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# Efficiency of usual irrigation systems and water productivity for crops in Mediterranean and semi-arid climates with reduce hydric requirements. Review

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## Abstract

The performance evaluation of the irrigation process in the field is clearing by to use efficiencies indicator, defined at different stages for irrigation usual systems. Therefore, application efficiency (Ea) is rate at 70 to 95 % in sprinkler irrigation and 100% in drip irrigation; consumption efficiency (Ec) is from 85% to 99% and the transpiration efficiency (Et) is between minimums from levels at 20% to 50% and maximums from 70% to 92%. Therefore, global irrigation efficiency (Eg) or efficiency of irrigation (EI) varies on interval of 49% at 79% in basin system, of 69% to 94% in sprinkler system, from 81% to 97% in drip system. Furthermore irrigation water use efficiency (IWUE) for crops in semi-arid climate regions, respectively in normal and in scarcity hydric conditions, expressed in Kg of product harvested / m3 of water consumed, are by major crops. Wheat (*Triticum sp.* L.): 1.2 to 1.5 vs 0.3 to 5.2. Sugar beet (*Beta vulgaris* L.): 6.0 to 15.0 vs 9.6 to 17.0. Alfalfa (*Medicago sativa* L.): 2.9 to 4.5 vs 1.8 to 4.9. Corn grain (*Zea mays* L.): 3.9 to 4.5 vs 3.7 to 4.9. Maize silage (*Zea mays* L.): 2.9 to 4.5 vs 1.8 to 4.5. Red chili pepper or others common names: Paprika or Niora (*Capsicum annuum* L.): 1.1 to 4.0 versus 1.1 to 1.3. Bulb Onion (*Allium cepa* L.): 9.3 to 16.1 vs 15 to 26.4. Fresh Olives (*Olea europaea* L.): 1.3 to 10.7 against at 1.5 to 12.3; Citrus fruits (*Citrus sp.* L.): 3.0 to 4.7 vs 3.8 to 4.0. We report that normal water use efficiency increases significantly with tolerable level water deficit; in last case, this parameter is improve by drip irrigation system of compared to sprinkler system and more enhanced of confronted to basin irrigation system.

*Keywords:* Irrigation system, Water use efficiency, Water scarcity, Crop productivity, semi-arid climate.

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## 1. Introduction

It is founding that the global water irrigation requirements of crop amount to a sum of 1,501 billion cubic meters per year. Therefore, it needs a global water volume withdrawal of 2,673 billion cubic meters per year, equivalent to the mean efficiency of 56%; by pressing on renewable irrigation water resources a ratio of only 5%. However, for countries of the North African and Middle East zone with different climates from the humid to the Saharan, including climates Mediterranean and semi-arid, respectively the first rate is nearly similar for the rate at 59%, while the second ratio is highly to 43%. Because, in this space, the trend is increasing scarcity of available water resources [1-10].

It is also indicating that the performance of water distribution at agricultural plot level is again dependent on irrigation system adopted, knowing that the reference efficiencies for frequently applied modes like basin, sprinkler and drip irrigation are in the range of ratio : 60%; 80% and 90% [11]. These rates of efficiencies are becoming lower in biotopes with a semi-arid climate [12-16].

In this context, the Mediterranean and semi-arid climate zones are more vulnerable to water scarcity in agriculture related to climate change [17-21]; it is therefore a question of conducting our deep bibliographical research to characterize the main frequently crops , with comparison their optimal irrigation water requirements at realize levels of theirs satisfactions in field.

In this fact, in this publication article, the first work begins to learn about the performance of irrigation systems usually adopted [12,22,23]. This is following by an analysis of the comparative agronomic behavior of crops cultivated under experimental conditions of water deficit, simulating the high natural aridity or technical anthropic intervention to economize water. It is carried out in relationship to their normal water situation, witch randomized at case-to-case frequent irrigation system [12,24-26].

In this context, our reflection is implicitly dealing with the latent problem of the recurrent future threat to irrigated agriculture in a semi-arid environment, in a model area in Mediterranean-North African region. This determinate space is the potential agricultural perimeter from Tadla to the Moroccan territory, with a surface area of 325,000 ha, with a rich diversity of irrigated strategic crops on a surface area of 120,000 ha, of major part by great hydraulic. Where is a serious risk of deficiency in irrigation water, consequently inciting public authorities to start important regional project for fundamental reconversion (88,000 ha surface's) of a dominant irrigation basin system, which is too wasted water by another more very efficient, the drip irrigation system [27].

## 2. Practical methods for determining irrigation efficiencies and crop water use

### 2.1. Irrigation efficiency indicator

The *irrigation efficiency* (EI) or *global efficiency* (Eg) is expressing as follows [28]:

- *Formula*. **EI (or Eg) = [Water used beneficially / Total water applied]**

This hydraulic indicator is more explicating as the following by pertinent sub-indicators [23]:

***Transport efficiency (Et)***: is referring on technological performance, in the range of 30 % to 70 % in basin irrigation system and 70 % to 90 % in pressure irrigation systems (sprinkler, drip,...).

***Application efficiency (Ea)***: shows accurate information on movement of flow in plot, by a ratio at water consumed by crop (Ec) with water really applied in the land (El) (Ea = (Ec/El).

***Irrigation efficiency (EI) or global irrigation efficiency*** (Eg): indicates the simple product: Ea x Et.

In this fact, the agronomic exploiting of water by a crop is defining at important indicator as *Irrigation water use efficiency (IWUE);* it is implicitly a relationship agricultural productivity of water [12].

### 2.2 Steps for determining irrigation efficiencies

The practical evaluation of water volumes by irrigation efficiency steps is basing on level precision of measurement instruments used, such as it is determining of efficient rainfall and crop evapotranspiration. We use in situ at field the direct methods or for the reasons of facilitating the empirical formulas afferent of indirect methods are employing. So, we are considering the water losses between headland of plot and a crop finish destination [11, 12, 29].

Therefore, any efficiency considered is highly depending of specific hydraulic stage, in relationship on level of irrigation water circulation [11]:

*Level 1*: Water progress in plot (Pi), a part is lost through equipment leaks.

*Level 2*: Water applied (Ai) for portions evaporate or lost during transport or intercept into way by the vegetation cover.

*Level 3*: The water passes at ground (Si) with parts by runoff or drainage.

*Level 4*: Water retained in the root zone of the plant (ZRi); with part of evapotranspiration from weeds of crop and part persistent after harvest.

*Level 5*: Water effetely is evapo-transpiring by crop (ETRi); with a part, which deleted of water evaporated directly from the soil.

*Level 6*: The water absorbed and transpired by crop (Ti), this is necessary for development and growth of the crop, factors that are concretizing in agricultural by the productive yield.

Thus, irrigation water efficiencies at farm plot are showing in the following priority steps [11]:

- *Step I*: *Plot distribution efficiency* (Ed) (= (Ai / Pi) = Applied Water / Plot Input Water); also called *uniformity coefficient (CU)*, so used in the case of performance control of pressurized networks including the drip irrigation system.
- *Step II*: *Application efficiency* (Ea); (= (Si / Ai) = Water reaching the soil / Water applied); Ea is generally at 100% for drip irrigation system.

- *Step III*: *Storage Efficiency* (Es) (= (ZRi / Si) = Water retained in root zone / Water arrives to soil).
- *Stage IV*: *Consumption Efficiency* (Ec) (=(ETRi/ZRi)=Evapotranspiration/Water stills in root zone).
- *Step V*: *Transpiration Efficiency* (Et) (= (Ti / ETRi) = Transpired water / Evapotranspired water).

These five steps then make up the *global irrigation efficiency* (Eg), result of product of the intermediate efficiencies with Eg = Ed x Ea x Es x Ec x Et.

## 3. Irrigation water efficiency

### 3.1 Usual water efficiencies in irrigation systems

Intermediate efficiencies of plot irrigation process for use crops, in conventionally irrigated systems and in different world regions are defining synthetically as following; its are detailing in **Table 1:**

-*Application efficiency* (Ea) : 70-95% of sprinkler and 100% of drip irrigation system.

-*Consumption efficiency* (Ec): 85 to 99% for all irrigation systems.

-*Transpiration efficiency* (Et): a range at minimum 20% to 50% to maximum 70% to 92%.

-The product: Ed x Ea x Es : for part of water accessible to crop, his percentage value is 35% to 95% in basin irrigation system; 72% to 90% in sprinkler system and 70% to 95% in drip irrigation system.

-The efficiency product Es x Ec: Where water arriving on the ground and evapotranspired by crop; it is corresponding of value is 86% in basin irrigation system in case of integral plant cover.

-Global irrigation efficiency (Eg): in final, the value efficiency is in range at 49% to 79% in basin irrigation; 69% to 94% in sprinkler irrigation and 81% to 97% in drip irrigation.

Specifically, on growing areas in Morocco, the irrigation efficiencies in practice are comparing to the potential values [12], which detail are showing in **Table 2**. In the irrigated perimeters of Morocco, global irrigation efficiency system's is practically at range [12]: at 60% to 80% in sprinkler and at 40% to 60% in basin (**Table 2**).

**Table 1:** Water efficiency by irrigation systems by global locations and crops

| Location of experiment | Crop (*) | Efficiencies (**) | Irrigation systems | Efficiency value (%) Average | Minimum | Maximum | Authors' references |
|---|---|---|---|---|---|---|---|
| Various locations | General case of crops | Ea | -Basin irrigation<br>-Drip irrigation<br>-Cannon irrigation reel | -<br>-<br>100 | 85 to 90<br>70 to 75<br>- | -<br>95<br>- | Granier and Deumier (2013) (***) |
| Spain | Corn (1) | Ea | -Full cover irrigation | 92 | - | - | Carrion & *al.*, 2014 (***) |
| General | General | Ec | -General system irrigation | - | 85 to 92 | 97 to 99 | [11,28] |
| | | Et | -General system irrigation | - | 25 to 50 | 70 to 92 | |
| Spain | Corn (1) | Es x Ec | -Full cover irrigation | 86 | 84 | 89 | Carrion & *al.*, 2014 (***) |
| | | Ed x Ea x Es x Ec | | 79 | 77 | 82 | |
| Italy | Corn (1) | Ed x Ea x Es by irrigation act | -Basin irrigation | - | 53 | 95 | Canone & *al.*, 2015 (***) |
| Various locations | General case | Ed x Ea x Es | - General system irrigation | - | 30 to 50 | 70 to 95 | [11,28] |
| Various locations | General case | Ed x Ea x Es | -Basin irrigation<br>-Drip irrigation | 75<br>87 | 50<br>70 | 95<br>95 | Howell (2003) (***) |
| Spain (Ebre Valley) | -Alfalfa (2)<br>-Corn (1)<br>-Sunflower (3) | Ed x Ea x Es | -Basin irrigation in alluvial soils with high RU | 62 | 51 | 81 | Lecina & *al.*, 2005 (***) |
| | -Alfalfa (2)<br>-Corn (1)<br>-Sunflower (3) | Ed x Ea x Es | -Basin irrigation surface in soils with high RU | 53 | 40 | 75 | |
| | -Tomato (4)<br>-Pepper (5) | Ed x Ea x Es | -Basin irrigation in soils of high RU | 35 | 27 | 39 | |
| Spain (Ebre Valley) | General case | Ed x Ea x Es x Ec | -Basin irrigation in soils of low RU | 49 | - | - | Causape & *al.*, 2006 (***) |
| | | Ed x Ea x Es x Ec | -Basin irrigation in deeper soils | 79 | - | - | |
| USA (New Mexico) | -Alfalfa (2)<br>-Cotton (6) | Ed x Ea x Es x Ec | -Basin irrigation | 66 to 60 | 11 to 14 | 90 to 95 | Ahadi & *al.*, 2013 (***) |
| Espagne (Huelva) | - Strawberry (7) in tunnel | Ed x Ea x Es x Ec | -Drip irrigation | 70 | 58 | 81 | Lozano & *al.*, 2016 (***) |
| Morocco | -Onion (8)<br>-Potato (9) | Ed x Ea x Es x Ec | -Drip irrigation | 57 | 25 | 97 | Benouniche & *al.*, 2014 (***) |
| Italy | -Onion (8)<br>-Industrial tomato (4)<br>-Tobacco (10) | Ed x Ea x Es x Ec | -Drip irrigation | 63 | 39 | 81 | Ghinassi, 2012 (***) |

*NB: (*): Nomenclature of cultures with latin names: (1) : Corn (Zea mays* L.) ; *(2) : Alfalfa (Medicago sativa* L.) ; *(3) :* Sunflower *(Helianthus annuus* L.) ; *(4) :* Tomato *(Solanum lycopersicum* L. ) ; *(5) :* Pepper *(Capsicum annuum* L.) ; *(6) :* Cotton *(Gossypium sp.* L.); *(7):* Strawberry *(Fragaria sp.* L.) ; *(8) :* Onion *(Allium cepa* L.) ; *(9) :* Potato *(Solanum tuberosum* L.) ; *(10) :* Tobacco (*Nicotiana tabacum* L.).

*(**): Abbreviations: Ed: distribution efficiency; Ea: application efficiency; Es: storage efficiency; Ec: consumption efficiency; Et: transpiration efficiency; EG: global irrigation efficiency; RU: water useful reserve of soil.*

*(***): References are citing by authors: Wittling & Molle (2017)* [11].

**Table 2:** Reference data of irrigation efficiencies at irrigated perimeters by great hydraulic in Morocco

| Irrigation system | Irrigation efficiency (%) | | | | | | References of authors |
|---|---|---|---|---|---|---|---|
| | Network | | Plot | | Global | | |
| | Potential (P) | Current (A) | P | A | P | A | |
| **Basin irrigation with « open sky » method's** | 85 | 80 | 70 | 50 | 60 | 40 | Bouaziz & Belabbes, 2002 [12] |
| **Sprinkler** | 95 | 85 | 85 | 70 | 80 | 60 | |

### 3.2. Usual agronomic efficiencies of irrigation water use

There are references to agronomic efficiencies in use of water for irrigated crops, in normal and water deficit situations with more current irrigation systems.

#### *3.2.1. Autumn cereals crops*

Durum Wheat (*Triticum durum* L.) in Chlef area (Algerian region), was tested of four water treatments under gravity irrigation as: *i)* Non-irrigated (rainfall regime); *ii)* early irrigation from emergence to heading; *iii)* late irrigation from heading to physiological maturity and *iv)* permanent irrigation from emergence to physiological maturity. Theirs values of efficiencies IWUE are at 2.3 to 5.2 kg grain per m3 water [30].

In Moroccan irrigated areas, major case by a great hydraulic process: the IWUE of wheat (*Triticum sp*. L.) in water deficit situations at Doukkala perimeter is value at 0.39 to 1.67 kg/m3 according by authors Belabbes and Kaddani (1999), cited by authors Bouaziz and Belabbes [12]. In Tadla perimeter, this efficiency parameter's is varying at 0.70 to 1.80 kg grain per m3 of water [12].

With positions of sprinkler irrigation system, experimented in lower Valley of Medjerdain (Tunisian region), for Durum Wheat cultivation, the IWUE is fluctuant at 0.8 to 1.3 kg/m3 [31].

In other test on Wheat crop in Haouz area's irrigated (Moroccan region), with support of space remote sensing technique by using the NDVI vegetative index, respectively parameter IWUE in drip and basin irrigation systems are 1.50 and 1.17 Kg/m3 , shows a percentage of deviation inter systems of +24% [32].

#### *3.2.2. Sugar beet crop (Beta vulgaris L.)*

The repetitive cropping tests on Sugar Beet (*Beta vulgaris* L.) in Tadla perimeter (Morocco) for four successively agricultural campaigns, approve that increasing a root production of water in drip irrigation system (mean IWUE: 13.78 kg /m3) in comparison with basin irrigation system (mean

IWUE : 7.67 kg /m3), corresponds a deviation to 113%. It is also better compared to sprinkler irrigation system (mean IWUE: 11.03 kg /m3) by presenting a ratio of increase to 72%. About a sugar production linking of water consumption, the drip irrigation system (mean IWUE: 2.58 kg /m3) improves it respectively vs two precedents systems with important deviation at 91% and at 53% of the IWUE (Basin: 1.33 Kg/m3 and Sprinkler: 2.03 Kg/m3) [33], results detailed in **Table 3**.

**Table 3:** Comparative agronomic water efficiencies for drip, sprinkler and basin irrigation systems for Sugar Beet crop (*Beta vulgaris* L.) in Tadla perimeter (Morocco) [33].

| | | **Agronomic water efficiency (IWUE) by Kg product / m3 water** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Root production** | | | **Sugar production** | | |
| Irrigation systems | | **Drip (D)** | **Sprinkler (S)** | **Basin (B)** | **D** | **S** | **B** |
| Tests by campaigns | 2011/2012 | 12.49 | 10.08 | 6.72 | 2.28 | 1.82 | 1.16 |
| | 2012/2013 | 18.91 | 14.45 | 10.64 | 3.26 | 2.48 | 1.69 |
| | 2013/2014 | 11.70 | 9.54 | 6.64 | - | - | - |
| | 2014/2015 | 12.02 | 9.99 | 6.65 | 2.20 | 1.80 | 1.15 |
| IWUE average | | **13.78** | **11.03** | **7.67** | **2.58** | **2.03** | **1.33** |
| CV % (*) sur IWUE | | **25%** | **21%** | **26%** | **23%** | **19%** | **23%** |

*NB (*) CV %: Coefficient of variation*

In this fact, under a basin irrigation system, the water deficit test on Sugar Beet crop, in potential productive areas of Morocco country, show that a water regime at 80% of evapotranspiration maximum (ETM) give consequently the best agronomic efficiency of water use [12], more information in **Table 4**.

**Table 4:** Agronomic water efficiencies for Sugar Beet crop (*Beta vulgaris* L.) under water deficit regime in the large irrigated perimeters of Morocco with basin irrigation system.

| **Zone** | **Water regimes** | **Agronomic water efficiency (IWUE) (Kg product / m3 water)** | | **References of authors** |
|---|---|---|---|---|
| | | **Root production** | **Sugar production** | |
| **Tadla perimeter** | Variants of regimes | 0,44 to 11,19 | - | Bouaziz & Belabbes, 2002 [12] |
| **Doukkala perimeter** | T1 (100 % ETM *) | 14.83 | 2.37 | Oussaid, 1996; reference is citing by authors: Bouaziz & Belabbes, 2002 [12] |
| | T2 (80 % ETM) | 16.73 | 2.61 | |
| | T3 (60 % ETM) | 15.16 | 2.30 | |
| | T4 (40 % ETM) | 12.34 | 1.86 | |
| | Control test farmer | 14.07 | 2.07 | |

*NB (*) ETM: Evapotranspiration maximum of crop*

So, under drip irrigation system with water deficit on Sugar Beet crop, where is according to the filling of the useful soil water reserve (RU) by experiment in Konya region (Turkey), in arid semi-arid climate. The five water regimes are testing: *i)* Control test; 100% RU; *ii)* 75% RU; *iii)* 50 % RU and iv) 25% RU. The values of results for respective IWUE are following at 7.91; 9.64; 10.30 and 11.50 Kg/m3 [34]. In therefore, a tolerant water deficit increases correlatively the hydric agronomic efficiency for this frequent sugar crop.

### *3.2.3. Alfalfa crop (Medicago sativa L.)*

The alfalfa crop (*Medicago sativa* L.) experimented in Morocco area, under basin irrigation, shows the high level of IWUE at 1.4 to 2.0 Kg of product by 1 m3 of water with deficit regime hydric at 40% ETM. On the drip irrigation system, with regimes lower volume water between to 40 at 100% ETM of crop, the IWUE is varying at 1.8 to 2.8 Kg/m3 [25].; detailed data's in **Table 5**.

**Table 5:** Efficiencies for alfalfa crop (*Medicago sativa* L.) under water deficit regime in large irrigated perimeters in Morocco.

| Zone | Irrigation system | Campain | Irrigation water use efficiency (IWUE) by hydric regim (Kg product / m3 water) | | | | References of author's |
|---|---|---|---|---|---|---|---|
| | | | T1 (100 % ETM) | T2 (80 % ETM) | T3 (60 % ETM) | T4 (40 % ETM) | |
| **Tadla perimeter** | Basin | 2009/2010 | 1.44 | 1.42 | 1.77 | 1.81 | Bouazzama & *al.*, 2015. [25] |
| | | 2010/2011 | 1.46 | 1.69 | 1.52 | 2.01 | |
| | Drip | 2009/2010 | 1.79 | 1.92 | 2.,21 | 2.18 | |
| | | 2010/2011 | 2.25 | 2.23 | 2.47 | 2.82 | |

### *3.2.4. Maize crop (Zea mays L.)*

The water use efficiency per silage maize crop (*Zea mays* L.) under normal water regime in the large irrigated areas of Morocco, by great hydraulic technic; gives the higher level under drip irrigation at value to 4.5 Kg/m3. On the basin irrigation system, this parameter is value at 2.85 to 2.99 Kg/m3. In experiment conditions with water deficit with 20% to 80 % ETM, the IWUE (1.84 to 2.77 Kg/m3) is lower at 24 to 35 % under basin irrigation when comparing in normal situations; but under the drip irrigation system, the levels of IWUE (4.23 to 4.5 Kg/m3) are maintaining constant in any situation of water scarcity [33,35]. Information detailed is showing in **Table 6**.

**Table 6:** Agronomic water efficiencies for maize crop (*Zea mays* L.) in deficit regime hydric under basin and drip irrigation systems in Tadla perimeter in Morocco

| Irrigation Systèms | Campains of tests | Hydric régimes | IWUE (*) Kg DM(**)/m3 | References of author's |
|---|---|---|---|---|
| Basin | 2008/2009 | T1 (100 % ETM) | 2.99 | Bouazzama & *al.*, 2012 [35] |
| | | T2 (80 % ETM) | 2.54 | |
| | | T3 (60 % ETM) | 2.44 | |
| | | T4 (40 % ETM) | 2,14 | |
| | 2009/2010 | T1 (100 % ETM) | 2.85 | |
| | | T2 (80 % ETM) | 2.77 | |
| | | T3 (60 % ETM) | 2.62 | |
| | | T4 (40 % ETM) | 2.41 | |
| | | T5 (20 % ETM) | 1.84 | |
| Drip | 2009/2010 | T1 (125 % ETM) | 4.26 | ORMVA of Tadla, 2017 [33] |
| | | T2 (100 % ETM) | 4,50 | |
| | | T3 (75 % ETM) | 4.23 | |
| | | T3 (50 % ETM) | 4.39 | |

*NB: (*): IWUE: Irrigation water use efficiency; (**): DM: dry matter of product at crop.*

It is also reporting results of experiment, in Coruche region (Portugal) a meso-mediterranean climate, that in case if more prolonged water supply at the end of the production cycle (hydric regime C) of grain maize (*Zea mays* L.), the IWUE is better in drip irrigation system (4.88 Kg/m3). Whereas this efficiency indicator still approximate constant on the sprinkler irrigation system with any deficit regime hydric (range: 4.40 to 4.47 Kg/m3) [24]; as indicated in **Table 7**.

### *3.2.5. Vegetables crops*

Across vegetables crops exploited in potential irrigated area of Tadla perimeter (Morocco country's) [27], it is referring at follow specifically onion crop (*Allium cepa* L.) and industrial crop Red Chilli Pepper (*Capsicum annuum* L.), which also named in basin Mediterranean by Paprika or by Niora.

#### a) Onion (*Allium cepa* L.)

It is found that on basin irrigation system, associated to experiment using early hybrid selection of vegetable material about yellow onions type ; which has characteristic by short production cycle of five-month. This cultivar is comparing to the late local genetic selection of red onions type with a production cycle at seven-month. In this fact, the reduction of irrigation water coinciding at sensitive physiological stage of bulb development, with a hydric regime of 60 % to 80 % ETM of crop, shows in all situation that the IWUE stills at the small interval of values at 9.3 to 9.6 kg of fresh onion bulb product per one m3 of water consumed [36].

**Tableau 7:** Agronomic efficiencies of irrigation water of grain maize crop (*Zea mays* L.) by modeling tests with deficit water regimes on pressure irrigation systems [24]

| **Irrigation system** | **Hydric regim**<br><br>(Management irrigation by fractions of RU)) | **Fractions (p) of the RU (*) assigned to the crop stages for irrigation management**<br>**Initial** | **Développement** | **Middle cycle** | **End cycle** | **Agronomic efficiency of water use production**<br><br>(Kg product / m3 water) |
|---|---|---|---|---|---|---|
| **Drip irrigation** | **A** (No deficit) | 0.65 | 0.65 | 0.65 | 0.65 | 3.90 |
| | **B** (Deficit in cycle start) | 1.2 x 0.65 (**) | 0.65 | 0.65 | 0.65 | 3.67 |
| | **C** (Deficit at end of cycle) | 0.65 | 0.65 | 0.5 | 1,2 x 0.65 | **4.88** |
| | **D** (deficit all cycle) | 1.2 x 0.65 | 1.2 x 0.65 | 0.65 | 1.2 x 0.65 | 3.77 |
| **Sprinkler** | **A** (No deficit) | 0.65 | 0.65 | 0.65 | 0.65 | 4.45 |
| | **B** (Deficit in cycle start) | 1.2 x 0.65 | 0.65 | 0.65 | 0.65 | 4.47 |
| | **C** (Deficit at end of cycle) | 0.65 | 0.65 | 0.65 | 1.2 x 0.65 | 4.40 |
| | **D** (deficit all cycle) | 1.2 x 0.65 | 1.2 x 0.65 | 0.65 | 1.2 x 0.65 | 4.76 |

*NB: (*): RU: utility reserve of soil, which based of management irrigation of crop.*

*(**): Underline indicates rationing of irrigation with deficit water dose at 20% RU in determinate stage of crop*

In conduct drip irrigation system, with reduction of water requirements for seasonal onion crop (*Allium cepa* L.), it has been tested in northwest China region, at semi-arid continental climate: The semi-arid area of northern China (SAC) accounts for about 11% of the arable land in China. Therefore, the agronomic efficiency of water use increases in relationship with hydric deficit, as a particularly the case about generalization this scarcity, affected to all the physiological stages of this vegetable plant (onion); the IWUE is varying at 14.2 to 26,4 kg/m3 [37]; detailed results in **Table 8**.

**Table 8:** Effects of water deficit on the agronomic efficiency of water production by onion (*Allium cepa* L.) cultivation under drip irrigation [37].

| **Designation** | | **Water regimes to reduce ETM in stages of cycle crop** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **All stages affected** | | | **Non affected** | **Selected stages affected** | | | |
| | | **T1** | **T2** | **T3** | **T4** | **T5** | **T6** | **T7** | **T8** |
| **Coefficients of reduce water regimes assigned to physiological stages** | **Initiation** (10 to 16 days) | 0.4 (*) | 0.6 | 0.8 | 1.0 | 0.4 | 1.0 | 1.0 | 1.0 |
| | **Development** (30 to 36 days) | 0.4 | 0.6 | 0.8 | 1.0 | 1.0 | 0.4 | 1.0 | 1.0 |
| | **Bulb stage** (36 to 46 days) | 0.4 | 0.6 | 0.8 | 1.0 | 1.0 | 1.0 | 0.4 | 1.0 |
| | **Maturity** (93 to 102 days) | 0.4 | 0.6 | 0.8 | 1.0 | 1.0 | 1.0 | 1.0 | 0.4 |
| **Irrigation water use efficiency (IWUE)** (per $Kg/m^3$) | **Minimum** | 19.18 | 15.92 | 16.12 | 14.22 | 15.61 | 15.00 | 15.92 | 15.82 |
| | **Maximum** | 26.40 | 19.61 | 18.80 | 16.05 | 17.75 | 17.49 | 18.95 | 17.95 |

*NB: (*) Underlined value indicating water reduction of culture at ETM in physiological stage determinate.*

#### b) Red Chilli Pepper (*Capsicum annuum* L.)

Under basin irrigation system, with of Red Chilli Pepper ( Paprika or Niora) crop trial, a period 200-day development cycle, has been experimented in Kairouan plain (Country of Tunisia), in Mediterranean climate, it was given value of IWUE at 3.71 to 3.95 kg of fresh matter product per m3 of water used [38].

In drip irrigation, for a three-month crop cycle, of experiment in greenhouse, conducting in South African continent, with management irrigation of using a pan class A affected by four correction coefficients value's: 0.4; 0.6; 0.8 and 1.0; show respectively the IWUE(s) following: 1.10; 0.93; 1.27 and 1.09 kg of fresh product per m3 of water employed. Globally, trend increasing of efficiency agronomic product for water consumptive evolves in sense of more deficit hydric situation [39-50].

### *3.2.6. Fruit trees*

Olive trees (*Olea europaea* L.) and citrus (*Citrus sp*. L.) are more dominant tree species in irrigated zones of Morocco area; therefore, it been selected two model potential perimeters of Tadla and Haouz at semi-arid and arid climates [27].

#### a) Olive trees (*Olea europaea* L.)

The results of experimentation on young olive orchards (*Olea europaea* L.; *subsp. europaea var. europaea*) in irrigated perimeter of Haouz (Morocco), approve that comparing to basin irrigation system, the drip irrigation system gives a significant increase ratio of product agronomic of water use, which multiplied by factor at 6 or 7. Also, in drip irrigation system, the water deficit regime with 70% ETM of crop, inducted a positive deviation of IWUE at 16%; when compared to normal hydric regime [51], more detailed in **Table 9**.

**Table 9:** Agronomic efficiencies of water use under deficits hydric in the olive orchards (*Olea europaea* L.) with basin and drip irrigation systems in Haouz irrigated perimeter (Morocco) [51]

| Irrigation system | Campain' test | Water regime | Irrigation water use efficiency (IWUE) (per Kg olive /m$^3$) |
|---|---|---|---|
| **Basin** | 2011/2012 | Farmer control test | Not yet productive |
| | 2012/2013 | Farmer control test | 1.83 |
| **Drip** | 2011/2012 | T1(100 % ETM)<br>T2(70 % ETM) | Not yet productive |
| | 2012/2013 | T1 (100 % ETM)<br>T2 (70 % ETM) | 10.67<br>12.32 |

Around the Mediterranean basin in potential olive plantations areas, where olive trees are conducted in a strictly rainfall or simplicity benefiting from supplemental irrigation or used regular water during the productive cycle. So, we are referring à drip irrigation system, with water reduction in relation to the optimal water requirement of the crop, improves the agronomic efficiency of water use. On experiments in those objects, the IWUE evolving over a wide range from 1.22 to 12.42 kg of fresh olives per one m$^3$ of water consumed [26, 62, 63]. The detail of relevant results at **Table 10**.

### b) Citrus trees (*Citrus sp.* L.)

In clementine orchards (*Citrus clementina T)* or *(Citrus reticulata L. clementine varietal group*) with a drip irrigation system using number to 4 or 6 drippers per tree in double ramps, efficiency product agronomic of water is the high [64].

The water deficit of orange trees (*Citrus sinensis* L.), under a drip irrigation system, is testing in the irrigated perimeter of Souss (Morocco) and is showing a better IWUE resulting of the water regimes from management irrigation at 25% and 30% reduction evaporation of pan Class A. In this order, is been found when the volume water irrigation increase at ratio variant at 5% to 15%, inducting conversely a decrease in IWUE of percentage at 22% to 25% [65]. Recapitulations results are presenting in **Table 11**.

**Tableau 10:** Agronomic water efficiency for olive orchards (*Olea europaea* L.) in the Mediterranean areas, under different water deficit regimes with drip irrigation system.

| **Experimental location** | **Water régimes** | **Irrigation water use efficiency (IWUE)** (per Kg olive /$m^3$) |
|---|---|---|
| **Izmir Region (Western Turkey) [62]**<br><br>-Initial age: 20 years<br>-Observation period: 2007-2010 | • T5 ($K_b$=1.25)<br>• T4 ($K_b$ =1.00)<br>• T3 ($K_b$ =0.75)<br>• T2 ($K_b$ =0.50)<br>• T1 ($K_b$ =0.25)<br>• T6 (as a function of soil humidity).<br>($K_b$ : evaporation coefficient ($E_v$.) in pan Class A; with formula: ETM=$K_b$ x $E_v$) | 1.22<br>1.54<br>1.72<br>2.74<br>4.07<br>1.28 |
| **Cordoba area (Spain) [62]**<br>-Initial age of olive trees: 17 years old<br>-Observation period: 2004-2006 | • T1 (100 % ETM)<br>• T2 (25 % ETM, continued deficit)<br>• T3 (25 % ETM, regularized deficit, without irrigation between July/Mid-September) | 2.51 to 5.62<br>9.46 to 11.76<br>6.82 to 12.42 |
| **Badajoz area (Southwest Spain) [63]**<br><br>-Initial age of olive trees: 4 years old<br>-Observation period: 2002-2007 | ***1st experiment (2002-2004) :**<br>• T1 (125 % ETM)<br>• T2 (100 % ETM)<br>• T3 (75 % ETM)<br>• T4 (Pluviometric regime)<br><br>***2nd experiment (2005-2007)** :<br>• T1 (115 % ETM)<br>• T2 (100 % ETM)<br>• T3 ( 75 % ETM) | <br>1.89<br>2.81<br>3.79<br>Not determined<br><br><br>1.63<br>2.16<br>4.57 |

**Table 11:** Water deficiency tests on citrus orchards (*Citrus sp.* L.) under drip irrigation system in irrigated perimeter of Souss (Morocco) [66]

| **Water régime** (Operated by fraction of the evaporation in pan Class A (Ev.)) | **Irrigation water use** efficiency (IWUE) (per Kg fruit /$m^3$ water) | **Deviation of the IWUE from the control regime (T5)** ( %) |
|---|---|---|
| **T1: 40 % Ev.** | 2.99 | -25% |
| **T2: 35 % Ev.** | 3.11 | -22% |
| **T3: 30 % Ev.** | 3.97 | -1% |
| **T4 : 25 % Ev.** | 3.78 | -6% |
| **T5 : Farmer Control Regime** | 4.01 | Calculation basis |

## Conclusion

The performance of the drip irrigation system is the highest from the point of view of both the intermediate efficiencies and global efficiency, from the head of the agricultural plot to the correct level of direct water used by the subject plant of the exploited crop. The agronomic production water crops in Mediterranean and semi-arid climates areas is significantly improving in the case of water deficit at the limit of the water stress tolerable by the plant cultivate ; it is also more favoring by the most efficient irrigation systems, as the first rank a drip irrigation method. In perspective works, it is suggesting to realize the studies of models water deficits for accurate projections in irrigation volumes at the just requirements. Therefore, the predicts to values of crops productions levels will be to accord with priority sustainable strategies by rigorous management a limited water resources in relationships at security human alimentary.

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