Sudan University of Science and Technology

College of Graduate Studies

Effect of Organic, Inorganic Fertilizer and Biofertilizer on Growth, Yield and Quality of Rice (*Oryza Sativa* L.) Under Sudan Conditions

تأثير السماد العضوي والغير عضوى والحيوي على نمو وإنتاجية و جودة محصول الأرز تحت ظروف السودان

By

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الآية

قال تعالي:

(مَثَلُ الَّذِينَ يُنْفِقُونَ أَمْوَالَهُمْ فِي سَبِيلِ اللَّهِ كَمَثَلِ حَبَّةٍ أَنْبَتَتْ سَبْعَ سَنَابِلَ فِي كُلِّ سُنْبُلَةٍ مِائَةُ حَبَّةٍ وَاللَّهُ يُضَاعِفُ لِمَنْ يَشَاءُ وَاللَّهُ وَاسِعٌ عَلِيمٌ)

صدق الله العظيم

الآية (261) من سورة البقرة

Dedication

To soul of my father

To my beloved mother, brothers, sisters

To my lovely wife

To rest of my family and to all my friends.

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ABSTRACT

An experiment was conducted in the Demonstration Farm of College of Agricultural Studies, Sudan University of Science and Technology at Shambat. The study was conducted for two summer seasons: 2011/2012 and 2012/2013. to study the effect of organic and inorganic fertilizers on growth, yield, and quality of rice (*Oryza sativa* L.). The experiment was arranged in Split plots, in randomized complete block design (RCBD) with four replications. The main plots consisted of three varieties: Kosti1 and Omgar, (Sudanese release cultivars); Nerica4 (African cultivar). Sub plots consisted of six fertilizers treatments, viz: effective microorganism (EM) at the rate of 15 liters/ha; compost (COM) at the rate of15 tons /ha; pellet granules organic manure (PM) at a rate of 50kg/ha; urea 46%N + superphosphate 48% P_2O_5 (US) at the rate of 83 kg N/ha, 50 kg p/ha respectively; combination of urea + superphosphate + compost (USC) and control. The results showed highly significant effect of fertilizers and varieties on plant height (cm), number of leaves per plant, leaf area (cm^2), number of productive tillers, number of spikelets per spike, panicle length (cm), number of seeds per panicle, percentage of empty seeds, 1000-seed weight, yield, plant dry weight, harvest index, proximate chemical analysis and physico-chemical proprieties in the two seasons, There was no significant effect of fertilizers on days to 50% flowering, days to maturity and unproductive tillers in the two seasons. Also there were no significant differences between cultivars in number of unproductive tillers, number of seeds per panicle and most of proximate chemical analysis parameters except carbohydrate content. All parameters showed no significant response to interaction between cultivars and fertilizers except leaf area, productive tillers and number seed per panicle. There were highly significant differences between the two seasons in most parameters except unproductive tillers, days to 50% flowering, days to maturity, harvest index and all chemical characters studied except moisture content.

The study showed that biofertilizer and organic fertilizers gave good results and high yield as compared to inorganic fertilizers. Also the cultivar Nerica4 showed better performance in the two seasons than the other cultivars.

ملخص الأطروحة

أجريت التجربة فى الحقل التجريبى لكلية الدراسات الزراعية جامعة السودان للعلوم والتكنولوجيا بشمبات، في موسمين صيفيين 2012/2011 و 2013/2012. بغرض دراسة تأثير الأسمدة العضوية والأسمدة الحيوية على نمو، إنتاجية وجودة محصول الأرز. صممت التجربة كتجربة عاملية وأستخدم فيها تصميم القطاعات العشوائية الكاملة بأربعة مكررات، وزعت ثلاثة اصناف فى الوحدات التجريبية الأساسية وهى: كوستى 1 وأم جر (أصناف سودانية مجازة) ونيركا4 صنف إفريقى أما الوحدات الفرعية فوزعت فيها الأسمدة كالآتى: السماد الحيوى بمعدل 15لتر للهكتار، سماد الكمبوست بمعدل 15 طن للهكتار، السماد العضوى المحبب بمعدل 50 كجم للهكتار، سماد اليوريا 46% نيتروجين+السيوبرفوسفيت 48% P_2O_5 بمعدل 83كجم/هكتار و50كجم/هكتار على التوالى و خليط اليوريا+السيوبرفوسفيت+الكمبوست إضافةً الى الشاهد. أوضحت الدراسة أنه توجد فروقات معنوية عالية بين الأسمدة وكذلك بين الأصناف في: طول النبات (سم)، عدد الأوراق في النبات، مساحة الورقة، وعدد الخلف المنتجة، وعدد السنيبلات في السنبلة، طول السنبلة (سم)، وعدد البذور في السنبلة، ونسبة البذور الفارغة، ووزن الألف بذرة، والإنتاجية، الوزن الجاف للنباتات، دليل الحصاد، والمكونات الكيميائية والصفات الفيزيائية في الموسمين. لا توجد فروقات معنوية بين الأسمدة في: عدد الأيام الي 50% إزهار، عدد الأيام الي النضج و عدد الخلف الغير منتجة في الموسمين. كذلك لا توجد فروقات معنوية بين الأصناف في: عدد الخلف الغير منتجة، عدد البذورفى السنبلة وفى معظم المكونات الكيميائية ماعدا الكربوهيدرت. التداخل بين الأسمدة والأصناف أظهر لم يحدث فروق معنوية علي كل الصفات المدروسة ماعدا مساحة الورقة، عدد الخلف الغيرمنتجة وعدد البذورفي السنبلة. ووجدت فروقات بين الموسمين في معظم القياسات المدروسة ما عدا عدد الخلف الغير منتجة، عدد الأيام الي 50% إزهار، عدد الأيام الي النضج، دليل الحصاد وجميع المكونات الكيميائية المدروسة ما عدا محتوى الرطوبة.

الدراسة أوضحت أن السماد الحيوي و الأسمدة العضوية أعطت نتائج أفضل وإنتاج أعلى مقارنةً بالأسمدة الغير عضوية. أيضاً الصنف نيريكا4 كان أداؤه أفضل من الأصناف الأخرى في الموسمين.

LIST OF CONTENTS

CHAPTER THREE

CHAPTER FIVE

CHAPTER SIX

LIST OF TABLE

CHAPTER ONE
INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the genus *Oryza* and the tribe *Oryzeae* of the family Poaceae. There are two cultivated species of rice; *Oryza sativa* L. (2n=24 *AA*), the Asian rice, and *Oryza glaberrima* Steud. (2n=24, A^gA^g) the African rice. *O. sativa* L. constitutes virtually all of the worlds cultivated rice and is the species grown in the United State (Chang, 1976). Of the 25 species distributed in parts of Asia, Africa, Australia, Central and South America, the species *O. sativa* comprises numerous ecotypes or geographical races and several genetic groups (Raemaekers, 2001).

Rice is the world leading cereal crop for human utilization, with cultivated area of almost 150 million hectares and a total production of almost 600000tons annually (Khush, 2005). It occupies an important place in cereal crops (Irshad *et al.*, 2000). Rice is cultivated in at least 114, mostly developing countries and is the primary source of income and employment for more than 100 million households in Asia and Africa (FAO, 2004). Of the 840 million people suffering from chronic hunger, over 50% live in areas dependent on rice production (FAO, 2004). About 80% of the world’s rice is produced on small farms, primarily to meet family needs, and poor rural farmers account for 80% of all rice producers (FAO, 2004). Less than 7% of the world’s rice production is traded internationally (MacLean *et al.*, 2002). Rice is a main staple food in the world, especially Southeast Asia's population, who represent two-thirds of the world's population. The world population is expected to reach eight billion by 2030 and Rice production must be increased by 50% in order to meet the growing demand for the world (Khush and Brar, 2002). About 90% of the global rice area is in the Asia continent, where more than 90% of the world's rice is produced and consumed. Rice is cultivated in Asia in irrigated (57%), shallow lowland (33.5%), upland (6.4%) and deep-water (2.7%) ecosystems

(Kang and Priyadarshan, 2007). Paddy yield vary greatly according to the types of cultivation, growing conditions and varieties. The fluctuation is between a few hundred Kg/ha in traditional cultivation and 9t/ha in irrigated cultivation while the average yield in Africa is 2 tones/ha (Raemaekers, 2001). Intensive production of food crops to meet the growing demand for food in the world required increasing amounts of chemical fertilizers. However, the indiscriminate use of such agrochemicals affected soil fertility and productivity in addition to environmental pollution. Prior to the introduction of chemical fertilizers, agricultural production was dependant on the use of organic amendments, including chicken manure and crop residues to maintain soil fertility and productivity for more sustainable agriculture. Therefore, Organic farming has emerged as an important system that relies on ecosystem management rather than external agricultural inputs (Samman *et al*., 2008) and as a priority area in view of the growing demand for safe and healthy food and long term sustainability (Karmakar *et al*., 2007). Application of biofertilizers is highly considered to limit the use of mineral fertilizers and decreasing agricultural costs, maximizing crop yield by providing the available nutritive elements and growth promoting substances (Metin *et al.,* 2010).One of the environmentally sound approaches for nutrient management and ecosystem function is the use of soil microorganisms which can either fix atmospheric nitrogen, solubilize phosphate, synthesizing growth promoting substances or by enhancing the decomposition of plant residues to release vital nutrients and increase humic content of soils (Wu *et al*., 2005).

In Sudan exotic rice cultivation was introduced since 1906 but stopped for a long period of time (Farah, 1981). In the last ten years many nationalitys entered the Sudan in large numbers from Asia, such as Japanese, Chinese, Bangladeshi, Indian and others to work in oil companies and other activities, and brought with them their food cultures which relied on rice as major food.

This necessitated the cultivation of rice to fulfill their foods and reduce the import of rice and make it available. Therefore, it was grown on 7.60 thousand hectares in Sudan most of them in the White Nile and Gazira. A yield average of 3.95 ton/ha (AOAD, 2008).

The traditional agriculture predominates in the Sudan, most technical packages and applications of modern agricultural practices were not known to the farmers, such as fertilization. Despite the success, of use of chemical fertilizers to gain increased productivity of many crops, heavy application of chemical fertilizers may cause negative effects on the environment and the accumulation of certain substances that pollute the soil and discourage some minor elements to be unavailable to plant. This justifies the need for alternatives to chemical fertilizers, to avoid the negative effects of chemical fertilizers. Organic manures and bio-fertilizers are the most suitable affirmatives of chemical fertilizers because they possess many desirable properties and exert beneficial effects on the soil physical, chemical and biological characteristics. However, the most optimum organic and bio-fertilizer doses as well as their effectiveness for upland crops have not been studied in details. Therefore an attempt has been made to study the influence of organic and bio-fertilizer in comparison to chemical fertilizers on rice production with the following objectives:

1- To compare the effectiveness of organic and biofertilizer in comparison to inorganic one in growth and yield of Rice.

2- To study the effect of organic, inorganic and biofertilizer on quality of rice.

3- To compare two Sudanese release cultivars with one African cultivar.

CHAPTER TWO

LITERATURE REVIEW

2.1. History of the Domestication of Rice:

Rice has been found in archaeological sites dating to 8000 BC, although the date of rice domestication is a matter of continuing debate. Two species of domesticated rice, *Oryza sativa* (Asian) and *Oryza glaberrima* (African) are grown globally. Numerous traits separate wild and domesticated rice including changes in: pericarp colour, dormancy, shattering, panicle architecture, tiller number, mating type and number and size of seeds.

The evolutionary history of rice is complex, but recent work has shed light on the genetics of the transition from wild (*O. rufipogon* and *O. nivara*) to domesticated (*O. sativa*) rice. The types of genes involved and the geographic and genetic distribution of alleles will allow scientists to better understand our ancestors and breed better rice for our descendents. Rice is the world's largest food crop, providing the caloric needs of millions of people daily. There are two distinct types of domesticated rice, *Oryza sativa*, or Asian rice and *Oryza glaberrima*, African rice, both of which have unique domestication histories. In order to examine the variation selected by humans over our long relationship with rice, we must first look at the ancestors of our modern cultivars. The genus *Oryza* contains 21 wild relatives of the domesticated rice (Vaughan *et al*., 2003). The genus is divided into four species complexes: the *O. sativa*, *O. officialis*, *O. ridelyi* and *O. granulata* species complexes. All members of the Oryza genus have n = 12 chromosomes and while interspecific crossing is possible within each complex, it is difficult to recover fertile offspring from crosses across complexes (Vaughan *et al*., 2003). The O. sativa complex contains two domesticated species: *O. sativa* and *O. glaberrima*, and five or six wild species: *O. rufipogon*, *O. nivara* (also considered to be an ecotype of *O. rufipogon*), *O. barthii*, *O. longistaminata*, *O. meridionalis* and *O.*

glumaepatula, all of which are diploids. *Oryza sativa* is distributed globally with a high concentration in Asia, while *O. glaberrima* is grown in West Africa. *Oryza rufipogon* can be found throughout Asia and Oceania. *Oryza barthii* and *O. longistaminata* are African species, *O. barthii* endemic in West Africa and *O. longistaminata* is found throughout Africa. *Oryza meridionalis* is native to Australia and *O. glumaepatula* is endemic in Central and South America. Given these distributions, it is easy to locate the ancestral pools from which modern rice were extracted. The African cultivars were domesticated from *O. barthii* (formally called *O. breviligulata*) and *O. sativa* was domesticated from *O. rufipogon*. There is still continuing debate over whether *O. rufipogon*, the perennial species, *O. nivara*, the annual species, or possibly both were the direct ancestors of *O. sativa*. For the purpose of this review we will reserve judgment and refer to both the annual and perennial forms as O. *rufipogon*.

2.2. Rice adaptations:

2.2.1. Temperature:

Rice (*O. sativa and O. glaberrim*) is one of the world's most important crops, particularly in Asia, but increasingly so in Africa and Latin America as well. Rice is extensively grown in irrigated cropping systems, allowing production in the warmer, high radiation post-monsoon and summer months. Rice production has also intensified in rainfed, lowland and dry land (upland) cropping systems, many of which are prone to drought and high temperatures (Coffman, 1977). Furthermore, global climate change is likely to exacerbate the current vulnerability of the crop to climatic change, with a projected global average surface temperature increase of 1.4–5.8 C^{o} by 2100 and the possibility of increased variability in this temperature range (IPCC, 2001). Simulations by Horie *et al*. (1996), for example, have suggested that the yield of current varieties in southern Japan would be reduced by up to 40% in future climates. Flowering (anthesis and fertilization), and to a lesser extent booting (microsporogenesis), are the most susceptible stages of development to temperature in rice (Satake and Yoshida, 1978; Farrell *et al*., 2006). Previous studies, summarized by Satake and Yoshida (1978), have shown that spikelets at anthesis that are exposed to temperatures >35ºC for about 5 days during the flowering period are sterile and set no seed. Sterility is caused by poor anther dehiscence and low pollen production, and hence low numbers of germinating pollen grains on the stigma (Matsui *et al*., 2000, 2001; Prasad *et al*., 2006). There is genotypic variation in spikelet sterility at high temperature (Matsui *et al*., 2001; Prasad *et al*., 2006) that can be defined by different temperature thresholds (Nakagawa *et al*.,2002). It has been suggested that *Indica spp* are more tolerant to higher temperatures than *Japonica spp* (Matsui *et al*., 2000), although heat tolerant genotypes have been found in both subspecies (Prasad *et al*., 2006; Matsui *et al*., 2001). Genotypes N22 (Prasad *et al*., 2006) and Akitakomachi (Matsui *et al*., 2001) are the most tolerant genotypes found to date among *indica* and *japonica spp*, respectively. The response to duration of exposure to temperature >35ºC appears to be quantitative, with shorter durations at higher temperatures having the same effect as longer durations at cooler temperatures (Satake, 1995). However, interactions between temperature degree and duration have not been quantified. Where responses to high temperature have been modeled, spikelet sterility increases in response to daily maximum temperature (Nakagawa *et al*., 2002). If there is an interaction between temperature degree and duration, then the response of spikelet fertility to temperature may be better modeled by a cumulative temperature response above a threshold temperature for peanut (Vara Prasad *et al*., 1999). Furthermore, if only a short period of high temperature causes sterility, then the timing of this episode in relation to peak flowering will be critical, both for phenotyping (i.e. to differentiate between escape and absolute tolerance) and modeling the impact of high temperature (Wheeler *et al*., 2000). It follows that effects of temperature on flowering pattern, which have not been studied, are also likely to be important with respect to escape and the total number of spikelets.

2.2.2. The effect of heat during anthesis in rice:

Rice is increasingly cultivated in more marginal environments that experience warmer temperatures where day/night temperatures average 28/22ºC (Prasad *et al*., 2006). In these environments, day temperatures frequently exceed the critical temperature of 33ºC for seed set, resulting in spikelet sterility and reduced yield (Nakagawa *et al*., 2002). The vulnerability of the crop will be increased with a projected global average surface temperature increase of 2.0–4.5ºC and the possibility of increased variability about this range by the end of this century (IPCC, 2007). Hence, in the future, rice will be grown in much warmer environments (Battisti and Naylor, 2009) with a greater likelihood of high temperatures coinciding with heat-sensitive processes during the reproductive stage. Seed set under high ambient air temperature primarily depends on successful pollination and fertilization. As was shown in reciprocal studies with pollen from control plants on heat-stressed pistils and vice versa, the male gametophyte and not the pistil, is responsible for spikelet sterility under high temperature in rice (Yoshida *et al*., 1981). Morphologically, large anthers (Suzuki, 1981) and longer stigmas (Suzuki, 1982) contribute to increased tolerance to cold stress during the booting stage, and the same may be true for high temperature tolerance at flowering (Matsui and Omasa, 2002). Among physiological processes occurring at anthesis, anther dehiscence is perceived to be the most critical stage affected by high temperature (Matsui *et al*., 1997;2001). Spikelet opening triggers rapid pollen swelling, leading to anther dehiscence and pollen shedding from the anthers’ apical and basal pores (Matsui *et al*., 1997). Increased basal pore length in a dehisced anther was found to contribute significantly to successful pollination (Matsui and Kagata, 2003), probably because of its proximity to the stigmatic surface. Longer stigmas may also be important for the same reason. After pollination, it takes about 30 min for the pollen tube to reach the embryo sac (Cho, 1956). Genotypic differences in pollen number and germinating pollen on the stigma and spikelet fertility (Matsui and Omasa, 2002; Prasad *et al*., 2006) under high temperatures in rice have been well described. Similarly, in several other crops, pollen germination and pollen tube growth are shown to be sensitive to high temperatures (Kakani *et al*., 2005; Salem *et al*., 2007).

2.2.3 Effect of water in Rice:

Water deficit has been described as the single physiological and ecological factor upon which plant growth and development depends more heavily than other factors (Kramer and Boyer, 1995). Climate change especially access to water threaten rice yields. Any shortage in water supply in relation to the requirement of plants results in water deficit hence plants become stressed. Water deficit evokes responses in plants which are based on the development of physiological drought making soil water unavailable to the plant. Water content has been widely used to quantify the water deficits in leaf tissues. Leaf water content is a useful indicator of plant water balance since it expresses the relative amount of water present on the plant tissues (Yamasaki and Dillenburg, 1999). The species adapted better to dry environments have higher relative water content at given water potential. Water deficit also causes leaf water potential and rates of elongation to decline more rapidly in rice than in maize or sorghum so that dry matter accumulation and nutrient uptake decline or cease. Leaf dehydration can be minimized by decreasing evapotranspiration or by increasing water absorption from the drying soil (Chaves *et al*., 2003). It has been established that water deficit is a very important limiting factor at the initial phase of plant growth and establishment. It affects both elongation and expansion growth (Anjum *et al*., 2003). Water stress causes deceleration of cell enlargement and thus reduces stem lengths by inhibiting inter nodal elongation and also checks the tillering capacity of plants. The importance of root system in acquiring water has long been recognized. A prolific root system can confer the advantage to support accelerated plant growth during the early crop growth stage and extract water from shallow soil layers that is otherwise easily lost by evaporation in legumes (Johansen *et al*., 1992). Differences in root length could confer tolerance to drought by some varieties. Greater plant fresh and dry weights under water deficit conditions are desirable characters. A common adverse effect of water deficit on crop plants is the reduction in fresh and dry biomass production. However some genotypes shown better stress tolerance than the others. Studies by Mohammadian *et al*. (2005) showed that mild water stress affected the shoot dry weight while shoot dry weight was greater than root dry weight loss under severe stress in sugar beet genotypes. Wullschleger *et al*. (2005) reported a decrease in the root dry weight under mild and severe water stress in populous species. Chlorophyll is one the major chloroplast components for photosynthesis and relative chlorophyll content has a positive relationship with photosynthetic rate. Chen *et al*.(2007) noted that assessment of pigment content has become an effective means of monitoring plant growth and estimating photosynthetic productivity while Fillella *et al*.(1995) reported that remote estimates of pigment concentration provides an improved evaluation of the spatial and temporal dynamics of plant stress. Chlorophyll concentration has been known as an index for evaluation of source therefore a decrease of this can be consideration of a non stomata limiting factor in the drought stress conditions. Water stress is reported to inhibit the incorporation of amino acids into proteins and to cause a decrease in the protein content of the tissues. Water deficit impedes protein synthesis at the ribosomal level: some proteins are apparently formed and inactivated quickly whereas others appear to be relatively stable. Studies on sunflower by Rao *et al.* (1987) showed that water deficit reduces seed protein content. Protein content, particularly soluble protein usually falls to about 40-60% of the initial content as the water deficit becomes intense in drought sensitive plants. Leaf chlorophyll fluorescence probe is a powerful and sensitive intrinsic measurement of the photosynthetic process that can be used to detect the influence of various environmental stress factors. According to Maxwell and Johnson (2000) the measurement of chlorophyll fluorescence in situ is a useful tool to evaluate the tolerance of the photosynthetic apparatus to environmental stress which reduces the maximum efficiency of PSII photochemistry. It is used to determine how light use efficiency for photosynthesis occurs at the cellular level. It can also be used to estimate the activity of the thermal energy dissipation in photosystem II which protects photosystems from the adverse effects of light and heat stress.

2.2.4. Rice and Salinity:

Unfortunately, rice is one of the most salt-sensitive cereal crops (Maas and Hoffman 1977). Previous studies of plant responses to salt stress have identified different physiological and morphological characters determining salt tolerance in plants Khatun (1995). For example Asch *et al.*, (1997); Maas and Hoffman (1977) demonstrated that ion uptake in rice was influenced by the growth of root systems. Ion concentration in leaves, an important parameter for assessing salt damage, depends on ion uptake, translocation, and plant growth. Plant growth vigor, e.g. plant height or shoot biomass, was reported to have dilution effects on sodium accumulation in leaves of rice Khatun (1997). Leaf area can also affect sodium concentration in rice leaves by confounding effects of dilution and the transpiration driving force Maas and Hoffman (1977); Shalhevet (1994). Additionally, leaf area has been shown to be highly correlated to grain yield in rice under salt stress Sharma and Sharma (1999). Finally, panicle weight, tiller numbers per plant, and harvest index are important agronomic characters for the prediction of final yield in rice.

These yield components are severely affected by salinity Zeng *et al*., (2003). One major approach in plant breeding is to maximize the genetic diversity between parental genotypes for intercrosses. Genetic diversity between parental genotypes is usually estimated by measurements of physiological and morphological differences of quantitative and economically important traits. The disadvantages of this conventional approach are the cost of time and labor during the measurements, and the influences of environmental factors. Often, these disadvantages are exacerbated in salt-tolerance breeding. For example any change in environment such as temperature, light or humidity can dramatically change the transpiration driving forces and, subsequently, ion uptake Khatun (1997); Zeng and Shannon (2000). Such changes may alter salt tolerance among genotypes. It is important to note that morphological characters are often limited in their numbers and may not adequately represent actual genetic relationships among genotypes.

2.3. Rice Fertilization:

2.3.1. Organic manures:

The organic fertilizer is traditionally an important source for supplying nutrients. Application of organic manures for increasing soil fertility has gained importance in recent years due to high cost and adverse impact of fertilizers. Incorporation of organic manures has given a hope to reduce the cost of production and minimize adverse effects of chemical fertilizers.. Shukla *et al.* (2001) reported higher growth and yield due to addition of poultry manure plus green manure. Use of farmyard manure not only acts as a source of N and other nutrients but also increases the efficiency of applied nitrogen (Sarvanan *et al*., 1987).Organic matter determine the fertility and nutrient status of a soil. Most of the tropical and sub-tropical regions are deficient in organic matter. The maintenance of soil organic matter around 2.5 to 3.0 % is desirable for satisfactory crop production. A good soil should have organic matter content of about 2.5% (BARC 1997).

2.3.2. Effective Microorganisms (EM):

A microbial culture named "Effective Microorganisms" (EM) was developed by Professor Teruo Higa of the University of Ryukyus, Japan after he began his

EM technology research in 1984, with the purpose of improving soil quality, soil health, and the growth, yield and quality of plants (Higa and Parr, 1994). Microorganisms are often used in organic agriculture, as they are useful for eliminating problems associated with chemical fertilizers and pesticides (Higa and Parr, 1994).

Effective microorganisms consist of around 80 species of selected beneficial microorganisms including lactic acid bacteria, yeasts, photosynthetic bacteria, and actinomycetes, among other types of microorganisms such as fungi (Xu, 2000). These produce a wide range of benefits arising from the increased microbial diversity in the soil as well as the individual effects of the particular types of microorganisms. Benefits to soil and plant health include the fixation of atmospheric Nitrogen, decomposition of organic wastes and residues, suppression of soil borne pathogens, and the increased availability of plant nutrients (Higa and Parr, 1994). It has been shown that the application of EM can improve photosynthetic efficiency and capacity due to an increase in nutrient availability, as well as increase root mass (Yamada and Xu, 2000).

Effective microorganism is an organic fertilizer used for soil and plant application to promote growth and increase yield, and is made from a solution of EM and molasses, usually added to bran or straw and then fermented (Daly and Okuda, 1998). It can also be made with oilseed cake, rice husk and bran, and fish processing waste (Xu, 2000). EM bokashi has been found to be a rich nutrient source (Xu *et al.*, 2000), as the addition of EM greatly accelerates the breakdown of the organic matter in the bokashi (Attanayake *et al.*, 1993). A microbial fermentation product containing dead microorganisms that promotes growth by stimulating microbial activity. Use of the microorganisms as environment friendly biofertilizer helps to reduce the use of much expensive phosphatic fertilizers. Phosphorus biofertilizers could help increase the availability of accumulated phosphate (by solubilization), efficiency of biological nitrogen fixation and increase the availability of Fe, Zn etc., through production of plant growth promoting substances (Kucey *et al.,* 1989). Trials on phosphate solublizing bacteria (PSB) indicated yield increases in rice (Tiwari *et al.,* 1989) and other cereals (Afzal *et al.,* 2005; Ozturk *et al.,* 2003). Ravikumar *et al.,* (2013) recorded that biofertilizer affected the inoculation of phosphate solublizing bacteria (PSB) which had a positive effect on growth, nutrient uptake, grain yield and yield components of *Oryza sativa.*

2.3.3. Nitrogen:

Nitrogen (N) is an essential nutrient of rice production, but excessive N application (as in organic sources) would lead to increased production cost and negative effects of blocking agricultural sustainable development such as environmental pollution and rice quality decline (Ghen *et al,* 2011). Nitrogen is the main nutrient associated with yield, its availability promotes crop growth and tillering, finally determining the number of panicles and spikelets during the early panicle formation stage. This nutrient also provides sink during the late panicle formation stage (Hirzel *et al,* 2011). Some of the promising N management techniques inclued split application, rate and timing of N rate critical for optimum rice grain yield (Doberman and fair hurst, 2000). So it is essential to find out the optimum rate of nitrogen application for efficient utilization of this element by the plants for better yield. The rice hybrid often benefit in rough and whole grain when N is top-dressed at the panicle emergence (early heading) growth stage (Walker, 2006). Nitrogen contributes to spikelet production during the early panicle formation stage, and contributes to sink size by decreasing the number of degenerated spikelets and increasing hull size during the late panicle formation stage. Nitrogen contributes to carbohydrate accumulation in culms and leaf sheaths during the pre-heading stage and in grain during the grain-filling stage by being a fertilization to prevent the occurrence of N deficiencies, as well as to prevent over fertilization, which contributes to increase lodging, poor grain filling due to mutual shading, and increased severity and incidence of diseases (Ghanbari-Malidareh-2011).

Rice tillering is an important agronomic trait for grain production and the number of tillers is dynamic and adjustable, although moderate tillering contributes greatly to rice yields, excessive tillering leads to high tiller abortion, poor grain setting, and small panicle size and ultimately reduces grain yield (Liu *et al*, 2011). Top dressing of N at heading helped the plants to maintain a high photosynthesis rate, with a subsequent significant increase of grain-filling rate, grain-filling duration, and higher percentage of filled grains, compared with basal application or top dressing of N at tillering (Wei *et al*, 2011). it is important that rice breeders consider selecting genotypes with high efficiency in remobilizing N from vegetative parts to the grain or genotypes with high grain protein concentration. Increase grain yield can be attributed to an increase in the number of grains per panicle (Ghanbari-Malidareh-2011). (Irshad *et al*, 2000) suggested that for getting maximum yield at least some nitrogen must be applied at tillering stage along with that applied at transplanting. Nitrogen is one of the most yield-limiting nutrients in lowland rice production, and proper N management is essential for optimizing rice grain yields (Fageria *et al.*, 1997). However, the energetic cost of synthesizing N fertilizers is very high and N fertilization often represents the most expensive energy input in cereal-based cropping systems (Crews and Peoples 2004). Nitrogen fertilization has been an essential tool for increasing crop yield and quality, especially for cereals, and for ensuring maximum economic yield (Hirel *et al.*,2001). World consumption of N fertilizers has averaged 83 million metric tons (Mt) in recent years, of which about 47 Mt is applied to cereal crops. Furthermore, the N fertilizer rate that produced maximum grain yield also produced the highest head rice yield (Bond and Bollich, 2007). Nitrogen rates for optimum grain yield vary based on cultivar and soil texture (Walker 2006). Furthermore, rice cultivars commonly grown in the lowland require and respond to large amounts of N. At a global scale, cereal production, cereal yields, and fertilizer nitrogen consumption have increased in a near-linear fashion during the past 40 years

(Dobermann 2005). More than 70% of the world's rice is produced in intensively cultivated, irrigated lowland systems (IRRI 1997). In these systems, large amounts of mineral nitrogen fertilizers are used. In general, a given percentage increase in yield will do much more for profitability than a similar percentage reduction in nitrogen use, because the ratio of nitrogen costs to gross revenue from paddy is typically 8% or less Dawe (2000). Also, reduction in nitrogen use may be possible in some areas without any sacrifice in yields (Wang *et al.,* 2001). While rice production in much of the world increasingly focuses on optimizing grain yield, reducing production costs, and minimizing pollution risks to the environment (Koutroubas and Ntanos, 2003). Increasing the nitrogen concentration in rice does not always increase grain yield due to diminishing returns, and it is not always optimal from an economic perspective (Samonte *et al.,* 2006), Although, the excessive use of nitrogen increases incidence of foliar pathogens and plant lodging (Samonte *et al.,* 2006).

Nitrogen and phosphorus fertilizers are major essential plant nutrients and key input for increasing crop yield (Alam *et al.,* 2009; Alinajoati and Mirshekari 2011; Dastan *et al.,* 2012). Nitrogen deficiency generally results in stunted growth and chlorotic leaves due to poor assimilate formation that leads to premature flowering and shortening of the growth cycle. Several field research reports have indicated that high and sustainable crops yields are only possible with integrated use of mineral fertilizer with organic manure (Satyanarayana *et al.,* 2002). Complementary application of organic and inorganic fertilizers increase nutrient synchrony and reduces losses by converting inorganic nitrogen to organic forms (Kramer *et al.*, 2002). Synthesis of chemical fertilizers consumes a large amount of energy and money. However, an organic farming with or without chemical fertilizers seems to be possible solution for these situations (Prabu *et al.,* 2003). The integration of organic sources and synthetic sources of nutrients not only supply essential nutrients but also have some positive interaction with chemical fertilizers to increase their efficiency and thereby reduce environmental hazards. There are two broad categories of soil amendments: organic and inorganic. Organic amendments come from something that is or was alive. Inorganic amendments, on the other hand, are either mined or man-made (Davis and Wilson, 2008). Organic matter improves soil aeration and water infiltration, and it also improves both water and nutrient-holding capacity of soils. They increase water retention by the soil and are important in maintaining soil tilth (Sarka and Siegh 2002). Ball *et al.*, (2005) noted that organic fertilizers are also responsible for the formation of soil aggregates. Livestock manure supplies all major nutrients (N, P, K, Ca, Mg, S,) necessary for plant growth, as well as micronutrients (trace elements), hence it acts as a mix fertilizer (Tremblay *et al.*, 2011). Manure application in a given year will influence not only crops grown that year, but also crops in the succeeding years, because decomposition of the organic matter is not completed within one year (Bayu *et al.*, 2006). Application of organic materials as fertilizers provides growth regulating substances and improves the physical, chemical and microbial properties of the soil (Belay *et al.*, 2001).

2.4. Nutrient Deficiency Symptoms in Rice:

Symptoms of nutrient deficiency or toxicity are not always readily apparent in a growing crop. Often, more than one nutrient or growing condition may be involved. In many field situations, when a deficiency is identified, it may be too late for treatment to correct the problem in the current crop. Leaves are yellowish-green in the omission plot where N has not been applied. Greater tillering occurs where N fertilizer has been applied. The following pages present some photos and brief information describing symptoms of nitrogen (N), phosphorus (P), potassium (K), and zinc (Zn) deficiencies in rice (BCI. 2002).

2.4.1 Nitrogen:

Nitrogen deficiency is the most commonly detected nutrient disorder observed in rice. Old leaves and sometimes all leaves become light green and chlorotic at the tip. Leaves die under severe stress. Except for young leaves, which are greener, deficient leaves are narrow, short, erect, and lemon yellowish. The entire field may appear yellowish. Nitrogen deficiency often occurs at critical growth stages such as tillering and panicle initiation, when the demand for N is large (BCI. 2002).

2.4.2. Phosphorus:

Stunted, dark green plants with erect leaves and reduced tillering may signal P deficiency. Leaves are narrow, short, very erect, and ‘dirty’ dark green. Stems are thin and spindly, and plant development is retarded. The number of leaves, panicles, and grains per panicle may also be reduced. Young leaves may appear to be healthy, but older leaves turn brown and die. Red and purple colors may develop in leaves if the variety has a tendency to produce anthocyanin. Leaves appear pale green when N and P deficiency occur simultaneously. Phosphorus is particularly important in early growth stages. It is mobile within the plant and promotes root development, tillering, early flowering, and ripening (especially where the temperature is low). Addition of mineral P fertilizer is required when the rice plant’s root system is not yet fully developed and the native soil P supply is small. Phosphorus is remobilized within the plant during later growth stages if sufficient P has been absorbed during early growth. Zinc deficiency results in stunting and uneven plant growth, as shown in foreground. Growth may be greatly reduced by Zn deficiency (at left in photo).Tillering is reduced where P is deficient. Even under less pronounced P deficiency, stems are thin and spindly, and plant development is retarded. Phosphorus-deficient plants are stunted and small (BCI. 2002).

2.4.3. Potassium:

While K does not have a pronounced effect on tillering, it does affect the number of spikelets per panicle, percentage of filled grains, and grain weight. Potassium improves the rice plant's tolerance of adverse climatic conditions, lodging, insect pests, and diseases. Deficiency symptoms tend to occur in older leaves first, because K is very mobile within the plant and is translocated to young leaves from old senescing leaves. Often, yield response to K fertilizer is observed only when the supplies of other nutrients, especially N and P, are sufficient. Dark green plants with yellowish brown leaf margins or dark brown necrotic spots first appear on the tips of older leaves. Under severe K deficiency, leaf tips are yellowish brown. Symptoms appear first on older leaves, then along the leaf edge, and finally on the leaf base. Upper leaves are short, droopy, and "dirty" dark green. Older leaves change from yellow to brown and, if the deficiency is not corrected, discoloration gradually appears on younger leaves. Leaf symptoms of K deficiency are similar to those of tungro virus disease. Unlike K deficiency, however, tungro occurs as patches within a field, affecting single hills rather than the whole field. Leaf margins become yellowish-brown when K is deficient. Dark brown spots appear on the leaf surface. Leaf bronzing is also a characteristic of K deficiency. Potassium deficiency symptoms are more likely to occur in hybrid rice (at left in photo) than in modern inbred varieties (right). Rice yields are often constrained by unbalanced fertilization where the response to N and P is constrained by insufficient K. Potassium-deficient rice plant roots may be covered with black iron sulfide (photo at left), compared with healthy rice roots which are covered with red-brown iron oxide (photo at right) (BCI. 2002).

2.4.4. Zinc:

Zinc deficiency symptoms are more common on young or middle-aged leaves. Dusty brown spots appear on upper leaves of stunted plants, sometimes two to four weeks after transplanting, with uneven plant growth and patches of poorly established hills. Under severe deficiency, tillering decreases and time to crop maturity may be increased (BCI. 2002).

2.5. Weed control:

Continuous rice cropping in the lowlands has resulted in serious weed problems. Weeding by hand is the common practice of controlling weeds in the Sub-Saharan African. This method is tedious due to shortage of labor and as such is usually curtailed and inadequately executed resulting in yield reductions (Rodenburg *et al.,* 2006). Common agronomic factors that contribute to weed problems are inadequate land preparation (soil tillage, soil leveling in lowland areas), inadequate water management, labor shortages for hand weeding, delayed and incorrect use of herbicide applications, non use of weed competitive varieties and other interventions (Becker and Johnson, 2001; de Vries *et al.,* 2010).

The use of herbicides have been effective in controlling weeds but because of the high rates normally recommended by manufacturers and cost involved in the purchase of herbicides, farmers hardly apply them. In addition, African farmers often lack sufficient financial means for the purchase of the product and application and protection equipment (Balasubramanian *et al.,* 2007). The incorrect use of herbicides, caused by the above cited problems, may accelerate the evolution of herbicide resistance in weeds (Johnson, 1995). Effective weed management involves the integration of many practices. Herbicides are undeniably the most effective, reliable technology available today for weed control in rice (Marwat *et al.,* 2004). However, an integrated approach involving the minimal use of chemicals with proper use of other cultural weed control and management techniques such as good land preparation and/or use of weed suppressive varieties will reduce the farmer’s dependence on a heavy application of herbicides and thus offers the best hope for increasing food production (Shakoor *et al.,* 2000).

2.6. Rice and climatic changes:

Nearly 50% of the world’s population depended on rice for a substantial amount of its calories (>800 kcal/person/day) (Nguyen, 2008). Population increases and climatic change have made it difficult to meet demand for rice (Teixeira *et al.*, 2011; Laborte *et al.*, 2012). However, yields in some areas have increased due to advances in plant breeding and crop management. A number of cultivars now offer increased yield potential (Moldenhauer *et al.*, 2001). Elite hybrid rice has increased yields 10-30% compared to elite inbred lines (Bueno and Lafarge, 2009).

Raising the yield potential may be possible through higher yielding varieties and reducing the yield gap in farmer’s fields (Laborte *et al.*, 2012).

Exploring new regions for rice production could help meet world demand. Rice has been raised from latitudes 53⁏N to 40⁏S, though 75% of global rice production in 2004 was in tropical regions (Nguyen, 2008). Rice grown outside of the temperate region is grown in the Tropics of Cancer and Capricorn. However, temperate rice generally has greater yields (Nguyen, 1998). In contrast to tropical regions, whose high temperatures can constrain rice production (Nguyen, 2008), example northern Missouri’s growing season temperatures and rainfall may increase the growing period and suitable land (Olesen and Bindi, 2002). Although damage from low temperatures commonly occurs in temperate regions and can reduce yield up to 30% (Yoshida, 1981), climate change may make this region even more favorable to rice production. With the growing worldwide demand for food and fiber, we felt it was time to evaluate new cultivars and their production potential in the region. In addition, with the need for cost-effective pharmaceutical production, crops have been targeted as an option for producing large quantities of pharmaceuticals (Elbehri, 2005). In 2005, there were 84 biopharmaceuticals serving 60 million patients (Elbehri, 2005). Rice has potential for pharmaceutical production because it is self-pollinated, has limited allergenic properties that can be removed, and because this region is isolated from commodity rice production. Two rice protein fractions are allergenic: glutelin, and globulin (Shibasaki *et al.*, 1979). These are easily extracted from rice grain endosperm using low concentrations of NaCl (Matsuda *et al.*,1988). In another study, rice grains pressurized at 100-400 MPa in distilled water released 0.2-2.5 mg per gram of proteins, which included globulins (Kato *et al*., 2000). Rice self pollination occurs for a very short time period, generally in the morning. Pollen grains are viable for approximately 5 minutes after emerging from the anther of the flower, thus reducing cross-pollination to less than 1% (Yoshida, 1981) and limiting pollen drift. In addition, this region may be ideal for biopharming due to strict federal requirements that pharmaceutical plants not enter the food and commodity population (Elbehri, 2005). This region is isolated from commodity rice production and has no known red rice (*Oryza sativa* L.), thus avoiding possible gene transfer.

2.7. Rice in Sudan:

In the Sudan, rice has been grown since 1905, but on limited acreage and information about methods of reproduction is lacking (Farah, 1981). Swamp and upland varieties were first tried at the Gezira research farm in 1951. Later, extensive rice trials were carried out at Malakal and several varieties were selected at the Gezira Research Station. Although rice cultivation in the Sudan was known for some time, especially in southern Sudan and the White Nile area, large scale production started only in the year 1950 in the upper Nile province (Malakal) and in 1960 in Aweel. But for security reasons production was abandoned. Rice production was started once again along the White Nile at Abu Gassaba (Awok *et al*., 1996).

Since 1974 up to 1979 rice research at Gezira research station has identified many of the major constraints to high yields in the Gezira. Environment and optimum cultural practices for the crop are now well established and grain yield of 6.7 tones/ha was obtained. Despite this, the

Agricultural policies did not encourage its production (Ghobrial, 1981). In recent ten years many nations entered the Sudan in large numbers from Asia, such as Japanese, Chinese, Bangladeshi, Indian and others to work in oil companies and take with them their food cultures which relied on rice as major food, making the government encourages the cultivation of rice again to fill their need of foods and reduce the import of rice and make it available. Rice in Sudan is grown on 7.60 thousand hectares producing 30 thousand tones. However, Sudan produce an average of 3947 kg/ha (AOAD, 2008).

2.8. Rice quality:

Most of the rice produced in the world is consumed as whole grain and the grain physical and chemical characteristics are therefore very important. There are different market classes of rice that are defined by a matrix of traits which include grain dimensions, grain chemistry, and grain appearance (Webb, 1991). Long Grain Rice has kernels which are 3 to 4 times longer than their width and relatively high amylose content (>20%) which causes the grains to remain separate after cooking. In the USA, certain long grain cultivars (e.g., Rexmont, Dixiebelle) with high amylose content (>24%) are recommended for canning purposes. Medium Grain Rice has kernels that are 2 to 2.9 times longer than their width and relatively low (16-18%) amylose content. Short Grain Rice has grain that is almost round with the kernels being 1.9 times longer than their width. Kelly, (1985) reported that medium and short grains are used for products that are served cold. Glutinous Rice is also called Sweet or Waxy Rice and the kernels are completely opaque white. Aromatic Rice possesses a natural flavor that is similar to buttered popcorn in aroma. The most popular types of aromatic rice are Basmati from India and Pakistan and Jasmine from Thailand. The primary chemical components of the grain are starch, protein and lipids. According to Kelly (1985), these components determine how the rice whole grain, flour, or starch can be used. Milling yield of rice is considered to be the most important component of quality (Adair *et al.*, 1973; Spadaro *et al.*, 1980). In the USA, a one percent change in breakage can cause a $100,000 difference in profit for an average-sized rice mill (Hosney, 1998). Cultivars grown in the world have variable cooking, sensory and processing qualities. Many chemists began to look into these cultivar differences in rice end-use in the twentieth century. The primary work on grain quality was conducted by Warth and Darabsett (1914) who studied the rice kernel response to dilute alkali. In the USA, three categories of rice - long, medium and short grain types - were found (Adair *et al.*, 1973). Progress was made in the USA since the inadvertent release of typical long-grain rice Century Patna 231 in the 1920s. Century Patna 231 had the dimensions of typical U.S. long-grain rice. Unfortunately, it had different cooking and processing characteristics. It was a financial disaster for the rice industry. In the 1950s, criteria were established by the rice industry in the USA. These criteria must be met before the release of any cultivar (Mackill and McKenzie, 2003). In collaboration with other scientists, mainly chemists, all selected cultivars in the USA for release fall within a specialty type or defined market classes (long, medium and short grain). It is then certain that the only quality types that people in the industry see are within a defined set of quality traits and the total amount of variation which exists in the germplasm around the world can be under-appreciated (Bergman *et al.*, 2004).

According to (Buddenhagen, 1978) “rice is not only Asian, rice is also African”. However, the cultivated Asian rice *Oryza sativa* (L) is different from *Oryza glaberrima* Steudel, the African rice that was selected by farmers

and has been grown in a diverse range of habitats in West Africa for several thousands of years (Carney, 2000). Rice cultivation ecology in Africa is highly diverse compared to the USA where irrigated rice is dominant. Cultivars in Africa also have a range of genetic variation. They comprise the two cultivated species - *O. sativa* L. and *O. glaberrima* Steud. - and their interspecific progenies called New Rice for Africa (NERICA), which have been developed by the Africa Rice Center and its partners. Some studies have already been conducted on the grain quality of *O. glaberrima* and NERICA cultivars. Nerica lines showed tremendous variability for cooking, sensorial and nutritional values. Results from the studies conducted by (Kishine *et al.,* 2008) showed that Nerica varieties with high amylose content (29%) inherited the gene from the glaberrima parents while the lower amylose content (22%) varieties received the gene from the sativa parents. Watanabe *et al.,* (2002) studied *O. glaberrima* lines, interspecific progenies and *O. sativa* lines and concluded that the progenies were superior to *O. glaberrima* parents based on the following traits: husking yield, milling yield, whiteness and translucency of milled rice. These selected references showed that germplasm from Africa needs to be further screened for different quality traits across different environments. Although rarely mentioned in Africa as a constraint, rice quality is considered the second most important problem after grain yield. Rice production in Africa is becoming more market-oriented where quality becomes a major issue, and quality is considered as an important character in the breeding program of Africa Rice Center. In some African countries, basic grain quality data are available in official documents (e.g. MINAGRA 1998).

2.9. African rice:

Rice has become the most rapidly growing food source in Sub Saharan Africa (Sohl, 2005). This is due to population growth (4% per annum), rising incomes and a shift in consumer preferences in favor of rice, especially in the urban centers (Balasubramanain *et al.,* 2007). The relative growth in demand for rice is faster in this region than anywhere in the world (WARDA, 2005). Africa’s annual rice production represents only 3% of the global production (IRRI, 2009) and accounts for 26.1% of global imports (WARDA, 2005). Low yield is one of the main challenges of rice production in Sub Saharan Africa because its locally adapted species *Oryza glaberrima* is inherently low yielding whilst its substitute, *Oryza sativa*, cannot tolerate the biotic and a biotic stresses (Jones et al., 1997). Conventional attempts to combine the desirable characteristics of the two species elsewhere proved futile because F1 plants exhibit complete sterility (WARDA, 2008). WARDA scientists used biotechnological interventions (that is, embryo rescue, another culture and double haploidization) to develop the first self fertile interspecific rice varieties popularly known as NERICAs (WARDA, 2008). Many such self fertile lines, which differ in several characteristics are available, giving a large gene pool from which desirable characteristics can be combined into a desirable plant type.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experiment site:

Two experiments were conducted in the demonstration farm of the Department of Agronomy, College of Agricultural Studies, Sudan University of Science and Technology at Shambat, Khartoum north, during summer seasons of 2011/2012 and 2012/2013. The objective of this research was undertaken to study the effect of organic, inorganic, and biofertilizers on growth, yield and quality of Rice (*Oryza sativa* L.).

The experiment site lies at latitude 15º 40'N and 32º 32' E and altitude 280m above sea level. The climate is described as tropical semi-arid. Annual rainfall ranges 750-800 mm, occurring during July to September. Relative humidity ranges between 31-51% during wet season and14-27%during dry season. The temperature varies between 45ºC maximum and 21ºC in summer and 15ºC in winter (Adam, 2002). The winter season from November to March and is relatively cool and dry. The summer season is hot and dry. The soil is salty clay loam with physical and chemical properties which make it ideal for vegetable and crop production. Pumping water from the river Nile is common as supplementary source of irrigation (Sayed 2012).

3.2. Land preparation:

The soil was ploughed with disc plough followed by disc harrow and then leveling. After that, field was divided into plots. The area of each plot was 3×3 meter. Treatments were arranged in a Randomized Complete Block Design (RCBD) with four replications. The experiment comprised 72 plots.

3.3. Sowing methods:

The seeds were sown manually in holes which were made in parallel lines with 25 cm spacing between the lines and between the holes at the depth of 5cm (using the knots rope to organize the spacing), at seeding rate of 3-4 seeds per hole.

3.4. Experimental layout and treatments:

The experimental layout was Split plot arrangement, laid out in randomized complete block design (RCBD) with four replications. The main plots were three varieties: Kosti1 and Omgar, (Sudanese release cultivars obtained from Agricultural Research Corporation, Wad Medani, Sudan). Nerica4 (African cultivar obtained from Jaica organization). Sub plots were six fertilizers treatments: effective microorganism (EM) biofertilizer; Compost (COM); pellet granules (PM) obtained from Thailand by Ministry of Agriculture; urea 46%N + triple superphosphate 48%P_2O_5 (US); urea + superphosphate + compost (USC) and control (without). Effective microorganism (EM) and Compost obtained from Murroog Company Khartoum Sudan. The rate of (EM) was 15 liters/ha applied by dropping with irrigation in the water and as foliar fertilization three times at growth stage, and the seeds were mixed until completely coated before sowing. Compost was added to the soil one week from sowing at the rate of15 tons /ha. The pellet granules manure was added at a rate of 50kg/ha. Urea and superphosphate were added at the rate of 83 kg N/ha, 50 kg p/ha respectively in addition to their combinations. All fertilizers were added at sowing except compost which was added before one week from sowing date.

3.5. Cultural Practices

3.5.1. Irrigation:

Irrigation was applied immediately after sowing, afterwards every three or five days until the end of season.

3.5.2. Weed control:

Weed control was manually done every two weeks, four weeding were done in the season.

3.5.3. Pest and diseases:

Rice grain was heavily attacked by birds, but the use of net partially controlled the birds attack. Termites appeared at early stages of growth, in both seasons and were controlled by spraying with Drospan 5000 ml/ha in 500-800 liters of water per hectare twice at 30 and 45 days after sowing. No diseases were recorded in two seasons.

3.6 Parameters Studied:

3.6.1. Vegetative parameters:

Data were collected from the central area of each plot. Ten plants were randomly selected and labeled and used for following observations:

3.6.1.1. Plant height (cm):

Plant height was determined by measuring height from the tip of the stem to the ground level in centimeter which was done every 30, 60 and 90 days after sowing and the mean ware calculated.

3.6.1.2. Number of leaves/plant:

Number of leaves of ten plans was counted at the flowering stage and mean was obtained.

3.6.1.3. Number of productive tillers/plant:

Number of productive tillers of ten plants was counted at the maturity stage and the mean was obtained.

3.6.1.4. Number of unproductive tillers:

Number of unproductive tillers of ten plants was counted at the maturity stage and then the mean was determined.

3.6.1.5. Leaf Area (LA) (cm^2):

Leaf area was measured by randomly selecting ten leaves from the ten labeled plants, and then the following equation was used to determine LA:

LA = length x width x 0.075

3.6.2. Phenological parameters:

3.6.2.1. Days to 50% flowering:

Number of days to 50% flowering for each treatment was recorded and then mean calculated.

3.6.2.2. Days to maturity:

Number of days to maturity was recorded and then mean for was calculated.

3.6.3. Yield components:

3.6.3.1. Spike length (cm):

Ten panicles were selected randomly from each plot and spike length was measured, then the mean was determined.

3.6.3.2. Number of spikelets per spike:

Spikeles per spike of the above-mentioned plant was calculated, and then the mean was calculated.

3.6.3.3. Number of seeds / spike:

Seed number per plant was counted then mean was determined of the above plants.

3.6.3.4. 1000-seed weight (gm):

Seed weight was obtained by weighting 1000-seeds selected randomly from each plot and the mean was determined.

3.6.3.5. Seed yield (t/ha):

Plants in the central square meter in each plot was harvested, the plants were air dried. Then, their seeds were threshed and weighed, seed weight per unit area and per hectare were determined.

3.6.3.6. Harvest Index (%):

Plants from one meter^2 harvested, dried and weighted, seed yield weight was recorded. Harvest index was calculated according to following equation:

$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.6.4. Quality parameters:

The laboratory experiment was conducted at Division of Cereal Technology, Food Research Center at Shambat.

3.6.4.1. Granules Size:

The granules size of rice was recorded using vernia calipers (model: E H B stainless, Hardened, Germany).

3.6.4.2. Grain Dimensions:

Using a caliper (photographic enlarger), 20 seed samples was randomly selected from each replicate and the dimensions were measured to obtain the mean length and width of the grains. To obtain the grain shape, the following equation was used:

$$\text{length to width ratio (L/W)} = \frac{\text{Average grain length, mm}}{\text{Average grain width, mm}}$$

Grain was classified based on International Organization for Standardization (ISO) for grain.

3.6.4.3 Physico-Chemical Analysis:

Physico-chemical analyses were carried out according to methods described in AACC (2000).The seed moisture content was determined at 105^{o}C/12h. Crude protein was determined by the Kajeldhal's method (Nx5.95). Ash content was determined at 550^{o}c/5h, crude fat in Soxhlet apparatus (solvent ether) and crude fiber was determined according above reference. Available carbohydrates were calculated by subtracting the sum of fat, protein, fiber and ash as a percentage as described by West *et al.,* (1988).

3.7. Statistical analysis:

Analysis of variance (ANOVA) was carried out for each character. Means were separated by the use of least significant differences (L.S.D) at $P \leq 0.05$ using Statistix 8 software package programme.

CHAPTER FOUR

RESULTS

4.1. Growth parameters:

4.1.1 Plant height (cm):

The analysis of variance showed that there were highly significant differences in plant height among varieties and fertilizers at 30, 60 and 90 DAS, but the interaction between fertilizers and varieties was not significant. Also the differences between seasons were not significant ($P \geq 0.05$) (Appendix 4).

In the first season, plant height at 30 DAS was similar between Kosti1 and Nerica4 (Table 1). Treated Nerica4 by EM, COM, USC and US increased plant height significantly by 36.2, 24.2, 26.4 and 35.5% respectively, in comparison to untreated control.

In the second season, Nerica4 exhibited greatest plant height followed in descending order by Kosti1 and Omgar (Table 1). However, plant height was increased significantly (28.5%) in Kosti1 after applied by PM, as compared to untreated control (Table 1). Plant height was increased significantly in Nerica4 applied with EM, PM, USC and US (31.9-50.6%).

Plant height at 60 DAS varied significantly with cultivars. In the both season, cultivar Nerica4 had the greatest plant height, while Omgar had the lowest. In the first and second seasons plant height increased significantly in Nerica4 with EM, PM, USC and US, by 30.3, 27.3, 25.8, 20.1,% and by 28.5, 35.4, 24.4, 19.2%, respectively as compared to the untreated control (Table 1).

Plant height at 90 DAS varied significantly with cultivars, fertilizers and seasons. In the first season, plant height at 90 DAS was similar between kosti1 and Omgar (Table 1). However, Nerica4 gave greatest plant height. Application of fertilizers to Nerica4 increased plant height significantly by 5.5 to 13.7%, in comparison to untreated control. In the second season, Kosti1 recorded highest plant height followed in descending order by Nerica4 and Omgar (Table 1).

However plant height was increased significantly (25.5%) in Kosti1 by EM, but Nerica4 increased by 14.2% with PM as compared to untreated control (Table 1).

4.1.4 Number of leaves per plant:

The analysis of variance showed highly significant differences in number of leaves between varieties, fertilizers and seasons (Appendix5), but no interaction between treatments. In the first season, Nerica4 displayed the highest number of leaves, while Omgar and Kosti showed lowest and comparable number of leaves. However, in the second season the number of leaves per plant was similar across cultivars (Table 2).

In the first season Nerica4 treated with EM gave highest number of leaves, (5.57 leaves/plant), in comparison to untreated control (Table 2).

4.1.5 Leaf area (cm^2):

Statistical analysis showed highly significant differences in leaf area among varieties, fertilizers and also between seasons but no significant interactions (Appendix5). In the first season, Nerica4 and Kosti1 showed highest and comparable leaf area, while Omgar had the lowest leaf area (Table 2). In Kosti1, leaf area increased significantly by 71.8, 56.1, 48.7, and 44.3%, when treated with EM, PM, USC and US, respectively, in comparison to the untreated control. Leaf area was increased significantly in Omgar by EM (Table 2). Leaf area in Nerica4 increased significantly when treated with EM, COM, PM, USC and US by 79.2 % to 29.0%, as compared to the control.

In the second season, Nerica4 displayed the highest leaf area, followed in descending order by Kosti1 and Omgar (Table 2). EM and USC increased leaf area in Kosti1significantly by 55.2 and 35.9%, respectively. In Omgar, the highest leaf area (26.3 cm^2) was scored by PM, while lowest (20.7 cm^2) was obtained from US.

Table.1: Effect of biological, organic and inorganic fertilizers on plant height of Rice varieties in two seasons.

Varieties	Treatments	Days after sowing (DAS)					
		30^{DAS}		60^{DAS}		90^{DAS}	
		Season I	Season II	Season I	Season II	Season I	Season II
Kosti1	**Control**	12.18^{ef}	12.48^{ef}	25.30^{ghi}	23.33^{hi}	59.11^{ef}	54.25^{g}
	EM	14.13^{bcde}	15.08^{bcde}	30.38^{def}	30.89^{cde}	64.23^{bc}	68.09^{a}
	COM	13.18^{def}	14.04^{bcdef}	26.68^{fgh}	23.58^{ghi}	60.87^{cdef}	57.65^{defg}
	PM	14.30^{bcde}	16.03^{abcd}	29.10^{efg}	29.05^{efg}	63.25^{bcde}	63.29^{abc}
	USC	14.02^{bcdef}	13.53^{cdef}	33.93^{bcd}	34.89^{bcd}	65.90^{ab}	64.05^{abc}
	US	13.75^{cdef}	13.94^{bcdef}	29.98^{def}	31.21^{cde}	65.48^{ab}	61.95^{bcde}
V. mean		13.59^{A}	14.18^{B}	29.22^{B}	28.83^{B}	63.14^{B}	61.55^{A}
Omgar	**Control**	11.18^{f}	11.83^{f}	18.63^{k}	18.69^{i}	59.71^{def}	56.43^{fg}
	EM	13.15^{def}	12.22^{ef}	23.05^{hijk}	23.45^{hi}	63.73^{bcd}	63.11^{abc}
	COM	11.80^{ef}	12.18^{ef}	20.83^{ijk}	21.14^{hi}	58.16^{f}	56.00^{fg}
	PM	12.63^{ef}	11.71^{f}	24.33^{hij}	24.85^{fgh}	63.30^{bcde}	60.79^{bcdef}
	USC	12.95^{def}	12.25^{ef}	19.93^{jk}	19.74^{hi}	65.28^{ab}	59.07^{cdefg}
	US	12.16^{ef}	11.71^{f}	19.28^{k}	20.06^{hi}	65.66^{ab}	60.30^{bcdef}
V. mean		12.31^{C}	11.98^{C}	21.00^{C}	21.32^{C}	62.64^{B}	59.28^{B}
Nerica4	**Control**	13.25^{def}	12.35^{ef}	30.00^{def}	30.08^{def}	60.87^{cdef}	57.25^{efg}
	EM	18.05^{a}	18.60^{a}	39.10^{a}	38.67^{ab}	69.23^{a}	64.37^{ab}
	COM	16.45^{abc}	12.90^{def}	33.17^{cde}	31.06^{cde}	64.84^{bc}	62.53^{bcd}
	PM	15.83^{abcd}	16.63^{abc}	38.18^{ab}	40.73^{a}	66.42^{ab}	65.36^{ab}
	USC	16.75^{ab}	16.88^{ab}	37.73^{abc}	37.41^{ab}	64.23^{bc}	62.37^{bcde}
	US	17.95^{a}	16.29^{abc}	36.04^{abc}	35.87^{abc}	65.40^{ab}	64.89^{ab}
V. mean		16.38^{A}	15.61^{A}	35.70^{A}	35.64^{A}	65.16^{A}	62.79^{A}
Season means		14.09^{A}	13.92^{A}	28.64^{A}	28.59^{A}	63.65^{A}	61.21^{B}
C V%		14.61	16.16	11.26	13.56	4.77	6.07
SE±		1.46	1.59	2.28	2.74	2.15	2.63

Means with the same small letter(s) within the same column are not statistically different among treatments; however means with the same capital letter(s) within the same column or rows are not statistically different between varieties and seasons respectively according to LSD at P≥0.05.

Treatments: Control = untreated treatment; EM (effective microorganism); com=compost; PM= pellet granules, USC= (urea + superphosphate + compost), US= (urea + superphosphate).

In Nerica4, lowest leaf area was exhibited by untreated control (24.1 cm^2). Treating Nerica4 by Com increased leaf area, but not significantly. However, treating Nerica4 by EM, PM, USC and US, increased leaf area significantly, in comparison to the untreated control (Table 2).

4.1.6 Number of productive tillers / plant:

The results presented in Table (3) showed that all treatments, irrespective of season and cultivars, increased number of productive tillers per plant, as compared to the control.

In the first season, Nerica4 and Kosti1 showed highest and comparable number of tillers, while Omgar displayed the lowest. Treating Kosti1 with EM, PM, USC and US increased number of productive tillers significantly by 33.2 to 108%, as compared to the control. However, EM COM, PM, USC and US, increased number of productive tillers in Omgar by 29 to 48%, in comparison to untreated control (Table 3). Treating Nerica4 with EM, increased number of productive tillers significantly (55.2%), however, other treatments increased number of productive tillers, but not significantly in this variety (Appendix5).

In the second season, differences in number of productive tillers between cultivars were not significant (Table 3). Treating Kosti1 and Nerica4 with EM and USC increased number of productive tillers significantly by 58.3, 9.1% and 70.1, 4.7% respectively, as compared to the control. However, treating Omgar with EM, COM and PM increased number of productive tillers by 25.6, 21.9, and 23.9%, in comparison to untreated control (Table 3).

In general, the highest and significant increments in number of productive tillers were obtained by the treating Kosti1 and Nerica4 with EM (108.1 and 55%, respectively (Table 3).).

Table.2: Effect of biological, organic and inorganic fertilizers on number of leaves/plant and leaf area (cm^2) of Rice varieties in two seasons.

Varieties	**Treatments**	**Number of Leaves/plant**		**Leaf area(cm^2)**	
		Season I	**Season II**	**Season I**	**Season II**
Kosti1	**Control**	4.25^{cdef}	3.90^{abc}	13.05^{fg}	24.38^{fgh}
	EM	4.50^{bcdef}	4.25^{ab}	22.41^{ab}	30.95^{cd}
	COM	4.75^{abcde}	4.35^{ab}	13.53^{efg}	22.11^{gh}
	PM	4.00^{def}	3.90^{abc}	20.36^{abc}	26.80^{defg}
	USC	4.75^{abcde}	4.10^{abc}	19.40^{bcd}	29.35^{cde}
	US	3.75^{ef}	3.50^{c}	18.83^{cd}	26.50^{defg}
V. mean		4.33^{B}	4.00^{A}	17.93^{A}	26.68^{B}
Omgar	**Control**	4.50^{bcdef}	3.95^{abc}	11.15^{g}	21.23^{h}
	EM	4.75^{abcde}	4.15^{abc}	14.89^{ef}	25.08^{efgh}
	COM	5.25^{abc}	4.10^{abc}	12.21^{fg}	22.05^{gh}
	PM	4.75^{abcde}	4.35^{ab}	13.86^{efg}	26.29^{defg}
	USC	4.50^{bcdef}	3.95^{abc}	14.11^{efg}	22.04^{gh}
	US	3.50^{f}	4.15^{abc}	12.72^{fg}	20.71^{h}
V. mean		4.54^{B}	4.11^{A}	13.16^{B}	22.90^{C}
Nerica4	**Control**	4.50^{bcdef}	4.40^{a}	12.92^{fg}	24.12^{fgh}
	EM	5.75^{a}	3.90^{abc}	23.14^{a}	37.43^{ab}
	COM	5.00^{abcd}	3.70^{bc}	16.67^{de}	28.10^{cdef}
	PM	5.38^{ab}	4.10^{abc}	21.41^{abc}	40.43^{a}
	USC	5.38^{ab}	4.15^{abc}	19.44^{bcd}	32.77^{bc}
	US	4.50^{bcdef}	3.70^{bc}	19.08^{cd}	31.22^{cd}
V. mean		5.08^{A}	3.99^{A}	18.77^{A}	32.34^{A}
Season means		4.65^{A}	4.03^{B}	16.62^{B}	27.31^{A}
C V%		16.28	11.44	13.74	12.77
SE±		0.54	0.33	1.62	2.47

Means with the same small letter(s) within the same column are not statistically different among treatments; however means with the same capital letter(s) within the same column or rows are not statistically different between varieties and seasons respectively according to LSD at $P \geq 0.05$.

4.1.7 Number of unproductive tillers / plant:

The analysis of variance indicated no significant differences in the number of unproductive tillers per plant between the two seasons, and also no significant differences of interaction of treatments (Appendix6).

In both seasons, the number of unproductive tillers in Kosti1 and Nerica4 was reduced, but not significantly, after treatment with different fertilizers, as compared to the untreated control (Table 3). Omgar control, in the two seasons, had the highest number of unproductive tillers, in comparison to other treatments (Table 3).

4.1.8 Days to 50% flowering:

The analysis of variance reveled no significant differences in days to 50% flowering among fertilizers, seasons (Appendix6). The results presented in table (4) showed there were highly significant differences in days to 50% flowering among varieties. Nerica4 displayed earliest flowering, as it reached 50% flowering at 66.7 and 69.2 DAS in season 1 and season 2, respectively, followed by Kosti1 reached (76.7 and 78.2 DAS in first and second season, respectively (Table 4).). However, Omgar showed latest flowering, (91 days from sowing, in the two seasons (Table 4).).

4.1.6 Days to maturity:

Statistical analysis showed highly significant differences among varieties in the number of days to maturity (Appendix6). Nerica4 reached earliest maturity at 107.7-110.5 days from sowing in the first and second season, respectively. Kosti1 reached maturity at 112 DAS. Omgar, had latest maturity at 130 days from sowing (Table 4).

Table.3: Effect of biological, organic and inorganic fertilizers on number of productive tillers and unproductive tillers of Rice varieties in two seasons.

Varieties	Treatments	Productive tillers		unproductive tillers	
		Season I	Season II	Season I	Season II
Kosti1	control	9.97^{gh}	12.60^{fg}	4.93^{bc}	3.98^{bcde}
	EM	20.75^{a}	19.95^{ab}	3.53^{bcd}	3.30^{bcde}
	COM	10.80^{fgh}	13.85^{efg}	3.73^{bcd}	2.83^{cde}
	PM	16.28^{bc}	16.88^{cd}	3.05^{cd}	2.85^{cde}
	USC	13.28^{def}	13.75^{efg}	4.13^{bcd}	3.95^{bcde}
	US	14.40^{cd}	12.70^{fg}	5.68^{ab}	4.08^{bcd}
V. mean		14.25^{A}	14.95^{AB}	4.17^{A}	3.50^{B}
Omgar	control	8.98^{h}	12.43^{g}	7.85^{a}	6.08^{a}
	EM	13.35^{def}	15.60^{de}	4.03^{bcd}	4.40^{abc}
	COM	12.70^{def}	15.15^{def}	4.83^{bc}	4.05^{bcd}
	PM	13.23^{def}	15.40^{def}	2.98^{cd}	2.98^{bcde}
	USC	11.98^{defg}	14.75^{defg}	4.55^{bcd}	3.93^{bcde}
	US	11.58^{efg}	14.35^{defg}	4.88^{bc}	4.73^{ab}
V. mean		11.97^{B}	14.61^{B}	4.85^{A}	4.36^{A}
Nerica4	control	11.95^{defg}	12.72^{fg}	4.50^{bcd}	4.02^{bcd}
	EM	18.55^{ab}	21.65^{a}	2.33^{d}	2.90^{cde}
	COM	12.73^{def}	15.15^{def}	3.68^{bcd}	4.60^{abc}
	PM	14.50^{cd}	18.40^{bc}	2.63^{cd}	2.45^{de}
	USC	12.53^{defg}	13.33^{efg}	2.85^{cd}	2.20^{e}
	US	14.08^{cde}	13.78^{efg}	2.88^{cd}	3.13^{bcde}
V. mean		14.05^{A}	15.84^{A}	3.14^{B}	3.22^{B}
Season means		15.14^{A}	13.42^{B}	4.05^{A}	3.69^{A}
C V%		13.49	12.09	13.79	38.48
SE±		1.28	1.29	1.17	0.90

Means with the same small letter(s) within the same column are not statistically different among treatments; however means with the same capital letter(s) within the same column or rows are not statistically different between varieties and seasons respectively according to LSD at $P \geq 0.05$.

Table.4: Effect of biological, organic and inorganic fertilizers on number of days to 50% flowering and number of days to maturity of Rice varieties in two seasons.

Varieties	Treatments	Days to 50% flowering		Days to maturity	
		Season I	Season II	Season I	Season II
Kosti1	Control	79.25^{b}	81.00^{b}	116.50c	115.3^{c}
	EM	77.00^{b}	79.25^{bcd}	112.50^{cde}	110.5^{cd}
	COM	74.00^{bcd}	71.75^{cde}	113.75^{cd}	111.0^{cd}
	PM	76.75^{bc}	79.75^{bc}	110.75^{def}	112.0^{cd}
	USC	77.50^{b}	78.50^{bcd}	108.50ef	111.5^{cd}
	US	76.00^{bc}	79.00^{bcd}	113.75^{cd}	111.5^{cd}
V. mean		76.75^{B}	78.21^{B}	112.6^{B}	112.0^{B}
Omgar	Control	91.00^{a}	91.00^{a}	134.75^{a}	133.5^{a}
	EM	92.25^{a}	92.50^{a}	125.25^{b}	127^{b}
	COM	91.00^{a}	91.00^{a}	131.25^{a}	128.3^{ab}
	PM	90.75^{a}	90.75^{a}	130.75^{a}	127.3^{b}
	USC	89.75^{a}	90.25^{a}	131.50^{a}	130.8^{ab}
	US	91.50^{a}	91.25^{a}	131.75^{a}	133.5^{a}
V. mean		91.04^{A}	91.13^{A}	130.9^{A}	130.0^{A}
Nerica4	Control	66.75^{de}	69.75^{e}	107.50^{ef}	111.5^{cd}
	EM	69.00^{cde}	71.00^{de}	107.50^{ef}	108.8^{d}
	COM	66.50^{de}	68.00^{e}	107.75^{ef}	108.5^{d}
	PM	66.75^{de}	69.75^{e}	108.00^{ef}	110.8^{cd}
	USC	65.25^{e}	67.75^{e}	108.25^{ef}	111.5^{cd}
	US	66.00^{e}	69.00^{e}	107.25^{f}	112.3^{cd}
V. mean		66.71^{C}	69.21^{C}	107.7^{C}	110.5^{B}
Season means		78.17^{A}	79.51^{A}	117.07^{A}	117.54^{A}
C V%		7.20	7.74	3.12	3.50
SE±		3.98	4.35	2.58	2.91

Means with the same small letter(s) within the same column are not statistically different among treatments; however means with the same capital letter(s) within the same column or rows are not statistically different between varieties and seasons respectively according to LSD at $P \geq 0.05$.

4.2. Yield components:

4.2.1 Number of spikelets /spike:

Analysis of variance indicated that there were highly significant differences among fertilizers and varieties in season one and among varieties only in season two, but there were no significant differences between two seasons in number of spikelets/spike, Also there were no significant interaction (Appendix7).

In the first season, Omgar and Nerica4 displayed highest and comparable number of spikelets per spike, while Kosti1 showed lowest number of spikelets (Table 5). Treating Kosti1 with different fertilizers increased number of spikelets per spike, but not significantly as compared to control. However, treating Omgar with EM, COM, PM, USC and US, increased number of spikeles per spike significantly by 59.9, 46.1, 43.1, 111.5, and 90.5%, respectively, in comparison to the control (Table 5). In Nerica4, the number of spikelets increased significantly (36.2%) with USC. However, with the other treatments the number of spikelets increased, but not significantly (Table 5) in this variety.

In the second season, Omgar displayed the highest number of spikelets followed in descending order by Kosti1 and Nerica4 (Table 5). Number of spikelets per spike, irrespective of varieties increased, but not significantly with different fertilizers (Table 5).

4.2.2 Spike (panicle) length (cm):

Analysis of variance (Appendix7) showed highly significant differences in the panicle length among fertilizers and varieties in season one and among varieties only in season two at ($p \geq 0.05$). Also there were significant differences between the two seasons (Appendix 1). There were no significant interaction between varieties and fertilizers presented in (Table 5).

In the first season, Omgar and Nerica4 showed highest and comparable panicle length, while Kosti1 displayed the lowest panicle length (Table 5). The panicle length increased significantly, in Kosti1when treated with EM, COM and US. However, in Omgar, the panicle length increased significantly when treated with the all fertilizers. The treatment of Nerica4 with EM increased panicle length significantly (36.7%), in comparison to untreated control.

In the second the season, Omgar displayed the highest panicle length, while Kosti1 and Nerica4 showed lowest and comparable panicle length (Table 5). Treating Nerica4 with COM and USE increased panicle length significantly by 9.0, and 12.7 %, respectively, as compared to the control (Table 5).

4.2.3 Number of seeds/panicle:

Analysis of variance indicated no significant differences between the two seasons in this parameter; also there was no significant interaction (Appendix7). In general, all fertilizers treatments increased the number of seeds per panicle as compared to the control (Table 6). In the first season, the number of seeds per panicle, increased significantly when the varieties were treated with fertilizers. Treating Omgar with USC increased number of seeds per panicle significantly (144.1%), as compared to the control. However, in Nerica4, the number of seeds per panicle increased over control by 78.5 to 31.5% (Table 6). Nerica4 displayed the highest number of seeds per panicle, while Kosti1 and Omgar showed lowest and comparable number of seeds per panicle (Table 6).

In the second season, the number of seeds per panicle increased significantly in Nerica4 after treatment with EM and PM, by 108.8 and 68.7%, respectively, in comparison to the control (Table 6).

Table.5: Effect of biological, organic and inorganic fertilizers on number of spikelets /spike and panicle length (cm) of Rice varieties in two seasons.

Varieties	Treatments	spikelets /spike		Panicle length (cm)	
		Season I	Season II	Season I	Season II
Kosti1	control	5.93^{fg}	8.60^{bcde}	7.38^{f}	19.03^{cdef}
	EM	7.55^{defg}	8.38^{cdef}	13.32^{abcd}	17.75^{f}
	COM	6.85^{defg}	9.08^{abcd}	11.75^{cde}	18.75^{def}
	PM	7.30^{defg}	8.35^{cdef}	11.07^{def}	17.68^{f}
	USC	8.25^{cdefg}	9.38^{abcd}	11.08^{def}	18.55^{ef}
	US	6.55^{efg}	9.15^{abcd}	11.68^{de}	19.64^{bcde}
V. mean		7.07^{B}	8.82^{B}	11.04^{B}	18.57^{B}
Omgar	control	5.80^{g}	10.00^{a}	8.35^{ef}	21.06^{ab}
	EM	9.28^{bcd}	9.50^{abc}	14.79^{abcd}	20.59^{abc}
	COM	8.48^{cde}	10.43^{a}	13.17^{abcd}	21.55^{a}
	PM	8.30^{cdef}	9.95^{ab}	16.49^{ab}	20.93^{ab}
	USC	12.27^{a}	10.33^{a}	13.34^{abcd}	21.35^{a}
	US	11.05^{ab}	10.10^{a}	15.30^{abcd}	21.05^{ab}
V. mean		9.19^{A}	10.05^{A}	13.57^{A}	21.09^{A}
Nerica4	control	8.63^{bcde}	7.30^{ef}	12.53^{bcde}	17.97^{f}
	EM	10.25^{abc}	7.57^{ef}	17.13^{a}	19.18^{cdef}
	COM	8.98^{bcde}	8.15^{cdef}	14.33^{abcd}	19.60^{bcde}
	PM	10.15^{abc}	7.18^{f}	12.53^{bcde}	18.50^{ef}
	USC	11.75^{a}	8.10^{def}	14.43^{abcd}	20.25^{abcd}
	US	10.18^{abc}	7.60^{ef}	16.00^{abc}	19.13^{cdef}
V. mean		9.98^{A}	7.65^{C}	14.49^{A}	19.10^{B}
Season means		8.75^{A}	8.84^{A}	13.03^{B}	19.59^{A}
C V%		19.88	11.09	23.13	5.80
SE±		1.23	0.69	3.13	0.80

Means with the same small letter(s) within the same column are not statistically different among treatments; however means with the same capital letter(s) within the same column or rows are not statistically different between varieties and seasons respectively according to LSD at $P \geq 0.05$.

4.2.4 Empty seeds (%):

Analysis of variance showed highly significant differences in empty seeds percentage among fertilizers, varieties and seasons (Appendix8). In the two seasons, Omgar displayed highest percentage of empty seeds, while Nerica4 showed the lowest percentage of empty seeds (Table 6). In all varieties, the untreated control displayed highest percentage of empty seeds. In the first season, treating Kosti1 by EM decreased empty seeds percentage significantly (32.7%), as compared to the untreated control. In Omgar, the percentage of empty seeds decreased significantly, after treated by EM, PM, USC and US in comparison to control (Table 6).

In Nerica4, the empty seeds percentage was reduced significantly, when treated with EM, COM, USC and US by 57.9, 45.9, 31.5 and 37.7% respectively, as compared to the untreated control (Table 6).

In the second season, the empty seeds percentage decreased significantly, in Kosti1 when treated with PM, while the other fertilizers. reduced the percentage of empty seeds, but not significantly (Table 6).

The percentage of empty seeds decreased significantly after treating Omgar with PM, USC and US by 27.9, 14.5, and 12.2% respectively as compared to the control. Treating Nerica4 with EM, PM and USC decreased empty seeds% significantly by 45.8, 30.9 and 30.7% respectively, as compared to the control (Table 6).

Table.6: Effect of biological, organic and inorganic fertilizers on number of seeds per panicle and empty seeds (%) of Rice varieties in two seasons.

Varieties	Treatments	Number of seeds/panicle		Empty seeds (%)	
		Season I	Season II	Season I	Season II
Kosti1	control	19.15^{fg}	34.30^{bc}	38.26^{bcde}	51.43^{ab}
	EM	29.33^{efg}	32.20^{bc}	25.75^{fgh}	39.09^{bcd}
	COM	33.23^{defg}	41.18^{bc}	31.86^{cdefg}	45.75^{abc}
	PM	27.50^{efg}	40.85^{bc}	27.48^{defg}	35.51^{cd}
	USC	24.25^{efg}	43.43^{abc}	30.14^{cdefg}	43.83^{abc}
	US	26.38^{efg}	46.30^{ab}	32.34^{cdefg}	40.42^{bc}
V. mean		26.47^{B}	39.71^{A}	31.02^{B}	42.67^{AB}
Omgar	control	17.48^{g}	41.20^{bc}	52.43^{a}	54.10^{a}
	EM	36.18^{cdefg}	36.78^{bc}	30.93^{cdefg}	47.40^{abc}
	COM	30.03^{efg}	40.83^{bc}	47.29^{ab}	50.01^{ab}
	PM	26.15^{efg}	43.85^{abc}	26.36^{efgh}	39.00^{bcd}
	USC	42.65^{bcde}	38.68^{bc}	40.10^{bcd}	46.28^{abc}
	US	34.25^{defg}	40.03^{bc}	37.42^{bcdef}	47.52^{abc}
V. mean		31.12^{B}	40.23^{A}	39.09^{A}	47.38^{A}
Nerica4	control	37.75^{bcdef}	28.98^{c}	41.88^{abc}	49.13^{ab}
	EM	67.38^{a}	60.50^{a}	17.63^{h}	26.62^{d}
	COM	52.38^{abcd}	34.60^{bc}	22.65^{gh}	46.44^{abc}
	PM	49.65^{abcd}	48.88^{ab}	30.48^{cdefg}	33.94^{cd}
	USC	55.88^{ab}	45.40^{abc}	28.68^{defgh}	34.03^{cd}
	US	54.70^{abc}	40.28^{bc}	26.08^{efgh}	38.18^{bcd}
V. mean		52.05^{A}	43.10^{A}	27.90^{B}	38.06^{B}
Season means		36.85^{A}	41.01^{A}	32.67^{B}	42.70^{A}
C V%		37.03	29.45	26.60	22.46
SE±		9.65	8.54	6.14	6.78

Means with the same small letter(s) within the same column are not statistically different among treatments; however means with the same capital letter(s) within the same column or rows are not statistically different between varieties and seasons respectively according to LSD at P≥0.05.

4.2.5 1000-seed weight (g):

In the first season, Nerica4 displayed highest 1000-seed weight (26.69g), while Omgar and Kosti1 showed lowest and similar 1000-seed weights (23.6g). The 1000-seed weight was increased significantly in Nerica4 by EM, PM, USC and US, in comparison to the control (Table 7).

In the second season, Kosti1 and Nerica4 showed highest and comparable 1000- seed weight (25.4g to 26.5g), while Omgar displayed the lowest (18.8g). The 1000-seed weight in Nerica4, increased significantly when treated with USC by 1.8%, over the control (Table 7).

4.2.6 Grain yield (ton/ha):

In the first season, Nerica4 displayed maximum grain yield (2.49 ton/ha) followed in descending order by kosti1 (2.0 ton/ha), and Omgar (1.6 ton/ha). Grain yield increased significantly in Kosti1 when treated with EM, COM and US by 277.2, 181.2, and 134.2%, respectively over the control. However, treating Omgar with EM and USC, increased grain yield significantly by 182 and 108.5%, respectively. Treating Nerica4 with COM, PM, USC and US increased grain yield but not significantly (Appendix8), as compared to the control. However, treating Nerica4 with EM increased grain yield significantly (65.8 %), (Table 7).

In the second season, grain yield was similar, across varieties. The grain yield of Kosti1 was increased significantly after treatment with USC (2.92 ton/ha). Treating Nerica4 with EM, PM, and USC increased grain yield significantly by 107.4, 77.5 and 107.2% respectively, as compared to the control (Table 7).

Table.7: Effect of biological, organic and inorganic fertilizers on 1000-seed weight (g) and grain yield (ton/ha) of Rice varieties in two seasons.

Varieties	**Treatments**	**1000-seed weight (g)**		**grain yield (ton/ha)**	
		Season I	**Season II**	**Season I**	**Season II**
Kosti1	**Control**	23.10^{cde}	23.50^{bcd}	0.81^{f}	1.79^{cd}
	EM	24.55^{be}	26.88^{abc}	3.07^{ab}	2.20^{abcd}
	COM	21.30^{e}	25.50^{abc}	2.29^{abcde}	2.30^{abcd}
	PM	23.05^{cde}	24.63^{abc}	1.86^{bcdef}	2.64^{abc}
	USC	25.10^{bcde}	26.00^{abc}	2.11^{bcde}	2.92^{ab}
	US	24.40^{bcde}	26.00^{abc}	1.90^{bcdef}	2.53^{abc}
V. mean		23.58^{b}	25.42^{a}	2.01^{AB}	2.39^{A}
Omgar	**Control**	23.10^{cde}	18.50^{e}	0.82^{f}	2.20^{abcd}
	EM	24.55^{bcde}	17.88^{e}	2.31^{abcde}	2.03^{cd}
	COM	21.30^{e}	18.25^{e}	1.50^{def}	2.36^{abc}
	PM	23.10^{cde}	19.63^{de}	1.22^{ef}	2.41^{abc}
	USC	25.10^{bcde}	19.50^{de}	2.06^{bcde}	2.40^{abc}
	US	24.40^{bcde}	18.88^{de}	1.71^{def}	2.15^{bcd}
V. mean		23.59^{b}	18.77^{b}	1.60^{B}	2.56^{A}
Nerica4	**Control**	22.00^{de}	27.75^{ab}	1.82^{cdef}	1.46^{d}
	EM	29.93^{a}	26.75^{abc}	3.39^{a}	3.02^{a}
	COM	26.33^{abcd}	25.00^{abc}	2.02^{bcdef}	1.49^{d}
	PM	27.30^{abc}	29.00^{a}	2.95^{abc}	2.59^{abc}
	USC	27.78^{ab}	28.25^{ab}	2.31^{abcde}	3.02^{a}
	US	28.05^{ab}	22.38^{cde}	2.44^{abcd}	2.28^{abcd}
V. mean		26.90^{a}	26.52^{a}	2.49^{A}	2.31^{A}
Season means		24.69^{A}	23.57^{B}	2.03^{B}	2.32^{A}
C V%		12.57	14.50	42.34	26.33
SE±		2.19	2.42	0.60	0.43

Means with the same small letter(s) within the same column are not statistically different among treatments; however means with the same capital letter(s) within the same column or rows are not statistically different between varieties and seasons respectively according to LSD at $P \geq 0.05$.

4.2.7 Plant dry weight (g/m^2):

In the first season, plant dry weight was similar, across varieties. However, in the second season, Omgar displayed the highest plant dry weight (38.6g), followed in descending order by Kosti1 (28.2g) and Nerica4 (23.2g). In the first season plant dry weight increased significantly in Kosti1after treatment with EM and US (Table 8). Omgar control gave the lowest plant dry weight (19.8g). However, treating Omgar with COM, USC and US increased dry weight by 24.4g, 27.8g and 27.3g, respectively (Table 8). The dry weight in Nerica4 was increased significantly by EM and US, by 42.4 and 35.7% respectively, as compared to the control (Table 8).

In the second season, Nerica4 control displayed a dry weight of 20.3g/m^2. Treating Nerica4 with EM and USC increased dry weight, but not significantly. However, in Nerica4 dry weight was increased significantly by US, (by 53.8%) in comparison to the control (Table 8).

4.2.8 Harvest index:

In the first season, Nerica4 exhibited the highest harvest index (0.43), while Omgar and Kosti1 showed lowest and comparable harvest index (0.39-0.40). However, in the second season all varieties showed comparable harvest index (Table 8). In the first season, EM increased harvest index significantly in Kosti1by 14% as compared to the control. Harvest index was increased significantly in Omgar by EM and USC (Table 8). In the second season treating Nerica4 with EM increased harvest index significantly (10%) as compared to the control, while treating Omgar with EM and US, increased harvest index significantly by 10 and 7%, respectively, in comparison to the control (Table 8).

Table.8: Effect of biological, organic and inorganic fertilizers on plant dry weight (g/m^2) and harvest index (H I) of Rice varieties in two seasons.

Varieties	Treatments	plant dry weight (g/m^2)		harvest index	
		Season I	Season II	Season I	Season II
Kosti1	Control	252.6^{ef}	470.5^{bcde}	0.32^{g}	0.37^{f}
	EM	649.5^{abc}	480.0^{bcde}	0.46^{ab}	0.46^{ab}
	COM	576.0^{abc}	566.3^{abcde}	0.37^{defg}	0.40^{cdef}
	PM	450.0^{bcdef}	587.6^{abcd}	0.41^{abcde}	0.44^{abcd}
	USC	535.3^{abcd}	709.3^{a}	0.39^{cdef}	0.41^{bcdef}
	US	506.3^{abcd}	647.0^{ab}	0.37^{efg}	0.38^{ef}
V. mean		495.0^{A}	576.8^{A}	0.39^{B}	0.41^{A}
Omgar	Control	228.8^{f}	577.3^{abcde}	0.35^{fg}	0.38^{ef}
	EM	512.8^{abcd}	444.2^{cde}	0.44^{abc}	0.46^{abc}
	COM	403.3^{cdef}	623.3^{abc}	0.36^{efg}	0.37^{f}
	PM	295^{def}	553.0^{abcde}	0.41^{bcdef}	0.43^{abcde}
	USC	506.5^{abcd}	619.3^{abc}	0.41^{bcdef}	0.40^{def}
	US	408.0^{f}	588.0^{abcd}	0.41^{bcdef}	0.37^{f}
V. mean		392.4^{B}	567.5^{A}	0.40^{B}	0.40^{A}
Nerica4	Control	467.3^{bcdef}	391.0^{e}	0.39^{cdef}	0.37^{f}
	EM	728.0^{a}	643,5^{ab}	0.47^{a}	0.47^{a}
	COM	490.3^{abcde}	404.5^{de}	0.42^{abcde}	0.37^{f}
	PM	672.3^{ab}	590.0^{abcd}	0.44^{abc}	0.44^{abcd}
	USC	561.5^{abc}	691.0^{a}	0.41^{abcde}	0.44^{abcd}
	US	572.3^{abc}	581.8^{abcd}	0.43^{abcd}	0.39^{def}
V. mean		581.9^{A}	550.3^{A}	0.43^{A}	0.41^{A}
Season means		489.8^{B}	564.9^{A}	0.40^{A}	0.41^{A}
C V%		36.0	23.6	10.4	9.7
SE±		124.65	94.18	0.03	0.08

Means with the same small letter(s) within the same column are not statistically different among treatments; however means with the same capital letter(s) within the same column or rows are not statistically different between varieties and seasons respectively according to LSD at P≥0.05.

4.3. Quality parameters:

4.3.1 Chemical composition:

Protein content, fiber, fat, moisture, ash and carbohydrate were significantly affected by fertilizers. Highest percentages of chemical contents were recorded in organic fertilizers and then in chemical fertilizers which were identical to control. The highest protein content was (7.30%) exhibited by Kosti1 treated with EM bio-fertilizer. Highest fiber content (5.59%) was recorded by Omgar in untreated control, fat (1.71%) with EM and it was identical to control and chemical fertilizers (Table 9). Ash (1.53%); (1.60%) was recorded by Kosti1 treated with PM in season I and season II respectively. Most of studied parameters were insignificantly affected by varieties except carbohydrate with highest percentage (87.04%) recorded by Kosti1. The interaction between fertilizers and varieties was significant in chemical contents: carbohydrate, fiber and ash in first season, but moisture, protein and fat contents were insignificant. All parameters were significant in second season except the fat. The combination between the two seasons showed no significant differences among all studied parameters except moisture content (8.59%) in season one and (8.45%) in season two (table 9).

4.3.2 Physical properties:

Table (10) showed that all the Physical properties (grain length, length/ width ratio and hundred seed weight) were significantly affected by treatments. Higher grain length (8.35cm) was recorded by Nerica4 treated with EM and higher ratio L/w (3.29) was obtained by Kosti1 treated with PM, Kosti1 and Nerica4 had a slender grain size but Omgar has a medium size. Hundred seed weight (2.87g) gave by (US) which were a highest value (Table 10).

The pannile taste showed that all treatments and varieties exhibited normal taste (Table 10).

Table.9: Effect of biological, organic and inorganic fertilizers on chemical composition (%) of Rice varieties in two seasons.

Varieties	Treatments	Chemical composition (%)			
		Moisture		Protein	
		Season I	Season II	Season I	Season II
Kosti1	control	8.49^{a}	8.69^{b}	6.18^{g}	6.22^{h}
	EM	8.63^{a}	8.20^{h}	7.30^{a}	7.14^{a}
	COM	8.60^{a}	8.11^{i}	6.23^{g}	6.20^{h}
	PM	8.61^{a}	7.96^{j}	6.93^{bcd}	6.74^{cdef}
	USC	8.49^{a}	8.74^{a}	7.07^{abc}	7.18^{a}
	US	8.49^{a}	8.75^{a}	6.89^{bcd}	6.81^{bcd}
V. mean		8.55^{A}	8.41^{C}	6.77^{A}	6.71^{A}
Omgar	control	8.55^{a}	8.12^{i}	6.16^{g}	6.31^{gh}
	EM	8.52^{a}	8.50^{d}	7.17^{ab}	6.83^{bcd}
	COM	8.50^{a}	8.45^{e}	6.48^{efg}	6.73^{cdef}
	PM	8.50^{a}	8.65^{b}	6.89^{bcd}	6.77^{cd}
	USC	8.56^{a}	8.31^{g}	6.80^{cde}	6.78^{bcd}
	US	8.55^{a}	8.50^{de}	6.72^{def}	6.45^{fgh}
V. mean		8.53^{A}	8.42^{B}	6.70^{A}	6.64^{A}
Nerica4	control	8.73^{a}	8.58^{c}	6.33^{g}	6.31^{gh}
	EM	8.59^{a}	8.12^{i}	7.12^{abc}	7.08^{ab}
	COM	8.60^{a}	8.60^{c}	6.38^{fg}	6.47^{cdef}
	PM	8.61^{a}	8.47^{ef}	7.01^{abcd}	7.01^{abc}
	USC	8.79^{a}	8.69^{b}	6.72^{def}	6.55^{defg}
	US	8.73^{a}	8.58^{c}	6.81^{cde}	6.76^{cde}
V. mean		8.67^{A}	8.51^{A}	6.73^{A}	6.70^{A}
Season means		8.59^{A}	8.45^{B}	6.73^{A}	6.68^{A}
C V%		3.09	0.26	3.05	2.72
SE±		0.22	0.02	0.17	0.15

Means with the same small letter(s) within the same column are not statistically different among treatments; however means with the same capital letter(s) within the same column or rows are not statistically different between varieties and seasons respectively according to LSD at $P \geq 0.05$.

Cont table.9:

Varieties	Treatments	Chemical composition %			
		Fat		Fiber	
		Season I	Season II	Season I	Season II
Kosti1	**Control**	0.71^{fg}	0.77^{f}	2.75^{e}	2.48^{i}
	EM	1.71^{a}	1.60^{a}	4.42^{abcd}	5.14^{abcd}
	COM	0.77^{efg}	0.78^{f}	4.78^{abcd}	4.66^{bcde}
	PM	1.52^{ab}	1.61^{a}	4.36^{abcd}	4.45^{def}
	USC	1.05^{cdefg}	0.89^{ef}	3.58^{de}	2.87^{hi}
	US	0.76^{efg}	0.87^{ef}	4.87^{abc}	5.64^{a}
V. mean		1.09^{A}	1.09^{A}	4.13^{A}	4.21^{B}
Omgar	**Control**	0.69^{g}	0.78^{f}	5.59^{a}	5.88^{a}
	EM	1.39^{abc}	1.31^{abcde}	4.05^{cd}	3.88^{efg}
	COM	1.02^{cdefg}	1.29^{abcde}	4.50^{abcd}	3.83^{efgh}
	PM	1.37^{abc}	1.37^{abcd}	3.55^{de}	4.13^{ef}
	USC	1.04^{cdefg}	1.44^{abc}	3.74^{cde}	3.15^{ghi}
	US	1.09^{cdef}	1.20^{abcdef}	3.71^{cde}	3.77^{efgh}
V. mean		1.10^{A}	1.23^{A}	4.19^{A}	4.11^{B}
Nerica4	**Control**	0.97^{defg}	0.93^{def}	5.57^{a}	5.47^{abc}
	EM	1.49^{ab}	1.49^{a}	3.54^{de}	3.57^{fgh}
	COM	0.88^{defg}	0.92^{ef}	5.45^{ab}	5.54^{ab}
	PM	1.40^{abc}	1.54^{a}	3.96^{cde}	4.53^{cdef}
	USC	1.26^{bcd}	1.03^{cdef}	4.71^{abcd}	4.50^{def}
	US	1.13^{bcde}	1.08^{bcdef}	4.26^{bcd}	4.61^{bcde}
V. mean		1.19^{A}	1.17^{A}	4.58^{A}	4.70^{A}
Season means		1.13^{A}	1.16^{A}	4.30^{A}	4.34^{A}
C V%		21.38	23.27	12.53	13.39
SE±		0.20	0.22	0.62	0.47

Cont table.9:

Varieties	Treatments	Chemical composition %			
		Ash		CHO	
		Season I	Season II	Season I	Season II
Kosti1	**Control**	0.65^{h}	0.91^{ef}	89.71^{a}	89.62^{a}
	EM	1.20^{b}	1.14^{bcd}	85.37^{e}	84.99^{j}
	COM	0.87^{efgh}	0.48^{g}	87.34^{bc}	87.87^{bc}
	PM	1.53^{a}	1.60^{a}	85.65^{de}	85.60^{ij}
	USC	0.75^{gh}	0.50^{g}	87.55^{b}	88.56^{b}
	US	0.88^{defgh}	0.84^{f}	86.60^{bcde}	85.85^{hij}
V. mean		0.99^{A}	0.91^{B}	87.04^{A}	87.08^{A}
Omgar	**Control**	0.80^{fgh}	0.96^{def}	86.76^{bcd}	86.08^{ghi}
	EM	1.11^{bcde}	1.01^{cdef}	86.28^{bcde}	86.98^{cdefg}
	COM	1.08^{bcde}	1.01^{cdef}	86.92^{bcd}	87.14^{cdef}
	PM	1.11^{bcde}	1.24^{b}	87.07^{bc}	86.49^{fghi}
	USC	0.90^{defgh}	0.97^{def}	87.53^{b}	87.66^{bcd}
	US	0.94^{bcdefg}	1.03^{cdef}	87.54^{b}	87.55^{bcde}
V. mean		0.99^{A}	1.04^{A}	87.02^{A}	86.98^{A}
Nerica4	**Control**	0.91^{cdefgh}	0.85^{f}	86.25^{bcde}	86.44^{fghi}
	EM	1.18^{bc}	1.05^{cde}	86.66^{bcde}	86.82^{defgh}
	COM	0.97^{bcdefg}	0.92^{ef}	86.32^{bcde}	86.16^{fghi}
	PM	1.07^{bcdef}	1.18^{bc}	86.55^{bcde}	85.74^{ij}
	USC	1.15^{bcd}	1.06^{bcde}	86.17^{cde}	86.86^{cdfg}
	US	0.99^{bcdefg}	0.94^{ef}	86.82^{bcd}	86.61^{efghi}
V. mean		1.05^{A}	0.10^{A}	86.46^{B}	86.44^{B}
Season means		1.01^{A}	0.98^{A}	86.84^{A}	86.83^{A}
C V%		16.45	11.26	0.93	0.70
SE±		0.14	0.09	0.66	0.50

Table.10: Effect of biological, organic and inorganic fertilizers on Physical properties of Rice varieties in two seasons.

Varieties	treatments	Physical properties					
		Grain length (mm)		Grain width (mm)		Grain length/ width ratio*	
		Season I	Season II	Season I	Season II	Season I	Season II
Kosti1	**control**	7.00^{defg}	7.00^{defg}	3.00^{a}	2.40^{bcde}	2.33	2.92
	EM	8.00^{ab}	8.20^{a}	2.60^{abcde}	2.90^{ab}	3.08	2.83
	COM	7.50^{c}	7.00^{defg}	3.00^{a}	2.30^{de}	2.50	3.04
	PM	7.50^{c}	7.30^{cde}	2.20^{de}	2.30^{de}	3.41	3.17
	USC	8.20^{a}	7.80^{bc}	2.50^{bcde}	2.40^{bcde}	3.28	3.25
	US	8.00^{ab}	7.60^{bc}	2.40^{bcde}	2.50^{bcde}	3.33	3.04
V. mean		7.70^{A}	7.48^{A}	2.62^{B}	2.47^{B}	2.99	3.04
Omgar	**control**	6.00^{i}	6.00^{i}	2.80^{abcd}	2.40^{bcde}	2.14	2.50
	EM	7.30^{bcd}	6.60^{gh}	2.60^{abcde}	3.00^{a}	2.81	2.20
	COM	6.20^{hi}	6.00^{i}	3.00^{a}	3.00^{a}	2.07	2.00
	PM	7.00^{defg}	6.40^{fgh}	3.00^{a}	2.20^{e}	2.33	2.91
	USC	7.00^{defg}	6.20^{hi}	3.00^{a}	2.80^{abcd}	2.33	2.21
	US	6.50^{fgh}	6.20^{hi}	2.90^{ab}	3.00^{a}	2.24	2.07
V. mean		6.67^{B}	6.23^{B}	2.88^{A}	2.73^{A}	2.32	2.32
Nerica4	**control**	7.00^{defg}	7.00^{defg}	2.70^{abcde}	3.00^{a}	2.59	2.33
	EM	8.40^{a}	8.30^{a}	2.70^{abcde}	2.70^{abcde}	3.11	3.07
	COM	7.00^{defg}	7.00^{defg}	2.30^{de}	2.40^{bcde}	3.04	2.92
	PM	7.20^{de}	7.00^{defg}	2.30^{de}	2.30^{de}	3.13	3.04
	USC	8.20^{a}	8.10^{ab}	2.60^{abcde}	2.80^{abcde}	3.15	2.89
	US	8.00^{ab}	8.00^{ab}	2.60	2.70^{abcde}	3.08	2.96
V. mean		7.63^{A}	7.57^{A}	2.53^{B}	2.65^{B}	3.02	2.87
Season means		7.33^{A}	7.09^{B}	2.68^{A}	2.62^{A}	2.78	2.74
SE±		0.16	0.17	0.08	0.10	0.11	0.11
CV		2.71	2.71	9.30	9.30	8.50	8.50

Means with the same small letter(s) within the same column are not statistically different among treatments; however means with the same capital letter(s) within the same column or rows are not statistically different between varieties and seasons respectively according to LSD at P≥0.05.

* L/W ratio: Slender Over 3.0 ; Medium 2.1 – 3.0 ; Bold 1.1 – 2.0; Round 1.0 or less.

Cont table.10:

Varieties	**Treatments**	**Physical properties**			
		100-seeds weight (g)		**Taste****	
		Season I	**Season II**	**Season I**	**Season II**
Kosti1	**Control**	2.00^{ef}	2.32^{cdef}	3.00	5.00
	EM	2.50^{abc}	2.91^{a}	4.00	5.00
	COM	1.81^{f}	2.51^{abc}	5.00	4.00
	PM	2.31^{cdef}	2.60^{abc}	5.00	4.00
	USC	2.30^{cdef}	2.34^{cdef}	4.00	4.00
	US	2.40^{bcde}	2.50^{abc}	5.00	4.00
V. mean		2.22^{B}	2.53^{B}	4.33	4.33
Omgar	**Control**	1.96^{f}	1.94^{f}	4.00	4.00
	EM	2.10^{def}	2.43^{bcde}	4.00	4.00
	COM	2.06^{ef}	1.86^{f}	2.00	4.00
	PM	1.90^{f}	2.72^{ab}	3.00	3.00
	USC	2.06^{ef}	2.12^{def}	4.00	5.00
	US	2.06^{ef}	2.19^{def}	5.00	4.00
V. mean		2.023^{C}	2.210^{C}	3.67	4.00
Nerica4	**Control**	2.22^{cdef}	2.33^{cdef}	3.00	3.00
	EM	2.64^{ab}	2.87^{a}	4.00	4.00
	COM	2.34^{cdef}	2.61^{abc}	4.00	5.00
	PM	2.47^{bcd}	2.70^{ab}	5.00	5.00
	USC	2.80^{ab}	2.80^{ab}	4.00	4.00
	US	2.87^{a}	2.87^{a}	5.00	5.00
V. mean		2.56^{A}	2.70^{A}	4.17	4.33
Season means		2.27^{B}	2.48^{A}	4.06	4.22
SE±		0.22	0.17	0.10	0.09
CV		7.51	7.51	15.78	15.78

Means with the same small letter(s) within the same column are not statistically different among treatments; however means with the same capital letter(s) within the same column or rows are not statistically different between varieties and seasons respectively according to LSD at P≥0.05.

** 5: Desirable, 3-4: Normal, 2-1: off test.

CHAPTER FIVE

DISCUSSION

Plant height, number of leaves, number of tellers and leaf area were increased significantly in both seasons with addition of different fertilizers. The available nutrients help in enhancing leaf area and plant height which resulted in higher assimilates and more dry matter accumulation. These results were supported by the earlier findings of Swarup and Yaduvanshi, (2000) and Yadana *et al.,* (2009).

Application of biofertilizer (EM) and organic fertilizer (PM) increased plant height in comparison to other fertilizers which might be due to greater availability of nutrients which is also stated by Sivakumar *et al.* (2007) and Nguyen *et al.,*(2004). Nutrient availability from biofertilizer and organic sources is due to microbial action and improved physical condition of soil (Sarker *et al.,* 2004). The variation in plant height due to nutrient sources was considered to be due to variation in the availability of major nutrients. Yadana *et al.,* (2009) reported similar results with the application of organic manure and compost in rice.

The variations in number of leaves of rice varieties may be attributable to differences in the genetic makeup of the varieties and their differences in the utilization ability of the different rates of soil amendments applied. These observations were in consistence with that of Halder *et al.,* (2000) and Hag *et al.,* (2002) who reported that increased rate of the NPK fertilizer favored the vegetative growth in rice plant.

The significant differences observed in the number of tillers and panicles per plant can be ascribed to differences in the ability of the cultivars to utilize the fertilizer as well as partition their photosynthates and accumulation of dry matter. The differences in the ability of crop cultivars to utilize available nutrients and optimally partition its photosynthesis had been recognized (Ndon and Ndaeyo, 2001). Halder *et al.,* (2000) and Hag *et al.,* (2002) reported that the number of panicles increased with increase in the nitrogen rates and that number of panicles per plant increased with increase in NPK rates. Highest number of productive tillers was recorded with bio and organic fertilizers which might be due to availability of nutrients in the soil. However nutrient availability from organic sources is due to microbial action and improved physical condition of soil. These results were supported by Miller (2007). Tillering is an important trait for grain production and is thereby an important aspect of rice growth improvement. Production of tillers in rice plant was also influenced by different fertilizer combination at all growth stages.

The variations in 50% flowering between rice cultivars might be due to genetic characteristics of rice cultivars, Nerica4 and Kosti1 is early flowering but Omgar is late flowering table (4).

Rice panicle length and grain yield were also significantly different among the rice varieties. These observations are apparently due to the availability of more nutrients to the rice plant following the soil amendment application relative to the control treatment and natural endowments of crop cultivars to optimally utilize available nutrients and subsequently partition its photosynthesis for dry matter accumulation and conversion to economic yield vary (Ndon and Ndaeyo, 2001).

In this study the addition of fertilizers decreased the percentage of empty seeds for rice cultivars, the organic and biofertilizer has a significant effect because of application of organic materials as fertilizers provides growth regulating substances that helped better grain filling and improve the physical, chemical and microbial properties of the soil (Belay *et al.,* 2001).

The significant increase in 1000-seed weight by the addition of fertilizers in comparison to control could be attributed to availability of nutrients during reproductive stage. Similar results were found by Dhanasekaran and

Govindasamy (2002) who reported that availability of nutrients during reproductive stage resulted in better grain filling and as a result grain weight was increased.

Grain yield of all cultivars increased significantly with addition of different types of fertilizer compared to control. This was due to the effect of organic, inorganic and biofertilizer on promoting the growth and consequently yields. The different fertilizers promoted tillers growth and contributed to spikelets production, consequently increasing yield. This is supported by Hired *et al.*, (2001) results. However, EM gave the best results among different fertilizers. This might be explained by the fact that it improved soil quality, soil health and crop yield. This was supported by Higa and Parr 1994 findings. It has been shown that the application of EM can improve photosynthetic efficiency and capacity due to the increase in nutrient availability (Yamadaoxu, 2000). Ravikumar *et al.,* (2013) recorded that biofertilizer affected the inoculation of phosphate solublizing bacteria (PSB) which had a positive effect on growth, nutrient uptake, grain yield and yield components of *Oryza sativa.* On the other hand, Davir and Wilson, (2008) reported that organic sources or synthetic sources did not only supply essential elements but have some positive interaction with inorganic fertilizers by increasing their efficiency and reduce environmental hazards. Complementary application of organic and inorganic fertilizers increases nutrient synchrony and reduces losses by converting inorganic nitrogen to organic forms (Kramer *et al.*, 2002).

The mean yield of Nerica4 was the highest (2.49t/ha) in the first season while Omgar had the highest mean yield (2.56t/ha) in the second season. The reason is the variability in the genetic makeup of the cultivar. This was supported by the results of Fatehelrahman *et al.*, (2015) who found high genetic variability among rice cultivars.

The yield of rice cultivars was higher for the second season (2.32t/ha) than the first one (2.03t/ha) which might be due to environmental differences (appendix 1).

The increase in grain quality with application of organic manures may be due to better nutrient availability and its uptake by crop. This might lead to accumulation of higher quantities of seed components like calcium and increased lipid metabolism which helps in increasing the protein content in seed. These results are in line with findings of Roy and Singh (2006).

The beneficial effects of these treatments might also be owing to improvement in physical, chemical and microbiological environment of soil favoring increased availability of plant nutrients. Sole use of some chemical fertilizers supply few elements with high amount that is not sufficient to improve the quality of rice grain. On the other hand, chemical fertilizers impair the physical properties and microbiological activities of soil. Similar result was reported by Pandey *et al.* (1999) and Hemalatha *et al.* (2004). They found that all the sources of organic manures improved the soil fertility, yield and quality of rice. Synthesis of chemical fertilizers consumes a large amount of energy and money. However, an organic farming with or without chemical fertilizers seems to be possible solution for these problems (Prabu *et al.,* 2003). Manure application in a given year will influence not only crops grown that year, but also crops in the succeeding years, because decomposition of the organic matter is not completed within one year (Bayu *et al.,* 2006).

CHAPTER SIX

CONCLUSION AND RECOMONDATIONS

The results from this study show that all cultivars Responded positively to all types of fertilizers applied. Biofertilizers application in agriculture will have greater impact on organic agriculture and also on the control of environmental pollution, soil health improvement and reduction in input use. The results confirmed that the appropriate use of biofertilizers and organic fertilizers are important to increase their potentiality and efficiency.

Growth, yield and quality parameters of rice were significantly increased in response to the application of biofertilizer, organic and inorganic fertilizers. Better rice grain yield from effective microorganism (EM) and organic fertilizers than those from inorganic fertilizer is a further indication that the nutrients supplied from the EM application were more effective than those supplied with inorganic fertilizer. In conclusion, Effective microorganism (EM) and Pellet granules (PM) were significantly better than other form of fertilizers in both seasons with different cultivars.

The organic manure (Compost) is less effective as it needs time for release.

Nerica4 and Kosti1 cultivars yielded better in the first season, in the second season there were no significant differences in grain yield between fertilizers, but Omgar gave the highest yield. Therefore, Nerica4 was the best rice variety in this study.

Yield displayed significant differences between the two seasons, season two being the better.

From the foregoing results and discussion of the present study, the use of biofertilizer, organic and inorganic fertilizer, particularly EM and the cultivation of the Nerica4 rice variety, are hereby recommended for the farmers in the experimental area.

Further studies may be needed regarding the optimum application levels of organic and inorganic fertilizers which give the best results.

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APPENDIXES

Appendix 1 Mean monthly temperature, wind speed and relative humidity at Shambat for season 2011/2012 and season 2012/2013.

Months	Mean temperature c^o	Wind speed km/h	Relative humidity %
July 2011	32	21	35
August 2011	33	22	55
September 2011	29	20	24
October 2011	31	18	20
November 2011	24	22	23
December 2011	24	19	30
January 2012	21	20	22
July 2012	27	21	39
August 2012	29	19	51
September 2012	36	18	25
October 2012	30	12	21
November 2012	27	17	17
December 2012	27	14	25
January 2013	21	18	19

Source: http://climatevo.com/

Appendix 2 General analysis for soil of the experiment site.

Pit No.		1	
Lab. No.		1	2
Depth (Cm)		0-15	15-45
C. Sand (%)		3	3
F. Sand (%)		13	6
Silt %		46	46
Clay %		38	45
Lab. Texture		ZCL	ZC
pH paste		7.3	7.4
ECe dS/m		1	1.6
Gyp. (%)		3.6	7.9
Exchangeable cations, cmol (+) kg-1	Ca+Mg	40.5	35.2
	K	1.6	1.3
	Na	0.9	6.5
	sum	43	43
CEC cmol(+) kg-1		43	43
BS (%)		100	100
O.M (%)		1.6	1.4
OC (%)		0.9	0.8
Total N (%)		0.12	0.1
C:N		7.5	8
CaCO3 (%)		4	4
Olsen P (Ppm)		7.8	3.2
ESP		2	15
SAR		4	9
Soluble cations (meq/l)			
Ca+Mg		3.7	3.5
K		0.5	0.3
Na		5.0	12.1
Sum		9.2	15.9
Soluble anions (meq/l) CO3			
HCO3		6.9	5.5
Cl		0.5	0.5
SO4		1.8	9.9
Sum		9.2	15.9
Sp (%)		69	72

Source Soil Lab-College of Agric- Study SUST.

Appendix 3 Nutrient elements contents in the experiment field before and after sowing at depth (5-30cm) in both seasons.

	2011/2012				**2012/2013**			
Ferti	**before**		**After**		**Before**		**After**	
	P	**Na**	**P**	**Na**	**P**	**Na**	**P**	**Na**
EM	5.6	33	4.3	16	8.2	23	8.0	12
PM	5.6	31	4.4	14	7.9	22	7.7	13
COM	5.6	29	4.2	15	8.5	22	8.6	13
US	5.5	34	5.0	16	8.1	19	8.9	14

Source Soil Lab-College of Agric- Study SUST.

Appendix 4 mean square and f. value of plant height at three time occasions (30, 60&90) days after sowing (DAS).

Source of variation	**d.f**	**Plant height (cm) at 30 DAS**				**Plant height (cm) at 60 DAS**				**Plant height (cm) at 90 DAS**			
		Season I		**Season II**		**Season I**		**Season II**		**Season I**		**Season II**	
		ms	**f. value**	**ms**	**f. value**	**ms**	**f. value**	**ms**	**f. value**	**ms**	**f. value**	**ms**	**f. value**
Replications	3	7.5	__	5.5	__	200.2	__	235.6	__	53.2	__	50.8	__
Varieties (V)	2	103.9	22.8**	80.1	18.5**	1302.2	96.5**	1230.3	74.8**	42.9	2.0	76.0	8.3**
Error (a)	6	4.6	__	4.3	__	13.5	__	16.4	__	22.0	__	9.2	__
Fertilizers (F)	5	12.5	3.0*	15.4	3.0*	74.6	7.5**	122.4	8.2**	72.2	9.6**	131.8	9.13**
VXF	10	2.3	0.6	7.5	1.45	15.4	1.5	27.9	1.9*	11.7	1.6	14.9	1.0
Error (b)	45	4.2	__	5.2	__	10.0	__	14.8	__	7.5	__	14.4	__
Season	1	1.0	0.2	1.0	0.2	0.1	0.01	0.1	0.01	214.6	19**	214.6	19**

*= significant at $P \leq 0.05$

** = significant $P \leq 0.01$

Appendix 5 mean square and f. value of Number of leaves/plant, Leaf area (cm^2) and Productive tillers/plant.

Source of variation	**d.f**	**Number of leaves/plant**				Leaf area (cm^2)				Productive tillers/plant			
		Season I		**Season II**		**Season I**		**Season II**		**Season I**		**Season II**	
		ms	**f. value**	**ms**	**f. value**	**ms**	**f. value**	**ms**	**f. value**	**ms**	**f. value**	**ms**	**f. value**
Replications	3	1.4	__	0.8	__	22.9	__	200.4	__	1.1	__	41.1	__
Varieties (V)	2	3.6	4.9*	0.1	0.2	220.2	14.9**	542.8	29.9**	38.4	14.4**	9.6	0.86
Error (a)	6	0.7	__	0.6	__	14.8	__	18.1	__	2.7	__	11.1	__
Fertilizers (F)	5	2.14	3.9**	0.2	1.2	99.6	25.3**	140.5	12.4**	74.0	22.0**	69.6	30.2**
VXF	10	0.5	0.8	0.3	1.9*	9.0	2.3*	31.8	2.8*	10.8	3.2**	9.1	4.0**
Error (b)	45	0.6	__	0.2	__	3.9	__	11.4	_	3.4	__	2.3	__
Season	1	13.8	31.5**	13.8	31.5**	4111.6	317.4**	4111.6	317.4**	105.6	27.2**	105.6	27.2**

*= significant at $P \le 0.05$

** = significant $P \le 0.01$

Appendix 6 mean square and f. value of unproductive tillers/plant, days to 50%flwoering & days to maturity.

Source of variation	d.f	Unproductive tillers/plant				days to 50%flwoering				days to maturity			
		Season I		Season II		Season I		Season II		Season I		Season II	
		Ms	f. value	ms	f. value	ms	f. value	ms	f. value	ms	f. value	ms	f. value
Replications	3	12.6	__	5.0	__	197.6	__	311.6	__	29.6	__	1.35	__
Varieties (V)	2	17.8	3.4	8.5	7.7*	3588.8	16.5**	2912.7	14.2**	3575.7	133.4**	2826.0	65.6**
Error (a)	6	5.2	__	1.1	__	217.2	__	205.5	__	26.8	__	43.1	__
Fertilizers (F)	5	12.2	5.1**	5.1	3.0*	9.2	1.3	25.7	1.7	29.0	2.5*	39.9	3.0*
VXF	10	2.4	1.0	2.0	1.2	6.0	0.9	12.7	0.8	20.2	1.7*	8.6	0.6
Error (b)	45	2.4	__	1.7	__	6.9	__	15.5	__	11.5	__	13.5	__
Season	1	4.8	2.15	4.8	2.15	65.3	1.9	65.3	1.9	8.0	0.5	8.0	0.5

*= significant at P≤0.05

** = significant P≤0.01

Appendix 7 mean square and f. value of spikelets /spike, panicle length (cm), number of seeds/panicle.

Source of variation	d.f	Spikelets /spike				Panicle length (cm)				Number of seeds/panicle			
		Season I		Season II		Season I		Season II		Season I		Season II	
		Ms	f. value	ms	f. value	ms	f. value	ms	f. value	ms	f. value	ms	f. value
Replications	3	2.9	__	1.2	__	66.8	__	0.9	__	350.5	__	117.7	__
Varieties (V)	2	54.6	19.2**	34.6	12.5**	76.3	3.6*	42.4	17.8**	4299.8	13.2**	80.4	0.1
Error (a)	6	2.8	__	2.8	__	21.1	__	2.4	__	363.7	__	635.1	__
Fertilizers (F)	5	20.8	6.8**	1.5	2.1*	45.7	6.1**	2.4	2.1*	552.9	3.4*	152.3	1.9
VXF	10	3.7	1.2	0.2	0.2	7.9	1.1	1.4	1.3	105.4	0.7	242.4	3.0**
Error (b)	45	1.2	__	0.7	__	7.5	__	1.1	__	162.5	__	8.7	__
Season	1	0.3	0.2	0.3	0.2	1545.1	265.4**	1545.1	265.4**	524.6	3.8*	524.6	3.8*

*= significant at P≤0.05

** = significant P≤0.01

Appendix 8 mean square and f. value of empty seeds (%), 1000-seed weight (g), grain yield (ton/ha).

Source of variation	d.f	Empty seeds (%)				1000-seed weight (g)				grain yield (ton/ha)			
		Season I		Season II		Season I		Season II		Season I		Season II	
		Ms	f. value	ms	f. value	ms	f. value	ms	f. value	ms	f. value	ms	f. value
Replications	3	446.3	__	316.0	__	4.0	__	21.4	__	0.8	__	0.2	__
Varieties (V)	2	800.3	3.1	522.1	4.4*	87.6	1.9	421.8	46.4**	4.8	2.0	0.1	0.1
Error (a)	6	255.6	__	117.8	__	45.8	__	9.1	__	2.3	__	1.1	5.2**
Fertilizers (F)	5	521.6	10.1**	409.3	4.6**	29.0	6.0**	8.8	0.7	3.8	7.2**	1.4	__
VXF	10	103.5	2.0*	50.2	0.6	7.5	1.6	11.5	1.0	0.4	0.8	0.6	2.3*
Error (b)	45	51.5	__	88.6	__	4.8	__	12.0	__	0.5	_	0.3	__
Season	1	3625.8	38.3**	3625.8	38.3**	45.2	4.3*	45.2	4.3*	3.0	5.3*	3.0	5.3*

*= significant at P≤0.05

** = significant P≤0.01

Appendix 9 mean square and f. value of Plant dry weight m^2/g and Harvest index %.

Source of variation	**d.f**	**Plant dry weight m^2/g**				**Harvest index %**			
		Season I		**Season II**		**Season I**		**Season II**	
		ms	**f. value**	**ms**	**f. value**	**ms**	**f. value**	**ms**	**f. value**
Replications	3	64678	__	19295.7	__	0.00089	__	0.00183	__
Varieties (V)	2	216045	2.27	4337.8	0.08	0.00953	1.24	0.00123	0.47
Error (a)	6	94971	__	52358.5	__	0.00770	__	0.00261	__
Fertilizers (F)	5	125098	5.55**	56928.9	4.34**	0.01311	13.41**	0.01577	11.37**
VXF	10	20884	0.93	28648.0	2.81*	0.00098	1.00	0.00064	0.46
Error (b)	45	22558	__	13123.4	__	0.00098	__	0.00139	__
Season	1	203070	7.88**	203070	7.88**	0.00141	0.84	0.00141	0.84

*= significant at $P \leq 0.05$

** = significant $P \leq 0.01$