بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

Effect of Microdosing Fertilizer on Growth and Forage Yield of Barley (Hordeum Vulgare L) .

أثر جرعات التسميد الصغيرة علي النمو وإنتاجية علف الشعير

A thesis Submitted in Partial Fulfillment for the Degree of M.Sc. in Agronomy.

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الايـه

قال تعالى:

﴿ وَآيَةٌ لَّهُمُ الْأَرْضُ الْمَيْتَةُ أَحْيَيْنَاهَا وَأَخْرَجْنَا مِنْهَا حَبًّا فَمِنْهُ يَأْكُلُونَ
﴿ 33 ﴾ وَجَعَلْنَا فِيهَا جَنَّاتٍ مِّن نَّخِيلٍ وَأَعْنَابٍ وَفَجَّرْنَا فِيهَا مِنَ الْعُيُونِ
﴿ 34 ﴾ ﴾.

صدق الله العظيم

سورة يس الآية (33-34)

Dedication

This work is dedicated

To my Father

To my Mother

To my Brothers

To my sisters

To my Teacher: Yassin Dagash

With love and respect

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Firstly and lastly thanks to Allah, the Lord of the World, who gave me strength and patience to complete this project successfully.

No words can adequately express my deep gratitude to my supervisor.

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For generously providing and for patience, constant support, advices and insight was invaluable to me. He was always available not only for consultation but also to solve any difficulties. My thanks were expressed to all doctors in the Department of Agronomy.

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Maiada

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Abstract

A field experiment was conducted in winter season 2017/2018, at the experimental farm of the College of Agricultural Studies, Sudan University of Science and Technology (SUST), at Shambat, to study the effect of microdosing fertilization at two different application times on forage barley. A spilt plot arrangement on completely block randomized design (RCBD) was used with three replicates. Sowing time viz. at planting and after 15 days of planting was set as the main plot while the microdosing treatments (control, 2g, 3g and 4g) were assingned in the Sub_ plot .Mono-ammonium phosphate (MAP) was the fertilizer used for microdosing. Plant height (cm), number of leaves per plant and stem diameter (ml) were measured 15, 30 and 45 days after planting. Other parameters measured were plant height (cm), number of leaves , stem diameter (ml) fresh weight per plant (g), dry weight per plant (g) , number of tillers per plant and forage yield(t/ha).The results revealed significant differences for number of tillers per plant for time of sowing and non-significant differences for the rest of the parameters. The microdosing showed significant differences for fresh weight (g), dry weight (g) per plant and yield (t/ha) and non significant difference for the rest of the parameters. Application after planting showed better results than sowing at planting . 4g microdosing showed the best results.

المستخلص

أجريت التجربه في الموسم الشتوى2018/2017 بالمزرعة التجريبيه بكلية الدراسات الزراعية – شمبات. جامعة السودان للعلوم و التكنولوجيا لدراسة تأثير اضافة كمية بسيطه من السماد مع الزراعة وبعد الزراعة على علف الشعير. أجريت التجربة بالقطع المنشقة وبتصميم القطع العشوائيه الكاملة بثلاثة مكررات. وكانت مواعيد الاضافه في القطعه الرئيسيه ومستويات سماد الMAP في القطعه الفرعيه(شاهد, 2جم ,3جم , 4جم). تم أخذ القراءات لطول النبات (سم) وعدد الأوراق وسمك الساق (ملم) كل أسبوعين 15 ,30 ,45 يوما . تم أخذ طول النبات (سم) وعدد الأوراق وسمك الساق (ملم) و الوزن الرطب (جم) , الوزن الجاف (جم) , وعدد الخلف والأنتاجيه (طن/ه) في نهاية التجربة . أوضحت النتائج فروقات معنوية لعدد الخلف في النبات لمواعيد الزراعة وعدم وجود فروقات معنوية لباقى القياسات . أوضحت الاضافه البسيطه للسماد فروقات معنوية للوزن الرطب (جم) والوزن الجاف (جم) للنبات والانتاجيه (طن/ه) وعدم وجود فروقات معنوية لباقى القياسات . التسميد بعد الزراعة أعطى أعلى معدلات , كما كان اضافه 4جم للنبات هى الأفضل .

CHAPTER ONE

INTRODUCTION

Barley (*Hordeumvulgare L.*) is grown as a commercial crop in one hundred countries worldwide and is one of the most important cereal crops in the world. Barley assumes the fourth position in total cereal production in the world after wheat, rice, and maize, each of which covers nearly 30% of the world's total cereal production (FAO, 2004). The yield of barley in Sudan is very low as compared to other barley producing countries. One of the most important effective factors is non-application of optimal plant population per hectare and barley genotypes differ in their response to plant density. Optimum plant densities vary greatly between areas according to climatic conditions, soil, sowing time and varieties. Growth analysis is still the most simple and precise method to evaluate the contribution of different physiological processes in plant development. The physiological indices such as leaf area index (LAI), total dry matter (TDM), crop growth rate (CGR) and relative growth rate (RGR) are influenced by genotypes, plant population, climate and soil fertility (Murphy *et al*, 1996). Weber *et al*,(1966) found that both total dry matter and leaf area index were poor predictors of grain yield. Dry matter production of crops depends on the amount of intercepting solar radiation and its conversion to chemical energy.

Today barley major utility as food crop has reduced but it is still used as fodder crop throughout the world. Many researchers have worked out the dual purpose plants. Yau *et al*, (1989) stated that single grazing at the tillering stage reduced both grain and straw yield of barley. Torbert *et al*, (2001) reported that yield and yield components of maize were increased by increasing the rate of applied nitrogen. El-shatnawi and Makhadmeh (2002) studied seedling growth and development of wild oat and dual-purpose barley in pots and under field conditions.

In Sudan, barley (*Hordum vulgare*) was grown in extremely negligible areas along the Nile valley in the northern states. Henceforth, it received limited attention research work in Sudan, involved mainly in the agronomy of grain production (Ibrahim and Imam, 1974). It was reported to be one of the winter crops that was successfully grown as forage in central and northern Sudan (Imam, 1972, Ibrahim and Imam , 1975) and produced high yield of good quality forage (Khair *et al*, . 2000,Salih *et al*, . 2006 , Khair , 2007) . The yield potential of barley grains in Sudan is 3.4 t/ha in Hudeiba and 2.2 t/ha in Khartoum and Gezira states (Ibrahim and Imam , 1975) using a harvest index of 50% the corresponding biomass yields for those mentioned above were 6.8 and 4.4 t/ha for grain production, (Lazim 1973) . More than 98% of the animal feed in Sudan is contributed by natural ranges and residues remain of crops. A considerable portion of that, however, is not accessible to livestock due to shortage of drinking water within grazing areas during the dry summer. The animal – forage relationships in Sudan, therefore, exhibit severe shortages particularly during summer. The situation is even more acute for the dairy cattle around big cities. A practical way to alleviate such shortages could be through forage production during the winter (Khair 2007).

Land degradation is particularly acute in sub-Saharan African regions where long-term overuse of soil and low, unpredictable rainfall are prime reasons for poor food production. The farmers are so poor that they take everything they can out of the soil and are not willing to invest in fertilizer because the growing season is very risky. The failure to replenish the soil fuels an unrelenting, vicious cycle. Unless nutrients are replaced, soils are depleted and yields and crop quality decline, leading to widespread hunger and under nutrition. To increase output, and attempt to combat declining soil fertility, farmers in West Africa apply inorganic fertilizer. Fertilizer recommendations tend to be generic guidelines based upon limited crop response trials and are a poor guide to maximize the benefits to farmers operating in variable environments (Vanlauwe & Giller, 2006). In addition, farmers are constrained in accessing fertilizer in sufficient quantities at the appropriate time due to poorly functioning input markets (Morris *et al*, 2007). Aside from addressing the underlying institutional factors that contribute to these shortcomings, there is a need in the short term for a technique tailored to the needs of resource-constrained farmers operating under challenging environmental and market conditions. Despite the economic potential of fertilizer microdosing as demonstrated through the aforementioned studies, reports indicate that fertilizer microdosing has not seen widespread adoption in the region. Thus, an examination of the factors that enable or constrain the adoption of fertilizer microdosing is of particular importance as researchers begin to promote fertilizer microdosing in Benin. Additionally, while researchers in Niger, Mali and Burkina Faso are contrasting microdosing against agronomically inefficient fertilizer application methods such as broadcasting, researchers in Benin are comparing the technique to a more efficient, precision application of fertilizer that the government has successfully promulgated throughout the country. This context changes the relative value of microdosing.

Traditional dry-land farming is the major production system in Sudan and it is the main source of livelihood for more than 75% of the population. The productivity of the crops is very low due to poor crop establishment and low soil fertility. The maintenance of soil fertility is becoming one of the most important interventions needed to increase crop productivity in the dry areas of western Sudan, where no recommendation has yet been made to apply inorganic fertilizers in this sector. This can be explained by priority being given to fertilizer distribution in the irrigated sector, low or no response to fertilizer in the rain-fed agriculture. Techniques and type of fertilizer vary depending on soil and climate conditions. Innovative techniques to apply microdoses of the appropriate fertilizer were developed. In Sudan microdosing is a new concept. It was introduced to Shambat, Sudan and tried in sorghum and maize. (Arbab and Dagash.2017).Osman *et al*, (2011) stated the possibility to increase productivity in the traditional rain-fed sector of Darfour and Kordofan regions of Western Sudan at a relatively low cost using microdosing techneques.

Thus, the objective of this study was to determine the forage yield response of barley to microdose fertilizer application.

CHAPTER TWO

LITERATURE REVIEW

Soil is an important factor in crop production and its degradation is one of the limiting factors for sustainable agriculture, (Lemenih *et al*, 2005). With the ever increasing population, soil fertility management by long fallow periods is practically impossible, (CSA 2008). The application of mineral fertilizer as sole soil fertility management method under intensive continuous cropping is also no longer feasible due to scarcity, high cost, (Decron and Hill 2009). where available and the numerous side effects on the soil. Sanchez (2002) Meshesha *et al,* (2012) Engida (2000), reported soil fertility depletion in smallholder farming is the fundamental biophysical root cause of stagnant per capital food production in Africa. The shortage of fertilizer additions has resulted in enormous nutrient depletion and a reduction in yields, due to shortages in nutrients for plant growth. The rate of nutrient depletion has increased over the last 20 years and most of the losses of nitrogen from the soil have occurred since 1985(Zingore *et al,* 2012). Currently, gross nitrogen losses from cultivated African soils exceed 4.4 TG yr-1 while the annual consumption of mineral fertilizer is 0.8 TG (Thematic Group) (excluding South Africa),(Zingore *et al* ,2012). The sub optimal application of fertilizers to agricultural soils and the removal of nutrients in farm produce and erosion losses and the reduction in soil organic matter due to the farming systems, result in mining of nutrients from the soil (Gille*r et al* ,2006), degradation and reduction in crop yields. The reduction in crop yields affects food security on the continent and contributes to high levels of poverty (Kassie *et al*, 2013). Optimization of nitrogen use to sustain life, and to minimize the negative impacts of nitrogen on the environment and human health is most important. N use efficiency (NUE), which is considered an important factor in the management of N applications in crop productivity, is expressed as the ratio between the grain yield and the total N accumulation. Biazin and Sterk (2013). Godfray *et al*,(2013). suggested the NUE in cereals should be improved through the optimal management for N applications, as well as through use of potential varieties to increase the crop yield. N applications are the most significant factors that can limit NUE and maize productivity. The assessment of the suitable N applications is a vital concern for the increase of N uptake efficiency (Fufa and Hassan ,2006).

Worldwide, nitrogen use efficiency (NUE) for cereal production (wheat, *Triticum aestivum* L.; corn, *Zea mays* L.; rice, *Oryza sativa* L. and *O. glaberrima* Steud.; barley, *Hordeum vulgare* L.; sorghum, *Sorghum bicolor* (L.) Moench; millet, *Pennisetum glaucum* (L.)R. Br.; oat, *Avena sativa* L.; and rye, *Secale cereale* L.) is approximately 33%. The unaccounted 67% represents a $15.9 billion annual loss of N fertilizer (assuming fertilizer-soil equilibrium). Loss of fertilizer N results from gaseous plant emission, soil denitrification, surface runoff, volatilization, and leaching. Increased cereal NUE is unlikely, unless a systems approach is implemented that uses varieties with high harvest index, incorporated NH_4-N fertilizer, application of prescribed rates consistent with in-field variability using sensor-based systems within production fields, low N rates applied at flowering, and forage production systems. Furthermore, increased cereal NUE must accompany increased yields needed to feed a growing world population that has yet to benefit from the promise of N_2-fixing cereal crops. The Consultative Group on International Agricultural Research (CGIAR) linked with advanced research programs at universities and research institutes is uniquely positioned to refine fertilizer N use in the world via the extension of improved NUE hybrids and cultivars and management practices in both the developed and developing world (Raon and Johnson,2017).

Researchers at ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) developed a technique called fertilizer microdosing,

which is the precision (or point source) application of small (less than the recommended dosage) quantities of inorganic fertilizer at sowing or within a short time after sowing. The amount of fertilizer used under microdosing and the timing of application vary depending upon the target crop, region, planting density, and fertilizer formulation among other factors. Initial research on microdosing advised application of fertilizer at sowing time and set the microdosing rate at 60 kg ha-1 of NPK (Buerkert & Hiernaux, 1998; Buerkert *et al*, 2001; Tabo*et al*, 2006). Emerging literature continues to inform the practice of microdosing, as researchers study how a range of fertilizer quantities and application dates affect agronomic efficiency and profitability. For example, Sime &Aune (2014) investigated the effect of three separate ‘microdosing’ rates of 27, 50 and 80 kg ha-1 of NPK on maize in Ethiopia. Hayashi *et al*, (2008) investigated the effect of delayed application of microdose quantities upon millet production. However, based upon studies thus far, microdosing at its various rates and timing has in general shown to be an effective technique in SSA for enhancing crop production and profitability while also addressing limited access to fertilizer
(Camara *et al*, 2013; Hayashi *et al*, 2008 ; Tabo*et al*, 2011; Twomlow *et al*, 2010). According to these same studies, microdosing can be an economically advantageous technique as compared to alternative fertilizer application techniques, such as broadcasting, or no fertilizer application. While microdosing was introduced in Niger, Mali, and Burkina Faso as early as 1998 (Tabo*et al*, 2011), the technique was only introduced into Benin in 2011.

Research carried out at ICRISAT indicate that land degradation affects more than half of Africa, leading to loss of an estimated US$42 billion in income and 5 million hectares of productive land each year. The majority of farmlands produce poor yields due to poor farming techniques, nutrient deficiency and lack of water (ICRISAT,2009).

Unable to feed their families or afford to buy food, farmers abandon unproductive land to clear forests and plow new land, and the cycle repeats. Clearing new lands for farming is blamed for an estimated 70% of the deforestation in Africa.

To address the problem of soil fertility, which is a greater constraint to food production than drought across much of sub-Saharan Africa, scientists at ICRISAT have developed a precision-farming technique called 'Microdosing'. Microdosing involves the application of small, affordable quantities of fertilizer with the seed at planting time or as top dressing 3 to 4 weeks after emergence. This enhances fertilizer use efficiency instead of spreading fertilizer over the field, and improves productivity. Rather than asking how a farmer can maximize her/his yields or profits, microdosing asks how a farmer can maximize the returns to a small initial investment – that might grow over time, turning deficits into surpluses (ICRISAT,2009).

Microdosing has reintroduced fertilizer use in Zimbabwe, Mozambique and South Africa in the southern part of the African continent. In western Africa, currently, some 25,000 smallholder farmers in Mali, Burkina Faso, and Niger have learned the technique and experienced increases in sorghum and millet yields of 44 to 120%, along with an increase in their family incomes of 50 to 130 %(ICRISAT,2009) .

Microdosing was designed to address the disjoint between the fertilizer recommendations that optimized yields/profits and the economic reality for many smallholder farmers with scarce resources. Microdosing is meant to maximize return on investment (i.e. an investment in small quantities of inorganic fertilizer) so that farmers will be more willing to take the risk of using inorganic fertilizer in very risky growing conditions. However, there are multiple barriers to adoption of this technique. These include poorly functioning input markets, credit constraints, liquidity constraints, information flows and inappropriate policies (ICRISAT, 2009). Several factors have been identified as major constraints to the widespread adoption of microdose technology. These include access to fertilizer; access to credit; insufficient flows of information and training to farmers; and inappropriate policies. Experiences from both west and southern Africa have shown that adoption of microdose technology requires supportive and complementary institutional innovation as well as input and output market linkages. Although the results have shown consistent yield increases, farmers have reported that microdosing is time consuming, laborious and difficult to ensure each plant gets the right dose of fertilizer. In an attempt to address these issues, researchers are looking at packaging the correct dose of fertilizer as a tablet that aids in application, and this is proving popular. ICRISAT is also exploring the use of seed coating as another option of further reducing the quantity of fertilizer to be used as well as the labor constraint.(Bagayoko *et al*,2011: Bationo *et al*,2011: Raon and Johnson,2017).

Under conventional crop management, chemical fertilizers are applied at recommended rates to rapidly replenish soil fertility and thus improve crop yield. In West Africa, however, recommended fertilizer application rates are costly and ,as a result ,are often only used for male-controlled cash crops (Abdoulaye *et al*,2013). Sogodogo *et al*,(2016) stated that women produce more sorghum and made more money by practicing microdosing fertilization. Studies on microdosing have compared microdosing against no fertilizer, traditional farmer practices, and conventional fertilizer application techniques such as banding or broadcasting (Bachmam, 2015). Microdosing of fertilizer was found by many researchers to increase yield (Aune *et al*,(2007): Hayashi *et al*,(2008): Aune and Ousman,(2011): Osman *et al*,(2011): Sime and Aune,(2014)). Bagayoko *et al*,(2011) stated that stover yield increases of pearl millet were 250 to 400 kg ha-1 on sandy soils and 500 to 2500 kg ha-1 on silt clay soils in Mali. Bielders and Gerad ,(2015) and Bielders,(2015) found a difference in millet grain yield between DAP and NPK micrdose plots. They stated the advantages of microdosing as : fertilizer input reduced by a factor of 3-4 compared to recommended broadcast fertilization: self-adjust to plant density: low initial financial investment : often substantial yield increase : on average , high water use efficiency than farmer practice and may help mitigate yield losses due to late onset of rainy season.

Agriculture is a major sector in the economies of developing countries in West Asia and North Africa (WANA) region. In WANA countries where dry land cropping systems dominate agriculture, barley is an important crop due to its resilience and its role in integrated crop-livestock systems and as a source of stable farm income.(Al-Dakheel *et al*,2012). Barley belongs to the family (Poaceae, tribe Triticaeae and genus *Hordeum*). *Hordeum* consists of 32 species and 45 taxa including diploid ($2n = 2x = 14$), tetraploid ($2n = 4x = 28$) and hexaploid ($2n = 6x = 42$) cytotypes with a basic chromosome number x = 7 Barley has a long history as a domesticated crop, as one of the first crops adopted for cultivation. Migration of people together with their crop seeds led to a major diversification and adaptation to new areas, and the crop is now virtually found worldwide. Conscious selection of desired genotypes by farmers at any early stage, together with natural selection, increased the diversity and created the rich gene pool source of variation found today in local varieties (Alakhdar *et al* , 2016). It is the major cereal in many dry areas of the world and is vital for the livelihoods of many farmers. Barley is an annual cereal crop and grown in environments ranging from the desert of the Middle East to the high elevation of Himalayas. It is the major food source in many North African countries (Alzamani, 2015). It is grown as a commercial crop in one hundred countries and is considered one of the most important cereal crops in the world (Abde-Mnem *et al*, 2013). In the year 2008/09, the area planted by barley was estimated at about 55.27 million hectare (ha) with global production of around 153.96 million metric tons (Hailu *et al*,2016). It is the most important crop with total area coverage of 1.02 million hectares and total annual production of about 1.9 million tons in main season (Aleminew and Legas,(2015).Barley is cultivated successfully in a wide range of climate. This crop has potentials for growing under drought and saline condition. It requires less input like, fertilizer, irrigation, and insecticides. In the world, barley is increasingly being used as cattle feed. The entire barley kernel is used as feed after grinding (Zaefizadeh *et al*, 2011). It is considered a primary staple food or feed crop in the semi-arid tropics of Asia, Africa, and South America. The grain is normally used as food and animal fodder, (Eshghi *et al*, 2010). Barley is typically cultivated in the arid and semi-arid regions, generally in areas with low precipitation that are not suitable for wheat (Naghaii and Aspharipour, 2011).It is a major crop ranked fourth in the world-wide production of cereals, (Baik and Ullrich, 2008). It is generally found in regions where other cereals do not grow well due to altitude, low rainfall, or soil salinity. It remains the most viable option in dry areas.

Traditional dry-land farming is the major production system in western Sudan and it is the main source of livelihood for more than 75% of the population .The productivity of these crops is very low due to poor crop establishment and low soil fertility. Nutrition and fertilization being among the most significant intensification nutrition and rationalization measures at spring barley growing . Sensitivity of spring barley to fertilization resulted from weaker developed root system and shorter growing season during which barley has to take up relatively large amount of nutrients (Hanackova and Slamka, 2012).

In the Gezira (Sudan), barley gives high yields of good quality forage under single cut system (Khair *et al*, 2001; Salih *et. al*,2006).Winter in the northern states of Sudan (Northern and River Nile States) is relatively cooler and longer than in other parts of the country . Hence, it is the most suitable area for growing barley.

CHAPTER THREE

MATERIALS AND METHODS

Site of experiment:

A field experiment was conducted at the experimental farm of the College of Agricultural Studies, Sudan University of Science and Technology (Shambat), Khartoum State , Shambat is located between (Latitude 15º.40′ North and longitude 32º.32′ East) and altitudes of 380 meters above sea level, during the winter season 2017/2018. The climate is characterized by semi-desert tropic with a low percentage of humidity and average rainfall of 158 mm per annum and temperature of 20.3Cº – 36.1Cº and clay Celtic soil (Khairy,2010).Soil pH7.5-8.7 as described by (Hamdon 2010).

Field design:

The treatments were arranged factorially in split- plot trial with three replications. The main plot consisted of two application times, T1= at planting, T2=15 days after planting in a randomized complete block design(RCBD) and the sub plot consisted of four fertilizers microdosing (control , 2g , 3g and 4g /plant).

Source of seed:

Seeds of barley, a local variety used in the study, were obtained from Shambat Research Station.

Cultural practice:

Land preparation:

The experimental site was disc ploughed and then followed by harrowing and leveling, riding up north- south. The spacing between ridges was 70 cm. The sowing date was in November 2017. The space of seeds was 20cm with fertilizer on the same hole. Weeding was done twice after three weeks from sowing and one month from the first hand weeding.

Irrigation:

The first Irrigation was done immediately after sowing and then when necessary.

Fertilizer:

Plots were fertilized by Mono Ammonium Phosphate (MAP) (12:61:0) 2g, 3g and 4g, the fertilizer was added immediately at planting and 15 days after planting.

Data collection:

Plant height (cm):

Five plants of barley were randomly selected from each plot and the plant height was measured from soil surface to the tip of flag leaf using a measuring tape and then the mean height was obtained.

Number of leaves / plant:

Five plants of barley were randomly selected from each plot and the average number of leaves per plant was counted.

Stem diameter (ml):

Five plants from each plot were taken and the diameter in the middle of the plant was measured using a strip and a ruler and then the mean stem diameter per plant was estimated.

Number of tillers/plant:

Five plants of barley were randomly selected from each plot and the average number of tillers per plant was counted.

Fresh weight/plant (g):

Forage fresh yield per plant was measured by weighing the plant.

Dry weight/plant (g):

Forage dry yield per plant was measured by drying the plant at the oven (80 C^o) for 48 hours.

The yield (t/ha):

Plant from an area of one meter square were taken, weighed and the yield was calculated as follows:

Area in m^2 (10000m^2) X forage weight per m^2(g) $\div$ weight unit 1000X1000

Statistical analysis:

The data were statistically analyzed according to split – plot arrangement using MSTAT-C package. Means were separated by Least Significant Difference (L.S.D) (Gomez and Gomez,1984).

CHAPTER FOUR

RESULTS AND DISCUSSION

Plant height (cm):

There were no significant differences in plant height at time of application, microdose or the interaction (Table 1). However application after planting showed a higher plant height (75.33cm) than application at sowing (71.76cm) (Table 2). Microdosing with 3g had the highest plant height (77.05cm) while the control had the lowest (67.88cm) (Table 3). The interaction of 4g microdose after planting had the highest plant height (79.67cm) while the control at planting gave the lower plant height (65.37cm) (Table 4).

The plant height at different growth stages increased with time for all microdosing treatments. At 15 days the plant height was not consistant with the planting time. Generally, the control had higher height for all the growth periods after planting. Generally, after planting had higher plant height for most microdosing treatments than at planting (Fig.1 a and b).

Number of leaves/plant:

There were no significant differences in number of leaves per plant at time of application, for microdose or the interaction (Table 1). However, application at planting had higher number of leaves (13.32) than application after planting (11.45) (Table 2). For microdose there was no significant difference for number of leaves (Table 3). The control at planting had the highest number of leaves (14.07) while the control after planting had the lowest number of leaves (10.27) (Table 4).

The number of leaves at different growth stages increased with time for all microdosing treatments. The control had higher number of leaves per plant after planting for 15 days and 30 days, while the other treatments showed higher number of leaves per plant at planting. Generally, most of the treatments showed higher number o leaves per plant when the microdosing was added at planting (Fig.2 a and b).

Stem diameter (mm):

The stem diameter showed no significant difference for time of application, microdose or the interaction (Table 1). Sowing at planting or sowing after planting had the same results for stem diameter (Table 2). The control had significantly lower stem diameter than the other microdose (3.27mm). However, there were no significant differences between 2g , 3g or 4g microdosing for stem diameter (Table 3).

application at planting and 3g microdosing resulted in the highest stem diameter (3.57mm) ,although there were no significant differences between application at planting or after planting for the different microdose fertilization (Table 4).

The stem diameter at different growth stages increased with time for all microdosing treatments. Application after sowing showed higher stem diameter at 15 days and 30 days but at 45 days had the higher stem diameter for all microdosing treatments expect for 4gm microdosing (Fig 3 a and b).

Number of tillers/plant:

There were significant differences in number of tillers per plant for time of application while no significant difference for number of tillers per plant for microdosing or the interaction (Table 1). Application after planting showed a lower number of tillers per plant (1.65) than that at planting (2.18) (Table 2). There were no significant differences between 3g and 4g microdosing which were higher than 2gm and control microdosing (Table 3).There were significant differences for the interaction at planting and interaction after planting for all microdose fertilization at planting were higher than all microdose fertilization after plant(Table 4).

Fresh weight/plant (g):

The fresh weight per plant showed significant differences for microdosing while no significant difference for time of application or the interaction (Table 1). The fresh weight per plant after planting had a significant fresh weight (8.14g) than at planting (6.80g) (Table 2). The fresh weight per plant was significantly higher for 4g and 3g (9.38 and 8.86 respectively) than 2g and control microdosing (Table 3). The fresh weight per plant was significantly higher after planting for 4g and 3g microdosing than the rest (Table 4).

Dry weight/plant (g):

The dry weight per plant was significant for time of application and microdosing while not significant for the interaction (Table 1).There were no significant differences in dry weight per plant for time of application but after planting showed higher dry weight (4.56g) (Table 2). 4g and 3g microdosing were significantly higher than the 2g and control micodosing. The highest dry weight per plant was given by 4g microdosing (5.57gm) (Table 3). The interaction showed great variation in the dry weight per plant, 4g and 3g microdosing after planting had the highest dry weight (Table 4).

Yield t/ha:

There were no significant differences in yield between application time or interaction of application time and microdosing. However, yield showed a significant difference between microdose fertilization (Table 1). Application after planting had a higher yield than application at planting, though not significant (Table 2). The highest significant yield was given by 4g microdosing (9.47t/ha) while the lowest was given by the control microdosing

(5.08 t/ha) (Table 3). The interaction showed that 4g and 3g microdosing after sowing were significantly higher than the rest (10.91 and 10.96t/ha respectively) (Table 4).

Application of small amounts of mineral fertilizer in the planting hole is a more efficient way to apply mineral fertilizer as compared to broadcasting. This method increases yields at a low cost and is far more efficient, and cost effective, to apply fertilizer (Hayashi *et al*, 2008, Aune *et al,*2007, Aune and Bationo, 2008). To increase output and attempt to combat declining soil fertility in small farms, farmers apply inorganic fertilizer in small doses. In addition, farmers are constrained in accessing fertilizer in sufficient quantities at the appropriate time due to poorly functioning input markets (Morris *et al*, .2007). With these consideration in mind, a technique called microdosing was developed in arid and semi- arid areas of Africa. The results of the analysis showed a general positive effect of micro fertilization. This might be due to the fact that the fertilizer was adjacent to seeds which ensure a high uptake. This was in line with Bielders and Gerad(2015), Sime and Aune(2014) who stated that microdosing enhanced fertilizer use efficiency instead of spreading fertilizer over the field and improve productivity. In general, application after planting had a better effect than at planting. This might be due to the fact that the plant after rooting can absorb the fertilizer better than seeding. 4g microdosing, which was the highest dose gave the highest yield and better result for all parameters except for plant height and stem diameter. The highest yield obtained was comparable with other researchers (Pale *et al,*2010, Bagayoko*et al,*2011) who indicated that microdose fertilizer application resulted in high pearl millet yield.

Table (1): Summary of the ANOVA tables for forage barley microdosing

Source of variation	**Degree of freedom**	**F- values**						
		Plant height (cm)	**No. of leaves**	**Stem diameter (mm)**	**No. of tillers**	**Fresh weight (g)**	**Dry weight (g)**	**Yield t/ha**
Replication	2	0.83	2.96	2.72	4.64	4.79	65.34	4.80
Time of sowing	1	0.45^{NS}	2.78^{NS}	2.33^{NS}	16.79*	2.91^{NS}	49.67^{NS}	2.99^{NS}
Error A	2	-	-	-	-	-	-	-
Microdosing	3	2.53^{NS}	0.09^{NS}	1.27^{NS}	0.32^{NS}	5.17*	3.84*	5.27^{*}
Time of sowing X Microdosing	3	0.99^{NS}	O.98^{NS}	0.37^{NS}	0.41^{NS}	2.39^{NS}	1.82^{NS}	2.41^{NS}
Error B	12	-	-	-	-	-	-	-
Total	23	-	-	-	-	-	-	-
Error mean of square	-	36.99	2.93	0.05	0.31	4.66	2.12	4.70
C.V.%	-	8.27	13.82	6.56	28.58	28.88	34.08	28.88

NS= not significant.

* = significant (5%).

**= high significant (1%).

Table (2): Forage Barley parameters at two different application times

application time	Plant height (cm)	No. of leaves	Stem diameter (ml)	No. of tillers	Fresh weight (g)	Dry weight (g)	Yield t/ha
At planting	71.76b	13.32a	3.44a	2.18a	6.80b	3.74a	6.90a
15days after planting	75.33a	11.45b	3.36a	1.65b	8.14a	4.56a	8.10a
Mean	73.54	12.38	3.4	1.91	7.47	4.15	7.50
SE±	2.48	0.69	0.09	0.22	0.88	0.59	0.87
C.V.%	8.27	13.82	6.58	28.58	28.88	35.08	28.88

Means followed by the same letter for each parameter are notsignificantly different at 5% level of LSD.

Table (3): Forage Barley parameters at different fertilizer microdosing .

Fertilizer microdosing	**Plant height (cm)**	**No. of leaves**	**Stem diameter (ml)**	**No.of tillers**	**Fresh weight (g)**	**Dry weight (g)**	**Yield (t/ha)**
Control	67.88b	12.17a	3.27b	1.73b	5.09b	3.09b	5.09c
2g	74.47a	12.43a	3.42a	1.93b	5.56b	3.31b	6.54b
3g	77.05a	12.27a	3.52a	2.00a	8.86a	4.63a	6.66b
4g	74.78a	12.67a	3.40a	2.00a	9.38a	5.57a	9.47a
Mean	73.54	12.38	3.40	1.91	7.22	4.65	6.94
SE±	4.61	0.97	0.05	0.11	0.68	0.10	0.68
C.V.%	8.27	13.82	6.58	28.58	28.88	35.08	23.88

Means followed by the same letter for each parameter are notsignificantly different at 5% level of LSD.

Table (4): Interaction of application time and microdose of forage barley

application time	Microdosing	Plant height (cm)	No. of leaves	Stem diameter (ml)	No. of tillers	Fresh weight (g)	Dry weight (g)	Yield (t/ha)
At Planting T1	Control	65.37c	14.07a	3.27a	2.07a	5.72c	3.60c	5.71d
	2g	75.27a	13.27a	3.53a	2.33a	6.92b	3.21c	6.91b
	3g	76.50a	13.00a	3.57a	2.27a	6.75b	3.27c	6.75b
	4g	69.90b	12.93a	3.40a	2.07a	7.83b	4.86b	7.83b
	Mean	71.76	13.31	3.48	2.18	6.80	3.73	6.8
	C.V.%	8.27	13.82	6.58	28.58	28.88	35.08	28.88
15 days after planting T2	Control	70.40b	10.27c	3.27a	1.40a	4.47d	2.58d	4.46d
	2g	73.67b	11.60b	3.30a	1.53b	6.20b	3.39b	6.2c
	3g	77.60a	11.53b	3.47a	1.73b	10.97a	5.88a	10.96a
	4g	79.67a	12.40a	3.40a	1.93b	10.92a	6.28a	10.91a
	Mean	75.34	11.45	3.36	1.64	8.14	4.55	8.13
	C.V.%	8.27	13.82	6.58	28.58	28.88	35.08	28.88

Means followed by the same letter for each parameter are not significantly different at 5% level of LSD.

Plant Height:

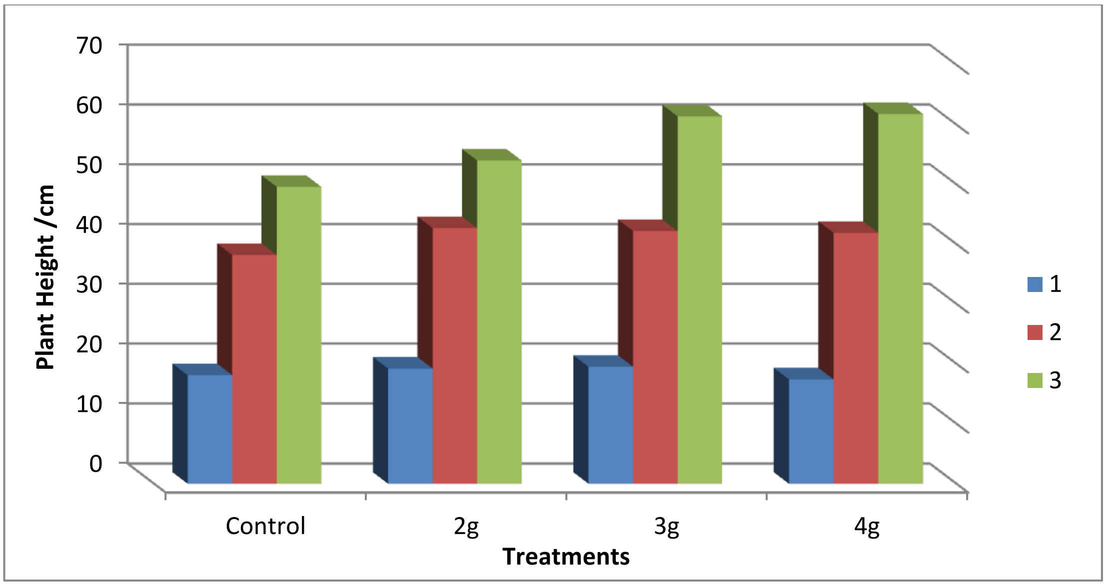

Fig. 1.a At planting

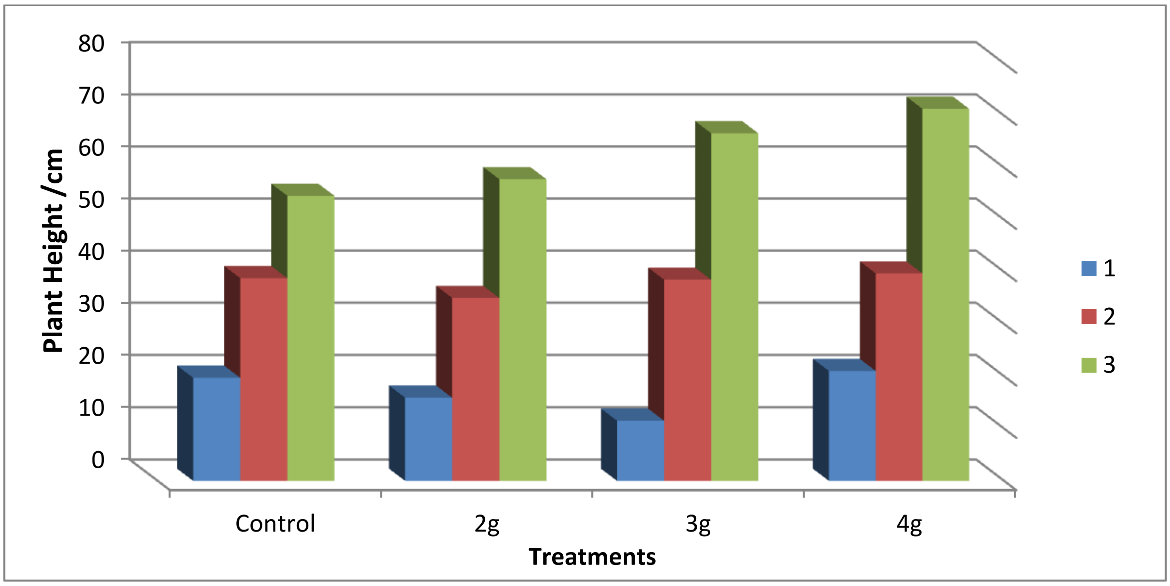

Fig. 1.b After planting

Fig.1 Plant height of Barley microdosing at different application time.

1: growth after 15 days.

2: growth after 30 days.

3: growth after 45 days.

Number of leaves:

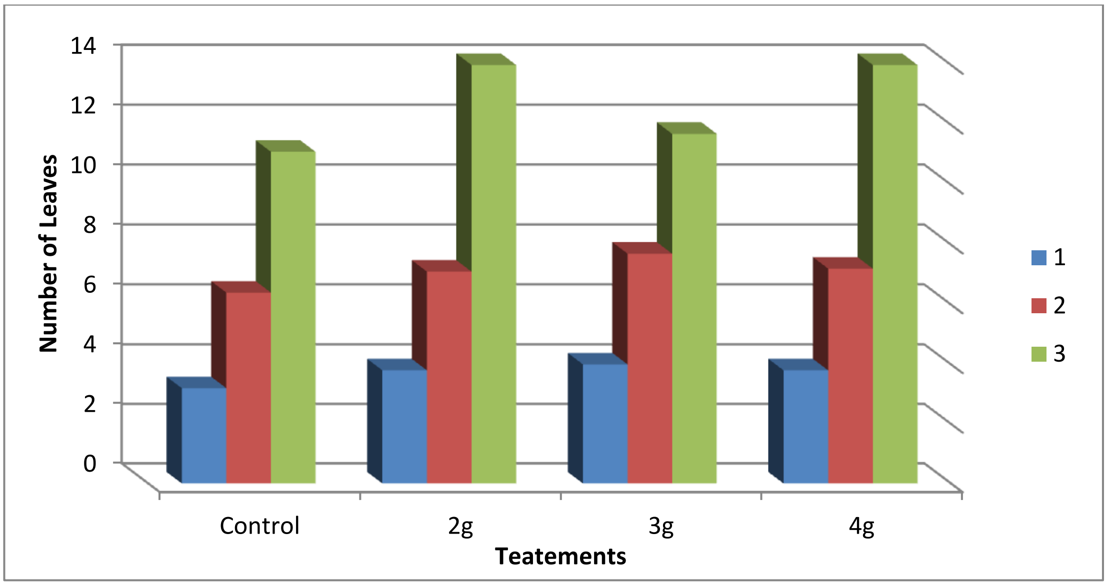

Fig. 2.aAt planting

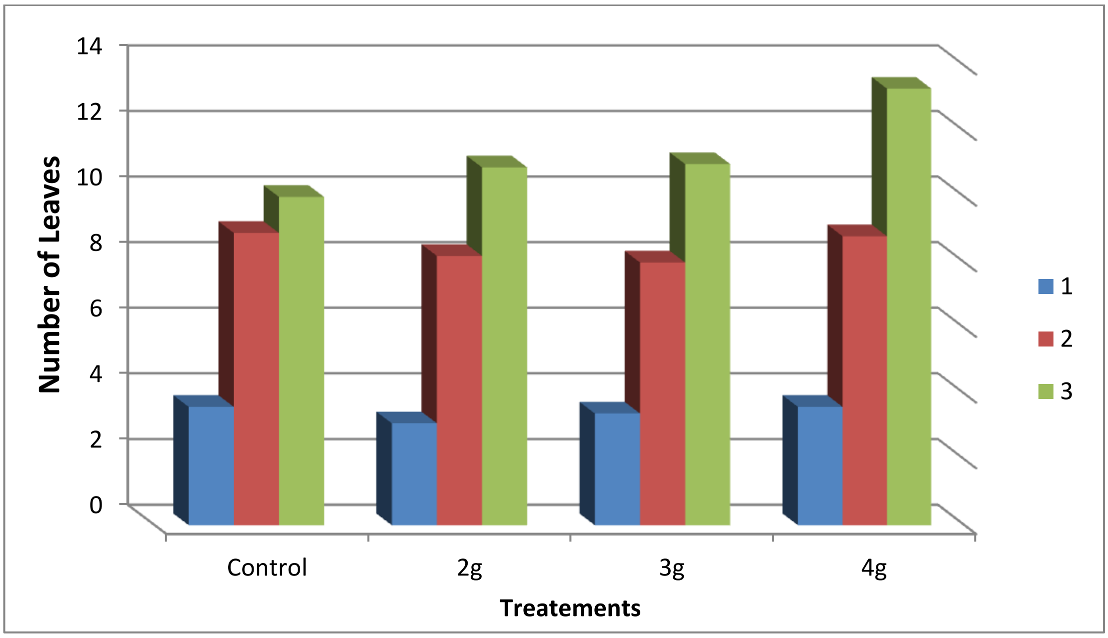

Fig. 2.b After planting

Fig.2. Number of leaves of Barley microdosing at different application time.

1: growth after 15 days.

2: growth after 30 days.

3: growth after 45 days.

Stem diameter:

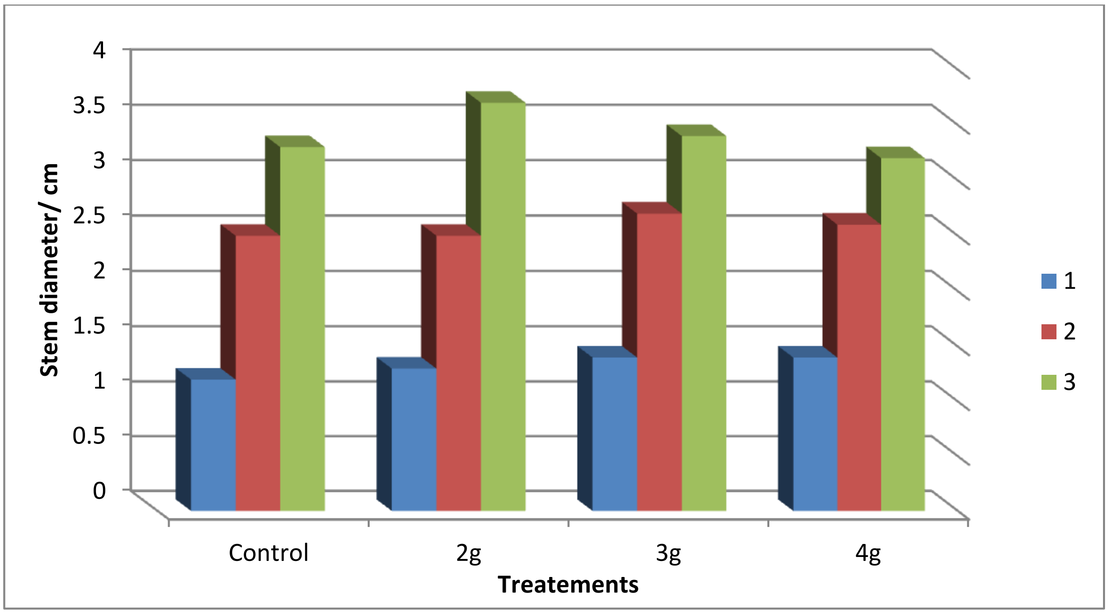

Fig.3.a At planting

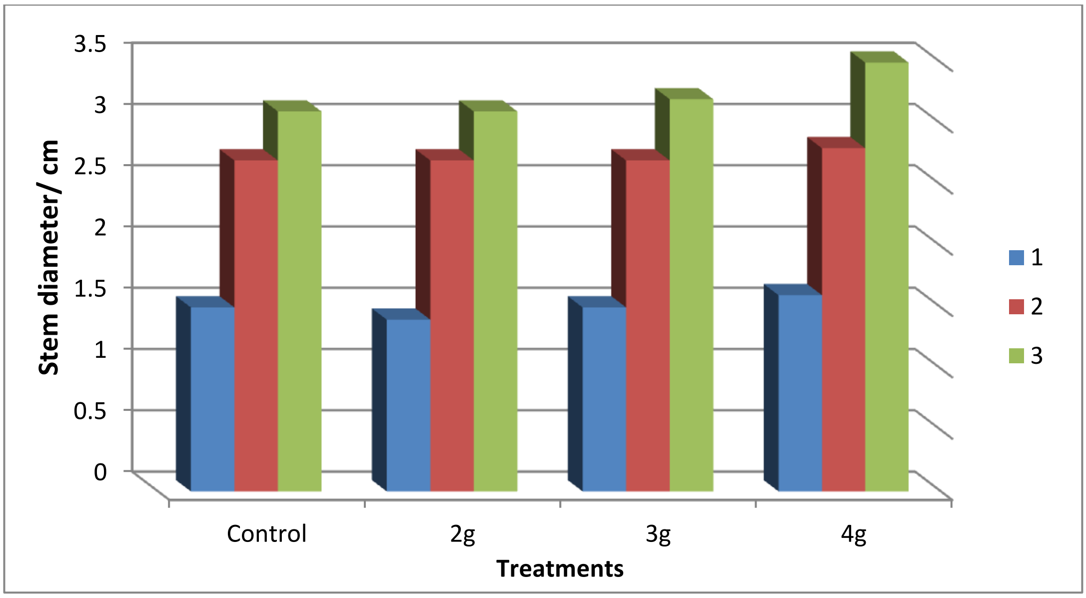

Fig.3.b After planting

Fig.3. Stem diameter of Barley microdosing at different application time.

1: growth after 15 days.

2: growth after 30 days.

3: growth after 45 days

Conclusions

The study addressed the effect of microdosing at sowing and after sowing on the performance of forage barley. The following can be concluded:-

1. Microdosing or adding small amount of fertilizer will increase productivity as the amount is put directly adjacent to the seed or plant.
2. Addition of fertilizer after sowing had better results than at sowing as the roots will absorb the fertilizer better.
3. The highest dose (4g/plant) gave the highest yield.
4. Microdosing is suitable for small holdings and when the price of fertilizer is not affordable.
5. The experiment should be repeated for another season to confirm the results.

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Appendix

Appendix: analysis of variance table:

(A)Plant height (cm):

Source of variation	Degrees of freedom	Sum of squares	Mean of squares	F values	Prob
Replication	2	280.776	140.388	0.8250	
Factor A	1	76.684	76.684	0.4507	
Error	2	340.323	170.161		
Factor B	3	280.335	93.445	2.5256	0.1068
AXB	3	110.055	36.685	0.9915	
Error	12	443.988	36.999		
Total	23	1532.160			

Coefficient of Variation: 8.27%

s_ for means group 1: 4.6120 Number of Observations: 8
y

s_ for means group 2: 3.7656 Number of Observations: 12
y

s_ for means group 4: 2.4832 Number of Observations: 6
y

s_ for means group 6: 3.5118 Number of Observations: 3
y

(B) Number of leaves/plant:

Source of variation	Degrees of freedom	Sum of squares	Mean of squares	F values	Prob
Replication	2	44.523	22.262	2.9597	0.2525
Factor A	1	20.907	20.907	2.7795	0.2374
Error	2	15.043	7.522		
Factor B	3	0.860	0.287	0.0979	
AXB	3	8.573	2.858	0.9763	
Error	12	35.127	2.927	2.927	
Total	23	125.033			

Coefficient of Variation: 13.82%

s_ for means group 1: 0.9696 Number of Observations: 8
y

s_ for means group 2: 0.7917 Number of Observations: 12
y

s_ for means group 4: 0.6985 Number of Observations: 6
y

s_ for means group 6: 0.9878 Number of Observations: 3
y

(C): Stem diameter (ml):

Source of variation	Degrees of freedom	Sum of squares	Mean of squares	F values	Prob
Replication	2	0.098	0.049	2.7209	0.2687
Factor A	1	0.042	0.042	2.3256	0.2668
Error	2	0.036	0.018		
Factor B	3	0.190	0.063	1.2667	0.3298
AXB	3	0.055	0.018	0.3667	
Error	12	0.050	0.600		
Total	23	1.020			

Coefficient of Variation: 6.58%

s_ for means group 1: 0.0473 Number of Observations: 8
y

s_ for means group 2: 0.0386 Number of Observations: 12
y

s_ for means group 4: 0.0913 Number of Observations: 6
y

s_ for means group 6: 0.1291 Number of Observations: 3
y

(D)Number of tillers / plant:

Source of variation	Degrees of freedom	Sum of squares	Mean of squares	F values	Prob
Replication	2	0.943	0.472	4.6393	0.1773
Factor A	1	1.707	1.707	16.7869	0.0547
Error	2	0.203	0.102		
Factor B	3	0.287	0.096	0.3185	
AXB	3	0.373	0.124	0.4148	
Error	12	3.600	0.300		
Total	23	7.113			

Coefficient of Variation: 28.58%

s_ for means group 1: 0.1127 Number of Observations: 8
y

s_ for means group 2: 0.0920 Number of Observations: 12
y

s_ for means group 4: 0.2236 Number of Observations: 6
y

s_ for means group 6: 0.3162 Number of Observations: 3
y

(E) Fresh weight/plant (g):

Source of variation	Degrees of freedom	Sum of squares	Mean of squares	F values	Prob
Replication	2	35.045	17.523	4.7883	0.1728
Factor A	1	10.667	10.667	2.9148	0.2299
Error	2	7.319	3.659		
Factor B	3	72.265	24.088	5.1728	0.0159
AXB	3	33.378	11.126	2.3893	0.1198
Error	12	55.881	4.657		
Total	23	214.555			

Coefficient of Variation: 28.88%

s_ for means group 1: 0.6763 Number of Observations: 8
y

s_ for means group 2: 0.5522 Number of Observations: 12
y

s_ for means group 4: 0.8810 Number of Observations: 6
y

s_ for means group 6: 1.2459 Number of Observations: 3
y

(F) Dry weight/plant (g):

Source of variation	Degrees of freedom	Sum of squares	Mean of squares	F values	Prob
Replication	2	10.853	5.427	65.3390	0.0151
Factor A	1	4.125	4.125	49.6676	0.0195
Error	2	0.166	0.083		
Factor B	3	24.372	8.124	3.8350	0.0389
AXB	3	11.579	3.860	1.8220	0.1968
Error	12	25.421	2.118		
Total	23	76.516			

Coefficient of Variation: 35.08%

s_ for means group 1: 0.1019 Number of Observations: 8
y

s_ for means group 2: 0.0832 Number of Observations: 12
y

s_ for means group 4: 0.5942 Number of Observations: 6
y

s_ for means group 6: 0.8403 Number of Observations: 3
y