Research Article

Evaluation of Water Productivity under Furrow Irrigation for Onion (Allium cepa L.) Crop

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Irrigation water management practices are the main strategies to improve water productivity. This research work was focused to study the performance of alternate and paired row furrow irrigation systems at three levels of irrigation (100%, 75%, and 50% of crop evapotranspiration) using different water productivity indicators for onion crops. The experiment had six treatments and replicated three times to evaluate the analysis of variance in SAS software. Water productivity indicators like crop water use efficiency, field water use efficiency, and field water expense efficiency were determined through bulb yield and water which were used by the crop. The crop yield was expressed as the total yield of onion bulbs, and crop water use was expressed as crop evapotranspiration (ETc), gross depth of irrigation, and water expense. The estimated maximum values of crop water use efficiency, field water use efficiency, and field water expense efficiency were 11.941, 16.152, and 9.361 kg m\(^{-3}\), respectively, for paired row furrow irrigation with 50% ETc. The performance of the paired row furrow irrigation system in crop yield and water use was better as compared to the alternate furrow irrigation system at all levels of irrigation.

1. Introduction

The water resource was limited by a lot of demand factors [1]. In line with this, agriculture is one of the consumer of this resource for agricultural crop production in the way of irrigation [2]. Irrigation is a source of water for agricultural production improvement to fulfill the growing food demands in the world [3]. The availability of water for irrigation is becoming limited from day to day because of the increasing consumption of water for different sectors such as home and industry. 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 [4, 5]. This water-scarce is a major problem in many areas of the world; in this case, studying the alternative mechanisms to solve the problem is very important [6].

Furrow irrigation is the common surface irrigation method for water application to cropped fields [7]; however, furrow irrigation as practiced by farmers in Ethiopia results in large deep percolation losses and uneven water application [8]. These not only result in large losses of limited water but also create problems of waterlogging and salinity [9]. Therefore, the development of efficient furrow irrigation systems and irrigation water management practices are essential for higher water productivity.

Techniques such as partial irrigation and deficit irrigation can increase or enhance water productivity. When water productivity decreases but irrigation water increases [10], there is an increasing interest to study the crop water productivity of furrow irrigation systems. The study of the water use efficiency of furrow irrigation systems for onion crops is important using deficit irrigation [11].

There are different possibilities of irrigation water applications in furrow irrigation systems. Conventional furrow irrigation (CFI) was the traditional method of furrow irrigation and was widely used by farmers in Ethiopia and any developing country [12–14]. The best water management techniques were alternate furrow irrigation (AFI), fixed
furrow irrigation (FFI), and also paired row furrow irrigation (PRFI). The crop planting in the case of PRFI is done at the top of the ridge in paired crop rows [15], and each crop row gets water from side furrows, but the furrow in between the crop rows is not constructed. The spacing between the furrows depends on crop type. The PRFI is similar to fixed furrow irrigation (FFI) in principle with the alternate irrigated furrow in which each irrigation is fixed. The difference is only the furrow spacing and construction of furrow in the case of FFI, but in the case of PRFI, the unirrigated furrow of FFI is not constructed. Thus, the cost of construction of the furrows is reduced; however, many studies have investigated and concluded that AFI is better as compared to CFI and FFI for water productivity [8, 11, 14]. Another option for AFI is there, which is PRFI, but AFI was never compared with PRFI under different irrigation water levels for water productivity throughout the world. Therefore, this study focused on the performance evaluation of AFI and PRFI at different levels of irrigation for water productivity.

2. Materials and Methods

2.1. The Description of Study Area. The field experiment was conducted at Arba Minch University demonstration farm-land in the Gamo Zone, SNNPR National Regional State of Ethiopia. The study area is geographically located at an altitude of 1203 m.a.s.l, latitude of 6°04′ N, and longitude of 37°33′ E. The location of the study area is shown in Figure 1.

Based on the data collected from the Arba Minch University Meteorological station, the mean monthly minimum and maximum air temperature in the study area vary from 17.4°C to 30.6°C, respectively. The average annual rainfall in the study area is 750 mm [16], although rainfall is erratic and uneven in distribution. The historical rainfall data show a bimodal behavior with an interval of February up to April and June up to September. The average relative humidity ranges from 39.4% (February) to 62.9% (May), and average annual daily sunshine duration varies from 6.3 hours to 9.1 hours. Based on climate properties of the study area, the agroecological zone of the study area was classified as dry low land [17].

2.2. Preexperimental Activities. To conduct this experimental research, primary and secondary data were collected. Secondary data such as climatic and agronomic data of onion were collected from the Arba Minch University Meteorological station and FAO [18], respectively. The climatic data were maximum and minimum temperature, relative humidity, sunshine hours, wind speed, and rainfall. Other primary data such as soil physical and chemical characteristics were collected.

2.3. Experimental Treatments. The experiment was conducted for alternate furrow irrigation (AFI) and paired row furrow irrigation (PRFI) systems with three levels of irrigation such as 100%, 75%, and 50%. The transplanting after 45 days of seedlings of the Red Bombay variety of onion was done in the ridge and furrow system following recommended agronomic practices.

The treatment plot size for the two systems was 1.6 m × 3 m and the central rows for each treatment were considered experimental rows for the collection of field data. The side rows were nonexperimental (a buffer row) to minimize the border effects, and the plant-to-plant spacing in each row was 10 cm which has a plant density of 30 plants per row. There were 6 treatments; each of the treatments was replicated three times; details of the treatments are given in Table 1. The location of different plots was decided by a randomized complete block design (RCBD). The spacing between each plot to plot and block to block was 1 m and 1.5 m, respectively. The total area required for this experiment was 240.7 m² (16.6 m × 14.5 m) (Figure 2).

2.4. Crop Water Requirement Estimation. The onion crop water requirement was estimated from reference crop evapotranspiration (ETo) and crop coefficient (Kc) using equation (1). The ETo was estimated using CROPWAT 8 software based on the Penman–Monteith method for 30-year monthly average climatic data.

\[ \text{ETo} = \frac{\text{Kc} \times \text{ETO}}{} \]  
(1)

After the determination of crop evapotranspiration using the above relation, the net irrigation requirement (I) was estimated using

\[ \text{NIR} = \text{ETc} - \text{Pe} - \text{GW} - \text{SM} \]  
(2)

where NIR represents the net irrigation requirement (mm), Pe represents the effective rainfall (mm), GW represents the groundwater contribution (mm), and SM represents the change in soil moisture (mm); the depth of the groundwater table during the crop season was more than 1.6 m; therefore, the groundwater contribution (GW) was negligible.

The gross depth of irrigation water application was expressed as

\[ \text{GIR} = \frac{\text{NIR}}{} \]  
(3)

where NIR represents the net depth of irrigation estimated using equation (2) and Ea represents the overall irrigation efficiency measured in the field and found to be equal to 64%.

2.5. Crop Water Productivity. The considered water productivity indicators were crop water use efficiency (CWUE), field water use efficiency (FWUE), and field water expense efficiency (FWEE) as expressed by the following equations [15, 19].

\[ \text{CWUE} = \frac{Y}{\text{ETc}} \]  
(4)

where CWUE represents the crop water use efficiency (kg m⁻²), Y represents the crop yield (kg ha⁻¹), and ETc represents the crop evapotranspiration in mm.
Figure 3.

The general framework for this study is shown in the diagram on the page. The framework includes various components such as water use efficiency, crop yield, and irrigation systems. The framework is used to analyze the impact of different irrigation methods on crop yield and water use efficiency.

The results of onion yield and water use efficiency were analyzed using the SAS 9.0 program. The least significant difference (LSD) was used to compare the mean of each treatment. The general framework for this study is shown in Figure 3.

3. Results and Discussion

The soil texture of the soil in the experimental area was determined by using hydrometer analysis, and the field capacity of the soil was also measured by pounding water at the soil surface to saturate the soil column up to about 150 cm soil depth, covering the soil surface with a trace to prevent water evaporation from the soil surface and start measuring soil moisture content after 24 hours. The permanent wilting point of the soil was considered as the soil moisture content at 15 atmospheric tensions. The soil bulk density was calculated by taking undisturbed soil samples in the experimental area. Values of soil physical properties which were measured or determined in the laboratory are given in Table 2.

The important information during each irrigation on intervals of this research work is given in Table 3. The estimated values of seasonal crop evapotranspiration, net and gross depth of irrigation, water, the expense, and collected value of the total bulb yield for each of the treatments are given in Table 4.

3.2. Water Productivity Indicators. The estimated values of different water productivity indicators using (4), (5), and (6) along with the results of statistical analysis are given in Table 6.

3.2.1. Statistical Analysis for Crop Water Use Efficiency (CWUE). Analysis of variance showed that the furrow irrigation system and irrigation levels significantly affected CWUE at $P < 0.05$. The furrow irrigation system as the main effect, the maximum CWUE (10.596 kg m$^{-3}$) obtained for PRFI, was significantly different from the lowest value (10.003 kg m$^{-3}$) obtained for AFI. Similarly, with irrigation level as the main effect, the maximum CWUE (11.691 kg m$^{-3}$) was obtained at 50% ETc, which was significantly different compared to CWUE recorded at 75% ETc (10.019 kg m$^{-3}$) and the lowest value (9.188 kg m$^{-3}$) obtained at 100% ETc.

The interaction effect of the furrow irrigation system and irrigation water level on CWUE was significant at $P < 0.05$. It is observed from Table 6 that the maximum value of CWUE (11.941 kg m$^{-3}$) was recorded for T4 (PRFI with 50 ETc). The maximum value of CWUE was significantly different compared to all other treatments. Contrary, the minimum CWUE (8.992 kg m$^{-3}$) was recorded for treatment T1 (AFI with 100% ETc), which was significantly different from all other treatments. On the other hand, there was no significant difference between T2 (AFI with 75% ETc) and T4 (PRFI with 100% ETc).

The CWUE increased as the denominator (water) decreased or CWUE increased as the numerator (yield) increased [23, 24]. This research work agrees with [25] which reported that CWUE decreased as the irrigation level increased. The maximum CWUE for treatment T6 was due to properly managed irrigation water. Contrary, the minimum CWUE for treatment T1 was due to the application of more...
irrigation water that may result in deep percolation or soil water evaporation. Therefore, the PRFI system with a 50% ETc level of irrigation can achieve the maximum CWUE. It results in 50% water-saving compared to full irrigation treatment (100% ETc). The irrigation water so saved may be used to bring more area under production. Therefore, areas having water-scarce should use a paired row furrow irrigation system to maximize crop water productivity rather than maximizing crop yield per unit area.

3.2.2. Statistical Analysis of Field Water Use Efficiency (FWUE). Analysis of variance showed that the furrow irrigation system and irrigation levels significantly affected FWUE at \( P < 0.05 \). The furrow irrigation system has the main effect; the maximum FWUE (12.121 kg m\(^{-3}\)) obtained for PRFI was significantly different from the lowest value (11.452 kg m\(^{-3}\)) obtained for AFI. Similarly, with irrigation level as the main effect, the maximum FWUE (15.813 kg m\(^{-3}\)) obtained at 50% ETc was significantly different compared to FWUE obtained at 75% ETc (10.811 kg m\(^{-3}\)) and the lowest value (8.736 kg m\(^{-3}\)) obtained at 100% ETc.

The interaction effect of the furrow irrigation systems and irrigation water levels on FWUE was significant at \( P < 0.05 \). It was observed from Table 5 that the maximum value of FWUE (16.152 kg m\(^{-3}\)) was obtained for treatment T6 (PRFI with 50% ETc). This maximum value of FWUE was significantly different compared to all other treatments. The minimum FWUE (8.549 kg m\(^{-3}\)) was recorded for treatment T1 (AFI with 100% ETc).

On the other hand, there was no significant difference between T1 (8.549 kg m\(^{-3}\)) and T4 (8.922 kg m\(^{-3}\)) for both treatments with a 100% level of irrigation. However, FWUE was slightly higher for treatment T4 (PRFI) compared to T1 (AFI). It indicates that PRFI had higher crop productivity performance compared to the AFI system (Table 5).

The results revealed that FWUE increased as irrigation water decreased (Table 6). The reason to obtain the maximum FWUE for treatment (T6) was the lesser gross irrigation depth compared to other treatments except for treatment T3. The FWUE for treatment T6 (PRFI with 50% ETc) was higher compared to treatment T3 (AFI with 50% ETc). Therefore, in areas of limited water resources, PRFI was preferable to AFI with 50% ETc to maximize FWUE. The saved water may be used to bring more area under irrigation.

### Table 1: Treatment combinations of different furrow irrigation systems with level of irrigation water.

| Furrow irrigation system | Alternate furrow irrigation (AFI) | Paired row furrow irrigation (PRFI) |
|--------------------------|----------------------------------|----------------------------------|
| Treatment T1             | T2 T3 T4 T5 T6                  |                                  |
| Deficit level of irrigation as ETc (%) | 100 75 50 100 75 50 |

Figure 1: The location map of the study area.
Figure 2: A general block framework illustrating the experimental design and field layout (all dimensions are in meters) (R, replication; T, treatment).

Figure 3: A general flowchart depicting the methodology of the study.
or for other commercial uses like domestic water supply for drinking or industrial use.

Corresponding to this, [22] concluded that water productivity was maximum at a medium level of a deficit than higher soil moisture availability (full irrigation water availability); similarly, [26] reported that water use efficiency decreased with increased water supply.

3.2.3. **Statistical Analysis for Field Water Expense Efficiency (FWEE).** The interaction effect of the furrow irrigation system and irrigation water levels on FWEE was significant at \( P < 0.05 \). As it is observed in Table 6, FWEE was slightly higher (9.361 kg m\(^{-3}\)) for treatment T6 (PRFI with 50 ETc) compared to all other treatments. This maximum FWEE was significantly different compared to all other treatments. The minimum FWEE (7.619 kg m\(^{-3}\)) was recorded for treatment T1 (AFI with 100% ETc) which was not a significant difference between T2 (7.68 kg m\(^{-3}\)) and T4 (8.014 kg m\(^{-3}\)). Furthermore, there was no significant difference between T4 and T5.

As shown in the result field, water expense efficiency was decreased with an increase in water expense. The differences in FWEE between treatments were very small due to soil moisture during transplanting being the same for all treatments, but during harvesting, different soil moisture for each treatment was collected. Practically, the amount of applied irrigation water for 100% ETc was different from 75% ETc and 50% ETc. Similarly, the soil moisture was also different for different treatments. That means the maximum soil moisture was observed for 100% ETc treatment less than 75% ETc and 50% ETc at the time of harvesting. This maximum soil moisture for 100% ETc was subtracted from soil moisture during transplanting (uniform value) to get a smaller value than 75% ETc and 50% ETc. Therefore, the depth of water expense becomes counterbalancing with the decreased gross depth of irrigation. Generally, FWEE was increased when irrigation water decreased [19].

Generally, water productivity was affected by different factors. In line with this, [25] reported that water productivity was affected by the furrow irrigation system, irrigation water level, crop yield potential, and climatic conditions of the crop grown region. In the same way, [27] reported that water productivity was increased by improving yield or reducing irrigation water. Anyways, in the present research,
system and 9.385–11.941 kg m−2 for the alternate furrow irrigation system and 8.014–15.474 kg m−2 for the paired row furrow irrigation system as irrigation level varied from 100% ETc to 50% ETc, respectively.

Therefore, the new outcome in this research was the paired row furrow irrigation system was identified with better performance than an alternate furrow irrigation system in water-saving, crop yield, and water productivity for onion crops. Therefore, the use of the paired row furrow irrigation system is recommended for practicing irrigation. Further studies will be needed for spatial and temporal evaluation of water productivity under two methods with different crops.

**Data Availability**

All the available data can be accessed through request.

**Conflicts of Interest**

The authors declare that there are no conflicts of interest.

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**References**

[1] M. An, L. Fan, J. Huang et al., “The gap of water supply-demand and its driving factors: from water footprint view in Huaihe River Basin,” *PLoS One*, vol. 16, no. 3, Article ID e0247604, 2021.

[2] G. G. Haile and A. K. Kasa, “Irrigation in Ethiopia: a review,” *Academia Journal of Agricultural Research*, vol. 3, pp. 264–269, 2015.

[3] J. K. Bidzakin, S. C. Fialor, D. Awunyo-Vitor, and I. Yahaya, “Impact of irrigation ecology on rice production efficiency in Ghana,” *Advances in Agriculture*, vol. 2018, Article ID 5287138, 2018.

[4] Food and Agriculture Organization of the United Nations, *Water for Sustainable Food and Agriculture: A Report Produced for the G20 Presidency of Germany*, FAO, Rome, Italy, 2017.

[5] L. D. Tshenyego, K. Mulonda, and I. N. Simate, “Estimation of dry season irrigation water abstraction in lunsemfwa, mulungushi, mwomboshi, and mkushi subbasins from 2013 to 2017 in Zambia,” *Advances in Agriculture*, vol. 2019, pp. 1–9, Article ID 8979837, 2019.

[6] K. B. Soomro, M. M. Shaikh, S. Andriyas, and M. R. Shahid, “Saline water impact on water use efficiency of bitter melon (Momordica charantia L.) using drip irrigation,” *Advances in Agriculture*, vol. 2022, pp. 1–7, Article ID 3189216, 2022.

[7] N. Kannan and B. Abate, “Studies on hydraulic performance of furrow irrigation to optimize design parameters suitable to onion field in Hawassa, Ethiopia,” *Water Utility Journal*, vol. 11, pp. 17–30, 2015.

[8] T. A. Eba and T. Seyoum, “The impact of alternate furrow irrigation on water productivity and yield of potato at small scale irrigation, Ejere district, West Shoa, Ethiopia,” *Applied Engineering*, vol. 2, pp. 1–18, 2018.

[9] B. Yadeta, M. Ayana, M. Yitayew, and T. Hordofo, “Performance evaluation of furrow irrigation water management

### Table 5: Effect of furrow irrigation systems with irrigation levels on the total bulb yield (ton ha−1).

| Furrow irrigation systems | Irrigation levels | Mean bulb yield (ton ha−1) |
|--------------------------|-------------------|---------------------------|
|                          | 100               | 75                        | 50                        | Mean |
| AFI                      | 36.278ab          | 28.981d                   | 23.078d                   | 29.4457 |
| PRFI                     | 37.863a           | 31.659c                   | 24.089e                   | 31.2037 |
| Mean                     | 37.0705           | 30.32e                    | 23.5835                   | -     |
| LSD (0.5)                | 0.784             | -                         | -                         | -     |
| CV (%)                   | 1.42              | -                         | -                         | -     |

*Means followed by different letters were significantly different at *P < 0.05.

### Table 6: Effect of furrow irrigation systems with irrigation levels on water productivity.

| Furrow irrigation systems | Irrigation levels | Irrigation effectiveness (kg m−2) |
|--------------------------|-------------------|----------------------------------|
|                          | 100% ETc          | 75% ETc                          | 50% ETc                        |
| AFI                      | 8.992<sup>a</sup> | 9.577<sup>a</sup>                | 11.439<sup>a</sup>             |
| PRFI                     | 9.385<sup>a</sup> | 10.462<sup>c</sup>              | 11.941<sup>a</sup>             |
| Mean                     | 9.577<sup>a</sup> | 10.773<sup>c</sup>              | 12.143<sup>a</sup>             |
| LSD (0.05)               | 0.330             | 0.431                            | 0.408                           |
| CV (%)                   | 1.760             | 2.009                            | 2.704                           |

*Means followed by different letters were significantly different at *P < 0.05.

the paired row furrow irrigation system resulted in maximum water productivity (CWUE, FWUE, and FWEE) with decreased irrigation water level (deficit irrigation condition) at 50% ETc. This method is very important in the area of water scarcity [16].

**4. Conclusion**

Water management in the furrow irrigation system was essential for the improvement of water productivity. Evaluation of water productivity under different furrow irrigation systems is important to identify the suitable furrow irrigation system with optimum levels of irrigation water.

In the present research, water productivity under alternate furrow irrigation and paired row furrow irrigation systems at three levels of irrigation water were studied. The crop water requirement was estimated using CROPWAT 8.0 software. The experiment was designed as a two-factorial and becomes six treatment and replicated three times. Statistically, the mean of collected data was separated using LSD at a 5% probability level in SAS software, and the effect of treatment was tested using bulb yield and water productivity indicators.

The water productivity evaluation indicators were crop water use efficiency, field water use efficiency, and field water expense efficiency. The estimated values of crop water use efficiency, field water use efficiency, and field water expense efficiency varied 8.992–11.439 kg m−2, 8.549–15.474 kg m−2, and 7.619–8.914 kg m−2 for the alternate furrow irrigation system and 9.385–11.941 kg m−2, 8.922–16.152 kg m−2, and 8.014–9.361 kg m−2 for the paired row furrow irrigation system as irrigation level varied from 100% ETc to 50% ETc, respectively.

Therefore, the new outcome in this research was the paired row furrow irrigation system was identified with better performance than an alternate furrow irrigation system in water-saving, crop yield, and water productivity for onion crops. Therefore, the use of the paired row furrow irrigation system is recommended for practicing irrigation. Further studies will be needed for spatial and temporal evaluation of water productivity under two methods with different crops.
practice under Wonji Shoa sugar estate condition, in central Ethiopia," *Journal of Engineering and Applied Science*, vol. 69, no. 1, 2022.

[10] D. Paul and M. Partson, *Effect of Irrigation Timing on Cotton Production under Various Tillage Strategies*, pp. 384–387, Beltwide Cotton, New Orleans, LA, USA, 2016.

[11] G. Gelu, "Evaluation of furrow irrigation systems on onion yield and water use efficiency in Meliskoza Woreda, southern Ethiopia," *Irrigation & Drainage Systems Engineering*, vol. 7, pp. 1–5, 2018.

[12] T. Gebremedhin, "Improving agricultural water productivity with alternate furrow irrigation in semi-arid conditions of northern Ethiopia," *Asian Research Journal of Agriculture*, vol. 7, pp. 1–8, 2017.

[13] Y. Teshome, B. Biazin, K. Wolka, and A. Burka, "Evaluating performance of traditional surface irrigation techniques in Cheleleka watershed in central rift valley, Ethiopia," *Applied Water Science*, vol. 7, pp. 1–8, 2018.

[14] J. N. Hassene and M. T. Seid, "Comparative performance evaluation of alternate and conventional furrow irrigation under different water application level on cabbage water use efficiency and economic analysis," *American Journal of Environmental and Resource Economics*, vol. 2, no. 3, pp. 123–131, 2017.

[15] K. G. Mandal, A. K. Thakur, and S. Mohanty, "Paired-row planting and furrow irrigation increased light interception, pod yield and water use efficiency of groundnut in a hot sub-humid climate," *Agricultural Water Management*, vol. 213, pp. 968–977, 2019.

[16] L. A. Asres, "Seasonal yield response factor for red Bombay onion (*Allium cepa* L.) variety in Arba Minch, Ethiopia," *Agricultural Science Digest*, vol. 42, no. 3, pp. 266–271, 2022.

[17] S. Mekonnen, "Characterization of sheep fattening at small holder level in different agro-ecological zones of Ethiopia-Amhara Region," M.Sc. Thesis, Bahir Dar University, Amhara, Ethiopia, 2016.

[18] R. G. Allen, L. S. Pereira, D. Raes, and M. Smith, "Crop evapotranspiration-guidelines for computing crop water requirements," *FAO Irrigation and Drainage Paper*, vol. 285, 1998.

[19] D. B. Kilemo, "The review of water use efficiency and water productivity metrics and their role in sustainable water resources management," *Open Access Library Journal*, vol. 9, Article ID e7075, 2022.

[20] M. A. Badr, W. A. El-Tohamy, S. D. Abou-Hussein, and N. S. Gruda, "Deficit irrigation and arbuscular mycorrhiza as a water-saving strategy for eggplant production," *Horticulturae*, vol. 6, no. 3, p. 45, 2020.

[21] Z. Akele, "Evaluation of alternate, fixed and conventional furrow irrigation with different water application level on onion yield in Dubti, Afar, Ethiopia," *Industrial Engineering Letters*, vol. 9, pp. 15–21, 2019.

[22] B. Enchawel, S. L. Gebre, M. Rabo, B. Hindaye, and M. Kedir, "Effect of deficit irrigation on water productivity of onion (*Allium cepa* L.) under drip irrigation," *Irrigation & Drainage Systems Engineering*, vol. 5, pp. 1–4, 2016.

[23] U. Poudel, H. Stephen, and S. Ahmad, "Evaluating irrigation performance and water productivity using EEFlux ET and NDVI," *Sustainability*, vol. 13, no. 14, 2021.

[24] K. T. Kassaye, W. A. Yilma, M. H. Fisha, and D. H. Haile, "Yield and water use efficiency of potato under alternate furrows and deficit irrigation," *International Journal of Agronomy*, vol. 2020, pp. 1–11, Article ID 8869098, 2020.

[25] M. Yemane, W. Abraham, and H. Solomon, "Response of onion (*Allium cepa* L.) to deficit irrigation under different furrow irrigation water management techniques in Raya valley, northern Ethiopia," *African Journal of Plant Science*, vol. 12, no. 5, pp. 105–113, 2018.

[26] J. F. Velasco-Munoz, J. A. Aznar-Sanchez, L. J. Belmonte-Urena, and M. J. Lopez-Serrano, "Advances in water use efficiency in agriculture: a bibliometric analysis," *Water*, vol. 10, no. 377, 2018.

[27] T. Temesgen, M. Ayana, and B. Bedadi, "Evaluating the effects of deficit irrigation on yield and water productivity of furrow irrigated onion (*Allium cepa* L.) in ambo, western Ethiopia," *Irrigation & Drainage Systems Engineering*, vol. 7, no. 1, 2018.