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COMPARATIVE WATER USE EFFICIENCY OF DRIP AND FURROW IRRIGATION SYSTEMS FOR OFF-SEASON VEGETABLES UNDER PLASTIC TUNNEL

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ABSTRACT

The experiment was conducted under plastic tunnel at Groundnut Research Station, Attock, Pakistan during 2006-2007 to 2008-2009 to determine water consumption by three off-season vegetables irrigated through drip and furrow systems, and to evaluate the comparative water use efficiency (WUE) of two irrigation systems in rain fed areas. Drip and furrow irrigation systems were tested on tomato, cucumber and bell pepper in this study. A permanent tunnel of 24 x 8 x 3 m was erected. Each crop was planted on 6 x 8 m under drip irrigation and on 6 x 2.70 m under furrow irrigation system. Water use efficiency was calculated as the ratio of total yield (kg) to total water consumed by the crop (m^3). Each crop consumed less water under drip irrigation as compared to furrow irrigation system. Amomg crops, cucumber comsumed the least amount of water irrespective of irrigation systems. Average water use efficiency increased by 250% for tomato, 274% for cucumber and 245% for bell pepper under drip irrigation system as compared to furrow system. On the contrary, the average fruit yield increased only by 2.05% for tomato, 3.32% for cucumber and 2.35% for bell pepper in furrow irrigation over drip irrigation. This suggested that drip irrigation has a greater scope for production of off-season vegetables especially in water scarce areas of Pakistan.

Keywords: Bell pepper, Cucumber, Drip irrigation, Furrow irrigation, Off-season vegetables, Plastic tunnel, Tomato, Water use efficiency

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INTRODUCTION

Vegetable crops are the eminent source of human nutrition in Pakistan. These are short duration crops and may be grown in small piece of land. Demand for fresh or canned vegetables is increasing day by day in the national and international market due to increasing population (Wallace, 2000). Production should be increased by several folds to meet up the vegetables demand for increased population as well as to keep its price within the capability of urban and rural poor (Ali and Niaz., 2008). Adequate source of irrigation water throughout the growing season is essential for commercial vegetables cultivation. But irrigation water is not available for vegetables cultivation in the country. Therefore, adoption of more efficient water use technology is indispensible which may contribute a lot in such case. Every summer crop may be grown under plastic tunnel in winter season but the researchers and farmers have paid little attention to tomato, cucumber and bell pepper. Off-season vegetables can provide 15 times higher net return compared to those of optimum sowing. Moreover, efficient use of irrigation water in plastic tunnel allow flexibility in planting time, establishing a more uniform plant stand, influencing soil temperature, utilizing certain herbicides and soil fumigants more effectively, and assuring reliable yields (Amjad et al., 2007). In rainfed areas of Pakistan, more than 60% of the farmers are small land holders having less than 2 hectares of land. Moreover, there is no source of supplying irrigation water when required. Therefore, farmers should grow summer vegetables in winter season under plastic tunnel to get more profit from small piece of land.

Despite high return, non-availability of irrigation water is hindering expansion of area under vegetables (Baksh and Ahmad, 2004). Drip or micro irrigation is an expensive, but efficient system of irrigating high value crops such as vegetables. Combined use of such systems with mulches and row covers for added efficiency should be taken into consideration (Amjad et al., 2007). Literature revealed that water use efficiency was maximum in drip system (75-95%) compared to surface furrow (25-50%), solid set sprinklers (70-80%) and portable sprinkler (65-75%) systems (Smajstrla et al., 1988; Sanders, 1990). Similarly, Maisiri et al. (2005), Mahajan and Singh (2006), and Ngouajio et al. (2007) reported higher irrigation water use efficiency (IWUE) in drip irrigation system in case of tomato. Malash et al. (2005) and Mahajan and Singh (2006) recorded higher yield of tomato under drip irrigation than surface irrigation system while Maisiri et al. (2005) observed no significant difference in vegetable yield between irrigation systems. Yields of bell pepper increased from 29.64 to 46.93 t ha^{-1} by using drip irrigation and plastic mulch culture together (Crespo-Ruiz, 1988). Palada et al. (2003) reported higher water use efficiency of drip system in combination with plastic mulch in case of bell pepper. Drip irrigation also improved marketable yield and fruit quality in case of tomato. However, literature regarding water consumption by off-season tomato, cucumber and bell pepper irrigated through drip and furrow systems under plastic tunnel in Pakistan is meager. Hence, this study was undertaken to determine water consumption by off-season tomato, cucumber and bell pepper irrigated through drip and furrow systems under plastic tunnel and to estimate the comparative water use efficiency of these irrigation systems for off-season crops in rain fed areas of Pakistan.

MATERIAL AND METHODS

The study was carried out under plastic tunnel at Groundnut Research Station, Attock, Pakistan during 2006-2007 to 2oo8-2009. Attock is situated within 33^0 $46^/$ North and 72^0 $22^/$ East. The soil was sandy loam with Ece 0.20-0.18 dsm^{-1}, pH 7.6-7.7, organic matter 0.60-0.45%, Olsen-P 4-2.5 mg kg^{-1} soil at 0-15 and 15-30 cm depth, respectively. Two irrigation systems viz. drip and furrow systems were tested on three off-season vegetables viz. tomato, cucumber and bell pepper in this trial. The methodology of seedling raising, transplanting and harvesting of tomato, cucumber and bell pepper are given in table 1. Seeds of tomato, cucumber and bell pepper were sown in plastic bags having mixture of soil, farmyard manure and sand in equal quantities, which were irrigated and were protected from diseases and insects. A permanent tunnel of 24 x 8 x 3 m was erected. The tunnel was divided into four equal parts. On three parts (6 × 8 m each), tomato, cucumber and bell pepper were transplanted under drip irrigation while the fourth part was again divided into three parts (6 × 2.70 m each). On these three parts, the three crops were transplanted as to provide them irrigation in furrows. The tunnel was covered with plastic sheet. The data of water applied through each drip and furrow irrigation was recorded through water meters. Two gram of each Urea, DAP and Potash were applied to each plant of tomato, cucumber and bell pepper at fortnight interval. Plant protection measures were adopted to avoid insect and disease attack as and when needed. Temperature data inside the tunnel were recorded on daily basis and shown in figure 1. Data regarding total water used, number of irrigations, water used per irrigation, water used per plant per irrigation, water used per plant per day and total yield were recorded from all vegetable crops on per unit area basis. After harvesting of the crops, water use efficiency of each irrigation system was calculated according to the following formula (Hillel, 1997):

$$WUE = \frac{\text{Total Marketable Yield (kg)}}{\text{Total Water Used (m}^3\text{)}}$$

RESULTS AND DISCUSSION

The life span of tomato crop varies from 6 to 7 months inside the plastic tunnel but in normal summer season it is 4 to 5 mongths. Averaged of three years, 116 irrigations as drip and 100 irrigations as furrow were applied to tomato crop grown in plastic tunnel (Table 2). Although the tunnel was covered with tarpaulins to protect the crops from severe cold at night inside the tunnel but the temperature remained uncontrolled from mid December to mid January. Owing to severe cold, irrigation frequency was increased in both the irrigation systems during that period for retrieving the crop to normal growth. Ali and Niaz. (2008) also provided more irrigations in their study. Amount of water used per plant per irrigation (10.33-13.91 litres) and water used per plant per day (3.26-7.27 litres) in furrow was much higher than that of drip irrigation (Table 2). Consequently, total amount of water used per hectare in furrow system was 18531-29805 m^3 while in drip irrigation it was 4501-7318 m^3 (Table 3). Averaged of three years, tomato consumed 22599 m^3 of irrigation water through furrow system and 6326 m^3 through drip irrigation. The results indicated that 257% more water was required for furrow irrigation compared to drip irrigation (Table 3). In drip irrigation water was applied drop by drop only to the root zone of the plants. Thus, a large amount of water could be saved. Average water use efficiency was higher in drip irrigation (6.50 kg m^3) than that of furrow irrigation (1.86 kg m^3) system. It showed that water use efficiency was enhanced by 250% (ranging from 157 to 319%) in drip irrigation system compared to furrow irrigation system (Table 4).. Other investigators (Smajstrla et al., 1988; Sanders, 1990; Ngouajio et al., 2007) also stated similar results. On the contrary, the fruit yield of tomato increased only by 2.05 % (ranging from 0.82 to 3.26%) in furrow irrigated plots over those of drip irrigated plots (Table 5). But Malash et al. (2005), and Mahajan and Singh (2006) observed higher fruit yield of tomato under drip irrigation than surface irrigation system.

The life span of cucumber varies from 3 to 4 month normally. Average of three years, 76 irrigations as drip and 71 irrigations as furrow were applied to cucumber crop grown in tunnel (Table 2). For cucumber, irrigation frequency was also increased by both the irrigation systems from mid December to mid

January due to severe cold wave. Similar to tomato, the amount of water used per plant per irrigation, and water used per plant per day in cucumber were also more in furrow irrigation than those in drip irrigation (Table 2). Cosequently, total amount of water used per hectare by cucumber was more in furrow irrigation than drip irrigation (Table 3). Averaged of three years, 287 % more water (ranging from 188-335%) was applied to the crop in furrow system compared to that through drip system (Table 3). This resulted in higher water use efficiency in case of drip irrigation (7.12 kg m^3) by saving 287% of water as compared to furrow irrigation (1.90 kg m^3) system (Table 4). The results showed enhanced water use efficiency by 274% (ranging from 171 to 323%) in drip irrigation system as compared to furrow system (Table 4). Similar results were mentioned by Palada et al. (2003). On the contrary, average fruit yield increased only by 3.32 % (ranging from 0.29-6.21%) from furrow irrigated plots over those of drip irrigated plots (Table 5). But Maisiri et al. (2005) reported similar vegetable yield in drip and surface irrigation systems.

Bell pepper completes its life cycle within 7 to 8 months. It was irrigated 113 times in case of drip irrigation and 97 times in case of furrow irrigation (Table 2). Like tomato and cucumber, amount of water used per plant per irrigation, water used per plant per day (Table 2) and total amount of water used per hectare (Table 3) in bell pepper were more in furrow irrigation than drip irrigation. Averaged of three years, 253 % more water (ranging from 165-311%) was applied to the crop in furrow system compared to that through drip system (Table 3). This resulted in higher water use efficiency in case of drip irrigation (3.07 kg m^3) by saving 253% of water as compared to furrow irrigation (0.89 kg m^3) system (Table 4). It showed enhanced water use efficiency by 245% (ranging from 153 to 303%) in drip irrigation system as compared to furrow system (Table 4). These results have been supported by the findings of Smajstrla et al. (1988). On the contrary, the average fruit yield increased only by 2.35 % (ranging from 0.20 to 4.76%) from furrow irrigated plots over those of drip irrigated plots (Table 5). These results are in agreement with the findings of Crespo-Ruiz (1988) and Palada et al. (2003) who reported higher irrigation efficiency of drip irrigation in combination with plastic mulch in case of bell pepper. Similarly, Maisiri et al. (2005) reported no significant difference in vegetable yield between drip and surface irrigation systems.

Among crops, bell pepper consumed the highest amount of water which was followed by tomato, while the lowest amount of water was used by cucumber in both the irrigation systems (Figure 2). Conversely, the maximum water use efficiency (WUE) was observed for cucumber which was close to that of tomato, and the minimum WUE was recorded for bell pepper in both the irrigation systems (Figure 3).

CONCLUSION

It may be concluded that all crops consumed much less amount of water under drip irrigation as compared to furrow system, while no considerable yield differences between two irrigation systems were observed. Higher water use efficiency was observed for crops grown under drip irrigation compared to furrow system. This suggested that drip irrigation system has a greater scope for the production of off-season vegetables grown under plastic tunnel especially in water scarce areas of Pakistan.

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Table 1. Sowing methodology of off-season vegetables grown in plastic tunnel

Crops	Nursery Sowing (Date)	Transplanting (DAS)	Harvesting (DAS)	Plant x Row Spacing (cm)	Variety
Tomato	15.09.2006	36	211	40 x 90	NSX-6658
	11.10.2007	36	238	40 x 90	NSX-6658
	15.09.2008	35	255	40 x 90	NSX-6658
Cucumber	15.09.2006	26	186	40 x 90	H6-01
	25.09.2007	23	164	40 x 90	Primo
	15.09.2008	21	179	40 x 90	Byblos F1
Bell Pepper	15.10.2006	41	248	40 x 90	Capistrano
	26.09.2007	42	259	40 x 90	Capistrano
	28.09.2008	39	242	40 x 90	Capistrano

DAS indicates Days after sowing

Table 2. Water requirement of off-season vegetables grown in plastic tunnel (3-year average)

Crops	Irrigation system	Irrigation (#)	Water used $plant^{-1}$ $irrigation^{-1}$ (litres)	Water used $plant^{-1}$ day^{-1} (litres)
Tomato	Drip	116	1.99- 3.44	0.90-2.14
	Furrow	100	10.33-13.91	3.26-7.27
Cucumber	Drip	76	1.96- 3.56	0.90-2.68
	Furrow	71	10.41-13.39	3.52-6.99
Bell Pepper	Drip	113	1.99- 4.08	0.88-2.28
	Furrow	97	10.26-13.21	3.55-7.00

Table 3. Water increase in furrow over drip irrigation system applied to off-season vegetables
grown in plastic tunnel

Crops	Years	Water used ha^{-1} (m^3)		Water increase in furrow over drip irrigation system (%)
		Drip	Furrow	
Tomato	2006-07	4501	19461	332
	2007-08	7318	29805	307
	2008-09	7158	18531	159
	Average	**6326**	**22599**	**257**
Cucumber	2006-07	3652	15885	335
	2007-08	4250	17565	313
	2008-09	2922	8416	188
	Average	**3608**	**13955**	**287**
Bell Pepper	2006-07	5530	22747	311
	2007-08	7257	29290	304
	2008-09	7786	20650	165
	Average	**6858**	**24229**	**253**

Table 4. Water use efficiency of off-season vegetables grown in plastic tunnel

Crops	Years	Water used efficiency (WUE) (kg m^{-3})		WUE increase in drip over furrow irrigation system (%)
		Drip	Furrow	
Tomato	2006-07	9.09	2.17	319
	2007-08	5.70	1.43	299
	2008-09	5.68	2.21	157
	Average	**6.50**	**1.86**	**250**
Cucumber	2006-07	9.12	2.16	323
	2007-08	4.46	1.08	312
	2008-09	8.48	3.13	171
	Average	**7.12**	**1.90**	**274**
Bell Pepper	2006-07	4.52	1.12	302
	2007-08	2.74	0.68	303
	2008-09	2.35	0.93	153
	Average	**3.07**	**0.89**	**245**

Table 5. Yield increase of off-season vegetables grown under furrow over drip irrigation system

Crops	Years	Yield (kg ha^{-1})		Yield increase in furrow over drip irrigation system (%)
		Drip	Furrow	
Tomato	2006-07	40898	42230	3.26
	2007-08	41683	42550	2.08
	2008-09	40690	41023	0.82
	Average	**41090**	**41934**	**2.05**
Cucumber	2006-07	33293	34255	2.89
	2007-08	18960	19015	0.29
	2008-09	24773	26310	6.21
	Average	**25675**	**26527**	**3.32**
Bell Pepper	2006-07	25003	25578	2.30
	2007-08	19910	19950	0.20
	2008-09	18330	19202	4.76
	Average	**21081**	**21577**	**2.35**

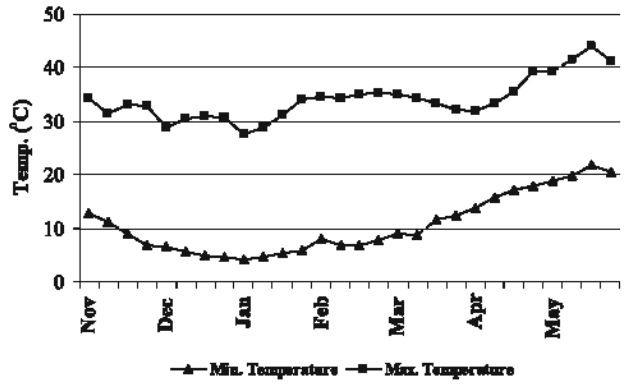

Figure 1. Weekly temperature inside tunnel (3-year average)

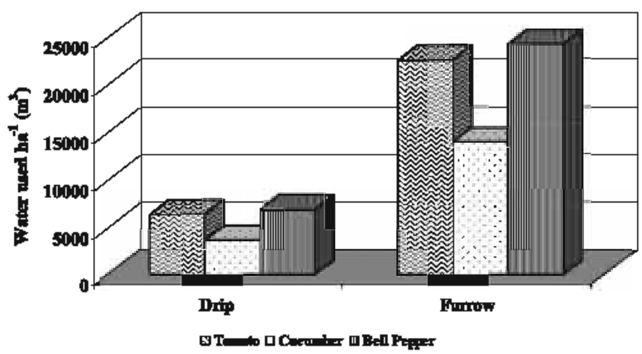

Figure 2. Comparison of water used by vegetables (3-year average)

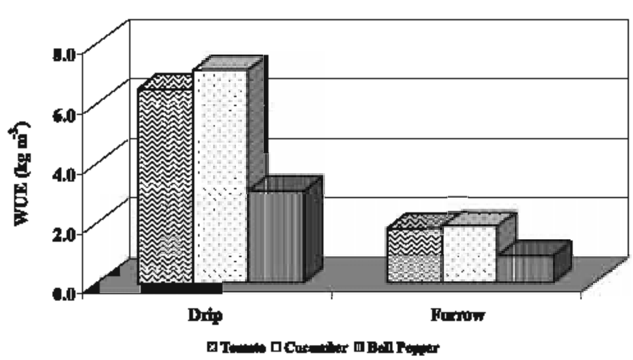

Figure 3. Comparison of water use efficiency of vegetables (3-year average)