RESEARCH
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Technical Report 2015 Activity: Water and land productivity Rainfed areas

Food security and better livelihoods
for rural dryland communities

I. Case of Deficit Irrigation of Vegetables and Olive Trees in Bitit Field Site in Meknes Region

1) Response of olive trees to different levels of continuous deficit irrigation regime in Sais region (Bitit field site)

Rachid Razouk (INRA) and Mohammed Karrou (ICARDA)

Introduction

In Sais region, the available irrigation water resources are not generally sufficient to satisfy the olive trees requirements. The irrigation of olive trees in this region is practically deficient and the levels of water applied are estimated to not more than to 20% of crop evapotranspiration from budburst to harvest where fixed frequency of water applications are adopted regardless of the climatic variations. In certain situations where water is abundant, excess irrigation water is supplied to the trees; thereby, resulting in significant water loss. To optimize irrigation applications of this crop under local conditions, different regimes of continuous deficit irrigation were tested on adult olive trees. This report presents the results of year 2015.

Materials and methods

The experiment was conducted in two olive orchards, located in Sais plain, on two different cultivars *Arbequine*, nine years old, planted at a density of 667 trees/ha (5x3m) and *Menara*, eight years old, planted at a density of 285 trees/ha (7x5m).

Water treatments tested were 50 and 75% of crop evapotranspiration (ETc) in comparison to full irrigation (100% ETc) and to the irrigation regime usually adopted by farmers (Table 1). The experiment was conducted in a randomized complete block design with three replications. For each cultivar, each treatment was tested on three randomized lines, composed each of fifteen trees.

Table 1: Water treatments tested on olive trees

Water treatment	Amount of water applied (mm/year)		Irrigation period	Effective rainfall (2) during irrigation period (mm)
	cv. Menara	cv. Arbequina		
HIR(1)	202	285	June to October	24
100% ETc	257	282		
75% ETc	187	206		
50% ETc	116	129		

(1): Habitual irrigation regime in the experimental field; (2): 80% of rainfall

Results

Fruit and oil yield

Statistical analysis (Table 2) showed that in both experiments, deficit irrigation at a level of 75% ETc had no effect on olive yield (fruit and oil yields). However, there was a significant reduction in olive productivity under deficit irrigation at level of 50% ETc. Compared to full irrigation regime, the latter irrigation regime induced a decrease in olive yield by an average of 23% for Menara and of 20% for Arbequina. Nevertheless, deficit irrigation at 50% Etc increased significantly fruit and oil water productivity.

Under the usual irrigation regime of the farmer, which was equivalent to 80% ETc for Menara and to 100% ETc for Arbequina, olive yields were equal to those obtained under full irrigation regime and under deficit irrigation of 75% ETc. Therefore, the farmer could save a significant amount of water by adopting a deficit irrigation of 75% ETc. Compared to this regime, the water loss generated by the farmer technique was estimated at 15 mm for Menara and to 80 mm for Arbequina. This result, particularly found on Menara, suggests the possibility to adopt a water regime of 75% ETc for olive irrigation with fixed frequency and amount throughout the irrigation period as it is easier to perform and increases yield as compared to 50% deficit irrigation and water productivity as compared to full irrigation.

Table 2: Olive yield and water use efficiency under all water treatments

Olive cultivar	Water treatment	Fruit yield (t/ha)	Oil yield (t/ha)	WUE	
				Fruit (kg /m^3/ha)	Oil (l/m^3/ha)
Menara	HIR	3.19 a	0,64 a	1,58 b	0,32 b
	100% ETc	3.72 a	0,72 a	1,45 b	0,28 b
	75% ETc	3.22 a	0,64 a	1,72 b	0,34 b
	50% ETc	2.86 b	0,61b	2,47 a	0,53 a
Arbequina	HIR	12.31 a	2,23 a	4,32 c	0,78 b
	100% ETc	12.10 a	2,19 a	4,29 c	0,78 b
	75% ETc	11.92 a	2,40 a	5,79 b	1,17 ab
	50% ETc	9.67 b	2,05 b	7,50 a	1,59 a

Values followed by the same letter are statistically equal following student test at 95%

Fruit weight and oil content

The applied levels of deficit irrigation increased significantly fruit oil content without change in fruit weight (Table 3). The regime 75% of ETc that was optimal for deficit irrigation of olive tree, based on yield levels, induced an increase in oil content by an average of 0.62% and 2.01%, respectively for Menara and Arbequina.

Table 3: Olive yield and water use efficiency under all water treatments

Olive cultivar	Water treatment	Fruit weight (g)	Oil content (% FM)
Menara	HIR	3.93 a	20.13 b
	100% ETc	3.51 a	19.35 c
	75% ETc	3.51 a	19.97 b
	50% ETc	3.13 a	21.21 a
Arbequina	HIR	2.09 a	18.09 c
	100% ETc	1.95 a	18.13 c
	75% ETc	1.87 a	20.14 b
	50% ETc	1.81 a	21.15 a

Values followed by the same letter are statistically equal following student test at 95%

Conclusion

Based on the results, deficit irrigation of olive trees at 75% of ETc may be considered optimal because it produce a yield level statistically equal to that obtained under full irrigation and improves water productivity as compared the latter regime. In addition, fruit oil content is significantly improved under this regime without changes in fruit weight.

2) Response of potato and onion to different levels of irrigation water in Bitit field site

Khalid Daoui (INRA) and Mohammed Karrou (ICARDA)

Introduction

Because of the subsidies provided by the government to the farmers on irrigation equipment and wells digging, the area of irrigated vegetable crops has increased in Meknes-sais region. This has put a lot of pressure on ground water resources. Potato and onion are two main vegetable crops grown under irrigation conditions in one of the field site, Bitit, of the action site of Meknes-Sais. Although irrigated by drip irrigation, the farmers apply excess water. In order to evaluate the effect of deficit irrigation on the performance and analyze the tradeoffs between land and water productivity of potato and onion, these species were exposed to different levels of irrigation water in a field trial in Bitit.

Materials and methods

The irrigation treatments studies were (R1) 33%, (R2) 66% and (R3) 100% of the average amount of irrigation water the farmers apply in the region. The experimental design adopted is a randomized complete bloc with four replications. The measurements taken were potato and onion yields and water used. Water productivity was calculated as a ratio of yield to the amount of irrigation water applied (kg /m3).

Results

The effect of irrigation rate on potato yield and water productivity was significant. Data in table 1 shows that the yield increased from 27.5 t/ha to 35.3t/ha (15% increase) and then dropped to 30.8 t/ha (13% decrease). However, water productivity decreased as the amount of water increased (Table 1). The decreases due to the application of 66% and 100% of farmer irrigation water rate were, respectively, 36 and 61% when compared to 33%. The application of 2/3 of irrigation treatment allowed a saving of 666 m3 of irrigation water and a yield gain of 4.5 t/ha.

Table 1: Effect of water regime on potato tuber yield and water use efficiency

Water regime	Yield (t/ha)	
R1	27.5	3.6
R2	35.3	2.3
R3	30.8	1.4

The effect of irrigation level on potato yield and water productivity was significant (Table 2). In fact, the yield increased with the increase of the amount of water applied; while water productivity increased significantly as the conditions become drier. The rates of increase between R1 and R2 and R2 and R3 were 17% and 6%, respectively. The increase rates were, respectively, 57% and 39% when high and medium water rates were compared to the driest condition (R1)

Table 2. Effect of water regime on onion tuber yield and water use efficiency

Water regime	Yield (t/ha)	WUE (kg/m3)
R1	36.3	5.1
R2	43.8	3.1
R3	46.7	2.2

Field visits for farmers/extension agents

A field visit was organized on July 13 to demonstrate trials on water productivity of potato and onion. Those trials were conducted on the INRA experimental station Taoujdate (Bitit). Sixteen farmers (13 male and 3 female) participated in this event.
e tree

II. Case of Supplemental irrigation of wheat in Tadla field sites

1) Strategies of improving land and productivity under water and high temperature stresses in dry areas of WANA region

Mohammed Boutfirass (INRA) and Mohammed Karrou (ICARDA)

Introduction

Under rainfed conditions, soil water loss by evaporation is the most important source of inefficient use of water in semiarid areas. In irrigated zones, the over- and misuse of scarce water is the main cause of the reduction of water productivity. The challenge in wheat production is to capture more water for use in transpiration in rainfed areas, to apply less water in irrigated zones, to use CO2 more effectively in producing biomass and to convert more of the biomass into grain.

One source of water loss by evaporation is related to planting period and pattern. As a matter of fact, most of the farmers in the region delay wheat planting until it rains enough in Fall to be able to till and cultivate the soil and hence to prepare a good seedbed and to control the early emerging weeds. Nevertheless, this technique involves wet soil disturbance and consequently increases soil water evaporation. Many experiments conducted on planting dates under rainfall conditions in WANA by the NARS and ICARDA showed that the early planting in Autumn is the best strategy because it allows the crop to take advantage from early rains and from the warm soil and air temperature required for the seedling growth and vigor; but also to escape terminal drought and heat. However, planting early is not easy to achieve because the probability of having enough rain to ensure a good seedbed preparation and a better stand establishment is very low. To by-pass this problem and be able to plant early in a rough seedbed (characteristic of farmers' fields in dry areas), there is a need for the use of the direct sowing using the zero-tillage that can put seeds deeper into the soil. However, increasing the sowing depth will not favor the emergence of standard widely used semi-dwarf wheat that contain Rht1 and Rht2 dwarfing genes that induce short coleoptiles. The potential solution is to use varieties that contain alternative dwarfing genes (Rht8) that can provide the benefits of short stems without restricting the maximum length of the coleoptiles.

Research conducted in the region demonstrated that supplemental irrigation using limited amounts of water at critical stages is another option that can increase significantly and stabilize yield and improve water productivity land productivity.

Another factor that influences cereal production is temperature. The predicted increase of temperature due to the emission of the greenhouse gases rise will have certainly a positive effect on crop yields in many developed countries which are in mid- to high-latitude locations. Warmer temperature may improve productivity by extending the growing season and exposing plants to their near optimal temperatures. However, in countries with low latitudes (tropical and sub-tropical areas) where the temperature is already high, global warming may lead to excessive high temperature that will have direct heat damage and/or the shortening of the life cycle duration of the crop. Both phenomena will reduce yields. So, one of the areas that may be affected negatively by the climate change is CWANA. Among the options that may help plants better adapt to drought and high temperature are the early planting date to escape terminal drought and heat, the application of limited amounts of irrigation at critical stages to maintain transpiration and its cooling effect on plants and adapted varieties to temperature and drought stresses. The two potential mechanisms of adaptation are the tolerance and escape but with high sink strength through the lengthening of the stem elongation period and optimal anthesis date.

The overall objective of this study is the sustainable increase of wheat yield in dry areas of WANA. The purpose is the development of options that improve the adaptation of wheat to high temperature and drought.

Materials and Methods

The factors studied were planting date (early D1 vs. Late D2), water regime (Rainfed vs. Supplemental irrigation) and the genotype (4 genotypes of durum wheat). The experimental design used was a strip-split plot with planting date as the main plot, water regime as the sub-plot and genotype as the smallest plot with 3 replications. The plot of the experiment was plowed twice with an offset disk. The early planting was established in November 11, 2014 and the late one in December 24, 2014. Rainfed treatment received only rainfall. However, supplemental irrigation plots received, in addition to rainfall, 160 mm of irrigation water in three applications for the early planting and 275 mm in five applications for the late planting, according to the rainfall events. The genotypes tested were Karim (V1), Louiza (V2), Nassira (V3), and PM9 (V4). The seeding rate was 160 kg ha. Phosphorus (P) and nitrogen (N) were applied at planting as DAP (18-46-0) at rate of 200 Kg ha-1. At tillering and stem elongation, 60 Kg N ha-1 were added as ammonium nitrate. The measurements taken were grain yield, actual evapotranspiration (ETa) and grain water productivity (WP) at harvest. Water productivity was calculated as the ratio of grain yield to actual evapotranspiration. Soil moisture was measured at planting and harvest using a gravimetric method. Measurements were taken at 0-30, 30-60, 60-90 and 90-100 cm. ETa was calculated using the water balance equation. All data were analyzed using SAS statistical software. The analysis of variance (ANOVA) was performed to examine the various treatment differences and interactions.

Results

Data on rainfall for the growth season are presented in figure 1.

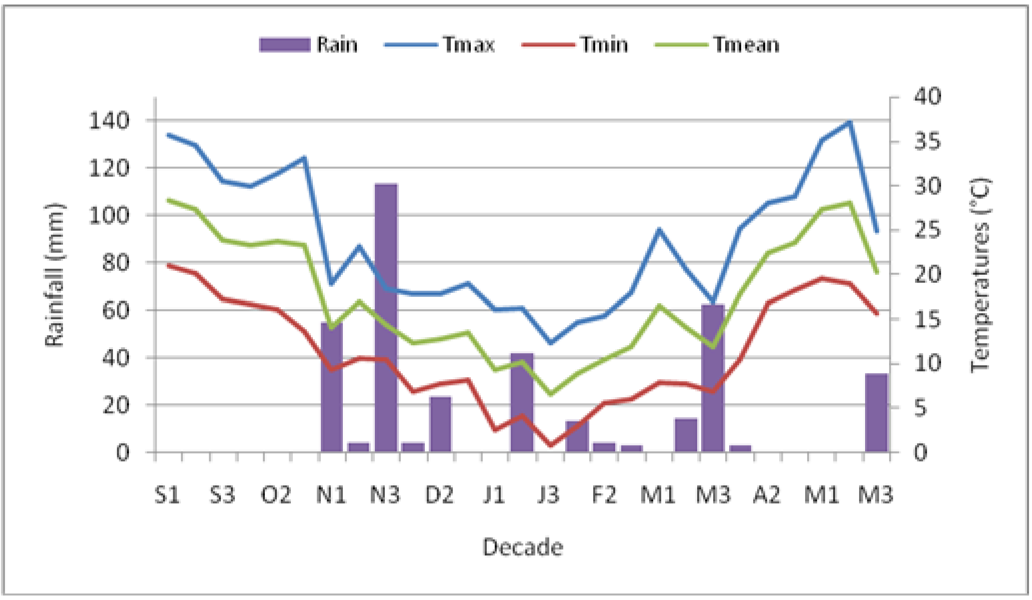

Figure 1. Monthly rainfall distribution and average temperatures (Tmin, Tmax and Tmean) in Afourer experiment station during 2014-2015 cropping seasons.

The prevailing climatic conditions during the first period of the 2014-2015 growing season are illustrated in Figure 1. The total amount of rainfall received from September 2014 to June 2015 is 378 mm. These amounts are very close to the average rainfall calculated for different regions over more than thirty years of data. Therefore, in terms of total rainfall received, this cropping season is considered as an average season for cereal production mainly wheat crop. However, the early rain received during November was quite high and handicapped the early planting of wheat in few cases of our demonstration trials (178 mm).

The temperature was quite adequate during the beginning of the season and allowed crop establishment and favorable development. However, in the end of the season higher temperatures were registered. These boosted the development of the crops and therefore the early maturation of the grain. From January to February, very low temperatures have been registered in both regions. The lowest temperature was less than -2 °C registered during the last week of January.

Grain yield per hectare obtained under different planting dates, water regimes and genotypes is presented in Table 1. The analysis of variance showed significant effects of planting date and supplemental irrigation. However, the effect of genotype was significant only under rainfed and early planting date, despite of yield differences between some of the genotypes. On the other hand, only D x WR interaction is significant. Early planting gave an average grain yield increase from 1.40 to 1.7 tons ha-1 under rainfed conditions and from 3.1 to 5.4 tons ha-1 under supplemental irrigation.

Table 1: Effect of planting Date (D), water regime (WR) and genotype on grain yield (tons ha-1) of durum wheat in Afourer, Morocco, during the cropping season 2014/2015.

Genotype	Date 1		Mean	Date 2		Mean
	Rainfed	SI		Rainfed	SI	
Karim	2,1	5,7	3,9	1,7	3,2	2,4
Louiza	1,8	5,3	3,5	1,4	3,3	2,3
Nassira	2,0	5,2	3,6	1,4	3,0	2,2
PM9	1,1	5,2	3,2	1,2	2,9	2,1
Mean	1,7	5,4	3,5	1,4	3,1	2,3

In terms of water consumption, the data of ETa are summarized in table 2. The analysis of variance showed a significant effect of WR , D and D x WR. However, the interactions involving the genotype were not significant
.

In average, supplemental irrigation had almost the same ETa for both planting dates. However, under rainfed the ETa in D1 is higher than that in D2.

Table 2. Effect of planting Date (D), water regime (WR) and genotype on actual evapotranspiration (mm) of durum wheat in Afourer, Morocco during the cropping season 2014/2015.

Genotype	Date 1		Mean	Date 2		Mean
	Rainfed	SI		Rainfed	SI	
Karim	285	445	365	182	457	320
Louiza	284	444	364	180	455	318
Nassira	286	446	366	179	454	317
PM9	287	447	367	181	456	319
Mean	286	446	366	181	456	318

Water productivity was affected significantly by planting date, water regime and D x WR. The genotype effect is significant only in the case of Rainfed Early planting (Table 3). In average, early season planting had higher WP than late planting. Supplemental irrigation increased WP from 0.6 to 1.2 kg/m3 under D1.

Table 3. Effect of planting Date (D), water regime (WR) and genotype on water productivity (Kg/m3) of durum wheat in Afourer, Morocco during the cropping season 2014/2015.

Genotype	Date 1		Mean	Date 2		Mean
	Rainfed	SI		Rainfed	SI	
Karim	0,7	1,3	1,1	0,9	0,7	0,8

Louiza	0,6	1,2	1,0	0,8	0,7	0,7
Nassira	0,7	1,2	1,0	0,8	0,7	0,7
PM9	0,4	1,2	0,9	0,7	0,6	0,6
Mean	0,6	1,2	1,0	0,8	0,7	0,7

Conclusion

The results of this year show clearly that advanced planting date and supplemental irrigation during the critical phases of the growing cycle of wheat can ensure an additive positive effect of the two technologies on grain yield, total water uptake and water productivity in the cereal prone regions where the Mediterranean climate type is prevailing. Generally, the tested genotypes were not significantly different even though some small differences were observed in certain cases. However, the attenuation of late planting negative effect on yield was observed in the case of tested genotypes.

2) Deficit supplemental irrigation package for improved water and land productivities of durum wheat in Tadla region, Morocco

Mohamed Boutfirass (INRA) and Mohammed Karrou (ICARDA)

Introduction

In Morocco, water is not only a limiting factor of agricultural production; but also a limited natural resource. Water scarcity is due to a high demand caused by accelerated demographic growth, an increase in water demand by sectors other than agriculture (industry, tourism, etc.), the mismanagement of this resource by farmers, and recurrent droughts. To reduce the effects of water shortage on agricultural production, it is urgent to adopt a new strategy of water use based on an integrated and efficient management of irrigation and rainwater. Research conducted in Morocco and other countries having similar climate showed that certain new technologies have given good results in experimental stations and under certain farms conditions. These technologies need to be disseminated at a large scale in order to increase the national crop production, contribute in water saving and ensure sustainability of agriculture in rainfed areas.

Deficit supplemental irrigation technique was already evaluated in Tadla area during the first phase of the Water Benchmark project. This technique had a positive impact in saving irrigation water in wheat production and enhancing the water productivity.
The proposed technology is a management package combining deficit supplemental irrigation and associated agronomic management practices including sowing times and fertilizer recommendations developed by within the Water Benchmark project. The package has been tested on a number of farms on the Tadla perimeter. The yields increased by 17-20o/o with average irrigation water saving of 1100 m3/ha.

The objective of this study is to disseminate the best-bet packages of deficit supplemental irrigation and associated cultural practices and to evaluate their impact on productivity and water use efficiency.

Methodology:

A number of meeting sessions were organized with the ORMVAT (Extension institution in charge of irrigation water) representatives and two communities were selected. Within each community, 30 farmers were identified to be part of the working group participating to the dissemination activities such as farmer's field school and field days.
Two on-farm demonstrations (Field demonstration platform) were implemented, one in each community. The improved management package combining deficit supplemental irrigation and associated agronomic management practices including sowing times and rate, fertilizer recommendations, weed and diseases control was used in these demonstration trails. This technological package is compared to the farmers' practice. Supplemental irrigation management is following the ORMVAT scheduling based on the climatic data from meteorological stations distributed within the region. However, soil samples were taken from the plots before and after each irrigation.

According to the plan of work that have been developed for the 2014-2015 season, the communities and the group of farmers to work with are identified. The farmers to implement the field activities are also identified as to host the Project Managed Demonstration Fields (PMDF), the Farmers Managed Demonstration Fields (FMDF) or the Neighbor-influenced Farms (NIF). However, the PMDF were the only implemented activities. This is due to the delay of the Agreement signature so was the delay in the funds disbursement. Therefore, most of the activities will be carried out next season.

In the implemented on-farm demonstration trials, different soil moisture measurements were taken at different depths (0-30, 30-60 and 60-90 cm). These data are used in the determination of water consumption of the crop. The irrigation water used is also calculated from the number of irrigation hours and the flow of the tertiary irrigation network.

At harvest, four samples from the PMDF plots and the farmers' plots are taken to the estimate the yield.

General features of the climate during the report period

The prevailing climatic conditions during the growing season 2014-2015 are illustrated in figure 1. The total amount of rainfall received from September 2014 to June 2015 is 378 mm. This amount is very close to the average rainfall calculated for over more than thirty years of data. Therefore, in terms of total rainfall received, this cropping season is considered as an average season for cereal production mainly wheat crop. However, the early rain received during November was quite high (178 mm).
The temperature was quite adequate during the beginning of the season and allowed crop establishment and favorable development in the targeted areas. However, at the end of the season, higher temperatures were registered. These boosted the development of the crops and therefore, the early maturation of the grain. From December to January, low temperatures have been registered. The lowest temperature was -2°C registered during mid-February.

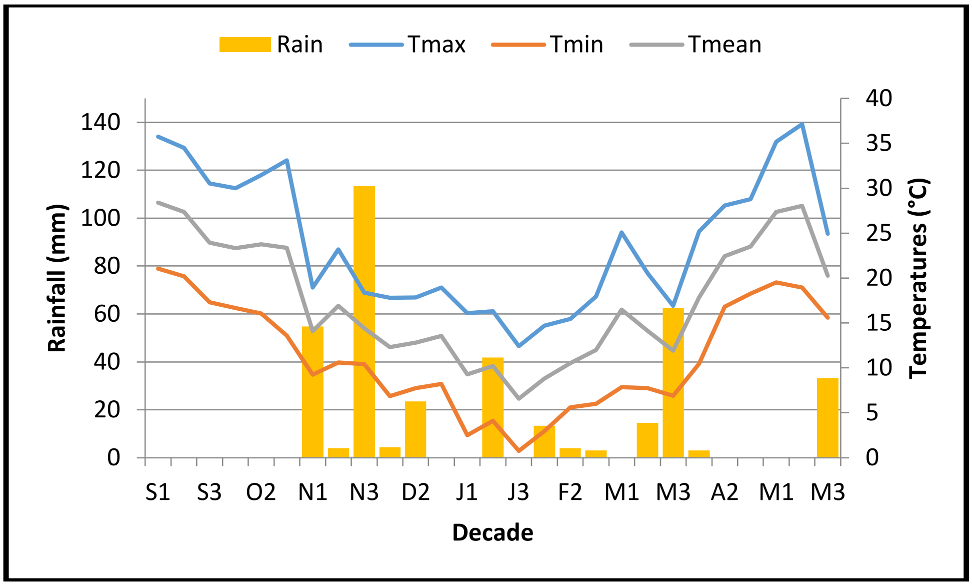

Figure 1. Monthly rainfall distribution, average temperatures (Tmin,T max and Tmean) at Tadla region during 2014-2015 cropping season.

Results

The treatments considered in the demonstration trials are full supplemental irrigation with the improved package (FSI), deficit supplemental irrigation with the same package (DSI) and the farmer's practices under full supplemental irrigation (check).

The main results of the field trials are presented in table 1. Grain yields obtained in the demonstration plots where the improved technological package for wheat production was introduced (FSI and DSI) over yielded the check in in the case of the farmer Erraji. In the case of Erraqioui, the difference is not that significant. Indeed, this farmer is mastering the technological package introduced and he is using it in his own plots given his long experience with hosting the demonstration trials in the area.

The average yield increment is 18% for FSI and 9% for DSI. However, the average yield difference between deficit irrigation and full supplemental irrigation in the demonstration plots is not statistically significant in both demonstration plots. The yields (Table 2) of the neighboring farmers vary from around 3.0 to 5.0 tons/ha which are equivalent to 50 to 75% of deficit irrigation package.
During the previous year (2014), the average yield gain and water saving were in average 1.1 t/ha (18%) and 1100 m3 (30%) of irrigation water.

Table 1. Grain yield, biomass, Irrigation water applied and rainfall during the growth period of wheat and water productivity in Tadla. 2014-2015

Farmer	**Erraqioui**			**Erraji**		
Treatment	FSI	DSI	Check	FSI	DSI	Check
Grain Yield (T/ha)	6.8	6.5	6.5	7.2	6.8	6.1
Total Biomass (T/ha)	15.3	14.2	15.3	17.1	15.1	13.7
Irrigation Water (mm)	271	194	271	418	316	418
Rainfall (mm)	283	283	283	283	283	283
∆ S (mm)	-0.7	1.6	4	-0.4		
Water productivity (kg/cm)	1.2	1.4	1.1	1.0	1.1	0.9

Table 2: Grain yields of neighboring farmers

Neighboring Farmers of Erraqioui	GY (T/ha)	Neighboring Farmers of Erraji	GY (T/ha)
El Mokhtari	4.0	Raiss	3.1
Hattat	4.5	Eddini	3.8
Safr	4.8	Moufssil	4.0
Sahel	5.0	Nahal	4.8
		Mounaim	5.2
		Falah	5.2

Considering the rainfall during the growing season of wheat in Tadla, that was only 283 mm, the farmers applied supplemental irrigation water less than last season during the non-rainy periods of the wheat growth cycle in order to sustain a good production. With deficit irrigation the average amount of water saving was from 770 m3 and 1020 m3 (table 1).
Under the climate changes and water scarcity that are occurring around the world and particularly in Morocco such saving of irrigation water is a challenge by itself.

More important, and this is an essential component that should be promoted at the farmers level, Water Productivity obtained with deficit irrigation was higher than that obtained with full supplemental irrigation even under the same improved production package. The lowest water productivity was observed at the check level.

Conclusion and main messages

Climatic changes occurring during last decades are leading to serious scarcity in water availability and the agricultural share for irrigation water is decreasing continuously. Water management at the irrigated perimeters should be then considered as one of the highest priorities in these systems, and effectively well-targeted for the sustainability of the systems. Deficit irrigation has proven it usefulness at the experimental level. This technique introduced in the Tadla area at farmers' level confirmed now its positive impact in saving irrigation water in wheat production and enhancing the water use efficiency. The water saving through the use of this technique is also proven to increase with the decrease in annual rainfall. Therefore it is very well coping with the water scarcity that the area is experiencing. However this deficit irrigation (which consists only to reduce by 30% the amount of water usually applied) should be combined with the improved technical package.

III. Field days and training

- Field days were conducted on wheat (35 farmers) and potatoes (35 farmers)
- Co-advising of an MS students (thesis document)
- Co-advising of a PhD on inputs use efficiency in mixed cropping (olive trees, faba bean, wheat).

Photo field visit (INRA experimental station

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The CGIAR Research Program on Dryland Systems aims to improve the lives of 1.6 billion people and mitigate land and resource degradation in 3 billion hectares covering the world's dry areas.

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