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Assessment of Water Productivity of Different Cropping Systems under Drip Irrigation in Arid Region of Western India

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Abstract: The production potential of four different cropping system were assessed for two successive years in field conditions during 2008-2010 at ICAR-CAZRI, Jodhpur. Among the four different cropping systems evaluated, based on their production potential, ladyfinger-tomato-melon system gave the highest total yield (117.2 t ha^{-1}) under drip irrigation system. This system also gave the highest water use efficiency (1.73 kg m^{-3}) while the lowest consumptive use of water (97.5 cm) was registered in ladyfinger-gladiolus-melon system. In terms of the economics, tomato-gladiolus-ladyfinger crop sequence was the most economical followed by ladyfinger-tomato-melon under both irrigation systems (check basin and drip). The ladyfinger-tomato-melon crop sequence was ranked first with respect to production and WUE, whereas it ranked second with respect to net returns. From the present study it is clear that ladyfinger-tomato-melon is the most suitable cropping system under arid ecosystem of western India.

Key words: Cropping system, water use, net returns, drip irrigation.

Undoubtedly, the water is a scarce and precious resource in arid regions. About 50% of the area is irrigated through ground water using conventional irrigation practices. This leads to heavy losses on sandy soils as a result of which groundwater is falling at the rate of 0.5 to 1.0 m yr^{-1} bringing 60-70% area under dark zone (Saxena *et al.*, 2014). The ground water is very deep, saline at many places and thus inappropriate for use. The situation of overexploitation of ground water is more serious in the region where out of 11 districts, 6 are in category of over exploited and remaining 5 are in category of semi-critical (grey zone). The average annual rainfall of the western arid region is 360 mm. The rainfall is highly variable and erratic with frequent spells of drought. This emphasizes the need for an efficient management of scarce water. The water in arid region shall remain very precious and scarce. Here, crop yields per unit of land are quite low. Furthermore, untimely and non-judicious delivery of irrigation water through traditional means of irrigation, and plant water stress at critical growth stages affect yield adversely. Reduction in crop water use may be achieved either by employing efficient irrigation methods or by proper crop selection in a system mode for economising water and income in wider perspectives.

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The cropping system diversification is necessary to get higher yield and economic gain, to maintain soil condition, optimum utilization of available resources and meet daily requirement of human (Samui *et al.*, 2004). Vegetable plays an important role in human nutrition and economic security. They are rich source of minerals and vitamins and are known as protective food. In Rajasthan area under vegetable cultivation is about 1.48 lakh hectares with an estimated production of 11.14 lakh tons and productivity of 7.50 t ha^{-1} (Anon., 2014). Strikingly, the productivity of the vegetables in Rajasthan is very low compare to all India vegetable productivity. Efficient cropping system with respect to water utilisation with higher produce is the need of the region besides, to insure round the year production and income to the farmers. Tomato is one of the most important crops and grown during rainy season and winter season. Both muskmelon and ladyfinger are grown during summer season, while ladyfinger is also taken during rainy season. Gladiolus, a prized winter cut flower can be a newer option for this region, where most of the high value crop produce arrive from adjoining states or even far places, prompting the higher produce price.

Considering the above, the present study was aimed to assess the production potential of different cropping systems involving commercial vegetables (tomato, ladyfinger, melon) and cut flower (gladiolus) for increasing profitability and to improve water use efficiency under drip irrigation system. Moreover, the identified cropping system such that could optimize the use of precious water with provide handsome returns to the farmers in arid region from round the year production.

Materials and Methods

The experiment was conducted at the Central Arid Zone Research Institute, Jodhpur (Latitude 26°18'N, Longitude 73°01'30"E) at an elevation of 231 m above mean sea level during 2008-2010 on soil with pH 8.1, organic carbon 0.22%, total nitrogen 0.03%, available phosphorus 16 kg ha^{-1} and available potassium 225 kg ha^{-1}. The moisture content at field capacity and permanent wilting point (-15 bar tension) was 10.5 and 3.4 (w/w), respectively. The bulk density of 1 m soil was 1.541 mg m^{-1}. The soil contained 85% sand, 8.1% silt and 5.5% clay and has been classified as coarse loamy, mixed, hyperthermic Camborthids according to US soil taxonomy. The region is characterized by a monsoon climate with the wet season extending from the end of June to September. About 95% of the average annual precipitation of 360 mm is received during this period.

Four different cropping systems were followed comprising of three vegetables crop and a cut flower (gladiolus) that were raised both under drip irrigation and check basin irrigation system during 2008-2010. The four cropping system were; i) ladyfinger-tomato-ladyfinger, ii) tomato-gladiolus-ladyfinger iii) ladyfinger-tomato-melon iv) ladyfinger-gladiolus-melon during rainy-winter-summer season in succession. The ladyfinger and tomato crops were taken in two different season, whereas, gladiolus and musk melon were taken in one season in different system. All the crops were grown in paired rows under drip irrigation. The treatment were imposed with three replication each in randomized block design. The cultivars of different crops used in this study were Sonal-F_1 (ladyfinger), Rashmi-F_1 (tomato), Kajri (melon) and Snow Princess (gladiolus). The crops were raised in the system by following the recommended package of practices. Irrigation was applied at weekly interval in check-basin and every alternate day through drip irrigation. Similar number of plants per unit area were accommodated in either of the irrigation system to avoid the variations among the irrigation system due to plant density.

Soil water content to a depth of 1 m was determined with neutron scattering techniques at 0.2 m increment in crop of the system. Soil moisture measurement were taken prior to sowing and after irrigation throughout the growing season. The similar quantity of water was applied in both drip and check basin irrigation system in each crop considering to 80% of cumulative pan evaporation through the crop season. Three access tubes were installed in check basin plot and each drip laterals to monitor the moisture dynamics for deciding the water application time in both system of irrigation in each crop and season. Two moisture readings at every depth in each access tube were taken and thus an average of six observations is used for each moisture value. Additional moisture data were taken after each rainfall. Total dry matter yield included only the above ground parts of the crop and moisture in mm from per cent data was obtained from the basic formula (Saxena *et al.*, 1997):

Water (mm) in 0.20 m depth = Water content (%) x bulk density x 0.20

Results and Discussion

Cropping system yield

Among the four different cropping system the highest total yield were recorded in ladyfinger-tomato-melon followed by ladyfinger-tomato-ladyfinger cropping sequence under drip irrigation, whereas in case of check-basin irrigation it was highest in ladyfinger-tomato-melon system, but very less compare to same system under drip irrigation (Table 1). The total cropping system yield was highest in drip irrigated ladyfinger-tomato-melon because the water applied through drip irrigation is equivalent to its consumptive use and crop did not experienced any moisture stress throughout the growing period (Saxena *et al.*, 2014). In previous reports, the fruit yield of different vegetables were also higher when these were irrigated through drip as compared to traditional system of irrigation (Singh and Singh 1978; Singh *et al*. (1989); Singh *et al.* (1999).

Table 1. Yield (t ha^{-1}) of different crop sequences (mean of two years)

System	Rainy	Winter	Summer	Total
Drip irrigation				
Ladyfinger-tomato-ladyfinger	9.3	61.1	5.2	75.6
Tomato-gladiolus-ladyfinger	49.5	40,000*	5.2	54.6+40,000*
Ladyfinger-tomato-melon	9.3	61.1	46.8	117.2
Ladyfinger-gladiolus-melon	9.3	40,000*	46.8	56.1+40,000*
Check-basin				
Ladyfinger-tomato-ladyfinger	3.9	49.2	3.4	56.2
Tomato-gladiolus-ladyfinger	41.0	40,000*	3.4	44.4+40,000*
Ladyfinger-tomato-melon	3.9	49.2	39.8	92.9
Ladyfinger-gladiolus-melon	3.9	40,000*	39.8	43.7+40,000*

*Represent number of spike obtained per hectare.

Consumptive use and water use efficiency of different cropping system

The moisture use by different crop sequences varied between 97.5 and 150.0 cm under drip while under check-basin it varied between 114.9 and 183.5 cm annually (Table 2). Water use was minimum with melon because it is hardy and summer season crop with short duration. The lowest water use efficiency (WUE) of 14.9 and 6.9 kg ha^{-1} mm^{-1} was recorded in ladyfinger- tomato-ladyfinger crop sequence with drip and check-basin irrigation system, respectively. Whereas, the maximum WUE and water productivity under drip (17.3 kg ha^{-1} mm^{-1} and 1.73 kg m^{-3}, respectively) and under check-basin irrigation (10.0 kg ha^{-1} mm^{-1} and 1.0 kg m^{-3}, respectively) with Ladyfinger-Tomato-Melon crop sequence (Table 2 and 3). Regardless of crops in different cropping system, melon has the lowest consumptive water use while highest water use efficiency. This could be due to its better adaptability to drier region, and the shorter growing cycle (Pandey *et al.*, 2013). The result are in accordance with the finding of Al-Mefleh *et al.* (2012) where they also noted the highest water use efficiency in melon under drip irrigation system.

Economics of cropping systems

The economic returns were highest for all the cropping system under drip irrigation system compare to check basin method. Tomato-gladiolus-ladyfinger crop sequence was the most economical followed by ladyfinger-tomato-melon under both irrigation systems (Table 4). Summer ladyfinger crop produce fetches higher price in the local market compared to rainy season crop. The cost of cultivation of gladiolus is high, therefore, this system is more suitable for resource rich farmers.

Ranking of different cropping sequences

Based on production, water use, WUE and on net returns basis the crop sequences were

Table 2. Water use (cm) of different sequences (mean of two years)

System	Rainy	Winter	Summer	Total
Drip irrigation				
Ladyfinger-tomato-ladyfinger	46.1	57.2	46.7	150.0
Tomato-gladiolus-ladyfinger	47.0	29.3	46.7	123.0
Ladyfinger-tomato-melon	46.1	57.5	22.1	125.7
Ladyfinger-gladiolus-melon	46.1	29.3	22.1	97.5
Check-basin				
Ladyfinger-tomato-ladyfinger	60.0	61.2	62.3	183.5
Tomato-gladiolus-ladyfinger	56.0	29.3	62.3	147.6
Ladyfinger-tomato-melon	60.0	61.2	25.6	146.8
Ladyfinger-gladiolus-melon	60.0	29.3	25.6	114.9
LSD (0.05)	5.6	7.8	9.1	20.3

Table 3. Water use efficiency and water productivity of different sequences (mean of two years)

System	Water use efficiency (kg ha^{-1} mm^{-1})				Water productivity (kg m^{-3})
	Rainy	Winter	Summer	Mean	
Drip irrigation					
Ladyfinger-tomato-ladyfinger	20.1	10.7	14.1	14.9	1.49
Tomato-gladiolus-ladyfinger	10.5	**	14.1	**	**
Ladyfinger-tomato-melon	20.1	10.7	21.2	17.3	1.73
Ladyfinger-gladiolus-melon	20.1	**	21.2	**	**
Check-basin					
Ladyfinger-tomato-ladyfinger	6.5	8.0	6.1	6.9	0.69
Tomato-gladiolus-ladyfinger	7.3	**	6.1	**	**
Ladyfinger-tomato-melon	6.5	8.0	15.5	10.0	1.00
Ladyfinger-gladiolus-melon	6.5	**	15.5	**	**

** Water use efficiency wasn't calculated for gladiolus crop because economical produce were spikes.

Table 4. Economics of cropping systems (,000 ha^{-1})

Cropping system	Rainy		Winter		Summer		Net returns
	I	E	I	E	I	E	
Drip irrigation							
Ladyfinger-tomato-ladyfinger	139.5	26.75	305.5	66.35	208.0	25.40	534.5
Tomato-gladiolus-ladyfinger	247.5	56.35	400.0	175.00	208.0	25.40	598.8
Ladyfinger-tomato-melon	139.5	26.75	305.5	66.35	234.0	21.20	564.7
Ladyfinger-gladiolus-melon	139.5	26.75	400.0	175.00	234.0	21.20	550.6
Check-basin							
Ladyfinger-tomato-ladyfinger	58.5	27.65	246.0	67.65	136.0	26.00	319.2
Tomato-gladiolus-ladyfinger	207.5	57.35	400.0*	175.00	136.0	26.00	485.2
Ladyfinger-tomato-melon	58.5	27.65	246.0	67.65	199.0	22.40	385.8
Ladyfinger-gladiolus-melon	58.5	27.65	400.0*	175.00	199.0	22.40	432.5

*Gladiolus crop grown with drip irrigation.
I = income in Rupees, E = expenditure in Rupees.

ranked (Table 5). Ladyfinger-tomato-melon crop sequence ranked first with respect to production and WUE, ranked second based on net returns. The ladyfinger-tomato-melon crop sequence was selected for further study. Based on their survey study, Meena *et al.* (2009) have also indicated that cropping system involving the commercial vegetables under irrigated conditions of arid region will enhance profitability of the growers.

Overall, tomato-gladiolus-ladyfinger crop sequence was the most economical in either of the irrigation system (drip and check basin), whereas ladyfinger-tomato-melon crop sequence ranked first with respect to production and WUE but ranked second with respect to net returns. Finally, it is clear from this study that ladyfinger-tomato-melon is the most suitable cropping system under arid ecosystem of western India.

Table 5. Ranking of different cropping sequences

Cropping sequence	Yield	Water use	WUE	Based on net returns
Ladyfinger-tomato-ladyfinger	II	IV	II	IV
Tomato-gladiolus-ladyfinger	IV	II	–	I
Ladyfinger-tomato-melon	I	III	I	II
Ladyfinger-gladiolus-melon	III	I	–	III

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