

بسم الله الرحمن الرحيم



Sudan University of Science and Technology
College of Agricultural Studies



The fertilizer microdosing technology for sorghum production at Shambat - Sudan

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B.Sc. in Agriculture (Honors)

By

Monirah Babiker Mohamed Arbab

Supervised By

Prof. (Dr.) Yassin Mohmad Ibrahim Dagash

Department of Agronomy

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الآية

قال تعالى:

وَإِذَا قِيلَ لَهُمْ آمِنُوا كَمَا آمَنَ النَّاسُ قَالُوا أَنُؤْمِنُ كَمَا آمَنَ السُّفَهَاءُ ^{قُلْ} أَلَا إِنَّهُمْ
هُمُ السُّفَهَاءُ وَلَكِنْ لَا يَعْلَمُونَ (١٣) وَإِذَا لَقُوا الَّذِينَ آمَنُوا قَالُوا آمَنَّا وَإِذَا
خَلَوْا إِلَىٰ شَيَاطِينِهِمْ قَالُوا إِنَّا مَعَكُمْ إِنَّمَا نَحْنُ مُسْتَهْزِئُونَ (١٤)

صدق الله العظيم

سورة البقرة الآية (13-14)

Dedication

To The soul of my dear GrandmoTher.

TO my greaT mOTher.

TO my amazing faTher

To my BroThers

To My Husband KHa lid MoHaMed

TO my lOvely family.

TO my a ll TEaCHERS aND FRIENDS

TO THE DEpa rTmEnT Of agrOnOmy

And The Col lege of Agricul turAl studies

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Abstract

The study was conducted at the experimental farm of Sudan University of Science and Technology, College of Agricultural Studies; Khartoum North- Shambat, to investigate the agronomic response and efficiency of fertilizer microdosing in Sorghum. An experiment with the following treatments was achieved: control without fertilizer, microdosing treatments with the rates of 1, 2, 3 and 4g NPK/plant hole at sowing.

The treatments were arranged in a completely randomized block design with four replications. The experiment was conducted during the growing season of 2015. Weeding was carried once after three weeks from seed germination and irrigated weekly. The following parameters were considered during experimentation; the number of leaves, plant height, node length and stem thickness, while the shoot fresh and dry weights were recorded at termination. The data collected were subjected to analysis of variance and the means were separated by Duncan's multiple rang test. The results obtained showed the progressive improvement of all Sorghum tested characters. There were highly significant differences in plant height, stem thickness, shoot fresh and dry weight. The number of leaves and the node length showed significant differences. The four gram microdose gave the best results.

CHAPTER ONE

INTRODUCTION

Sorghum (*Sorghum bicolor* L.) Moench; is the world's fifth most commonly grown cereal crop after wheat, rice, maize and barley Poehlman, 1994. Sorghum has many types of cultivated varieties, such as grain genotypes, fodder, fiber and sugar genotypes and dual purpose genotypes. Sorghum belongs to C4 plant characteristic for tolerate a biotic stresses more than many crops Gnansounou *et al.*, 2005. Recently, sorghum had received significant attention because of the newer use as a Biofuel feedstock (Paterson, 2008). Assessment of the genetic variability within cultivated crops and varieties has a strong impact on plant breeding strategies and conservation of genetic resources (Dean *et al.*, 1999; Simioniuc *et al.*, 2002) and is particularly useful in the characterization of individuals, accessions and cultivars in germplasm collections and for the choice of parental genotypes in breeding programs (Davila *et al.*, 1998; Ribaut *et al.*, 1998). In the past, indirect estimates of similarity based on morphological information have been widely used in many species including sorghum (Ayana, 1999). However, morphological variation does not reliably reflect the real genetic variation because of genotype environment interactions and the largely unknown genetic control of poly-genetically inherited morphological and agronomic traits (Smith and Smith, 1992). Molecular analyses in conjunction with morphological and agronomic evaluation of germplasm are recommended, because these provide complementary information and increase the resolving power of genetic diversity analyses (Singh *et al.*, 1991). Land degradation affects more than half of Africa, leading to loss of an estimated 42 billion dollars and 5 million hectares of productive land each year. The majority of farm lands produce poor yields due to

poor farming techniques (nutrient deficiency and irregular watering), (ICRISAT, 2009).

The decline in fertility of croplands is the basis of food insecurity in households especially the poor peasants are the most numerous in agriculture in the Sudan region of Mali. According to Sime and Aune (2014), the fallow which was the traditional way to restore the fertility of the land has almost disappeared in some places and in others its duration was significantly reduced because of demographic pressure. The technical packages to sustainably increase production are not within their reach. From the 1980s, there has been a decline in public funding in agriculture and paralysis of the sector of small producers in developing countries because of the structural adjustment policies of the IMF and the World Bank (Azoulay and Saizal, 1994; FAO, 1995; World Bank, 2007). Many governments in sub-Saharan Africa have made efforts in improving agricultural productivity through the creation of agricultural extension services. But these creations have not fulfilled the expectations of farmers mainly rural women (FAO, 2008). The development of sub-Saharan agriculture took from that moment an approach for the identification of technical innovation and communication giving more space to the farmers in the development of appropriate strategies for development. The farmer field school is one of these strategies lying in the extension approach of "bottom up" allowing farmers to join the basis for understanding what to achieve in finding appropriate solutions to their development issue. It was piloted in 90 countries and reached 10 to 15 million farmers worldwide (Waddington *et al.*, 2014).

There are a lot of results on the evaluation of farmer field schools: Togola *et al.*, (2010), FAO (2011), Braun *et al.*, (2006), Feder *et al.*, (2004), and Piyadasa Tripp (2005). There is, against few results on the diffusion of

technology from a farmer field school in sub-Saharan Africa (Davis, 2006; Baah, 2007).

The microdose technology is the application of small mineral fertilizer doses in the seed hole during sowing or next to the seedling after emergence (10 days after sowing). The advantages of this technology as reported by Agricultural technologies of Borkina Faso (2010) are:

- a. Location of the fertilizer near the root, thus obtaining a high concentration area which makes assimilation of nutrients easier.
- b. To limits phosphorus fixation phenomena by the soil.
- c. To reduce loss of Potassium (K) and Nitrogen (N) through leaching.
- d. To achieve an early start of plant growth.
- e. To increase the efficiency of fertilizer used.
- f. To minimize production cost.
- g. To improve small producers income.
- h. To increase the number of mineral fertilizer users.

However, ICRISAT (2009) mentioned some difficulties accompanied with this technology, which include:-

- a. The technology is time consuming, or laborites and difficult to ensure each plant gets the right dose.
- b. Access to fertilizer, access to credit, insufficient flow of information and in appropriate training polices to the farmers.
- c. The adoption of the technology requires supportive and complementary institutional innovation as well as input and output market linkage.

As mentioned by many researchers, the technology uses only about one-tenth of the amount typically used on wheat and one-twentieth of the

amount used on corn in USA. Yet, the African crops are so starved of nutrients such as phosphorus; potassium and nitrogen even that micro amount often doubles crop yields (Bationo *et al.*, 2015; Biolderr, 2015).

This study also investigates if people are more likely to adopt the technology if they receive it free of charge and how knowledge passes from farmer via social networks. Thus, the study aimed to fulfill the following objectives:

1. To test the response of sorghum to microdosing practices under Shambat clay soils.
2. To determine suitable microdosing levels that lead to increase in vegetative yield and consequently the seed.
3. To minimize the cost of fertilizer application by the minimum dose of fertilizer with maximum utilization by the plant.

CHAPTER TWO

LITERATURE REVIEW

Sorghum (*Sorghum bicolor* L.) Moench; originated in Africa and India, had historically been one of five major world cereal crops along with rice (*Oryza sativa* L.), maize (*Zea mays* L.), wheat (*Triticum aestivum* L.) and pearl millet (*Pennisetum glaucum* (L.) R. Br.) are used as human food. Grain sorghum, along with pearl millet, constitutes the staple cereal of millions of people living in the very hot, drought-prone tropical regions in West Africa and India (Maunder, 2002). In addition to its use as food, sorghum is used as feed for animals and feedstock for ethanol, mainly in the western hemisphere. The primary quality criterion of selection of sorghum varieties for traditional beer is their potential to produce malt with high *alpha*- and *beta*-amylase activities (Taylor and Dewar, 2001). Red sorghum grain generally has higher amylase activities than white grain which likely explains the preference of red grain sorghums for dolo 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 and 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. With these considerations in mind, 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 (ICRISAT, 2000; 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. In the West Africa Sahel, supply and demand constraints reduce adoption of technology such as improved sorghum seed and micro-dosing techniques. Although pockets and periods of higher adoption have occurred, national area shares, and yields, are generally far less than rice, maize or other specialty crops. Because sorghum is the region’s main food staple and most widely cultivated dry land crop small improvements in production techniques would have a large impact on farmers’ well-being. Thus, the researchers are seeking ways to enhance production and support the development of local sorghum value chains. 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; Savadogo *et al.*,

1998). 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. 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 and because neither the private nor public sectors have been able to supply improved seed or fertilizer in reasonable quantities, development organizations and donors have sought alternative means to strengthen the linkages along the agricultural input supply chain. Approaches include training and financing local agro-dealers and seed traders, and enabling farmer unions to supply improved seed and fertilizer micro-packs, a complementary scheme that promotes the application of small amounts of fertilizer (micro-dosing) at planting, which when applied to improved sorghum varieties considerably raises yields. Agricultural output has accelerated in Sub-Saharan Africa the last two decades, but agricultural productivity in the region remains low, especially compared to other regions of the world. (USDA, 2013) concluded that, the Greater use of inorganic fertilizer and improved seeds

are widely considered necessary to ensure African farmers boost production and farm profitably, but adoption of these technologies has been slow in the region. (Druilhe *et al.*, 2012) reported that, previous research indicates farmers invest in fertilizer when provided with small, time-limited discounts just after harvest, when they have income. To contribute evidence on the mechanisms that help people save enough money to buy fertilizer and seeds, this evaluation replicates this influential fertilizer study in the West African context with a fertilizer and seed, as opposed to only fertilizer.

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 major food crops grown are millet and sorghum, while groundnut and sesame are the major cash crops. Other crops grown are watermelon, Roselle, cowpea, maize, wheat, cotton, and okra. The productivity of these crops is very low due to poor crop establishment and low soil fertility. The main soil types of the region are the Goz sands that are very low in nitrogen, phosphorus and organic matter (Bationo, 1998).

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, unavailability of fertilizers and low purchasing power of the Small holders (Spencer, (1994 and 1995). 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; Klaij *et al*, 1994, Aune *et al*, 2007, Aune and Bationo 2008). Seed priming, a

process of soaking seeds in water for a specific time prior to sowing, is another low cost approach to increase yields under marginal dry-land conditions (Harris *et al.* 2001; Harris *et al.* 2005; Harris 2006 and Aune and Bationo, 2008).

Pearl millet and Sorghum are the most important food crops produced in semi-arid West Africa (FAOSTAT, 2011). They are grown under environmental conditions with limited and erratic rainfall, high temperatures, and poor soil conditions and low nutrient levels to harsh for other cereal crops (National Academy of Science, 1996). Research has indicated that pearl millet and grain Sorghum yields increase with fertilizer application, but little adoption has occurred due to availability and cost of fertilizer, and low grain prices (Abdoulaye and Sanders, 2005; Vitale and Sanders, 2005). Fertilizer use rates in Africa are only 8 kg ha⁻¹ with most of fertilizer applied to cash crops for export (Buerkert *et al.*, 2000; Morris *et al.*, 2007).

Studies indicate that the quantity of nutrients removed by crops is far greater than additions in West Africa, thus degrading the soil natural resource critical to crop management (Bagayoko *et al.*, 1996; Bekunda *et al.*, 1997; Sanchez *et al.*, 1997). It is generally considered that P is the most limiting nutrient for pearl millet and Sorghum production in West Africa, with N being the second most limiting (Bationo and Mkwunye, 1991). Animal feces and urine contribute to nutrient needs, but the supply is inadequate to meet plant nutrient needs (Giller *et al.*, 1997; Bationo *et al.*, 1998), thus increased chemical fertilizer application is essential to increase yields and maintain/improve the soil nutrient status. Leaving crop residues in the field also increase infiltration of water into soils (Nicou and Charreau, 1985), increases soil organic matter content (Klaij and Hoogmoed, 1993) increases nutrient recycling (Geiger *et al.*, 1992), increases soil pH and nutrient levels (Coulibaly *et al.*, 2000; Michels *et*

al., 1995) and increases yield (Bationo *et al.*, 1993; Coulibaly *et al.*, 2000), but is seldom are crop residues left in fields due to high economic value and use as livestock feed and fuel (Schlecht and Buerkert, 2004). Increased stover production would increase the likelihood of meeting livestock and fuel needs while having more stover available to be left in fields. Chemical fertilizer application rates are low except for cash crops that can consistently be marketed for a profit (Buerkert *et al.*, 2000).

Point application (microdose) has been widely promoted due to the low fertilizer application rate, high probability of yield response (Muehlig-Versen *et al.*, 2003; Palé *et al.*, 2009) and due to a favorable fertilizer/grain price ratio (Abdoulaye and Sanders, 2005; Vitale and Sanders, 2005). Microdose application can reduce P fixation, promote early season shoot and root growth, enhance infection with vesicular arbuscular mycorrhiza leading to increased nutrient uptake of grain and stover yields (Bagayoko *et al.*, 2000). Research on the combination of microdose fertilizer application combined with N and P fertilizer application has not been reported.

The objective of this study was to determine the grain and stover yield response of Sorghum to microdose fertilizer application along and in combination with N and P fertilizer across years and locations in Sudan-Africa.

CHAPTER THREE

MATERIAL AND METHODS

3.1 Experimental site:

A field experiment was conducted at the demonstration farm of the College of Agricultural Studies, Sudan University of Science and Technology, Shambat Khartoum North, (Latitude 15.40 N., 32, 32 E., elevation 380 m above Sea level). The climate is semi-desert with a low relative humidity and annual rainfall rate 150 mm and a mean temperature of (20.3 C°- 36.1 C°) and clay soil celtic pH 7.5-8.7 Abdulha Feez (2001).

3.2 Treatments:

1. Control (without fertilizer).
2. 1 gm compound fertilizer microdosing.
3. 2 gm compound fertilizer microdosing
4. 4 gm compound fertilizer microdosing.

3.3 Source of seed

Sorghum (*Sorghum bicolor* L.) local variety, were obtained from College of Agricultural Studies, Sudan University of Science and Technology (Shambat).

3.4 Land preparation and sowing

The experimental site was disc ploughed and harrowed, then followed by harrowing and leveling, riding up North- South. The spacing between ridged was 70 cm. Five replications were divided into four plots, each plot was 3×3, consisting of five rows.

The sowing data was in December 2015. The seeds were sown in holes each 40 cm apart, the seed were sown at the depth of 20 cm. With fertilizer in the same hole. Weeding was done two times after three weeks from sowing and after one month from the first hand weeding.

3.5 Irrigation

The plants were watered according to the need.

3.6 Data collection

50% flowering, the following data were recorded.

3.6.1 Plant hight

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

3.6.2 Number of leaves per plant

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

3.6.3 Length inter node (cm)

Five plants from each plot were taken and the average length of inter nodes per plant was measured.

3.6.4 Stem diameter (cm)

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 .

3.6.5 Forage fresh yield per plant (g)

Five plants from each plot were taken and weighted and the mean weight per plant was taken.

3.6.6 Forage dry yield/ plant (g)

The five plant from each plot used for fresh weight were dried at the oven (80 C°) for 48 hours and then weighed per plant was recorded.

3.6.7 Statistical analysis

The data analyzed according to the standard statistical procedure for a randomized complete block design as described by Comez and Gomez (1984) using MSTAT. C computer package.

CHAPTER FOUR

RESULTS

The results of the study for all tested parameters are indicated in (Table 1) and separate detailed figures from (1-6).

According to (Table 1), the results revealed that, there are highly significant differences among the treatments for the plant height, stem thickness, shoot fresh and dry weights; while there is a significant difference for the node length and number of leaves.

The coefficient of variation for all tested parameters ranged between 3.73 – 14.47%.

The plant height was higher for the 3g microdose treatment (136cm) and the lowest for the control (108cm) (Table 2/ Figure 1).

The highest node length was recorded for 4g microdose (16cm) while the control resulted in the lowest value (12.5 cm) (Table 2/ Figure 2).

The best number of leaves was obtained from the 4g microdose treatment (9) and the lowest was recorded for the control (7) (Table 2/ Figure 3).

The 4g microdose treatment resulted in the best stem thickness (4.36cm) and the lowest value was recorded for the control (2.63cm) (Table2/ Figure 4).

The highest values of shoot fresh and dry weights were recorded from 4g microdose treatment (125 & 54.50g) while the lowest values were obtained from the control (49.5 & 20.5g) respectively (Table 2/ Figure 5 and 6).

Table 1. Summary of ANOVA (F. value) of *Sorghum bicolor* on micro dose experiment.

F. value							
Source of variation	Degree of freedom	Plant height (cm)	Node length (g)	Number of leaves	Stem thickness (cm)	Shoot fresh weight (g)	Shoot dry weight (g)
Replication	3	0.4996	3.2727	0.9057	1.1211	1.2496	0.6128
Fertilizer	4	36.9939**	4.9773*	5.3774*	15.1966**	237.4937**	57.1195**
Error	12	-	-	-	-	-	-
Total	19	-	-	-	-	-	-
C.V. %	-	3.73	8.53	8.31	10.08	9.41	14.47
Lsd. value	-	5.94	1.80	0.98	0.51	5.73	5.18

Ns= not significant, * Significant (5%), ** highly significant (1%),

Table 2. The average means of *Sorghum bicolor* on micro dose experiment.

NPK levels (g)	Plant height (cm)	Node length (cm)	Number of leaves	Stem thickness (cm)	Shoot fresh weight (g)	Shoot dry weight (g)
Control	108.0d	12.5d	7.00c	2.63d	49.50d	20.50d
1.0	116.0c	13.5c	7.50bc	2.90cd	55.80c	25.88c
2.0	124.0b	14.0c	8.25ab	3.35bc	77.00b	29.00c
3.0	136.0a	15.0b	8.25ab	3.75b	74.60b	36.75b
4.0	124.a	16.0a	9.00a	4.36a	125.00a	54.50a
Lsd. value	5.94	1.80	0.98	0.51	5.73	5.18
c.v. %	3.73	8.53	8.31	10.08	9.41	14.47

* Means followed with the same letter (s) within the column are not significantly different.

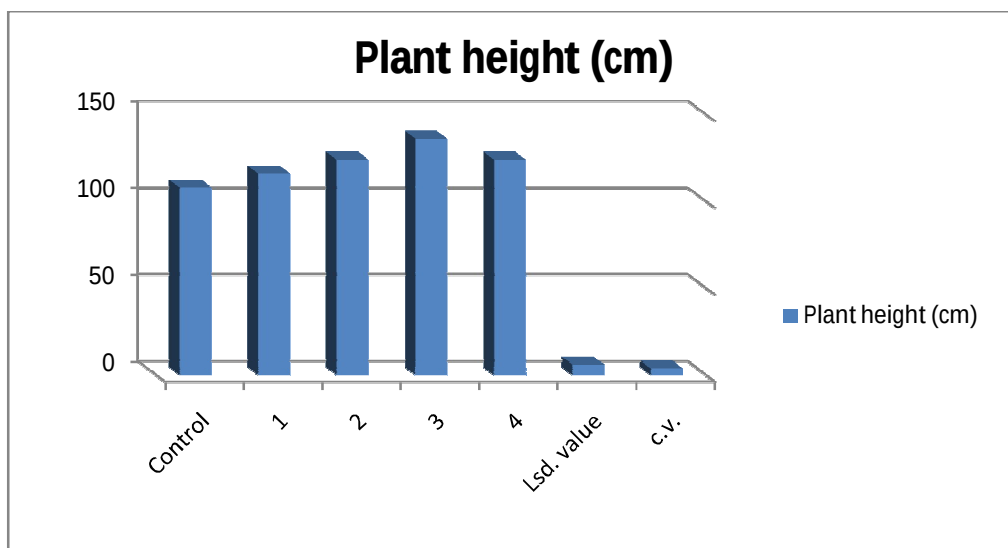


Figure 1. Plant height of sorghum microdose

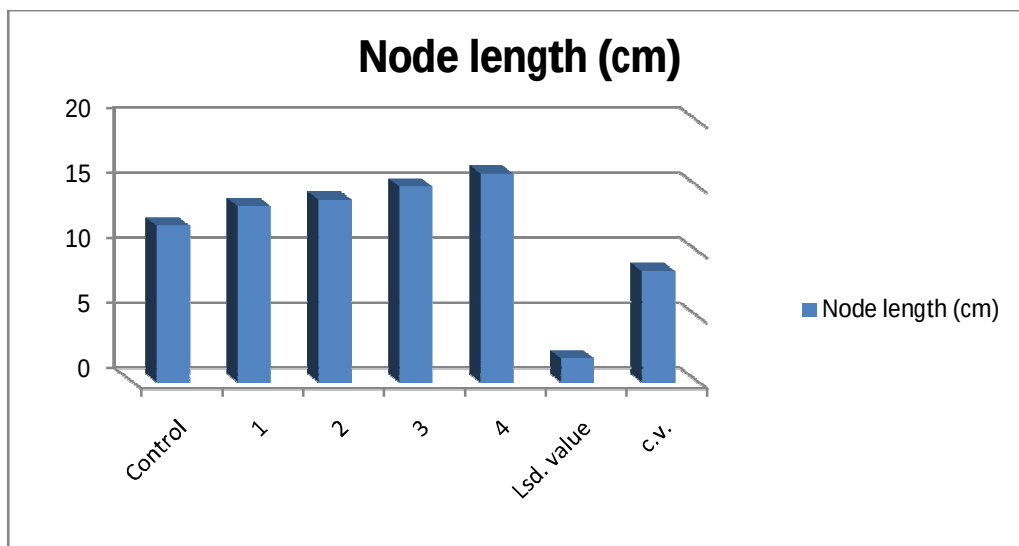


Figure 2. Node length of sorghum microdose

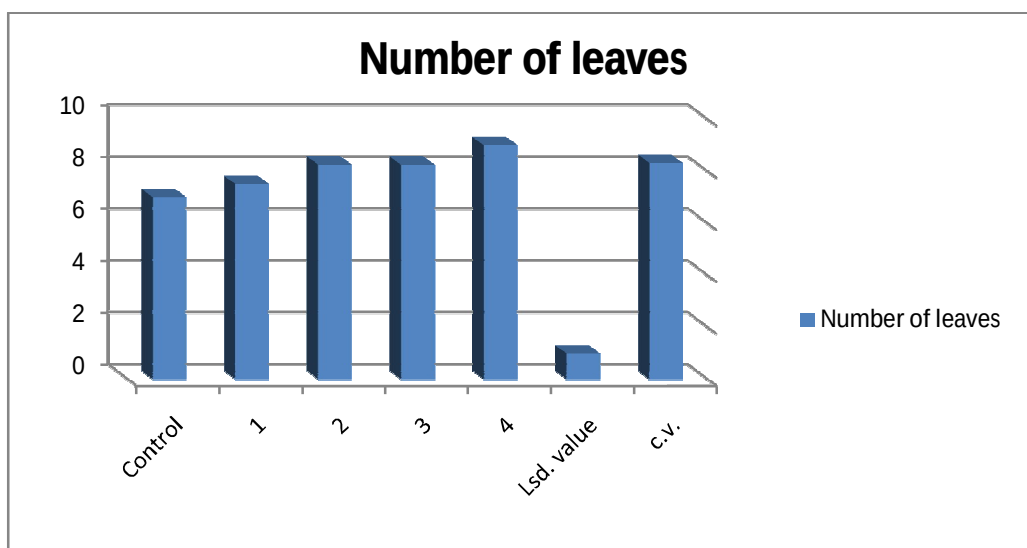


Figure 3. Number of leaves of sorghum microdose

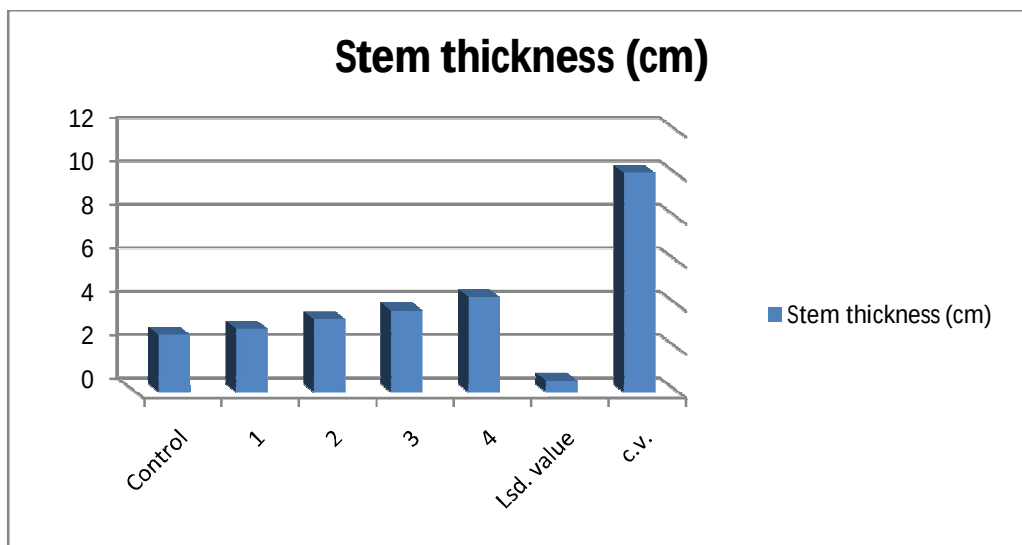


Figure 4. Stem thickness of sorghum microdose

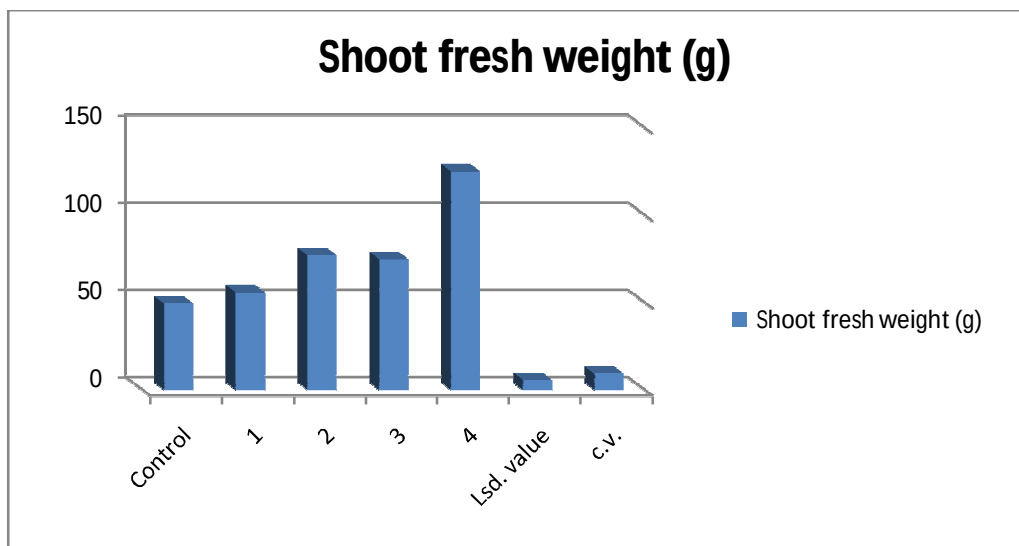


Figure 5. Shoot fresh weight of sorghum microdose

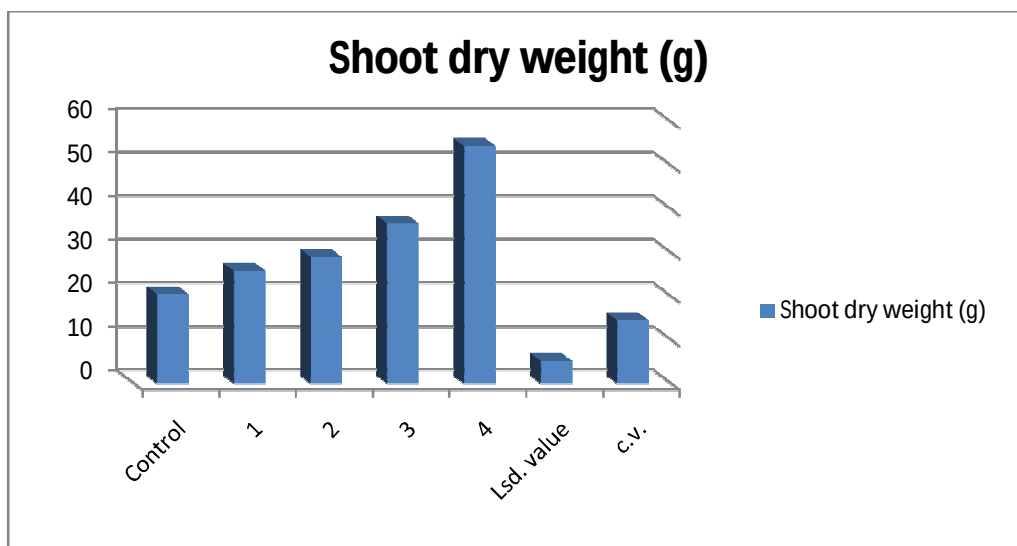


Figure 6. Shoot dry weight of sorghum microdose

CHAPTER FIVE

DISCUSSION

Response of Sorghum Characters to Fertilizer Microdosing:

Irrespective of different adverse conditions in the study site during the experimentation, all of the fertilizer rates (microdosing) increased yields compared to the control. This shows that there is a need for applying fertilizer in Sorghum production at most soils of our country. A fertilizer application method that is efficient with a smaller amount of fertilizer is to be the most important for marginal farmers in the central Sudan. Such a method will have high potential to increase farmers' interest, economic viability and sustainability with respect to applying fertilizer in Sorghum. In this respect, results of this study showed that the microdosing method of fertilizer application was found to improve Sorghum yields with smaller quantities of fertilizer. The results of the study are strongly agreed with those obtained by Khatam *et al.*, 2013; Morris *et al.* (2007).

Previous studies on the response of Sorghum and pearl millet reported by Palé *et al.* (2009); Vitale and Sanders (2005), had also shown similar effects that lower fertilizer rates increased crop yields more than the higher rates in microdosing in sub-Saharan countries. Inasmuch as, the results of the study concerning the adoption of microdose technology reported by Agricultural Technologies in Burkina Faso (2010), showed that, the lowest fertilizer rate in microdosing was able to improve sorghum yield more than that of broadcasting in sub-Saharan countries. Similar results were also reported by Bationo *et al.* (1998); Bagayoko *et al.* (1992) as they concluded that, the cereals in general revealed lower yield response to the highest fertilizer rate in microdosing and this can be owed that, there is a limit to the dose of fertilizer that can be applied through microdosing. They also noticed that, the high levels of fertilizer

found to depress pocket seed germination and lower plant population at harvest and these negative effects on maize performances might be attributed to the burning effects of high doses of fertilizer in the microdosing method of application. Such remarks were also reported by Druilhe and Jesús (2012); FAOSTAT (2011); Coulibaly *et al.* (2000).

Therefore, if the farmers are practicing microdosing, they can obtain a good yield at a low rate of fertilizer application. Yet, further study based on long-term data is required to rectifying optimum fertilizer rates for the different sites of sub- Sahelian countries depending on soil quality and other governing agro-ecological conditions.

As a result, the microdosing method of fertilizer application becomes more efficient in increasing the yield of cereals than the banding and broadcasting method of fertilizer application. This might be due to the fact that placing fertilizer close to the seed in soils increases fertilizer uptake by crops as reported by (FAOSTAT 2011).

This indicates that under a better soil management system and favorable seasonal rainfall conditions, farmers can still get reasonable yields from crops through the application of microdose technology. Although the labor demand in microdosing (4.8 man-days ha⁻¹) is nearly twice that in banding (2.3 days ha⁻¹) for the application of fertilizers, the microdosing method still appears attractive and viable. Like in several other areas in Ethiopia, the opportunity cost for labor is low in the central rift valley.

Conclusions and Recommendations:

- Microdosing in Sorghum is an interesting option for farmers, because it gives a high yield, as well as favorable gross margins.
- Both fertilizer microdosing and banding improves yields.
- The lowest fertilizer rates improve yields as much as higher rates under both microdosing and banding.
- Microdosing shows that it is more efficient than banding, which may increase farmers' interest in applying fertilizer with the microdosing method.

In conclusion, lower fertilizer rates under microdosing are more productive and profitable than higher rates under microdosing or banding methods.

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Appendices

A N OVA table for Plant height

K Value	Source	D.F.	Sum of Squares	Mean Square	F. Value	Prob.
1	Replication	3	32.950	10.983	0.4996	
2	Factor A	4	3253.000	813.250	36.9939	0.0000
-3	Error	12	263.800	21.983		
	Total	19	3549.750			
-	Coefficient of Variation: 3.73%					

A N OVA table for (Node length)

K Value	Source	D.F.	Sum of Squares	Mean Square	F. Value	Prob.
- 1	Replication	3	14.400	4.800	3.2727	0.0589
2	Factor A	4	29.200	7.300	4.9773	0.0134
-3	Error	12	17.600	1.467		
-	Total	19	61.200			
	Coefficient of Variation: 8.53%					

A N OVA table for (Number of leaves)

K Value	Source	D.F.	Sum of Squares	Mean Square	F. Value	Prob.
1	Replication	3	1.200	0.400	0.9057	
2	Factor A	4	9.500	2.375	5.3774	0.0102
-3	Error	12	5.300	0.442		
	Total	19	16.000			
Coefficient of Variation: 8.31%						

A N OVA table for (Stem thickness)

K Value	Source	D.F.	Sum of Squares	Mean Square	F. Value	Prob.
1	Replication	3	0.394	0.131	1.1211	0.3792
2	Factor A	4	7.112	1.778	15.1966	0.0001
-3	Error	12	1.404	0.117		
	Total	19	8.909			
Coefficient of Variation: 10.08%						

A N OVA table for (Fresh weight)

K Value	Source	D.F.	Sum of Squares	Mean Square	F. Value	Prob.
1	Replication	3	55.449	18.483	1.2496	0.3352
2	Factor A	4	14051.550	3512.888	237.4937	0.0000
-3	Error	12	177.498	14.791		
Total		19	14284.498			
Coefficient of Variation: 5.04%						

A N OVA table for (Dry weight)

K Value	Source	D.F.	Sum of Squares	Mean Square	F. Value	Prob.
1	Replication	3	22.490	7.497	0.6128	
2	Factor A	4	2795.200	698.800	57.1195	0.0000
-3	Error	12	146.808	12.234		
Total		19	2964.497			
Coefficient of Variation: 10.50%						