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RESEARCH ARTICLE

EFFECT OF IRRIGATION METHODS AND PLANTING MEDIA ON HARDENING TIME OF BANANA PLANTLETS

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ABSTRACT

Experiment was conducted during January to April of 2022 and 2023 in plastic greenhouse. Plantlets of the released banana cultivar Grand Naine were produced in the Plant Tissue Culture Laboratory of Kassala and Gash Research Station. The experiment consisted of two factors, planting media and irrigation methods; each factor consisted of three types. The treatments were randomly laid out in a split-plot design with three replications. The results showed that the irrigation methods affected plant height, plant girth, number of leaves per plant, leaf length, leaf width, root length, root girth and number of roots per plant and the values were recorded under drip irrigation with silt. Therefore, the percentages of applied water saving by drip irrigation and sprayer irrigation were (80% and 84%) and (62.5% and 64%), for season one and two respectively, as compared to surface irrigation. Therefore, the economic evaluation indicated that using of drip irrigation with silt was the most stable and economically feasible treatment.

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INTRODUCTION

Banana is considered as one of the most important crops grown in the world and plays an important role in the economy of tropical and subtropical countries (Hassan *et al.*, 2021). On the other hands, water is one of the major constraints which significantly influence the quality and productivity of banana. Many earlier workers have reported that water deficit adversely affects the crop growth and yield (Mohmoud, 2006). Generally, in Sudan surface irrigation is the common irrigated method used in the open field and orchard which is characterized by low efficiency and larger losses of irrigation water. There is growing awareness now of the importance of introducing modern irrigation systems. Drip irrigation can apply water both precisely and uniformly at a high irrigation frequency compared with furrow and sprinkler irrigation (Hanson and May, 2007). Culture medium is an important factor for improving the growth parameters of the tissue cultured plantlets during acclimatization. In contrast, Parkhe *et al.* (2018) claimed that from different potting mixtures; garden soil, cocopeat, farm yard manure (FYM), vermicompost and sand with different combinations, 100 % hardening success was conducted to banana plantlets of cv. Grand Naine when garden soil and FYM (3:1) were used. Moreover, Ali *et al.* (2011) reported that application of potting mixture containing soil: sand: farm yard

manure (2:1:1 v/v/v) was superior treatment for increasing vegetative growth of banana plantlets. In addition, plum plantlets were successfully acclimatized in combination of peat moss and sand at the rate of 1:1 (Hassan *et al.*, 2021). Chamling *et al.* (2021) conducted experiment to study some of treatments having the secondary hardening media, he reported that the different hardening media used gave significant result with respect to the field survivability, vegetative growth parameter and development. Currently, due to the shortage of groundwater in Kassala, there is a need to evaluate different irrigation systems to identify the most efficient and profitable irrigation system and planting media for shorter time of hardening. Therefore, the objective of this study was to determine the best planting media and irrigation methods for growth of banana plantlets in greenhouse.

MATERIAL AND METHODS

The trail was established in plastic green house during January to April of 2022 and 2023. Plantlets were produced in the Plant Tissue Culture Laboratory of Kassala and Gash Research Station. It is located at latitude 15° 27' N, longitude 36° 21' E and altitude 505 masl. Plantlets of the released banana cultivar Grand Naine were used. The plantlets were raised in 18×20cm black polyethylene bags. The experiment consisted of two factors, planting media and irrigation methods; each factor consisted of three types. Three types of irrigation were used *viz*: surface irrigation, spraying and drip

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irrigation were arranged in the main plot. The media composed of three types (sand: silt 1:1; sand: silt 1:2 and silt) and arranged in the sub-plot. The nine treatments were randomly laid out in a split-plot design with three replications. The plant height (cm), plant girth (cm), number of leaves per plant, leaf length (cm) and leaf width (cm) were recorded at 6 and 12 weeks after planting. Root length (cm), root girth (cm), number of roots per plant and total amount of irrigation water applied (l/plant) were recorded at the end of experiment. Marginal rate of return was analyzed according to CIMMYT (1988) and used the field information and data collected for evaluation. Data was subjected to analysis of variance procedures. Treatment means were separated using Duncans Multiple Range Test at 5% level of significance.

RESULTS AND DISCUSSION

Effect of irrigation methods and planting media on plant height, plant girth and number of leaves per plant of banana plantlets: The irrigation treatments showed significant differences on plant height, plant girth and number of leaves per plant of banana plantlets on both seasons at 6 and 12 weeks after planting (Table 1 and 2). The highest values of plant height, plant girth and number of leaves per plant were recorded under drip irrigation followed by sprayer irrigation, while the lowest were obtained with surface irrigation on both seasons at 6 and 12 weeks after planting (Table 1 and 2).

Table 1. Effect of irrigation methods and planting media on plant height, plant girth and number of leaves per plant of banana plantlet after 6 weeks from planting

Treatments	Plant height (cm)		Plant girth (cm)		Number of leaves per plant	
	Season one	Season two	Season one	Season two	Season one	Season two
Surface irrigation W ₁	9.6c	8.4b	0.88c	0.77c	5.98c	6.77c
Drip irrigation W ₂	13.2a	10.5a	1.17a	0.98a	7.57a	8.48a
Sprayer irrigation W ₃	10.7b	9.1b	0.97b	0.88b	6.47b	7.84c
LSD	0.91	0.67	0.09	0.08	0.36	0.22
CV%	6.23	5.47	6.91	6.96	4.10	2.22
Significant level	***	**	**	***	***	***
Media (1silt:0 sand) M ₁	13.7a	11.2a	1.16a	1.04a	7.72a	8.76ab
Media (1silt:1 sand) M ₂	10.3b	8.7b	0.84c	0.84b	5.71c	6.91c
Media (2silt:1 sand) M ₃	9.5c	8.2b	1.00b	0.73c	6.58b	7.42b
LSD	0.63	0.51	0.10	0.07	0.29	0.19
W ₁ M ₁	12.1b	10.3b	1.0bc	0.87c	6.90cd	7.30de
W ₁ M ₂	7.7d	7.2c	0.70e	0.63c	5.03h	6.17g
W ₁ M ₃	9.5c	7.9c	0.93cd	0.80cd	6.0fg	6.83f
W ₂ M ₁	14.9a	11.9a	1.37a	1.20a	8.63a	9.77a
W ₂ M ₂	12.2b	9.5b	1.00bc	0.83cd	6.63de	7.60d
W ₂ M ₃	12.5b	10.0b	1.10b	0.90b	7.43bc	8.07c
W ₃ M ₁	14.1a	11.3a	1.10b	1.07de	7.53b	9.20b
W ₃ M ₂	8.7cd	7.8c	0.8de	0.73de	5.47gh	6.97ef
W ₃ M ₃	9.4c	8.2c	1.0bc	0.83cd	6.30ef	7.37d
LSD	1.27	0.98	0.15	0.13	0.54	0.34
CV%	5.50	5.34	9.29	8.24	4.18	2.36
Significant level	***	***	***	***	***	***

** and *** indicate significance at $P < 0.01$ and $P < 0.001$, respectively.

Table 2. Effect of irrigation methods and planting media on plant height, plant girth and number of leaves per plant of banana plantlet after 12 weeks from planting

Treatments	Plant height (cm)		Plant girth (cm)		Number of leaves per plant	
	Season one	Season two	Season one	Season two	Season one	Season two
Surface irrigation W ₁	16.3b	15.7b	1.7c	1.4b	7.5b	7.7b
Drip irrigation W ₂	21.3a	19.1a	2.2a	1.7a	9.7a	9.1a
Sprayer irrigation W ₃	15.6b	16.5b	1.9b	1.5b	8.1b	7.9b
LSD	0.53	0.97	0.09	0.13	0.92	0.93
CV%	2.28	4.36	3.64	6.29	8.31	8.57
Significant level	***	***	***	***	***	**
Media (1silt:0 sand) M ₁	21.7a	19.6a	2.3a	1.8a	9.9a	9.5a
Media (1silt:1 sand) M ₂	15.2c	15.3c	1.6c	1.4c	7.3c	7.2c
Media (2silt:1 sand) M ₃	16.1b	16.3b	1.8b	1.5b	8.1b	8.1b
LSD	0.28	0.61	0.15	0.11	0.73	0.75
W ₁ M ₁	19.5d	17.5cd	1.97cd	1.5c	9.1bc	9.0ab
W ₁ M ₂	15.5f	14.4f	1.40f	1.4cd	6.3e	6.6d
W ₁ M ₃	15.8e	15.0f	1.70de	1.3de	7.1de	7.7cd
W ₂ M ₁	24.2a	22.5a	2.60a	2.0a	10.7a	10.2a
W ₂ M ₂	20.3c	16.3de	1.80ce	1.5c	9.0bc	8.4bc
W ₂ M ₃	19.4d	18.4bc	2.10bc	1.7b	9.2bc	8.8bc
W ₃ M ₁	21.2b	18.9b	2.20b	1.8b	9.8ab	9.2ab
W ₃ M ₂	12.7g	15.0f	1.60e	1.2e	6.7de	6.6d
W ₃ M ₃	13.0fg	15.6ef	1.70de	1.5c	7.9cd	8.0bc
LSD	0.66	1.29	0.23	0.20	1.37	1.40
CV%	1.52	3.49	7.77	6.83	8.46	8.85
Significant level	***	***	***	***	***	***

** and *** indicate significance at $P < 0.01$ and $P < 0.001$, respectively.

This might be due to positive effect on soil moisture improvement and also sprayer may be created a microclimate that reduced canopy temperature. These results are in agreement with those of Khalifa (2012) who reported that the highest values of plant height, plant girth and number of leaves per plant of banana crops were recorded under the drip irrigation than the surface irrigation. In the interaction between irrigation methods and planting media, the results showed that there was highly significant difference on plant height, plant girth and number of leaves per plant of banana plantlets on both seasons at 6 and 12 weeks after planting (Table 1 and 2). The taller plant, thicker plant girth and higher number of leaves per plant were recorded under drip irrigation with (1silt:0sand) while the shorter plants, less plant stem diameter and a smaller number of leaves per plant were observed at (1silt:1 sand) under surface irrigation on both seasons at 6 and 12 weeks after planting (Table 1). These results are in agreement with those reported by Atif *et al.* (2008) who reported that mixture of silt + leaf manure + coconut compost (1:1:1) gave the highest values of growth parameter such as number of leaves per plant, plant height and number of side branches of Zinnia Elegans.

Moreover, Scaranari *et al* (2009) reported that when plantlets reach 20-30 cm height, they are considered acclimated and become available to the market.

Effect of irrigation methods and planting media on leaf length and leaf width of banana plantlets: Leaf length and leaf width were significantly affected by irrigation methods (Table 3 and 4). The maximum leaf length and leaf width of banana plantlets were recorded under drip irrigation followed by sprayer irrigation while, the lowest were recorded with surface irrigation at 6 and 12 weeks after planting in both seasons. These findings are in agreement with Khalifa (2022) who revealed that, higher growth parameters of tomato were produced under drip irrigation than the surface irrigation. Among the interaction between irrigation methods and planting media the highest values of leaf length and leaf width were recorded under drip irrigation with (1silt:0 sand) and it was significantly superior to all other treatments and lowest values were recorded under surface irrigation (1silt:1 sand) in both seasons at 6 and 12 weeks after planting (Table 3 and 4).

Table 3. Effect of irrigation methods and planting media on leaf length and leaf width of banana plantlet after 6 weeks from planting

Treatments	Leaf length (cm)		Leaf width (cm)	
	Season one	Season two	Season one	Season two
Surface irrigation W ₁	12.6c	11.1c	6.1c	5.8b
Drip irrigation W ₂	17.5a	15.8a	8.8a	7.9a
Sprayer irrigation W ₃	14.5b	12.7b	7.1b	6.5b
LSD	1.48	0.89	0.37	0.79
CV%	7.60	5.13	3.81	8.98
Significant level	***	***	***	***
Media (1silt:0 sand) M ₁	17.7a	15.6a	8.7a	7.7a
Media (1silt:1 sand) M ₂	13.9b	11.4c	6.2c	6.0b
Media (2silt:1 sand) M ₃	13.1b	12.6b	7.1b	6.4b
LSD	1.31	0.69	0.27	0.63
W ₁ M ₁	15.5bc	13.1c	7.83c	6.4cd
W ₁ M ₂	11.1e	9.2f	5.13e	5.4d
W ₁ M ₃	11.4e	11.0de	5.47e	5.7d
W ₂ M ₁	19.9a	17.7a	9.53a	8.5a
W ₂ M ₂	16.2b	14.9b	8.07c	7.2bc
W ₂ M ₃	16.5b	14.9b	8.90b	7.8ab
W ₃ M ₁	17.7ab	16.1b	8.86b	8.3ab
W ₃ M ₂	11.9de	10.2ef	5.53e	5.5d
W ₃ M ₃	13.8ed	11.8d	7.00d	5.8d
LSD	2.36	1.31	0.52	1.18
CV%	8.58	5.08	3.54	9.04
Significant level	***	***	***	***

***indicate significance at $P < 0.001$.

Table 4. Effect of irrigation methods and planting media on leaf length and leaf width of banana plantlet after 12 weeks from planting

Treatments	Leaf length (cm)		Leaf width (cm)	
	Season one	Season two	Season one	Season two
Surface irrigation W ₁	16.3c	19.9b	9.4c	8.8b
Drip irrigation W ₂	25.1a	24.4a	12.5a	10.7a
Sprayer irrigation W ₃	21.3b	20.6b	10.4b	9.1b
LSD	1.93	1.32	0.65	0.57
CV%	6.74	4.65	4.56	4.60
Significant level	***	***	***	***
Media (1silt:0 sand) M ₁	25.8a	24.9a	12.8a	11.4a
Media (1silt:1 sand) M ₂	19.3b	19.6b	10.2b	8.3c
Media (2silt:1 sand) M ₃	20.7b	20.4b	9.4b	8.9b
LSD	1.94	1.51	0.98	0.49
W ₁ M ₁	22.1cd	23.3b	11.3c	10.3b
W ₁ M ₂	17.2e	17.8c	8.0e	7.6f
W ₁ M ₃	18.5e	15.7c	9.0de	8.0ef
W ₂ M ₁	28.2a	26.5a	13.9a	12.9a
W ₂ M ₂	22.6b	22.8b	11.6bc	9.2cd
W ₂ M ₃	24.4bc	23.8b	12.1bc	10.0bc
W ₃ M ₁	27.0ab	24.8ab	13.9ab	10.7b
W ₃ M ₂	18.0e	18.2c	8.6de	8.0ef
W ₃ M ₃	19.0de	18.9c	9.6d	8.7de
LSD	3.34	2.50	1.53	0.89
CV%	8.64	4.96	8.86	4.86
Significant level	***	***	***	***

***indicate significance at $P < 0.001$.

This might be due to less nutrient losses through leaching and favorable soil moisture. This result corroborated the findings of Ritu *et al.* (2010) who found that the soil types also differed significantly in growth parameters of Terminalia arjuna.

Effect of irrigation methods and planting media on roots length, root girth and number of roots per plants of banana plantlets: The results showed that all treatments differences were highly significant in roots length, root girth and number of roots per plants of banana plantlets for both seasons at 6 and 12 weeks after planting (Table 5 and 6). The highest values of roots length, root girth and number of roots per plants were observed under drip irrigation which was closely followed by sprayer irrigation system while, the lowest values were observed in surface irrigation system on both seasons 6 and 12 weeks after planting (Table 5 and 6). This may be due to the availability of water near the root zone that improved the roots growth.

Drip irrigation system with (1silt:0s and) recorded higher roots length, root girth and number of roots per plants among treatments at 6 and 12 weeks after planting in both seasons (Table 5 and 6). This may be justification because silt media reduces water loss through evaporation and leaching. Similar results were reported by Ritu *et al.* (2010) who observed that root biomass in control condition was higher than in other two types of soil ratios for 80:20 (Sand: Normal Soil) and 40:60 (Sand: Normal Soil) of Terminalia arjuna.

Effect of irrigation methods and planting media on total water applied of banana plantlets: The total water applied to banana plantlets were 180 and 200l/plantlet, 36 and 31.5l/plantlet and 67.5 and 72l/plantlet, under surface irrigation, drip irrigation and sprayer irrigation for season one and two, respectively (Fig. 1). The percentages of the applied water saved were (80% and 84%) and (62.5% and 64%) for drip irrigation and spryer irrigation, respectively compared to surface irrigation for season one and two (Fig. 2).

Table 5. Effect of irrigation methods and planting media on roots length, root girth and number of roots per plants of banana plantlet after 6 weeks from planting

Treatments	Root length (cm)		Root girth (cm)		Number of roots per plant	
	Season one	Season two	Season one	Season two	Season one	Season two
Surface irrigation W ₁	17.0c	16.5c	0.32c	0.35c	12.5c	11.6c
Drip irrigation W ₂	23.8a	22.5a	0.50a	0.52a	16.0a	15.6a
Sprayer irrigation W ₃	19.8b	19.4b	0.39b	0.41b	13.8b	13.9b
LSD	1.41	1.04	0.04	0.01	0.23	0.47
CV%	4.09	5.32	7.13	1.84	1.25	2.61
Significant level	***	***	***	***	***	***
Media (1silt:0 sand) M ₁	24.4a	23.2a	0.55a	0.58a	16.8a	16.4a
Media (1silt:1 sand) M ₂	17.1c	16.3c	0.30c	0.30c	11.9c	11.7c
Media (2silt:1 sand) M ₃	19.0b	18.9b	0.36b	0.40b	13.5b	13.0b
LSD	0.80	0.45	0.02	0.01	0.30	0.39
W ₁ M ₁	19.2c	18.4c	0.44c	0.51d	15.3d	14.3c
W ₁ M ₂	15.6f	15.3e	0.25f	0.23g	10.3h	9.8h
W ₁ M ₃	16.3ef	15.9e	0.27ef	0.30f	11.8g	10.7g
W ₂ M ₁	29.3a	26.0a	0.67a	0.65a	18.3a	17.6a
W ₂ M ₂	18.7cd	17.3cd	0.35d	0.37e	13.5e	13.6d
W ₂ M ₃	23.3b	24.2b	0.47c	0.54c	16.2e	15.5b
W ₃ M ₁	24.8b	25.3ab	0.55b	0.57b	16.8b	17.2a
W ₃ M ₂	17.1def	16.3de	0.29e	0.31f	12.0fg	11.7f
W ₃ M ₃	17.5cde	16.5de	0.33d	0.35e	12.5f	12.8e
LSD	1.49	1.21	0.04	0.02	0.48	0.71
CV%	2.23	3.87	3.99	2.73	2.10	2.75
Significant level	***	***	***	***	***	***

***indicate significance at $P < 0.001$

Table 6. Effect of irrigation methods and planting media on roots length, root girth and number of roots per plants of banana plantlet after 12 weeks from planting

Treatments	Plant height (cm)		Plant girth (cm)		Number of leaves per plant	
	Season one	Season two	Season one	Season two	Season one	Season two
Surface irrigation W ₁	16.3b	15.7b	1.7c	1.4b	7.5b	7.7b
Drip irrigation W ₂	21.3a	19.1a	2.2a	1.7a	9.7a	9.1a
Sprayer irrigation W ₃	15.6b	16.5b	1.9b	1.5b	8.1b	7.9b
LSD	0.53	0.97	0.09	0.13	0.92	0.93
CV%	2.28	4.36	3.64	6.29	8.31	8.57
Significant level	***	***	***	***	***	**
Media (1silt:0 sand) M ₁	21.7a	19.6a	2.3a	1.8a	9.9a	9.5a
Media (1silt:1 sand) M ₂	15.2c	15.3c	1.6c	1.4c	7.3c	7.2c
Media (2silt:1 sand) M ₃	16.1b	16.3b	1.8b	1.5b	8.1b	8.1b
LSD	0.28	0.61	0.15	0.11	0.73	0.75
W ₁ M ₁	19.5d	17.5cd	1.97cd	1.5c	9.1bc	9.0ab
W ₁ M ₂	15.5f	14.4f	1.40f	1.4cd	6.3e	6.6d
W ₁ M ₃	15.8e	15.0f	1.70de	1.3de	7.1de	7.7cd
W ₂ M ₁	24.2a	22.5a	2.60a	2.0a	10.7a	10.2a
W ₂ M ₂	20.3c	16.3de	1.80ce	1.5c	9.0bc	8.4bc
W ₂ M ₃	19.4d	18.4bc	2.10bc	1.7b	9.2bc	8.8bc
W ₃ M ₁	21.2b	18.9b	2.20b	1.8b	9.8ab	9.2ab
W ₃ M ₂	12.7g	15.0f	1.60e	1.2e	6.7de	6.6d
W ₃ M ₃	13.0fg	15.6ef	1.70de	1.5c	7.9cd	8.0bc
LSD	0.66	1.29	0.23	0.20	1.37	1.40
CV%	1.52	3.49	7.77	6.83	8.46	8.85
Significant level	***	***	***	***	***	***

** and *** indicate significance at $P < 0.01$ and $P < 0.001$, respectively.

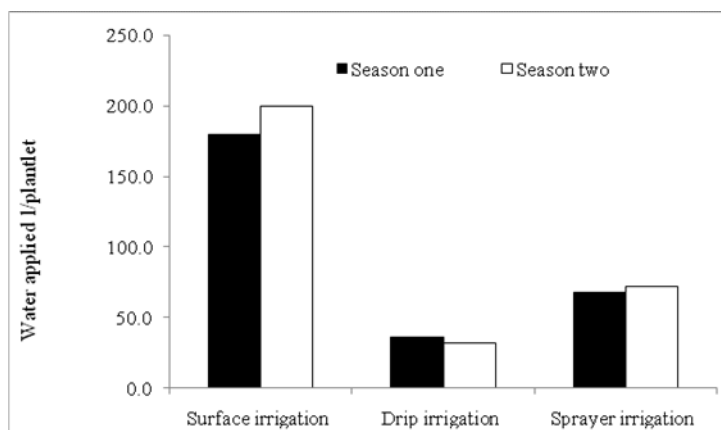


Figure 1. Effect of irrigation methods and planting media on total water applied of banana plantlets

Table 7. Effect of irrigation methods and planting media on economic analysis of banana plantlets

No	Treatments	Cost of media SDG/1000 plantlets	Cost of irrigation SDG/1000 plantlets	Cost of waterman SDG/1000 plantlets	Total Cost SDG/ 1000 plantlets
	Surface +(1silt:0 sand)	15000	2000	10000	27000
	Surface +(1silt:1 sand)	12500	2000	10000	24500
	Surface +(2silt:1 sand)	10000	2000	10000	22000
	Drip +(1silt:0 sand)	15000	16000	5000	36000
	Drip +(1silt:1 sand)	12500	16000	5000	33500
	Drip +(2silt:1 sand)	10000	16000	5000	31000
	Sprayer +(1silt:0 sand)	15000	5000	15000	35000
	Sprayer +(1silt:1 sand)	12500	5000	15000	32500
	Sprayer +(2silt:1 sand)	10000	5000	15000	30000

The one plantlets price depends on plant height (20-25 cm =750 SDG) and less than 20 cm =500 SDG.

Table 8. Partial and dominance analysis for banana plant lets produced in Kassala

Treatments	Plant height (cm)	Price SDG/ plantlets	Gross retrain SDG/1000 plantlets	Total Cost SDG/ 1000 plantlets	Net retrain SDG/1000 plantlets	Dominated
Surface +(2silt:1 sand)	15	400	400000	22000	378000	
Surface +(1silt:1 sand)	15	400	400000	24500	375500	D
Surface +(1silt:0 sand)	19	500	500000	27000	473000	
Sprayer +(2silt:1 sand)	16	500	500000	30000	470000	D
Drip +(2silt:1 sand)	19	500	500000	31000	469000	D
Sprayer +(1silt:1 sand)	14	400	400000	32500	367500	D
Drip +(1silt:1 sand)	18	500	500000	33500	466500	D
Sprayer +(1silt:0 sand)	20	750	750000	35000	715000	
Drip +(1silt:0 sand)	23	800	800000	36000	764000	

These results are in agreement with those reported by Mohammad *et al.* (2010) who found that drip and sprinkler irrigation methods were more effective and efficient than surface irrigation. Khalifa *et al.* (2013) found that drip irrigation system saved irrigation water of banana by 74% and 72% for the mother crop and first ratoon, respectively, compared to surface irrigation.

Economic evaluation: Results showed treatment of drip + (1silt:0 sand) had significantly resulted in the highest net return. This result indicates the profitability and superiority of these treatments for producing banana plantlets in Kassala (Tables 6 and 7). Therefore, the economic evaluation based on partial budget and dominance analysis indicated that using of drip irrigation+ (1silt:0 sand) was the most stable and economically feasible treatment.

CONCLUSION

The highest growth parameters, roots length, root girth and number of roots per plants of banana plantlets were obtained with planting media of (1silt: 0s and) under drip irrigation.

Recommendation: Base in the results and economic analysis planting media of (1silt: 0sand) under drip irrigation is recommended for banana plantlets.

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