



Drip Irrigation of Tomatoes in Biskra: Water Saving and Economic Profitability

Kamel Djaghroui, Mohammed Faci* and Hacène Cherif

Center for Scientific and Technical Research on Arid Regions
(CRSTRA), University campus, B.P. 1682 RP, Biskra, Algeria

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fm_alg@yahoo.fr

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Abstract: A field survey of thirty tomato growing greenhouses in Biskara region of Algeria was undertaken to find out the kind of the irrigation method being used and to assess their water productivity and economics. 30% of the greenhouses employed drip irrigation (9 farms), 20% (6 farms) utilized furrow irrigation, while the rest used the mixed irrigation. The sowing/transplantation of tomato in greenhouses in the region was carried out from August to October. The production started from March and ended in June. The selling price per kilogram of tomatoes ranged between 25 and 105 Algerian Dinar (DA). Results revealed that greenhouses using drip irrigation had higher water productivity and lower total water requirements. Greenhouses using drip irrigation produced 71.7 tons tomatoes ha⁻¹, which is 33.7% higher than that using furrow irrigation. Drip irrigated greenhouses exhibited maximum water productivity of 20.4 kg m³. Total water consumption in the greenhouses using drip was 3722.2 m³ ha⁻¹ while it was 10248 m³ ha⁻¹ in the furrow irrigated. Average financial returns from the drip irrigated greenhouses were about 36% higher than farms using furrow irrigation.

Key words: Drip irrigation, surface irrigation, water saving, agronomic efficiency, climate change.

Agriculture is the largest consumer of water globally, accounting for about 70% of all freshwater withdrawals (FAO, 2017). In some countries, this figure can be as high as 95% (Duehrkoop, 2009). In Algeria, total freshwater withdrawal in 2019 was estimated at 9,802 km³ of which 63.7% was used in agriculture. With water stress level now being around 137.9% water scarcity is now being increasingly felt (The World Bank, 2023a, b, c). Therefore, the agricultural sector in the Sahara region needs to focus on water conservation efforts. Desert regions heavily depend on groundwater for irrigation which is a non-renewable resource. In Algeria, it is estimated that 131,776.74 ha land is irrigated using groundwater, against only 5,490.7 ha which is irrigated with furrow water. Overexploitation of groundwater resources raises concerns about the sustainability of irrigation, agricultural and thus negative impact on farmers' earnings (Côte, 2011; The World Bank, 2023a, b, c). The situation can be addressed by (i) a system of governance that guarantees an efficient, equitable and sustainable allocation of the resource (Daoudi *et al.*, 2017) and (ii) by using improved irrigation methods like drip and sprinkler systems. Improving

irrigation methods could be very useful as nearly 70% of agricultural land in Algeria is irrigated by furrow irrigation (Boulahia, 2016). These methods, provide precise water delivery directly to the plant roots, maintain consistent soil moisture levels, promote crop growth, higher yields, higher water use efficiency and better economics besides reducing wastage of water.

Greenhouse tomato cultivation is an agricultural practice that is gaining increasing popularity due to its ability to provide high-quality yields throughout the year. These green houses in the Biskra region use drip, furrow or the combination of the two methods for irrigation. These methods vary in their initial, maintenance and operational cost and consequently also in the agronomic efficiency of the water used which can affect the productivity, profitability and the total water consumption in the green houses. Therefore, a study was undertaken to compare total water use, water use efficiency, water productivity and profitability of the greenhouse using different methods of irrigation. Evaluating the economic profitability of irrigation systems in greenhouse tomato cultivation is crucial for producers. But, several economic aspects like initial, establishment and operational cost must be considered to evaluate the profitability of an irrigation system in greenhouse tomato cultivation. Initial costs can vary depending on the type of irrigation system used (Lekakis *et al.*, 2018) and also within the same type it could vary depending on efficiency and uniformity of water distribution and energy consumption (Kassam *et al.*, 2009, Savvas *et al.* 2019; Seginer *et al.*, 2021).

This study was aimed to identify the most cost-effective system. But despite its importance, there is limited research and accurate data on this topic in the Biskra region. Therefore, a farmer's field survey-based analysis was undertaken in the Biskra region of Algeria; wherein, farmers cultivating tomatoes in green houses were selected following drip, submerged or mixed system of irrigation. The study was aimed to know the tomato productivity and profitability under these systems.

Materials and Methods

The field survey was carried out on thirty farms in the Biskra region of Algeria, which is

known by early market gardening (Fig. 1). The farms were chosen based on specific criteria, such as their location within the region, practice of greenhouse cultivation of tomatoes, and utilization of both drip and furrow irrigation techniques simultaneously. In the absence of such farms, two farms that utilized different irrigation techniques for the same crop were selected, provided they were situated within a 500-meter radius of each other. Additionally, the farm managers were required to have no less than three years of experience in greenhouse farming, to prevent yield losses due to poor cultural practices.

The questionnaire utilized in this inquiry was tailored to elicit data on distinct aspects of the farms, including technical features, consumption of irrigation water, costs and revenues. Data was collected during periodic visits to the farms, every fifteen days during two agricultural campaigns; and documented in an Excel spreadsheet for subsequent evaluation. The questionnaire focused on obtaining information about the irrigation system employed, the type of crop, the cultivated area, the soil type, the volume of water used, the frequency and duration of irrigation, as well as the costs and revenues of the farm; such as irrigation costs, labour costs, input costs, and revenue from crop sales.

The process of selection involved the identification of two farms from each region with comparable soil compositions, while using both irrigation methods. Farmers were asked to install volumetric meters to calculate water consumption, also recorded all technical aspects throughout the two farming seasons (Fig. 2). Regular monitoring of water consumption was conducted at 30 farms equipped with volumetric meters. Meter readings were taken every 15th days to track water usage. Survey forms were then filled in during each periodic visit. Information related to initial cost, maintenance cost and operational expenditure in maintaining irrigation systems was recorded. Apart from this other operational expenditure incurred during tomato cultivation like towards soil preparation, spreading drip lines, sowing, planting, irrigation, energy cost, fertilizers, phytosanitary measures, marketing and labour were also recorded. Total expenditure during the season was calculated by summing up

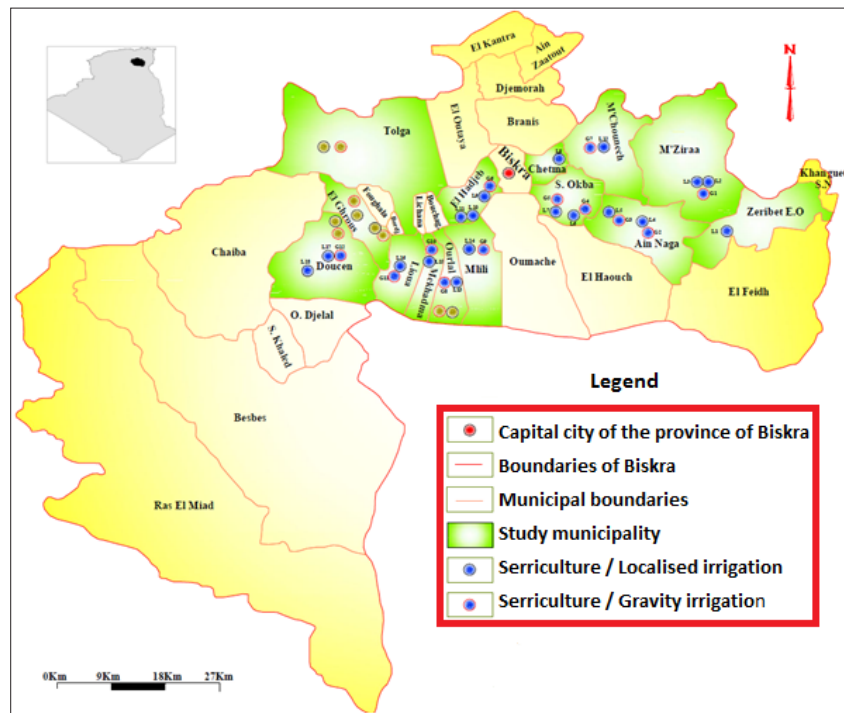


Fig. 1. Spatial distribution of farms of the study.

operational expenditure towards greenhouse management and tomato cultivation.

To accurately define the concept of yield per hectare for greenhouse production, meticulous field measurements were conducted to determine the maximum number of

greenhouses that can be accommodated in a single hectare, taking into account the spacing between rows of greenhouses and between individual greenhouses. After thoroughly examining approximately thirty farms, it was concluded that an average of 16 greenhouses

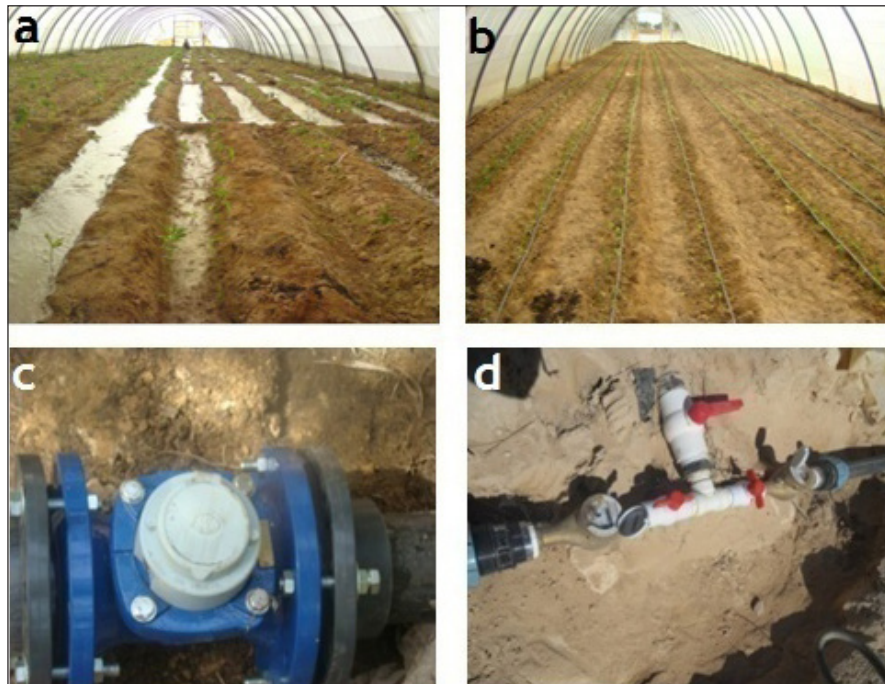


Fig. 2. Irrigation methods and volumetric meters; (a) furrow irrigation, (b) drip irrigation, (c) meter installed in a furrow-irrigated greenhouse, (d) meters installed in a drip-irrigated greenhouse.

per hectare is a suitable representation based on the actual practices observed on the ground. This number has been carefully chosen, taking into consideration the specific conditions of the farms surveyed, which feature greenhouses with a surface area of 450 m² (50 m × 9 m) and a spacing of 3 m between the greenhouses and 10 m between the rows, reserved for ventilation of the greenhouses. Total sales were calculated by multiplying the unit price by the quantity sold for each transaction, and then summing the results

Standards established by Zella (2009) to estimate the theoretical water requirements for greenhouse tomatoes were referred. According to these standards, the recommended water requirement for a vegetative cycle of 140 days is 157 liters per plant. Water productivity was calculated as crop yield per cubic meter of water.

Results and Discussion

Results showed that “Sahara” and “Toufon” were the two major cultivars of tomato in the region. The former comprised 70% of the sample (21 greenhouses) and the latter 30% (9 greenhouses). Concerning irrigation modes, 30% of the farms employed drip irrigation (9 farms), 20% (6 farms) utilized furrow irrigation, while the remainder used the mixed irrigation. The sowing/transplantation of tomato in green houses in the region was carried out from August to October. The production started from March and ended in June. The selling price per kilogram of tomatoes ranged between 25 and 105 Algerian Dinar (DA).

Further, on the basis of survey data the farms were divided into four classes i.e using only drip (CL1), using submergence (CL2), for combination of drip and submergence irrigation. The farms were further divided into two classes-generating a very low net margin below obtained average (CL3), generating a high net margin above average (CL4). Tomato

yields obtained in different class of farms ranged from 37.35 to 71.72 t ha⁻¹ (Table 1).

The production cycle (duration, in days, between the planting of tomato seedlings and the cessation of production) varied between 220 and 250 days. It is apparent that CL1 farms have demonstrated exceptional levels of efficiency in terms of yield and agronomic performance. Despite having a comparatively shorter vegetative period in comparison to other classes, these farms have achieved an impressive yield of more than 70 t ha⁻¹, which is 30% above the average yield. SAB (2021) reported water savings up to 80%, as well as energy savings and higher water use efficiency using drip irrigation. Chrysargyris *et al.* (2020) have reported higher yield of tomatoes in green houses using drip. The remarkable yields recorded in class 1 farms are due to proper fertilization and irrigation at the right times and in appropriate quantity. The second highest productivity was recorded in CL4 (mixed farms) farms i.e. 63.8 t ha⁻¹. This was 15% above the average yield but 11% lower than the yield of CL1. However, the water consumption in this class was significantly higher, leading to lower agronomic efficiency. Class 2 farms (CL2) recorded a yield of around 47 t ha⁻¹, which was almost 14% below the average yield and almost 34% below the Class 1 yield., Class 3 (CL3 mixed farms) had the lowest yield of 37.3 t ha⁻¹, almost 32% below the average yield and less than 48% below that of CL1. Lower yields were due to the several factors like non adherence to technical itineraries, including irrigation, fertilization, and phytosanitary treatments etc. In addition, crop protection against weather accidents, such as frost, and against tomato leaf miner, has caused significant yield losses for some greenhouses.

The average tomato yield recorded during the course of this study (55.11 t ha⁻¹) is lower than that reported by Rekibi (2014), who cited a yield ranging between 84.8 and 100.8 t ha⁻¹ in

Table 1. Tomato yield in different classes of green house

Classes	CL1	CL2	CL3	CL4	Average
Irrigation mode	Drip	Furrow	Mixed	Mixed	
Production cycle (days)	220	229	211	250	228
Yields (tons ha ⁻¹)	71.72	47.52	37.35	63.84	55.11
Gain in yield over average production (%)	30.1	-13.7	-32.2	15.8	-
Change in yield over CL 1 (%)	-	-33.7	-47.9	-11.00	-

Table 2. Water productivity by class and mode of irrigation

Classes	CL1	CL2	CL3	CL4	Average
Irrigation mode	Drip	Furrow	Mixed	Mixed	
Water productivity (kg m ³)	20.4	4.9	8.8	9.3	10.8
Change over average (%)	88.9	-54.9	-18.5	-13.9	-
Change over CL1 (%)	-	-316.3	-131.8	-119.3	-

Table 3. Total water consumption by class and by mode of irrigation

Classes	CL1	CL2	CL3	CL4	Average
Irrigation mode	Drip	Furrow	Mixed	Mixed	
Consumption (m ³ ha ⁻¹)	3722.2	10248	5478.9	7242	6673
Change over average (%)	-44.2	53.5	-17.9	8.5	-
Change over CL1 (%)	-	175.2	47.1	94.5	-

the Biskra region. In other parts of the world, yields vary between 57.6 and 318 t ha⁻¹ (Rezvani Moghaddam *et al.*, 2011) have been reported.

Tomato crop in class 1 farm (CL1) exhibited the highest water productivity of 20 kg m³ which was higher than that reported by Molden *et al.* (2010) (Table 2). On the contrary, CL2 farms, which rely on furrow irrigation, demonstrated the lowest water productivity which was around 5 kg m³. Water productivity was about 9 kg per m³ in greenhouses of CL3 and CL4 classes.

The average water productivity of tomatoes in the study region was 10.8 kg m³ which is twice of the world average (5.4 kg m³) Nederhoff and Stanghellini (2010).

Total consumption was 44.2% lower than the average consumption in CL1. In contrast water consumption was almost three times higher in CL2 *vis a vis*. CL1 indicating high water losses (Table 3). Furthermore, in the case of CL3 (mixed), the water consumption is 18%

lower than the average and one and a half times higher than the consumption of Class 1. Water losses are also considerable in CL 4. The results obtained show that actual consumption significantly exceeded theoretical requirements, indicating that considerable water is wasted during irrigation (Fig. 3). Minimum water wastage was under drip.

In the absence of a suitable approach for estimating potential evapotranspiration at greenhouse scale, the water requirements for greenhouse tomatoes were approximated using the guidelines established by Zella (2009).

The average expenditure incurred in all the four farm classes was 887,200 DA ha⁻¹, or 55,400 DA greenhouse⁻¹. This expenditure covered all costs during the season. Sowing/ planting and fertilization activities within the greenhouses accounted for the largest share of expenses, making up nearly half of the total budget (44.1%), which amounts to 248,200 DA per hectare and two-third of this amount being

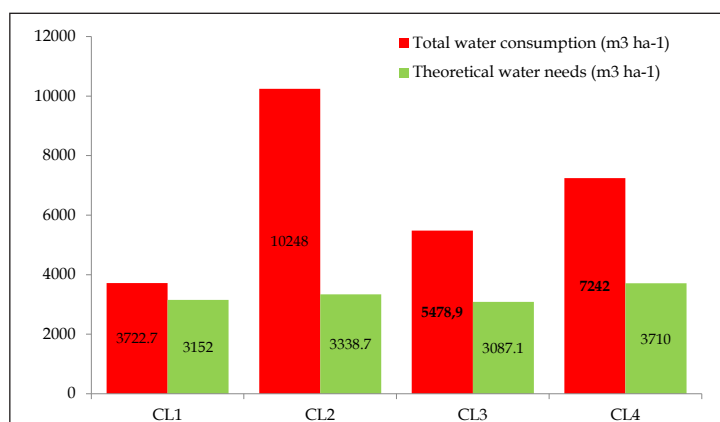


Fig. 3. Gap between actual water consumption and theoretical water requirements for greenhouse-grown tomatoes; (X axis) the theoretical and real needs for irrigation water by class in the study region (Y axis) the volume of water (m³ ha⁻¹).

accounted for fertilisation. The expenditure towards soil preparation and greenhouse maintenance work ranked second, constituting about 14.1% of the total budget, equivalent to 125,000 DA ha⁻¹. Expenditure on marketing and labour was almost the same i.e. 9.8% and 9.3% respectively of overall expenditure. It is crucial to note that marketing expenses were high due to higher transportation costs as about 70% of farmers have to rent transportation vehicles. Expenses incurred towards phytosanitary treatment and land rental account for 8.7% and 7.5% of the total expenditure, respectively costed 77,200 DA ha⁻¹ and 66,800 DA ha⁻¹ i.e. about 3.4% and 3.1% of the total expenditure, respectively. It is important to note that expenses linked to the irrigation network only apply to the drip irrigation system, as the furrow network incurs fewer equipment costs and, therefore, is less expensive.

However, there were variations between different classes. Use of organic fertilizer, constituted approximately 25% of the entire expenditure in CL2 greenhouses (Fig. 4). Owing to the percolation of nutrients caused by furrow irrigation and high irrigation rates, farmers add manure in multiple splits during the season. During colder periods, poultry manure is used as its decomposition helps to warm the soil (Fattouche, 2022). Apart from organic fertilizer, CL2 farms also used mineral fertilizers to meet the nutrients requirement of the crop which accounted for almost 10% of

the total. The expenses towards fertilizers and manures touched 34% of the total expenditure amounting to 264,400 DA ha⁻¹ or 16,500 DA greenhouse⁻¹. As a result CL2 farms not only consumed highest amount of water but also of fertilizers.

Class 1 farms (CL1) incurred minimal expenditure towards fertilizers in comparison to other classes which was about 9% below the average and approximately 15% lower than those of farms practicing furrow irrigation (CL2). In the case of Class 1 farms, the expenses linked to fertilization do not exceed 26% of the total expenditure assigned to greenhouses per campaign. Additionally, the costs associated with the drip irrigation network for this category account for only 6% of the total expenses, which equates to an investment of 3,200 DA greenhouse⁻¹. The savings in fertilizer inputs, as compared to CL2, offset this investment. Moreover, the marketing costs for CL1 are minimum, representing only 7% of the total expenditure with about 80% of the marketing cost being allocated for transportation.

Total expenses were higher in farms in CL3 farm averaging 916,600 DA ha⁻¹ and in CL4 averaging 993,700 DA ha⁻¹ because of the higher cost of workers (117,000 and 124,400 DA ha⁻¹ respectively). In comparison total expenditure in class 1 and 2 was 64,400 and 24,700 DA ha⁻¹). Additionally, the amount required for the payment of agricultural land rent was also highest in class 4 farms (153,200 DA ha⁻¹). The

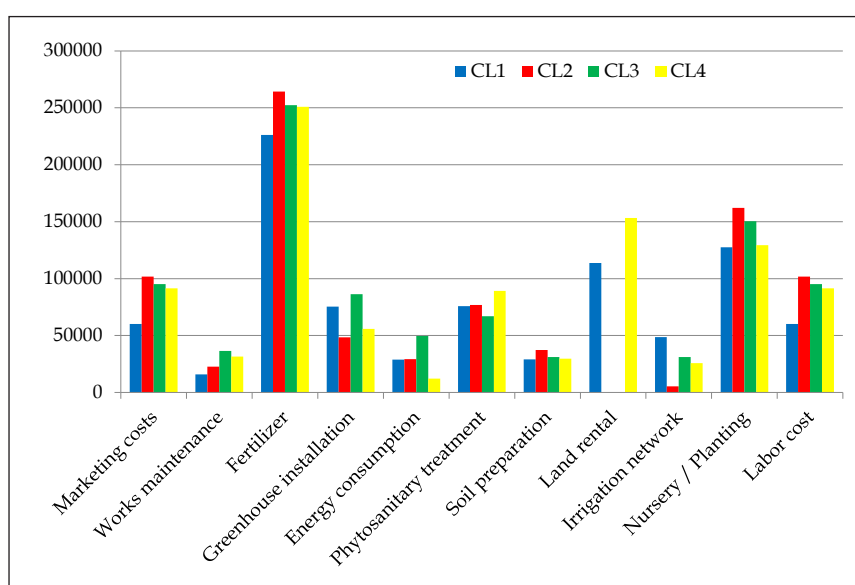


Fig. 4. Total expenditure by operation and by class of farms (In DA ha⁻¹).

Table 4. Added values and net margins generated by exploitation class

Classes	CL1	CL2	CL3	CL4	Average
Irrigation mode	Drip	Furrow	Mixed	Mixed	
Total sales	2253000	1570100	866600	2879700	1892300
Net margin	1789600	1133400	364600	2362700	1412800

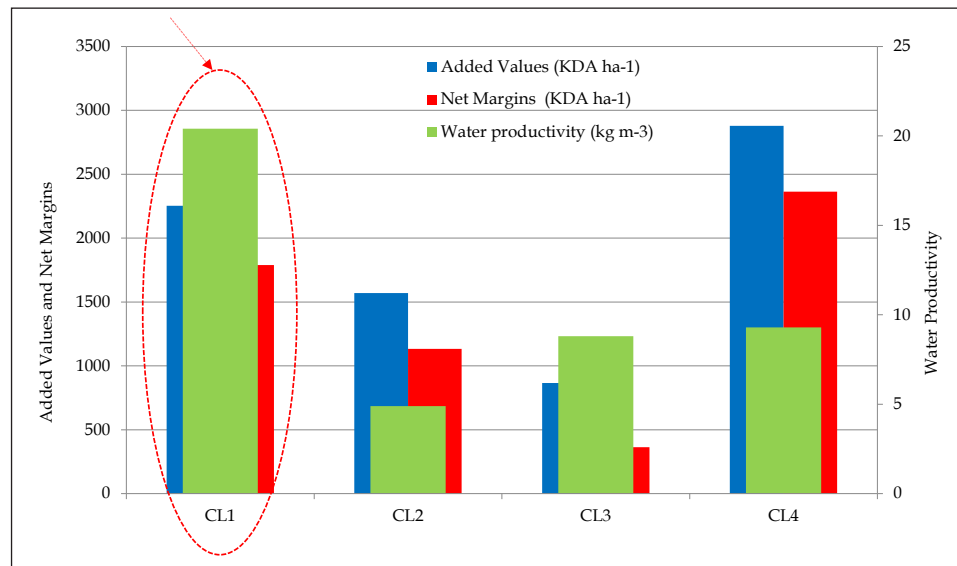


Fig. 5. Gross added values and net margins in relation to water productivity.

total costs of greenhouse tomato production in the Biskra region, calculated at the time of this study (887,000 DA ha⁻¹), were lower than those reported by Rekibi (2014), who reported costs ranging from 119,940.12 to 145,330.75 DA.

The net margin from the greenhouse of CL1 was approximately 178.900 DA ha⁻¹ which was surprisingly lower than from greenhouses of CL3 and CL4 (Table 4).

Our survey has shown that average selling price per kilogram of tomatoes varied over four times from a minimum of 25 to a maximum of 105 DA. Considering this wide range the net margin was more a function of marketing capability of the grower and was not related to any other agronomic efficiency parameter. According to the study by Rekibi (2014), the profit margin for greenhouse tomatoes in the Biskra region varies between 2,255,000 and 3,467,000 DA ha⁻¹. Compared to these figures, the profit margin on the farms considered in this study is below average, except for Class 4 farms (Fig. 5).

Conclusions

The investigation highlights the advantages of drip irrigation in farming. Drip irrigation

farms yield 30% more than the average, with 33.7% higher yields compared to furrow irrigation. Additionally, these farms save 175% more water, using nearly three times less than furrow irrigation. Their agronomic water efficiency is also notable, producing 20.4 kg of tomatoes per cubic meter of water, which is four times more efficient than gravity irrigation. Financially, drip irrigation farms achieve a net margin 36% higher than those using furrow irrigation and a raw benefit 61% greater.

Farmers using less efficient systems should consider transitioning to drip irrigation to improve agronomic efficiency and profitability. Additionally, farms with indirect ownership models tend to have higher net margins, possibly due to larger scale and resource access. These findings emphasize the importance of drip irrigation for sustainable water use, higher yields, and better financial returns, particularly in regions like Biskra, where furrow irrigation is less effective.

Statements and Declarations

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Competing Interests and Funding

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