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Effect of *Moringa olifera* Leaf Extract on Growth and Productivity of Three Cereal Forages

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Abstract

Moringa olifera leaf extract at different concentrations were used to evaluate their effects on three cereal forages (*Sorghum bicolor* L. Moench, *Penisetum typhoideum* Rich and *Sorghum Sudanese*) grown under stress environment of soil and water salinity in an arid environment. Three independent experiments carried out at King Abdulaziz University Experimental Station, Makkah province during 2015 and 2016. Treatments consisted of four concentrations *of Moringa olifera* leaf extract: (C1 = 1 ml of juice + 10 ml of distilled water ,C2 = 1 ml of juice + 20 ml of distilled water, C3 = 1 ml of juice + 30 ml of distilled water and C4 = 1 ml of juice + 40 ml of distilled water in addition to distilled water alone as a control). Results showed that the higher concentration C1 contained the highest amount of inorganic elements and growth hormones compared to other concentrations. This in turn reflected in significant higher growth and forage yields of the three forage crops tested. Significant increases in growth and forage yields in both seasons reported for the higher concentration C1 compared to others. Fresh and dry forage yields of Millet, during 2016, increased by the higher concentration over the control treatment by 17.67 and 4.87%, respectively. Results indicated the effectiveness of Moringa leaf extract in improving growth and increasing productivity of cereal forages under harsh environment of salinity and aridity.

Keywords: cereal forages, growth hormones, Moringa leaf extract, productivity, salinity

1-Introduction

The origin of *Moringa olifera* tree is the Hamalanian Mountains in the Indian Continent (Osman & Abohassan, 2015). The geographic distribution of Moringa extends from Asia, India, Arabian Pensiula, and Africa to South and Central America. The tree is rich in its nutritive values for human and animals as well as containing many medicinal and chemical substances for other uses to be called the miracle tree (Osman & Abuhassan, 2015). This feature coupled with its geographical distribution gives the tree a special importance as its growth cover places that are highly populated with high poverty rates (Osman & Abohassan, 2015). Among the different usages of Moringa is the leaf extract as a growth hormone promotor for many crops (Price, 2007; Muhamman et al., 2013; Amirigbal et al., 2014).

The use of Moringa leaf extracts as a possible plant enhancer can provide a relatively environmentally friendly, easily accessible and affordable means of increasing crop yields to meet the growing demand for food all over the world, considering the global increasing population rate with its threatening hunger waves. Extracts from fresh Moringa leaves could be used to produce an effective plant growth promoter increasing yield by 25-30% for nearly any crop (Price, 2007). Amirigbal et al. (2014) reported that three sprays of Moringa and brassica leaf extracts significantly affected plant height, number of branches per plant, number of pods per plant, number of seeds per pod seed yield as well as biological yield of canola as compared to their sole application.

The leaf extract of Moringa reported to increase the yield of many crops (Alkinbode & Ikotun, 2008; Foidle et al., 2001). This positive effect of Moringa leaf extract on growth and yields has also been reported for many field

crops: Mvumi et al. (2012) and Emongor (2015) on onion and kidney beans, Muhamman et al. (2013) on tomato, Abdalla (2013) on rocket, and Mohammed et al. (2013) on onions.

The significance of Moringa leaf juice lies in the Zeatin. Zeatin is one of the phytohormones that are the major components of oil and protein structure (Mir et al., 2009). Zeatin is a part of the compound cytokinins, which stimulate cell division, growing cell tissue, delay the process of senescence and ageing in plant tissue and promote nutrient partitioning and uptake (Emongor, 2002; Andrews, 2006; Taiz & Zieger, 2002).

Traditionally, there are five groups of growth regulators including auxins, gibberellins, abscisic acid, ethylene and cytokinins (Prosecus, 2006). Cytokinins enhance food production, and Zeatin is one of the most common forms of naturally occurring cytokinins in plants. Moringa leaves gathered from various parts of the world were found to have high Zeatin concentrations of between five and 200 μg/g of leaves (Alawady, 2003).

Cereal crops (grain and forages) are important sources of carbohydrates and fibers for humans and animals. Their production, area wise and quantities, exceeded any other agronomic crops. For people living in rural areas and in most developing countries enhancing crop production via high cost inorganic fertilizers are beyond their financial capabilities. Therefore, the objective of this study was to look into alternatives that are cost effective, available and environmentally friendly. All these features are strongly true in Moringa trees, and considering its wide spread natural growth in Africa, Asia, South America and many other parts of the world, which makes it a higher candidate for such research. Yasmeen et al. (2013) reported that Moringa leaf extract when it applied for drought or salt stressed plants modified plant phenotypic response to positively affect growth and productivity with alteration in metabolic processes. Moreover, environmental stresses of soil and water salinities under arid lands, where this research was conducted, was another objective as to evaluate Moringa leaf extracts on performance of the tested crops under such environment.

2. Materials and Methods

Moringa trees, from which leaves were collected for the extraction of juice, were seven years old growing in the same experimental farm in which the field experiments were conducted.

2.1 Moringa Leaf Extract

Moringa olifera leaf extract was prepared after collection of fresh green leaves using a conventional electric mixer, afterwards The mixture was passed through a cloth sieve to separate the juice from the residue, The juice was collected into 500 liter flask and four different concentrations were then prepared as follows:

1) 1 ml from juice mixed with 10 ml of distilled water (1:10 by volume) – (C1);

2) 1 ml of juice mix with 20 ml of distilled water (1:20) – (C2);

3) 1 ml of juice mix with 30 ml of distilled water (1:30) – (C3);

4) 1 ml of juice mix with 40 ml of distilled water (1:40) – (C4);

5) Distilled water only as a control – (C5).

These four concentrations in addition to the control sprayed on three cereal crops at a rate of 25 ml/plant at an interval of two weeks following emergence. The cereal crops were Sudan grass, forage sorghum, and millet, and each crop was planted as an independent field experiment.

A randomized complete block design with three replicates was used for each experiment; each replicate contained five randomly assigned treatments with plot size (experimental unit) of 1 × 1 m for each treatment. The three forage crops were planted in continuous rows 80-cm apart and watered via perforated plastic pipes along the row. Borehole was the source of irrigation water that contained 3000 TDS (ppm) and the soil was a saline one. Measurements of growth parameters were taken at forage harvest. Ten randomly selected plants from middle row were used for each growth parameter measured. For yield parameter, the entire plot (1 × 1 m) was used to estimate forage fresh and dry yields.

The following growth and yield parameters taken during the course of the study, which lasted for two years: plant height, leaf area, number of leaves/plant, stem diameter, fresh and dry yields.

2.2 Chemical Analysis of Hormonal and Inorganic Minerals

2.2.1 Hormonal Analysis

Juice extract was prepared from green Moringa leaves and green twigs after crushed by a conventional kitchen mixer. The juice separated from residue using a cotton cloth as a filter. The same treatments described above were used for hormonal analysis:

Afterwards each concentration (C1 to C5) mixed with cold redistilled 95% ethanol, kept in a dark bottle, and deep-freeze overnight before assay started. The fraction of the ethanol extract was carried out according to the method described by Wasfy et al. (1974). The Acidic fraction contain the acidic hormones (IAA, GA, and ABA) while the aqueous fraction comprised the cytokinins. The growth promoters (auxins, gibberellins and cytokinins) and the growth inhibitors ABA quantified using high performance liquid chromatography (HPLC) according to the method of Muller and Hilgenberg (1986).

2.2.2 Inorganic Minerals

Mineral elements extracted from leaf tissues according to Chapman and Pratt (1961), Phosphorus determined according to the method described by Humphries (1956) while Potassium determined photometrically according to Williams and Twine (1961), Calcium and Magnesium determined by atomic absorption spectrophotometer according to AOAC (1984) and total nitrogen was determined by Micro-kejeldhal, Tector model 1026 after digestion in sulphuric acid (Horwiz, 2002).

2.3 Soil and Water Analysis of the Experimental Site

Soil chemical analysis of the experimental site, in top 30 cm depth, showed a soil pH of 8.25, an Ec of 1.61 ds^{-1}, OM of 0.1% and N, P, K, Ca, Mg, and Na of 0.32, 0.129, 2.5, 3.6, 6.3 and 16.8 mg kg^{-1}, respectively. Irrigation water (which was a borehole water), analysis contained 3000 TDS (ppm) with Nacl the dominant salt.

3. Results

Inorganic contents of leaf extract are presented in Table 1. The concentration of all inorganic contents dropped with dilution of the juice. The control treatment (C5) contained negligible amounts of the inorganic compounds, as it was distilled water.

Table 1. Inorganic contents of Moringa (mg/kg dry weight)

Treatment	N	P	K	Ca	Mg
C1	37.5	8.2	16.5	48.5	5.7
C2	32.4	7.3	12.7	38.6	4.2
C3	27.5	5.4	10.3	32.4	3.6
C4	19.3	2.3	8.7	21.2	2.5
C5	0.0008	0.0001	0.0001	0.0001	0.0002

Note. C1 = 1 ml of Moringa juice with 10 ml of distilled water; C2 = 1 ml of Moringa juice with 20 ml of distilled water; C3 = 1 ml of Moringa juice with 30 ml of distilled water; C4 = 1 ml of Moringa juice with 40 ml of distilled water; C5 = only distilled water.

Similar to inorganic contents, the hormonal concentration dropped with increase in dilution rate, while no hormones in the control treatment (distilled water) as shown in Table 2.

Table 2. Hormonal contents of Moringa extract (mg/kg fresh weight)

Treatment	Cytokinins	Auxins	Gibberellins	ABA
C1	27.5	15.9	16.8	10.5
C2	23.7	13.0	14.5	8.2
C3	19.6	9.6	12.2	7.6
C4	15.3	5.3	6.7	5.4
C5	-	-	-	-

Note. C1 = 1 ml of Moringa juice with 10 ml of distilled water; C2 = 1 ml of Moringa juice with 20 ml of distilled water; C3 = 1 ml of Moringa juice with 30 ml of distilled water; C4 = 1 ml of Moringa juice with 40 ml of distilled water; C5 = only distilled water.

3.1 Effect of Treatments on Growth and Yield of Sudan Grass

Results of different concentrations of Moringa leaf extract on Sudan grass are presented in Table 3 for both seasons 2015 (April) and 2016 (February and April). All growth parameters of Sudan grass were significantly (P

< 0.05) affected by the different concentrations of the Moringa Juice extract in both seasons, with exception of plant height in 2015 and stem thickness in 2016. Taller, thicker and leafy Sudan grass plants were recorded for the higher concentration C1 compared to other concentrations.

Table3. Effect of different concentrations of Moringa leaf extract on growth parameters of Sudan grass

Teat. Conc.	Plant height (cm)			Stem thickness (mm)			Leaf number		
	Apr., 2015	Feb., 2016	Apr., 2016	Apr., 2015	Feb., 2016	Apr., 2016	Apr., 2015	Feb., 2016	Apr., 2016
C1	121.83a	181.6a	135.0a	6.23a	0.49a	0.41a	5.80a	6.5a	5.9a
C2	107.90a	174.86b	122.6b	5.50ab	0.35ab	0.40a	5.4ab	6.3ab	5.45b
C3	116.50a	173.30bc	118.6c	4.33b	0.27b	0.40a	4.5b	6.2ab	5.45b
C4	119.67a	172.49c	118.5c	4.63ab	0.30b	0.39a	5.3ab	6.0ab	4.35b
C5	115.40a	140.1d	117.9c	5.53ab	0.27b	0.37a	4.8ab	5.1b	4.00c
LSD	31.64	1.67	3.85	1.68	0.17	0.11	1.2	1.19	0.35
CV	14.45	0.57	1.67	17.07	27.65	15.81	12.43	10.58	25.03

Note. C1 = 1 ml of Moringa juice with 10 ml of distilled water; C2 = 1 ml of Moringa juice with 20 ml of distilled water; C3 = 1 ml of Moringa juice with 30 ml of distilled water; C4 = 1 ml of Moringa juice with 40 ml of distilled water; C5 = only distilled water); Values with same letters are not significantly different from each other; LSD = least significant difference; CV = coefficient of variation.

The effect of different concentrations of Moringa juice on fresh and dry yields of Sudan grass is presented in Table 4. Significant differences in fresh and dry yields of Sudan grass were reported for the different concentrations in comparison to the control (C5) in both seasons. The higher concentration C1 always recorded higher fresh and dry yields in both seasons, whereas the control C5 resulted in the lowest fresh and dry yield.

Table 4. Effect of different concentrations of Moringa leaf extract on fresh and dry yields Sudan grass

Treat. Conc.	Fresh Weight (ton ha^{-1})			Dry Weight (ton ha^{-1})		
	April, 2015	Feb., 2016	April, 2016	April, 2015	Feb., 2016	April, 2016
C1	15.60a	26.62a	15.96a	8.80a	17.94a	4.51a
C2	12.80b	21.84b	12.77ab	7.20a	14.71b	4.00ab
C3	12.59b	16.82c	11.49b	3.90b	11.29c	3.50bc
C4	11.50b	13.08d	12.15b	3.70b	9.49d	3.54bc
C5	11.40b	12.90d	11.30b	2.60b	8.38d	3.37c
LSD	2.30	1.01	3.39	2.90	1.38	0.55
CV	14.3	2.96	14.20	29.95	5.93	7.75

Note. C1 = 1 ml of Moringa juice with 10 ml of distilled water; C2 = 1 ml of Moringa juice with 20 ml of distilled water; C3 = 1 ml of Moringa juice with 30 ml of distilled water; C4 = 1 ml of Moringa juice with 40 ml of distilled water; C5 = only distilled water); Values with same letters are not significantly different from each other; LSD = least significant difference; CV = coefficient of variation.

3.2 Effect of Treatments on Growth and Yield of Forage Sorghum

Results of the effect of Moringa Juice extract on growth parameters of forage sorghum are presented in Table 5. Moringa leaf juice extract had a significant effect on growth parameters of forage Sorghum in both seasons except pant height and stem thickness in 2015 and number of leaves per plant in 2016. Taller, thicker and leafy Sorghum forage plants were recorded for the higher concentration C1 compare to other concentrations and the control, which recorded the lowest height, thickness and number of leaves.

Table 5. Effect of different concentrations of Moringa leaf extract on Moringa leaf extracts growth parameters of forage Sorghum

Treat. Conc.	Plant height (cm)		Stem thickness (mm)		Leaf number		Leaf area (cm^2)		Leaf stem ratio	
	Apr., 2015	Mar., 2016	Apr., 2015	Mar., 2016	Apr., 2015	Mar., 2016	Apr., 2016	Mar., 2016	Apr., 2015	Mar., 2016
C1	125.27a	98.53a	6.12a	0.80a	6.86a	5.66a	5.94a	6.30a	1.94a	1.85a
C2	122.76a	93.76b	6.07a	0.76a	6.76a	5.66a	5.83a	6.18b	1.94a	1.83a
C3	120.93a	92.91b	6.00a	0.76a	6.55a	5.53a	5.72a	5.83c	1.58b	1.65b
C4	118.15a	90.16bc	5.24a	0.74a	6.11bc	5.60a	5.83a	5.80c	1.36c	1.60b
C5	114.50ab	87.33c	5.23a	0.73a	5.96c	5.20a	5.52a	4.70d	1.34d	1.24c
LSD	7.05	4.54	2.24	0.20	0.49	1.17	0.90	0.20	0.11	0.15
CV	15.99	2.6	20.77	14.38	4.08	11.27	8.29	8.50	15.20	13.70

Note. C1 = 1 ml of Moringa juice with 10 ml of distilled water; C2 = 1 ml of Moringa juice with 20 ml of distilled water; C3 = 1 ml of Moringa juice with 30 ml of distilled water; C4 = 1 ml of Moringa juice with 40 ml of distilled water; C5 = only distilled water); Values with same letters are not significantly different from each other; LSD = least significant difference; CV = coefficient of variation.

Effect of treatments on fresh and dry yields of forage Sorghum are presented in Table 6. Significant ($P < 0.05$) differences on fresh and dry yields, because of Moringa leaf extract, were recorded during both seasons. Similar to Sudan grass results, higher fresh and dry yields were recorded for the higher concentration C1 and the lowest yield was recorded for the control. It is worth mentioning here that higher yields recorded during second season of 2016 compared to 2015 regardless of treatments used. This might be due to weather variations (especially rain and temperature) during both seasons.

Table 6. Effect of different concentrations of Moringa leaf extract on fresh and dry yields of forage Sorghum

Treat. Conc.	Fresh weight (ton ha^{-1})		Dry weight (ton/ha)	
	April2015	March2016	April2015	March2016
C1	1.08a	12.49a	0.27a	3.12a
C2	1.05a	12.13a	0.26ab	3.03a
C3	0.99a	8.98b	0.24bc	2.24b
C4	0.86b	8.41b	0.22cd	2.10b
C5	0.83b	8.40b	0.20d	2.10b
LSD	0.10	1.80	0.02	0.003
CV	28.5	9.46	4.54	8.07

Note. C1 = 1 ml of Moringa juice with 10 ml of distilled water; C2 = 1 ml of Moringa juice with 20 ml of distilled water; C3 = 1 ml of Moringa juice with 30 ml of distilled water; C4 = 1 ml of Moringa juice with 40 ml of distilled water; C5 = only distilled water); Values with same letters are not significantly different from each other; LSD = least significant difference; CV = coefficient of variation.

3.3 Effect of Treatments on Growth and Yield of Millet

Results of the effect of treatments on growth and yield parameters of millet are presented in Tables 7 and 8, respectively. Significant differences for growth parameters of plant height stem diameter and number of leaves per plant were reported in both seasons except April of 2016 for number of leaves per plant (Table 7). The tallest, thickest and leafy plants recorded for the higher concentration C1 except for plant height in April 2015 and March 2016, when taller plants recorded for the Control C5 and the concentration C2, respectively.

Table 7. Effect of different concentrations of Moringa leaf extract on growth parameters of millet

Treat. Conc.	Plant height (cm)		Stem thickness (mm)		Leaf number		Leaf area (cm^2)		Leaf stem ratio	
	Apr., 2015	Mar., 2016	Apr., 2015	Mar., 2016	Apr., 2015	Mar., 2016	Apr., 2016	Mar., 2016	Apr., 2015	Mar., 2016
C1	103.33c	100.66b	4.76a	0.42a	6.26a	5.10a	5.94a	5.85a	1.46a	1.42a
C2	116.66bc	107.10a	5.56ab	0.37b	6.53a	4.80ab	5.93a	5.67a	1.40a	1.39a
C3	123.33b	100.23bc	5.26b	0.36b	6.56a	4.80ab	5.85a	5.52a	1.32b	1.18b
C4	105.66c	104.60a	6.23a	0.33c	5.96b	4.80ab	5.83a	4.70b	1.23b	1.14b
C5	152.00a	97.36c	5.16b	0.32c	5.90b	4.50b	5.77a	4.30b	1.22c	1.00c
LSD	16.25	2.97	0.86	0.02	0.27	0.54	0.66	0.80	0.07	0.13
CV	7.18	1.54	8.48	4.03	9.47	5.97	5.98	6.99	20.97	16.96

Note. C1 = 1 ml of Moringa juice with 10 ml of distilled water; C2 = 1 ml of Moringa juice with 20 ml of distilled water; C3 = 1 ml of Moringa juice with 30 ml of distilled water; C4 = 1 ml of Moringa juice with 40 ml of distilled water; C5 = only distilled water); Values with same letters are not significantly different from each other; LSD = least significant difference; CV = coefficient of variation.

Effects of treatments on fresh and dry yields of millet are presented in Table 8. Fresh and dry yields of millet were not significantly affected by treatments in April 2015. However, significant differences were recorded for both fresh and dry yields during 2016. Again, variations in weather conditions could be an explanation for this. Fresh and dry yields, during 2016, increased by the higher concentration over the control treatment by 17.67 and 4.87%, respectively.

Table 8. Effect of different concentrations of Moringa leaf extract on forage fresh and dry yields of millet

Treat. Conc.	Fresh weight (ton ha^{-1})		Dry weight (ton ha^{-1})	
	April 2015	March 2016	April 2015	March 2016
C1	4.54a	18.67a	0.13a	5.87a
C2	4.30a	15.40b	0.12a	4.53b
C3	3.75a	13.96b	0.11a	4.50b
C4	3.60a	13.31b	0.11a	4.17b
C5	3.42a	11.54b	0.10a	3.88b
LSD	2.69	3.25	2.69	1.30
CV	30.45	30.07	30.46	29.94

Note. C1 = 1 ml of Moringa juice with 10 ml of distilled water; C2 = 1 ml of Moringa juice with 20 ml of distilled water; C3 = 1 ml of Moringa juice with 30 ml of distilled water; C4 = 1 ml of Moringa juice with 40 ml of distilled water; C5 = only distilled water); Values with same letters are not significantly different from each other; LSD = least significant difference; CV = coefficient of variation.

4. Discussion

4.1 Effect of Moringa Leaf Extract on Growth Parameters

Chemical and hormonal analysis of Moringa leaf extract clearly showed that the higher concentration treatment (C1) revealed the highest inorganic contents compared to other concentrations. Furthermore, the higher concentration (C1) showed the higher concentration of the hormones, especially cytokinins, compared to other concentrations. Consequently, it expected to affect growth attributes of plant height. Stem diameter and number of leaves in a positive way. Moringa leaf juice is rich with growth hormones, especially Zeatin, that has been reported to increase the crop yield in the range of 10 to 45% (Muhammad, 2014). Moringa leaf juice also contains micronutrients in sufficient amounts and suitable proportions that increase the growth and yield of a variety of crops ranging from cereals to oil crops, from fiber to sugar crops and from forages to tuber crops (Price, 2007; Muhamman et al., 2013; Amirigbal et al., 2014). Rehman et al. (2017) reported that Moringa leaf extract when applied to wheat plants increased plant height, number of tillers, increased grain yield and delayed leaf senescence. They related that to Moringa leaf extract being rich in Zeatin, a cytokinins maintained the green photosynthetic area, therefore contributed to higher grain yield. It should be recalled that the three cereals

forages were grown under stress environment of water and soil salinities. Yasmeen et al. (2013) reported that Moringa leaf extract when applied on for drought or salt stressed plants modified plant phenotypic response positively affect growth and productivity with alteration in metabolic processes

4.2 Effect of Moringa Leaf Extract on Yield

Forage yield largely determined by growth attributes of plant height, stem diameter, size, and number of leaves carried by the plant, that resemble the resultant of yield. As shown from the results, forage yield increased significantly by the higher concentration (C1) of Moringa Juice extracts in both seasons compared to other concentrations. Several researchers found similar results with different crops: Mvumi et al. (2012) and Emongor (2015) on onion and kidney beans, Muhamman et al. (2013) on tomato, Abdalla (2013) on rocket, and Mohammed et al. (2013) on onions. As cytokinins are considered to be regulators of leaf senescence (Davis, 2007), therefore we hypothesized that with rich in Zeatin type of cytokinins and other regulators (Rady & Mohamed, 2015), Moringa leaf extract can play a role to maintain photosynthetic area by delaying senescence and affecting source-sink strength to increase yield.

5. Conclusion

It can be concluded from the results of this study that Marina leaf extract without or with little dilution can increase growth and productivity of cereal forages grown in stressed environment. The spread of this tree in the Southern Hemisphere characterized by human explosions, poverty and aridity gives the tree special importance to be called the miracle tree. We recommend that under aridity, where salt stress prevails, use of Moringa leaf extract be used to replace inorganic expensive and environmentally polluting fertilizers.

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