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Influence of Sulfur Fertilizer on Growth and yield of *Aloe vera* plants

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ABSTRACT

This study was carried out at Shambat to investigate the effect of Sulfur fertilizer on growth and yield of *Aloe vera* plants under nursery conditions of Shambat, Khartoum North, Sudan. Elemental Sulfur was tested as soil application to the potting media in black polyethylene bags at rates of 0.0, 0.5, 1.0, 2.0 and 4.0 g/plant. The study was accomplished in complete randomized design and each treatment was replicated 8 times. Treatments were repeated every 3 month. Data were collected 12 months after the commencement of the study. Data analysis revealed significant enhancement in growth parameters in sulfur treated plants compared to the control. Except for the peel weight and chlorophyll content, the highest values of measured parameters were obtained from the 4.0 g sulfur treatment / plant. Under the conditions of the study, these results elucidated the benefit of sulfur fertilizer as a tool for enhanced production of *Aloe vera.*

INTRODUCTION

Aloes are xerophytes in the *Aloeaceae* family that are cultivated for ornamental, medicinal, vegetable, and cosmetic purposes in Africa, North America, Europe, and Southeast Asia (Tawaraya *et al.*, 2007). Approximately 500 species had been described in the genus *Aloe*, ranging from diminutive shrubs to large tree-like forms and it is represented in several biodiversity hotspots (Zapata *et al*., 2013). Basically, all the *Aloe* species have similar constituents; however, *Aloe barbadensis* Miller (often called *Aloe vera* L.) and *Aloe arborescens* Miller are the most extensively cultivated in the world (Liao *et al*., 2006). The chemical composition of the leaf gel is very complex, composed mainly of polysaccharides and soluble sugars followed by proteins, many of which are enzymes, amino acids, vitamins, and anthraquinones (Liu *et al*., 2007). It had been shown that polysaccharides derived from *Aloe vera* enhance immunity activity and exert antioxidant effects (Zhanhai *et al.,* 2009) and most of the activity was attributed to β-polysaccharides (Ramachandra and Srinivasa Rao, 2008). Anthraquinones are the second class of bioactive metabolites, including C-glucosyl derivatives such as barbaloin (10-glucopyranosyl-1,8-dihydroxy-3-hydroxymethyl-9–10H-anthracenone), a mixture of the two diastereoisomers aloin A and B, as well as glucose-free compounds such as aloe-emodin (Fanali *et al*., 2010). Anthraquinones were reported to have cathartic effects, anti-inflammatory effects *in vivo* as well as anti- (bacterial, viral and cancer) effects (Park, *et al*., 2009; Pellizzoni *et al*., 2012). The demand for the aloe products is increasing with growth of cosmetic and neutraceutical markets (Danhof, 1987). According to Ndhlala *et al.,* (2016), the global market of aloe products is currently estimated to be USD 13 billion and it has appeared in more than 50 categories of products since 2012. Research aiming to the economic exploitation of this plant under Sudan conditions is almost lacking, although badly needed.

Sulfur is among the essential macro nutrient elements that limit plant growth. Its deficiency has deleterious effects on plant growth. In *Aloe vera* plants, sulfur deficiency resulted in reduced leaf size, retarded growth and caused chlorosis (Ergle *et al.,* 2005). The functional chloroplasts are normally rich in sulfur (Hanson *et al*., 2011) and the chloroplast morphology is considerably affected by sulfur deficiency (Hall *et al.,* 2002; Repica *et al*., 2001). According to Pirson (1955), sulfur deficiency upsets photosynthesis in a profound way which, after readdition of external sulfate, can only be corrected slowly through the synthesis of new protein and chloroplasts. However, beneficial responses to sulfur fertilization had been reported in date palm *(Phoenix dactylifera* L.) (Idris *et al.,* 2012) and banana (Musa AAA) (Idris *et al.,* 2014) under Sudan conditions. Based on these considerations, this study aimed to investigate the influence of sulfur fertilizer on growth and yield of *Aloe vera* plants.

MATERIALS AND METHODS

This test was conducted in complete randomized design in the nursery of Sudan University of Science and Technology, at Shambat, Khartoum North, Sudan, to determine the impact of sulfur fertilization on growth attributes and yield of *Aloe vera* plants. The experimental materials were tillers of the plant 12-15 cm long, planted in 25X30 cm plastic bags containing river Nile sedimentary soil (Gureira). Prior to test, each plant received a dose of 2 g urea. A month after establishment, they were used as test plant material. Elemental Sulfur was tested in rates of: 0.0, 0.5, 1.0, 2.0 and 4.0 g/plant as soil dressings in 25X30 cm plastic bags. Each treatment was replicated 8 times and each plant in a bag was considered as a replicate. All tested plants received a dose of 2 g urea once, at the beginning of the study. The Sulfur applications were repeated every 3 months and irrigation was applied according to need. Final data were collected after 12 months for number of leaves, leaf length, leaf width, leaf thickness, number of tillers, number of roots, root length, shoot fresh and dry weights, root fresh and dry weights, leaf weight, leaf gel weight, leaf peel weight, and chlorophyll 'a' and 'b' contents. For dry weights, the harvested shoots and roots were subjected to sun drying for 30 days, prior to oven drying for a week at 70° C until weights were constant. For determination of leaf gel content, the leaves were cut into several portions with scalpel blades to ease gel extraction after weighing the leaves. The remaining peels were weighed separately with a portable digital balance. Determination of chlorophyll content was performed according to the method of Arnon (1949) by using the chlorophyll flourometer (Li-Cor, Lincoln, NE, USA). Two hundred milligrams of fresh leaf samples were ground with 10 ml of 80% acetone at 4^{o}C and centrifuged at 2500 rpm for 10 minutes at 4^{o}C. Three milliliters aliquots of the extract were transferred to a cuvette and the absorbance was read at 665 and 649 nm with spectrophotometer after which the chlorophyll (a) and (b) were determined by Vernon's models. The collected data were subjected to analysis of variance and means were separated by Duncan's Multiple Range Tests with the aid of MstatC computer program.

RESULTS

The result of the influence of Sulfur fertilizer treatments on number, length, width and thickness of leaves is indicated in Table 1. Compared to the control, no significant differences were observed for number of leaves, leaf width and leaf thickness. However, longest leaves were obtained from the 4 g sulfur treatment with significant difference from the 2 g sulfur treatment, but without significant difference from the other treatments.

Table 1: Impact of sulfur applications on number, length, width and thickness of *Aloe vera* plants

Sulfur level (g/plant)	**No. of leaves**	**Leaf length** (cm)	**Leaf width** (cm)	**Leaf thickness** (cm)
0.0	15.4a	37.20ab	4.02a	0.88a
0.5	17.0a	38.90ab	4.25a	1.08a
1.0	16.0a	39.54ab	4.26a	1.02a
2.0	15.8a	36.02b	4.40a	1.04a
4.0	16.8a	41.00a	3.30a	1.10a
C.V.	7.87	8.65	25.11	18.70

* Means with the same letter (s) in the same column are not significantly different at 95% confidence limits.

Table (2) presents the results of the impact of sulfur fertilizer treatments on number of tillers, number of roots and root length. The number of tillers was best increased by the 4 g sulfur treatment, with significant difference from the control and the 0.5 g sulfur treatment, while the other treatments ranked intermediate. All sulfur treatments increased the number of roots and root length significantly in comparison to the control. The highest values for number of roots were recorded for the 4 and 2 g sulfur treatments which were significantly higher than the 1.0 and 0.5 g sulfur treatments. Likewise, all sulfur treatments increased root length significantly compared to the control. The 4 g treatment was best although it did not differ significantly from the other sulfur treatments.

Table 2: Impact of sulfur levels on number of tillers, number of roots and root length of *Aloe vera* plants

Sulfur level (g/plant)	**No. of tillers**	**No. of roots**	**Root length** (cm)
0.0	19.8b	26.2c	19.0c
0.5	19.8b	29.4b	22.5ab
1.0	22.0ab	29.4b	22.4ab
2.0	22.0ab	35.4a	21.4ab
4.0	23.6a	36.4a	25.2a
C.V.	12.27	10.87	11.70

* Means with the same letter (s) in the same column are not significantly different at 95% confidence limits.

Results regarding the impact of sulfur applications on shoot and root fresh and dry weights are compiled in Table 3. Except the shoot fresh weight, all sulfur treatments enhanced these parameters significantly compared to the control. The 4.0 g treatment resulted in best increase in shoot fresh and dry weights. The increase was significant compared to other treatments. The 2 g sulfur treatment enhanced root fresh and dry weights significantly and ranked top, sharing this position with the 4 g sulfur treatment for the root dry weight.

Table 3: Impact of sulfur application on shoot fresh and dry, root fresh and dry weights of *Aloe vera* plants

Sulfur level (g/plant)	**Shoot fwt** (g)	**Shoot dwt** (g)	**Root fwt** (g)	**Root dwt** (g)
0.0	654.2d	065.12d	15.77d	1.562c
0.5	753.0c	075.10c	23.89bc	2.310b
1.0	807.4b	080.74bc	21.83c	2.290b
2.0	657.2d	084.06b	26.90a	2.670a
4.0	913.2a	132.00a	24.46b	2.660 a
C.V.	3.58	5.41	8.19	8.83

* Means with the same letter (s) in the same column are not significantly different at 95% confidence limits.

The statistical analysis of data concerning leaf, gel and peel weights and chlorophyll content is illustrated in Table 4. Except for the peel weight, all sulfur treatments enhanced these parameters significantly compared to the control. The 4 g sulfur treatment resulted in best leaf and gel weights but without significant difference from the 1.0 and 2.0 g treatments for the gel weight. The peel weight decreased in all sulfur treatments significantly compared to the control and the least value was recorded for the 4 g sulfur treatment. The highest chlorophyll 'a' and 'b' contents were recorded for the 0.5 g sulfur treatment. However, the least value for chlorophyll 'a' was obtained from the control, while the least chlorophyll 'b' content was obtained from the 4 g sulfur treatment.

Table 4: Impact of sulfur applications on leaf, gel and peel weights and chlorophyll content of *Aloe vera* plants

Sulfur level (g/plant)	Leaf Wt (g)	Gel Wt (g)	Peel Wt (g)	Chlorophyll (mg/g) a	Chlorophyll (mg/g) b
0.0	212.8d	103.0c	109.8a	14.10d	10.08c
0.5	245.4c	141.2b	104.2b	25.06a	13.06a
1.0	258.8b	155.4ab	103.8b	21.58b	11.48b
2.0	258.9b	156.0ab	097.8c	17.69c	10.60c
4.0	267.0a	166.0a	094.4c	19.93b	08.06d
C.V.	3.46	7.34	5.21	6.98	6.81

* Means with the same letter (s) in the same column are not significantly different at 95% confidence limits.

DISCUSSION

Manipulation of target compounds in plants such as phytochemicals and antioxidants by the management of the mineral nutrients had been recognized as a research area attracting applied scientists interest (Fallovo *et al*., 2009a, 2009b; Fanasca *et al*., 2006a, 2006b). Proper management of the fertilization and the use of suitable irrigation water can provide an effective tool to improve the target compounds in plants such as phytochemicals and antioxidants (Rouphael *et al*., 2012a). Sulfur is one of the most essential macro-nutrient minerals that play different structural and physiological roles in plant. It is a constituent of some amino acids such as cysteine, and methionine and thus contributes to protein synthesis and buildup of plant mass. In this study the *Aloe vera* plant responded positively to the low doses of sulfur fertilizer as reflected in most measured growth and yield parameters. This growth and yield enhancements obtained from sulfur application in this study is in line with preceding research findings as Ross (2005) reported positive effects from sulfur application on the growth and gel content of *Aloe vera* plants. The result also agreeds with the findings of Korikanthimath (1994) and Lalitha and Gopala (2004), who reported significant increase in number of leaves and other growth parameters in sulfur treated *Aloe vera* plants compared to the control. The improvements obtained from sulfur applications might also be interpreted by efficient utilization of nutrient elements as suggested by Kumar and Singh (1994), who attributed low yield of onions under conditions of sulfur deficiency to poor utilization of macro and micronutrients.

According to Pareek *et al.* (2012) and Minard (1978), sulfur is often regarded a limiting factor for biomass production in natural ecosystems. Besides, Lewis *et al.* (2014) and Korikanthimath (1994) reported that inadequate level of sulfur prolongs the life cycle of *Aloe vera* plant, delays maturity and decreases its economical yield. The improvements obtained in this study might be interpreted by efficient uptake and metabolism of nitrogen under conditions of sulfur availability. According to Nasreen *et al.,* (2005), absorption of nitrogen is disrupted in soils deficient in sulfur. Improved growth upon use of a combination of nitrogen and sulfur fertilizers had been reported by Smriti *et al.,* (2002) for onion, Idris *et al.,* (2012) for date palm and Idris *et al.,* (2014) for banana. Regarding chlorophyll content, the application of sulfur at 0.5-1.0 g /plant was associated with increases in both chlorophyll 'a' and 'b' compared to the control. This result is partially contradictory to the findings of Hanson, *et al*, (2011), who reported increase in leaf chlorophyll content with sulfur application, but the increase was steady with the increase of sulfur dose. This might be explained by differences in soils sulfur content. Nevertheless, the 4 g/plant sulfur treatment was found most enhancive for leaf weight and gel content which are the most important yield parameters of this plant and the result is matching that of Idris *et al.,* (2014) and Salih (2013) who reported growth enhancements in banana propagules planted in *Gureira* soil under the same conditions of this study, they found that, application of sulfur increased banana leaf chlorophyll content with the raise in level and they concluded that, leaf chlorophyll content is directly correlated with sulfur rate. The results of this study disagreed with the findings of Hanson *et al.*, (2011) and Zheng *et al.,* (2009) who claimed a positive correlation between sulfur concentration and leaf chlorophyll content; the disagreement may owe to differences in soils used in the two studies. The enhanced formation of tillers due to sulfur treatments is an advantage to propagators as tillers are the major propagation means of the plant. The enhanced gel formation by 1-4 g sulfur treatments is a privilege as the gel is the economically valued harvest, and therefore the 1 g sulfur treatment might seem more attractive on cost reduction bases. In conclusion, regarding commercial production of *Aloe vera* under Sudan conditions, the overall results of this study may seem encouraging enough for adoption of a pilot project to found the basis for future expansions. The sulfur nutrition should be accompanied as a cultural due to its significant impact on growth and gel yield of the plant. Besides, the positive result obtained here from sulfur fertilization, fortifies the limited preceding reports on the positive impact of sulfur fertilization and may justify further research on sulfur nutrition of other plant genera and species under Sudan conditions.

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