# RATIONALIZATION OF IRRIGATION WATER IN AGRICULTURAL SECTOR THROUGH INTEGRATED WATER MANAGEMENT AND COMMUNITY PARTICIPATION

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## ABSTRACT

The limited water and land resource in Egypt is faced with the challenge of currently feeding more than 85 million people and about 100 million by the year 2025. As there are no new water resources expected in the near future and that more water is diverted to domestic and industrial purposes. There is an urgent need to increase water productivity to meet the increasing demand for food and food security. In this respect, National Agricultural Research System (NARS) in Egypt, had joined hands with the International Center for Agricultural Research in the Dry Areas (ICARDA) to initiate a community-based participatory approach for identifying and disseminating interventions for increasing water productivity. Based on the socio economic and technical criteria four farms at Monofia Governorate (Nile Delta) were selected to research options for improving water productivity (WP) at the farm and community scheme levels. New interventions included:

1- Planting wheat, berseem and maize crops on wide furrows (raised -seed bed).

2- Irrigating wheat, berseem clover and maize under deficit irrigation. The field trials were executed in 2007/2008 and 2008/2009 seasons. The most important findings could be as follows :-

* Planting wheat, berseem and maize crops on raised - seed bed saved water, increased yield and improved WP as compared to farmer practice.
* Under irrigation regime at 1.2 ETc and deficit irrigation at 0.70 ETc, the reductions in water applied for wheat and berseem crops reached 6.90 and 39.85% and 5.77 and 26.69%, respectively, comparable with the farmer practice. Similar trend was noticed with maize crop where the reductions in water applied, due to irrigating at 1.2 and .075 ETc, ranged from 5.89 to 25.54%, compared with farmer practice. In 2007/2008 season full and deficit irrigation(0.70 ETc) regimes slightly reduced wheat grain yield by 0.83 and 2.65%, whereas in 2008/2009 season, full and deficit irrigation (0.70 ETc) regimes increased wheat grain yield by 6.78 and 1.95%, respectively, in comparison with farmer practice. In 2008 season, maize yield was reduced by 8.01 and 12.49% due to full and deficit (0.75 full irrigation) irrigation regimes, respectively, as compared with farmer practice. In 2009 season, the trend was differed where full irrigation exhibited higher maize grain yield value (7.34%) and deficit irrigation still reducing the maize grain yield by 28.85%, in comparison with farmer practice.

Water productivity value for wheat under fulll irrigation regime(1.2ETc) ranged from 6.25 to 19.88% and, while under deficit irrigation (0.70 ETc), the figures ranged from 46.05 to 61.25%, comparable with farmer practice. Water productivity values for berseem were increased by12.40 and 25.16% higher than those under farmer practice, respectively, due to irrigating at 1.2 and 0.70 ETc regimes. Full and deficit irrigation (0.75 full irrigation) regimes still improving WP for maize to be 24.36 and 43.13% in 2008 season and 13.79 and 21.41% in 2009 one, respectively, as compared with farmer practice.

**Key words:** Wheat crop-maize crop-raised-seed bed-deficit irrigation-water productivity

## INTRODUCTION

Water availability is the most limiting factor for increasing agricultural production in Egypt. Agricultural sector is receiving the lion's share of the available water, since over 80% of the water sources are allocated for agriculture. However, the demand on water resources in this field is growing up due to the expansion of irrigated areas to provide the increasing population with needed food and fibers. The dilemma to be faced is how to increase the water supply to the agriculture sector in the time that all the other sectoral water uses are suffering from water shortages. The solution lies in the agricultural sector itself through increasing on-farm water productivity, i.e., decreasing water losses and, thereby, making good water-saving that compensates for the water shortages. In another word, obtaining more crop production from the same amount of water or more crops per drop expressing the physical productivity of water in agriculture. Optimum crop yields under deficient irrigation practices can be obtained by allowing a certain level of yield reduction of a given crop while higher returns can be obtained with saved water, which, can be diverted to irrigate other areas or crops. Therefore, this innovative concept is given different names such as deficient irrigation, deficient evapotranspiration irrigation and limited irrigation and the like, **English *et al.* 1990**. Deficient irrigation practice is now widely planned and used in many countries. Furthermore, **Hamidreza Salemi *et al.* (2011)** irrigating maize with 100, 80 and 60% of crop evapotranspiration reported that the corresponding grain yield values amounted to 9450, 9250 and 8377 kgha$^{-1}$, comparable with conventional irrigation (9271 kgha$^{-1}$). The authors added that 80% of crop evapotranspiration is the most advantageous treatment when water is not limited. However, to save water and to get higher water productivity values, 60% irrigation level is recommended. **Zwart and Bastiaanssen (2004)** reported that the range of crop Water Productivity (WP) of maize, based on a review of 84 literature sources, is very large (1.1–2.7 kg m$^{-3}$) and it thus offers new water management practices for increasing crop production with 20–40% less water resources. The authors concluded that in order to achieve optimum crop WP in water short regions, it would be wise to irrigate maize and wheat with less water. In addition, **Geerts and Raes (2009)** had reviewed many research from around the world and confirmed that deficit irrigation is successful in increasing WP for various crops without causing severe yield reductions. Moreover, **Ouda *et al.* (2010)** stated that water productivity for berseem clover was gradually increased due to deficit irrigation treatments e.g. 95, 90, 85, and 80% of full irrigation.

Irrigation technologies and irrigation scheduling may be adapted for more-effective and rational uses of limited supplies of water.. It is necessary to develop new irrigation approaches and schemes, not necessarily based on full crop water requirement, but ones designed to ensure the optimal use of allocated water. **Ghani Akbar *et al.* (2010)** reported that narrow beds (65 cm) used 3-7% less water than the basins while the medium (130 cm) and wide beds (180 cm) used 16-17% and 18-22% less water, respectively, comparable with traditional flat basin system. Moreover, **Fahong *et al.* (2011)** stated that wheat productivity increase under bed planting ranged from 6.6 to 12% over 5 locations, comparable with basin practice and such yield increase is attributed to optimizing wheat morphological traits and enhance plant lodging resistance. **Stone *et al.* (1982)** stated that wide- spaced furrow irrigation method reduced evapotranspiration losses and can reduce water requirements.and such codition could be attributed to applying the irrigation water into the root zone while maintaining a relatively dry soil surface.

This work was conducted aiming at introducing new, simple and practicable techniques with the involvement and partnership of farmers to increase crop water productivity for wheat, berseem and maize crops. On-farm improvement concerning water management to reduce water losses and achieve better water-saving was considered.

## MATERIALS AND METHODS:

On-farm trials were conducted in four farms at Monofia Governorate to identify and test with communities the interventions that improve water productivity and sustain its use and generate the data required for an economic impact assessment and in modeling aspects and to support the writing of water productivity (WP) for three major field crops namely wheat, berseem and maize .

The interventions tested in the selected farmes for developing water-saving technologies were as follows:.

$I_1$: Farmer traditional method in the site.

$I_2$: Required irrigation amount in the site (1.2 ET).

$I_3$: Deficit irrigation of the required irrigation .

- $I_3$.a. Deficit irrigation ( 0.70 full irrigation) with wheat and berseem crops.
- $I_3$.b. Deficit irrigation ( 0.75 full irrigation) with maize crop. and

$I_4$: Raised-bed irrigation method for growing wheat, berseem clover and maize (wheat on raised bed was in hills or broadcasting before implementing raised bed).

Both adopted irrigation practices and irrigation regimes were tested in the Randomized Complete Block Design with four replicates. The plot experimental area equals 100 $m^2$. All of the agronomic practices i.e. seed bed preparation, seeding rate, N &P fertilization, weeds and pests control…….etc were done as common in the area.

### Water requirement calculation:

CROPWAT (version 4.3) is a computer program uses Penman-Monteith combination method for calculating reference evapotranspiration (ETo) values. These estimates are used in crop water requirements and irrigation scheduling calculations (Smith,1992). Agroclimatological data for Monufia Governorate are shown in Table 1 .

**Reference evapotranspiration (ETo)**

The FAO Penman-Monteith method can be expressed as :-

$$ETo = \frac{0.408\,\Delta\,(Rn - G) + \gamma\,\frac{900}{T + 273}\,u2\,(es - ea)}{\Delta + \gamma\,(1 + 0.34\,u2)}$$

Where:

- ETo: reference evapotranspiration (mm $day^{-1}$)
- Rn: net radiation at the crop surface (MJ $m^{-2}$ $day^{-1}$)
- G: soil heat flux density (MJ $m^{-2}$ $day^{-1}$)
- T: mean daily air temperature at 2m height ($^oC$)
- u2: wind speed at 2m height (m $s^{-1}$)
- es: saturation vapor pressure (kPa)
- ea: actual vapor pressure (kPa)
- es-ea: vapor pressure deficit (kPa)
- Δ: slope vapor pressure-temperature curve (kPa $^oC^{-1}$)
- γ: psychrometric constant (kPa $^oC^{-1}$)

**Table 1 : Agroclimatological data for Monufia Governorate (Average 1997-2006)***

| Month | T. max. | T. min. | W.S | R.H | R.F | Epan |
|---|---|---|---|---|---|---|
| September | 33.1 | 20.0 | 172.8 | 59 | 0.0 | 6.1 |
| October | 29.5 | 17.2 | 172.8 | 64 | 0.0 | 4.7 |
| November | 25.0 | 13.3 | 172.8 | 64 | 1.6 | 2.8 |
| December | 21.0 | 9.8 | 172.8 | 66 | 4.1 | 2.1 |
| January | 19.4 | 7.5 | 207.4 | 65 | 4.9 | 1.8 |
| February | 19.9 | 7.7 | 207.4 | 64 | 4.6 | 2.5 |
| March | 22.6 | 9.2 | 216.0 | 63 | 1.4 | 3.6 |
| April | 27.2 | 12.2 | 198.7 | 56 | 0.8 | 5.3 |
| May | 32.0 | 16.4 | 190.1 | 56 | 0.0 | 7.2 |

*Tmax and Tmin = Maximum and minimum temperatures ($C^o$, WS = wind speed ($msec^{-1}$),*
*RH = Relative humidity, RF = Rain fall(mm) and Epan = Pan evaporation ($mmday^{-1}$)*

* Source : Water requirements and field irrigation research department

**2- Crop water requirements:**

Crop water requirements (ETcrop) over the growing season are determined from ETo and crop coefficient (Kc) according to the following equation:

$$\textit{Crop water requirement } (ETcrop) = ETo \ X \ Kc / \textit{Irrigation efficiency}$$

## RESULTS AND DISCUSSION

### 1. Wheat crop

#### 1.a. Raised- seed bed (Wide Furrows) irrigation:

Data in Table 2 revealed that raised – seed bed irrigation technique and the assessed irrigation regimes seemed to reduce irrigation water applied for wheat crop, comparable with the farmer irrigation practice. The reduction in water applied, as wheat was grown in hills, on raised – seed bed reached 28.49 and 24.07%, as compared with farmer practice, respectively, in 2007/2008 and 20082009 growing seasons. Furthermore, growing wheat in broadcasting system on raised – seed bed in 2008/2009 season, resulted in water saving amounted to 23.59% higher than the farmer practice. It is obvious that irrigation wheat crop via raised – seed bed technique leads to appreciable saving in water applied. These findings are in parallel with those reported by **Stone *et al.* (1982)** who stated that wide- spaced furrow irrigation method applies water to the root zone while maintaining a relatively dry soil surface. This condition reduced evapotranspiration losses and can reduce water requirements. In addition, **Fahong *et al.* (2004)** found that, changing flat planting under basin irrigation to raised –bed planting and furrow irrigation, saved 17% of applied water for wheat crop. **Ghani Akbar *et al.* (2010)** reported that narrow beds (65 cm) used 3-7% less water than the basins.

While, the medium (130 cm) and wide beds (180 cm) used 16-17% and 18-22% less, respectively, comparable with traditional flat basin system. **Walker and Skogerboe (1987)** reported that using furrows or bed – and – furrows irrigation methods has considerable advantages over basin irrigation systems, because they provide better on-farm water management, evaporative losses can be reduced, and higher efficiencies are in general achieved. Moreover, **Ahmad *et al.* (2010)**,evaluate different irrigation techniques (border/flat, bed and furrow method) to irrigate wheat crop, and found that bed furrow method consumed about 35.6% less water, as compared to flat border irrigation method.

Data in Table 2 illustrated that wheat yield tended to increase due to irrigating using raised – seed bed techniques, in comparison with farmer practice. The increases in wheat yield comprised 5.07 and 6.47%, respectively, in 2007/2008 and 2008/2009 seasons, as wheat was grown in hills system on raised bed, comparable with farmer practice. Similar finding was true, as wheat was grown in broadcasting system on the raised- seed bed in 2008/2009 season, where the wheat yield was increased by 9.51%, as compared with that under farmer practice. In this sense, **Ghani Akbar *et al.* (2010)** found that wide (180 cm) beds produced higher wheat (15%) than traditional flat basin system**.** Moreover, **Fahong *et al.* (2011)** stated that wheat productivity increases under bed planting ranged from 6.6 to 12% over 5 locations, comparable with basin practice and such yield increase is attributed to optimizing wheat morphological traits and enhance plant lodging resistance.

**Table 2: Applied irrigation water, grain yield and water productivity for wheat crop in 2008/2009 and 2008/ 2009 seasons**

| Irrigation practice | Farmer practice | Full irrigation (1.2 ETc) | 0.70 full irrigation | Wide furrows (hills) | Wide furrows (broadcasting) |
|---|---|---|---|---|---|
| | 2007- 2008 season | | | | |
| | Applied water, mm | | | | |
| Farm 1 | 540 | 500 | 436 | 400 | - |
| Farm 2 | 557 | 530 | 430 | 416 | - |
| Farm 3 | 511 | 490 | 396 | 344 | - |
| Farm 4 | 540 | 480 | 420 | 376 | - |
| Average | 537 | 500 | 323 | 384 | - |
| | Grain yield, $tha^{-1}$ | | | | |
| Farm 1 | 9.429 | 9.464 | 9.321 | 8.964 | - |
| Farm 2 | 7.607 | 7.393 | 8.321 | 8.607 | - |
| Farm 3 | 7.750 | 6.646 | 7.679 | 8.393 | - |
| Farm 4 | 9.440 | 10.440 | 8.000 | 10.00 | - |
| Average | 8.557 | 8.486 | 8.330 | 8.991 | - |
| | Water productivity, $Kgm^{-3}$ | | | | |
| Farm 1 | 1.75 | 1.89 | 2.14 | 2.24 | - |
| Farm 2 | 1.37 | 1.39 | 1.94 | 2.07 | - |
| Farm 3 | 1.52 | 1.36 | 1.94 | 2.44 | - |
| Farm 4 | 1.75 | 2.18 | 1.90 | 2.66 | - |
| Average | 1.60 | 1.70 | 2.58 | 2.35 | - |
| | 2008 – 2009 season | | | | |
| | Applied water, mm | | | | |
| Farm 1 | 675 | 595 | 466 | 490 | 493 |
| Farm 2 | 633 | 562 | 443 | 478 | 479 |
| Farm 3 | 608 | 570 | 449 | 487 | 490 |
| Farm 4 | 560 | 487 | 379 | 424 | 429 |
| Average | 619 | 554 | 434 | 470 | 473 |
| | Grain yield, $tha^{-1}$ | | | | |
| Farm 1 | 6.064 | 6.399 | 6.239 | 6.472 | 6.668 |
| Farm 2 | 6.074 | 6.449 | 6.110 | 6.340 | 6.614 |
| Farm 3 | 6.373 | 6.415 | 5.920 | 6.442 | 6.550 |
| Farm 4 | 6.148 | 7.070 | 6.870 | 7.003 | 7.170 |
| Average | 6.165 | 6.583 | 6.285 | 6.564 | 6.751 |
| | Water productivity, $Kgm^{-3}$ | | | | |
| Farm 1 | 0.898 | 1.075 | 1.339 | 1.321 | 1.353 |
| Farm 2 | 0.960 | 1.148 | 1.379 | 1.326 | 1.381 |
| Farm 3 | 1.048 | 1.125 | 1.318 | 1.323 | 1.337 |
| Farm 4 | 1.098 | 1.452 | 1.813 | 1.652 | 1.670 |
| Average | 1.001 | 1.200 | 1.462 | 1.406 | 1.435 |

Water productivity for wheat crop seemed to be higher, under raised – seed bed techniques, than that under the farmer practice, Table 2. Growing wheat on raised bed, in hills system, water productivity values were 46.88 and 40.46% higher than those under farmer practice, respectively, in 2007/2008 and 2008/2009 seasons. Similar trend for water productivity was noticed due to growing wheat crop on raised bed, broadcasting system in 2008/2009 season, where water productivity value increased by 43.36%, comparable with the farmer practice. In connection, **Khan *et al.* (2007),** stated that although broad furrow irrigation system seems to consume maximum energy, it achieves the highest water use efficiency for wheat crop, comparable with basin and narrow bed irrigation systems. In addition **Ghani Akbar *et al.* (2010)** in North-West Pakistan, stated that permanent raised bed generally resulted in higher Gross Production Water Use Indices (kg/ha/mm), compared to traditional flat basin system.

**1.b. Deficit Irrigation**

In the context of improving water productivity, there is a growing interest in deficit irrigation, which is an irrigation practice whereby water supply is reduced below maximum levels and mild stress is allowed with minimal effects on yield. The assessed irrigation regimes e.g. full irrigation (1.2 ETc) and deficit irrigation (0.70 ETc) seemed to reduce the irrigation water applied to wheat crop, Table 2. The reduction in applied water reached 6.90 and 39.85% in 2007/2008 season and comprised 10.51 and 29.89% in 2008/2009 one, respectively, under full irrigation and deficit irrigation (0.70 ETc) regimes, as compared with the farmer practice. **Abdou *et al.* (2011)** recorded that irrigating wheat crop at 1.2 Epan produced the highest values of $ET_C$ which ranged from 41.03 to 43.50 cm, while irrigating at 0.8 Epan the ETc ranged from 37.41 to 40.98 cm.

Data in Table 2 revealed that both full and deficit irrigation(0.70 ETc) regimes slightly reduced wheat grain yield by 0.83 and 2.65%, respectively, in 2007/2008 season , as compared with the farmer practice. The trend was reversed in 2008/2009 season where the wheat grain yield values seemed to increase by 6.78 and 1.95%, respectively, under full irrigation and 0.70 full irrigation, comparable with the farmer practice. In connection**, Stegman *et al.* (1980)** stated that deficit irrigation ensures optimum and sustainable agricultural production, in a given region and maximizes incomes of the growers if irrigation water resources are limited or expensive. **Abdou *et al.* (2011)** found that irrigating wheat crop at 1.2 Epan resulted in the highest averages of wheat grains and straw yields.

In 2007/2008 season, water productivity value under fulll irrigation regime did not greatly alter (6.25%), as compared with that recorded for farmer practice. Nevertheless, deficit irrigation (0.70 full irrigation) exhibited higher water productivity value comprised 61.25% than that obtained with farmer practice. In 2008/2009 season, both full and deficit irrigation regimes resulted in higher water productivity values, comparable with farmer practice, where the increases amounted to 19.88 and 46.05%, respectively. **Abdou *et al.* (2011)** revealed that the highest WUE values for wheat crop ranged from 1.17 to 1.19 kg grainsm$^{-3}$ water consumed were detected from irrigating wheat at 1.2 Epan, while lower WUE ranged from 1.01 to 1.06 kg grains m$^{-3}$ water consumed was due to irrigation at 0.8 Epan and the authors attributed such lower WUE to the drastic reduction in grain yield.

**2. Maize crop**

**2.a. Raised-bed (Wide Furrows)**

Data in Table 3 illustrated that raised – seed bed irrigation technique and the assessed irrigation regimes seemed to reduce irrigation water applied for maize crop, comparable with the farmer irrigation practice. The reduction in water applied, as wheat was grown in hills, on raised – seed bed reached

25.14 and 19.10%, as compared with farmer practice, in 2008 and 2009 growing seasons, respectively,. Furthermore, growing. It is obvious that irrigation maize crop under raised – seed bed technique leads to appreciable saving in water applied. These findings are in parallel with those reported by **Stone *et al.* (1982)** who stated that wide- spaced furrow irrigation method reduced evapotranspiration losses and can reduce water requirements and such codition could be attributed to applying the irrigation water into the root zone while maintaining a relatively dry soil surface. In addition, in Egypt, **El-Marsafawy *et al.* (1998),** found that irrigation with 140 cm apart furrows, comparable with 70 cm apart furrows, resulted in 8% reduction in evapotranspiration and improved root environment which increased absorption media and encouraged growth characteristics for maize crop. Furthermore, **Wentworth and Jacobs (2001)** with maize crop, found that water saving using permenant beds irrigation amounted 31.1%, comparable with furrow irrigation. In connection, **Ghani Akbar *et al.* (2010)** reported that narrow beds (65 cm) used 6.65% less water ,while the medium (130 cm) and wide beds (180 cm) used 15.93% and 17.50% less water applied for maize crop, respectively, comparable with traditional flat basin system.

Data in Table 3 illustrated that maize yield tended to increase due to irrigating using raised – seed bed techniques, in comparison with farmer practice. The increases in maize yield comprised 6.04 and 7.25%, respectively, in 2008 and 2009 seasons, as maize was grown on raised- seed bed, comparable with farmer practice. In this sense, **Ghani Akbar *et al.* (2010)** found that wide (180 cm) beds produced higher maize yield (26.47%) than traditional flat basin system.

Water productivity (WP) for maize crop seemed to be higher, under raised – seed bed technique, than that under the farmer practice, Table 3. Growing maize on raised bed, water productivity values were 53.59 and 34.09% higher than those under farmer practice, respectively, in 2008 and 2009 seasons. In connection, **Wentworth** and **Jacobs (2001)** stated that water productivity for maize crop was enhanced due to permenant beds irrigation by 31.34% over that reported under furrow irrigation. **Ghani Akbar *et al.* (2010)** in North-West Pakistan, stated that growing maize on permanent raised bed generally resulted in higher Gross Production Water Use Indices (kg/ha/mm), compared to traditional flat basin system.

**2.b. Deficit Irrigation**

Data in Table 3 revealed that irrigation water applied for maize under full and deficit(0.75 full irrigation) irrigation regimes were lower by 10.10 and 25.54% in 2008 season and by 5.89 and 20.04% in 2009 one, comparable with farmer practice, respectively. Furthermore, **Hamidreza Salemi *et al.* (2011)** irrigated maize with 100, 80 and 60% of crop evapotranspiration and found that the water applied values were 9851, 7881 and 5911 $m^3ha^{-1}$ compared with conventional irrigation (10836 $m^3ha^{-1}$).

**Table 3: Applied irrigation water, grain yield and water productivity for maize crop in 2008 and 2009 seasons**

| Irrigation practice | Farmer practice | Full irrigation (1.2 ETc) | 0.75 full irrigation | Wide furrows |
|---|---|---|---|---|
| | 2008 season | | | |
| | Applied water, mm | | | |
| Farm 1 | 574 | 564 | 463 | 451 |
| Farm 2 | 656 | 600 | 499 | 483 |
| Farm 3 | 655 | 563 | 483 | 498 |
| Farm 4 | 648 | 550 | 441 | 464 |
| Average | 633.2 | 569.3 | 471.5 | 474.0 |
| | Grain yield, $tha^{-1}$ | | | |
| Farm 1 | 10.10 | 10.00 | 9.64 | 10.50 |
| Farm 2 | 9.41 | 8.23 | 7.75 | 7.23 |
| Farm 3 | 9.64 | 8.06 | 7.69 | 9.44 |
| Farm 4 | 9.28 | 9.08 | 8.55 | 9.15 |
| Average | 9.61 | 8.84 | 8.41 | 9.03 |
| | Water productivity, $Kg\backslash m^3$ | | | |
| Farm 1 | 1.760 | 1.773 | 2.082 | 2.328 |
| Farm 2 | 1.434 | 1.372 | 1.553 | 1.497 |
| Farm 3 | 1.472 | 1.432 | 1.592 | 1.896 |
| Farm 4 | 1.432 | 1.651 | 1.939 | 1.972 |
| Average | 1.252 | 1.557 | 1.792 | 1.923 |
| | 2009 season | | | |
| | Applied water, mm | | | |
| Farm 1 | 825 | 761 | 651 | 676 |
| Farm 2 | 776 | 740 | 625 | 619 |
| Farm 3 | 758 | 708 | 600 | 592 |
| Farm 4 | 820 | 783 | 666 | 685 |
| Average | 794.8 | 748.0 | 635.5 | 643.0 |
| | Grain yield, $tha^{-1}$ | | | |
| Farm 1 | 8.86 | 8.68 | 8.48 | 8.86 |
| Farm 2 | 11.50 | 12.24 | 12.29 | 12.82 |
| Farm 3 | 15.86 | 16.40 | 14.35 | 16.46 |
| Farm 4 | 12.29 | 14.76 | 12.01 | 14.24 |
| Average | 12.13 | 13.02 | 11.78 | 13.10 |
| | Water productivity, $Kgm^{-3}$ | | | |
| Farm 1 | 1.074 | 1.141 | 1.303 | 1.311 |
| Farm 2 | 1.482 | 1.653 | 1.967 | 2.072 |
| Farm 3 | 2.092 | 2.316 | 2.392 | 2.780 |
| Farm 4 | 1.499 | 1.885 | 1.803 | 2.079 |
| Average | 1.537 | 1.749 | 1.866 | 2.061 |

The tested irrigation regimes seemed mostly to reduce maize grain yield in comparison with farmer practice, Table 3. In 2008 season, maize yield was reduced by 8.01 and 12.49% due to full and deficit (0.75 full irrigation) irrigation regimes, respectively, as compared with farmer practice. In 2009 season, the trend was differed where full irrigation exhibited higher maize grain yield value amounted to 7.34% while deficit irrigation still reducing the maize grain yield by 28.85%, in comparison with farmer practice. So on water conservation, it is advisable to irrigate the maize crop at full irrigation regime (1.2 ETc). In this sense**, Payero *et al.* (2008)** showed that the differences in seasonal water requirements among irrigation depth treatments significantly ($P \leq 0.05$) affected dry matter production and yield components of maize. In addition, **Javaid and Khalid (2009)** found that the maximum maize yield of 2933 kg/ha was obtained when plots were irrigated according to 0.75 Epan. Furthermore**, Hamidreza Salemi *et al.* (2011)** irrigated maize with 100, 80 and 60% of crop evapotranspiration and reported that the corresponding grain yield values amounted to 9450, 9250 and 8377 $kgha^{-1}$, comparable with conventional irrigation (9271 $kgha^{-1}$). The authors added that 80% irrigation level is the most advantageous treatment when water is not limited. However, to save water and to get higher water productivity,60% irrigation level treatment is recommended.

Data in Table 3 illustrated that water productivity (WP) for maize crop tended to increase under full and deficit irrigation (0.75 full irrigation) regimes in comparison with farmer practice. The increase percentages under full and deficit irrigation (0.75 full irrigation) regimes amounted to 24.36 and 43.13% in 2008 season and to 13.79 and 21.41% in 2009 one. Similar trend was reported by **Hamidreza Salemi *et al.* (2011)** who stated that WP for maize crop were increased as the water applied decreased where WP comprised 0.86, 0.96, 1.17 and 1.42 $kgm^{-3}$ under conventional irrigation, 100, 80 and 60% of crop evapotranspiration, respectively. In general, **Geerts** and **Raes (2009)** had reviewed many research from around the world and confirmed that deficit irrigation is successful in increasing WP for various crops without causing severe yield reductions. In connection, **Payero *et al.* (2008)** found that water use efficiency was more sensitive to irrigation water and decreased explicitly with irrigation. Moreover, **Chen *et al.* (2009)** revealed that increase of irrigation amount resulted in more crop yields, but the water amount required to gain maximum WP was much less than that required for obtaining the maximum crop yield.

**3- Berseem**

**3.a. Raised –seed bed**

Data in Table 4 indicated, on four farms average basis, that growing berseem on raised- seed bed reduced the applied water quantity by 17.08%, comparable with that applied with farmer practice. In connection, **Shawan *et al.* (2011)** in Middle Nile Delta - Egypt, reported that seasonal applied water for berseem clover under bed-furrow irrigation practice ranged from 19.78 to 21.14%, comparable with farmer practice. The potency of raised- seed bed practice in saving irrigation water with different crops were previously reported. **Wentworth** and **Jacobs (2001),** with maize crop, found that water saving using permenant beds irrigation amounted 31.1%, comparable with furrow irrigation. In addition, **Pramanik *et al.* (2009)**, found that, on an average, raised bed planting saved 37.5 to 50% of irrigation requirement for chickpea over flat bed planting.

Data in Table 4, on 4 farms average, exhibited higher fresh yield value comprised 22.20% due to growing berseem on raised –seed bed, more than that recorded under farmer irrigation practice. This finding could be attributed to proper soil moisture status in crop root zone which encourage water and nutrients absorption. In connection, **EL-Marsafawy *et al.* (1998),** stated that irrigation with 140 cm apart furrows, comparable with 70 cm apart ones, improved root environment which increased absorption media and encouraged growth characteristics for maize crop. On the contrary, **Shawan *et al.* (2011)** found that reduction in total fresh yield of berseem clover, on 4 cuttings basis, under bed-furrow irrigation practice ranged from 9.89 to 14.22%, comparable with the farmer practice and attributed such reduction to less applied irrigation water under bed-furrow irrigation practice. In this sense, **Lovelli *et al.* (2007)** stated that water supply significantly modified the growth of root in relation to above ground plant part i.e. the amount of harvestable biomass of the forage in relation to total biomass.

**Table 4: Applied irrigation water, fresh yield and water productivity for berseem under the adopted irrigation practices 2009/2010 season**

| Irrigation practice | Farm 1 | Farm 2 | Farm 3 | Farm 4 | Average |
|---|---|---|---|---|---|
| | Applied Water (mm) | | | | |
| Farmer practice | 651 | 587 | 511 | 679 | 607.0 |
| Raised - bed | 524 | 481 | 448 | 560 | 503.3 |
| Full irrigation, 1.2 ETc | 601 | 554 | 492 | 641 | 572.0 |
| Deficit irrigation, 0.70 ETc | 480 | 432 | 391 | 477 | 445.0 |
| | Fresh yield (tonha$^{-1}$) | | | | |
| Farmer practice | 99.476 | 84.762 | 86.905 | 99.452 | 92.645 |
| Raised - bed | 125.000 | 100.00 | 102.833 | 125.000 | 113.208 |
| Full irrigation, 1.2 ETc | 105.310 | 91.952 | 90.500 | 105.310 | 98.268 |
| Deficit irrigation, 0.70 ETc | 90.095 | 80.167 | 80.405 | 90.167 | 85.209 |
| | Water productivity (kgm$^{-3}$) | | | | |
| Farmer practice | 15.28 | 14.44 | 17.00 | 14.65 | 15.34 |
| Raised - bed | 23.85 | 20.79 | 22.95 | 22.32 | 22.48 |
| Full irrigation, 1.2 ETc | 17.52 | 16.60 | 18.39 | 16.43 | 17.24 |
| Deficit irrigation, 0.70 ETc | 18.77 | 18.56 | 20.56 | 18.90 | 19.20 |

Water productivity is an efficiency term quantified as a ratio of product output (goods and services) over water input. The output could be biological goods such as crop grain, fodder….etc. So, data in Table 4 indicated that WP value seemed to increase under raised – seed bed irrigation by 46.54%, comparable with the value recorded with farmer practice (4 farms average basis). Similar trend was found by **Shawan *et al.* (2011)** who reported that bed-furrow irrigation practice resulted in higher water productivity values (on total fresh yield basis) ranged from 6.01 to 29.84%, as compared with farmer irrigation practice.

### 3.b. Deficit irrigation

As irrigation was practiced under full irrigation (irrigating at 1.2 ETc) and deficit irrigation (irrigating at 0.7 ETc) regimes, the reductions in water applied reached 5.77 and 26.69% less than that obtained with farmer practice.

In connection, **Kirda (2000)** stated that the proper application of deficit irrigation practices can generate significant savings in irrigation water allocation.

Data in Table 4 revealed that irrigating berseem crop according to 1.2 ETc (full irrigation regime) resulted in fresh yield value reached 6.07% higher than that obtained with farmer practice. Nevertheless, irrigating at 0.70 ETc (deficit irrigation regime) exhibited lower fresh yield value comprised 8.03 less than that reported under farmer irrigation practice. In connection, **Lazaridou, Martha and Koutroubas (2004),** at Drama, Macedonia, Greece, stated that water stress resulted in a reduction of the above ground dry biomass to one third of irrigated berseem plants (2.3 vs 6.8 g/plant).

Data in Table 4 illustrated that irrigating berseem according to either 1.2 (full irrigation) or 0.7 ETc (deficit irrigation) regimes resulted in WP values (on fresh yield basis) reached 12.39 and 25.16% higher than that obtained with farmer practice. In this sense **Lazaridou, Martha** and **Koutroubas (2004)** stated that water stress resulted in an increased water use efficiency for irrigated berseem crop. Moreover**, Ouda *et al.* (2010)** stated that water productivity for berseem was gradually increased under all deficit irrigation treatments e.g. 95, 90, 85, and 80% of full irrigation.

On conclusion, in order to save water resources and to accomplish higher water productivity for wheat, berseem clover and maize crops it is advisable to grown such crops on raised – seed bed which proved to an effective practice in water conservation. In addition, deficit irrigation technique, at 0.70 ETc for wheat and berseem crops and at 0.75 ETc for maize crop, proved to be effective in saving water and improving water productivity for such crops.

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**زيادة إنتاجية مياه الري عن طريق البحث والمشاركة المجتمعية**

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نظرا للحاجة الملحة لزيادة إنتاجية مياه الري لمقابلة الزيادة في الاحتياجات الغذائية وتوفير الأمن الغذائي فقد تم التعاون مع الأيكاردا والمشاركة المجتمعية لزيادة إنتاجية مياه الري وقد تم اختيار أربع مزارع بمحافظة المنوفية - مصر طبقا للظروف الاقتصادية والفنية وتم تطبيق المعاملات الآتية :

١- زراعة القمح والبرسيم المسقاوي و الذرة الشامية على مصاطب .
٢- ري القمح والبرسيم المسقاوي الذرة الشامية تحت ظروف نقص المياه .

وفيما يلي أهم النتائج المتحصل عليها :-

أ- الزراعة علي المصاطب أدت إلي التوفير في مياه الري المضافة وزيادة المحصول مما أدي إلي تحسين إنتاجية المياه للمحاصيل تحت الدراسة.

ب- أدي الري المنقوص، عموما، إلي تقص الناتج من المحاصيل تحت الدراسة، ولكنة أدي إلي تحسن ملموس في إنتاجية المياه لهذه المحاصيل نظرا للتوفير في مياه الري المضافة. يمكن تبني هذا الأسلوب في ري المحاصيل في مناطق عدم وفرة مياه الري.