Effect of Irrigation Methods and Plastic Mulch on Yield and Crop Water Productivity of Okra

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Abstract: A field experiment was conducted during 2014-15, aiming to observe the efficiency of irrigation methods and plastic mulch on the yield and crop productivity of Okra. Okra seeds (cv. Subzpari) were grown on ridges with plastic under two different irrigation methods *i.e.* Every Furrow Irrigation (EFI) and Alternate Furrow Irrigation (AFI). The soil physical properties of ridges being affected by plastic mulched were analyzed before sowing and after harvesting. The results revealed that dry density of soil decreased by 0.03 g cm^{-3} and 0.04 g cm^{-3} for AFI and EFI methods, respectively. The total volume of irrigation water applied under AFI method (2169.70 m^3 ha^{-1}) was calculated to be half of the total irrigation water applied to EFI method (4340.91 m^3 ha^{-1}). Yield obtained under EFI method was 8518 kg ha^{-1} which was 10.5% greater than yield obtained under AFI method (7621 kg $ha^{-1)}$ and 31.40% when compared with traditional method. The crop water productivity (CWP) for AFI method (3.51 kg m^{-3}) was calculated to be greater than CWP obtained under EFI method (1.96 kg m^{-3}). The study concluded that both EFI and AFI methods, under plastic mulched ridges practices were beneficial to increase the crop yield with improved crop water productivity.

Keywords: Irrigation method, Okra Crop, Plastic Mulching, Yield, Water Productivity.

1. INTRODUCTION

Water is an important factor for agricultural sustainability, financial development and environmental security. Even though water is copious, the issue really is the quantifying of the available freshwater resources [1]. Water use for agriculture sector is becoming critical for food security, as it also remains the world's largest freshwater consuming sector [2]. Pakistan is now moving towards a water scarce country, the water accessibility has dropped significantly from 5650 m^3 to 1200 m^3 per person in last five decades and expected to be less than 1,000 m^3 per person in 2025 [3]. Moreover, in Pakistan, the surface irrigation method is usually adopted to irrigate the crops by flooding the field surface, which in result is a great loss of freshwater.

EFI is considered as an efficient conventional method of surface irrigation which is now being widely used for irrigating row crops, by selecting proper combination of spacing, length and slope of furrows and duration of water application [4]. The AFI method significantly enhanced root growth in arid areas, resulting high crop yield saving irrigation water up to 50% [5, 6]. The AFI involved manipulation of soil water to make the crop's inherent response to drought conditions improve their water use efficiency [7].

Mulching with synthetic material and crop residues are established practices, increasing the profitability of crops [8, 9]. Plastic mulching enhances plant growth, improves crop water productivity and controls salinity in the root zone [10, 11, 12]. Plastic mulching has been used in various areas of the world for the higher production of vegetables in order to get maximum water use efficiency by the field crop [13, 14]. The vegetable plants grown on plastic mulched had shown earlier maturity (7 to 14 days) and increased yields (2 to 3 times) as compared to bare soil [15, 16]. Plastic mulching was observed to be an effective practice to improve the yield and crop water productivity in the semiarid area [17, 18]. Yield of alternate partial root-zone irrigation (APRI) method with plastic mulching was greater as compared to practices applied without mulching [19].

Okra "*Abelmoschus-esculentus (L.)*" is widely cultivated in Kharif and Rabi seasons. The total production of okra in the world about is 4.8 million tons. Major contribution of okra is being produced by India with 70%, followed by Nigeria 15%, Pakistan 2%, Ghana 2%, Egypt 1.7% and Iraq 1.7% [20]. In Pakistan, the total area under okra cultivation is about 14.78 thousand hectare (ha) and the total production is about 0.112 million of tons with an average yield of about 7.55 tons/ha [21].

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Keeping in view, the research study was conducted to determine the effect of plastic mulching on yield and crop water productivity of okra crop under every furrow and alternate furrow irrigation methods under plastic mulching.

2. MATERIAL AND METHODS

2.1. Description of the Experimental Site

The experiment was conducted, during Kharif season of 2014-15 at experimental field of Faculty of Agricultural Engineering, Sindh Agriculture University Tandojam. The total area of the experimental plot was 1200 m^2 (25 m x 48 m) which was then divided into twelve sub-plots each of 66 m^2 (11 m x 6 m). The area has a high temperate semi-arid climate, with an average annual precipitation of 180 mm.

2.2. Design of the Field Experiments with the Plastic Mulching Application Description

The field experimental plot included two irrigation methods (*i.e.* Every Furrow Irrigation and Alternate Furrow Irrigation) with plastic mulch ridge cover. The experimental plots were deep ploughed by moldboard plough, leveled and then pulverized by disc harrow. The width of each ridge was kept as 0.40 m and ridge x ridge distance was kept as 0.50 m, the total length of each furrow and ridge was 11 m under both methods. The ridges were covered with polyethylene plastic sheets (0.030 mm) while furrow beds were kept uncovered (Figure **1**). The experiment was laid down using randomized complete block design (RCBD) with six replications.

Figure 1: Cover ridges with Plastic Mulching.

2.3. Soil Sampling and Field Measurements

The metrological data for the growing season was collected from the Drainage Reclamation Institute of Pakistan (DRIP) Tandojam, with average monthly temperature (^{0}C), average monthly evaporation (mm), sunshine hours and total rainfall (mm). During the okra-growing season, the soil water content was measured at Saturation Capacity (0 bar), Wilting Point (33.34 kPa) and other characteristics of soil water were recorded through pressure plate apparatus. Soil samples were collected from both experimental methods from three different locations on various depths *i.e.* 20, 40, 60 and 80cm for the determination of physical properties of soil before and after harvesting (Table **1**). The relative percentage of soil separates and textural classes in the soil samples were determined by mechanical analysis method using Bouyoucous Hydrometer [22] and soil dry density before sowing and after harvesting was calculated only for the upper portion of soil at a depth of 0-20 cm with the help of tube sampler of known diameter from both experimental methods using the core method with following equation [23].

$$\text{Dry density} = \frac{\text{Dry weight of soil}}{\text{Total Volume of soil}}$$

2.5. Selection and Sowing of Crop

Okra (cv. Subzpari) was selected and grown for determining the effect of plastic mulch on crop yield and water productivity. After placing the plastic sheets on ridges, the okra seed was planted on 10th May 2014 having plant to plant spacing of 20 cm. The germination of the seeds started after 4-5 days under both methods.

2.6. Irrigation Management

A soaking dose of 80 mm was applied to plots for both EFI and AFI methods for providing a sufficient moisture for seed germination. The time required irrigating the furrows, discharge, and depth of the water applied to each method was calculated by using equation given below [24]. Where “Q” is the discharge in m^3/sec, “T” is the time in second, “A” is the area in square meter and “D” is the water depth in meter.

$$QT = A \times D$$

2.7. Crop Water Productivity

The Crop Water Productivity (CWP) is defined as, crop yield per unit application of irrigation water which was calculated using following equation [25]. Where “CWP” is the Crop water productivity in kg-m^3, “Y” is the Total cropping yield in kg and “WR” is the Total volume of water consumed in m^3.

$$CWP = \frac{Y}{WR}$$

Table 1: Soil Physical Properties at before the Experiment

Soil Profile (cm)	Soil Physical Analysis				
	Sand %	Silt %	Clay %	Textural Class (USDA)	Dry Density (g cm^{-3})
0-20	28.20 ±0.291	48.60 ±0.155	23.20 ±0.367	Loam	1.28 ±0.015
20-40	32.50 ±0.266	50.23 ±0.118	17.30 ±0.123	Silt Loam	-
40-60	34.74 ±0.100	47.63 ±0.131	17.65 ±0.193	Loam	-
60-80	35.76 ±0.234	45.54 ±0.224	18.70 ±0.221	Loam	-

Soil Water Characteristics (0-80cm)					
Porosity (n) %	Infiltration rate (mmhr^{-1})	Field capacity (vol %)	Wilting Point (vol %)	Saturation Capacity (%)
0-80	51.00 ±0.295	15.65 ±0.257	32.63 ±0.163	16.32 ±0.115

±Standard Error.

2.8. Crop Yield

The crop yield of both methods was compared, while the increase in yield (%) was computed using the following equation [26]. Where "Y_{EFI}" is the Total yield in kg ha^{-1} of okra under every furrow irrigation method and "Y_{AFI}" is the Total yield (kg ha^{-1}) of okra with alternate furrow irrigation method.

$$\text{Yield Increase}(\%) = \frac{Y_{EFI} - Y_{AFI}}{Y - EFI} \times 100$$

3. RESULTS

3.1. Soil Dry Density

The dry density of the soil samples before sowing and after harvesting is presented in Table **2**. It indicated that the dry density of soil samples before sowing was same (1.28 g cm^{-3}) under EFI and AFI methods, which slightly increased from 1.28 g cm^{-3} to 1.32 g cm^{-3} under EFI and from 1.28 g cm^{-3} to 1.30 g cm^{-3} under AFI. However, with the plastic mulched ridges, the soil dry density slightly decreased from 1.25 g cm^{-3} to 1.22 g cm^{-3} under EFI and from 1.23 g cm^{-3} to 1.19 g cm^{-3} under AFI method.

3.2. Irrigation Water Use

The irrigation water applied under AFI method was 2169.70 m^3 ha^{-1}, which was exactly half of the irrigation water used under EFI method (4340.91 m^3 ha^{-1}), the data was also compared to other traditional irrigation methods used in which water applied was 7200 m^3 ha^{-1} under flood irrigation practices (Table **3**).

3.3. Crop Yield & Water Productivity

Okra yield was recorded to be 8518 kg ha^{-1} and 7621 kg ha^{-1} under EFI and AFI irrigation methods

Table 2: Soil Dry Density for Furrows and Ridges under both Methods

Soil Profile Depth (cm)	Soil Dry Density (g cm^{-3})							
	Before Sowing				After Harvesting			
	Furrow		Ridge		Furrow		Ridge	
	EFI	AFI	EFI	AFI	EFI	AFI	EFI	AFI
0-20	1.28	1.28	1.25	1.23	1.32	1.30	1.22	1.19

Table 3: Irrigation Water Use in both Methods

Methods	Crop Water depth (mm)	Rainfall (mm)	Total Water depth (mm)	Volume of water used (m^3/sub-plot)	Water applied (m^3/ha)
EFI	434	0.17	434.17	28.65	4340.91
AFI	434	0.17	434.17	14.32	2169.70
Flood	-	-	-	-	7200*

*Reference values from [32].

respectively (Figure **2**). Thus, the crop yield was 10.5% more with EFI method when compared to AFI. Statistically, the effect on the yield of okra crop was found significant ($P<0.05$) under both irrigation methods (Table **4**). The comparative analysis of every furrow and alternate furrow irrigation methods showed a significant difference in the crop water productivity. Consequently, the crop water productivity under EFI and AFI irrigation methods were calculated to be 1.96 kg m^{-3} and 3.51 kg m^{-3} respectively. Hence, the crop water productivity was remarkably higher under AFI when compared to EFI.

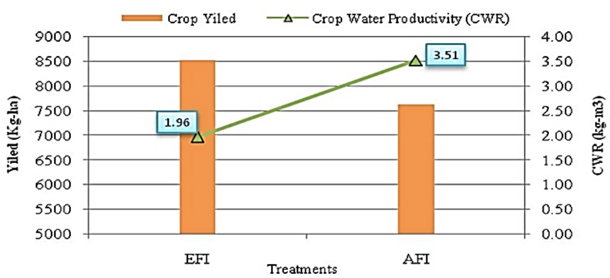

Figure 2: Crop Water Productivity and yield under both methods.

3.4. Statistical Analysis

The effects of the plastic cover ridge were examined on the base of soil physical properties, crop yield, and water productivity. Hypothesis, whether they are different from each other, were tested. The experimental finding results were statistically confirmed by using the Analysis of Variance (ANOVA) under selected replications on different of irrigation methods. The statistical results are presented in Tables **4** to **6**.

4. DISCUSSION

The availability of the fresh water is decreasing with increasing demand therefore, to grow more crops with available fresh water is to be achieved by adopting effective irrigation methods. Plastic mulches recently has been successfully adopted to reduce the evaporation and to save the maximum amount of water to grow more crops with better crop yields. This study therefore was conducted to examine the effects ridge-cover plastic mulching on yield and water productivity of okra crop.

Soil Texture has an important influence on the physical behavior of the soils and it has a significant role in the productivity of the soil. Particles size distribution results showed that most of the soils of the experimental area were loamy in texture and remain unchanged after harvesting of the crop. The results are in accordance Zhang *et al.*, they also reported that there wasn't any effect of plastic mulching on soil

Table 4: Effects of Methods (EFI & AFI) on Crop Yield

Crop Yield					
Source	**DF**	**SS**	**MS**	**F**	**P**
Replications	5	16295	3259	0.17	0.0021
Method	1	182657	182657	9.73	
Error	185	3473159	18774	-	-
Total	191	3672111	-		

Grand Mean 554.74 CV 24.70.

Table 5: Tukey HSD All-Pairwise Comparisons Test (Average and Standard Error for Crop Yield)

Crop Yield		
Irrigation Method	**Every Furrow (EFI)**	**Alternate Furrow (AFI)**
***Mean**	**523.90**	**485.58**
Homogeneous Group	**B**	**A**
Alpha	0.05	
Critical Q Value:	2.772	
Standard Error for Comparison	19.777	
Critical Value for Comparison	38.761	
Error term used	185 DF	

*All 2 means are significantly different from each other.

Table 6: Tukey HSD All-Pairwise Comparisons Test (Average and Standard Error for Crop Water Productivity)

Crop Yield		
Irrigation Method	**Every Furrow (EFI)**	**Alternate Furrow (AFI)**
***Mean**	**1.9550**	**3.5100**
Homogeneous Group	**B**	**A**
Alpha	0.05	
Critical Q Value:	3.633	
Standard Error for Comparison	0.0348	
Critical Value for Comparison	0.0894	
Error term used (Replication × Method	05 DF	

*All 2 means are significantly different from each other.

texture or structure [27]. The average dry density of soil after harvesting (Table **3**) slightly increased in furrows under EFI and AFI, while after plastic mulched ridges substantially decreased under both methods. This was mainly associated with the minimum depletion of moisture with enhanced aeration and microbial activities in the soil. It has been similarly reported by many researchers that dry density of the soil with plastic mulched ridges was lower than the dry densities of the control fields [28, 29, 30]. Total irrigation used in AFI method was less when compared to EFI. The results followed a similar trend as reported by Shaozhong *et al.,* that the alternate irrigation method used saved about 50% of irrigation water when compared to every furrow irrigation method [6].

The highest okra pod yield was observed under EFI method as compared to AFI method (Figure **2**). Lower okra yield produced under AFI method was due to lower volume of irrigating water applied during cropping period [31, 32, 33], the same has been also reported by many researchers, stating that the okra crop under plastic mulch with every furrow and alternate furrow irrigation methods enhanced crop yield, as it increased soil temperature, advanced flowering suppresses weed growth, reduces soil water loss and conservation of moisture [34, 35].

Crop water productivity was significantly higher under AFI as compared to EFI method. These results are fully supported by Ibrahim *et al.,* who found that crop water productivity was considerably higher as compared to EFI method because less volume of irrigation water was used under AFI method [36]. These results are also in line with other researchers, who concluded that the crop water productivity was recorded greater in a plastic mulched method when compared with un-mulched method [37, 38].

5. CONCLUSION

The dry density of the soil decreased by 0.03 and 0.04 g cm^{-3} for AFI and EFI methods. The crop water productivity was observed to be higher i.e. 3.51 kg m^{-3} under AFI while it was 1.96 kg m^{-3} under EFI method. Although the okra yield was higher (8518.30 kg ha^{-1}) under EFI as compared to AFI method (7621.32 kg ha^{-1}), but the difference in yield here is minor and could be well compensated by saving a considerable amount of irrigation under AFI method. EFI and AFI methods with plastic mulched ridged is suggested for improving the growth and development of crops by preventing evapotranspiration, enhancing crop yield and reducing costs incurred on the eradication of weeds by increasing the soil temperature. Further research should be carried out to evaluate the effect of plastic mulching types and colors on different crops in different climatic regions.

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