Sudan University of Science and Technology

College of Graduate Studies

Effect of Bio-Fertilizers and on Growth and Yield of Two Maize (*Zea mays* L.) Cultivars at Shambat

تأثير السماد الحيوي على نمو وإنتاجية صنفين منزرعين من محصول الذرة الشامية في شمبات

A Thesis Submitted to the Sudan University of Science and Technology in Fulfillment of the Requirements for the Degree of M.Sc. in Agriculture Agronomy

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DEDICATION

To my dear mother, to my husband (Rafe)
and to my late son (Ahood)
with love.

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First of all, Praise to **Allah** for giving me strength and health to complete this work successfully.

I am deeply indebted to my supervisor **Dr. Atif Elsadig Idris** for his helpful guidance, honorable advice, supervision and understanding even on a personal level throughout the course of this work.

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ABSTRACT

A field experiment in randomized complete block design with three replications based on a split-plot arrangements was conducted on a salty loam soil located at the Demonstration Farm of the College of Agricultural Studies, Sudan University of Science and Technology at Shambat, Sudan, during two growing winter seasons of 2011-2012 and 2012-2013. The study was undertaken to assess the effect of Bio-fertilizer on growth and yield of two maize cultivars and to determine level of fertilizer and the optimum combination suitable for improving crop production at Shambat area, Sudan. The bio-fertilizer (Effective Microorganisms, EM, at rates zero, 6.25,12.50,18.75 and 25 L/ha corresponding to F1, F2, F3, F4 and F5 while the two maize cultivar are HODAIBA(V1) and MOGTAMA 45(v2)were used. Characters studied were plant height, stem diameter, number of leaves per plant, leaf area, cob length, cob diameter, number of rows per cob, number of grains per cob, 100-grain weight and grains yield per hectare. The results showed that, growth parameters (plant height and stem diameter), cob length, number of rows per cob, number of grains and grains yield were higher in HODAIBA than MOGTAMA45 while reverse trend was observed in case of leaf area and 100-grain weight. Also, plant height, leaf area and stem diameter, cob length, number of rows per cob, number of grains per row and 100- grain weight were highly influenced by bio-fertilizer application at F4 level. The highest plant height, LA, stem diameter, cob length, number of rows per cob, number of grains and grains yield was recorded in (F4x V1) interaction treatment in both seasons. The highest grain yield (t/ha) was obtained by HODAIBA with application of 18.75L/ha.

ملخص الأطروحة

أجريت تجربة حقلية باستخدام تصميم القطاعات الكاملة العشوائية بثلاث مكررات مبنيا على القطع المنشقة لموسمين شتويين متتالين (2011\2012و2012\2013) بالمزرعة التجريبية - كلية الدراسات الزراعية - جامعة السودان للعلوم و التكنولوجيا - شمبات. أهداف هذه الدراسة بحث تأثيرات مستويات مختلفة من السماد الحيوي علي نمو وإنتاجية صنفين منزرعين من محصول الذرة الشامية الحبوب. وتحديد المستوي المناسب للسماد الحيوي على الإستجابة الكلية لمحصول الذرة الشامية بمنطقة شمبات. تمت زراعة صنفي مجتمع 45 وحديبة من هجن الذرة الشامية وكانت مستويات السماد الحيوي صفر و 06.25 و12.50 و18.75 و25.00 لتر للهكتار. تمت دراسة الصفات التالية: طول النبات، سمك الساق، عدد الأوراق بالنبات، المساحة الورقية، وطول الكوز، سمك الكوز، عدد الصفوف بالكوز، عدد الحبوب بالكوز، وزن الحبوب للكوز، وزن المائة حبة وإنتاجية الهكتار للحبوب. أوضحت نتائج الدراسة أن كلاً من مؤشرات النمو (طول النبات، سمك الساق) طول الكوز، عدد الصفوف والحبوب بالكوز وإنتاجية الحبوب كانت مرتفعة في صنف حديبة بينما انعكس النمط لصفات المساحة الورقية ووزن المائة حبة. كما أوضحت نتائج الدراسة أن طول النبات، سمك الساق، المساحة الورقية، طول الكوز،عدد الصفوف والحبوب بالكوز وإنتاجية الحبوب تأثرت كثيرا بإضافة السماد الحيوي بجرعة 18.75 لتر للهكتار في الصنف حد يبة أكثر من الصنف مجتمع 45 ولوحظ عكس هذه النتائج لمسافة الورقة ووزن المائة بذرة. كما أن أعلى طول للنبات والكوز، مساحة ورقية، سمك للكوز، عدد الصفوف والحبوب بالكوز وإنتاجية الحبوب سجلت في معاملة التداخل عند زراعة صنف حديبة تحت معدل التسميد بجرعة 18.75 لتر للهكتار في كلا الموسمين. اعلى انتاجية للحبوب بالطن هكتار تم الحصول عليها من صنف حديبة إضافة جرعة السماد الحيوي (18.75لتر للهكتار)

CHAPTER ONE

INTRODUCTION

Maize (*Zea mays* L.) is one of the oldest food grains, which belongs to the grass family Poaceae (Gramineae), tribe Maydeae and is the only cultivated species in this genus. Maize growths over wider geographical and environmental ranges than any other cereal among the world's cereal crops, maize ranks second to wheat in production, with milled rice ranking third. However, among developing economics, maize ranks first in Latin America and Africa but third after milled rice and wheat in Asia (CIMMYT, 1989). Because of its importance, maize area has been either increasing or remaining stable in the majority of producing countries in recent decades, while other crop species might be reduced because of declining land availability or farming adjustment (Salem *et al*., 1983; Pingali and Pandey, 2001; Ibrahim, 2010).

Maize has replaced ancient local food crops like sorghum and millet in many areas in Asia and Africa where the climatic conditions are favorable. Sixty four percent (64%) of the world's maize area is found in developing countries, however, the average yield is only 2.5 t/ha, compared with 6.2 t/ha, for industrial countries. The average yield level is a consequence of environmental and technological factors (Dowswell, *et al.* 1996). During the last four production seasons (2010-2014), the average world maize areas were about 176.19 million hectares producing 930.13 million metric tons with average yields estimated at 5.78 tons per hectare (FAO-OECD, 2014).

Maize is palatable and nutritious, 4% higher in fats than rice and wheat, and contains about (10%) protein (Dowswell *et.al.*, 1996). Corn is used in many ways than any other cereals. It is considered as multi - purpose crop and has been put to a wider range of uses as human food, animal and poultry feed and for hundreds of industrial purposes (Timothy and Harvey,1988). The use of maize in the advanced countries differs from that in the developing countries. As standard of living increases, maize tends to be used more for livestock feed and is replaced with wheat, rice and other starch sources in the human diet.

Introduction of maize to Sudan is not known, however, it might have come through West Africa where it was introduced by Portuguese, or through Egypt (Tothill, 1948). Therefore, the crop is grown in the Sudan for a long time and is characterized by high genetic variability, which can be exploited in improving the crop. Corn is the fourth cereal crop in Sudan after sorghum, wheat and millet. It is cultivated on small scales as subsistent rainfed crop around villages in Nuba Mountains, southern Sudan and the Blue Nile. The crop is also grown under irrigation in central, eastern and northern Sudan. Elhassan (2004), reported that, corn is one of the promising crops in Sudan for export especially to the Arab World. Furthermore, the establishment of starch and glucose factories that take place in the country would certainly encourage corn growing. Nour and Lazim (1997) stated that, maize has a high potential in northern Sudan, being grown during both summer and winter seasons for grain and forage yields ranging from 2-5 (t/ha) can be obtained under optimum conditions. Recently there has been increasing interest in maize production in Sudan (Nour *et al*., 1997). Research on maize has started since early sixties of the last century at Hudeiba Research Station. The work at that time, however, focused more on breeding aspects rather than crop management (Nur Edein, 2006). Also, maize was grown in Gezira Scheme in the year 1991 on small scales and in New Halfa (Elkhidir, 2003).

Maize is among the substitute crops to replace wheat in the agricultural schemes, especially in Gezira scheme. It can occupy an important position in the economy of the country due to the possibility of mixing it with wheat for bread making (Mohamedein, 2006). Meeting the increasing food demand of the growing population in developing countries including the Sudan, is a challenge that requires extensive research work to increase yield of food crops including maize and rice. Particularly, maize has a high potential under the environmental conditions of the Sudan and it can be grown during two seasons (summer and winter) for grain and forage production (Elkhidir, 2003).

The crop is less popular as food; hence, it received little attention as a potential food crop in the Sudan. Most of the improved varieties grown in the Sudan are open- pollinated varieties such as var. 113, composite Giza 2, Mujtamaa 45, Hudeiba. Furthermore, response of the above mentioned released maize cultivars to different plant population were not fully investigated. The reasons for low yield are manifold: some are varietal and some are agronomic management especially improper fertilizers application. Costly and environmentally risky chemical fertilizers cause continuous problem for increasing maize production in developing countries including Sudan. These problems are likely to become serious in future. In Sudan, few studies have been conducted on the effects of bio-fertilizer compared to control on maize cultivars. One of the most important means to achieve the goals of organic agriculture is to extent the application of biological fertilizers. Considering the above facts, the present study was undertaken to assess the effect of bio-fertilizers on growth and yield of two maize cultivars and to determine the optimum combination suitable for improving crop production at Shambat area, Sudan.

CHAPTER TWO

LITERATURE REVIEW

2.1 Variability in maize

Badda (1995) conducted an experiment at two locations to evaluate some exotic and local maize cultivars. The reported results showed significant differences among genotypes in number of leaves/plant, cob length, number of rows/cob, grain yield/ plant, plant height, stem girth and grain yield/ha at the two locations. On the other hand, non-significant differences were observed in 100- grain weight at one of the two locations. Nour *et al*. (1997) reported from a study of seven maize cultivars together with two local checks (Geza 2 and Mujtamaa 45), evaluated at three different locations, including irrigated and rainfed areas, that significant differences were observed for plant height, and grain yield. Ibeawuchi (2008) studied yield of local and improved maize cultivars. The results showed that, the cultivar maize varieties in all characters performed significantly better than the local. Turi *et al*. (2007) carried out a study in maize (*Zea mays* L.) genotypes. The results revealed significant variability among genotypes for cob length, kernel rows per cob, 100-grain weight and grain yield (t/ha). The maximum cob length was 16 cm, while the least one was 11 (cm). Grain rows per cob ranged between 13 to 16 rows and grain yield ranged between 4.3 to 11.9 tons/ha.

2.2. Historical background

Nur Eldein *et al.* (1999 - 2001) observed that, the cultivars grown varied significantly in their yield potential. Hudeiba1 and Hudeiba 2 gave similar yields but exceeded Mujtamaa 45 by 24.7 and 25.5 %, respectively. The cultivar Mujtamaa 45 was the tallest 139 (cm), compared to the other two cultivars. The results revealed that the average yields over two years for the three densities were 4.46, 4.38 and 4.59 (tons/ha), respectively. Matho *et al.* (2001) in a study including ten white seeded inbred lines of maize, reported significant differences in grain yield, days to maturity, and 100-grain weight.

2.3 The effects of bio-fertilizers on maize plant characters

Bio-fertilizer is defined as a substance, contains living microorganisms which colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrient and/or growth stimulus to the target crop, when applied to seed, plant surfaces, or soil (Vessey, 2003). Sahu *et al.* (2012) reported that, bio-fertilizers have various benefits. Besides accessing nutrients, for current intake as well as residual, different bio-fertilizers also provide growth-promoting factors to plants.

The bio-fertilizer are natural fertilizes, which are living microbial inoculants of bacteria, algae, fungi alone or in combination and they augment the availability of nutrients to the plants. Bio-fertilizers containing beneficial bacteria and fungi improve soil chemical and biological characteristics, phosphate solutions and agricultural production (El-Habbasha *et al.*, 2007; Yosefi *et al.*, 2011). The Bio-fertilizer includes mainly the nitrogen fixing, phosphate solubilizing and plant growth promoting microorganisms (Goel *et al.*, 1999). Among bio-fertilizer benefiting the crop production are Azotobacter, Azospirillium, Blue Green Algae, Azolla, P-solubilizing micro organisms, Mycorrhizae and Sinorhizobium (Hegde *et al.*, 1999). However, Suleiman zadah and Ghoo chchi (2013) reported that, plant height was significantly affected by biological fertilizer and the maximum plant height of 187.3 cm obtained in bacteria inoculation and the minimum plant height of 169.5 cm was obtained in control treatment which was not significantly different from mycorrhiza inoculation and among the all of treatment, highest and lowest LA obtained in plots with bio-fertilizer and control.

The efficiency of EM (Effective recommended, microorganisms) as a bio-fertilizer is attributed to its role in accelerating the mineralization processes of organic matter and helping the release of nutrients resulting in, enhancing the utility values of soil organic matter contents and cation exchange capacity (Yadav, 1999). Therefore, bio-fertilizers are gaining importance as they are ecofriendly, non hazardous and nontoxic products (Sharma *et al*., 2007).

2.4 The effects of bio-fertilizers on yield of maize

Yield parameters specially ear length, kernels per rows and 1000 grains weight were highly influenced by Azotobacter inoculation and only inoculation of Azotobacter increased maize grain yield up to 35% over non inoculated treatment (Baral and Adhikari, 2013). Also, Kader *et al.*, (2002) reported that Azotobacter increases N availability in the soil which could enhance the numbers of grains and 1000 grains weight. Good produce of hundred kernel weight were performed by BIO-121 (Ramansyah *et al.*, 2013). Moreover, Bio-fertilizers × cultivars interaction was not significant on yield parameters as showed by (Khaksar *et al., 2009)*.

CHAPTER THREE

MATERIALS AND METHODS

3.1 General

The experiment was conducted at the Demonstration 2011/2012-2012/2013 Farm of the College of Agricultural Studies, Sudan University of Science and Technology at Shambat located at longitude 32.35"E and latitude 15.31"N, the climate of this area is semi-arid and with low relative humidity, the annual rainfall is about 151.8 mm (Adam, 2002).The soil of the site is described by (Abdelhafiz, 2001) as loam clay it is characterized by a deep cracking, moderately alkaline clays, and low nitrogen content and pH (7.5- 8) and high exchangeable sodium percentage (ESP), in subsoil. The climate of this area is semi-arid and with low relative humidity, the annual rainfall is about 151.8 mm (Oliver, 1965).

3.2 Experimental treatments and layout

The experiment was designed to study the effect of five bio-fertilizers on the performance of two maize cultivars. The bio-fertilizers rates in this study are designated as F1, F2, F3, F4 and F5 corresponding to bio-fertilizer rates of Zero, 6.25, 12.5, 18.75 and 25.00 L/Ha, respectively. These levels were added every watering intervals during growth period, which conducted ten times. The two maize cultivars are designated as V1 and V2 corresponding to HODAIBA and MOGTAMA45 respectively. Bio- fertilizer in the form of effective microorganisms (EM) was applied at sowing in the two seasons. The design of the experiment was a randomized complete block design with replications. The experiment was arranged in 2 × 5 split-plot arrangement. Main plots were allotted for cultivars treatments and the subplots for bio-fertilizer treatments. Each cultivar was planted in ridges, 5 meter-long and 70 cm between ridges. Sowing was carried out on the third week of July. In each subplot the two inner ridges were used for sampling and the two outer ridges were left as guard.

3.3 General cultural practices

All cultural practices were uniformly carried out whenever needed. Irrigation was applied at an interval of 10 - 12 days till physiological maturity. At both seasons, weeding was carried out manually. The crop was treated with pesticide (Furadan and Sumicidin) for pest control.

3.4 Characters studied

3.4.1 Growth attributes

Five plants were randomly selected and tagged in each sub-plot to determine the following growth parameters.

3.4.1.1 Plant height (cm)

Plant height was measured using a meter tape from the base of the stem to the youngest leaf or to the tip of the plant. The average plant height was determined from the ten tagged plants in each sub-plot.

3.4.1.2 Stem diameter (cm)

Stem diameter was measured using a verneia apparatus (cliber) at 10 cm of the base of the stem.

3.4.1.3 Number of leaves per plant

From all randomly tagged plants, all the leaves were counted and the mean number of leaves per plant was obtained.

3.4.1.4 Leaf area (LA)

Leaf area per plant was computed according to Sticker *et al.* (1961) method as follows:

$$Leaf\ area\ (LA) = L \times W \times K$$

Where:

L = maximum leaf length (cm).

W = maximum leaf width (cm).

K = Adjustment factor (0.75).

3.4.2 Yield attributes

The inner rows in each subplot were used for the determination of the following yield components.

3.4.2.1 Cob length (cm)

Ten cobs from each subplot were randomly selected and the average length of cob was measured.

3.4.2.2 Cob diameter (cm)

Cob diameter was measured using a verneia apparatus and the average diameter of cob was determined.

3.4.2.3 Number of rows cob^{-1}

From the ten selected cobs the average number of rows per cob was determined.

3.4.2.4 Number of grains cob^{-1}

The previous cobs were threshed manually and the average number of grains per cob was determined.

3.4.2.5 100-grain weight (g)

From each subplot, 100 grains were randomly selected and weighed using sensitive balance to determine the average100- grain weight.

3.4.2.6 Grains yield (kg ha^{-1})

In each sub-plot, all plants grown in an area of two m^2 of the central ridges were harvested, air-dried, weighed to determine the average yield per unit area.

3.5 Statistical analysis

Data were statistically analyzed according to the analysis of variance (ANOVA) for strip-split plot arrangements using MSTAT-C computer software package. Mean comparisons were worked out by Duncan's Multiple Range Test (DMRT) at 5% level of probability.

CHAPTER FOUR

RESULTS

4.1 Growth attributes

4.1.1 Plant height (cm)

Analysis of variance on plant height showed significant effects due to cultivars at 30, 60 and 90 days sampling occasions in both seasons while application of bio-fertilizer were significant at 30. 60 and 90 days sampling occasion only in first season (Appendices 1 and 2). Whereas, interaction effects were significant only at 30, 60 and 90 days in both seasons.

The result revealed that HODAIBA cultivar (V1) significantly increased the mean plant height relative to MOGTAMA45 cultivar (V2) at all sampling dates (Table 1). Also, the results showed that the best bio fertilizer was F4 at 60 and 90 days but F2 was the best at 30 days in first season, whereas in the second season the best bio- fertilizer was F4 at 30 and 60 days. However, the interaction (V1x F4) treatment significantly increased plant height compared to other interaction treatments in both seasons (Table1).

4.1.2 Stem diameter (cm)

Statistical analysis showed significant effects of both cultivars on stem diameter at 60 and 90 days sampling occasions in first season only while effects due to fertilizer and inter action were significant in both seasons (Appendices 1 and 2).

The result revealed that cultivar (V1) significantly increased the mean stem diameter relative to cultivar (V2) in both seasons (Table 2). Also, the results showed that the best bio fertilizer was F4 at 60 and 90 in both seasons. The interaction (V1×F4) treatment significantly gave the higher values of stem diameter in both seasons (Table 2).

Table 1. Effects of cultivars and bio-fertilizer on mean plant height (cm) during two consective winter seasons of 2011 and 2012

Seasons	Treatments	30dV1	V2	Mean	60dV1	V2	Mean	90aV1	V2	Mean
2011 – 2012	F1	25.89	23.61	24.75[c]	53.993	52.147	53.04[d]	106.092	105.488	105.790[d]
	F2	34.42	27.12	30.77[a]	60.275	58.025	59.150[c]	125.300	127.150	126.22[c]
	F3	26	26.92	26.50[b]	70.475	61.708	66.09[b]	150.983	145.725	148.35[b]
	F4	24.96	23.45	24.20[c]	75.255	71.950	73.60[a]	174.505	154.675	164.59[a]
	F5	21.25	23.47	22.36[d]	66.790	60.150	63.47[b]	126.650	129.775	128.21[c]
	Mean	26.51[a]	24.91[b]		65.34[a]	60.79 b		136.70a	132.56	
	$LSD_{0.05}$	1.48			3.77			5.92		
	$LSD_{0.05}$	2.48			5.59			5.18		
	$LSD_{0.05}$	1.11			2.50			2.3		
2012 - 2013	F1	44.115	47.755	45.93[b]	76.012	88.138	82[c]	80.335	94.713	87.52[a]
	F2	45.663	42.755	44.20[b]	80.212	90.650	85.43[c]	108.675	86.025	97.35[a]
	F3	38.410	43.950	41.18[b]	95.775	76.400	86.08[c]	87.200	86.808	87[a]
	F4	51.677	43.352	47.51[ab]	89.110	106.000	97.55[b]	113.932	121.250	117.59[a]
	F5	61.585	46.372	53.97[a]	117.050	110.035	113.54[a]	109.800	114.790	112.29[a]
	Mean	48.290	44.83		91.63	94.24	91.63	94.24	99.98	100.71
	$LSD_{0.05}$	8.48			ns			Ns		
	$LSD_{0.05}$	6.73			11.20			43.35		
	$LSD_{0.05}$	Ns			ns			21.74		

DAS=days after sowing

V1 and V2 ≡ zea maiz cultivars: HODAIBA(V1) and MOGTAMA45 (V2).

F1, F2,F3,F4 andF5 ≡ bio-fertilizers level at (0, 15,30,45 and 60 kg ha^{-1}) , respectively.

$LSD_{0.05}$: Least significant difference at 0.05 level of probability

Table 2. Effects of cultivars and bio-fertilizer on mean stem diameter during two consective winte 2012

Seasons	Treatments	V1	V2	Mean	V1	V2	Mean	V1
2011 - 2012	F1	3.510	3.180	3.34	7.000[c]	6.450[cd]	6.72[a]	7.255
	F2	3.535	3.090	3.31	5.875[de]	5.350[e]	5.61[a]	6.750
	F3	3.978	3.725	3.85	8.358[ab]	9.025[a]	8.6[a]	9.635
	F4	4.175	3.975	4.07	8.300[ab]	7.908[ab]	8.1[a]	9.425
	F5	3.818	3.325	3.57	8.675[b]	6.850[a]	7.76	10.425
	Mean	**3.80**	**3.45**		**7.64[a]**	**7.11[b]**		**8.69a**
	$LSD_{0.05}$	**ns**			**0.48**			**3.03**
	$LSD_{0.05}$	**ns**			**3.75**			**ns**
	$LSD_{0.05}$	**ns**			**0.69**			**1.24**
2012- 2013	F1	3.210	2.790	3.00[e]	4.325	4.050	4.18 d	7.275
	F2	3.408	4.100	3.75[d]	5.825	6.075	5.95 c	7.425
	F3	4.375	4.175	4.27[c]	8.025	7.475	7.75 a	8.550
	F4	6.865	6.455	6.66[a]	6.100	7.700	6.90 b	10.100
	F5	4.730	4.505	4.61[b]	7.125	7.125	7.12 b	9.475
	Mean	**4.51**	**4.40**		**6.28**	**6.48**		**8.56**
	$LSD_{0.05}$	**ns**			**ns**			**Ns**
	$LSD_{0.05}$	**0.321**			**0.372**			**0.490**
	$LSD_{0.05}$	**0.459**			**0.56**			**0.50**

4.1.3 Number of leaves per plant

Analysis of variance on number of leaves per plant due to cultivars showed significant effects at all sampling occasions in both seasons, whereas application of bio-fertilizer was significant at 90 days sampling occasion only in first season. Also, interaction effect was significant only at 30, 60days in both seasons (Appendices 1 and 2).

The result indicated that cultivar (V2) kl significantly increased the mean number of leaves relative to cultivar (V1) at all sampling dates (Table 3). Also, result showed that the best bio-fertilizer was F4 in both seasons (Table 4). However, the interaction (V2 F4) treatments recorded the highest number of leaves in both seasons (Table 3).

4.1.4 Leaf area per plant (cm^2)

Analysis of variance of leaf area showed that varieties treatment was significant at 30, 60 and 90 days sampling occasions in both application of bio-fertilizer were significant at 30. 60 and 90 days sampling occasion in two season. Whereas, interaction effects was significant only at 30, 60 and 90 days in both seasons (Appendices 1 and 2). Also, result showed that the best bio fertilizer was F4 at 60 and 90 days whereas in the 2nd season the best bio-fertilizer was F4 at 30 and 60 days (Table1). The interaction (F4) effect significantly increased LA in 30 days, 60 days and 90 days (Table 4).

Table 3. Effects of cultivars and bio-fertilizer on mean number of leaves per plant during two consective winter seasons of 2011 and 2012

Seasons	Treatments	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
2011 winter	F1	5.4cd	4.65^{d}	5.02^{c}	7.5^{d}	6.8^{e}	7.15^{c}	8.6^{d}	7.8^{e}	8.22^{d}
	F2	5.9bc	6.7^{ab}	6.35^{b}	6.9^{e}	7.5^{d}	7.23^{c}	$8.5d^{e}$	10^{c}	9.28^{c}
	F3	6.6ab	7.12^{ab}	6.88^{ab}	8.45^{c}	9.8^{ab}	9.13^{b}	10.7^{b}	10.8^{b}	10.77^{ab}
	F4	7.7a	6.8^{ab}	7.27^{a}	9.6^{b}	10.2^{a}	9.92^{a}	10.9^{ab}	9.8^{c}	10.02^{b}
	F5	7.2a	7.2^{a}	7.27^{a}	9.7^{ab}	8.7^{c}	9.25^{b}	10.7^{b}	11.5^{a}	11.16^{a}
	Mean	**6.60**	**6.52^{a}**		**8.46^{a}**	**8.62^{a}**		**9.91**	**10.02^{a}**	
	LSD$_{0.05}$	**0.45**			**0.234**			**Ns**		
	LSD$_{0.05}$	**0.81**			**0.44**			**0.77**		
	LSD$_{0.05}$	**1.1**			**0.52**			**0.16**		
2012 winter	F1	4.8^{ef}	5.3^{de}	5.10^{c}	7^{g}	7.4^{fg}	7.23^{e}	8.9^{g}	10.2^{ef}	9.58^{c}
	F2	4.5^{fg}	4.2^{g}	4.36^{d}	9^{e}	8.05^{f}	8.55^{d}	9.9^{f}	10.7^{de}	10.35^{b}
	F3	5.2^{e}	5.9^{cd}	5.61b	9.2^{de}	9.8^{cd}	9.51^{c}	12.3^{ab}	11.2^{cd}	11.75^{a}
	F4	6.3^{ab}	6.6^{a}	6.45a	10.2^{bc}	10.1^{c}	10.13^{b}	12.8^{a}	10.9^{de}	11.85^{a}
	F5	7.2^{a}	6.5^{bc}	6.82	10.9a	10.7^{ab}	10.85^{a}	11.9^{bc}	10.8^{de}	11.38
	Mean	**5.63**	**5.70**		**9.30**	**9.21**		**11.18^{a}**	**10.78^{b}**	
	LSD$_{0.05}$	**Ns**			**ns**			**0.37**		
	LSD$_{0.05}$	**0.46**			**0.51**			**0.62**		
	LSD$_{0.05}$	**0.63**			**0.63**			**0.83**		

Table 4. Effects of cultivars and bio-fertilizer on mean leaf area during two consective v and 2012

Seasons	Treatments	V1	V2	Mean	V1	V2	Mean	V1
2011	F1	18.050^{g}	21.780^{g}	19.91^{e}	67.650^{g}	98.650^{f}	83.15^{e}	295.8
	F2	44.453^{e}	46.722^{de}	45.58^{c}	203.825^{e}	196.500^{e}	200.16^{d}	310.63
	F3	34.977^{f}	30.158^{f}	32.56^{d}	300.875^{d}	302.655^{d}	301.76^{c}	580.6
	F4	82.085^{a}	76.133^{b}	79.10^{a}	503.075^{b}	526.975^{a}	515.02^{a}	656.5
	F5	57.095^{c}	51.842^{d}	54.46^{b}	490.975^{b}	399.350^{c}	445.16	527.785
	Mean	**47.33**	**45.32**		**313.28**	**304.82**		**474.19**
	$LSD_{0.05}$	**ns**			**ns**			**Ns**
	$LSD_{0.05}$	**1.56**			**17.18**			**50.88**
	$LSD_{0.05}$	**5.17**			**22.44**			**73.68**
2012	F1	77.782^{f}	83.260^{f}	80.52^{d}	113.085^{g}	117.325^{g}	115.20^{e}	136.760^{g}
	F2	101.565^{e}	114.065^{de}	107.81^{c}	220.025^{f}	243.640^{e}	231.83^{d}	214.208^{e}
	F3	125.625^{cd}	136.120^{cd}	130.87^{b}	324.225^{b}	310.650^{c}	317.43^{b}	322.015^{d}
	F4	199.075^{ba}	151.743^{b}	175.40^{a}	425.318^{b}	353.490^{a}	339.40^{a}	394.625^{c}
	F5	137.295^{bc}	141.085^{bc}	139.19^{b}	296.480^{d}	306.300^{c}	301.39^{c}	394.043^{a}
	Mean	**128.269**	**125.255**		**255.82^{b}**	**266.28^{a}**		**285.51^{b}**
	$LSD_{0.05}$	**ns**			**4.25**			**2.99**
	$LSD_{0.05}$	**8.77**			**7.67**			**5.14**
	$LSD_{0.05}$	**16.25**			**9.50**			**2.99**

4.2 Yield attributes

4.2.1 Cob length (cm)

All treatments had significant effect on mean cob length in both seasons (Appendices 4 and 5). Addition of F3 and F4 levels and sowing of V1 cultivar significantly increased the mean cob length (Table 5). Similarly, sowing of V1 cultivar with application of F4 in first season or sowing of V2 with F3 in second season significantly increased the mean cob length compared to other interaction treatments (Table 5).

4.2.2 Cob diameter (cm)

Analysis of variance indicated that the mean cob diameter was significantly affected by cultivars treatment only in the first seasons (Appendices 4 and 5). In this regard, the difference between fertilizers levels or cultivars on mean cob diameter was slightly fewer particularly in the second season (Table 6).

4.2.3 Number of rows per cob

Differences in the number of rows per cob due to all treatments were significant in the first season only (Appendices 4 and 5). Higher number of rows per cob values was recorded in treatments receiving F4 level of fertilizer with cultivar of V1 (Table 7). However, cultivar of V1 with F3 and F4 levels resulted in a significantly greater number of rows per cob than other treatments when they were applied solely (Table 7).

Table 5. Effects of cultivars and bio-fertilizer on mean cob length (cm) during two consective winter seasons of 2011 and 2012

Seasons	**2011 winter**			**2012 winter**		
Treatments	**V1**	**V2**	**Mean**	**V1**	**V2**	**Mean**
F1	7.52^{f}	7.175^{f}	7.35^{e}	9.55^{e}	8.62^{e}	9.05^{c}
F2	13.125^{c}	9.800^{e}	11.46^{d}	9.47^{e}	10.97^{d}	10.22^{bc}
F3	14.300^{b}	11.75^{d}	13.25^{c}	12.99^{b}	14.97^{a}	13.98^{a}
F4	15.25^{a}	14.200^{b}	14.61^{a}	11.85^{cd}	11.92^{cd}	11.88^{abc}
F5	14.125^{b}	13.75^{c}	13.60^{b}	12.57^{bc}	14.22^{a}	13.40ab
Mean	$\mathbf{12.820^{a}}$	$\mathbf{11.200^{b}}$		$\mathbf{11.28^{a}}$	$\mathbf{12.144^{b}}$	
$\mathbf{LSD_{0.05}V}$	**0.537**			**0.973**		
$\mathbf{LSD_{0.05}F}$	**0.43**			**3.7**		
$\mathbf{LSD_{0.05}FxV}$	**0.23**			**0.43**		

Table 6. Effects of cultivars and bio-fertilizer on mean cob diameter (cm) during two consective winter seasons of 2011 and 2012

Seasons / Treatments	2011 winter			2012 winter		
	V1	**V2**	**Mean**	**V1**	**V2**	**Mean**
F1	8	7.22	7.62	7	6.45	6.72
F2	9.87	9.60	9.73	5.87	5.35	5.61
F3	9.55	10.15	9.8	8.35	9	8.68
F4	11.9	11.85	11.9	8.30	7.9	8.10
F5	12.95	12.25	12.600	8.67	6.85	7.76
Mean	**10.47**	**10.21**				
$LSD_{0.05}$V	**ns**			**Ns**		
$LSD_{0.05}$F	**ns**			**Ns**		
$LSD_{0.05}$FxV	**ns**			**Ns**		

Table 7. Effects of cultivars and bio-fertilizer on mean number of rows per cob during two consective winter seasons of 2011 and 2012

Seasons / Treatments	2011 winter			2012 winter		
	V1	**V2**	**Mean**	**V1**	**V2**	**Mean**
F1	11.75[g]	9.30[h]	10.52[d]	9.42	8.82	9.12
F2	16.17[e]	14.82[f]	15.50[c]	29.00	10.02	19..51
F3	28.87[a]	25.12[cd]	27.00[a]	22.96	21.55	22.25
F4	29.70[a]	26.15[b]	27.92[a]	25.91	25.22	25.57
F5	25.57[bc]	24.35[d]	24.96[b]	26.95	27.20	27.00
Mean	**22.41[a]**	**19.950[b]**		**22.85**	**18.56**	
$LSD_{0.05}$V	**0.861**			**Ns**		
$LSD_{0.05}$F	**1.09**			**Ns**		
$LSD_{0.05}$FxV	**0.384**			**Ns**		

4.2.4 Number of grains per cob

All treatments had significant effect on mean number of grains per cob in both seasons (Appendices 4 and 5). In this regard, HUDIBA or addition of F4 fertilizer level significantly increased the mean number of grains per cob (Table 8). However, the highest mean of number of grains per cob was recorded for V1 in the second season (Table 8).

4.2.5 100-grain weight (g)

The analysis of variance revealed that the sowing of maize cultivars and interaction was significant effects on 100-seed weight in the both seasons. Whereas fertilizer treatments were not significant (Appendices 4 and 5). The best fertilizer treatments were F3 in first season and F5 in the second season (Table 9).

4.2.6 Grain yield (ton per ha)

Analysis of variance indicated that, Cultivar treatments had significant effect on mean grains yield per unit area in both seasons while no significant difference due to application of bio-fertilizer and interaction (Appendices 4 and 5). In this regard, sowing of V1 or V2 was similar in their mean grains yield per unit area (Table 10).

Table 8. Effects of cultivars and bio-fertilizer on mean number of seeds per cob during two consective winter seasons of 2011 and 2012

Seasons / Treatments	2011 winter			2012 winter		
	V1	**V2**	**Mean**	**V1**	**V2**	**Mean**
F1	208.3[e]	203.22[e]	205.7[d]	124.62[F]	121.15[F]	122.89[A]
F2	257.07[d]	255.70[d]	256.38[c]	200.08[E]	202.45[E]	201.26[a]
F3	304.17[c]	303.40[c]	303.78[b]	268.37[D]	290.95[C]	279.66[a]
F4	402.32[a]	395.12[b]	398.72[a]	310.77[B]	311.22[B]	311.00[a]
F5	307.87[c]	306.17[c]	307.02[b]	348.80[a]	342.75[a]	345.77[a]
Mean	**295.95[a]**	**292.72[b]**		**250.53**	**253.70**	
$LSD_{0.05}$V	**ns**			**7.73**		
$LSD_{0.05}$F	**ns**			**269.8**		
$LSD_{0.05}$FxV	**ns**			**Ns**		

Table 9. Effects of cultivars and bio-fertilizer on mean 100-seed weight (g) during two consective winter seasons of 2011 and 2012

Seasons / Treatments	2011 winter			2012 winter		
	V1	**V2**	**Mean**	**V1**	**V2**	**Mean**
F1	19.60^{f}	20.08^{f}	19.84^{c}	14.7^{7c}	10.9^{d}	12.87c
F2	22.92^{cd}	25^{ab}	23.96^{ab}	12.67^{cd}	14.82^{c}	13.75c
F3	24.85^{ab}	23^{bc}	24.23^{a}	19.35^{b}	19.57^{b}	19.46^{b}
F4	21.80^{de}	25.20^{a}	23.50^{ab}	19.17^{b}	22.12^{ab}	20.65^{b}
F5	23.58^{bc}	20.50^{ef}	22.04^{b}	22.92^{a}	23.62^{a}	23.27^{a}
Mean	**22.55**	**22.75**		**17.78**	**18.22**	
$LSD_{0.05}$V	**1.511**			**Ns**		
$LSD_{0.05}$F	**2.044**			**2.98**		
$LSD_{0.05}$FxV	**ns**			**2.03**		

Table 10. Effects of cultivars and bio-fertilizer on mean seeds yield (ton per ha) during two consective winter seasons of 2011 and 2012

Seasons / Treatments	2011 winter			2012 winter		
	V1	**V2**	**Mean**	**V1**	**V2**	**Mean**
F1	3.35	3.07	3.21[d]	4.22	4.17	4.198
F2	4	4.22	4.11c	5.500	5.500	5.500
F3	4.25	4.67	4.46[c]	5.51	5.61	5.564
F4	5.65	5.87	5.76[a]	5.74	5.400	5.57
F5	5.35	5.27	5.313[b]	5.34	5.20	5.27
Mean	**4.52**	**4.62**		**5.26**	**5.17**	
$LSD_{0.05}$V	**0.44**			**Ns**		
$LSD_{0.05}$F	**ns**			**Ns**		
$LSD_{0.05}$FxV	**ns**			**Ns**		

CHAPTRE FIVE

DISCUSSION

The efficiency of EM (Effective Recommended Discussion Microorganisms) as a bio-fertilizer is attributed to its role in accelerating the mineralization processes of organic matter and helping the release of nutrients resulting in, enhancing the utility values of soil organic matter contents and cation exchange capacity (Yadav, 1999).

In the present investigation, the treatments which received high dose of bio-fertilizer produced taller plants had thicker stems with more number of leaves and consequently high leaf area. These results indicated that application of bio-fertilizer at rate of had tremendous effects on plant growth and development in maize. However, the increase in aforementioned growth characters might be due to the promotion of nitrogen, fixed by EM, in increasing of cell division and enlargement as well as its effect in metabolic processes in plant organs and consequently increased of leaf area per plant. These results have conformity with findings of Baral and Adhikari (2013) who reported that, inoculation maize grain with bio-fertilizer (Azotobacter) significantly increased plant height and leaf area per plant. In addition to the positive attributes of bio-fertilizer (EM) application enhanced growth and yield of maize is most likely due to promotion of root growth by the decreased ethylene levels attributed to ACC-deaminase activity (Shaharoona *et al.*, 2006). In this regard, Yosefi *et al.* (2011) reported that, bio-fertilizers containing beneficial bacteria and fungi improve soil chemical and biological characteristics, phosphate solutions, which is improve growth and development of corn plant. Moreover, yield parameters specially cob length, number of rows per cob, number of grains per row and 100- grain weight were highly influenced by bio-fertilizer application. The increase in the above mentioned yield components might be resulted in increased availability of nitrogen which increased LA. The obtained results were agreement with findings of Kader *et al,* (2002) who reported that bio-fertilizer (Azotobacter) increases N availability in the soil which could enhance the numbers of grains and 100-grain weight. Application of F4 dose of bio- fertilizer showed major influencing factor in yield attributes in 2011/2012 season.

On the other hand, the HODAIBA and MOGTAMA45 cultivars differ significantly with each other in their morphological and growth parameters. This variation was dependant on genetic factors and environmental conditions and their interaction. These results agree with those reported by many researchers. e.g Sharifi *et al.* (2007). In this regard, Shaharoona *et al.* (2006) concluded that differences in plant growth parameters between two varieties were under genetic control the effect was more pronounce in combined application of bio-fertilizer F4 on the HODAIBA cultivar than other applications. However, growth parameters (plant height and stem diameter), cob length, number of rows per cob, number of grains and grains yield were higher in HODAIBA than MOGTAMA45 while reverse trend was observed in case of leaf area and 100-grain weight. Grain yield per ha is ultimate product of growth and yield parameters, better growth and yield parameters expressed in sowing of MOGTAMA45 resulted in higher grain yield. Therefore, the significant increased in grain yield per ha might be attributed to the increased in yield components in MOGTAMA45. The highest 100-seed weight in MOGTAMA45 (by using bio-fertilizer F4 level) can be related to the longer growth period and higher active leaf. The similar results and observations were also reported by Khaksara *et al,*. (2009).

CHAPTER SIX

SUMMARY AND CONCLUSIONS

6.1 Summary

A field experiment in a split-plot design arrangements with three replications was conducted on a silty loam soil located at Demonstration Farm of the College of Agricultural Studies, Sudan University of Science and Technology at Shambat, Sudan, during two growing successive winter seasons of 2011/2012 and 2012/2013. The study was undertaken to assess the effect of bio-fertilizers on growth and yield of two maize cultivars and to determine critical level of fertilizer and the optimum combination suitable for improving crop production at Shambat area, Sudan.

6.2 Conclusions

Based on the findings of this study, the following conclusions could be drawn:

1- Effect of cultivars was significant for most of the characters. This variation led to different amounts of grain yield per hectare within the cultivars. According to these results, Hudeiba 1 revealed best performance under Shambat conditions.

2- Biofrtilizer effect detected significant differences in plant height (cm), number of rows per cob and 100 - seed weight. The presence of variation in agronomic characters is clear, particularly with application of 18.75L/ha. rate.

3-For the interaction, cultivars×bio-fertilizer, maximum grain yield produced by Hudeiba, grown with application of 18.75L/ha. Bio-fertilizer.

4. Further research is recommended for the most suitable prolific cultivar in the area.

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APPENDICES

Appendix (1): Mean squares of the mean plant height, number of leaves, stem diameter as affected by cultivars and bio-fertilizers during 2011/winter season

Source of variation	d.f	Plant height (cm)			Number of leaves			Stem diameter (mm)		
		30 day	60day	90 day	30day	60day	90day	30 day	60 day	90 day
Block	2	2.147	9.440	79.199 ^{ns}	0.050 ^{ns}	0.221^{ns}	0.618 ^{ns}	0.265	0.118	0.114
Cultivars(H)	1	81.242**	472.378**	4059.034**	7.960	15.913**	7.703**	15.059 ^{ns}	15.388	11.159
Error (a)	12	1.863	12.001	29.561	0.179	0.216	0.322	0.087	0.110	H0.203
Fertilizer (F)	4	25.664**	206.980**	171.686**	0.049	0.072	1.600*	0.127	0.420	0.110
H×F	4	26.830**	18.320^{ns}	174.291**	0.677	0.728*	3.703**	0.426	1.395	er1.415
Error (b)	15	2.728	13.800	11.858	0.176	0.198	0.304	0.093	0.142	0.114
CV%					7.40%	4.82%	5.02%			

Appendix (2): Mean squares of the mean plant height, number of leaves, stem diameter as affected fertilizers during 2012 winter season

Source of variation	d.f	Plant height (cm)			Number of leave			Ste	
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	
Block	2	19.590 ns	65.918 ns	29.308 ns	0.032 ns	0.013 ns	0.099 ns	0.585 ns	
Cultivars (H)	1	181.626*	1334.7**	1583.15**	7.060**	12.816**	11.510**	0.865 ns	1
Error (a)	12	38.125	105.7	22.307	0.562	0.166	0.500	0.364	
Fertilizer (F)	4	119.23 ns	68.252 ns	5.308 ns	0.072 ns	0.256 ns	0.110 ns	1.183 ns	
H×F	4	146.752*	465.85 ns	397.843**	1.147 ns	1.867**	2.261**	0.031 ns	
Error (b)	15	31.663	208.11	114.680	0.541	0.121	0.222	0.496	
CV%		12.08%	15.52%	4.31%	11.21%	4.08%	4.73%	19.40%	

Appendix (3): Mean squares of the mean leaf area as affected by cultivars and bio-fertilizers during winter seasons

Source of variation	d.f	LA 2011			LA 2012	
		45 day	60day	74 day	45 day	60 day
Block	2	37.93 ns	90.68ns	33.05 ns	19.242**	168.320
Cultivars (H)	1	10070.10**	66141.98**	83017.27**	4056.791**	247785.370*
Error (a)	12	64.99	49.65	22.22	2.066	248.572
Fertilizer (F)	4	90.84	1093.17**	1173.86**	40.200 ns	714.701 ns
H×F	4	1252.85**	551.87**	1031.92**	42.610*	4813.411**
Error(b)	15	116.3275	39.745	19.77	11.784	221.703
CV%	-	8.51%	2.41%	1.53%	7.41%	4.82%

Appendix (4): Mean squares of the mean yield components as affected by cultivars and bio-fertilizer season

Source of variation	d.f	Block	Cultivars (V)	Error (a)	Fertilizer (F)	V×F	E
		2	1	12	4	4	
Cob length		0.231 ^{ns}	34.28**	0.32	7.319**	3.05**	
Number of row cob^{-1}		184.17 ^{ns}	404.54 ^{ns}	152.55	183.61 ^{ns}	135.56 ^{ns}	
100-WT		3.454 ^{ns}	162.630**	3.377	1.980^{ns}	13.658*	
Number of seeds cob^{-1}		52.53 ^{ns}	64565.91**	23.24	100.87 ^{ns}	256.97**	
Cob diameter		0.36*	31.10**	0.095	0.676 ^{ns}	0.633 ^{ns}	
Yield (kg ha^{-1})		0.134 ^{ns}	2.736**	0.418	0.078 ^{ns}	0.054 ^{ns}	

Appendix (5): Mean squares of the mean yield components as affected by cultivars and bio-fertilizer

season

Source of variation	d.f	Block	Cultivars (V)	Error(a)	Fertilizer(F)	V×F	E
		2	**1**	**12**	**4**	**4**	
Cob length		0.44 ns	64.69**	0.154	26.244**	3.171**	
Number of row		0.73 ns	478.9**	0.99	60.76**	2.80**	
100-WT		556.896 ns	972.508 ns	746.546	752.556 ns	894.166 ns	78
Seed cob		77.81**	40865.51**	13.33	104.006*	15.48 ns	2
Cobdim		0.36*	31.11**	0.09	0.6 7 ns	0.62 ns	
Yield		0.082 ns	8.072**	0.165	0.111 ns	0.154 ns	0