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Nature and Science

MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

Determination of growing medium and irrigation water amount suitable for the best growth of *Gasteria carinata* var. verrucosa (Mill) van Jaarsv. succulent plant

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Abstract: An experiment was performed under saran house at the nursery of Hort. Res. Inst., ARC, Giza, Egypt during 2018 and 2019 seasons to select the most proper growing medium and water quantity necessary for the production of picturesque and floriferous specimens from the succulent ox-tongue gasteria plant in pots. Thus, uniform offsets of *Gasteria carinata* var. verrucosa (Mill) van Jaarsv. were transplanted in 20 cm diameter polyethylene black bags filled up to 3 cm past the bag rim with one of the following mixtures (media) pure sand (as control), sand + loam (2: 1, v/v), sand + animal compost (3: 1, v/v), sand + Nile compost (3: 1, v/v), sand + loam + animal compost (2: 1: 1 v/v/v) sand + loam + Nile compost (2: 1: 1, v/v/v) and sand + animal compost + Nile compost (2: 1: 1, v/v/v). After two weeks from planting, the plants received the different water treatments as follows: 100, 150and 200 ml of freshwater/ bag (plant). The effect of interactions between growing medium and water treatments on growth, flowering, offset production and quality was also studied.
The obtained results indicated that planting in the sand alone gave the highest mean values of No. leaves/ plant, leaf length, width and thickness, No. flowering stems/plant, flowering stem length, No. leaves/offset, as well as offset fresh and dry weights over the means recorded by planting in the other media in the two seasons. However, the longest root length, highest No. offsets/plant and N, P and K concentrations in the leaves were attained in both seasons by planting in sand + Nile compost (3: 1, v/v) mixture, whereas the heaviest plant fresh and dry weights in the two seasons were acquired by planting in sand + animal compost (3: 1, v/v) medium. The highest concentrations of chlorophyll a, b and carotenoids were found due to planting in either sand + loam + Nile compost (2: 1: 1, v/v/v) mixture or sand + animal compost + Nile compost (2: 1:1, v/v/v) one, as these two mixtures replaced giving the highest records in both seasons. Also, the effect of water amount treatments on the previous measurements was unsteady, but the prevalence was for 100 ml/plant water treatment, which gave the utmost high values in most cases of the two seasons. The interactions exerted, as well a significant effect on the different traits of growth, flowering, offset production and chemical constituents, but the dominance was mostly for combining between planting in either sand alone or sand + Nile compost (3: 1, v/v) media and irrigating with 100 ml of water/ plant, which fulfilled the greatest averages in most characters relative to the other combinations in both seasons.
Thus, it can be recommended to culture *Gasteria carinata* var. verrucosa (Mill) van Jaarsv. plant in either pure sand or sand amended with Nile compost (3: 1, v/v) and irrigating it with only 100 ml of water/ plant, twice a week to produce drought tolerant and picturesque succulent pot plant suitable for xeriscaping.
[Neima F. El-ghazaly, Khaled A. Emam and Sayed M. Shahin **Determination of growing medium and irrigation water amount suitable for the best growth of *Gasteria carinata* var. verrucosa (Mill) van Jaarsv. succulent plant** Nat Sci 2021; 19(12);88-98]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). http://www.sciencepub.net/nature. 12. doi:10.7537/marsnsj191221.12.

Key words: Ox-tongue, *Gasteria carinata* var. verrucosa, media, water requirements, vegetative and root growth.

1. Introduction

Gasteria carinata var. verrucosa (Mill) van Jaarsv., ox-tongue is a proliferous variety that belongs to Fam. Asphodelaceae with erect, pointed (not retuse) spreading leaves that remain distichous and dense white tubercles in dispersed arrangement in adulthood, native to the Western Cape Province, South Africa **(Bailey, 1971)**. Gasteria species are recognizable from their thick, hard, succulent, tongue-shaped leaves and their unique inflorescence with their curved, belly-shaped flowers. They are grown in well-drained, sandy soils under full sun to light shade and may occur in rocky areas, and can be propagated by seed (germination usually occurs within 8-30 days depending on the species), by offsets and leaf cuttings which can be rooted easily **(van Jaarsveld, 2007)**. Flowering times vary between species but mostly in spring and summer. However, *G. carinata* flower all year with a peak in the spring. It can be grown well indoor and outdoor in desert and rocky gardens and is suitable for growing in containers and plate arrangements **(van Jaarsveld, 2020)**.

Because their roots are limited by container sizes and its medium volumes, containerized succulent plants require a careful selection of growing medium and water amount suitable for optimum growth and development. Such truth was

demonstrated by **Moore and Broschat (2001)** on areca palm, crossandra, pentas and Philodendron, **Shahin *et al.* (2007)** on *Agave amricana* cv. Marginata, **Shahin *et al.* (2009)** on tuberose, **Saadawy *et al.* (2011)** on *Ficus nitida* "Hawaii", **Mazher *et al.* (2012)** on Amaranthus tricolor, **Nofal *et al.* (2014)** on *Hymenocallis speciosa*, **Said (2016)** on *Duranta erecta* var. Variegata, **Hazrati *et al.* (2017)** on *Aloe vera*, **El-Fouly *et al.* (2020)** on Asparagus densiflorus "Myers" and **Shahin and Sayed (2021)** on *Ochna serrulata*.

Sandy soil is considered marginal soil characterized by sandy texture, loose structure, low fertility, low cation exchangeable, high temperature during the day coupled with high wind speed lead to high evaporation rate **(Yuwono, 2009)**. Thus, it is necessary to improve this poor quality through amending the sand with the proper local ameliorants for the cheap, commercial production. In this regard, **Hoseini (2013)** found that applying pigeon manure and litter compost to sand increased *Aloe vera* growth parameters, respectively at 180 g/plant level which gave the highest No. leaves and fresh weight, leaf length, leaf diameter, No. suckers/ plant and chlorophyll index over either 90 or 270 g/ plant levels. Similar observations were also obtained on *Aloe vera* by **Darini (2017), Darini (2020), Darini and Sulistyaningsih (2020)** and **Singh *et al.* (2021)**.

Due to crassulacean acid metabolism (CAM) and differ their morphological and physiological structures from most other plants, so, most cacti and succulent plants require less water than conventional crop especially when grow on marginal soils with low nutrients availability such as sandy one **(Nobel and Zutta, 2007)**. This because such plants exhibit a high water use efficiency (WUE) in arid regions **(Delatorre-Herrara *et al.*, 2010)**. The higher WUE in CAM plants may be ascribed to that stomata in these plants can open at night for gas exchangeable and CO2 fixation **(Herrara, 2009)**, besides low stomata density and osmotic biosynthesis **(Deltatorre-Herrera *et al.*, 2010)**. Also, cacti and succulents able to store high amounts of water in their tissues and their cells able to withstand dehydration. In this concern, **Nobel (1988)** mentioned that the leaves of agaves and cacti stems usually have great amounts of water storage parenchyma which can store large quantities of water help such plants to survive well under longer periods of drought. During drought, water can move from parenchyma to the chlorenchyma, where photosynthesis and other vital metabolic processes take place. The epidermis of succulents and cacti tends to become less permeable to water because the cuticle thickness usually increased with age **(Nobel, 1994)**. Although water deficit limits growth and development of cacti and succulents, such plants showed a high WUE under drought conditions due to CAM phenomenon which they **(Nobel and Zutta, 2007; Delatorre-Herrera *et al.*, 2010)**.

However, this work aims to choose the most suitable medium and water quantity reliable for the best growth, flowering and quality of the potted *Gasteria carinata* var. verrucosa succulent plant.

2. Material and Methods

This investigation was conducted under Saran house at the nursery of Hort. Res. Inst., ARC, Giza, Egypt during 2018 and 2019 consecutive seasons in order to select the most proper growing medium and water volume necessary for production of picturesque and floriferous specimens from the succulent ox-tongue gasteria plant in pots.

Therefore, homogenous offsets of *Gasteria carinata* var. verrucosa (Mill) van Jaarsv. at a length of about 10cm with 4 small leaves were transplanted on April, 15th for every season in 20 cm. diameter polyethylene black bags filled up to 3 cm. before the bag rim with one of the following media: pure sand (as control), sand + loam (2: 1, v/v), sand + animal compost (3: 1, v/v), sand + Nile compost (3: 1, v/v), sand + loam + animal compost (2: 1: 1, v/v/v) sand + loam + Nile compost (2: 1: 1, v/v/v) and sand + animal compost + Nile compost (2: 1:1, v/v/v). The physical and chemical properties of the sand and loam used in the two seasons are shown in **Table (a)**, while those of animal compost and Nile compost are illustrated in **Table (b)**.

Immediately after transplanting, all bags were irrigated with 350ml of fresh water/bag, twice every week till May, 1st, where they received the following treatments of water amounts, two times weekly till the end of the experiment on September, 30th in each season: 100, 150 and 200 ml/bag. Each treatment of media was combined factorially with each one of water quantity to create 21 interaction treatments.

The layout of the experiment in the two seasons was a complete randomized design in factorial experimental type, replicated thrice, as each replicate contained four plants **(Mead *et al.*, 1993)**. Moreover, all the other agricultural practices needed for such plantation were done whenever required as usually grower did. At the end of every season, data were recorded as follows: No. leaves/plant, leaf length (cm), leaf width (cm) at the base, leaf thickness (cm), root length (cm), plant fresh and dry weights (g), No. flowering, stems/plant, flowering stem length (cm), No. offsets/plant, No. leaves/offset, as well as offset fresh and dry weights (g). In fresh leaf samples, photosynthetic pigments concentrations (chlorophyll a, b and carotenoids, mg/g f.w.) were determined according to the method of **Sumanta *et al.* (2014)**,

while in dry ones, the percentages of nitrogen, phosphorous and potassium were measured by the methods described by **Chapman and Pratt (1975).**

The data were then tabulated and statistically analyzed using the Assistant Softwar Program explained by **Silva and Azevedo (2016)**, followed by Duncan's New Multiple Rang t-Test **(Steel and Torrie, 1980)** to verify the mean values of different treatments.

Table (a): The physical and chemical properties of the sand and loam used in the two experimental seasons of 2018 and 2019.

Soil texture	season	Particle size distribution%				S.P.	EC (ds/m)	pH	Cations (meq/l)				Anions (meq/l)		
		Coarse sand	Fine sand	Silt	Clay				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Hco_3^{-}	Cl^{-}	So_4^{--}
Sand	2018	86.33	3.75	1.50	8.42	23.76	3.51	7.95	10.38	1.76	26.95	0.76	3.50	21.90	14.45
	2019	85.63	5.58	1.36	7.43	21.98	3.33	7.88	18.50	5.17	11.39	0.81	1.78	13.50	20.59
Loam	2018	13.50	43.65	20.11	22.74	34.79	3.15	8.10	16.33	11.50	18.93	0.71	5.63	11.98	29.86
	2019	10.93	45.70	21.36	22.01	35.00	3.10	8.03	17.50	9.88	20.10	0.75	6.17	12.67	29.39

Table (b): Some physical and chemical analysis of animal and Nile composts used in the two experimental seasons.

Property	Unit	Animal compost	Nile compost	Property		Unit	Animal compost	Nile compost
Weight of m^3	Kg	840.00	550.50	Macro elements	N	%	0.83	3.00
Humidity	%	30.00	55.60		P_2O_5	%	0.77	0.50
Organic matter	%	23.18	47.70		K_2O	%	0.41	2.51
Organic carbon	%	13.45	27.33		$CaCO_3$	%	1.53	1.60
C/N ratio		16.2/1	17.5/1		MgO	%	0.76	0.96
pH (1: 10)		7.78	6.00	Micro elements	Fe	ppm	1336.5	1240.0
E.C.	dS/m	2.51	1-1.5		Mn	ppm	148.3	324.0
Water retention	%	100.00	100.00		Zn	ppm	40.5	33.5
Ash	%	76.82	79.50		Cu	ppm	10.3	31.6

3. Results and Discussion

Effect of growing medium, water amount and their interactions on:

1- Vegetative and root growth parameters:

It is evident from data presented in Tables (1) and (2) that planting in the sand medium significantly gave the highest mean values of No. leaves/plant and leaf length, width and thickness (cm) traits over the means recorded by planting in the other media in the two seasons, except for No. leaves/plant character that reached to 7.37 leaves in the second season by planting in sand + loam + animal compost (2:1:1, v/v/v) mixture to be statistically at par with that attained by planting in the sand (7.96 leaves). However, the longest root length (cm) was acquired in the two seasons by planting in a mixture of sand + Nile compost (3:1, v/v), whereas the heaviest plant fresh and dry weights (g) in both seasons were obtained by planting in sand + animal compost (3: 1, v/v) growing medium. In general, the least records in most of the aforementioned characters were scored in both seasons by planting in the sand amended with animal and Nile compost (2:1:1, v/v/v) medium, especially leaf length and thickness, root length and plant fresh and dry weights parameters. This means that excessive organic compost may lead to adverse effects on growth of such succulent plant. In this regard, **van Jaarsveld (2007)** stated that gasteria species are grown in well-drained sandy soil and may occur in rocky soils.

On the other side, effect of water amount treatments on the previous growth traits was fluctuated, where 150ml/plant water treatment attained the highest No. leaves/plant in both seasons, and followed by 100 ml one with non-significant differences among themselves, but water amounts of

150 and 200 ml/plant scored the longest leaf length in the two seasons. Irrigating with only 100 ml of water/plant gave the widest and thickest leaves, longest root and heaviest plant fresh and dry weight over all the other water treatments in the first and second seasons. This may be reasonable because succulent plants are usually require little water for good growth. In this concern, **Nobel and Zutta (2007)** indicated that most cacti and succulent plants need less water than other ordinary crops when grow on marginal soils with new nutrients availability due to CAM phenomenon and differ their morphological and physiological structures from most other plants. **Delatorre-Herrera *et al.* (2010)** suggested that these plants exhibit a high WUE in arid regions, and this may be attributed to that stomata of such plants can open at night for gas exchangeable and CO2 assimilation **(Herrera, 2009)**. Moreover, **Nobel (1988)** reported that leaves of agaves and cacti stems usually store great amounts of water in parenchyma cells help them to survive well under longer periods of drought. **van Jaarsveld (2007)** cited that gasteria species are considered drought-tolerant suitable for xeriscaping. They are prone to fusarium root rot if they are over watered.

Great variable responses were also noticed regarding the effect of interaction treatments on growth parameters (Tables, 1 and 2), where combining between planting in the pure sand medium and any rate of water gave, in general the highest No. leaves, and the longest, widest and thickest leaves compared to most other combinations in both seasons. However, the superiority was for a combination of planting in the sand + irrigating with 100 ml of water/plant, which raised the mean values of most previous attributes to maximum in the two seasons. Also, connecting between planting in either sand or sand + loam + animal compost (2: 1: 1, v/v/v) mixture and watering with 150 ml/plant level increased the No. leaves in the first season to 7.75 leaves to be closely near to the mean of superior combination. Likewise, a combination of planting in sand + animal compost (3: 1, v/v) mixture + 150 ml of water/plant in both seasons, and of planting in sand + loam + animal compost (2: 1: 1, v/v/v) mixture + 100 ml/plant water amount in the second season gave a similar trend to that of the superior one. In addition, interaction of planting in sand + Nile compost (3: 1, v/v) mixture + 100 ml of water/plant level elevated mean of the root length to the utmost high values in both seasons, whereas interaction of planting in sand + animal compost (3: 1, v/v) mixture + 100 ml of water/plant recorded the heaviest plant fresh and dry weights in the two seasons.

The present results conform with those declared by **Hazrati *et al.* (2017)** who found that water use efficiency of *Aloe vera* plant increased with less water amount (20% of F. C. rather than 40, 60 and 80% of F.C.). The greatest No. leaves and pup and the highest leaf and gel fresh weight were observed when the plants irrigated with 40% of F.C. and the sand amended with 8g zeolite/Kg soil mixture. Similarly, **Singh *et al.* (2021)** revealed that maximum fresh leaves (60.6 t ha^{-1}), gel (25.8 t ha^{-1}) and juice yield (22.7 t ha^{-1}) were attained by irrigation with 20% available soil mixture. On *Hymenacallis speciosa*, **Nofal *et al.* (2014)** recommended to plant this bulbous plant in sand + compost (2:1, v/v) mixture and supplying the plants with moderate irrigation level (50% of F.C.) to get best growth, high quality and save a good deal of water for other uses. On *Gladiolus grandiflorus* cv. Peter pears, **Elghazaly (2016)** proposed to use the low irrigation level (2L/plant) rather than moderate (4L/plant) and high (6L/plant) with low level of kristalon (2g/L) to achieve the highest growth and quality. Furthermore, **Darini and Sulistyaningsih (2020)** stated that applying cow manure at 30 t ha^{-1} to sandy soil hastened growth and leaves fresh weight of *Aloe vera* plant more than a rate of 45 t ha^{-1}, especially combining with humic urea.

2- Flowering parameters and offset production

From data averaged in Table (3), it is obvious that planting in sand standalone gave the highest No. flowering stems/plant and the longest flowering stem (cm) relative to all the other media in the two seasons, while the least records were acquired by plants grown in sand + animal compost + Nile compost (2: 1: 1, v/v/v) mixture. This may be ascribed to that amending the sand with organic additives usually increase the water holding capacity of the resulted mixture, and that affects negatively on growth and flowering of succulents. In this respect, **van Jaarsveld (2007)** emphasized that gasterias need to well-drained sandy soil and light shade for good and floriferous growth. Gasteria species are prone to infect with fusarium root rot, if they are over-watered.

However, the mean values of these two criteria were gradually decreased with increasing water supply to be minimum in the two seasons by 200 ml of water/plant treatment. So, the maximum values are registered by 100 ml/plant water level showing that gasteria plants indeed require little water for irrigation.

Accordingly, combining between planting in sand alone and irrigation with the lowest water quantity (100 ml/plant) significantly improved flowering stem production plus elongating their lengths to the maximal values comparing with all the other combined treatments employed in this study in both seasons. On the contrary, plants grown in either

sand + loam (2: 1, v/v) mixture or sand + animal compost + Nile compost (2: 1: 1, v/v/v) one and irrigated with 150 ml of water/plant failed to flower in the two seasons. A similar trend was also obtained by plants grown in sand + loam + animal compost, sand + loam + Nile compost and sand + animal compost + Nile compost (2: 1:1, by volume for all) media and irrigated with 200 ml of water/plant. This may be attributed to that such plants subjected to these combinations are still juvenile due to their poor growth.

As for offset production, data in Table (3) clear that planting in either pure sand or sand + Nile compost (3: 1, v/v) mixtures gave the highest No. offsets/plant over all other media in the 1st season, but in the 2nd one, all growing media, except of sand + animal compost (3: 1, v/v) and sand + animal compost + Nile compost (2: 1: 1, v/v/v) ones increased means of such trait to maximum without significant differences in between. The dominance in both seasons, however was for sand + Nile compost (3: 1, v/v) medium that raised mean of this trait to 2.71 and 2.47 offsets in the first and second seasons, successively. This may be referred to the benefits of Nile compost in improving the sand structure and other physical properties, increasing water hold capacity, decreasing drainage and supplying the plants with enough amounts of nutrients necessary for high production **(Darini and Sulistyaningsih, 2020).** In this connection, **Hoseini (2021)** reported that applying 3% (180g) of pigeon manure to sand increased No. suckers/*Aloe vera* plant in pot to maximal value.

Table (1): Effect of medium, water amount and their interactions on leaf traits of *Gasteria carinata* var. verrucosa (Mill) van Jaarsv. plant during 2018 and 2019 seasons.

Water amount (ml/plant) / Medium	No. leaves/plant				Leaf length (cm)				Leaf width (cm)				Leaf thickness (cm)			
	100	150	200	Mean	100	150	200	Mean	100	150	200	Mean	100	150	200	Mean
First season : 2018																
Sand (s)	8.12a	7.75a	7.22ab	7.69a	9.43d	19.84a	18.34a	15.87a	3.30a	2.83b	3.26a	3.10a	1.52a	1.11bc	1.36a	1.33a
S + L (2:1)	6.52b	6.27	6.77b	6.52ac	13.97c	14.70c	16.66b	15.24b	2.36c	2.26c	2.30c	2.31c	1.26b	1.03bc	0.84c	1.05bc
S + AC (3:1)	6.66b	8.18a	6.84b	7.23ab	13.85c	15.81c	13.53c	14.36c	2.33c	2.81b	2.50bc	2.55bc	0.83c	1.02bc	1.08bc	1.04bc
S + NC (.3:1)	6.10c	4.41	3.82e	4.78c	14.66c	12.47cd	14.44c	13.86c	2.82b	2.60bc	2.80b	2.75b	1.30b	1.27b	1.12bc	1.23ab
S + L + AC (2: 1: 1)	7.38ab	7.75a	6.13c	7.09ab	14.38c	12.24cd	11.50cd	12.71d	2.66bc	2.40c	2.33c	2.47bc	1.15bc	0.78c	0.71c	0.88c
S + L + NC (2: 1: 1)	6.91b	7.14ab	6.73b	6.92ab	15.62c	16.56c	13.36c	15.51b	2.65bc	2.76b	2.90b	2.77b	0.72c	0.85c	0.45d	0.67d
S + AC + NC (2:1:1)	6.48b	7.50ab	5.27d	6.42b	11.75cd	10.01d	16.00c	12.98d	2.92b	2.55bc	2.58bc	2.63bc	0.34d	0.40d	0.51d	0.42e
Mean	6.88ab	7.00a	6.11b		13.52ab	14.79a	14.73a		2.72a	2.60ab	2.64a		1.02a	0.95b	0.87b	
Second season : 2019																
Sand (s)	8.24a	7.82b	7.83b	7.96a	9.64d	21.35a	19.66a	16.88a	3.06a	3.05a	2.76b	2.96a	1.82a	0.95bc	1.37b	1.38a
S + L (2:1)	6.27d	6.12d	7.20bc	6.53ab	13.00c	13.68c	18.34b	15.00b	2.44c	2.25d	2.36cd	2.35d	1.36b	1.08bc	0.96c	1.13b
S + AC (3:1)	5.57e	8.68a	6.46c	6.90ab	14.27c	15.70c	13.40c	14.46c	2.50c	2.64b	2.68b	2.61bc	0.57de	1.31b	1.01c	0.96c
S + NC (.3:1)	7.94ab	4.44ef	3.93e	5.43b	14.01c	12.71cd	13.94c	13.55d	2.75b	2.67b	2.72b	2.71b	1.21bc	1.45ab	0.96c	1.20b
S + L + AC (2: 1: 1)	8.22a	7.87b	6.01d	7.37a	14.70c	13.56h	10.17d	12.81e	2.66b	2.27d	2.56c	2.49cd	1.36b	0.75d	0.81cd	0.97c
S + L + NC (2: 1: 1)	6.53c	7.63b	6.48c	6.88ab	14.16c	19.11b	15.90c	16.36ab	2.70b	2.68b	2.95ab	2.78b	0.55de	1.01c	0.50de	0.69d
S + AC + NC (2: 1: 1)	6.87c	7.62b	5.46d	6.65ab	13.10c	9.92d	15.44c	12.49e	2.78b	2.48c	2.55c	2.60bc	0.32e	0.34e	0.52de	0.39e
Mean	7.09a	7.17a	6.19ab		12.98b	14.98a	15.08a		2.70a	2.58b	2.65a		1.03a	0.98a	0.87b	

-L: loam, Ac: animal compost and NC: Nile compost.
-Means followed by the same letter in a column or row are not differ significantly according to Duncan's New Multiple Rang t-Test at 5% level.

In addition, water amount at either low (100 ml/plant) or high (200 ml/plant) amount elevated the No. offsets to the highest averages, scoring in the 1st season 2.05 and 1.99 offsets/plant and in the 2nd one 1.95 and 2.09 offsets/plant, respectively with non-significant differences among themselves. Thus, the

best results of this character were attained by interacting between planting in sand alone and irrigating with 200 ml/plant water treatment, as such combination gave the utmost high No. offsets/plant in the two seasons. Also, combining between planting in a mixture of sand + Nile compost (3: 1, v/v) + 150 ml water level in the first season and between raising in the same mixture + 100 ml water level in the second one hastened offsets production to the same rank of the best combination mentioned above.

These gains could be supported by those of **Shahin *et al.* (2007)** who decided that planting *Agave americana* cv. Marginata in sand + 10% loam + 10% chicken manure compost medium and irrigating with 150 ml of water/ plant gave the highest productivity and best quality of the new formed suckers. On tuberose, **Shahin *et al.* (2009)** observed that plants grown either in sand and irrigated with 200 ml of water or in loam and irrigated with 150 ml of water/ plant achieved the highest No. bulblets/plant and the heaviest fresh and dry weights of the new bulblets.

Table (2): Effect of medium, water amount and their interactions on root length and fresh and dry weights of *Gasteria carinata* var. verrucosa (Mill) van Jaarsv. plant during 2018 and 2019 seasons.

Water amount (ml/plant) / Medium	Root length (cm)				Plant f. w. (g)				Plant d. w. (g)			
	100	150	200	Mean	100	150	200	Mean	100	150	200	Mean
First season : 2018												
Sand (s)	18.17b	12.91bc	12.72bc	14.60b	223.58bc	167.70c	191.11c	194.13b	39.11b	28.34c	33.81bc	33.75b
S + L (2:1)	12.13b	9.23c	9.28c	10.21c	249.73b	198.79bc	206.65bc	218.39b	44.31b	33.6bc	36.46bc	38.12b
S + AC (3:1)	22.56a	13.15bc	14.02bc	16.58b	341.47a	247.35b	215.85bc	268.22a	60.62a	41.92b	37.05bc	46.86a
S + NC (.3:1)	25.82a	21.50a	20.73a	22.68a	211.15bc	200.36bc	218.16bc	209.89b	37.84bc	34.31bc	38.59bc	36.91b
S + L +AC (2: 1: 1)	12.65b	10.04b	11.55bc	11.41c	206.87bc	172.73c	193.19c	190.93b	36.67bc	29.19c	34.16bc	33.34b
S + L + NC (2: 1: 1)	8.15c	5.71d	5.51d	6.46d	224.07bc	206.28bc	200.92bc	210.42b	39.86b	34.96bc	35.4bc	36.74b
S + AC + NC (2: 1: 1)	5.81d	4.36d	4.92d	5.03d	108.29d	103.61d	95.03d	102.31c	19.22d	17.48d	16.81d	17.84c
Mean	15.04a	10.99b	11.25b		223.59a	185.26b	188.70b		39.66a	31.40b	33.33b	
Second season: 2019												
Sand (s)	19.21b	13.11c	13.05c	15.12b	222.25c	170.37d	190.98b	194.53c	39.98b	29.04c	33.88bc	34.30b
S + L (2:1)	12.84c	14.09c	14.25c	13.73c	251.08b	200.25cd	207.11ab	219.48b	45.16b	34.13bc	36.74bc	38.68b
S + AC (3:1)	23.41ab	14.21	14.55c	17.39b	345.06a	250.31b	217.15a	270.84a	62.07a	42.67b	38.52b	47.75a
S + NC (.3:1)	27.06a	22.63ab	22.04ab	23.91a	210.65	202.12cd	217.84a	210.20b	37.89bc	34.45bc	38.64b	37.00b
S + L + AC (2: 1: 1)	13.23c	11.11c	12.14c	12.16c	208.15cd	174.04d	191.66b	191.28c	37.44bc	29.67c	34.00bc	33.70b
S + L + NC (2: 1: 1)	7.85d	6.32d	5.69d	6.62d	225.14c	208.46	201.03ab	211.54b	41.50b	35.53bc	35.66bc	37.23b
S + AC + NC (2: 1: 1)	6.65d	5.14d	5.22d	5.67d	109.02e	100.21e	92.85e	100.69d	19.61d	17.08d	16.47d	17.72c
Mean	15.75a	12.37b	12.42b		224.48a	186.54b	188.37b		40.38a	31.80b	33.42b	

-L: loam, Ac: animal compost and NC: Nile compost.
-Means followed by the same letter in a column or row are not differ significantly according to Duncan's New Multiple Rang t-Test at 5% level.

3. The new formed offset characters:

A similar response to that of leaf criteria was also observed regarding the mean values of the new offset characters (Table, 4), where planting in the sand alone gave in both seasons the highest No. leaves/offset and heaviest offset fresh and dry weights (g) in comparison to those of the other media. However, amending the sand with either Nile compost or Nile compost and loam acquired also better results giving means greatly close to those attained by planting in sand medium. Besides, irrigating with the low water level (100 ml/ plant) significantly improved the means of various new offset criteria mentioned before over the medium and high water levels (150 and 200 ml/ plant, respectively). So, interaction between planting in pure sand and irrigating with only 100 ml of water/ plant produced the best offsets, wherefrom No. leaves/ offset and their fresh and dry weights relative

to all the other interaction treatments, with few exceptions in the two seasons.

Identical effects to those of the current work were also revealed by **Darini (2017)**, **Darini (2020)** and **Darini and Sulistyaningsih (2020)** on *Aloe vera* plants grown in sand supplemented with cow manure. In this respect, **Shahin *et al.* (2007)** found that irrigating *Agave americana* cv. Variegata plants grown in sand + 10% loam + 10% chicken manure compost mixture with 150 ml of water/ plant significantly increased No. suckers and their length. Likewise, **Hoseini (2013)** on *Aloe vera*, noticed that amending the sand with 180 g of pigeon manure increased No. suckers in pot to maximum compared to either 90 or 270 g levels. **Nofal *et al.* (2014)** proposed to plant *Hymenocallis speciosa* plant in sand + compost (2: 1, v/v) mixture and irrigation with 50% of F.C. to achieve the highest bulbs productivity and quality. Furthermore, **Hazrati *et al.* (2017)** told that the highest No. suckers obtained from *Aloe vera* plant when irrigated with less water volume (40% of F.C.) and more zeolite application (8g Kg^{-1} soil).

Table (3): Effect of medium, water amount and their interactions on No. flowering stem, flowering stem length and No. offsets of *Gasteria carinata* var. verrucosa (Mill) van Jaarsv. plant during 2018 and 2019 seasons.

Water amount (ml/plant) / Medium	No. flowering stem/plant				Flowering stem length (cm)				No. offsets/plant			
	100	150	200	Mean	100	150	200	Mean	100	150	200	Mean
First season : 2018												
Sand (s)	2.00a	1.00b	1.00b	1.33a	75.13a	35.69	59.11b	56.64a	2.33c	1.06e	4.06a	2.48ab
S + L (2:1)	1.00b	0.00c	1.00b	0.67c	47.90c	0.00h	15.11f	21.00bc	1.55d	1.51d	2.40c	1.82ab
S + AC (3:1)	1.00b	1.00b	1.00b	1.00b	3.00g	24.73e	4.14g	10.62bc	1.37d	0.80f	2.07d	1.41bc
S + NC (.3:1)	1.00b	1.00b	1.00b	1.00b	27.14e	47.70c	4.70g	26.55b	3.03b	4.03a	1.06e	2.71a
S + L +AC (2: 1: 1)	1.00b	1.00b	0.00c	0.67c	53.27b	24.35	0.00h	25.87b	2.47c	1.73d	2.05d	2.08ab
S + L + NC (2: 1: 1)	1.00b	1.00b	0.00c	0.67c	34.40d	41.33c	0.00h	25.24b	2.35c	2.61c	1.16e	2.04ab
S + AC + NC (2: 1: 1)	1.00b	0.00c	0.00c	0.33d	2.23g	0.00h	0.00h	0.74d	1.24d	1.01e	1.14e	1.13c
Mean	1.14a	0.71b	0.57c		34.72a	24.83bc	11.88c		2.05a	1.82b	1.99a	
Second season: 2019												
Sand (s)	1.67a	1.00b	1.00b	1.22a	63.45a	33.40c	62.95a	53.26a	1.88d	075e	3.86a	2.16ab
S + L (2:1)	1.00b	0.00c	1.00b	0.67c	32.14c	0.00g	12.09e	12.09bc	1.46e	1.62de	2.93b	2.00ab
S + AC (3:1)	1.00b	1.00b	1.00b	1.00b	1.00g	13.53e	4.38f	6.30c	0.40f	0.64	2.35bc	1.13bc
S + NC (.3:1)	1.00b	1.00b	1.00b	1.00b	27.88d	48.78b	5.53f	27.40b	3.75a	2.46bc	1.20d	2.47a
S + L + AC (2: 1: 1)	1.00b	1.00b	0.00c	0.67c	57.51a	26.10d	0.00g	27.87b	2.68b	1.77d	2.29c	2.24ab
S + L + NC (2: 1: 1)	1.00b	1.00b	0.00c	0.67c	36.87c	25.44d	0.00g	20.77bc	2.45bc	2.83b	1.59d	2.29ab
S + AC + NC (2: 1: 1)	1.00b	0.00c	0.00c	0.33d	2.40f	0.00g	0.06g	0.82d	1.00e	0.74e	0.37f	0.70c
Mean	1.10a	0.71b	0.57c		31.60a	21.03ab	12.14c		1.95a	1.55b	2.09a	

-L: loam, Ac: animal compost and NC: Nile compost.

-Means followed by the same letter in a column or row are not differ significantly according to Duncan's New Multiple Rang t-Test at 5% level.

4. Chemical composition of the leaves:

Data listed in Table (5) exhibit that both sand + loam + Nile compost (2: 1: 1, v/v/v) and sand + animal compost + Nile compost (2: 1: 1, v/v/v) media increased chlorophyll a, b and carotenoids concentrations (mg/ g f.w.) to the highest values

relative to the means of other media, as well increasing irrigation water quantity to 200 ml/ plant attained the highest concentrations of the three previous pigments over 100 and 150 ml water levels. Therefore, combining between planting in the forenamed two media and any level of water treatments, especially 200 ml/ plant level increased such three pigments to the highest concentrations compared to the other combinations.

Regarding the percentages of N, P, and K, data in Table (5) show that they were significantly increased to maximum by raising in sand + Nile compost (3: 1, v/v) mixture, and followed by raising in sand + animal compost (3: 1, v/v) one. This may be due to improving fertility of the growing mixture by these two organic additives. On the other hand, effect of 100ml water treatment on elevating concentrations of the three previous nutrients surpassed that of the other two water treatments. Hence, interacting between planting in sand+ Nile compost (3: 1, v/v) medium and 100 ml/ plant water level acquired the utmost high N, P and K concentrations at all. Also, combined treatments of planting in sand + Nile compost (3: 1, v/v) + 200 ml water level and planting in sand + animal compost (3: 1, v/v) + 100 ml water level recorded N concentrations very close to that of the best combined treatment mentioned before.

A parallel trend was also reported by **Shahin *et al.* (2007)** on *Agave americana* cv. Marginata, **Hoseini (2013)** on *Aloe vera*, **Darini (2017)** on *Aloe vera* and **Hazrati *et al.* (2017)** who stated that never water stress (20% of F.C.) reduced leaf yield and growth of *Aloe vera* plants grown in sandy soil, but maximized proline, glucose and fructose content. However, zeolite application at 8g Kg^{-1} soil alleviates adverse effects of water deficit. Likewise, **Darini (2020)** noticed that fortified the sandy soil with 30t ha^{-1} of cow manure with humic urea significantly increased chlorophyll a and b content, N reducatase activity and proline content in *Aloe vera* leaves. Also, **Darini and Sulistyaningsih (2020)** proved that consolidated the sandy soil with 45t ha^{-1} of cow manure with KNO_3 or urea HA caused a significant increment in carbohydrates, proteins, fat, ash and fibers content in *Aloe vera* leaves. On *Dchna serrulata* bush, **Shahin and Sayed (2021)** observed that the highest concentrations of chlorophyll a, b, carotenoids and total sugars resulted from planting in sand + FYM compost (3: 1, v/v) mixture and irrigation once every 2 days.

Table (4): Effect of medium, water amount and their interactions on the new offset traits of *Gasteria carinata* var. verrucosa (Mill) van Jaarsv. plant during 2018 and 2019 seasons.

Water amount (ml/plant) / Medium	No. leaves/ offset				Offset F.W. (g)				Offset D.W. (g)			
	100	150	200	Mean	100	150	200	Mean	100	150	200	Mean
First season : 2018												
Sand (s)	4.88a	4.55ab	4.31ab	4.58a	18.50a	17.20b	16.19c	17.30a	5.67a	5.30ab	4.96b	5.31a
S + L (2:1)	3.90b	3.75bc	4.00b	3.88b	15.23de	14.65e	15.62d	15.17c	2.95d	2.83d	3.03cd	2.94d
S + AC (3:1)	3.33d	3.63c	3.50c	3.49d	10.03g	10.96f	10.54fg	10.51e	3.20cd	3.50c	3.44c	3.38cd
S + NC (.3:1)	3.65c	4.00b	4.10b	3.92c	14.25e	15.50d	15.98cd	15.24c	4.46b	4.53b	5.02ab	4.67b
S + L +AC (2: 1: 1)	3.96bc	4.00b	3.76c	3.91c	11.36f	11.50f	10.73f	11.20d	2.38e	2.41e	2.22e	2.34e
S + L + NC (2: 1: 1)	4.20b	4.00b	4.03b	4.08b	16.50c	15.67d	15.71d	15.96b	3.84c	3.63c	3.65c	3.71c
S + AC + NC (2: 1: 1)	3.33d	3.00d	3.20d	3.18e	10.81f	10.30fg	10.36fg	10.49e	3.50c	3.28cd	3.33c	3.37cd
Mean	3.89a	3.85a	3.84a		13.81a	13.68a	13.59a		3.71a	3.64a	3.66a	
Second season: 2019												
Sand (s)	5.00a	4.63b	4.50b	4.71a	18.97a	17.33b	16.99b	17.76a	5.82a	5.33b	5.16b	5.44a
S + L (2:1)	3.78c	3.67c	4.30b	3.92c	14.76c	14.33d	16.80b	15.30c	2.86d	2.78e	3.27d	2.97de
S + AC (3:1)	3.36cd	3.33cd	3.60c	3.43cd	10.11f	10.03f	10.93e	10.36e	3.21d	3.20d	3.50d	3.30d
S + NC (.3:1)	4.71ab	4.50b	3.80bc	4.34b	18.33ab	17.50b	15.00c	16.94b	5.53b	5.28b	4.39c	5.07b
S + L + AC (2: 1: 1)	3.78c	3.56c	4.00bc	3.78c	10.85e	10.23f	11.50e	10.86d	2.29ef	2.17f	2.45e	2.30e
S + L + NC (2: 1: 1)	4.75ab	4.76ab	4.10bc	4.54a	18.63a	18.36ab	16.50b	17.83a	4.36c	4.28c	3.79d	4.14c
S + AC + NC (2: 1: 1)	3.10cd	2.38d	2.76d	2.75d	10.06f	7.79h	9.00g	8.95f	3.25d	2.56e	2.95de	2.92d
Mean	4.07a	3.83b	3.87b		14.53a	13.65b	13.82b		3.90a	3.66b	3.64b	

-L: loam, Ac: animal compost and NC: Nile compost.

-Means followed by the same letter in a column or row are not differ significantly according to Duncan's New Multiple Rang t-Test at 5% level.

Table (5): Effect of medium, water amount and their interactions on chemical composition of *Gasteria carinata* var. verrucosa (Mill) van Jaarsv. leaves during 2019 season.

Water amount (ml/plant) / Medium	Chlorophyll a (mg/f.w.)				Chlorophyll b (mg/f.w)				Carotenoids (mg/f.w)			
	100	150	200	Mean	100	150	200	Mean	100	150	200	Mean
Sand (s)	0.600f	0.568g	0.603f	0.590e	0.402f	0.421f	0.432f	0.418e	0.504e	0.491e	0.535e	0.510e
S + L (2:1)	0.920e	0.931e	0.946e	0.932d	0.532e	0.501e	0.594e	0.542d	0.701d	0.687d	0.711d	0.700d
S + AC (3:1)	1.141d	1.200c	1.222bc	1.188c	1.142c	1.122c	1.165c	1.143b	1.015b	1.000b	1.037	1.017b
S + NC (.3:1)	1.212bc	1.215bc	1.241b	1.223b	1.050d	1.025d	1.069d	1.048c	0.946c	0.917cd	0.977c	0.947c
S + L +AC (2: 1: 1)	1.246b	1.220bc	1.280b	1.249b	1.130c	1.103cd	1.141c	1.125b	1.011b	1.009b	1.028ab	1.016b
S + L + NC (2: 1: 1)	1.401a	1.378ab	1.405a	1.395a	1.328a	1.311ab	1.356a	1.332a	1.134a	1.121ab	1.159a	1.138a
S + AC + NC (2: 1: 1)	1.362ab	1.357ab	1.388ab	1.369a	1.321a	1.298ab	1.357a	1.325a	1.140a	1.139a	1.153a	1.144a
Mean	1.126b	1.124b	1.155a		0.986b	0.969b	1.016a		0.922ab	0.909b	0.943a	
	N%				P%				K%			
Sand (s)	2.361b	1.870f	1.947e	2.059e	0.313e	0.187f	0.295e	1.195f	0.677c	0.552d	0.583d	1.103e
S + L (2:1)	2.340b	1.551g	2.248c	2.046e	0.655b	0.426d	0.537c	1.343d	0.600cd	0.610cd	0.707b	1.193d
S + AC (3:1)	2.543a	2.211c	2.348b	2.367b	0.633b	0.501c	0.622b	1.506b	0.760b	0.593d	0.675c	1.343b
S + NC (.3:1)	2.653a	2.356 b	2.582a	2.530a	0.751a	0.510c	0.680b	1.667a	0.877a	0.673c	0.711b	1.459a
S + L + AC (2: 1: 1)	2.320b	1.998e	2.243c	2.187d	0.615b	0.507c	0.560c	1.479c	0.685c	0.603cd	0.623cd	1.265c
S + L + NC (2: 1: 1)	2.113d	1.547g	1.790fg	1.817f	0.391de	0.251g	0.300e	1.173f	0.580d	0.407e	0.493e	0.987f
S + AC + NC (2: 1: 1)	2.412ab	2.177d	2.288c	2.292c	0.307e	0.287e	0.332e	1.257e	0.601cd	0.473e	0.537d	1.195d
Mean	2.392a	1.959c	2.207b		0.524a	0.381c	0.475b		0.683a	0.559c	0.619b	

-L: loam, Ac: animal compost and NC: Nile compost.

-Means followed by the same letter in a column or row are not differ significantly according to Duncan's New Multiple Rang t-Test at 5% level.

From the previous results, it can be advised to planting *Gasteria carinata* var. verrucosa in sand alone or sand amended with Nile compost (3: 1, by volume) and irrigating with only 100 ml of water/ plant to obtained good performance and floriferous pot plant.

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12/25/2021