ENHANCING WATER PRODUCTIVITY THROUGH MICRO-IRRIGATION TECHNOLOGIES IN INDIAN AGRICULTURE

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Annals of Plant and Soil Research 17 (Special Issue): 601-605 (2015)

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ABSTRACT

India is the largest freshwater user in the world and the country's total water use is greater than any other continent. The Agricultural sector is the largest user of water, followed by the domestic sector and the industrial sector. As water demand from cities and industries is increasing rapidly, pressure is also mounting on agriculture to enhance water efficiency. In intensive agriculture, both fertilizer and irrigation management have contributed immensely in increasing the yield and quality of crops. Traditional irrigation methods are no longer viable. The dominant method of irrigation practiced in large parts of the country is surface irrigation under which crop utilize only less than one half of the water released and remaining half gets lost in conveyance, application, runoff and evaporation. Micro irrigation (MI) methods like drip and sprinklers need to be employed for efficient distribution and application of water for crop production. Drip and sprinkler irrigation is a solution that reduces conveyance and distribution losses and allows higher water use efficiency. Drip irrigation has the greatest potential for the efficient use of water and fertilizers through fertigation. Hence, this present study was undertaken to examine the yield using different irrigation and fertigation schedules by drip irrigation and to suggest the most efficient irrigation practice. Comparison of normal furrow irrigation efficiencies with drip and sprinkler method with mulch and without mulch yield of maize was noted. Both the efficiencies i.e. water application and water use efficiency, were maximum in case of sprinkler irrigation system as compared to furrow irrigation system. Use of sprinkler irrigation during early crop season helped in saving water when the soil infiltration rate was very high and need of water in the root zone was less. Using sprinkler irrigation system, 30.8% and 28.3% higher water use efficiency and 21.1% and 9.0% more water application efficiency was achieved as compared furrow irrigation system.

Key words: Micro irrigation, water productivity and yield

INTRODUCTION

In India, both surface and groundwater are dependent on the monsoon. More than 85% of groundwater is used for irrigation. Thus, rainfed, surface water irrigated and groundwater irrigated agriculture suffers from the vagaries of monsoon. In world, India has the second largest net irrigated area, after China. The irrigation efficiency under canal irrigation is not more than 40% and for ground water schemes, it is 69%. The net irrigated area in the country is about 61 m ha, which is about 43% of the total sown area. Although considerable area has been brought under irrigation since independence; there is much scope for its expansion in the future. Irrigation water for agriculture finds competition from domestic use, industrial and hydroelectric projects. At present, the efficiency of the irrigation systems adopted is less than 40%. As such as 50% of the water release at the project head is lost in transmission of the canal outlet. Additional loss occurs in water courses which is directly proportional to their length and duration of water flow. Considerable scope exists for enhancing the water use efficiency to bring additional area under irrigation. Scientific management of irrigation water is necessary to improve crop productivity and alleviate irrigation related problems such as shortage of irrigation water, water logging, salinity etc. Even all the water resources have been tapped for irrigation; almost 50% area will still remain rainfed. But, whether it is irrigated or rainfed agriculture water holds the key for enhancing and sustaining agricultural production. Since, sustainability and enhanced productivity are the need of the hour; the focus has to shift from crops to cropping systems that are more input use efficient going with resource conservation technologies. Out of the 250 cropping systems in India, 30 are the most common ones and out of them, several are well fitted under drip and sprinkler irrigation system. There is immense scope for conservation, distribution and on farm utilization of water and attaining higher water use efficiency through micro irrigation system; yield can be maximized significantly with a limited amount of water. Modern irrigation techniques like sprinkler and drip should be promoted where water is scarce and the topographic and soil condition do not permit conventional methods of irrigation.

Why Modern Irrigation Technologies are Needed?

- The productivity of irrigated land is low compared to its potential
- The productivity per unit water is very low
- Water available for irrigation is becoming scarce
- Cost for generating water source is ever increasing
- The predominance of soils with low water retention capacities and very low hydraulic conductivities make the arid and semi-arid regions an ideal case for light and frequent irrigations through micro-irrigation
- Micro-irrigation will increase the irrigation cover using the existing available water
- Micro-irrigation with fertigation will enhance production per unit input in these nutrient poor, shallow and sloppy soils

REASONS FOR ACTION

Conventional irrigation methods are employed for more than 80% of the world's irrigated lands yet their field level application efficiency is only 40-50%. In contrast, drip irrigation has field level application efficiencies of 70-90% as surface runoff and deep percolation losses are minimized. All agricultural operations require energy in the form of electricity, the magnitude of which varies as per different agro-climatic zones and even from farmer to farmer. The largest share of energy is utilized for pumping of irrigation water. Various research studies have shown that water saving, electricity saving, irrigation efficiencies and yield of crops using drip irrigation are substantially higher than crops irrigated by the conventional flood irrigation method. The modern irrigation systems, drip and sprinkler can act as a mitigation measure over this problem. Eventually with little water available in Indian subcontinent, crop can survive and we can virtually come out the over dependency on monsoon. Because, whatever rain is available in arid regions can be will be stored and water applied to root zone with drip, will bring this region out 'rain feed' clutches with increased productivity. The crops, area irrigated, productivity, consumptive use, common method of irrigation and water use efficiency (WUE), indicate that the highest area irrigated is in the paddy crop, followed by sugarcane, maize, groundnut, sunflower, coconut, arecanut, wheat and bengal gram. Flow irrigation is the common method followed, while drip irrigation is emerging as the innovative method for crops like coconut, grapes, mulberry, pomegranate, fig, vegetables and off late for close spaced food crops. The water-use efficiency obtained by dividing the yield obtained per ha by the water used per ha, has given the highest value for cabbage, followed by grapes, brinjal, mulberry and banana. Thus, WUE is higher for fruits and vegetable crops compared to cereals and pulses. Even in value terms this holds good. Drip irrigation saves water up to 30% to 70% for various crops. Drip irrigation also improves the yield of the 30% to 200% for various crops (Kadasiddappa M.M., 2015). This assures good technology transfer and knowledge tool in the hands of illiterate farmers. The water savings due to widely spaced crop is 300 mm year^{-1} and closely spaced crops like maize is 100-150 mm year^{-1} (Kadasiddappa *et al*., 2013) and this water savings is directly proportional to energy savings (Narayanmurty, 2007).

WATER SAVING AND WATER PRODUCTIVITY IMPACTS OF MI SYSTEMS IN THE FIELD

The real water saving impact of micro irrigation (MI) systems at the field level depends on the improvements in water use efficiency. All the available data on the efficiency impact of micro-irrigation systems are on application efficiency. The classical definition of irrigation efficiency is the ratio of the amount of water consumed by the crop to the amount of water applied. The work of Sivanappan (1994) provides the data on application efficiencies at various stages such as conveyance efficiency, field application efficiency and soil moisture evaporation. But in estimating water-saving, what matters is the amount of depleted water, rather than the amount of water applied. The depleted water includes moisture evaporation from the exposed soil and non-recoverable deep percolation. It would be less than the applied water so long as the unconsumed water is not lost in natural sinks like saline aquifers or swamps (Allen *et al*., 1998). This means, the application of the concept of irrigation efficiencies is no longer useful in analyzing the performance of irrigation systems, with a greater understanding of agro hydrology and appreciation of deep percolation from irrigated fields as a component of the available water resources. The drip and sprinkler systems were first developed in the groundwater-scarce Israel during the 1960s. This technology is spreading to different water-scarce regions of the world, including western and southern India and north China. In India, drip irrigation was introduced in the 1970s. Drip irrigation has been a success for citrus, orange and grapes in Maharashtra, for coconuts in Tamil Nadu, and mulberry, coconut, grapes, sugarcane and cotton and in Karnataka.

With continuous R&D efforts and engagement with farmers, it has encompassed almost all crops, under microirrigation technologies (e.g. drip irrigation, sprinklers). Experimental results are also quite encouraging for water intensive crops. The adoption rate of micro-irrigation technologies is increasing and today nearly 4% of area out of irrigated land is under micro-irrigation. To break the perfect nexus of water-energy-food, this will be great boon, if drop by drop water is provide to the root zone without wastage of water, with great efficiency, saving electricity (or providing electricity where there is no electricity by solar pump technology) and producing more from less area or producing good crops where it was only rain fed crop. Our ultimately objective is to increase the productivity of the famers per unit area and per unit of water available, adoption of technology to a large number of farmers and increase the area under drip irrigation in India, and expand to other crops, which are not currently under drip irrigation through research and development.The results of field level data pertaining to three crops *viz.,* sugarcane, banana and grapes are somewhat different from the experimental results. The pattern of water use for crops is totally different between the two methods of irrigation. The drip adopters have applied more number of irrigation per hectare when compared to the non-drip adopters in all the three crops considered for the analysis. However, hours required per irrigation to irrigate per hectare of guava, sapota, sugarcane, grapes and banana are significantly less for the drip adopters as compared to the non-drip adopters. Water consumption (in quantity) per hectare is much less under drip method of irrigation as compared to flood method of irrigation in all the three crops. Water saving in sugarcane due to drip method of irrigation is about 44%, while the same is estimated to be about 37% in grapes and 29% in the case of banana. Additional area can also be brought under irrigation from the saving of water realised through the adoption of drip method of irrigation. The additional irrigated area possible from the saving of water is estimated to be 0.80 ha in sugarcane, 0.60 ha in grapes and 0.41 ha in banana. Water use efficiency is also significantly higher in drip-irrigated crops when compared to the same crops cultivated under non-drip irrigated condition. Sugarcane cultivated under drip method of irrigation consumes only 1.28 horse power (HP) hours of water to produce one quintal of sugarcane as against 2.83 HP hours of water under flood method of irrigation, i.e., about 1.55 HP hours of additional water is consumed to produce one quintal of sugarcane under flood method of irrigation. Banana crop under DMI consumes only 11.60 HP hours of water to produce one quintal of output as against the use of 21.14 HP hours of water under non-drip irrigated condition. In grapes, each quintal of output involves the use of just 13.60 HP hours of water under DMI as compared to the use of 25.84 HP hours of water under non-drip irrigated conditions (Narayanamoorthy, 2005). Higher saving of water by drip method of irrigation to guava crop was noticed with irrigation at 40% PE (17.16%) and 60% PE (12.46%) over basin method of irrigation to guava crop during mid growth stage (Table 1). Guava crop compare to other fruit crops is adoptable to a wide variation in irrigation moisture regimes and fertilizer levels during *kharif, rabi* and summer seasons. Higher yields of guava can be obtained only when crop is supplied with optimum moisture and nutrients (Khot, 2011). Pooled data indicated the superiority of higher as well as moderate of moisture regimes (80% and 60% PE, respectively) in obtaining higher guava fruit yields 162.44 and 163.59 q ha^{-1}, respectively (Table 2) and sopota fruit yield indicated the superiority of lower as well as moderate of moisture regimes (40% and 60% PE, respectively) in obtaining higher fruit yields 2826 and 2512 q ha^{-1}, respectively. Similar results were noticed by Shelke *et. al.* (1999) and Shinde *et. al*. (2004). Excess moisture i.e. 80% PE for mid growth stage of sapota crop might have been resulted in decreasing the fruit yields. Excess moisture i.e., 80% PE for mid growth stage of guava crop might have been resulted in decreasing the fruit yields. In addition to achieving higher fruit yields with 60% PE and 80% PE there was 4.21% and 12.46% saving of water over surface method (basin) of irrigation. Economics of gross income, net income, B:C ratio and water use efficiency was recorded significantly different due to moisture regimes and fertilizer levels (Table 3). Guava yield, irrigating at 60% PE and 80% resulted in higher gross income (₹ 81, 796 ha^{-1} and ₹ 81,221 ha^{-1}, respectively). Thus, higher net returns ₹ 43,934 ha^{-1} and ₹ 42, 109 ha^{-1}, respectively and B:C ratio of 2.50 and 2.29, respectively were significantly higher over surface method of irrigation **(**Ashoka *et al.*, 2013)

Sprinkler irrigation systems imitate natural rainfall. Water is pumped through pipes and then sprayed onto the crops through rotating sprinkler heads. These systems are more efficient than surface irrigation, however, they are more costly to install and operate because of the need for pressurized water. Conventional sprinkler systems spray the water into the air, losing considerable amounts to evaporation. Low energy precision application (LEPA) offers a more efficient alternative. In this system the water is delivered to the crops from drop tubes that extend from the sprinkler's arm. When applied together with appropriate water-saving farming techniques, LEPA can achieve efficiencies as high as 95%. Since this method operates at low pressure, it also saves as much as 20 to 50% in energy costs compared with conventional systems. Table 4 and 5 reveals that, maize yield using sprinkler irrigation with 0.8 IW/CPE ratio were 82.86, 88.10 and 90.53 q ha^{-1} during 2008-2011 respectively. The corresponding maize yield were 79.41, 87.73 and 81.60 q ha^{-1} with 0.6 IW/CPE ratio, where as 59.43, 63.38, and 85.86 q ha^{-1} with 0.4 IW/CPE ratio and 70.45, 74.03 and 85.86 q ha^{-1} with normal irrigation as formers practice. The three years pooled maize yield (85.91 kg ha^{-1}) with 0.6 IW/CPE ratio recorded results is on par with 0.8 IW/CPE ratio sprinkler irrigation level. Mulching with maize straw @ 5 t ha^{-1} recorded a superior grain yield about 77.01, 82.88 and 99.53 q ha^{-1} during 2008, 2009 and 2010 respectively. The three years pooled data showed a superior grain yield of 86.47 q ha^{-1}. Interaction effect between irrigation 0.6 IW/CPE ratio with maize straw mulching @ 5 t ha^{-1} shows a higher yield of maize 84.19, 93.84 and 92.94 q ha^{-1} (Table 4 and 5). The corresponding three years pooled grain yield recorded 90.32 q ha^{-1}. But all these are on par with 0.8 IW/CPE ratios with the mulch treatment. In water use efficiency depicted in Table 5 which records a significantly superior water use efficiency (18.05 and 19.94 kg $ha\text{-}mm^{-1}$) during 2008 and 2009, respectively. Significantly higher water use efficiency with mulch treatment (17.82, 19.16 and 23.47 kg $ha\text{-}mm^{-1}$) was recorded. Interaction effect between irrigation 0.6 IW/CPE ratio and mulching recorded significantly superior water use efficiency (19.13, 21.33 and 21.12 kg $ha\text{-}mm^{-1}$) compared to the other treatment (Neelakanth *et al.,* 2013).

CONCLUSIONS

Increased water scarcity conditions in this century will result in reduced availability of irrigated land for food production than in the past. The main challenge confronting both rainfed and irrigated agriculture is to improve productivity or use efficiency of water and sustainable water use for agriculture. The adoption of MI systems is likely to pick up fast in arid and semi-arid, well-irrigated areas, where farmers have independent irrigation sources, and where groundwater is scarce. Further, high-average land-holdings, large size of individual plots, and a cropping system dominated by widely spaced row crops, which are also high-valued, would provide the ideal environment for the same. The extent of real water-saving and water productivity improvements at the field level through the adoption of MI systems would be high for irrespective of the spacing followed for the crops and type of the crops in arid and semi-arid conditions. In adopting MI technology ensures increased crop yield, high water use efficiency, reduced water and energy consumption and minimal weed problems. MI (Drip and sprinkler irrigation) has a potential of utilizing saline and sewage water in agriculture but it should not be regarded as a universal substitute for long established proven methods such as basin, flood, and furrow. It is just another way of irrigating and the advantages and disadvantages of which have to be considered in comparison with the conventional method in each particular case.

Table 1. Total Water applied (mm) through drip and basin method of irrigation during 2009 to 2011 and mean of three years.

Treatments	2009	2010	2011	Pooled (mm)	Saving over basin method of three years (%)
	Total Water applied (mm)	Total Water applied (mm)	Total Water applied (mm)		
80% PE	1015.72	673.2	824.8	837.91	4.21
60% PE	914.82	622.8	759.6	765.74	12.46
40% PE	826.54	614.4	732.9	724.61	17.16
Basin(Control)	1053.10	698.6	872.4	874.70	--

Table 2. Effect of irrigation and fertigation levels on guava fruit yield, WUE, gross and net income and B:C ratio (pooled 2009 to 2011).

Irrigation levels	Fruit Yield (kg ha^{-1})	WUE (kg ha- mm^{-1})	Gross Income (000' ` ha^{-1})	Net Income (000 ` ha^{-1})	B:C Ratio
PE levels (%)					
I_1=80	16244	32.42	81221	42109	2.29
I_2=60	16359	42.34	81796	43934	2.50
I_3=40	15807	52.66	79040	40430	2.07
I_4=Bain (Control)	14817	27.03	74081	36375	1.95
SEm ±	184.34	0.56	1776.06	1095.28	0.06
CD (0.05)	537.29	1.93	4894.19	3086.96	0.19
Fertilizer levels (RDF %)					
F_1 = 125	16296	39.44	81482	43122	2.15
F_2 = 100	16499	40.67	82498	44470	2.38
F_3 = 75	15712	37.92	78555	41267	2.09
F_4 = 50	14720	36.41	73602	36989	1071
SEm ±	254.72	0.78	1409.22	1801.40	0.07
CD (0.05)	714.79	2.29	3974.80	5126.22	0.26
Interaction (I x F)					
SEm ±	949.24	1.47	4746.91	4633.94	0.13
CD (0.05)	NS	NS	NS	NS	NS

Table 3. Effect of irrigation and fertigation levels on sapota fruit yield, WUE, gross and net income and B:C ratio during (pooled 2009 to 2011).

Irrigation levels	Fruit Yield (kg ha^{-1})	WUE (kg ha-mm^{-1})	Gross Income (000' ` ha^{-1})	Net Income (000' ` ha^{-1})	B:C Ratio
PE levels (%)					
I_1=80	2475	5.71	26107	11920	2.15
I_2=60	2512	6.96	26537	13217	2.22
I_3=40	2826	8.18	29886	17483	2.82
I_4=Bain (Control)	2089	3.68	21012	9264	1.60
SEm ±	206.90	0.78	1871.37	1712.10	0.259
CD (0.05)	585.35	2.14	5578.17	4994.93	0.758
Fertilizer levels (RDF %)					
F_1 = 125	2689	5.98	27287	14393	2.19
F_2 = 100	1378	7.09	32258	17627	2.69
F_3 = 75	2220	4.97	23562	10932	1.99
F_4 = 50	1916	3.50	19436	8832	1.73
SEm ±	155.69	0.39	1263.00	1205.00	0.124
CD (0.05)	427.70	1.08	3687.17	3548.00	0.362
Interaction (I x F)					
SEm ±	302.71	0.40	3305	3278.02	0.328
CD (0.05)	NS	NS	NS	NS	NS

Table 4. Water use efficiency (WUE) as affected by sprinkler and surface irrigation with mulching in maize crop (pooled of three years).

Treatment	**WUE (kg ha-mm^{-1})**			
Irrigation levels	**2008**	**2009**	**2010**	**Pooled**
I_1 = 0.8 IW/CPE (Sprinkler)	16.57	17.62	18.10	17.43
I_2 = 0.6 IW/CPE (Sprinkler)	18.05	19.94	18.54	18.84

I_3 = 0.4 IW/CPE (Sprinkler)	16.98	18.11	25.88	20.32
I_4 = 0.6 IW/CPE (Surface)	16.01	16.83	19.51	17.45
SEm± CD(0.05)	0.27 0.83	0.21 0.64	1.35 4.17	0.61 1.88
Mulches				
M_1 = Maize straw @ 5 t ha^{-1}	17.82	19.16	23.47	20.15
M_2 = Without Mulch	15.98	17.09	17.55	16.87
SEm± CD(0.05)	00.17 00.52	00.16 00.48	00.55 01.64	00.30 00.88

Table 5. Effected of sprinkler and surface irrigation with mulching on yield of maize crop (pooled of three years)

Treatment	**WUE (kg ha-mm^{-1})**			
Irrigation levels	**2008**	**2009**	**2010**	**Pooled**
I_1 = 0.8 IW/CPE (Sprinkler)	82.86	88.10	86.29	85.75
I_2 = 0.6 IW/CPE (Sprinkler)	79.41	87.73	81.60	82.91
I_3 = 0.4 IW/CPE (Sprinkler)	59.43	63.38	90.59	71.13
I_4 = 0.6 IW/CPE (Surface)	70.45	74.03	85.86	76.78
SEm± CD(0.05)	1.19 3.67	0.94 2.90	5.83 17.09	2.65 7.89
Mulches				
M_1 = Maize straw @ 5 t ha^{-1}	77.01	82.88	99.53	86.47
M_2 = Without Mulch	69.00	73.74	74.76	72.49
SEm± CD(0.05)	0.76 2.26	0.72 2.15	2.26 6.79	1.24 3.73

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