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RESEARCH ARTICLE

EFFECT OF THE IRRIGATION METHOD ON ONION YIELD IN STATION, SENEGAL

Mahecor Diouf[1], Dior Diallo[1], Atoumane LY[1], Assane Goumbala[1] and El Hadji Bamba Diaw[2]

1. National School of Agriculture (ENSA).
2. International Institute for Water and Environmental Engineering-2ie.

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Abstract

Conducted at the Center for the Application of Agricultural Techniques (CATA) of the National Higher School of Agriculture (ENSA) in Thies-Senegal, this study aims to contribute to the optimization of productive water resource use. Three irrigation methods (sprinkler, drip, and micro-sprinkler) were tested to assess their efficiency and their effect on onion yield.The results showed that at the beginning of the cropping season, all three irrigation methods exhibited irrigation efficiency above the reference threshold (drip: 96%, micro-sprinkler: 89%, and sprinkler: 87%). In the middle of the season, the uniformity efficiency of the drip irrigation method declined sharply. From an agronomic perspective, sprinkler irrigation produced the best results with an average yield of 26.4 t/ha, followed by micro-sprinkler irrigation with a yield of 22.2 t/ha, and finally drip irrigation with an average yield of 20.5 t/ha. This study confirmed that drip irrigation is not suitable when irrigation water is high in iron, limestone (calcium carbonate), and magnesium.

Introduction:-

As a cornerstone of the Senegalese economy, agriculture supports 95% of rural households and employs more than 65% of the rural population. While it contributes 9.6% to the overall GDP, it remains the dominant force within the primary sector, generating nearly 66% of its total value-added through a predominantly family-based farming model.However, the effects of climate change, soil fertility loss, and rainfall irregularities have led to a decline in agricultural production. Added to this is exponential population growth, which implies an increase in food production demand. In this context, irrigation represents one of the key solutions to meet the growing food demand and to contribute to the development of the agricultural economy. Significant investments have been directed toward irrigation from independence to the present through various policies and strategies, leading to the development of numerous irrigation schemes across the country.Groundwater resources, which provide most of the mobilizable water for meeting horticultural needs (except in the Senegal River Valley and the Anambé area), are now threatened by localized salinization due to intense exploitation. Moreover, the small size of irrigated plots—rarely exceeding one hectare—and the abstraction of irrigation water from multiple intake points such as mini-boreholes or traditional wells generate high irrigation water demand, which consequently poses a real threat to groundwater resources.

Corresponding Author:-Mahecor Diouf
Address:-National School of Agriculture (ENSA).

Furthermore, Senegal, through its current socio-economic development policy following a sustainability-oriented trajectory—implemented via strategic development projects under the Vision Sénégal 2050 plan—aims to honor its commitment to environmental preservation and to promote multi-stakeholder management in order to reduce losses and improve irrigation efficiency in a context of high demand (a projected increase of 30 to 60% by 2035, World Bank, 2025). Hence, effective water management and protection have become a priority for all stakeholders and will undoubtedly be facilitated by the development of Water Resources Management Plans (WRMPs) nationwide at the level of sub-Management and Planning Units (MPUs).Given this situation, the use of more water-efficient irrigation systems appears to be an appropriate strategy for ensuring ecological balance. Sound water management will not only help meet the challenge of food demand but will also contribute to achieving Sustainable Development Goals (SDGs) 6, 13, and 17 by 2030, as well as the African Water Vision for 2025, while promoting increased incomes for Senegalese producers.It is within this broad perspective that the present study, entitled "Effect of the Irrigation Method on Onion Yield," is conducted.

Description of the Study Area:-

The present study was carried out on Experimental Plot No. 3 at the Centre for the Application of Agricultural Techniques (CATA) of ENSA in Thiès.The study began in January 2025 in the Thiès region, specifically in the rural community of Fandène, on Experimental Plot No. 3 of the National Higher School of Agriculture (ENSA) in Thiès. The site is located along the Khombole road and contains both crop production and experimental plots. The map below provides further information on the study area.

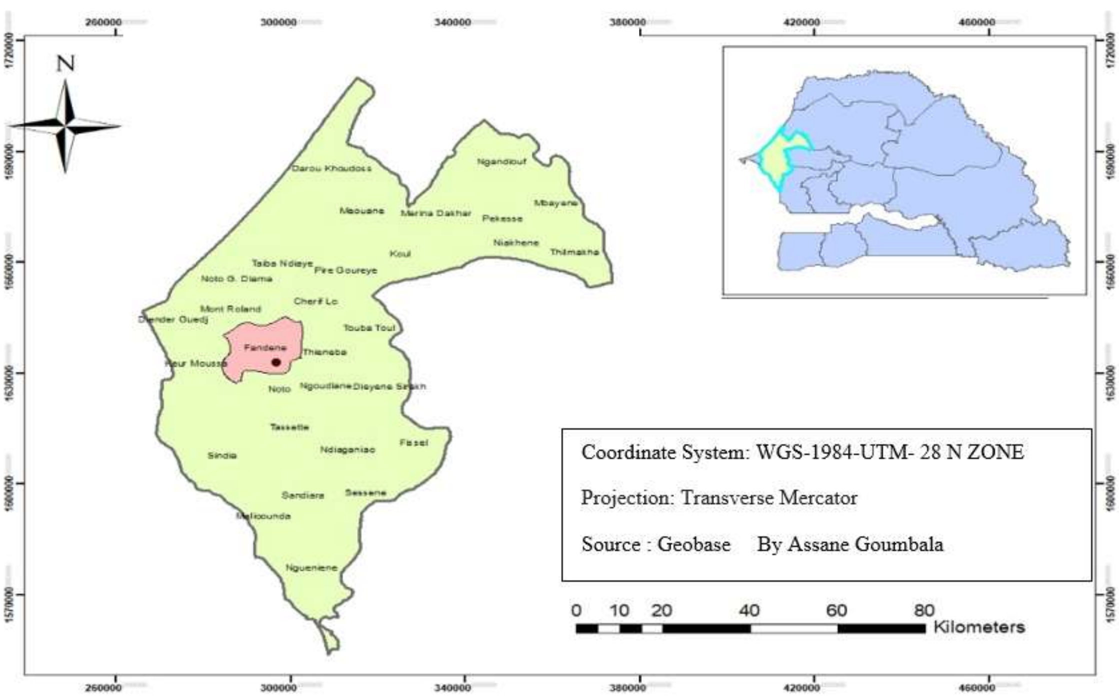

Figure 1: Location Map of the Study Area

Experimental Plot No. 3 is located within the National Higher School of Agriculture (ENSA) in Thiès, itself situated in the rural community of Fandène, at coordinates 14°45′44″ N, 16°53′16″ W, and an altitude of 53 m. The choice of this site is justified by its water availability, the prior knowledge of its already documented physico-chemical parameters, and the fact that its location within ENSA facilitates more rigorous supervision. The plot covers a total area of 0.9 ha; however, the study focuses on only 0.6 ha, as illustrated on the map below.

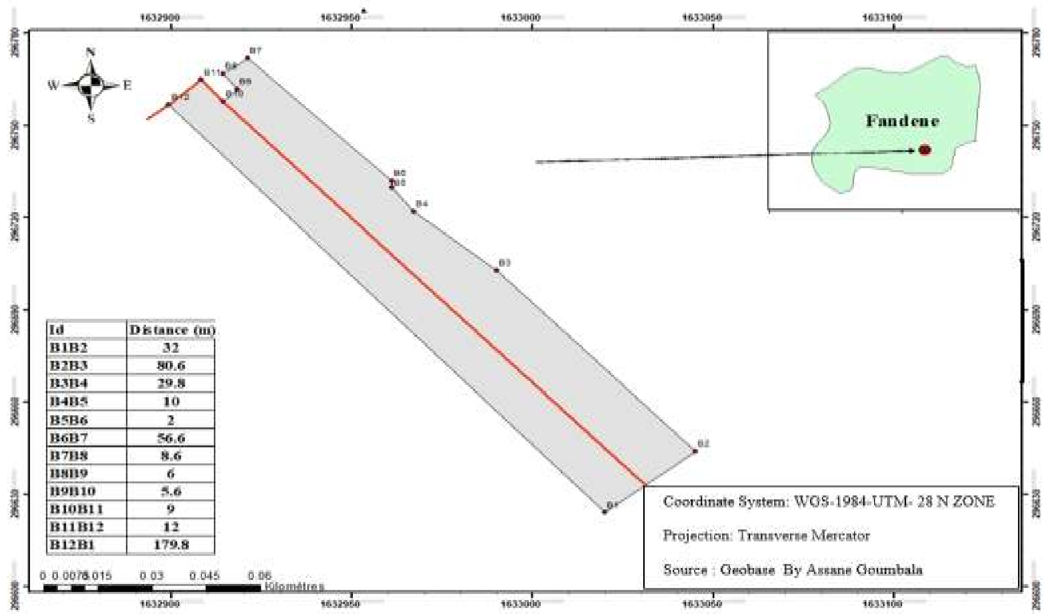

Figure 1: Map of CATA Plot No. 3

Experimental Design:
The experimental design adopted was a randomized layout with three treatments (irrigation methods: drip irrigation, sprinkler irrigation, and micro-sprinkler irrigation) and three replications. Each treatment, or irrigation method, was applied to a sub-plot of 500 m².
Observations and measurements were carried out for each treatment according to the position of the elementary plot in order to identify the effects of the irrigation method and the uniformity of water distribution within the plot on:

- the volume of water applied to meet crop water requirements; and
- the average yield of the cultivated plot.

The objective was to determine, at the end of the cropping season, the volume of water used and the yield of each production plot.To enable this comparison, the experimental layout described below was adopted. The area allocated to the trial was 0.5 ha. This area was divided into nine plots of 500 m² each: Plot I was assigned treatment T1, Plot II treatment T2, and Plot III treatment T3, and so on until the last plot. The spacing between the elementary plots was set at 1 m, as shown in the diagram below.

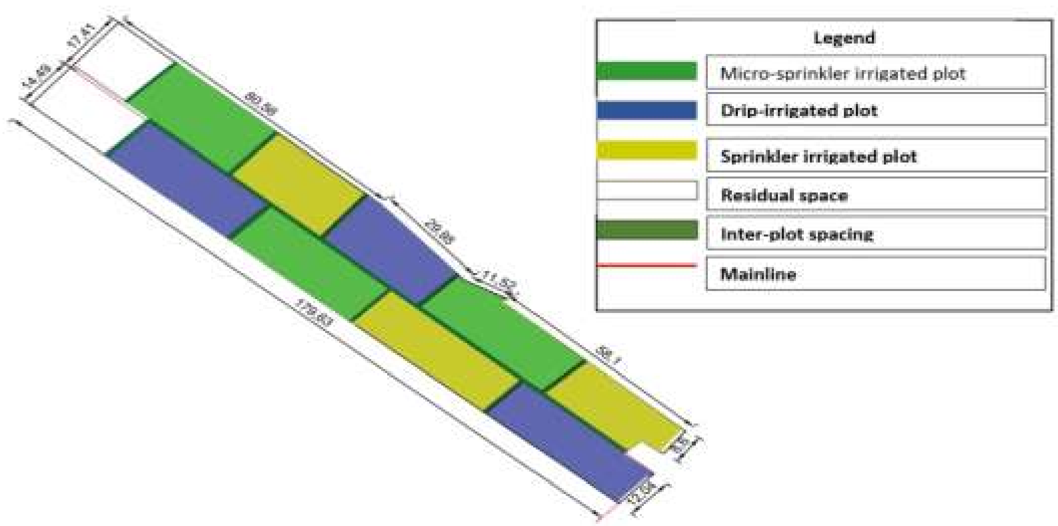

Figure 3: Randomization Map of the Study Plot

Data Collection :
Agronomic data were collected using yield quadrats according to the Z-method.

Plant Material:
The plant material used was the onion (Allium cepa), specifically the Orient F1 variety. The onion is a biennial plant belonging to the Alliaceae family (Liliaceae subgroup) and the genus Allium. Recognizable by its red color and pinkish scales, this variety has a production cycle of 100 to 115 days.In Senegal, onions are mainly cultivated in the Niayes region and the Senegal River Valley. Cultivation can be carried out either by direct seeding or via a nursery. For this study, the nursery method was chosen for greater reliability, as it is widely adopted by producers. The nursery period lasted 40 days, with a seeding density of 5 to 6 kg/ha. The choice of the Orient F1 variety is justified by its excellent adaptation to local conditions, its high yield potential (30 to 70 tons/ha), and its compatibility with standard cultural practices and inputs.

Irrigation Equipment:
The irrigation equipment consisted of three systems: a sprinkler irrigation network, a micro-sprinkler network, and a drip irrigation network. These plot-specific networks were all connected to the same main pipeline, with devices installed to control irrigation water volume, pressure, and rainfall. This setup allowed the service pressure to be adjusted according to the specific requirements of each irrigation method. Irrigation was carried out on a demand basis.

Figure 4: Monitoring device for rainfall, pressure, and dripper water volume

Data Processing :
Software From map generation to the final production of this report, several software tools were utilized. These include:

- ArcGIS: Used for producing land cover, topographic, soil (pedological), and geographic location maps.
- Archicad and Twinmotion: Utilized for the 3D modeling of the study site.
- AutoCAD: Employed for the design and schematic drafting of the irrigation network.
- CROPWAT and CLIMWAT: Used for the acquisition and processing of climatic data.
- IRRIGATE_SOIL_TOOL: Utilized to acquire and analyze soil (pedological) data.

Results and Discussion:-

Analysis of Hydraulic Verification Results:
Drip Irrigation Mode The installation showed a flow rate variation of +7%, which is below the ±10% threshold. The high uniformity coefficient (UC = 96%) reflects an excellent water distribution, indicating both a rigorous design and stable operation. These results are consistent with the recommended standards for high-performance installations (UC ≥ 90% according to Keller &Bliesner, 1990).Sprinkler Irrigation Mode With a flow rate variation of +5% and a UC of 87%, the sprinkler system remains fully compliant with performance requirements. According to Burt et al. (1997), a UC higher than 85% is considered satisfactory for long-range or medium-range sprinklers. This suggests a fairly homogeneous distribution, with low sensitivity to pressure losses or pressure irregularities.
Micro-sprinkler Irrigation Mode The flow rate difference of –8%, indicating slight under-watering at certain points, remains within acceptable tolerances. The UC of 89% shows that the distribution remains highly homogeneous

throughout the network. This result also aligns with the recommendations of Keller &Bliesner (1990), who consider a UC above 85% to be satisfactory for this type of system.

Results of Agronomic Parameters:
The results of the various water volume measurement points are presented in the following graph:

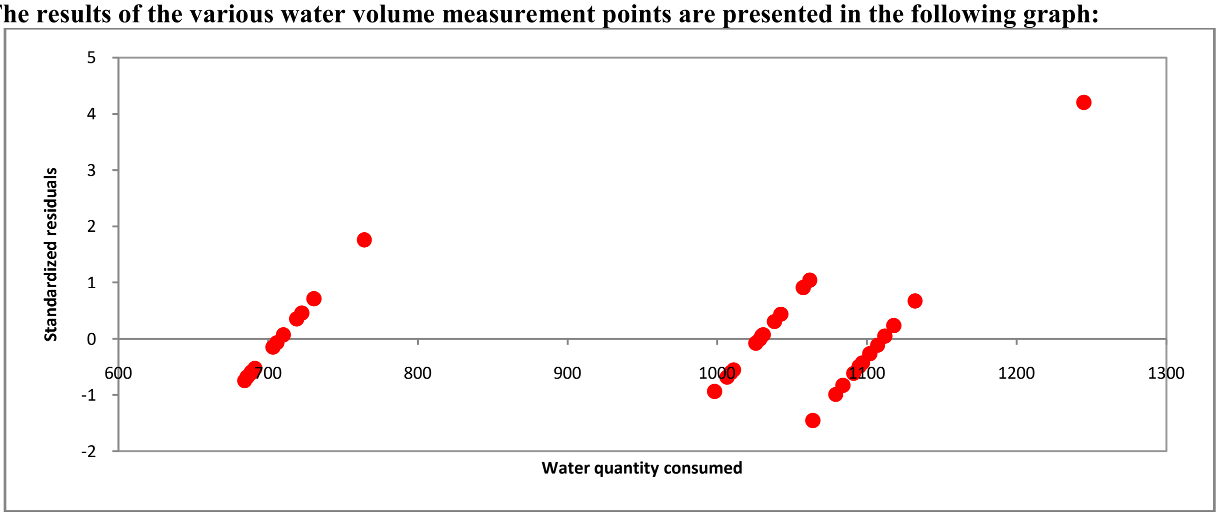

Figure 5: water volume measurement

The drip irrigation mode stands out from the other two irrigation methods (sprinkler and micro-sprinkler), which consume significantly more water. These findings correlate with the results of the study conducted by Mahecor et al. in the Potou area of Senegal.At the beginning of the season, the irrigation efficiency of our installation was 98% for the drip irrigation mode, 92% for micro-sprinkler irrigation, and 88% for sprinkler irrigation.In the middle of the season (60 days after the start of irrigation), we re-verified the irrigation uniformity of the system. The UC (Uniformity Coefficient) dropped from 96% to 75% for the drip irrigation mode, while it remained at 87% for micro-sprinkler irrigation (no change) and 89% for sprinkler irrigation (no change).The variation in the uniformity coefficient for the drip irrigation mode, under the same testing conditions as the previous one, leads us to analyze the chemical composition of the irrigation water.

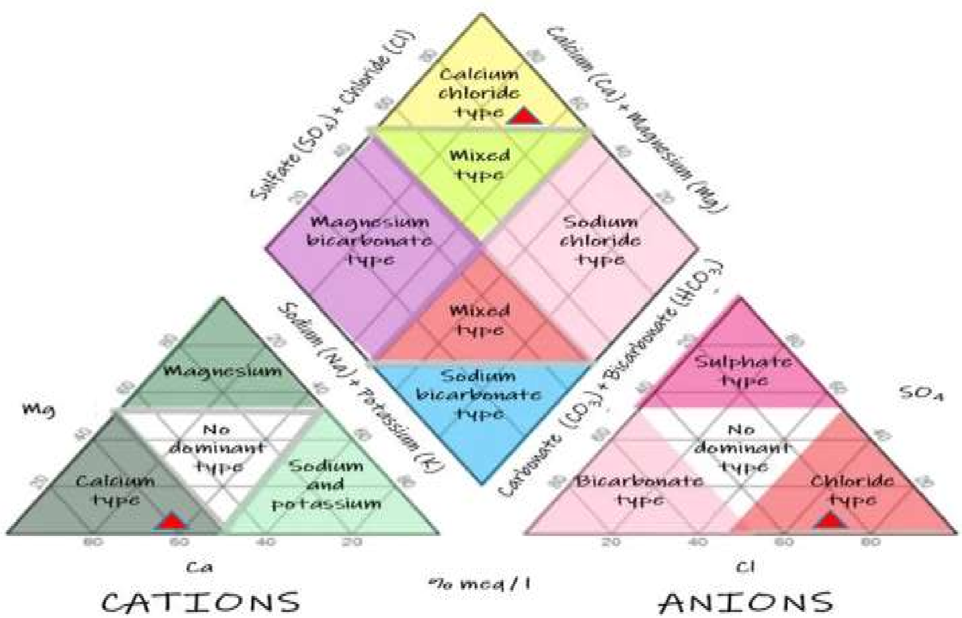

Figure 6: Piper iagram - irrigation Water Quality

Analysis of the Piper diagram shows that the proportion of cations is balanced (no dominant ions), while the dominant anions are chloride (Cl^-) and nitrate (NO^{-3}^-$). These results provide information on the mineralogical composition of the tapped aquifer, which is characterized as a chloride and sulfate calcium-magnesium water type.
The Schoeller-Berkaloff diagram allowed us to confirm that the water quality from the ENSA borehole remains within WHO standards, thus making it suitable for consumption.Our irrigation water falls into class (C2-S1) of the Riverside diagram. This class is characterized by water of good to medium quality; it can be used for irrigation, but precautions must be taken for poorly drained soils and sensitive plants.A chloride and sulfate calcium-magnesium facies describes water rich in chloride, sulfate, calcium, and magnesium ions. This is often associated with naturally hard mineral waters resulting from interaction with saline or sulfate rocks, indicating "hard" or "very hard" water containing salts such as calcium chloride, calcium sulfate, magnesium chloride, and magnesium sulfate. This facies often evolves toward more sodic types during concentration or leaching, as seen in surface waters.This water leads to the clogging of dripper orifices. This explains the variation in the irrigation uniformity coefficient observed in the drip irrigation mode mid-season.

Determination of Mean Yield Quadrats:
The production results are presented in the table below. They represent an essential step in evaluating the effect of the irrigation mode on agricultural yield.

Table 1: Yields obtained per yield quadrat

Treatments	Mean yield (t/ha)
Micro- sprinkler	20.5
Sprinkler	26.4
Drip irrigation	22.2

The sprinkler irrigation mode shows the highest yield, with an average of 26.4 t/ha.

Table 2: Analysis of variance

Treatments	Difference	Standardized difference	Critical value	Critical difference	Significant
G à G ~ micro aspersion	0,788	6,888	2,454	< 0,0001	Yes
G à G ~ Aspersion	0,427	3,732	2,454	0,002	yes
Aspersion ~ micro aspersion	0,361	3,156	2,454	0,009	Yes

The analysis of variance (ANOVA) reveals significant differences between the treatments. The maximum values are observed for the treatments using the sprinkler irrigation mode, with a peak value of forty (40) tons per hectare for treatment T9.Dunnett's test (comparing the groups with the micro-sprinkler control group, using a 95% confidence interval) also shows a significant difference, with a critical value of 0.264.

Table 3: Standard deviation

Treatments	Difference	Standardized difference	Critical value	Critical difference	Significant
Drip irrigation ~ micro Sprinkler	0,788	6,888	2,311	0,264	Oui
Sprinkler ~ micro Sprinkler	0,361	3,156	2,311	0,264	Oui

The results of the variance and standard deviation calculations reveal that the weightsobtained for each sample remain relatively dispersed, but without extreme outliers.

Table 4: Classification and grouping of non-significantly different groups:

Treatments	Mean	Groupings		
Sprinkler	2,872	A		
Micro - Sprinkler	2,444		B	
Drip irrigation	2,083			C

In fact, these results reflect a certain degree of homogeneity within each treatment (irrigation mode). This suggests that the measurements are generally reliable and consistent.However, a slight difference in variability between the systems is noted: the sprinkler mode shows a slightly more pronounced dispersion than the micro-sprinkler mode, which in turn shows a more marked distribution than the drip irrigation mode.Overall, the average measured yield stands at 2.303 kg, which is appropriate for the study conditions. Nevertheless, a significant dispersion around this mean is observed, with a standard deviation of 0.707 kg and an overall coefficient of variation of nearly 30%, indicating that the results vary noticeably from one replication to another.

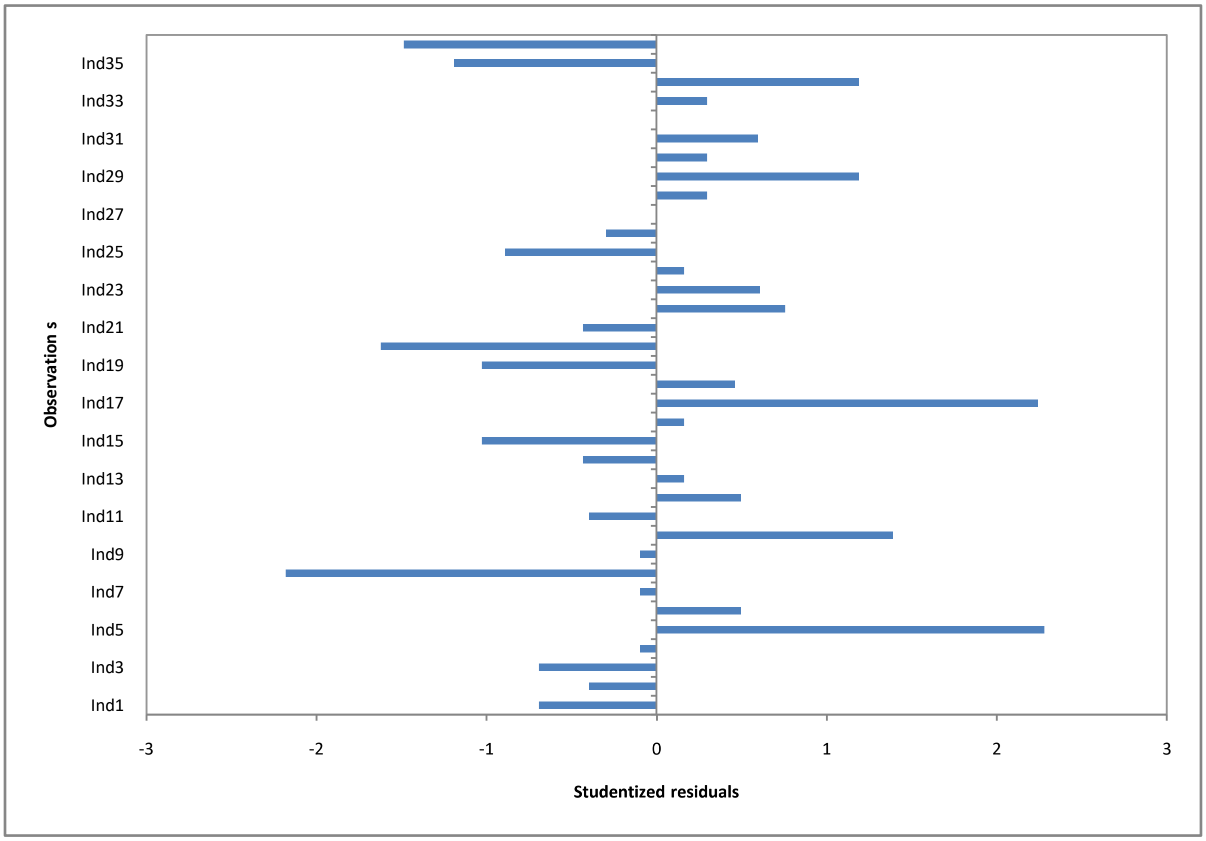

Figure 6: Studentized residuals

When the analysis is focused on each irrigation type, it is observed that the sprinkler mode presents the highest average yield at 2.640 kg. This observation is accompanied by high variability (standard deviation of 0.907 kg) and a coefficient of variation of nearly 31%, suggesting that results are not always consistent from one plot to another. The relatively wide confidence interval (1.514 to 3.766 kg) confirms this uncertainty.

Conversely, drip irrigation shows a slightly lower average (2.050 kg), but its standard deviation remains very low (0.349 kg) and its coefficient of variation drops to 14.1%. In other words, the yields are much more consistent, and the confidence interval is narrow (1.786 to 2.654 kg), reflecting better homogeneity of the results.Finally, micro-sprinkling records an intermediate average (2.220 kg) with a still marked dispersion (0.758 kg, with a coefficient of variation of 33.1%) and a wider confidence interval (1.108 to 2.992 kg), revealing a certain irregularity in the yields obtained.Overall, these results suggest that while sprinkler irrigation stands out with a higher average production, drip irrigation appears to be more reliable and stable. As for micro-sprinkling, it remains less effective in this regard.

Conclusion:-

This study on the effect of irrigation methods on onion yield has enabled an evaluation of the efficiency of different systems (sprinkler, micro-sprinkler, and drip) and their impact on agricultural productivity.The results reveal that all three studied irrigation modes demonstrate interesting performance levels. The sprinkler irrigation mode yielded the highest result at 2.640 kg per square meter, followed by micro-sprinkling at 2.220 kg per square meter, and finally drip irrigation at 2.050 kg per square meter. Statistical analysis reveals that while the sprinkler mode shows more marked variability between plots, drip irrigation stands out for its superior homogeneity, as evidenced by a lower standard deviation and a coefficient of variation reduced to only 14.1%. This reflects a more consistent management of the applied water. The observed difference in yield can be explained by the irrigation water quality, which is heavily loaded with magnesium and lime, leading to the clogging of the drippers.In conclusion, this work provides concrete evidence to further the reflection on improving water management within cultivated hydrosystems. It highlights the importance of combining technical rigor, innovation, and precise performance monitoring to build more efficient and resilient agricultural systems in the face of current challenges.

Based on these results, it is recommended to:

- Conduct this study in other agro-ecological zones;
- Integrate soil-climatic parameters, cultural practices, weed pressure, and the technical expertise of the operator in any future research along these lines;
- Test deficit irrigation and its impact on the bottom line (income statement).

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