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COMPOST AND FOLIAR IRON ENHANCED FRUIT PRODUCTION AND QUALITY OF *GREWIA TENAX* (FORSK.) FIORI. UNDER STRESSED ENVIRONMENT

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ABSTRACT

Grewia tenax is a multi-values tree well adapted to high salinity and prolonged drought spells. However, the species still remains underutilized in the natural fields. In this study field performance and production of *Grewia* was investigated in arid saline land using a combination of compost addition and foliar spraying of EDDHA iron chelate during the years 2016- 2017. The combined effects of compost with chelated iron resulted in higher Canopy Cover (CC) and Relative Monthly Branch Increment (RMBI). The increase in CC and RMBI accompanied with better Fruit Set Rate (FSR) and fruit production. In turn, trends in CC over time showed seasonal pattern reflecting adaptation to changes in atmospheric conditions. Fruit individual sugars (Fructose, Glucose, Sucrose and Maltose), macro elements (K, Ca and Mg) and minor elements (Fe, Cu and Zn) contents were positively affected by fertilization rate, except Na that showed reverse trend. Whereas fructose, glucose and K contents were the higher. In most of the studied traits compost + iron obtained greater values, even at lower compost doses. The results revealed that under arid conditions compost and foliar iron increased the green canopy that enhanced growth performance and fruit quantity and quality. This high light the potential prospects of domesticating this species in arid environments.

Keyword: Compost, foliar iron, canopy cover, fruit, minerals, sugars.

INTRODUCTION

Grewia tenax (Forsk.) Fiori. known as white cross-berry (common name), Shohat (local, KSA) and Gudeim (local, Sudan), is a member of over hundred trees and shrubs belonging to the family *Teliacaea* (Zia-Ul-Haq *et al*., 2013). It is a shrubby or small multi-stemmed plant of dry arid and semi arid areas adapted to high salinity and prolonged drought spells (Sohail *et al*., 2015). It is recognized as multi purpose food, fodder, fuel wood and fiber producing tree species (Sharma and Patni, 2012). It also, serves as shelterbelt, agroforestry and wasteland rehabilitation plant (Fadl *et al*., 2015). In addition to that, it is a plant of high medicinal and pharmaceutical values (Aboagarib *et al*., 2014). However, the four carpels orange-red fruits, which contains high levels of sugars, minerals and phytochemical properties, are the most valued part of the plant (Aboagarib *et al*., 2015). The fruits have been used to increase the levels of hemoglobin in children (Ahmed *et al*., 2012), pregnant women and peoples with anemia (Elhassan and Yagi, 2010) and as ice cream flavor and refreshing drink (Abdualrahman *et al*., 2011). G. *tenax* naturally spread on dry land forests and rocky high altitudinal areas of Saudi Arabia. It occurs within the vegetation communities of Al-Hejaz area (Al-Zubaide *et al*,. 2017). In this zone it can be found in high altitudinal areas as high as Alshafa of the Taif (Alsherif and Fadl, 2016). It is also recorded in Farasan Island (Atiqur Rahman *et al*., 2002). Compost is useful to the plants by its gradual multiple effects in improving soil physical and chemical properties (Wu *et al*., 2013). It also, mitigate N_2O emissions from the soils (Ding *et al*., 2013), and enhance bio-stimulation in the soil that increase soil microorganisms (Valarini *et al*., 2009). Organic manure also, increase nutrient uptake (Pane *et al*., 2015). Iron is a micronutrient essential to plants due to its vital role in DNA and chlorophyll synthesis and as a component of several enzymes and pigments in plants (Rout and Sahoo, 2015). Although, iron required by plants in very small quantities, but it is one of most important limiting factor for plant growth as it is available in insoluble form in the soil (Jeong *et al*., 2017). Iron represents important element of Gudeim fruit (Abdualrahman, 2011). That is why wild fruit from this species used by local people as a source of high iron given to pregnant women, people with anemia or as famine food.

Despite its high potential as fast growing, stress tolerant and a multi uses and values evergreen tree, still remains in the wild as underutilized tree species. Little attention was given for domesticating this tree. This may suggest the need for ex-situ cultivation of this species in the dry lands. The main objective of this study was to assess growth and production of *G. tenax* in arid saline soils under different fertilization treatments. Specifically, to examine the combined effects of compost addition and foliar iron spraying on tree growth, canopy cover and fruit production and composition.

MATERIALAS AND METHODS

Study Site: This experiment was established in arid saline stressed environment at the research farm of the King Abdulaziz University at Al-Gumoom area Northeast of Jeddah. The seeds of *Grewia* used in this experiment were procured from Sudan National tree seed Centre. The seedlings raised during the season 2012/2013 and transplanted in the field during the season 2013/2014. The planting distance in the field was 4 X 4 meter, giving 625 trees per hectare. The trees were regularly irrigated by drip irrigation at frequency of once a week.

Experimental Design: The design used was factorial complete randomized block design with three replicates and two treatments (compost and foliar iron applications). The manure was added once every season in the form of Al-Morroj Compost (3.13% total nitrogen, 40% organic matter, 5.34 C/N ratio, 16.71%, total organic carbon 1.52% P and 0.23% K on dry matter basis). Three rates were used; dose one (M_1) was addition of manure at the rate of 2.5 kg/tree, dose two (M_2) at the rate of 5 kg/tree and the third (M_3), amount of 7.5 kg/tree, plus control without manure. Whereas iron was applied through foliar spray at the rates of 30 gram/gallon/ tree (I_1), 45 gram/ gallon /tree (I_2) and control (I_0). There was 10 experimental unit per block; combination of (M_1I_1, M_1I_2, M_1I_0, M_2I_1, M_2I_2, M_2I_0, M_3I_1, M_3I_2, M_3I_0 and control M_0I_0). During each season, iron treatment was divided into three equal doses and sprayed three times, to ensure that newly formed foliage treated with iron fertilizer. The iron was mixed thoroughly with water and sprayed with hand held sprayer. Iron fertilizer used was Fe EDDHA chelate of 6% w/w. In the beginning of each season and before addition of the compost the irrigation system was repaired, the wholes around the tree were thoroughly weeded and the under branches of the trees were pruned. The climatic conditions of the study area is shown in Table-1.

Canopy Cover: Changes in green canopy cover over time was monitored throughout the year using *Canopeo* green canopy cover measurement tool (Patrignani and Ochsner, 2015). Six consecutive measurements at the interval of every two months (August 2016, October 2016, December 2016, February 2017, April 2017 and June 2017) were done. To measure the tree canopy, the smart phone camera was faced downward and kept parallel to the tree canopy at least 60 cm from the top in order to minimize over estimation due to interception by big branches. Then a photo was taken and canopy cover percent was processed with the software as percent cover.

Branch Measurements: Branch characteristic were measured on four branches covering the four sites per tree. Branch lengths, number of lateral branches per main branches were measured at three month interval. Relative monthly branch increment (RMBI) was derived as (last measurement – initial measurement divided by number of months between measurements). While due the initial variation in the length of the main branches, number of lateral branches per main branches was converted into number of branches per one meter of the main branch.

Table-1. Mean monthly Temperature (Temp) and relative humidity (RH) and total monthly rainfall in the study site during the period of data collection.

Year	Month	Temp_mean C	RH_mean %	Rainfall_total mm
2016	1	21.8	69.82	4.01
2016	2	24.52	58.7	0
2016	3	27.84	58.94	0
2016	4	29.35	55.29	34.53
2016	5	32.34	45.63	9.4
2016	6	34.66	35.2	0
2016	7	33.94	41.34	0
2016	8	33.42	55.54	0.66
2016	9	32.94	58.55	9.65
2016	10	30.29	59.51	3.65
2016	11	27.41	64.98	0.2
2016	12	24.05	71.56	1.55
2017	1	24.76	68.04	0.15
2017	2	24.44	55.51	0.35
2017	3	29.2	63.46	0
2017	4	25.92	54.43	0.27
2017	5	27.74	54.92	0
2017	6	31.23	51.51	0

Source: Meteorological Station at Hada Al-Sham Experimental Farm, King Abdulaziz University.

Fruit Set Rate (FSR): In each of the branches previously selected for branch measurements, number of flowers and fruit set were counted during flowering and fruiting periods. Then fruit set rate was calculated as a number of fruits divided by the numbers of flowers in each branch.

Fruit Production: Fruit production per tree and per each treatment were determined during the two years (2016 and 2017). To estimate production, ripe fruits were manually collected from the trees. This process was repeated several times, until all fruits were completely collected. Then fruit production (KG) per tree was determined. Production per hectare was calculated as production of the tree multiplied by number of trees per hectare.

Mineral Elements: Fruit macro-elements (K, Ca, Na and Mg) and micro-elements (Fe, Cu and Zn) were analyzed by atomic absorption spectrophotometry as described by (Hanlon, 1998).

Sugar Contents: Quantitative determination of Fructose, Glucose, Sucrose, Maltose and Lactose sugars were analyzed by High-performance liquid chromatography

(HPLC) according to method described by (Puwastien *et al*., 2011). In brief, a sample of fruit was extracted with aqueous ethanol. The solution was filtered through filter paper (repeated three times), then the ethanol was evaporated in a rotary evaporator. The remaining aqueous solution was transferred to volumetric flask and made up to volume with distilled water and filtered through ultrafilter. The sample solutions and sugar standards were then injected into the HPLC. The results were expressed as g/100 g (percentages).

Data Analysis: The results of the data analysis for this study were generated using SAS/STAT software version (9.4), University Edition, copyright (2017), (SAS Institute Inc, 2017). ANOVA was analyzed to determine the effects of the main treatments and the means were separated by new Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Canopy Cover: Canopy cover of *Grewia* trees treated with compost and chelated foliar iron significantly differed among the main treatments in all measurements, except the first measurement (Table-2). A combination of higher compost and iron doses resulted in higher canopy cover. Whereas the greater amount of canopy cover % was obtained in a combination of compost at the rate of 7.5 kg/tree with iron at the rate of 45 gram/tree in most measurements, compared to trees treated with compost only or control untreated trees. The increase in canopy cover obtained in this study was associated with increased growth, fruit production and quality traits for this species. Earlier studies supported the relationship between canopy cover with photosynthate production and dry matter accumulation (Jun Luo *et al*., 2014), fruit production (Elfeel and Abohassan, 2016) and as indicator to measure gross primary production (Street *et al*., 2007).

In addition to the effects of compost and foliar iron fertilization, time of measurements also has an effect on canopy cover. Changes in canopy cover trend over time showed a seasonal pattern (Fig. 1). During the hot months of August and October canopy cover values were low, reaching peak in cold months of December and February and then dropped again during the hottest months of April and June. Although, this tree is evergreen, but low CC during hot season means shedding of the leaves to reduce transpiration loss. Reduction of total leaves area is a good fitness adaption of trees in arid environments.

Branch Measurements: Number of lateral branches per meter of main branch showed non-significant differences among treatments. Whereas relative monthly branch increment statistically differed among the main treatments (Table-3). Application of compost at the rate of 7.5 kg/tree along with foliar iron at the rate of 45 gram/tree resulted in higher RMBI. In general a combination of iron fertilization with addition of compost obtained higher RMBI values than compost application only and control untreated trees. On this branchy tree, improving the levels in RMBI means better overall growth. Spraying iron in composted trees produced higher RMBI at all compost rates, compared to trees treated with compost only. For instance, applying iron at the rate of 45 g/tree with lowest doses of compost (5 and 2.5 kg/tree), revealed higher RMBI than highest compost rate of 7.5 kg/tree without iron.

Fruit Set Rate (FSR): Addition of fertilizers revealed higher FSR compared to control unfertilized trees (Table-3). However, higher doses of compost accompanied with higher iron fertilizers resulted in higher FSR. The levels of FSR decreased with decreased compost/iron combination levels with the least values in the control untreated trees. Higher FSR (0.64) was obtained in both compost at the rate of 7.5 kg/tree and 5 kg/tree combined with iron at the of 45 g/tree. In turn, applying iron at the rate of 45 g/tree with compost at the rate of 5 kg/tree resulted in higher FSR, compared to compost at the rate 7.5 kg/tree with no iron or with 30 g Fe/tree. This indicates that FSR was decreasing with decreasing compost dose. However, with lower compost dose the results can be improved by application of iron fertilizer.

Fruit Production: In both the first and second years, the results of fruit production showed highly significant differences among the main treatments (Table-3). However, in general production was higher during the second year compared to the first year. During the two years, addition of 7.5 kg compost per tree and spraying of 45 grams of chelated iron produced higher fruits. Fruit production per hectare reached about 872 kg for high compost and iron doses, compared to 352kg for control with no fertilization. *Grewia* trees produced fruits twice a year during both years. However, the data for production in this study was included only the high season production during April. The low season production of December was not included. The reason is that fruit production during December is relatively low. At the same time there is very high competition by the birds. The birds catches the fruit immediately when the color start to change from green to orange or red, leaving very little or nothing to collect. Even during April there is bird competition, but at this time production is very high. Therefore, in fact fruit production data presented in this study is actually underestimated due to substantial amount lost by birds. However, in general field observations showed that the natural regeneration of the trees in its natural range is at a large extent achieved by birds dispersal of the seeds. This is supported by Tews *et al*., (2006) who found that birds dispersal of seeds is very crucial in *Grewia flava* regeneration and cover dynamics. The higher fruit production showed during the second year (Table-3), may be due to the residual effects of gradual decomposition of the compost and the effects the increasing amount of the iron applied. Also, due to the increased growth in the second year.

Mineral Elements: The results revealed highly significant differences in fruit for macro and micro elements analyzed among the different fertilization rates applied (Table-4). Most of the elements analyzed increased with high compost/iron doses, except Na that declined with increasing rates. K is the highest element in fruit of *Grewia* in this study. This is in accordance with many studies that reported k as the highest element in *grewia* fruits (Aboagarib *et al*., 2015). The iron although, significantly varied among various treatments, but it is relatively low. This may debate the general local communities believes that this fruit contains very high iron content the reason that is given to pregnant women and peoples with anemia. This was in accordance with Nour Eldaim and Elnadi, (2014), Who concluded that the iron in *Grewia* was below normal compared to other sources. However, this is contrasting with the findings of Elhassan and Yagi, (2010), who supported the local believes that the fruits from this species contains high amount of iron. K is important elements to plants due to its role in regulating opening and closing of guard cells and osmoregulation in plant (Cushman, 2001). Application of compost and iron fertilizers reduced Na content compared to the control and trees treated with low amounts of compost and iron.

Sugar Contents: *Grewia* fruits contained high levels of individual monosaccharides sugars of fructose and glucose and were differed with different fertilization rates applied. Also, disaccharides (sucrose and maltose) varied with various fertilization types and rates (Fig. 2). HLPC results showed no amount of lactose sugars in any of the fruit samples tested. That is why the lactose was not presented here. Under all compost rates, iron at the rate of 45 g/tree resulted in higher amount of individual sugar contents. Whereas within compost treatment without iron the sugar contents increased with increasing compost doses.

Table-2. Effects of compost addition and foliar iron spray on canopy cover trend of *Grewia tenax* grown under arid saline land.

TRT	Cover1	Cover2	Cover3	Cover4	Cover5	Cover6
M_3I_2	39.6a	74.0a	77.1a	80.1a	69.9a	67.4a
M_3I_1	38.2a	69.5abc	71.0abc	73.0ab	69.1ab	67.3a
M_3I_0	50.7a	72.9ab	72.8ab	73.5ab	69.4ab	62.3abc
M_2I_2	51.1a	72.1ab	71.4abc	74.6ab	66.3	64.0ab
M_2I_1	44.5a	65.1abcd	63.8bcd	70.5ab	65.1ab	63.2ab
M_2I_0	47.0a	65.4abcd	65.8abc	66.5bc	63.9ab	57.0abc
M_1I_2	37.7a	65.7abcd	67.0abc	70.2bc	64.0ab	61.4abc
M_1I_1	32.7a	62.8bcd	59.7cd	64.4bc	60.0bc	58.9abc
M_1I_0	43.2a	57.8d	53.9cd	57.6c	53.1c	51.7c
C	43.3a	60.0cd	58.6cd	65.9bc	63.3ab	55.1bc
C. V.	18.7	8.1	9.1	7.8	7.5	9.2
F. Value	0.94	2.97	3.50	3.40	3.06	2.33
P	ns	*	**	**	*	*

* = ≤ 0.05 ** = ≤ 0.01 ns = not significant

Means with different letters in the same column were significantly different at (p = 0.05), using new Duncan's Multiple Range Test.

Table-3. Effects of compost addition and foliar iron spray on fruit set rate (FSR), branch number per meter (Brno/m), relative monthly branch increment (RMBI) and fruit production of *Grewia tenax* grown under arid saline land.

TRT	FSR	Brno/m	RMBI Cm	Production 2016		Production 2017	
				Kg/tree	Kg/Ha	Kg/tree	Kg/Ha
M_3I_2	0.64a	14a	13.43a	0.86a	542.7a	1.41a	887.1a
M_3I_1	0.61ab	14a	11.35ab	0.85b	532.1b	1.15e	722.1e
M_3I_0	0.58ab	13a	7.46bc	0.78c	504.5c	0.95g	595.0g
M_2I_2	0.64a	15a	11.35ab	0.85b	533.3b	1.38b	872.5b
M_2I_1	0.56ab	13a	11.23ab	0.74d	467.1e	1.31c	700.4
M_2I_0	0.40ab	13a	87.51b	0.65g	410.6f	0.82g	517.1g
M_1I_2	0.44ab	13a	6.78c	0.85b	532.1b	1.31c	818.7c
M_1I_1	0.39ab	15a	6.61c	0.76d	477.1e	1.29d	807.5d

M_1I_0	0.40ab	14a	6.60c	0.69f	433.3f	0.77h	486.4h
C	0.23b	14a	4.33b	0.49h	306.4h	0.57j	361.4j
C. V.	39.3	21.6	26.02	0.50	0.50	0.64	0.64
F. value	1.96	0.38	3.98	937	937	748	748
P	*	ns	**	**	**	**	**

* = ≤ 0.05 ** = ≤ 0.01 ns = not significant

Means with different letters in the same column were significantly different at (p = 0.05), using new Duncan's Multiple Range Test.

Table-4. Effects of compost addition and foliar iron spray on mineral elements contents of *Grewia tenax* fruits grown under arid saline land.

TRT	K g/100g	Ca g/100g	Na g/100g	Mg g/100g	Fe Mg/kg	Cu Mg/kg	Zn Mg/kg
M_3I_2	0.44a	0.130a	0.030c	0.186a	9.016a	0.850ef	2.396c
M_3I_1	0.43a	0.126ab	0.030c	0.166c	8.943b	0.850ef	2.446c
M_3I_0	0.40bc	0.120abc	0.031c	0.166c	8.850c	0.830f	2.096de
M_2I_2	0.43a	0.123abc	0.030c	0.166c	8.783de	0.830f	1.783de
M_2I_1	0.41b	0.113cd	0.031c	0.156b	8.746ef	1.000c	1.996e
M_2I_0	0.41b	0.106d	0.031c	0.176b	8.713fg	0.950cd	3.016b
M_1I_2	0.41b	0.113cd	0.050a	0.156d	8.730fg	0.900def	2.196d
M_1I_1	0.40bc	0.116bcd	0.050a	0.126e	8.800cd	0.930vdf	1.996e
M_1I_0	0.40bc	0.106d	0.043b	0.166c	8.580h	1.250b	2.163d
C	0.39c	0.106d	0.043b	0.156d	8.680g	1.500a	3.133b
C. V.	2.16	6.67	6.63	1.65	0.33	5.53	3.61
F. Value	12.18	3.61	40.00	1.03	55.94	47.94	117.18
P	**	**	**	**	**	**	**

* = ≤ 0.05 ** = ≤ 0.01 ns = not significant

Means with different letters in the same column were significantly different at (p = 0.05), using new Duncan's Multiple Range Test.

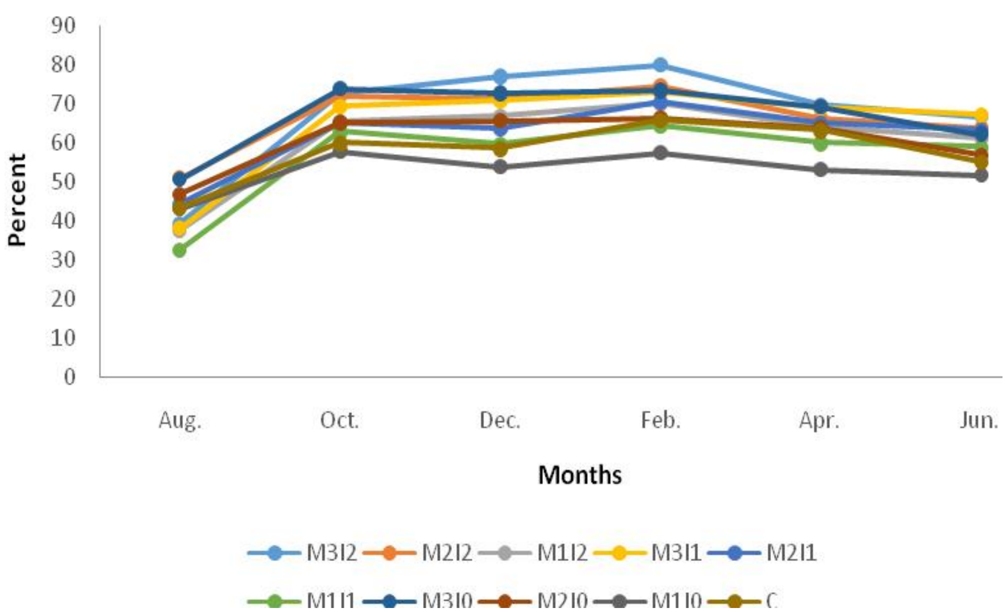

Fig.1. Trend in canopy cover over time of *Grewia tenax* as affected by combined effects of compost and iron fertilization

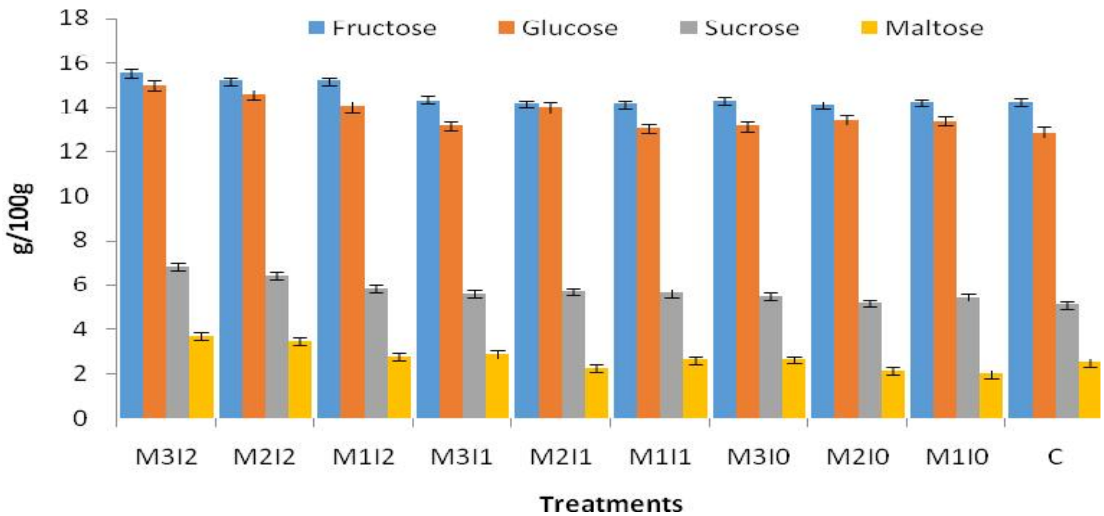

Fig.2. Effects of compost addition and foliar iron spray on individual sugar contents of *Grewia tenax* fruits grown under arid saline land.

Conclusion: It may be concluded that a combination of compost and iron under such environments have a great effects on tree growth and fruits production and composition of *Grewia tenax*. Foliar spraying of iron on composted trees produced highly positive effects on fruit quantity and quality. The study highlights the importance of domesticating *Grewia tenax* (important multipurpose) shrubby tree in arid environments. In such environments, growth and production of *Grewia tenax* can be improved by combined application of compost and iron.

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