pH is more a factor influencing NH_3 loss than temperature (Jayaweera and Mikkelsen, 1990).

Ammonium ions fixation by clay minerals is another way of building the nitrogen pool in soil to optimize N crop recovery and decrease losses into the environment (Liu *et al*., 2008) through ammonia volatilization. Ammonium ions fixed into clay minerals are protected against nitrification (Guo *et al*., 1986) which eventually leads to N losses. Ammonium fixation is highest in 2:1 clay minerals such as illite, vermiculite and montmorillonite (Neider *et al*., 1996). Fixation varies in sizes depending on the nature and amount of clay mineral. Neider *et al*. (1996) reported that illite and vermiculite greater at fixing ammonium ions than montmorillonite.

2.8.2 Denitrification

Denitrification is a major phenomenon by which nitrogen is lost from waterlogged soils. Denitrification is a special characteristic of flooded soils

(Reddy and Patrick, 1976) where nitrate produced from nitrification in aerobic zone rapidly move into anaerobic soil layer where it used as electron acceptor and reduced to N_2O and N_2. A gradient of NO_3^- concentration across aerobic-anaerobic interface which is caused by high demand for electron acceptors and adequate supply of electron donors (organic C) in anaerobic zones favors influx of NO_3^- from aerobic to anaerobic zones (Reddy *et al.*, 1976). Denitrification is caused by heterotrophic micro-organisms and its rate is controlled by NO_3^- levels and available C that are used as source of energy.

Factors such as pH, temperature, organic matter, wet/dry cycles, and fertilizer management also influence denitrification (Dobermann and Fairhust, 2000). According to Sahu and Samant (2006), high temperature, high organic matter, and moisture regime enhance denitrification loss.

2.9. Mitigation of N losses in rice field

Deep placement of USG is among the best N management practices that reduces N losses through denitrification. In flooded soil conditions, deep placed USG remain in the root zone as ammonium ions which is less susceptible to nitrification (Savant and De Datta, 1982). The ammonium formed as a product of urea hydrolysis tend to accumulate at the placement site, though its fixation with clay minerals may increase with time, a high concentration gradient of ammonium is created at placement site. The transport of ammonium from the placement site is mainly through diffusion and this manner of N transformation reduces N losses

(Savant and De Datta, 1979). This can ensure a continuous N release to rice plants throughout the cropping season.

2.10 Urea deep placement as N management strategy in irrigated rice fields

An effective strategy of reducing volatilization losses is the deep placement of the fertilizer into the anaerobic soil zone (De Datta, 1981). USG is deep placed into a reduced layer at a depth of 7- 10 cm. The use of USG has one great advantage because the briquettes are used only once throughout the growing season unlike traditional urea application where 2-3 split applications are done. The total amount of urea needed throughout the season can be reduced, thus reducing production cost of rice. Deep placement of USG could synchronize release of N with plant requirements and provide in a single dose sufficient N to meet plants' requirements while keeping low concentrations of soil mineral N for the whole cropping season (De Datta and Patrick, 1986). The movement of ammonium is slow at the placement site because it is mainly a diffusion process caused by ion-exchange (Gaudin, 1987). Using these fertilizers has remarkably reduced the whole loss of N fertilizer (Choudhury *et al*., 1997). The rationale behind the use of these fertilizers is to coincide the quantity of N released with for growing plants N requirement, particularly at the tillering and heading stages, and hence reduce losses of N. This placement method pushes urea into the anaerobic soil layer, hence minimizing denitrification losses; reducing N diffusion into the floodwater and hence reduced NH_3 volatilization and N losses through runoff; and improving fertilizer - root contact and decreasing weed competition (Cai *et al*., 2002). Craswell and Vlek (1979) reported that the use of USG significantly increased rice yield by 42% over broadcast prilled urea (PU). Depending on climate and N dose applied, UDP can assist achieving up to 65% saving of urea fertilizer with a mean of 33% and can help to increase rice yields up to 50% over that of the same quantity N applied in split as PU (Savant and Stangel, 1990).

2.11 Comparative assessment of UDP and other N management on irrigated rice yield and yield components

Adopting the appropriate application method of nitrogen fertilizer to rice in order to optimize yield is becoming important because nitrogen plays important role in rice crop production**.** Due to the huge cost of nitrogenous fertilizer, it is very important for farmers to get the optimum economic benefit out of this huge recurring expenditure.

In an experiment to determine the impact of fertilizer deep placement with USG on NUE of irrigated rice in Sourou Valley (Burkina Faso), Bandaogo *et al*. (2015) observed that, USG deep placement produced higher panicle number, tiller numbers, rice yield and straw weight than PU and control in both dry and wet season.

In an experiment to assess the impact of nitrogen fertilizer deep placement of on growth, yield and nitrogen uptake of aerobic rice, Xiang *et al*. (2013) reported that, UDP significantly increased rice yield, above ground total biomass, harvest index, panicles m^{-1} and filled grain percentage compared with the surface placement of urea. According to the authors, USG deep placement increased grain yield by 48.9% compared with the surface placement of urea. Craswell and Vlek (1979) observed that the use of USG impacted rice yield by 42% over broadcast PU . It is also confirmed by Savant and Stangel (1990) that the use of USG deep placement can boost grain yields up to 50% over that of the same amount of split-applied N as PU.

Naznin *et al*. (2013) reported that grain yield, straw yield and NUE were impacted by N fertilizer placement methods. Deep placement of N fertilizers (USG and NPK briquette) showed better yield and NUE of rice compared to traditional application of PU. The largest rice yield of 3.93 t ha^{-1} was obtained with 104 kg N ha^{-1} of USG which was not statistically different from the use of 120 kg N ha^{-1} of PU, 78 kg N ha^{-1} of USG and 78 kg N ha^{-1} of NPK briquette but, significantly larger than the control 2.12 t ha^{-1} from the control plot. This surmise could be associated to slow N release from deep placed fertilizers (USG and NPK briquette) throughout the rice growth period.

Ahmed *et al*. (2002) conducted a field trial to study the impact of point placement of USG and PU as a source of N in transplanted Aman rice. The study revealed deep USG placement was more effective than PU at all different level of nitrogen in producing all yield parameters and in turn grain and straw yield. Deep placement of USG produced highest grain yield which was significantly superior to that obtained from any other level and source of N. In a field experiment to the determine the impact of deep placement of USG on Aman rice. Islam Roy and Black (1998) reported that plots treated with USG produced higher grain yields than the PU plots while applying 30-40% less urea in the form of USG.

In a study to assess the impact of deep placement USG or PU on two cultivars (Jaya and Govind) of rice, Lal *et al*. (1983) reported that with random transplanting, deep placement of USG increased yield of cv. Jaya and Govind by 0.4 and 1.1 t ha^{-1} respectively over yields with broadcast application of PU. Hasan (2007) found that different of level of USG significantly influences every yield components except thousand grain weight. In his experiment, the highest grain (5.20 t ha^{-1}) and straw yields (7.45 t ha^{-1}) were obtained from fields applied with USG at 3 pellets/4 stand or 90 kg N ha^{-1} as USG.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study site

The study was carried out at the Tono irrigation scheme located at the South-West of Navrongo in the Upper East region of Ghana during the January-April, 2018 dry season. The irrigation scheme lies on latitude 10° 45' N and longitude 1° 10' W and covers a total area of 3,860 ha with a potential irrigable area of 2,680 ha of which 2,490 ha has been developed. The irrigable area is divided into the following two zones; upland and lowland. The common soil texture is clay loam in the lowland irrigable area and sandy loam in the upland area. The scheme has a reservoir with a highest surface area of 1860 ha and a highest storage volume of 93 Mm^3 to provide 37 Mm^3 of water for irrigation. The irrigation system is based on gravity flow through three canal systems: main canal, lateral and sub-lateral. The main canal comprises right and left bank canal with total length of 42 km and a network of lateral and the sub-lateral of about 210 km long (Asare 2000; Salifu, 1998).

The scheme is divided into 24 zones. The layout of the zones are as follows; zone A, B, C, D, E, F, H, I, J, G, K, L, M, N, O, Q, S, U, V, X, P, R, T, U and W (Figure 3.1). There are eight beneficiary villages living and farming within the scheme area, namely Bonia, Gaani, Korania, Wuru, Yigania, Yigwania, Biu and Chuchuliga. The major crops cultivated are rice (*Oryza sativa*), tomatoes (*Solanum lycopersicum*), and onion (*Allium cepa*) while the minor crops are cowpea (*Vigna unguiculata*), okra (*Hibiscus esculantus*) and roselle (*Hibiscus sabdariffa*).

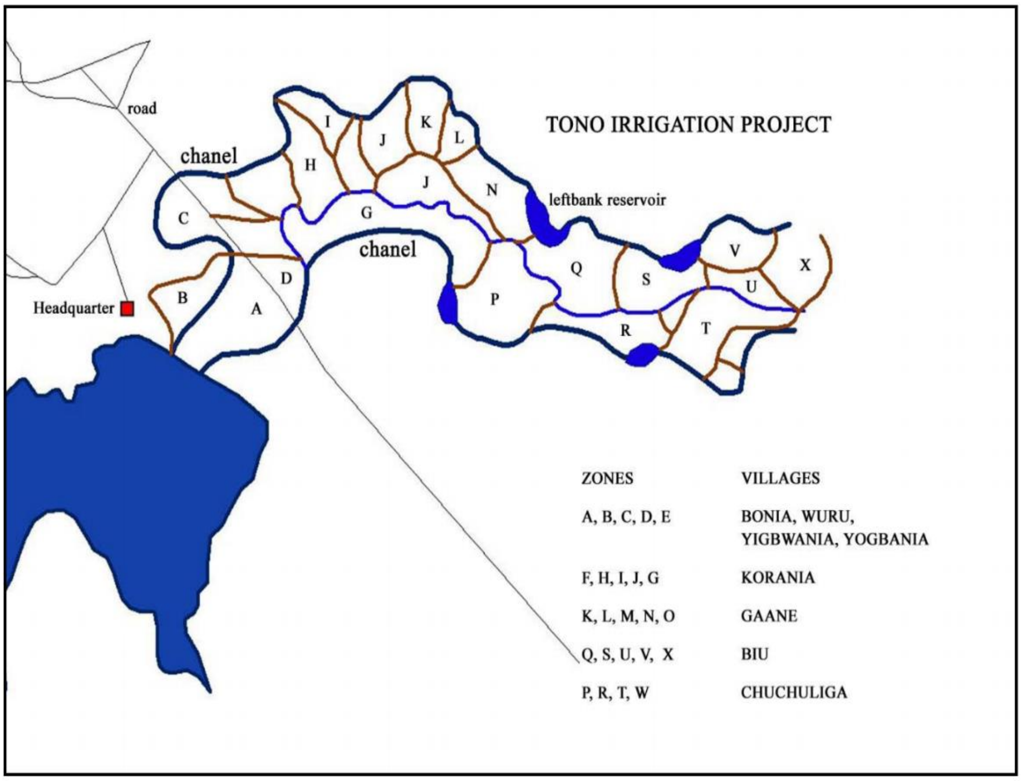

Figure 3.1: Map of the Tono Irrigation Project

3.1.1 Climate

Harmattan and monsoon are the two air masses that influence the climate of the experimental area. The harmattan brings dry air and dust from the Sahara Desert and the second monsoon brings humid air from the Atlantic Ocean. The harmattan is experienced between November and April and temperature during this period ranges between 42^{o}C during the day and 18^{o}C in the night. The monsoon wind is felt between May and October. This brings mean annual rainfall in the area of 950 mm with a monomodal distribution which normally begins in May, reaches a peak in August, then drop drastically in October. Thereafter, a long dry season runs from November to the end of April.

3.1.2 Vegetation

The Tono irrigation scheme lies within the Guinea Savannah woodlands ecological zone of Ghana and is characterized by sparse trees and tall grasses. The common economic tree *is Vitellaria paradoxa* (Shea butter) while Teak a foreign tree, occurs scattered throughout the area. Other important trees include, *Parkia biglobosa* (dawadawa tree), *Adansonia digitata* (baobab tree) occur in association with few medium and tall grasses including *Pennisetum pedisellatum*, *Rottboelia exaltata* and *cochinchinensis* and *Hyparrhenia rufa* and *hirta*.

3.2 Soils of the study area

The soils in the scheme are classified as ferric luvisols (FAO/UNESCO,2003) and alfisols (USDA soil taxonomy). These soils are red to reddish dark brown, porous, well drained, near neutral and moderately acidic and interspersed with black patches or dark-grey clay soils and are suitable for the cultivation of cereals, legumes and vegetables.

3.3 Field experimental protocol

The study is divided into two parts: (1) an agronomic evaluation of the UDP technology, and (2) detailed socioeconomic survey. The study involved two groups of farmers in 3 zones (H, I, and J) within the Tono irrigation scheme

(Figure 3.1). One group consisted of farmer volunteers who have adopted the technology. This group is henceforth referred to as UDP farmers. The second group is a group of farmers who had plots within the perimeter but did not adopt the UDP technology. These farmers are henceforth referred to as the non-UDP group. Both group of farmers had received training and extension service on UDP technology from Agricultural Technology Transfer (ATT) project and staffs of Irrigation Company of Upper Region of Ghana (ICOUR). The rice variety planted by both farmer groups (UDP and Non-UDP farmers) was AGRA rice.

Cultural practices of UDP system

1. Nursing rice seedlings
2. Transplanting of seedlings in rows at least 3 weeks after nursing
3. Placement of urea supergranules at center of four rice plants ten days after seedlings transplanting (Figure 3.2).

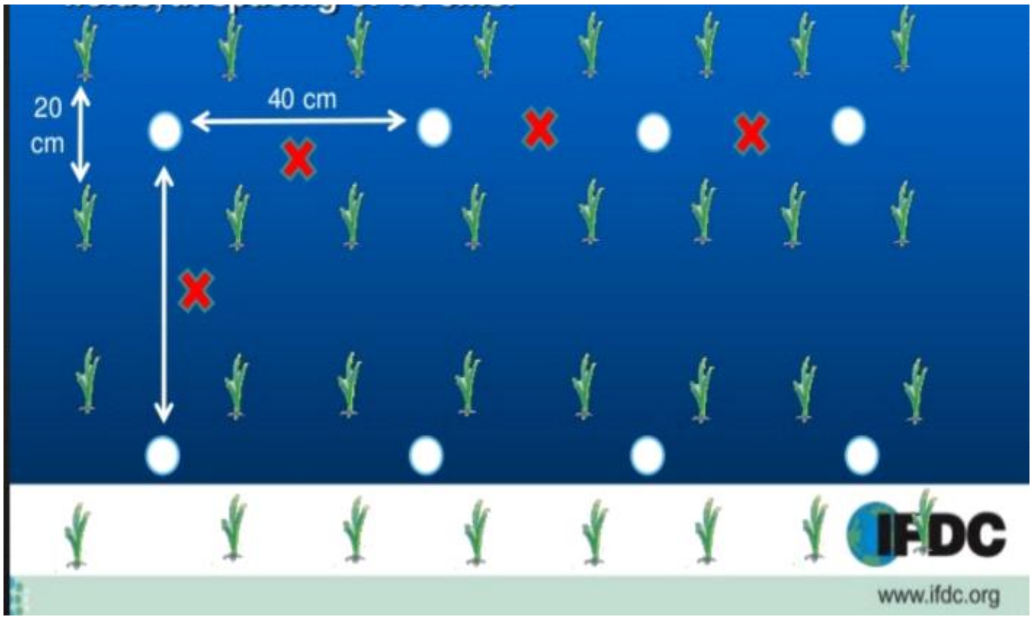

Figure 3.2: Urea supergranules and placement (Source: IFDC, 2014)

Cultural practices of Non-UDP system

1. Nursing rice seedlings
2. Transplanting of seedlings at least 3 weeks after nursing in a nonstructural pattern (referred to as “rasta” by local farmers).
3. Application of basal fertilizer three days after transplanting
4. Top dressing (by broadcasting) with a combination of NPK fertilizers and urea/ sulphate of ammonia 2 to 3 times before harvesting

3.4 Experimental design and treatments

Five UDP and five non-UDP fields were randomly selected in each zone for agronomic evaluation (Figures 3.3, 3.4 and 3.5). A list of volunteer farmers was made for each zone and grouped into UDP and non-UDP farmers. The 2rd, 4th, 6th, 8th and 10th farmer on the list (for UDP and non-UDP) was selected and his/her field identified for field experimentation. The field experiment was laid out in a Randomized Complete Block Design with number of zones treated as blocks while the UDP and non-UDP are treated as treatments in the subsequent statistical analysis.

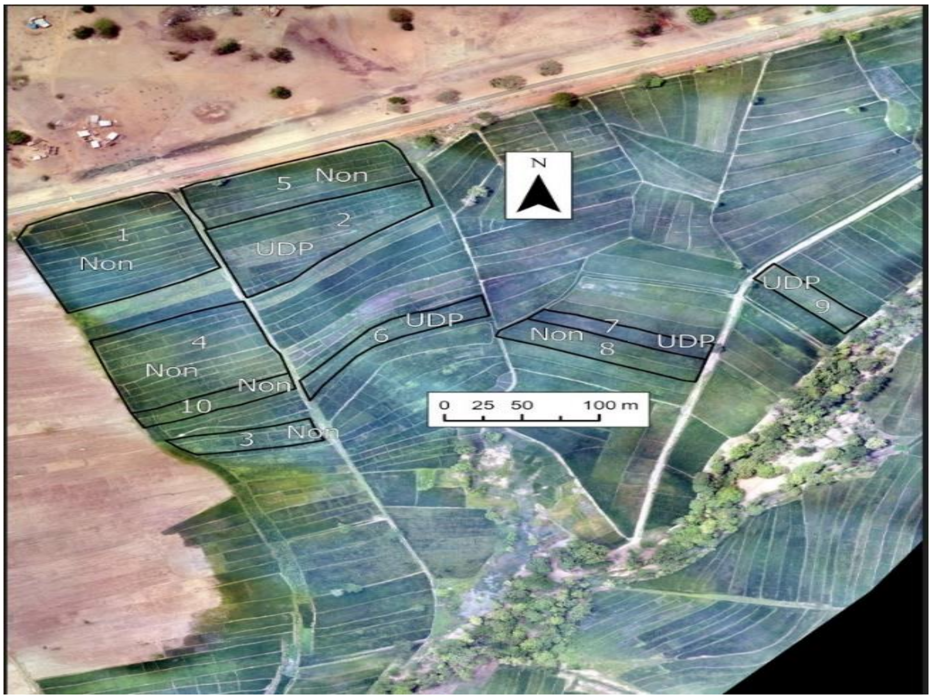

Figure 3.3: Lay out of experimental plots in zone H

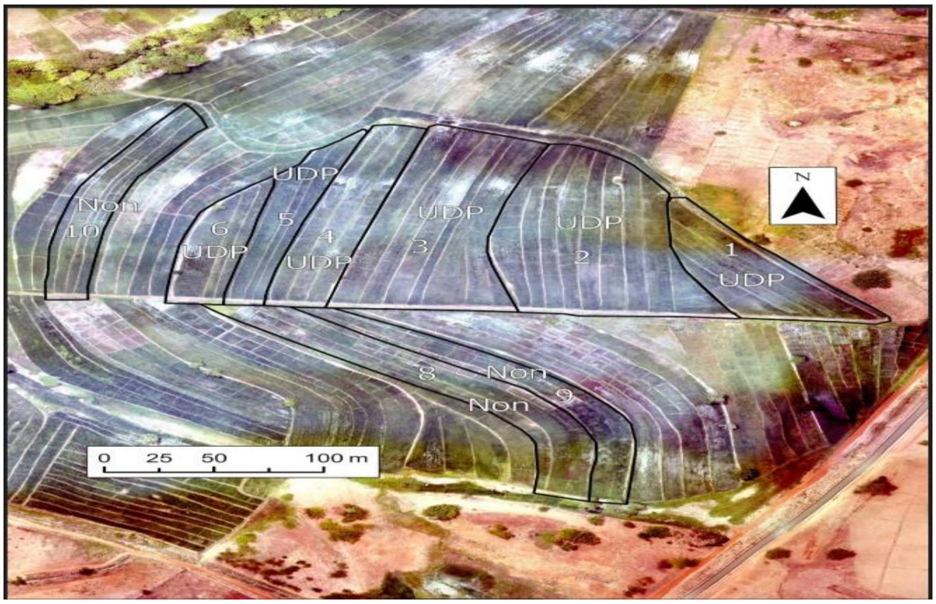

Figure 3.4: Lay out of experimental plots in zone I

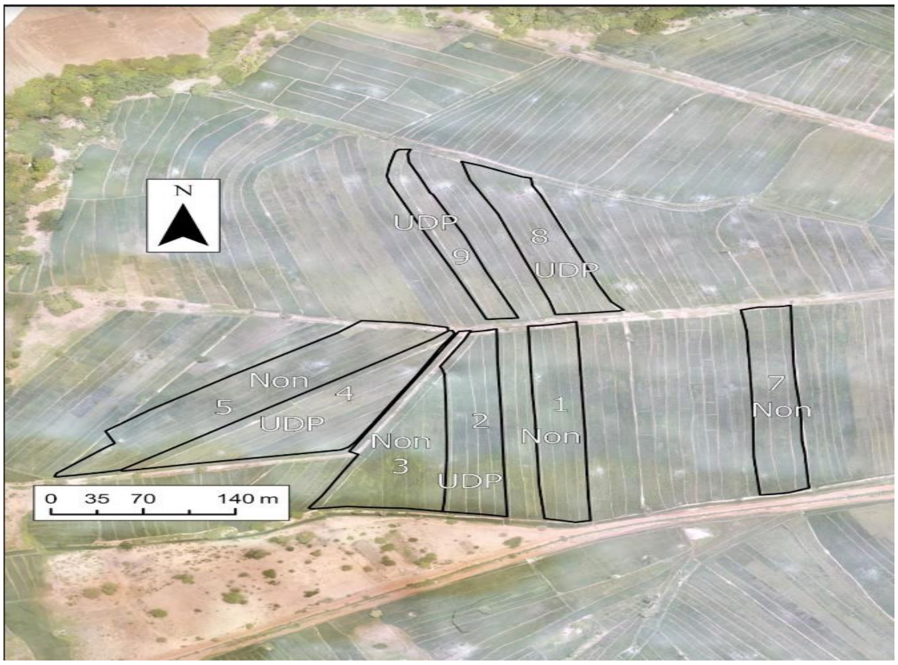

Figure 3.5: Lay out of experimental plots in zone J

3.5 Data collection

3.5.1 Survey

The socioeconomic component involved administering of questionnaires to willing collaborating farmers from the three selected zones to learn about farmer perceptions on and management strategies with respect to UDP and any other N management practices. The survey collected information on farmer profiles such as gender, and educational background, landownership, labour needs and rice production strategies including, irrigation, water management, pest and weed control as well as their off-season activities. Copies of questionnaires are attached as Appendix 2.

3.5.2 Agronomic evaluation of UDP and non-UDP fields

3.5.2.1 Soils sampling and analyses

Disturbed soil samples for laboratory analysis were taken at a depth of 0 – 25 cm from 2 m x 2 m plots from which rice grain yield data were also collected. The soil samples were air dried and sieved to pass a 2-mm sieve. Particle size analysis on the 2 mm sieved disturbed soil samples was determined in the soil characterization laboratory of the Agronomy Department of Iowa State University. All chemical analyses were done at the Midwest Laboratories, Omaha, NE

Disturbed soil samples for laboratory analysis were taken at a depth of 0 – 25 cm from 2 m x 2 m plots from which rice grain yield data were also collected. The soil samples were air dried and sieved to pass a 2-mm sieve.

3.5.2.1.1 Particle size distribution

This was determined using the pipette method (Walter *et al*., 1978).

3.5.2.1.2 Soil pH

Soil pH was measured using an Orion pH meter in a soil to water ratio of 1:1 (Thermo Scientific, 2015; Peters *et al*., 2012).

3.5.2.1.3 Organic matter and total nitrogen

These were determined by dry combustion using a Leco Truspec CN analyser. (Combs and Nathan, 1998).

3.5.2.1.4 Soil phosphorous (P)

This was extracted in a 0.025 normal HCl and 0.03 normal NH_4F (Bray-1 extractant) solution. Phosphorus concentration was determined with an ICP-AES (Spectro Ciros CCRD). (Frank *et al*., 1998).

3.5.2.1.5 Cation Exchange Capacity and Exchangeable cations (Ca, Mg, K)

Exchangeable bases were extracted with ammonium acetate (NH_4OAc) (pH 7.0) solution. Concentrations of cations were determined with an ICP-AES (Warncke and Brown, 1998). Cation exchange capacity (CEC) was computed as the sum of exchangeable cations.

3.5.2.2 Measurement of plant growth, yield and yield parameters

Five 50 cm x 50 cm quadrats (labeled A, B, C, D and E) were randomly sited in each farmers field and phenological data (including plant number, tiller numbers and productive tiller numbers and grains per panicle) were collected from these quadrats and aggregated for each farmer throughout the growing season.

3.5.2.2.1 Growth parameters

Plant stand were counted at transplanting, active tillering and heading stage of rice plant development. Tiller numbers and productive tiller numbers were counted at active tillering and at heading stages, respectively. Grains per panicle from five randomly selected plants were counted and recorded.

3.5.2.2.2 Grain yield

Grain yield data were collected after harvesting three 2 m x 2 m quadrats from each farmers field. Moisture from the grains was determined using grain moisture meter. The grain yield (kg/ha) was determined using the following formula;

$$\text{Grain yield (kg/ha)} = \frac{(\text{Grain yield (kg/net plot m)})*(10000\ \text{m/net plot m})*(100-\ \text{measured grain mc\%})}{(100 - 14\%\ \text{standard grain mc})}$$

Where:

mc= moisture content

3.5.2.2.3 1000 grain weight

One thousand (1000) grains from each farmers yield were counted using digital seed counting machine and weighed using an electronic scale.

3.5.2.2.4 Time lapse camera

Time lapse cameras were installed in zone H, one each in non-UDP and UDP fields to capture videos every five minutes during the growing season. Data collected was used to develop a 2-minute video that shows the physiological development of the rice crop in non-UDP and UDP fields over the growing season. The video will be used as an extension tool to validate the efficiency of UDP technology over conventional broadcasting of urea fertilizers. Link to watch the video is attached as Appendix 1.

Figure 3.6: Installing time lapse camera in zone H of the Tono Irrigation Scheme

3.6 Statistical Analysis

Yield and yield components data were subjected to analysis of variance using Statistix 10 package to determine the significance of the effects of N management practices (UDP and non-UDP) on yield components and grain yield. Least Significant Difference (LSD) was used to compare treatment means at 0.05 probability. Excel software was used to do graphical presentations. Relationships among grain yield, yield parameters and transplanting dates were established using Linear regression analysis.

Survey data were analyzed using STATA version 13.1. Descriptive statistics were used to obtain percentage and frequencies to describe the socio-economic characteristics of farmers. The treatment effect model, an approach to measure adoption and its impact on output of farmers was employed in this study.

The Analytical framework - Treatment Effect Model

The treatment effect model is one form of Hackman two stages procedure for correcting selection bias. The main distinguishing feature of the treatment effect model is that, the adoption (UDP technology in this case) is added to a substantive equation to measure the impact on output (Maddala, 1983). The main advantage of this model is the additional regressor that is added to the output equation which comes from the adoption equation.

Consider an equation below

$Y = Xi + \delta Ai + \varepsilon i$……………………………………………………………...1

Where Y is the yield (output) variable, X; is a set of factors, the independent variable which explains the factors which determines the output model such as gender, distance to the scheme, age, education, farming experience, off- farm income, farm size and urea briquette that influence rice output, A*i* is a dummy variable which represents the adoption of UDP. δ is the coefficient of the adoption variable "A*i*". Maddala (1983) observed that estimating equation 1 with Ordinary Least Square (OLS) will not measure the true effects of the variable on output. In other words, although could be specified correctly, δ may not measure the true value of A*i*. Also, Maddala (1983) explained that we will overestimate the parameter δ, if we estimate the equation 1 by OLS. Greene (2002) suggested we predict selected values of A*i* and use it as an additional aggressor in the second stage:

$Ai = \gamma Zi + u_2$…………………………………………………………………………………..2

A*i* = 1 if A*i* > 0, or 0 otherwise

Since there is correlation between εi and μ_2, if we estimate the adoption equation without first estimating the treatment equation, the estimates of β would be bias, since the adoption variable is endogenous which means it is also determined by other socio-economic factors. Then the expected values of adopters (UDP farmers) will be given as

$$E\{Xi|Ci = 1\} = Zi\beta + \delta\ E\{u2i\ |Ci = 1)$$

$$Zi\beta + \delta + \rho\sigma\lambda i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where

$$\lambda i = \frac{ø(-Zi\gamma)}{1-\Phi(-Zi\gamma)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

The lambda (λ) is known as the Inverse Mill Ratio (IMR)

Equation 4 implies that when we estimate equation 2 without the IMR, the coefficients β and δ will be biased

When output of both adopting farmers and non-adopting farmers are considered then equation (1) takes the form;

$$Y = \beta(\Phi iXi) + \ \delta\ (\Phi iCi) + \sigma\phi + e_{2i}$$

Where

$\Phi i = \Phi\ (Zi\ \gamma)$

Emperical Model specification

The theoretical models above then give rise to the following empirical models;

Adoption=δ_o+δ_1*Gender*+δ_2*Distancetoscheme*+δ_3*Age*+δ_4*Education*+δ_5*Training*+ δ_6*Farming experience*+ δ_7*off-farm income*+ δ_8*farm size*+ u_2 (Adoption Model)

Output of rice model= β_0+ β_1*Gender* + β_2*Distancetoscheme*+ β_3*Age*+ β_4*Education*+ β_5*Farmingexperience*+β_6*Off-farmincome*+β_7*Farmsize* + β_8*Urea briquettes(UDP)*+ β_9*thinning out* + β_{10} *seedling nursing* + u_1

CHAPTER FOUR

RESULTS

4.1 Socio-Economic characteristics of farmers in the irrigation scheme

4.1.1 Nearness of farmers residence to the study site

Table 4.1 show the nearness of farmers residence to the Tono irrigation scheme. Majority of the farmers across the three zones (H, I and J) live in the villages close to the scheme. 74% of UDP farmers across the three zones live in communities that are less than 1.6 km from Tono irrigation scheme whereas 26% live in communities that are between 1.6 and 6.4 km away from the Tono irrigation scheme. For non-UDP farmers, 69% live very close to the scheme, less than 1.6 km away, while 31% live between 1.6 and 6.4 km away from the scheme. No farmer lives more than 6.4 km away from the irrigation scheme.

Table 4.1: Farmers nearness to the irrigation scheme

Variable	UDP	Percentage	Non-UDP	Percentage
Less than 1.6 km	14	74%	33	69%
Between 1.6 to 6.4 km	5	26%	15	31%
More than 6.4 km	0	0.00%	0	0.00%

4.1.2 Gender structure of respondents

Figure 4.1 shows that rice cultivation at the study site is mainly dominated by male farmers, who make up 89%. Female farmers only make up 11% of the farmers. The ratio of male to female farmers appear similar irrespective of urea management practice.

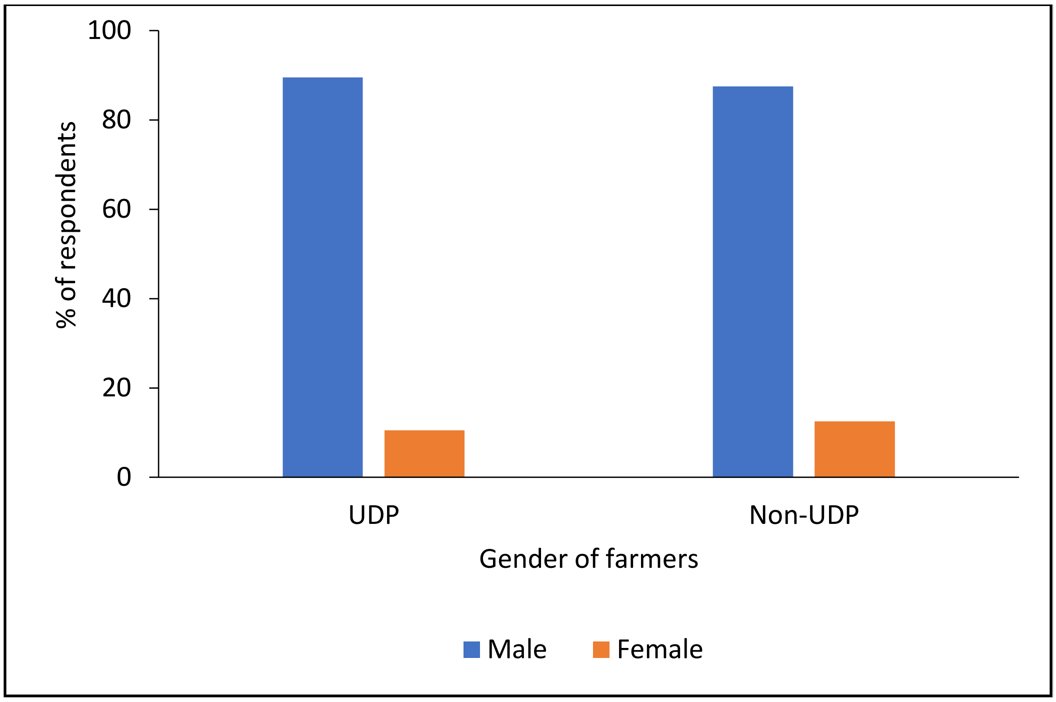

Figure 4.1: Gender structure of respondents

4.1.3 Age distribution of farmers

Majority (95%) are within the economically active/working age group (18-55years) (Table 4.2). Few of the farmers in the selected zones belong to the aged group (more than 65 years) representing about 5%. No individual was recorded between the ages of 65 and 74 years. The modal age group of both UDP farmers and non-UDP farmers is 34-44. The mean age of UDP farmers and non-UDP farmers is 45 years and 40 years respectively.

Table 4.2: Age distribution of farmers

Age (years)	UDP	Non-UDP	Total percentage
18-24	3	4	12.06
25-34	0	15	15.63
35-44	7	16	35.09
45-54	4	6	16.78
55-64	4	5	15.74
65-74	0	0	0.00
>74	1	2	4.72

4.1.4 Education level of farmers

Majority of the farmers irrespective of their urea management practice had some form of formal education (from basic to tertiary education). More of UDP farmers (79%) have at least one form of basic education compared to non-UDP farmers (64%). Thirty five percent of non-UDP farmers have no form of education. Farmers who practiced UDP have attained university education as the dominant form of education (Figure 4.2).

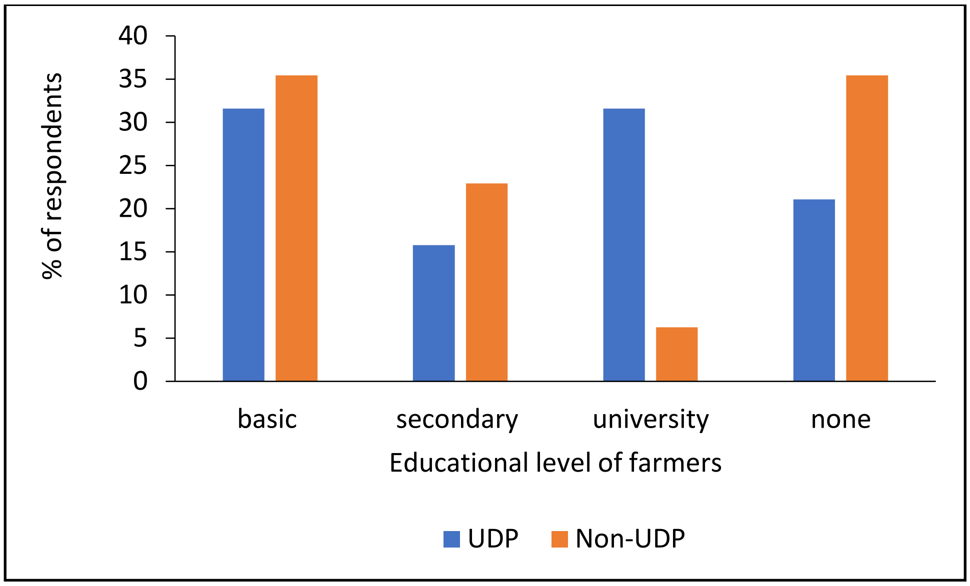

Figure 4.2: Educational level of farmers

4.1.5 ATT training of farmers on UDP technology

Figure 4.3 shows the accessibility of farmers to training from ATT project and other extension services on UDP technology and management system. UDP farmers had more access (100%) to ATT trainings and other extension services than non-UDP (73%) at the Tono irrigation scheme.

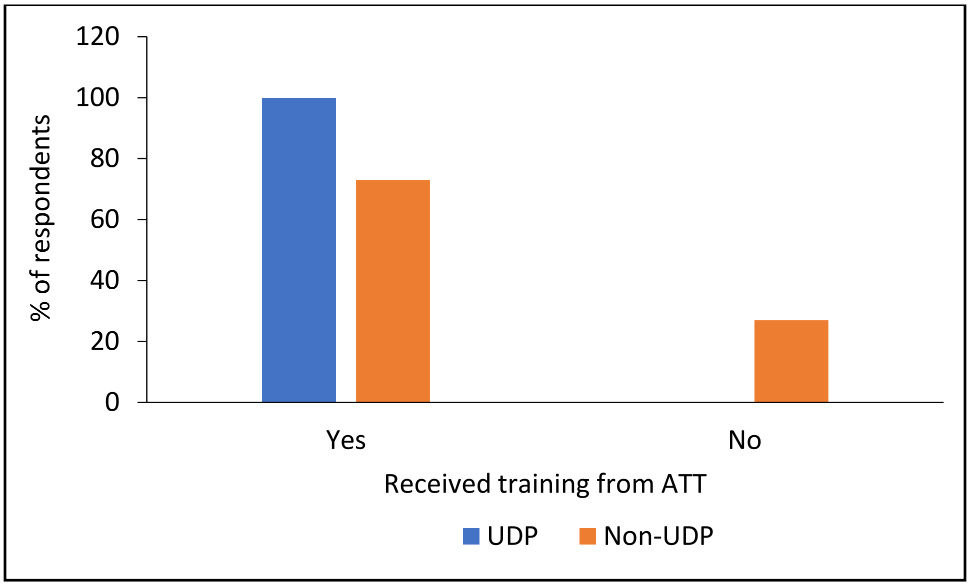

Figure 4.3: ATT training of farmers on UDP technology

4.1.6 Farming experience of respondents

Farming experience in this context is used to show the years a farmer has been farming. Figure 4.4 shows the number of years the respondents have been farming. As presented in the figure, majority of the farmers in the study area had over 10 years farming experience, with a minimum of 2 years and a maximum of over 30 years. The modal years of farming experience range for UDP farmers and non-UDP farmers are 20-30 years and 10-20 years, respectively. The mean years of experience for UDP farmers is 15 years while that of their non-UDP counterpart is 13 years. This shows that those who practice UDP technology are experienced farmers.

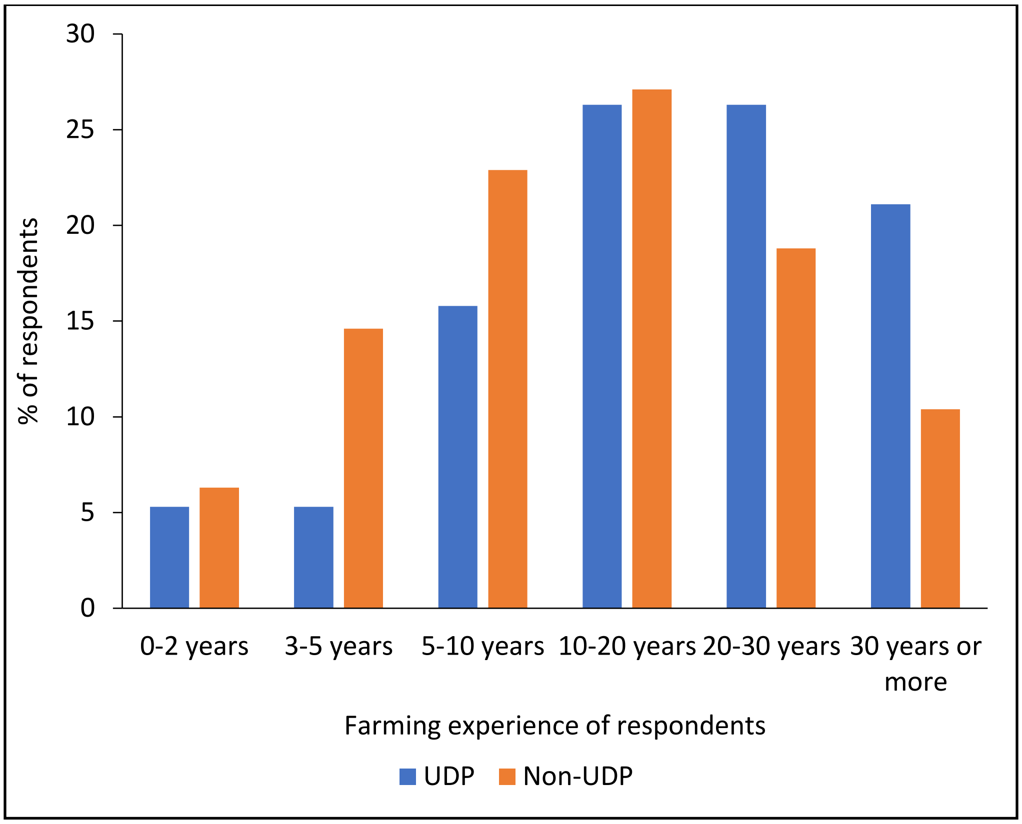

Figure 4.4: Farming experience of respondents

4.1.7 Land ownership among farmers

Figure 4.5 presents the structure of land ownership among UDP and non-UDP farmers. About 42% and 33% of UDP farmer and non-UDP farmers respectively own their farmlands. About 43% and 33% of UDP farmer and non-UDP farmers respectively, acquired their farmland through leasing. Very few of the farmlands in the scheme were family lands making up about 16% and 27% for UDP and non-UDP farmers respectively.

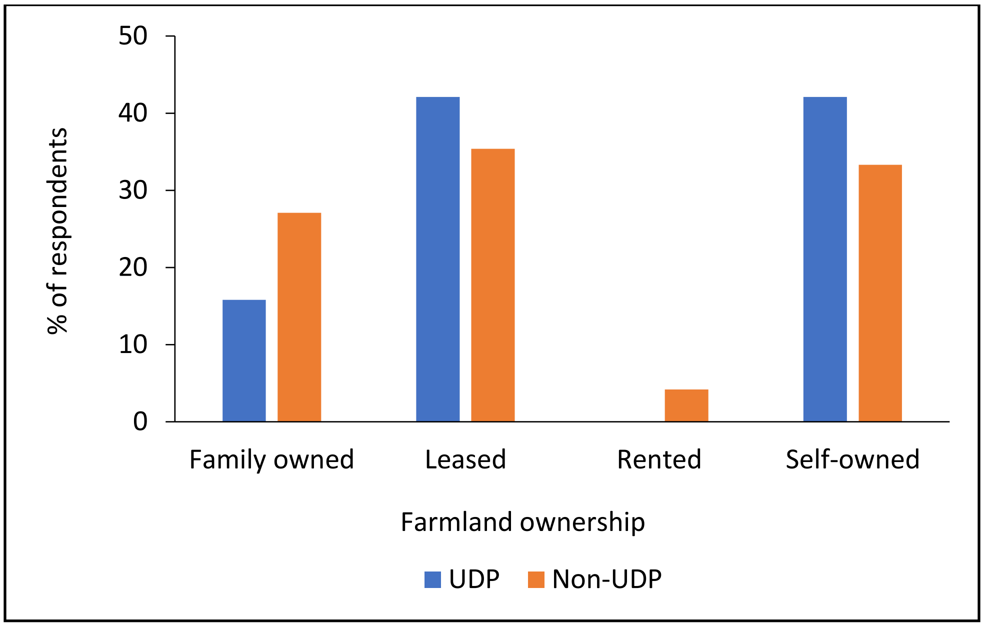

Figure 4.5: Land ownership structure of respondents

4.1.8 Principal occupation of farmers

Figure 4.6 is a representation of farmers who do farming as their main occupation at the study site. Majority of the farmers do farming as their principal occupation. As many as 75% of non-UDP farmers have farming as their principal occupation while the remaining 25% are engaged in other non-farm income generating activities. To the contrary, a smaller percentage of UDP farmers are engaged in other income generating activities aside farming.

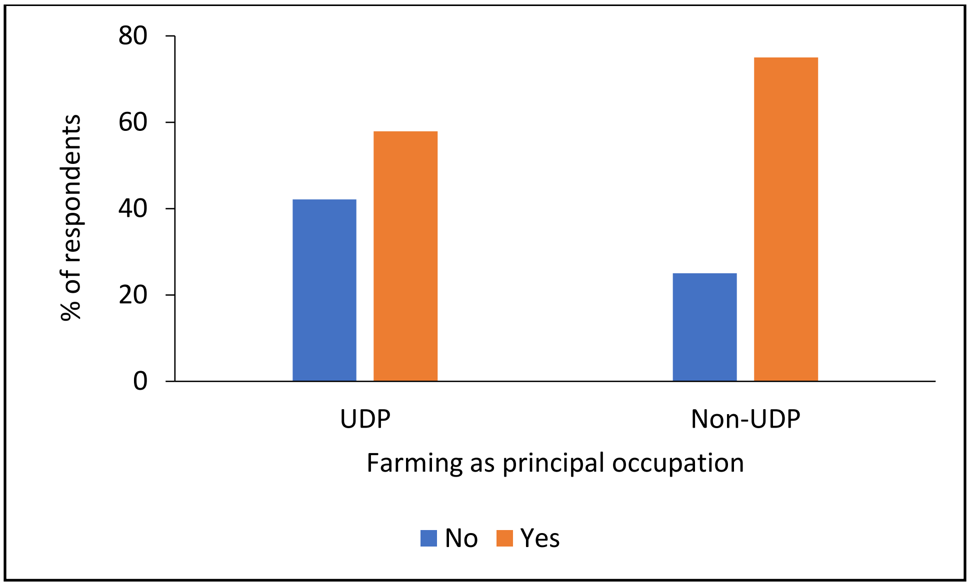

Figure 4.6: Principal occupation of farmers

4.1.9 Farm sizes of respondents

Majority of the farmers cultivate farm size of more than 0.2 ha. 39% of UDP farmers have farm size of more than 2.0 ha while majority of Non-UDP farmers (38%) have farm size between 0.2 and 0.4 ha (Figure 4.7). No UDP farmer has less than 0.2 ha farm size. The modal farm size range for UDP farmers and non-UDP farmers is >2.0 and 0-0.2 respectively. The average farm size of 0.83 ha for UDP farmers is higher than 0.53 ha for non-UDP farmers.

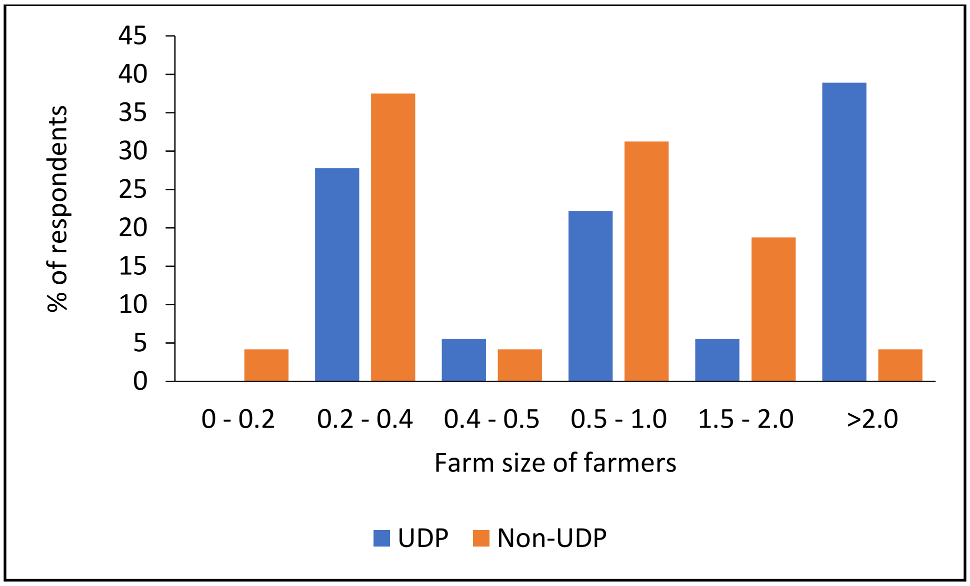

Figure 4.7: Farm size distribution of farmers

4.2 Rice production characteristics in the scheme

4.2.1 Land preparation

Figure 4.8 represents the various forms of land preparation at the scheme. Majority of the farmers use tractor to prepare their fields. With UDP farmers surveyed, majority of the farmers (100%) use tractor service. Majority of non-UDP farmers (94%) also prepare their farmlands using tractor while a few (6%) of the farmers use other manual means.

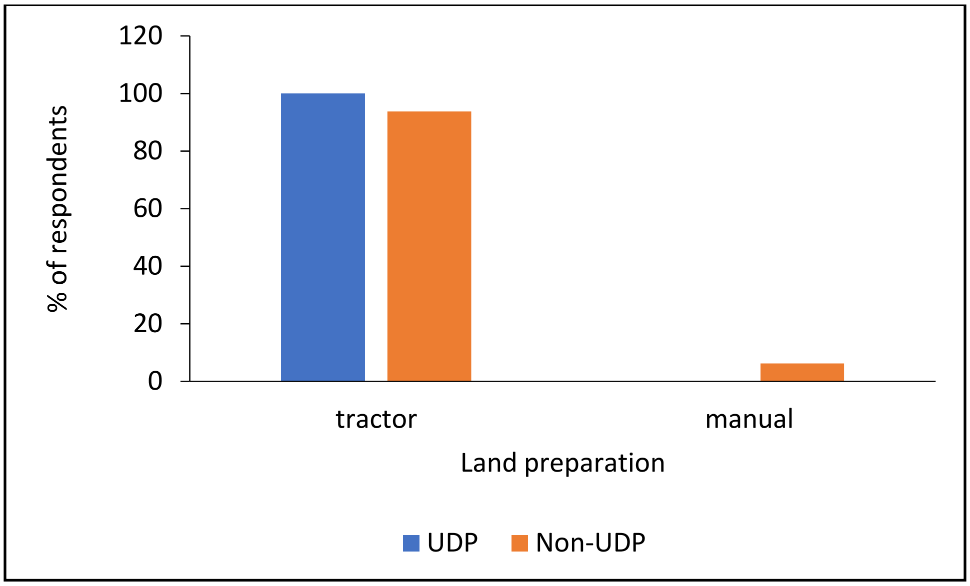

Figure 4.8: Land preparation methods of respondents

4.2.2 Period of nursery at the Tono irrigation scheme

Majority of the farmers (56%) irrespective of their urea management transplanted rice seedlings three (3) weeks after nursery (Table 4.3). None of the non-UDP farmers transplanted their seedlings after one week. On the contrary a few UDP farmers (5%) transplanted after one week. About 29 % and 26% of Non-UDP farmers and UDP farmers respectively transplanted rice seedlings four weeks after nursery (Table 4.3).

Table 4.3: Number of weeks farmers nursed seedlings

Number of weeks	Non-UDP farmers		UDP farmers	
	Frequency	**Percentage**	**Frequency**	**Percentage**
One week	0	0.00	1	5.26
Two weeks	2	4.17	4	21.05
Three weeks	30	62.50	8	42.11
Four weeks	14	29.17	5	26.32
More than four weeks	2	4.17	2	10.53
Total	**48**	**100.0**	**19**	**100.0**

4.2.3 Number of seedlings transplanted by farmers

The mean number of seedling per stand transplanted by non-UDP and UDP farmers is 3 and 2, respectively (Figure 4.9 and Figure 4.10). The modal number of seedlings transplanted by UDP farmers is 2 while that of their non-UDP counterparts is 3. A small minority of non-UDP farmers (6%) transplanted more than 3 seedlings per stand (Figure 4.9). The range of seedlings transplanted by UDP farmers is 1-3 compared to 1-6 seedlings transplanted by non-UDP farmers.

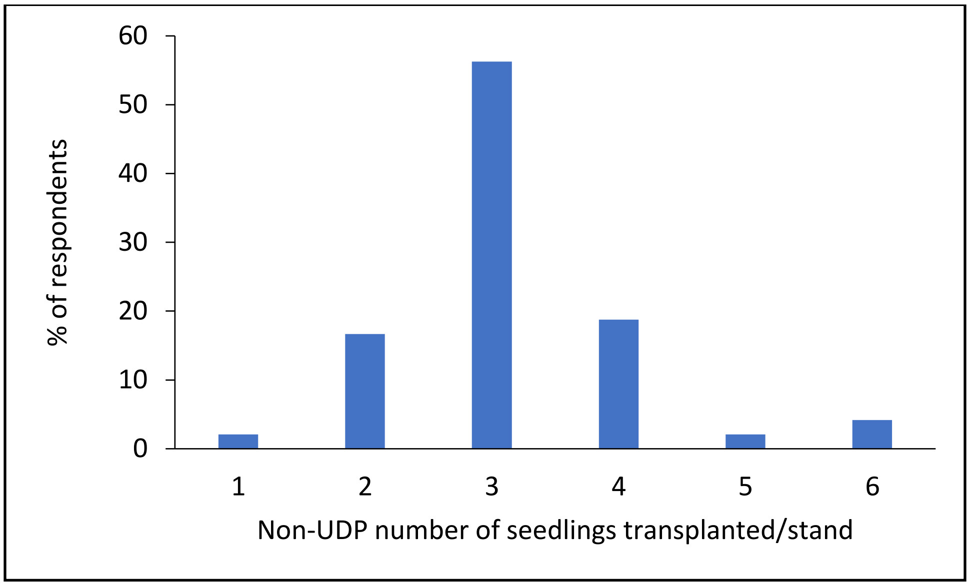

Figure 4.9: Non-UDP fields seedling number per stand

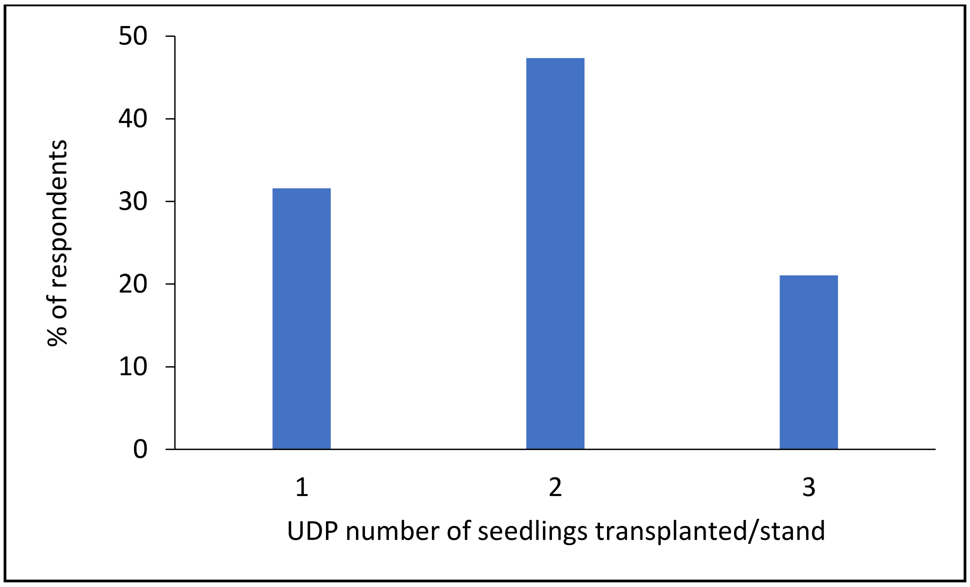

Figure 4.10: UDP fields seedling number per stand

4.2.4 Fertilizer application prior to seedling transplanting

The survey results show that most of the farmers irrespective of their urea management practice did not use any basal fertilizer before transplanting. Only a small minority of farmers, who make up about 4% and 16% of non-UDP and UDP farmers, respectively apply any basal fertilizer to the soil before transplanting (Figure 4.11). This is an indication that fertilizer application before seedling transplanting is not a common practice in the scheme.

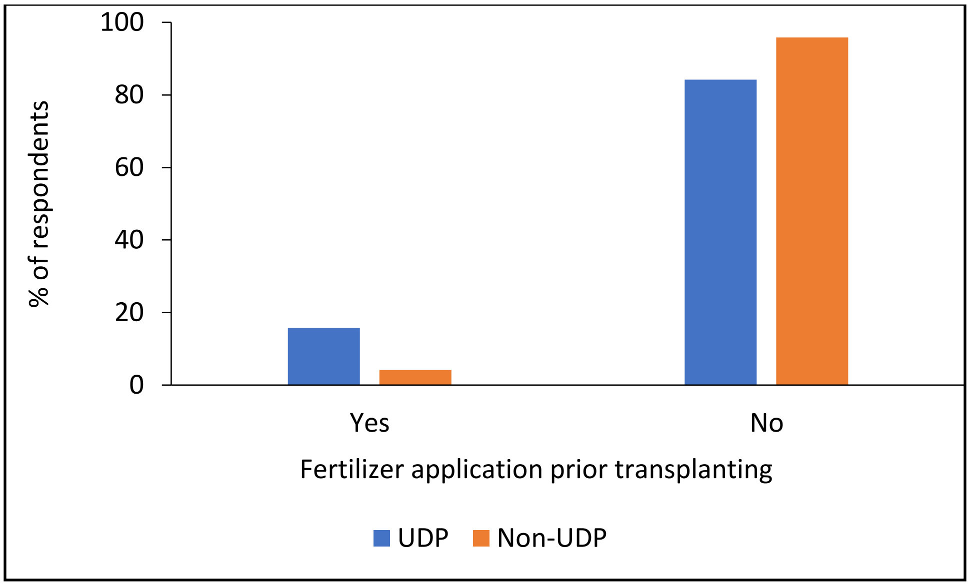

Figure 4.11: Fertilizer application prior to seedling transplanting

4.2.5 Frequency of N fertilizer application after transplanting

Comparing number of times farmers apply N fertilizer after seedling transplanting, 20% of UDP farmers did not apply any N fertilizer after deep placement of Urea supergranules (USG), while 58 % applied N fertilizer once after deep placement of USG (Figure 4.12). Majority of non- UDP farmers (65%)

applied N fertilizer more than two times (split application) after transplanting (Figure 4.13).

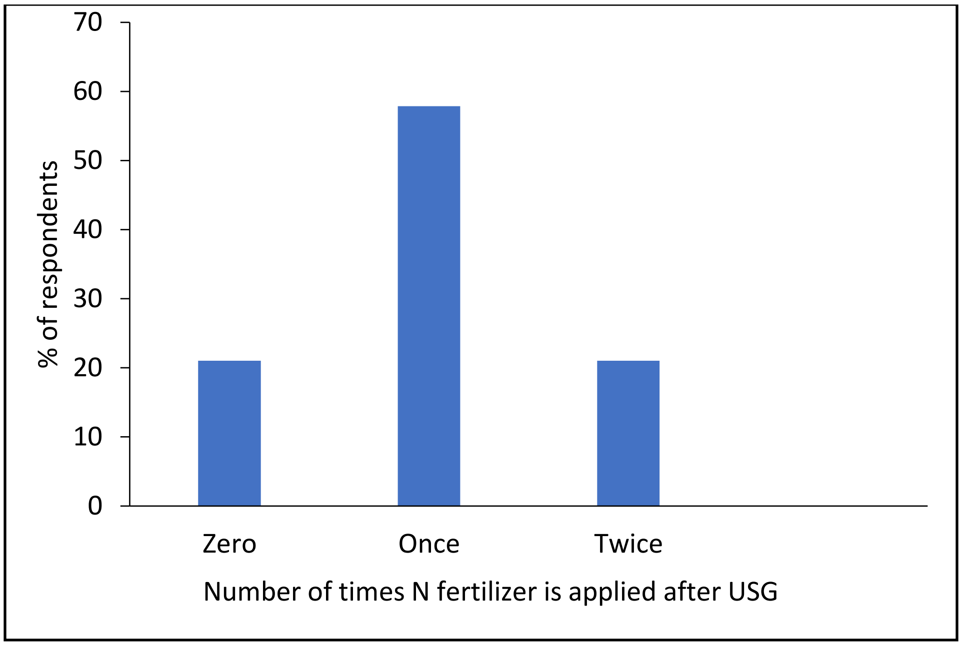

Figure 4.12: Number of times UDP farmers apply N fertilizer after USG

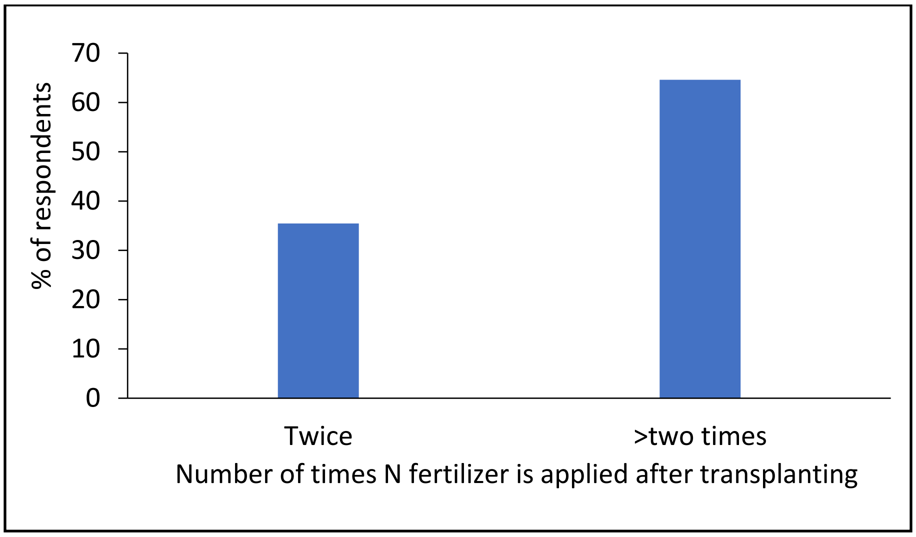

Figure 4.13: Number of times Non-UDP farmers apply N fertilizer after transplanting

4.2.6 Farmers experience in ATT recommended UDP technology

Farmers were also assessed on the number of years they have practiced the UDP technology. The results showed that no farmer had less than two (2) years experience. Majority of farmers had three years experience in the use of UDP (Table 4.4).

Table 4.4: Number of years farmers used UDP technology

Technology used (years)	Frequency	Percentage
2 years	7	36.84
3 years	9	47.37
More than 3 years	3	15.79
Total	**19**	**100.0**

4.2.7 UDP farmers' perceptions about the UDP technology

A relatively large percentage of UDP farmers (46%) perceived UDP technology to produce high grain yield through enhanced plant growth and development. About 18% of the farmers said the technology is easy to practice, 14% said it cuts down the cost of fertilizer application while 11% said it reduces soil nutrient loss. 6% said the technology improves aeration within plant-soil system (4%) (Table 4.5).

Table 4.5: UDP farmers perception about UDP technology

Perception	Frequency	Percentage
Gives more yield	13	46
Good growth of rice	2	7
Easier to do	5	18
Reduces cost of fertilizer	4	14
Reduces loss of nutrients	3	11
Gives better row spacing	1	4
Total	**28**	**100**

4.2.8 Non-UDP farmers' perceptions about UDP technology

Majority of non-UDP farmers (54%) perceived UDP technology to be good and high yielding, however, it is more expensive to practice (Table 4.6). 17% of the farmers said the technology is good, 6% of the farmers said that the technology is difficult to practice while 10% of them said there is limited access to to urea briquette. 2% mentioned that row transplanting is laborious and time consuming while 8% said the technology requires more water delivery (Table 4.6).

Table 4.6: Non-UDP farmers perception about UDP technology

Perception	Frequency	Percentage
It is good	9	17
It gives more yield but more expensive	28	54
It is a good technology but tedious	3	6
Row transplanting is laborious	1	2
Limited access to urea briquettes	5	10
It requires more water delivery	4	8
Urea briquettes stay long in the soil	2	4
Total	**52**	**100**

4.2.9 Decision of farmers to use UDP in the future

Majority of the non-UDP farmers (92%) responded positively to the use of UDP in the future as a result of the perceived benefits they have about the technology. All UDP farmers interviewed wished to continue with the use of the technology. (Figure 4.14). About 4% of the non-UDP farmers said no while about 4% are undecided to use the technology in the future.

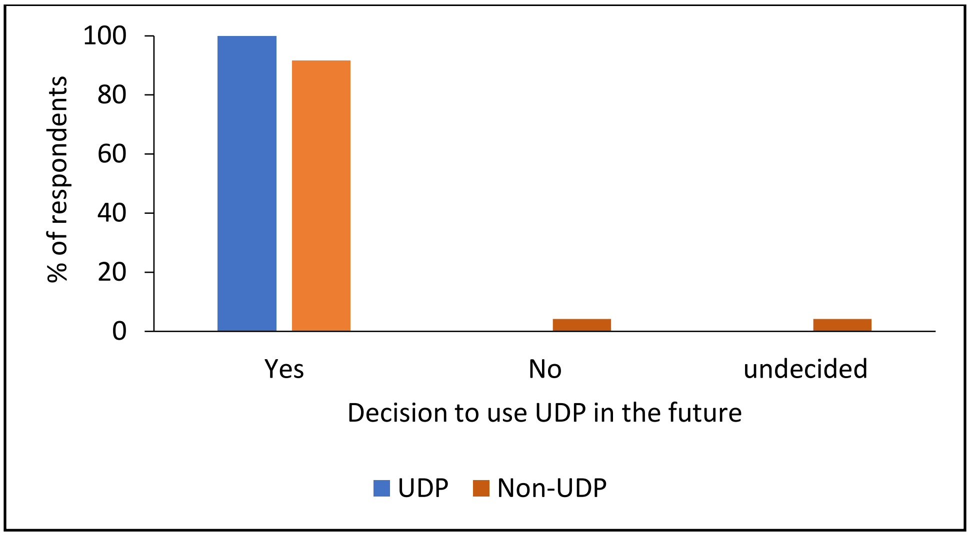

Figure 4.14: Farmers decision to use UDP in the future

4.3 Determinant of rice yield in the scheme

Results from the model adopted for this study show that gender, educational status, farming experience and urea briquettes (UDP) were found to influence rice grain yields (Table 4.7). Gender of farmers was found to be significant at the 10% level and positively influenced rice grain yields. The model suggests that male farmers would have 0.66 MT/ha of rice yield more than their female counterparts. Educational status of farmers had a positive and significant impact at 10% level on rice yield which implies that the more educated farmers are, the higher the rice yield (output) they obtain. Farming experience had a positive and significant effect at 5% level on rice yield. This implies that, relatively more experienced farmers have higher rice output. In other words, if years of farming increase by one year, rice yield will increase by 0.018 MT/ha. The UDP technology was found to be significant at 10% and positively influenced rice yield. This implies that, a farmer who practiced UDP would have 0.556 MT/ha of rice more than his counterpart who did not adopt UDP technology.

Table 4.7: Determinant of rice yield in the scheme

	Variable	**Coefficient**	**Standard Error**	**z value**	**P >|z|**
Dependent	**Yield (MT/ha)**				
Independendt					
	Gender	0.665*	0.555	1.2	0.073
	Distance to irrigation *(km)*	-0.018	0.395	-0.05	0.961
	Age (*years*)	-0.038	0.028	1.38	0.137
	Education status	0.086*	0.404	0.21	0.083
	Farming experience (*years*)	0.018**	0.040	0.44	0.040
	Off-farm income	0.368	0.361	-1.85	0.117
	Farm Size (*hectares*)	0.418	0.284	1.47	0.124
	Urea briquettes (UDP)	0.556*	0.443	1.25	0.061
	Thinning out	0.91	0.71	1.28	0.2
	Seedling nursing (days)	-0.48	0.67	-2.2	0.3
	Constant	2.843	0.783	3.63	0.112
	Lambda	-0.74	0.52		
	Rho	-0.59			
	Sigma	1.26			

Wald chi^2 (9) = 61.95

Prob > Chi^2 = 0.000

Number of Observation = 67

*= Significant at 10%, **=Significant at 5%

4.4 Field observation of growth parameters, grain yield and yield components

4.4.1 Physicochemical properties of the soils

The physical and chemical properties of the soils at the study site are presented in Table 4.8 The particle size analysis showed high sand content (70.3%) for Zone I and relatively low content for Zones H (53.3%) and J (57.2%). Clay content was in the order; zone H>zone J> Zone I. Zone J had the highest silt content (28.6 %) with zone H and I recording 26.2 % and 16.40 % respectively. According to USDA texture classification, Zone H, I and J soils can be classified as Sandy loam soils. pH marginally increased from 5.4 in zone H to 5.7 in zone I. Zone H soils can be described as strongly acidic (pH 5.4) while zone I and J were moderately acidic (5.7 and 5.6). Total N increased marginally from 0.06% in zone H to 0.08% in zone J. Zone H had the highest Organic matter (1.92%) with zone I and J recording 1.22% and 1.82% respectively. Bray P values range from 10 to 14 mg kg^{-1}. The highest value of 14 mg kg^{-1} occured in zone H compared to 10 mg kg^{-1} and 12 mg kg^{-1} in zone I and J respectively. CEC values increased significantly from 7.61 (cmol(+)/kg) in zone J to 12.11 (cmol(+)/kg) in zone H.

Table 4.8: Physiochemical properties of the soils used in the study site

Zone	Sand	Silt	Clay	Texture	OM	Total N	pH	Bray P	CEC	Ex K	Ex. Mg	Ex. Ca
	%				%			(mg/kg)	(cmol(+)/kg)			
H	55.3	26.2	18.5	Sandy loam	1.92	0.06	5.4	14	12.11	0.14	2.4	6.0
I	70.30	16.40	13.3	Sandy loam	1.22	0.07	5.7	10	7.98	0.10	1.6	4.5
J	57.2	28.6	14.2	Sandy loam	1.18	0.08	5.6	12	7.61	0.12	1.3	4.3
Non-UDP	54.73	28.05	12.22	Sandy loam	1.56	0.08	5.6	13	10.22	0.13	2.0	5.4
UDP	64.98	21.45	13.57	Sandy loam	1.32	0.06	5.6	11	8.25	0.11	1.5	4.4

4.4.2 Correlation between physicochemical properties of the soil and grain yield

Pearson's correlation was used to find relationships between soil Physico-chemical properties and grain yield. The result is in shown in table 4.9. Clay content had a strong and positive relationship with OM ($r = 0.77$, $P<0.01$), CEC ($r = 0.90$, $P<0.01$), K ($r = 0.88$, $P<0.01$), Mg ($r = 0.87$, $P<0.01$) and Ca ($r = 0.91$, $P<0.01$). OM correlated positively with CEC ($r = 0.79$, $P<0.01$), K ($r = 0.68$, $P<0.05$), Mg ($r = 0.57$, $P<0.05$), Ca ($r = 0.62$, $P<0.05$) and N ($r = 0.61$, $P<0.05$). CEC had a strong and positive relationship with exchangeable bases K ($r = 0.82$, $P<0.01$), Mg ($r = 0.92$, $P<0.01$) and Ca ($r = 0.92$, $P<0.01$). Bray P was the only soil property that showed a strong and positive relationship with rice yield ($r = 0.63$, $P<0.05$).

Table 4.9: Relationship between physicochemical properties of the soil and grain yield

	Clay	Silt	OM	Bray P	pH	CEC	K	Mg	Ca	N	Yield
Sand	-0.78	-0.89	-0.65	0.29	-0.13	-0.76	-0.71	-0.71	-0.71	-0.47	0.1
clay		0.41	0.77**	-0.37	0.27	0.9**	0.88**	0.87**	0.91**	0.47	-0.21
Silt			0.38	-0.15	0	0.44	0.39	0.4	0.36	0.34	0.01
OM				-0.13	-0.23	0.79**	0.68*	0.57*	0.62*	0.61*	-0.06
Bray P					-0.09	-0.46	-0.18	-0.51	-0.39	-0.16	0.63*
pH						0.14	0.4	0.45	0.49	-0.26	-0.04
CEC							0.82**	0.91**	0.91**	0.48	-0.12
K								0.81	0.9	0.42	0
Mg									0.95	0.29	-0.19
Ca										0.33	-0.12
N											-0.04

$^{*}P < 0.05$. $^{**}P < 0.01$

4.4.3 Yield components

4.4.3.1 Plant population (Plants/ha)

Transplanting pattern significantly ($p<0.05$) affected plant population. Estimated plant population of 351,200 in non- UDP fields, is significantly higher than 319,013 in UDP fields (Table 4.10). Random transplanting in non-UDP fields resulted in 10% higher plant population than row transplanting in UDP fields.

Table 4.10: Rice yield components for the entire study site

N Management	Plant population (Plants/ha)	Number of tillers	Effective tillers	Grains per panicle	1000 grain weight
Non-UDP	351,200a	11a	8a	162a	29.5a
UDP	319,013b	15b	12b	188b	29.3a
Lsd (5%)	14109	0.8	0.7	5.7	0.22
CV	11.53	17.95	18.63	8.96	4.42

Columns with the same letter are not significantly different (p =0 .05)

4.4.3.2 Number of tillers and effective tillers

Tiller numbers and effective tiller numbers were significantly ($p<0.05$) impacted by nitrogen management practices. Rice plants in UDP fields developed about 36 percent more tillers which produced about 50 percent more effective tillers than plants in non-UDP fields (Table 4.10).

4.4.3.3 Grains per panicle

Nitrogen management practice significantly ($p<0.05$) affected grain per panicle. Average grains per panicle in UDP fields is 188 which is significantly higher than 162 for non-UDP. (Table 4.10).

4.4.3.4 Grain yield (MT/ha) and 1000 grain weight

Per unit area rice grain yields were determined in UDP and non-UDP fields as shown in Figure 4.15. Grain yields were significantly affected by nitrogen management practices. Average yield of 7.05 MT/ha in UDP fields is significantly higher than 6.19 MT/ha in non-UDP fields. The weight of thousand grain weight did not vary much between non-UDP and UDP (Table 4.10).

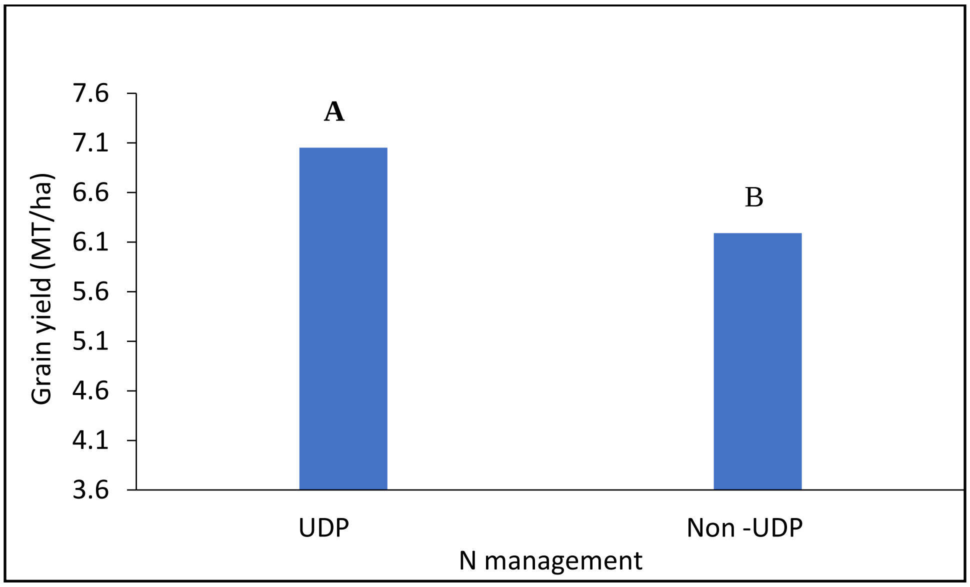

Figure 4.15: Effect of N management on rice grain yield. Different letters show significant differences ($P < 0.05$)

4.4.3.5 Yield variability: Non-UDP vs. UDP

Box-Whisker plot was used to explain yield variability in UDP and non-UDP fields (Figure 4.16). The non-UDP system recorded more variability with grain yield. Rice grain yields in non-UDP varied from 1.92 – 9.91 MT/ha compared to 3.37 – 10.84 MT/ha in UDP. Median yields in non-UDP and UDP are 6.03 and 6.77 MT/ha, respectively. The interquartile yield range in non-UDP is between 4.98 and 7.84 MT/ha with a difference of 2.86 MT/ha. The UDP fields has a narrower interquartile yield range of 5.54 and 7.88 with a difference of 2.34 MT/ha. This could probably account for the yield variability between non-UDP and UDP.

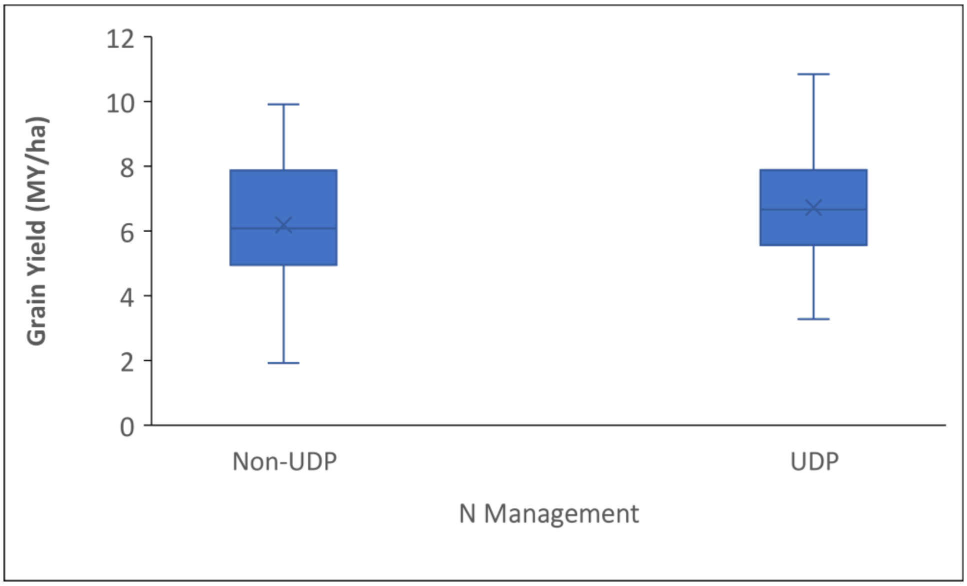

Figure 4.16: Box-Whisker plots of rice grain yields in non-UDP and UDP fields

4.4.3.6 Factors Influencing rice grain yields: Transplanting Date

Rice seedling transplanting dates from nursery and number of farmers who transplanted for each day are shown in Figure 4.17 for non-UDP farmers and Figure 4.18 for UDP farmers. For non-UDP farmers, transplanting started on February 18, 2018 (49 Julian day) and lasted for 36 days. The UDP farmers started transplanting on February 16 (47 Julian days) and lasted for 31 days, five days earlier than their non-UDP counterparts. The modal date, or the dates where the highest number of farmers transplanted their fields in the non-UDP system is February 18, 2018 (49 Julian day) compared to March 4, 2018 (63 Julian day) for their UDP counterparts.

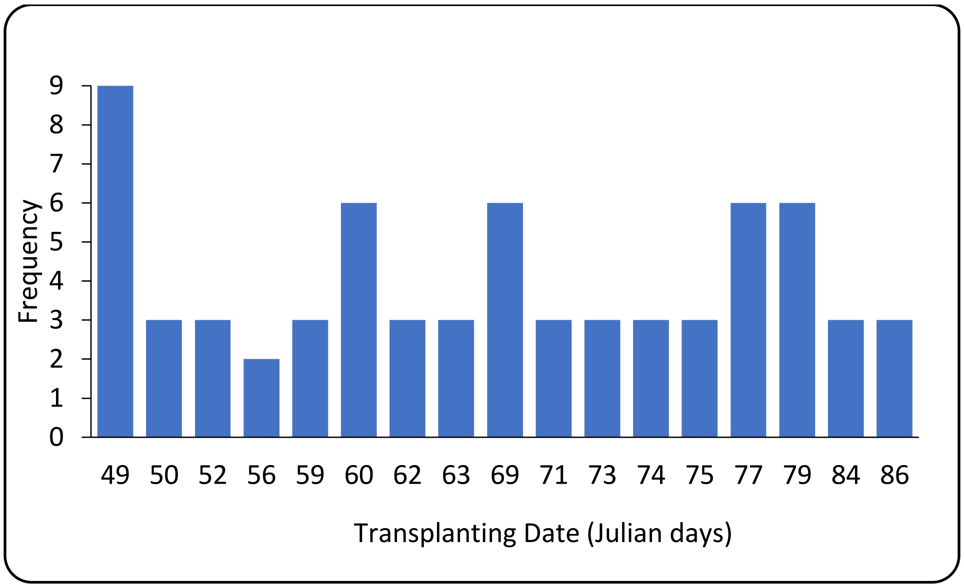

Figure 4.17: Dates and numbers of non-UDP farmers who transplanted on those dates

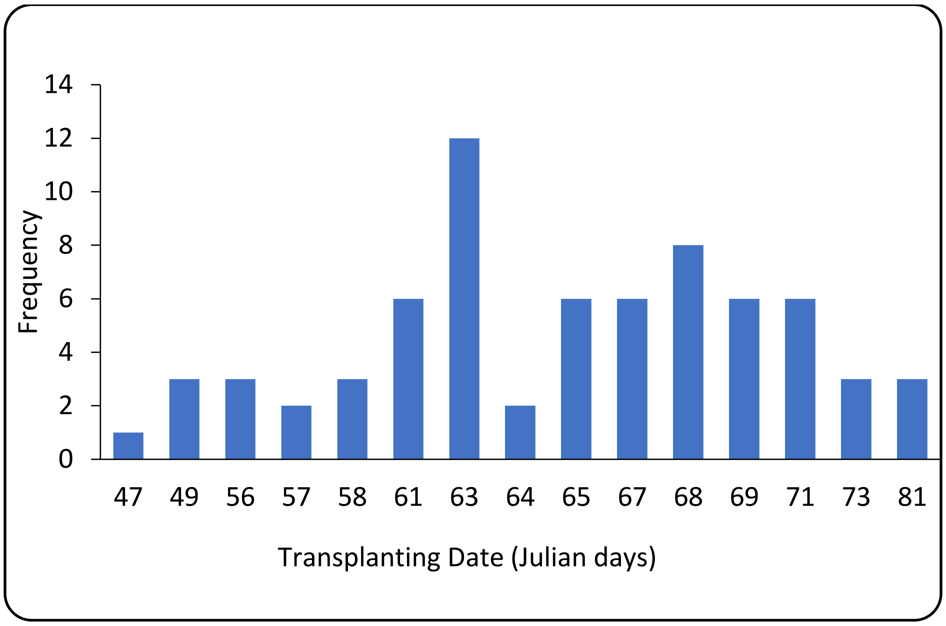

Figure 4.18: Dates and numbers of UDP farmers who transplanted on those dates

4.4.3.6.1 Variability in transplanting date

Box - Whisker plot was used to explained variability in seedling transplanting dates (Julian calendar) among non-UDP and UDP farmers (Figure 4.19). Non-UDP system showed a higher variability in transplanting dates. Median transplanting date for non-UDP is March 10 and their interquartile date range is between February 28 and March 17, 2018 with a difference of 17 days. Median transplanting date for UDP farmers is March 6, and their interquartile date range is between March 4 and March 9, 2018 with a difference of 5 days. The difference in interquartile date range between the two systems could probably account for more variability in transplanting date in non-UDP systems.

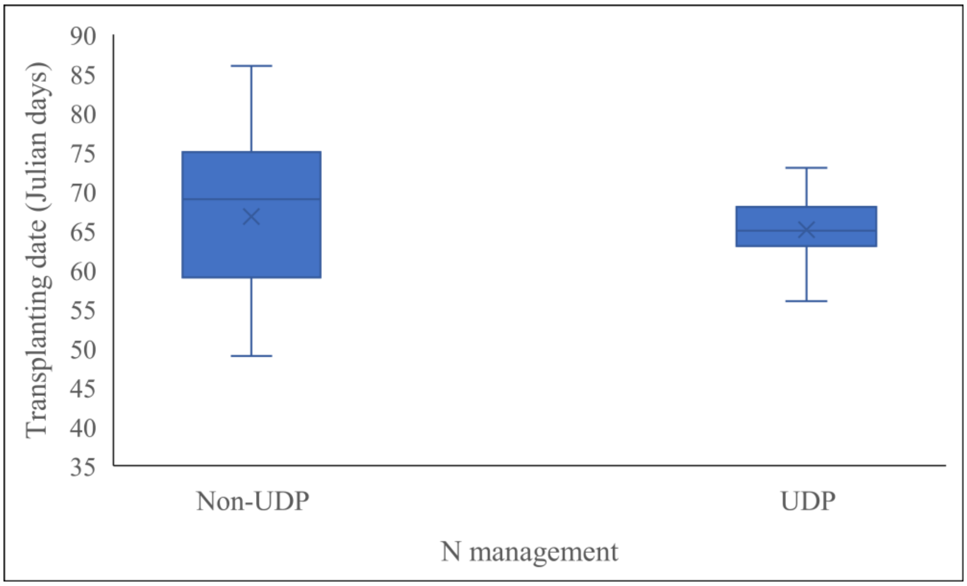

Figure 4.19: Box-Whisker plots of seedling transplanting dates non-UDP and UDP fields

4.4.3.6.2 Relationship between seedling transplanting dates and grain yield

Relationship between rice seedling transplanting dates and rice grain yields in both non-UDP and UDP fields is presented in Figure 4.20. The figure indicates that negative relationship was observed between rice seedling transplanting date and rice grain yield (r = -0.28). The negative relationship suggests that delaying transplanting resulted in decreased rice yields. Separating data into non-UDP and UDP in Figure 4.21, the figure shows that decrease in yield resulting from delayed transplanting is more influenced under UDP (r = -0.27) than non-UDP (r = -0.21).

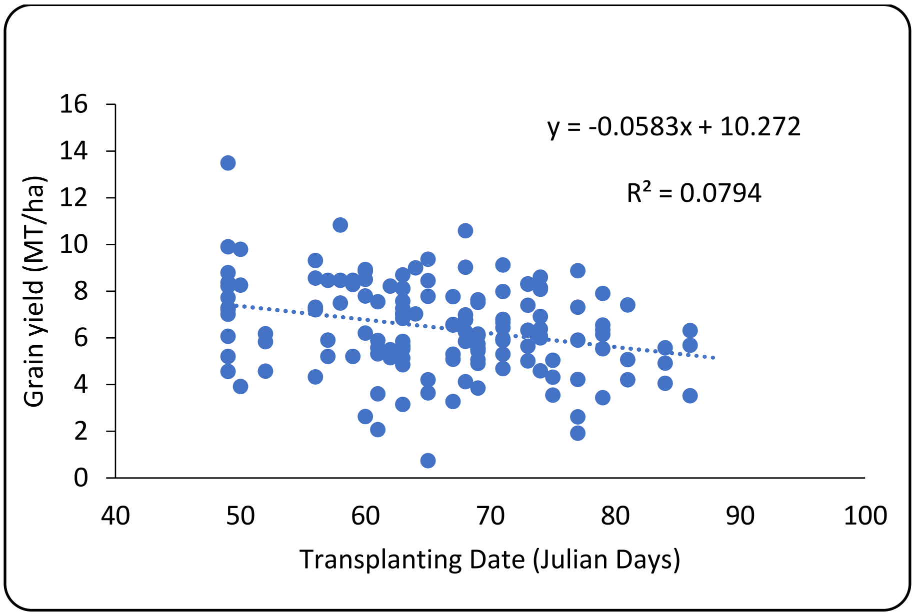

Figure 4.20: Relationship between seedling transplanting date and grain yield from all fields combined

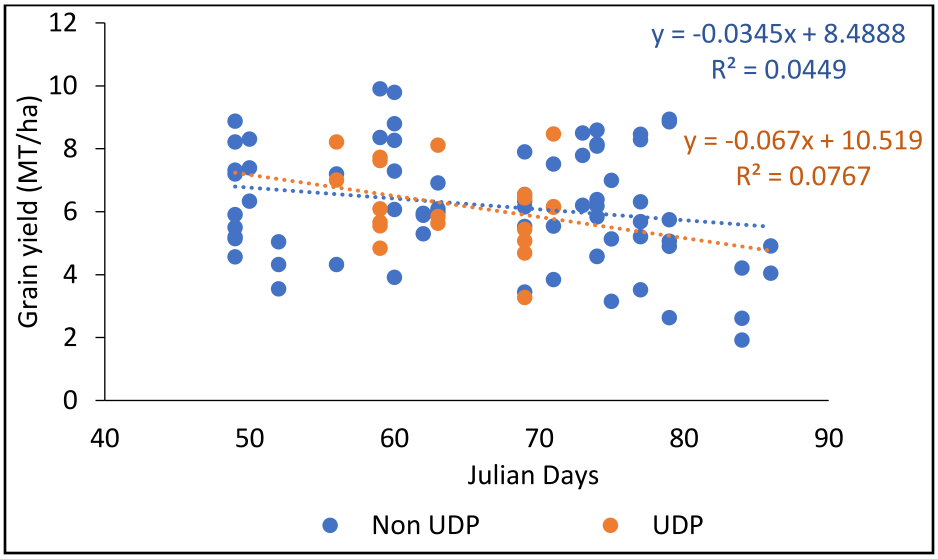

Figure 4.21: Relationship between seedling transplanting date and grain yield in non-UDP and UDP

Rice grain yields were estimated from non-UDP and UDP fields assuming transplanting is carried out between mid-February and mid-April (Table 4.11). It can be projected from the table that transplanting at the end of February using UDP as N management system could potentially result in 3.15 MT/ha of grain loss which is 31% less than what can be obtained when transplanting is done mid-February. In a similar case with non-UDP, yield loss of 1.52 MT/ha (19%) with the 14-day delay could be expected. Subsequent loss in grain yield with increased delay in transplanting is shown in Table 4.11.

Table 4.11: Yields associated with transplanting dates in non-UDP and UDP

		non-UDP			UDP		
Julian Date	Day of the Year	Estimated yield from study (MT/ha)	Yield Loss (MT/ha) from previous date	% Yield Loss from previous date	Estimated yield from study (MT/ha)	Yield Loss (MT/ha)	% Yield Loss
44	February 15	7.97			10.13		
59	February 28	6.45	1.52	19	6.99	3.15	31
74	March 15	5.94	0.52	8	5.92	1.07	15
89	March 30	5.92	0.52	9	4.84	1.07	18
105	April 15	4.87	0.55	10	3.70	1.14	24

Results from the table suggest that delaying seedling transplanting at the beginning of the season has a negative effect on rice yield at the end of the season. The results further suggest that declining yield effect due to delayed transplanting is more severe in UDP systems.

CHAPTER FIVE

DISCUSSION

5.0 Socio-Economic characteristics of farmers in the irrigation scheme

5.1.1 Nearness of farmers residence to the irrigation scheme

Majority of UDP farmers live less than 1.6 km from the scheme compared to their non-UDP counterparts. This supports the work of Donkor *et al*. (2018) who claimed that location of farmers is one remarkable factor that determines adoption of a number of farm technologies in Northern Ghana. According to the authors, access to support facilities such as extension, credit and good road networks is determined by farmers' location. The accessibilty to these services encourage farmers to adopt more farm technologies in their rice fields. Farmers living in close proximity to the scheme become easily aware of information about new innovation and this could influence adoption. These farmers are also able to attend trainings workshops of new innovations and this may encourage adoption.

5.1.2 Gender distribution of farmers

Generally, there were low number of females who were involved in rice farming at the scheme. This corroborates the work of Donkoh *et al*. (2012) who observed that male farmers are more than female farmers in the rice cultivation in the Tono irrigation scheme in the northern region of Ghana. Similarly, Addison *et al*. (2016) also observed low female participation in rice cultivation at Ahafo Ano North District in Ashanti Region of Ghana. Ojo *et al.* (2018) also observed low female farmers involved in rice cultivation in Ekiti State of Nigeria. This result does not suggest that females were least involved in rice production. Activities in rice production appeared to be led by the males because they own the lands on which production activities are carried out. Women, however assist their male counterparts in providing labour for transplanting, weeding and harvesting.

5.1.3 Age distribution and farming experience of farmers

The mean age of UDP farmers is higher than their non-UDP counterparts. This is similar to the work of Adenuga *et al*. (2016) who observed that the mean age of adopters of improved rice technology was higher than that of non-adopters. Anang (2019) also observed that adopters of improved rice varieties were older than non-adopters in northern Ghana. There is a general remark in previous studies that older farmers stick to their old ways of production and are usually not willing to adopt new improved technology. On the contrary, the adoption of Urea deep placement by UDP farmers who on the average are older than non-UDP farmers could be attributed to the amount of knowledge, experience and wealth they have acquired with age. Older farmers are known to be richer than the younger farmers as a result of the wealth they amass over the years in farming. So, they are able to buy the necessary inputs to undertake new improved technologies.

UDP farmers had more years of farming experience than non-UDP farmers. It is not surprising that UDP farmers adopted UDP technology in the Tono irrigation scheme. This supports assertion of Donkoh *et al*. (2016) that farmers' experience in rice production influence of adoption of farm innovation. The authors also argued that more experienced farmers can assess benefits of improved rice technologies based on the knowledge they have accumulated over the years. Similarly, Mamudu *et al*. (2012) reported skills of production improve as farmers become more experienced. Thus, a more experienced farmer may have a lower level of uncertainty about innovations and they are therefore able to make and take better decisions with regard to adoption of innovation introduced.

5.1.4 Education level of farmers

Generally, more UDP farmers have at least one form of formal education than their non-UDP counterpart. This supports the work of Adenuga *et al*. (2016) who found high level of education with adopters of improved rice varieties in Nigeria. The result also supports findings of Foltz (2003) who claimed that formal education help farmers to understand the knowledge about a technology which eventually promotes the adoption of the technology. Lin (1991) and Welch (1976) reported that better educated farmers are more eager and faster to adopt new technologies and modern practices. Similarly, education gives farmers the opportunity to evaluate and react more quickly to new information (Uaiene *et al*., 2009).

5.1.5 Access to ATT training and extension

The UDP farmers recorded 100% extension training and services on the UDP technology compared to their non-UDP counterparts. These trainings were mostly conducted by trained staff of IFDC, through famer-led demonstrations and learning centers. This could have inspired adoption of UDP technology by UDP farmers. This supports work of Azumah *et al*. (2017) who reported that farmers who were trained on UDP technology adopted the technology than their counterpart who did not attend trainings. Doss and Morris (2000) also observed that farmers' contact with extension services facilitate adoption of a new technology, since extension officers assist farmers with both inputs and technical advice. Extension services in Africa, have proven to be a major driving force behind awareness and adoption of new technologies (Mariano *et al*., 2012).

The UDP technology is a new technology for rice farmers in Ghana. Farmers therefore needed to be trained on its procedure and application processes in order for them to be efficient and effective in its usage.

5.1.6 Land rights and landholdings of farmers

A large proportion of UDP fields are self-owned. This corroborate findings of Paltasingh (2018) who observed that land security by ownership increases the likelihood and adoption rate of new rice technology in India. The author argued that farmers who own their farmlands are more probable to adopt new technologies than tenant farmers. He also added that land ownership reduces cost of production because no payment is made for land use. Similarly, Kassie *et al*. (2011) observed that land tenure security has a strong impact on adoption of sustainable agricultural practices by farmers.

UDP farmers had bigger field sizes than their non-UDP counterparts. Adoption of urea deep placement by UDP farmers could be attributed to the larger farm sizes they have over their non-UDP counterpart. A study by Donkoh *et al*. (2016) revealed that farmers with big farm size adopted more farm technologies than those with small farm sizes in Kassena-Nankana and Bawku districts of Northern Ghana.

5.1.7 Principal occupation of farmers

The number of UDP farmers who are engaged in income generation through non-farm task was higher than their non-UDP counterpart. This could be extra motivation for adoption of UDP technology because new improved rice innovations come with incurring extra cost to farmers. So, farmers who engage in off- farm activities get extra money to pay for cost of adopting new farm innovations. Kinuthia and Mabaya (2017) also found that access to income from non-farm activities increase the likelihood of new rice technologies adoption in Uganda.

5.2 Rice production characteristics of the scheme

5.2.1 Land preparation

Majority of the farmers in the scheme use tractor service for land preparation with the exception of few who use manual and other means. Vincent *et al.* (2015) have observed that majority of farmers use tractor service for land preparation in northern Ghana. The finding is indicative of modern trend in the use of tractor services by rice farmers in the scheme. The few who use manual and other means could be attributed to budget constraints of some households in northern Ghana.

Success of UDP technology could hinge on timely land preparation, therefore the use of tractor by large majority of UDP farmers was no surprise because tractor services enhance quick and efficient land preparation.

5.2.2 Nursery of rice seedlings at the scheme

Results from the survey revealed that all farmers interviewed nursed their rice seedlings before transplanting with no direct seeding. Umeh and Chukwu (2013) observed a relatively high nursery establishment adoption level among rice farmers in Eboyin state, Nigeria. The finding is indicative of modern trend of nursery practice by rice farmers in the scheme. By raising rice seedlings in nursery, only germinated seeds are transplanted and this increase plants per unit area. Another advantage of raising rice seedlings in nursery before transplanting is that only healthy seedlings are transplanted.

Majority of the farmers transplanted rice seedlings three weeks after nursery. Among the factors that affect rice yieldi, seedling age is rated high because it has tremendous effect on rice growth and yield characters such as plant height, tiller production, panicle length, and grain formation (Ali *et al*., 1995). Transplanting younger seedlings has been reported to increase rice yield and yield components. The work of Sarwar *et al*. (2011) revealed that the highest rice yield and yield parameters were recorded with 10 days old and 20 days old seedlings. The work of Yenni (2013) also revealed that 21-day-old seedlings (three weeks) produced more tiller numbers and productive tiller numbers which ultimately produced more grain yield. Rizwan *et al*. (2013) also observed decreasing number of tillers and productive tillers with delayed transplanting. Young transplanted seedlings may not have suffered from irreparable damage of the roots during transplanting (Ros *et al*., 2003) and as result, the root establish fast and induce good vegetative growth. Ros *et al*. (2003) stated that, the older the seedling, the greater is its depressing vigour after transplanting due to the impairment of root growth in the nursery. Delay transplanting seedlings stress caused by disturbing the root system and time to recover from this stress hinders the development of tillers (Masdar *et al*., 2006).

Seedling number per stand is an important factor in rice growth, as it impacts tiller formation, reception solar radiation, and nutrient absoption. Majority of UDP farmers maintained less seedling numbers per stand (1-3 seedling range) compared to non-UDP farmers with more seedlings (1-6 seedling range). The work of Yenni (2013) revealed that decreasing number of seedlings per stand from five to three, and one increased tiller numbers and productive tiller numbers with one seedling number per stand producing more tiller numbers and productive tiller numbers. Syatrianty *et al*. (2012) found decreasing tiller numbers and productive tiller numbers with increasing seedling number per stand.

5.2.3 Fertilizer application and frequency of application after transplanting

Majority of the farmers in the scheme irrespective of their nitrogen management do not apply basal fertilizer to the soil before transplanting. This is an indication that basal fertilizer application prior to transplanting is not a common practice in the scheme. However, farmers apply N fertilizers after transplanting their fields.

For non-UDP farmers, N fertilizer is applied in a multi-split broadcasting (2 or 3 splits) method over the cropping season. A basal application of N fertilizers is done at 7- 10 days after transplanting followed by top dressing with urea or sulphate of Ammonia at rapid tillering and before panicle initiation stage. The split application of N fertilizer by non-UDP farmers implies more cost is incurred in fertilizer application which eventually increase overall cost of production.

For UDP farmers, N fertilizer is applied by placing USG below the soil surface (about 7 cm) and centered between four rice seedlings within 7-10 days after transplanting. UDP technology requires N fertilizer to be applied only once for the entire crop season, unlike traditional urea application where 1-2 split applications are needed (mainly broadcasting first and then top-dressing subsequently) in Ghana. However, a few UDP farmers applied N fertilizer once after USG deep placement. This could probably be due to very low N status across the zones (Table 4.8) coupled with high N demand at reproductive stage of rice and farmers applied additional N fertilizer to boost rice yield. The principle of UDP technology is to reduces cost of fertilizer application in single dose while maintaining greater returns on investment (IFDC, 2014).

5.2.4 Perceived benefits of UDP and willingness of farmers to use UDP technology in future

Majority of farmers irrespective of their N management appear to show higher prospect of using UDP technology in the future. This decision could be associated with the positive benefits perceived of the UDP technology by the farmers. They cited minimizing N losses, reducing cost of fertilizer application in single dose, urea briquette stays longer in the soil, good yields among other benefits.

Adoption of UDP technology generally was low despite majority of farmers (both UDP and non-UDP) received training and extension service on the technology from ATT project. This could be attributed to some constraints revealed in the survey such as limited access to urea briquette, laborious nature of USG application and laborious and time consuming nature of row transplanting.

Majority of farmers complained about limited access to urea briquette. During interviews, farmers cited lack of urea briquette machine at the scheme and Kassena Nanakani district. So, farmers have to travel to Bolgatanga to have their PU briquetted. A 50 kg bag of PU was briquetted at a cost of GH¢ 20 plus additional cost to cover transportation (plus urea briquette) from Bolgatanga to Navrongo. It was clear that adoption of UDP technology depended on availability of urea briquette machine at rice producing communities where farmers have easy access. This is in agreement with Tarfa and Kiger (2013) observation that limited supply of USG could hinder adoption of UDP technology. Laborious and time-consuming nature of USG application was also mentioned during interviews. USG application requires special skills and protocol which many farmers say it is complex. Additionally, hand application requires heavy and expensive labour and time-consuming which many farmers say add to cost of fertilizer application and reduce the monetary profitability of the technology. Farmers also found row transplanting as laborious and time consuming. This is in line with findings of Ajibola *et al*. (2017) who found row/line transplanting as laborious and time consuming and a major constraint of adoption of UDP technology among rice farmers in North-Central Nigeria.

5.3 Determinant of rice yield in the scheme

On factors that influenced rice yield, gender of farmers positively influenced rice yield. This means that male farmers were more likely to have more rice yield compared to their counterpart female rice farmers. Contrary to the work of Donkoh *et al*. (2018), gender was not a significant factor in rice output of farmers in Northern Ghana. When female farmers have access to the same resources as men, they are more productive than men farmers. Saito (1994) reported that in Kenya the average gross value of output per ha from female-managed irrigated plots was usually 22 % higher than male managed plots with the same resources. Educational status of farmers positively and significantly impact on rice yield. This is consistent with finding of Mabe *et al*. (2018) who observed that educational status of farmers had a positive and significant impact on rice yield of farmers in Volta region. The explanation for this is that, higher educational status increases farmers' awareness about the benefits of adopting new improved technologies and hence results in an increase in grain yields. Farming experience positively and significantly impacted rice yield. This supports the work of Donkoh *et al*. (2018) who observed that farming experience positively impacted rice yield in northern Ghana. The work of Baba *et al*. (2015) showed similar finding where farmers with more years' experience in farming have more knowledge about agronomic techniques in rice production which led to yield increases compared to farmers who do not. The explanation for this is that, more experienced farmers are able to determine benefits of new rice technologies based on the knowledge they have amassed over the years. Urea briquette (UDP) was found to be significant at 10% and positively impacted rice yield. This supports the work of Azumah *et al*. (2017) who observed that deep placement of urea briquette positively and significantly impacted rice yield. The authors found that urea briquette deep placement increased rice yield of adopters by 21.5%. This finding is also in consistent with Bandaogo *et al*. (2015) who suggested that Fertilizer Deep Placement (FDP) can be used by farmers to improve nitrogen use efficiency and increase grain yields in the irrigated rice cropping system.

5.4 Soils, growth parameters, grain yield and yield components

5.4.1 Physiochemical properties of the soils used in the study site

Total N and Organic matter in the three zones recorded low values (Bruce and Rayment, 1982; Charman and Roper, 2000). Available phosphorus values as rated by Mallarino *et al*. (2013) were very low for the three zones. According to Landon (1996), all soils in the three zones had low CEC values. Results from this study reinforces the general assertion of the low fertility status of soils in Northern Ghana.

5.4.2 Plant population

Non-UDP recorded higher plant population (Plant/ha) than UDP. This could be attributed to the underlying transplanting pattern behind both N-management systems. In the non-UDP system, seedlings are transplanted in a nonstructural pattern, referred to as 'raster' by local farmers. This results in high and variable plant densities compared to the row spacing pattern required in the UDP system.

5.4.3 Number of tillers and effective tiller

Nitrogen supply strongly influence tillering of rice plant. The use of UDP could synchronize release of N with plant demand and in a single dose provide adequate N throughout the season (De Datta, 1986). Nitrogen management practices significantly impacted tiller numbers and effective tiller numbers. Urea deep placement recorded the highest tiller numbers and effective tiller numbers. Fields treated with UDP produced 36.3% more total tiller numbers and 53.0% more effective tiller numbers than fields treated with broadcasted urea. Hasan (2007) reported that deep urea placement significantly impacted tiller numbers. Mirzeo and Reddy (1989) also observed that USG deep placement produced the highest tiller numbers in transplanted rice. Hasanuzzaman *et al*. (2012) and Masum *et al*. (2008) reported that the USG deep placement recorded the highest effective tillers numbers, which consequently gave higher grain yield. Naznin *et al*. (2013) and Khatun *et al*. (2015) also reported higher number of tillers with urea deep placement than PU. This could be linked to the fact that nitrogen supply with USG coincided with plant demand for N. Probably the continuous supply of N from USG assisted in cell division due to higher photosynthetic activities that helped in increasing tiller numbers. The slow release of nitrogen from deep placed USG ensured long term supply of N to the rice plants and helped to produce higher tillers.

Higher tiller numbers and effective tiller numbers recorded with UDP could also be related to the underlying philosophy of row seedling transplanting under UDP. Sultana *et al*. (2012) reported significant increase in tiller number and effective tiller numbers with row spacing. Miah *et al*. (1990) stated that row spacing ensures plants grow well utilizing more solar radiation and nutrients with their aerial and underground parts. There is more available space, nutrient and solar radiation under row spacing.

5.4.4 Grains per panicle

Urea deep placement significantly impacted grains number per panicle. The grains per panicle increases with UDP over non-UDP by 16%. This is in consonance with the finding of Bandaogo *et al*. (2015) who observed that grains number per panicle significantly increased with deep placement of USG than PU. Rama *et al*. (1989) also reported that grains number per panicle was significantly greater due to deep placement of USG than prilled urea (PU).

The higher grain per panicle observed with deep placement of USG could be associated to reduced loss of N from soil with deep placement of USG. Incorporation of USG into the soil reduced the release of ammonium into floodwater and reduced ammonia losses. Deep placement of USG promotes slow N release over the critical growth period in synchrony with the plant demand.

5.4.5 Grain yield

Deep placement of USG significantly increased rice grain yield. This corroborates previous studies that UDP technology significantly increases rice yields over other N management practices used in flooded rice production systems (Savant and Stangel, 1990). Other authors such as Bowen *et al*. (2004) and Pasandaran *et al*. (1998) also reported significant yield impact with deep placement of USG over broadcasting of PU. Mamun *et al*. (2013) also reported that USG was better N fertilizer than PU in increasing grain yield. Deep N fertilizer placement of in the form of USG recorded the highest yield parameters which consequently produced higher grain yield. Rice grain yield increase could be attributed to the availability of N over the entire season with deep placement of USG that could increase rice growth. USG increases rate of absorption, enhances soil health and consequently impact yield (Savant *et al*., 1991).

5.4.6 1000 grain weight

Deep placement of USG did not statistically increase thousand grain weight. This gives credence to the findings of Mohammed *et al*. (2014) who observed that nitrogen management practices did not significantly impact 1000 grain weight. Hassan (2007) and Azam (2009) made similar observation. The observation could be due to multi-split broadcasting of prilled urea by non-UDP farmers at 7- 10 days following transplanting, at rapid tillering and before panicle initiation stage which made N available at grain filling stage which produced similar 1000 grain weight with UDP. According to Datta *et al*. (1986), nitrogen supply at the reproductive and ripening stages enhance grain filling which eventually increase the spikelets number per plant and the percentage of filled spikelets.

5.4.7 Relationship between transplanting dates and grain yield

Delaying seedling transplanting at the beginning of the season has a negative effect on rice grain yield. Generally, delaying seedling transplanting decrease grain yield in both UDP and non-UDP. This result is in conformity with findings of Salam *et al*. (2004) and Vishwakarma *et al*. (2016) who observed delayed rice seedling transplanting decreased rice grain yield.

The delay in transplanting of rice seedlings significantly impacted UDP than non-UDP field yields. This could be attributed to split application of N based fertilizers which was very frequent in non-UDP than UDP systems which can result in over application and or reduce root injury damages in non-UDP fields.

Root injury damage may be common in UDP fields due to toxicity effect of earlier ammonium-N fertilizers application on transplanted plants. Application of USG is followed by high ammonium release around the placement site in the soil system which becomes toxic to young tillers establishment and root elongation. The tendency of young rice roots to avoid toxicity of high ammonium concentration near the USG placement site can negatively affect rice nutrients uptake and physiological processes and furthermore impact on its growth and yield.

5.4.8 Relationship between soil Physico-chemical properties and grain yield

Bray P was the only soil parameter that showed a strong and positive relationship with grain yield ($r = 0.63$, $P < 0.05$). This confirms the work of Sahrawat and Sika (2002) who recorded a strong and positive relationship between Bray P and grain yield. This relationship could be associated to more availability and utilization of P under submerged soil conditions (Khalid *et al*., 1979). Ponnamperuma (1972) asserted that submerged soil conditions transform unavailable P to forms that can readily be utilized by irrigated rice crop.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

Nitrogen is a significant nutrient in the rice production system. The study aimed at validating the efficiency of the UDP technology under on-farm conditions. The study used socioeconomic, cultural and scientific surveys, field experiment and short time-lapse video to validate the efficiency of UDP technology over traditional N management. Fields in the zones were managed by two groups of rice producers, non-adopters and adopters of UDP technology.

The major findings are as follows:

- Rice farming in the Tono irrigation scheme was male dominated.
- UDP farmers were older than non-UDP farmers implying that age is likely to affect the adoption decisions of farmers.
- University education was the dominant level of education among UDP farmers. This implies that high education is likely to affect adoption decision of farmers.
- More UDP farmers received training and extension services from ATT project compared to their non-UDP counterparts. This could explain why UDP farmers adopted urea deep placement technology.
- Limited access to urea briquette, laborious and time-consuming nature of USG application and laborious and nature of row transplanting were major constraints of adption of UDP technology to non-adopters.

- Factors that influenced rice yield (output) are gender, education, farming experience and adoption of UDP. Output of farmers increased for farmers who are males, formally educated, more experienced and adopted UDP technology.
- UDP increased yield and yield components; tiller numbers, effective tiller numbers, grains per panicle and grain yield.
- Delayed seedling transplanting decreased grain yield for both UDP and non-UDP fields. The delayed in transplanting impacted UDP fields more than non-UDP fields.
- N management trials conducted in the scheme confirm the assertion that using UDP significantly increase rice yields over traditional farmer management practices.

6.2 Recommendations

The following recommendations are made, based on the study findings:

- Institutions responsible for disseminating UDP technology such as IFDC should assist farmers by making briquette machine and other input available in rice producing communities.
- Local research into machinery and simple tools to make the USG application fast as well as cheap is imperative.
- UDP technology can be used to improve rice yields in irrigated rice cropping systems

- A one-time field measurement for yields is not adequate and a multi-year or multi-seasonal research should be done to improve data accuracy.

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APPENDICES

APPENDIX 1: Time lapse camera video

Time lapse camera video of Rice development under UDP and non-UDP methods at Tono irrigation. Available at:

https://m.youtube.com/watch?v=MI3afKdsfoM&feature=youtu.be

APPENDIX 2

A SURVEY QUESTIONNAIRE FOR COLLECTING PRIMARY DATA FROM UDP AND NON-UDP RICE FARMERS IN TONO IRRIGATION SCHEME

Q1 - What is your name?

………………………………

Q2 - What is your gender?

(a) Male (b) Female

Q3 - How far away do you live from the Tono Irrigation Scheme?

(a)Less than 1 mile from Tono (b) 1 - 4 Miles (C) >4 miles

Q4 - What is your age?

(a)18-24 years old (b)25-34 years old (c)35-44 years old (d)45-54 years old (e)55-64 years old

(f)65-74 years old (g)75 years or older

Q5 - What is your education level?

(a)Primary School (b)Junior Secondary School (c)Senior Secondary School (d)University (e)Islamic (f)None

Q6 – Have you received any training from ATT or any other project?

(a)Yes (b) No

Q7 - How long have you been farming

(a)0-2 years (b)3-5 years (c)5-10 years (d)10-20 years (e)20-30 years (f)30 years or more

Q8 - How many farms do you have?

(a)1 (b)2 (c)>2

Q9 - Please define the ownership of your farmland?

(a)Self owned (b)Leased (c)Rented (d)Family owned

Q10 - Is farming your principle occupation? If yes, answer none in question 11.

(a)Yes (b) No

Q1-What other occupations do you have? …………………

Q12 - Do you have farms outside of the Tono Irrigation Scheme?

(a)Yes (b)No

Q13 - Which crops do you farm during the off season outside of Tono?

(a)Maize (b)vegetables (c)Soya (d)Others (e)None

Q14 - Which zone or zones do you farm in the Tono Irrigation Scheme?

…………………………………..

Q15 - How many hectares do you farm in the Tono Irrigation scheme?

(a)0 - 0.2 (b)0.2 - 0.4 (c)0.4 - 0.5 (d)0.5 - 1.0 (e)1.5 - 2.0 (f)>2.0

Q16 - How did you estimate the farm acreage?

(a)Project estimated (b)Self -declared (c)other

Q17 - How do you prepare your farmland?

(a)Manual (b)Tractor (c)Power tiller (d)Other

Q18 - Did you grow rice in Tono in 2017?

(a)Yes (b) No

Q19 - What variety of rice will you grow?

(a)AGRA rice (b)Gbewaa (jasmine 85) (c)Katanga (d)Togo marshal (e)Others

Q20 - Why did you choose that variety of rice?

……………………………………….

Q21 - How many weeks did you nurse the plants?

(a)1 (b) 2 (c)3 (d)4 (e)>4

Q22 - How many seedlings did you transplant on the average?

……………………………………………

Q23 - Did you thin out the seedlings?

(a)Yes (b)No

Q24 - How many weeks after transplanting did you thin? (If you did not thin, answer none)

(a)1 (b)2 (c) 3 (d)4 (e)>4 (f)none

Q25 - How many years have you used ATT recommended Urea Deep Placement technology? (Applicable to only UDP farmers)

(a)0 (b)1 (c)2 (d)3 (e)>3

Q26 - Do you use any basal fertilizer prior to transplanting?

(a)Yes (b)No

Q27 - If you answered yes to question 22, what type of fertilizer do you use? (If no, answer none)

Q28 - What other fertilizer do you use after transplanting?

………………………………………………..

Q29 - How many times do you fertilize after transplanting?

(a)Zero (b)Once (c) Twice > (d) two times

Q30 - What other fertilizer do you use after the urea briquettes placement if any? (Applicable to only UDP farmers)

……………………………………..

Q31 - How many times after the urea briquette placement do you fertilize? (Applicable to only UDP farmers)

(a)Zero (b)Once (c)Twice (d)> two times

Q32 - How do you pay for water?

(a)Taxed (b) Levi (c) By quantity of water used Water

Q33 - How do you manage your water throughout the growing season?

………………………………………………………

Q34 - Which pests and diseases have been a problem in the past?

…………………………………………………….

Q35 - How do you manage weeds?

(a)Chemicals (b)Manual labor (c)both (d)other

Q36 - How do you harvest the rice?

(a)Combine Manual (b) (Family Labor & Hired) (c) Rippers Hand Cutting (using sickle)

(d)Other

Q37 - How do you thresh the rice?

(a)Hand Threshing (b)Tractor Threshing (c)Combine harvester (d)Others

Q38 - How do you pay for the threshing?

(a)In Kind (b)Paid (c)Others

Q39 - Rank the following components of rice production in order of easiest to hardest (1 - 7).

(1) Nursery Establishment (2) Land Preparation (Leveling) (3) Transplanting (4) Fertilizing (5) Pest Control (6) Cutting (7) Threshing

Q40 - What do you think about UDP technology?

……………………………………………

Q41 - Will you use UDP technology in the future? (Applicable to non-UDP farmers only)

…………………………………………

Appendix 3: ANOVA table for plant population

Source	DF	SS	MS	F	P
Replication	4	0.7555	0.37776		
treatment	1	4.8562	4.85616	5.20	0.0310
Error	24	24.2622	0.93316		
Total	29	29.8739			

Appendix 4: ANOVA table for max tiller number

Source	DF	SS	MS	F	P
Replication	4	21.631	5.408		
Treatment	1	103.844	103.844	12.76	0.0015
Error	24	195.382	8.141		
Total	29	320.858			

Appendix 5: ANOVA table for effective tiller number

Source	DF	SS	MS	F	P
Replication	4	6.901	1.725		
Treatment	1	119.461	119.461	24.31	0.000
Error	24	117.956	4.915		
Total	29	244.317			

Appendix 6: ANOVA table for Grains per panicle

Source	DF	SS	MS	F	P
Replication	4	256.6	64.15		
Treatment	1	5808.8	5808.8	34.63	0.000
Error	24	4026.2	167.76		
Total	29	10091.6			

Appendix 7: ANOVA table for 1000 grain weight

Source	DF	SS	MS	F	P
Replication	4	2.0999	0.52498		
Treatment	1	1.9152	1.91521	2.36	0.1376
Error	26	19.4846	0.81186		
Total	29				

Appendix 8: ANOVA table for grain yield

Source	DF	SS	MS	F	P
Replication	4	3.1131	0.77828		
Treatment	1	5.5579	5.55788	6.76	0.0157
Error	24	19.7222	0.82176		
Total	29	28.3932			