Nile Valley University Publications
Nile Journal for Agricultural Sciences (NJAS)
(ISSN: 1585 – 5507)
Volume 10, NO. 02, 2025
nilevalley.edu.sd

Impact of Drip irrigation Regimes and Surface Irrigation on the Yield and Water Productivity of Garlic (*Allium sativum* L.) in Khartoum State, Sudan

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Received : 29. Jun. 2025 Accepted :29. Sep. 2025 Published : 23. Nov. 2025

Abstract

Irrigation water management practices are the main strategies for improving water productivity. The objective of this study was to investigate the effect of drip irrigation systems with three irrigation levels of total water requirement (100%, 75%, and 50%) on the water productivity of two varieties of garlic (V1 Baladi and V2 Egyptian) compared with furrow irrigation (control). The treatments are two irrigation type furrow irrigation (C) and 3 level of drip irrigation system (D1 100, D2 75and D350). The field experiment was arranged in a split plot design with three replicates. The results showed that taller plant and the highest number of leaves were recorded with drip irrigation of 100% ETc for both seasons compared to other treatments. Higher yields were produced with 100% ETc under drip irrigation, while the lowest yields were recorded with 50%ETc and surface irrigation in both seasons. Moreover, the highest values of water productivity and economic water productivity were obtained under 50% ETc. Drip irrigation with 100% ETc was the most economic and had a higher net benefit.

Keywords: *drip irrigation, water requirement, Crop evapotranspiration, water productivity and economic water productivity.*

أثر مستويات الري بالتنقيط والري السطحي على الانتاجية و انتاجية الماء في الثوم تحت ظروف في ولاية الخرطوم، السودان

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المستخلص

ممارسات إدارة مياه الري هي من الاستراتيجيات الرئيسية لتحسين إنتاجية المياه. الهدف من هذه الدراسة هو الحصول على تأثير نظام الري بالتنقيط بثلاثة مستويات للري من إجمالي الاحتياجات المائية (50 %,75%,100%) على إنتاجية المياه لصنفين من الثوم (V1 بلدي و V2 مصري) مقارنة مع الري السطحي (Control). المعاملات عبارة عن نوعين من الري، السطحي بالسرب (C) و 3 مستويات من نظام الري بالتنقيط ($D_1$100% ، D_2 75% ، $D_3$50%). تم ترتيب التجربة الحقلية في تصميم القطع المنقسمة بثلاث مكررات. أظهرت النتائج أن أكبر طول نبات وأكبر عدد من الأوراق تم الحصول عليه مع الري بالتنقيط بنسبة ET_c 100% لكلا الموسمين مقارنة بالمعاملات الأخرى. اعلي انتاجية تم الحصول عليها في 100% ET_cتحت الري بالتنقيط بينما سجلت أقل انتاجية في ET_c 50% تحت الري السطحي في كلا الموسمين. علاوة على ذلك، تم الحصول على أعلى قيم إنتاجية المياه والإنتاجية الاقتصادية للمياه تحت ET_c 50%. كان الري بالتنقيط بنسبة ET_c 100%هو الأكثر اقتصادا وكان له فائدة صافية أعلى.

الكلمات المفتاحية : *الري بالتنقيط ، الاحتياجات المائية ، نتح بخر المحصول ، انتاجية المياة والانتاجية الاقتصادية للمياة .*

Introduction

Garlic (*Allium sativum L.*) is the second most vital cultivated *Allium* species after onion worldwide regarding its production and economic value. It is used as a seasoning in many foods worldwide (Ministry of Agriculture, River Nile State, 2018). There are several varieties grown in Sudan such as: Baladi varieties (Selim, Al-Hasa, and Zalingei) characterized by small bulbs and strong flavor, the Chinese variety, distinguished by lobes with large size, a white peel interspersed with a pink color, and the imported varieties (Egyptian, Syrian, Turkish and Ethiopian) characterized by large lobes and proven successful, especially the Ethiopian variety, which is grown in the Berber region of River Nile State (Ministry of Agriculture, River Nile State, 2018). The production ranges between (4.8–9.5) t ha^{-1}, depending on the variety grown (Ministry of Agriculture, Khartoum State 2018).

Irrigation water management refers to polices to conserve water supplies, reduce impact on water quality and improve the net economic returns of crops by applying less water than the crop required (deficit irrigation), shifting to alternative crops or high yield varieties of the same crop that use less water, or adopting more efficient irrigation technologies (Patil *et al*., 2015). The water efficient use at the field level will lead to saving water and improving the quantity and quality of crop production as mentioned by Panigrahi, *et al.* (2012).

Drip irrigation may help to achieve water conservation by reducing evaporation and deep percolation when compared to other types of irrigation such as surface irrigation or overhead sprinklers because water can be more precisely applied to the plant roots. A drip irrigation system ensures higher water use efficiency (Ghaemi and Sadri, 2012). Agriculture is the largest water consumer, but overall irrigation efficiency in the case of surface irrigation at the farmers, fields is very low or insufficient (Tshenyego, *et al*., 2017). This water scarcity is a major problem in many areas of the world; in this case, studying alternative mechanisms to solve this problem is essential (Soomro, *et al*., 2022). Drip irrigation reduces evaporation from the soil surface, minimizes runoff and deep percolation, and enables even application of water in fields, consequently increasing irrigation efficiency (Chomsang, *et al*., 2021).

Increasing the irrigation level from 60% to 100% of ET_c significantly increased plant height, leaf number and pod production in bean varieties (Hegab, *et al*., (2014). Mandefro and Quraishi (2015) found that using a drip system and applying a 100% ET_c regime improved the growth parameters, yield and yield contributing parameters of garlic and has more efficiency than surface irrigation. The application of the drip irrigation system produced the highest WUE water-use efficiency with an average of 5.2 kg m^{-3}, while the obtained WUE under the furrow system averaged 2.7 kg m^3, and the water saved by the drip relative to the furrow system was about 44% to 55%. In this direction, Ghadami *et al.,* (2010) and Gyanendra *et al.,* (2016) reported that the drip irrigation system has a significant influence on garlic productivity. The garlic vegetative growth and water use efficiency values were the highest under 75% of the pan evaporation treatment and declined with increasing irrigation amounts to 100 and 125% of the pan evaporation. Abd El-Hady and Ebtisam (2016) reported that a drip irrigation system has a recognized impact on increasing growth characteristics, garlic yield, and water productivity. Therefore, the objective of this study was to examine the effects of a drip irrigation system on the water productivity and yield of garlic in Khartoum state, Sudan.

Materials and methods

The field experiment was conducted during the two consecutive seasons 2019/20 and 2020/21 at a private field located in the west Omdurman area of Khartoum State, 36 km west of Omdurman (latitude 15° 63´ N and longitude 32° 53´ E). The area lies in the arid and semi-arid zones with low relative humidity; annual rainfall is less than 100 mm and the maximum temperature in summer 45^{0}C. The topography of the experimental site was uniform and leveled and the soil was sandy loam soil texture with more than 100 cm depth. Drip irrigation was installed in the experimental area with the main line 90mm PVC pipe, sub-main line 63mm PVC pipe, lateral length 30 m, 0.3 m distance between drippers (built in drippers), at a discharge rate of 4 L h^{-1}, 1 m between laterals.

Two irrigation systems were used: a drip irrigation system with three irrigation water regimes namely: 100% ET_c, 75% ET_c and 50 ET_c as treatments and conventional irrigation (furrow). These treatments were arranged in a split plot design with three replicates.

Meteorological data (maximum and minimum air temperature, relative humidity, sunshine duration and wind speed at 2-meter height) were taken from the Khartoum Meteorological Station and used to compute the reference evapotranspiration (ET_o) according to (Allen *et al*. 1998).

Crop evapotranspiration (ET_c) was calculated using the following formula:

$$\mathrm{ET_c} = \mathrm{ET_0} \times \mathrm{Kc} \ldots\ldots (1)$$

Where:

ET_c=Crop evapotranspiration (mm/day), K_c=Crop coefficient (dimensionless)

ET_0 =reference evapotranspiration (mm/day).

The standard $K_c$of for every growth stage (initial, mid, and end) for garlic was taken from the FAO 56 (Table 1) and adjusted to local information using the following equation according to Allen et *al*. (1998):

$$\mathrm{K_{ci}} = \mathrm{K_{c\,prev}} + \left[\frac{\mathrm{i}-\sum(\mathrm{L_{prev}}}{\mathrm{L_{stage}}}\right](\mathrm{K_{c\,next}} - \mathrm{K_{c\,prev}})\ldots\ldots\ldots (2)$$

where:

i =day number within the growing season, $K_{c\,i}$ =crop coefficient on day I, L_{stage} =length of the stage under consideration [days] and $\sum(L_{prev})$ =sum of the lengths of all previous stages [days].

Table 1. Garlic crop coefficient.

Crop	$K_c$ini	K_c mid	K_c end
Garlic	0.70	1.00	0.70

Source: (Allen, *et al*., 1998)

The volume of water to be applied was calculated according to Bagali et *al*. (2012) using the following equation:

Quantity of water to be applied (liters) = ET_c (cm) × area (ha) × 100000 …… (3)

The irrigation water was added to each treatment in the morning and the time of irrigation was calculated using the following equation:

$$\text{Irrigation time (hr/day)} = \frac{\text{Water requirement (l/day)}}{\text{Application rate (l/hr)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Water productivity (WP) was calculated as the ratio of the crop yield to the seasonal irrigation water applied using the following formula.

$$WP\ (kg/m^3) = \frac{\text{Yield (kg /ha)}}{\text{Total water applied } (m^3/ha)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Economic water productivity (EWP) was calculated as the gross income in Sudanese Pounds (SDG) per gross water supplied in m^3 using the following equation:

$$EWP = GI/GIWR \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where:

GI is the gross income from the sale of garlic (SDG/ha) and GIWR is the gross irrigation water applied (m^3/ha).

The measured parameters in each sub-plot to determine the number of leaves, plant height and total yield (t/ha).

Economic indicators such as the partial budget and benefit cost ratio were used to evaluate and compare the profitability of the tested factors as described by (CIMMYT, 1988). Total income was calculated by multiplying the crop yield (t/ha) by the crop value, (The price was set in May 2021, according to the Omdurman market, and was converted to US dollars)

The data were analyzed according to the standard statistical procedure using STATISTICS 10. The mean separation for the different parameters was computed using least significant difference (LSD) at ($p \leq 0.05$) .

Results and discussion

Effect of drip irrigation regimes and surface irrigation on plant height and number of garlic leaves

There was no significant difference in plant height, but there was a highly significant difference in the number of leaves of garlic at ($p \leq 0.05$). The taller plants and the highest number of leaves were observed under 100% ET_c with drip irrigation for both seasons compared with the other treatments (Table 1). For the interaction between irrigation and varieties, the results showed that there was a significant difference in plant height in both seasons, but the higher plants were recorded with 100% ET_c under drip irrigation (Table 1), this may be due to the fact that the crop has obtained its actual water needs. In the number of leaves, there was a significant difference in both seasons. The highest number of leaves per plant was recorded in 100% ET_c under drip irrigation, while the lowest number of leaves was recorded in 75% ET_c and surface irrigation in both seasons. This result corroborated the findings of Sankar, *et al*. (2008) who found that drip irrigation at 100% ETc recorded the highest plant height and number of leaves compared to surface and sprinkler irrigation of garlic. Moreover, Khalifa et *al*. (2022) reported that taller plants and higher numbers of leaves of tomato were recorded under drip irrigation compared with surface irrigation.

Table 1. Effect of drip irrigation regimes and surface irrigation on the plant height and number of garlic leaves during two consecutive winter seasons, 2019/2020 and 2020/2021.

Treatments	Plant height (cm)		No. of leaves	
	2019/20	20/2021	2019/20	20/2021
Surface irrigation (D_1)	48.6	49.9	6.9	6.7
Drip irrigation with 100% of ET_c (D_2)	60.5	62.6	9.1	10.0
Drip irrigation with 75% of ET_c (D_3)	59.1	60.4	8.4	8.9
Drip irrigation with 50% of ET_c (D_4)	52.4	53.4	7.2	7.1
LSD	0.99	2.47	0.39	0.49
CV%	0.93	2.24	4.52	3.09
Baladi variety (V_1)	55.0	55.7	7.9	8.3
Egyptian variety (V_2)	55.3	55.7	7.9	8.0
LSD	1.50	2.17	0.29	0.19
D_1V_1	47.7	47.2	6.9	6.5
D_1V_2	49.5	52.6	6.9	6.9
D_2V_1	60.7	62.1	8.8	9.9
D_2V_2	60.3	63.1	9.4	10.0
D_3V_1	59.3	60.1	8.4	9.4
D_3V_2	59.0	60.0	8.1	8.2
D_4V_1	52.4	52.6	7.3	7.2
D_4V_2	52.4	52.6	7.1	7.0
LSD	2.38	3.92	0.55	0.55
CV%	3.06	4.32	4.05	2.66

Effect of drip irrigation regimes and surface irrigation on the total yield of garlic

Yield was significantly affected by irrigation, and the maximum yield of garlic was recorded with 100% ET_c under drip irrigation, while the lowest yield was recorded with 50% ET_c and surface irrigation in both seasons (Table 2). Among the interactions between irrigation methods and varieties, the highest yield was recorded with 100% ET_c under drip irrigation and the lowest yield was recorded under surface irrigation in both seasons (Table 2). This confirms the earlier findings of Khalifa et *al*. (2022), who found that the highest yield components and quality of tomato were recorded with 100% ETc under drip irrigation, while the lowest were recorded with 75% ETc and surface irrigation in both seasons. On the other hand, Sankar et *al*. (2008) reported that the highest yield of garlic was obtained with drip irrigation at 100% compared to surface irrigation.

Table 2. Effect of drip irrigation regimes and surface irrigation on the yield of garlic leaves during two consecutive winter seasons, 2019/2020 and 2020/2021.

Treatments	Yield (t/ha)	
	2019/20	20/2021
Surface irrigation (D_1)	4.6	4.5
Drip irrigation with 100% of ET_c (D_2)	7.8	7.9
Drip irrigation with 75% of ET_c (D_3)	7.1	7.1
Drip irrigation with 50% of ET_c (D_4)	5.3	5.3
LSD	0.26	0.26
CV%	2.18	2.17
Baladi variety (V_1)	6.2	6.3
Egyptian variety (V_2)	6.2	6.1
LSD	0.11	0.14
D_1V_1	4.5	4.5
D_1V_2	4.7	4.6
D_2V_1	7.9	7.9
D_2V_2	7.7	7.8
D_3V_1	7.2	7.3
D_3V_2	7.0	6.9
D_4V_1	5.5	5.4
D_4V_2	5.1	5.2
LSD	0.30	0.32
CV%	2.07	2.63

D= Drip irrigation system, V = Varity

Effect of drip irrigation regimes and surface irrigation on the total water applied of garlic

The total water applied to garlic through drip irrigation regimes were 8,620 m3/ha, 12,640 m3/ha, 6,465 m3/ha, 9,480 m3/ha, 4,310 m3/ha, and 6,320 m3/ha at 100% ETc, 75% ETc, and 50% ETc for the seasons 2019/20 and 2020/2021, respectively, while Surface irrigation were 20,230 m3/ha and 22,370 m3/ha at 100% ETc, for the seasons 2019/20 and 2020/2021, respectively. From the above results, it is noted that drip irrigation saving 50% of irrigation water at 100% ETc. Similar results of saving irrigation water by the drip irrigation system were reported by Khalifa, *et al*. (2013) who found that the micro sprinkler irrigation system saved water by about 119% and 101% for two seasons, respectively, as compared to the surface irrigation. Sankar, *et al*. (2008) indicated that the drip irrigation saved applied water by 38% compared to the surface method of irrigation on garlic.

Effect of drip irrigation regimes and surface irrigation on the water productivity of garlic

The highest values of water productivity and economic water productivity were recorded under drip irrigation with 50% ET_c while, the lowest values were recorded under surface irrigation for seasons 2019/2020 and 2020/2021, respectively (Figure 1 and 2). These results are in agreement with those reported by Abd El-Latif and Abdelshafy (2017) who reported that water use efficiency and water productivity values were higher under the drip system than the surface system in the two respective seasons of garlic.

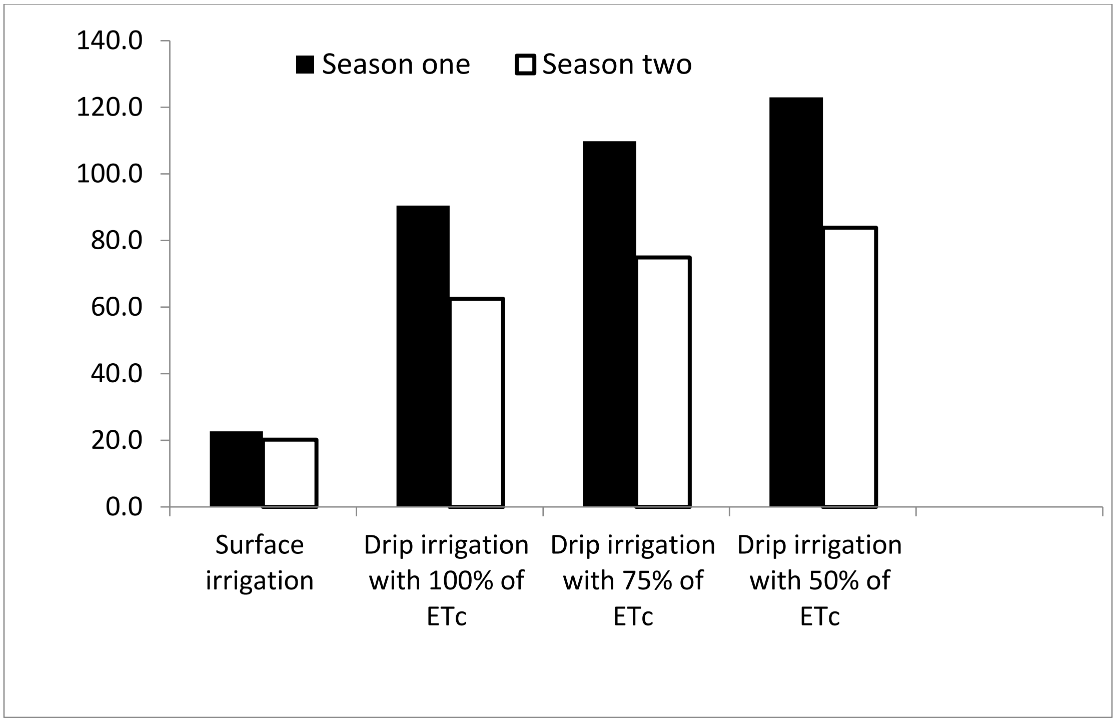

Figure 1. Effect of drip irrigation regimes and surface irrigation on the water productivity of garlic during two consecutive winter seasons, 2019/2020 and 2020/2021.

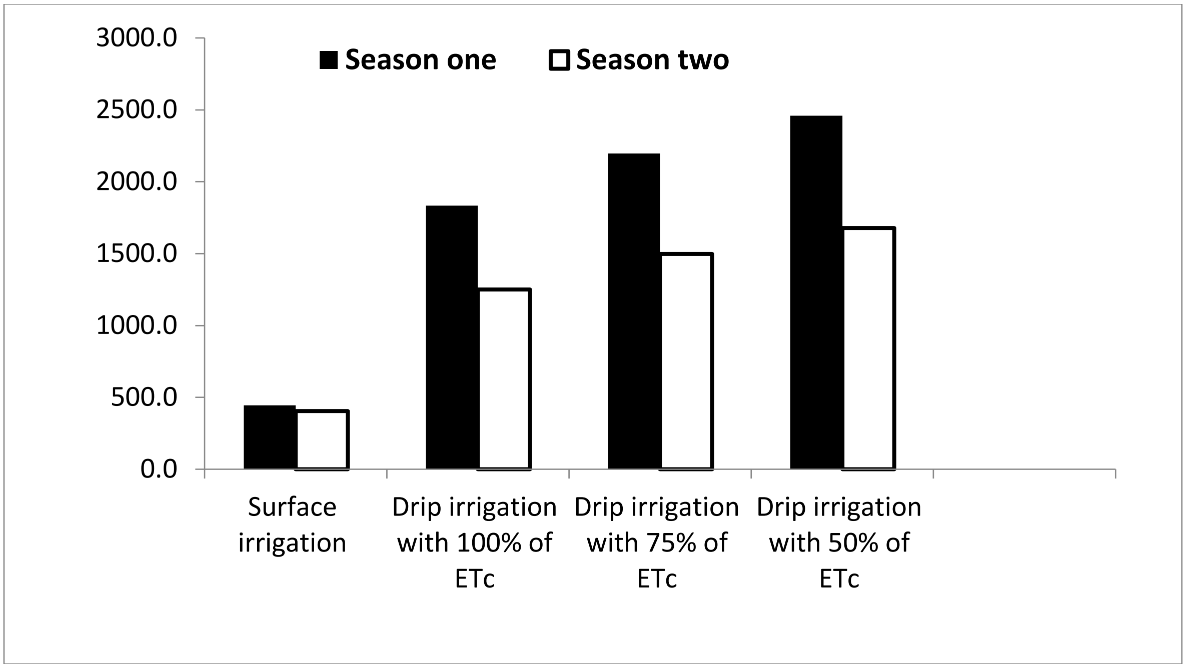

Figure 2. Effect of drip irrigation regimes and surface irrigation on the economic water productivity of garlic during two consecutive winter seasons, 2019/2020 and 2020/2021.

Effect of drip irrigation regimes and surface irrigation on the economic analysis of garlic

The variable costs of the drip irrigation regimes and surface irrigation for garlic are shown in Table 3. The benefit-cost ratio showed that drip irrigation with 100% of ET_c had a higher benefit-cost ratio compared to other treatments (Table 4). The benefit-cost ratio was higher under the drip irrigation regimes compared to surface irrigation (Table 4). These results are in agreement with those reported by Khalifa *et al*. (2014) who found that the benefit-cost ratio was obtained in drip irrigation and the lowest was obtained in surface irrigation.

Table 3. Variable cost of drip irrigation regimes and surface irrigation of garlic during two consecutive winter seasons, 2019/2020 and 2020/2021.

No	Particulars	Treatments			
		Drip irrigation regimes			Surface irrigation
		100% ET_c	75% ET_c	50% f ET_c	
1	Variable cost (SDG/ha)				
	a. Irrigation system	150000	150000	150000	0
	Irrigation staff	200000	200000	200000	500000
	b. Fertilizer application	0	0	0	30000
	c. Canal maintenance	0	0	0	30000
	d. Power (SDG/ha)	21600	16200	10800	57600
	Land preparation	1500	1500	1500	3600
	Hand labor	1056	1056	1056	1800
2	Total cost (SDG/ha)	374156	368756	363356	623000

Table 4. Benefit cost ratio of drip irrigation regimes and surface irrigation of garlic during two consecutive winter seasons, 2019/2020 and 2020/2021.

Treatments	Total Cost (SDG)	Yield (t/ha)	Total income (SDG/ ha)	Net return (SDG/ha)	Benefit cost ratio
Surface irrigation	623000	4.6	920000	297000	0.48
Drip irrigation with 100% of ET_c	374156	7.9	1580000	1205844	3.22
Drip irrigation with 75% of ET_c	368756	7.1	1420000	1051244	2.85
Drip irrigation with 50% of ET_c	363356	5.3	1060000	696644	1.92

Conclusion

Drip irrigation with 100% of ET_c recorded the highest yield and benefit cost ratio of garlic compared with surface irrigation, highest values of water productivity and economic water productivity were obtained under 50% ETc.

References

Abd El-Hady, M.; Ebtisam, I. E. (2016). Maximize the Crop Water Productivity of Garlic by Modified Fertilizer Management under Drip Irrigation. International Journal of Chemistry Technology Research, 5: 144-150.

Abd El-Latif, M.; Abdelshafy, A. A. (2017). Response of Garlic Productivity to Surface and Drip Systems and Irrigation Amounts Middle East Journal of Agriculture Research. 6(4): 981-995.

Allen, R. G.; Pereira, L. S.; Raaes, D.; Smith, M. (1998). Crop Evapotranspiration. Guidelines for Computing Crop Water Requirement, FAO, Irrigation and Drainage, Paper 56. United Nation. Rome. Italy.

Bagali, A. N.; Patil, H.B.; Ruled, M.B.; Patil, R.V. (2012). Effect of scheduling drip irrigation on growth, yield, and water use efficiency. Karnataka Journal of Agricultural Science 25 (1): 116-119.

Chomsang, K.; Morokuma, M.; Agarie, S.; Masanore, T. (2021). Effect of using drip irrigation on the growth, yield and its components of soybean grown in a low rainfall region in Japan. Plant Production Science 24 (41): 1-5.

CIMMYT. (1988). From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edition, Mexico .D.F. ISBN 968-6-18-6.

Ghadami, A.; Nasseri, A.; Nosrati, A. (2010). Water use efficiency and yield of garlic responses to the irrigation system, Intra-row spacing and nitrogen fertilization. Journal of Food and Agriculture Environment. 2: 344-346.

Ghaemi, A.; Sadri, S. (2012). Effect of deficit Irrigation by both ordinary and alternative tape and furrow methods on yield of sugar beet dripping irrigation and conventional irrigation and alternate irrigation on sugar beet yield. J.Sci. Water Soil. 21(3): 128-137.

Gyanendra, P. M. S.; Imtiyaz, M.; Dennis, M.D. (2016). Garlic (Allium sativum L.) yield as influenced by different levels of irrigation water by the drip irrigation system. International Journal of Innovation in Engineering Research and Management 3 (1): 2348-4918.

Hegab, A. S. A.; Fayed, M.; Hamada, M.A.;Abdrabbo, M.A.A. (2014). Productivity and irrigation requirements of faba bean in the North Delta of Egypt in relation to planting dates. Annals of Agricultural Science, 2: 185-193.

Khalifa, A. B.; Saeed, A.B.; Ahamed, S. B.; Eltigani, E. Bashier. E. (2022). Effect of irrigation methods and mulching on the growth, yield and water productivity of tomato (*Lycopersicon esculentum* Mill.) under Kassala State Conditions, Sudan. Journal of Agricultural Sciences 6(2):21-40.

Khalifa, A. B.; Ali, M.A.; Yagoub, A.Y. (2014). Optimizing the water productivity, yield, and quality of grapefruit irrigated by bubbler and surface irrigation under Khartoum State conditions. The 56th Meeting of the National Crop Husbandry Committee, Agricultural Research Corporation. Wad Medani, Sudan.

Khalifa, A. B.; Ali, MA.; Ibrahim, M.I.; Shaker, B.A.; Hassan, O. (2013). Comparison of the surface and drip irrigation regimes for banana (*Musa* AAA) cv. Grand Nain in Gezira. The 54th Meeting of the National Crop Husbandry Committee, Agricultural Research Corporation. Wad Medani, Sudan.

Mandefro, C.; Quraishi, S. (2015). Effect of deficit irrigation on the yield and water productivity of garlic (*Allium sativum* L.) under drip irrigation and mulching at wolaitasoddo, Ethiopia. International Journal of Life Sciences, 4: 232-239.

Ministry of Agriculture, Khartoum State. (2018) Bulletin for Garlic. (2018). Technology Transfer and Extension Sector. Ministry of Agriculture, Khartoum State-September 2018.

Ministry of Agriculture, River Nile State. (2018). Winter Crop Hand book, Technology Transfer and Extension - Ministry of Agriculture, River Nile State - November 2018.

Panigrahi, P., Srivastava, A. K and Huchche, A.D. (2012). Effects of drip irrigation regimes and basin irrigation on Nagpur mandarin agronomical and physiological performance.” Journal of Agricultural Water Management. (104): 79-88.

Patil, V. C.; Madugundu, K.; Tola, R.; Marey, E.H.; Aldosari, S.; Gowda, P.H. (2015). Assessing agricultural water productivity in the desert farming system of Saudi Arabia. Earth Observations Remote Sens. 8(1):1-14.

Sankar, V.; Lawande, K.E.; Tripathi, P.C. (2008). Effect of micro irrigation practices on growth and yield of garlic (*Allium sativum* L.) var. G. 41. Journal of Spices and Aromatic Crops.17 (3): 230-234.

Soomro, M.; Shaikh, M; Andriyas, S.; Shahid, M.R. (2022). Saline water impact on the water use efficiency of bitter melon (Momordica charantia L) using drip irrigation. Advances in Agriculture pp 1-7.

Tshenyego, L. D.; Mulonda, K.; Simate, I.N.(2017). Estimation of dry season irrigation water abstraction in lunsemfwa, mulungu, gombosi, and mushi subbasins from in Zambia, Advances in Agriculture, pp. 1-9.