EFFECT OF FERTILIZER AND MANURE APPLICATION ON GROWTH AND AREA ADAPTABILITY OF THREE COMMON ALOE SPECIES IN A SEMI-ARID EASTERN KENYA

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Abstract

Semi-arid lands have limited sustainable cash crops that can survive the dry climatic conditions and provide a stable source of income to the people in the region. Aloes, which grow wildly in this region controls a large world market valued at U$ 20 billion and are a source of natural products that are used in cosmetic and pharmaceutical industries worldwide. In order to commercialize this crop in the dry lands of eastern Kenya, studies were conducted to investigate adaptability, response to fertilizer and/or manure application and growth of three commonly occurring aloe varieties in the semi–arid lands. The 3 aloes were tested for response to 9 fertilizer and/or manure treatments (Nil fertilizer or manure, 20 kg P_2O_5/ha, 10 kg P_2O_5/ha, 4 t FYM /ha, 2 t FYM/ha, 20 kg P_2O_5 + 2 t FYM/ha, 10 kg P_2O_5 + 2 t FYM/ha, 20 kg P_2O_5 +4 t FYM/ha, 10 kg P_2O_5 +4 t FYM/ha) and their environmental adaptability in a randomized complete block design in a split plot arrangement at Kambi ya Mawe in Makueni district from 2007-2009. The results revealed that, aloe *secundifolia Engler* and aloe *vera barbadensis* Miller had a significantly ($P \leq 0.05$) better survival proportion of 96% and 92% after first and 93% and 79.5% at end of second year of growth respectively. Leaf area index (LAI) which is a measure of aloe growth, was significantly ($P \leq 0.05$) higher in aloe *secundifolia* Engler and aloe *turkanensis* Christian than aloe *vera barbadensis* Miller. After the 2 years of study, the 3 aloes species did not respond significantly ($P \leq 0.05$) to fertilizer and/or manure application. Participating farmers were empowered on aloe agronomy and processing. It was recommended that, A. *secundifolia* Engler was most adaptable for growing in the semi-arid lands followed by A. *vera barbadensis* and can be grown up to 2 years without fertilizer or manure application in very low fertile soils. However, more data is required to show how long the aloes can be grown without soil fertility improvements.

Key words: aloes, environmental adaptability, fertilizer and/or manure response, growth. Processing.

Introduction

Currently about 1,000 metric tons worth US$ 20 billion of aloes are being traded in the world market. This trade is mostly controlled by United States of America (Njuguna, 2005). Most of the aloe is used in cosmetics and pharmaceutical industries (Wabuyele *et al.* 2006) due to increased demand for natural health products in these industries. Kenyan trade in aloe is in the form of smuggled aloe and gum products leaving out as disguised commodities from parts of Samburu, Marsabit, Moyale, Wajir, Baringo and Kajiado districts to markets in Italy, Pakistan, Singapore, Thailand, China and Middle East. In South Africa, aloe products are internationally marketed and used locally. Most of aloe products from South Africa are exported to Europe, (Italy, France and German) accounting for 600 metric tons in the world market (Njuguna, 2005; Wabuyele *et al*., 2006).

There are 220 taxa of aloes in East Africa with over 100 of these species being cultivated world-wide (CITIES, 2003). Kenya has the greatest aloe diversity among the East African countries. There are close to 80 species of aloe in the country with 80% of them being found in the arid and semi-arid lands (Wabuyele *et al.,* 2006). Interest has been shown in aloe's commercialization in the semi arid districts where they grow naturally in the wild (Njuguna, 2005). Aloes have been found to be the crop that can be used for climate change adaptation in drought prone areas where other plants dry up and aloe remains green (Senelwa, 2009; Aloe vera cultivation services, 2010) Their cultivation and industrialization in these areas would serve as a secure cash income in places of uncertain food security, improve environmental conservation and increase household incomes. The plant is able to establish and survive under hostile conditions (Njuguna, 2005; Senelwa, 2009; Aloe vera cultivation services, 2010) but information on agronomic requirements and environmental suitability for increased growth for commercial aloe farming in arid and semi-arid lands in the country was still lacking. There are reports that, some aloes needs fertilizer nitrogen and potassium application at rate of 100 kg potassium + 200 kg nitrogen/ha for increased growth and leaf yield (Hossain *et al.,* 2007). Elsewhere it is reported application of nitrogen may result in higher gel yields, faster leaf formation and higher gel yield per leaf but application of large amounts of nitrogen may reduce gel quality (Wabuyele *et al*., 2006). It was noted that, although aloes will require soil nutrient replenishment, the amounts and sources of nitrogen and phosphorus to be used to grow aloes for commercial purpose without compromising the aloe product quality was still very unclear. Most suitable aloes among the common occurring varieties to grow for processing for income generation in the region were still very gray to farmers and scientists.

This project was started to expose farmers to aloe farming and its value addition for income generating and poverty alleviation within the semi-arid lands and to determine the aloes that are most adaptable for growing in the semi-arid lands and their fertilizer and manure requirements for commercial production. Makueni district was used as a pilot semi-arid district for the study.
The objectives of the study were to determine the effect of fertilizer and/or (FYM) manure on the survival and performance of aloe species grown in semi-arid Makueni district.

Materials and Methods

This project was conducted at Kambi ya Mawe agricultural field station within Wote division of Makueni district (1^o 50'S, 37^o40'E). The station lies within agro ecological zone 5 (AEZ 5) (Jaetzold and Schmidt, 1983) in the semi-arid region of eastern Kenya The area receives mean annual rainfall of 231mm in the long rains (March - May) and 361mm in short rains (October - January). Ascertaining environmentally best suitable aloe species for the region and determination of agronomic requirements was carried out between 2007 and 2009. Three commonly found aloe varieties in the region (aloe *vera barbadensis* Miller, aloe *secundifolia* Engler and aloe *turkanensis* Christian) were tested for adaptability, growth and agronomic requirements at Kambi ya Mawe in Makueni district. The experimental design was a randomized complete block design in a split plot arrangement with 3 replicates. The aloes were planted at a spacing of 100 cm x 60 cm for Aloe *Vera barbadensis* Miller, 100 cm x 100 cm for Aloe *secundifolia* Engler and 100 x 80 cm for Aloe *turkanensis* Christian in plots measuring 5M x 2 M with spacing of 1.5 M between plots.

Population density at planting was 24 plants per plot for aloe *vera barbadensis* Miller and 18 for aloe *secundifolia* Engler and aloe *turkanensis* Christian. Soils samples were taken from 0-20 cm soil depth from the experimental field. These samples were analyzed for macro and micro nutrients following procedures described by Hinga *et.al.* (1980).

There were 9 treatments (10 kg P_2O_5/ha, 20 kg P_2O_5/ha, 2 t FYM/ha, 4 t FYM/ ha, 10 kg P_2O_5 + 2 t FYM/ ha, 10 kg P_2O_5 /ha, + 4 t FYM /ha, 2 t FYM /ha. + 20 kg P_2O_5/ha, 20 kg P_2O_5 /ha + 4 t FYM /ha and Nil). These treatments were based on manure and inorganic fertilizer requirements for crops in the semi-arid lands in eastern Kenya (Ikombo *et al.,* 1984, Watiki *et al*.,1998) and the requirements that much nitrogen application on aloes can affect the quality of the aloe products (Wabuyele *et al*., 2006). Phosphate fertilizer was applied as NPK (20:20:0). Manure used was cow boma manure. Half the rate of recommended manure for crops in the semi-arid lands was applied in order to check on amount of nitrogen applied.

The 9 treatments were randomly placed in 9 plots measuring 5M x 2M for each aloe variety separated by 1.5 meter space between plots. There were 9 plots for each aloe variety and arranged on the field in such a way that the aloe varieties formed a block with 3 varieties with 9 treatments randomly placed in 9 experimental plots. This constituted a replicate. This arrangement was replicated 3 times in the field. The experimental lay out was a split plot in a randomized complete block design with 3 replicates.

Aloe survival which was a measure of adaptability to the environmental conditions was measured by counting the number of aloes surviving after 1 and 2 years after planting. Leaf area (LAI) was used as a measure of growth of the aloes. This was measured by taking leaf width at the base of the widest leaf base width and the length of the same leaf and multiplying the product of leaf length and corresponding leaf base width with 70% (Waldir C de J Jr. *et al.,* 2001). The leaf area measurements were carried out after first and second year of aloe growth in the experimental field.
Effect of fertilizer and manure application and environmental interactions was observed as effect of treatments on aloe survival and growth. Aloe survival data was collected by counting number of aloes surviving in each treatment plot after first and second year after planting. This was done for all treatment plots and for all varieties. The leaf area (LAI) was used as a measure of growth for the aloes and this was related to the treatments and aloe varieties through statistical analysis. The data was analyzed using Genstat statistical soft ware.
The aloes were harvested for processing after two and half years. Aloe *secundifolia* Engler and aloe *turkanensis* Christian leaves were cut near the base and placed in a bucket for the sap to drip into the container for 10-15 minutes (Figure 1). One needs to harvest 10-15 fully grown leaves to receive 200 ml of aloe sap. The aloe *vera barbadensis* Miller leaves were cut at the base and cleaned with clean water, and then split diagonally into two (Figure 2). The aloe gel was then scooped using a knife into a container. Aloe *vera barbadensis* Miller gives colorless gel (Figure 2) while the other 2 aloe varieties give a dark yellowish sap (Figure 1).

Fig. 1: Aloe secundiflora harvesting process

Fig. 2: Aloe vera barbadensis harvested by farmers in Makueni district (2009)

Figure 3: Aloe vera gel being stirred for processing into juices at Makueni (2009).

Results and Discussion

The results on initial soil analysis from the experimental site (Table 1) revealed that, soil was low in available phosphorus, total nitrogen and organic carbon. Available P was 8.1 mg/kg soil. The critical level of available P in Kenya soils for majority of crops is 20 mg/kg soil (Hinga *et al.,* 1980). This implied it was necessary to apply phosphate fertilizer for any crop planted at this site. Organic carbon and total soil nitrogen were low when compared against adequate level of 2% for Kenyan soils (Hinga *et al.,* 1980). This implied organic matter had to be corrected through application of manure at recommended levels for majority of crops (Ikombo *et al.,* 1984). Aloes require low levels of nitrogen in order to preserve the quality of their extracts (Wabuyele *et al.,* 2006). The exchangeable bases were in adequate amounts (Hinga *et al.,* 1980) and required no corrections for all aloes. This implied there was no need of applying fertilizers containing these exchangeable bases.

Table 1: Initial analysis of 0-20 cm soil depth from aloe experimental site at Kambi ya Mawe, Makueni district (2007).

Soil test parameter	Test level	Test rating
Soil pH(1:2.5)	5.86	Slightly acid
N(total) %	0.09	Very low
Available P (ppM)	8.10	Very low
Exch. K meq/100g soil	0.99	adequate
Exch.Ca meq/100g soil	3.83	adequate
Exch. Mg meq/100g soil	1.94	adequate
Org. C %	1.16	low
Exch. Na meq/100g soil	2.18	Threshold

The results on aloes adaptability assessment for semi-arid Makueni are shown in Table 2. Aloe *secundifolia* Engler had significantly ($P \leq 0.001$) higher percent survival followed by aloe *vera barbadensis* Miller ($P \leq 0.05$). Aloe *turkanensis* Christian had the lowest percent survival. The results showed aloe *secundifolia* Engler and aloe *vera barbadensis* Miller are more adaptable in the semi-arid areas of Makueni compared to aloe *turkanensis* Christian. These results are in agreement with those obtained by Wabuyele *et al.* (2006) that, aloe *secundifolia* Engler is widely distributed in many parts of east Africa in grasslands and open dry deciduous woodland on sandy, stony soils at altitudes ranging between 600-2000 meters above sea level (Wabuyele *et al.,* 2006). The low survival of aloe *turkanensis* Christian may be attributed to the fact that, the aloe was collected from Turkana land and the environmental conditions of Makueni district and Turkana district are very different. The survival or adaptability of the aloe varieties to Makueni district was not significantly influenced by fertilizer or manure application (Table 3 and 4). This implied that aloes can be grown without application of manure, fertilizer phosphate or their combination. The other explanation may be that, the varieties have not been bred to respond to high fertile soil conditions or the aloes are good nutrient uptake plants even when soil moisture is limiting. This is collaborated by the fact that aloes are the only plants that remain green in very dry weather and are a future crop for global climatic change adaptation (Senelwa, 2009; Aloe vera cultivation services, 2010). This was a unique observation as very low levels of fertilizer and/or manure were used at planting (Tables 3 and 4). However, analysis of leaf area (LA) as a measure of growth revealed that aloe *secundifolia* Engler had higher ($P \leq 0.05$) LA than all the

Table 2: Adaptability of three aloe varieties planted in Makueni district (2007-2009)

Aloe variety	Percentage survival	
	2008	**2009**
Aloe *vera barbadensis*	92.2***	79.5*
Aloe *secundifolia*	96.15***	93.4**
Aloe *turkanensis*	84.74	71.30
Grand mean	91.20	81.40
LSD ($P \leq 0.05$)	3.946	7.32
CV%	7.9	16.5
Significant test	significant	significant

Means in the same column followed by different asterisks differ ($p \leq 0.05$).

Table 3: Effect of fertilizer and manure application on survivability of aloe varieties planted in Makueni district (2007-2009).

Treatments	Variety mean % survival	
	2008	**2009**
1.10kg P_2O_5 /ha	91.33	82.1
2.20kg P_2O_5/ha	94.89	78.3
3. 2t FYM/ha.	89.33	81.4
4.4t FYM/ha	90.22	84.2
5.10kg P_2O_5 + 2t FYM /ha	90.11	78.1
6. 10kg P_2O_5 /ha +4t FYM/ha	93.11	84.9
7.2t FYM/ha. +20kg P_2O_5/ha	85.89	79.7
8. 20kg P_2O_5/ha +4t FYM/ha	94.00	83.2
9. Nil	91.89	80.6

Grand mean	91.20	81.4
LSD (P 0.05)	3.406	12.68
Significant test	NS	NS

Table 4: Effect of fertilizer and /or manure application on mean survival of aloe varieties at Makueni district (2007-2009).

Treatments	Mean survival (%)					
	Aloe *vera barbadensis*		Aloe *secundifolia*		Aloe *turkanensis*	
	2008	**2009**	**2008**	**2009**	**2008**	**2009**
1.10kg P_2O_5 /ha	93.33	87.30	96.00	92.3	84.67	66.7
2.20kg P_2O_5/ha	94.67	72.30	96.00	90.3	94.0	72.3
3. 2t FYM/ha.	96.00	92.70	98.00	94.3	74.0	57.3
4.4t FYM/ha	87.67	76.7	98.00	98.0	85.0	78.0
5.10kg P_2O_5 + 2t FYM /ha	94.67	75.00	94.33	89.0	81.33	70.3
6. 10kg P_2O_5 /ha +4t FYM/ha	94.33	79.0	100	96.0	85.0	79.7
7. 2t FYM/ha. +20kg P_2O_5/ha	82.00	67.0	94.33	98.0	81.33	74.0
8. 20kg P_2O_5/ha +4t FYM/ha	98.67	90.3	96.80	92.3	87.0	67.0
9. Nil	93.0	75.0	92.33	90.7	90.33	76.0
LSD ($P\leq 0.05$)	11.839	21.96	11.839	21.96	11.839	21.96
Signf. test	NS	NS	NS	NS	NS	NS

other two aloe varieties after first year of growth (2007-2008) as shown in Table 5. Leaf area (LA) measured 2 years later (2009) after planting still revealed aloe *secundifolia* Engler to be growing significantly ($P\leq0.05$) better than all the other two varieties. Aloe *turkanensis* Christian had a significantly large LAI than aloe *vera barbadensis* Miller after 2 years of growth although it was not significantly ($P\leq0.05$) adaptable to the area (Table 2). This is speculated to have been caused by growing of side suckers by aloe *vera barbadensis* Miller with time of growth in the field as some farmers who de-sucked their aloe *vera barbadensis* Miller reported observation of large leaves and good growth vigor. However aloe vera grows well under irrigation as observed in aloe nurseries where irrigation is practiced.

Table 5: Effect of duration of growth on leaf area index of aloe varieties planted in Makueni district (2007-2009).

Aloe variety	LAI, 2008	LAI, 2009
Aloe *vera barbadensis*	60.2 B	59.3 C
Aloe *secundifolia*	110.5 A	172.1 A
Aloe *turkanensis*	76.2 B	128.2 B
Grand mean	82.3	119.9
LSD (P 0.05)	19.28	28.84
CV%	21.4	27.6

Means in same column followed by different letters differ ($P\leq0.05$)

Aloe LA was not significantly influenced by fertilizer or and manure applications (Table 6). This implied that, the aloes and particularly the aloe *secundifolia* Engler could be grown without nutrient application. These results are unique in the sense that, some other aloe *vera indica* varieties of aloe vera has been found to grow faster and produce higher leaf weight, more gel and higher protein content with application of 100 kg of potassium and 200 kg of nitrogen ha^{-1} at 18 meters above sea level (AEZ-9) in Bangladesh (Hossain *et al.,* 2007). However aloe quality analysis needs to be carried out to find out if quality is not affected by applying fertilizers, manures or combination of these nutrients as there are reports of aloe quality being affected by application of large amounts of nitrogen (Wabuyele *et al*., 2006).

Table 6: Effect of nutrients application and duration of growth on leaf area index of aloe planted in Makueni (2007-2009).

Treatments	Aloe varieties mean LAI cm^2					
	Aloe *vera barbadensis*		Aloe *secundifolia Engler*		Aloe *turkanensis Christian*	
	2008	**2009**	**2008**	**2009**	**2008**	**2009**
1.10kg P_2O_5 /ha	77.0	60.3	154.7	258.7	69.7	97.3
2.20kg P_2O_5/ha	53.0	58.0	134.0	201.0	72.7	109.0
3. 2t FYM/ha.	68.3	80.0	73.7	90.7	62.0	107.7
4.4t FYM/ha	47.0	64.7	126.0	173.7	63.0	137.0
5.10kg P_2O_5 + 2t FYM /ha	45.7	48.0	130.7	194.7	79.0	137.0

6. 10kg P_2O_5 /ha +4t FYM/ha	64.0	46.0	92.3	149.3	84.0	168.3
7. 2t FYM/ha. +20kg P_2O_5/ha	60.0	51.7	78.3	155.7	78.7	162.0
8. 20kg P_2O_5/ha +4t FYM/ha	77.3	67.0	104.0	161.0	84.0	133.3
9. Nil	49.7	58.3	100.7	164.0	92.7	102.3
LDS ($P \leq 0.05$)	28.82	86.53	28.82	86.53	28.82	86.53
	NS	NS	NS	NS	NS	NS

The aloe sap and gel were processed into aloe soap, liquid detergent, cream, lotion, hair treatment, hair food, jelly, hair conditioner, shampoo, aloe juice and aloe tonic juice. Aloe *vera barbadensis* Miller gel was further processed into juice and tonic juice in addition to other products. It was observed that, aloe sap was easy to handle because it does not require special storage like the aloe gel from aloe *vera barbadensis* Miller.

Conclusions

Aloe *secundifolia* Engler is most adaptable followed by aloe *vera barbadensis* Miller for growing in semi-arid Makueni district as measured by percent survival in 2 year duration (2007-2009). However, on leaf area index, aloe *secundifolia* Engler is the most suitable aloe followed by aloe *turkanensis* Christian for growing in the district. These aloes can be grown without fertilizer or manure application. Aloe *secundifolia* Engler sap has best handling properties than aloe *vera barbadensis* gel. The aloes needs to be analyzed for quality to find out if the quality of the sap or gel is affected by planting the aloes with fertilizer, manure or their combination. Further research need to be done to verify the fact that aloes did not respond to fertilizer and/or manure application. May be the aloes had not been domesticated or bred to be elastic in soil nutrient response.

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