Water resource conservation technologies for crop sustainability and diversification in North West Himalayas

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KEYWORDS

Conservation tillage, rain-water harvesting, poly-lined tanks, water use efficiency, drip irrigation

ABSTRACT

The Hill Agriculture is facing a shift from subsistence agriculture to profitable crop production. The experiments conducted by CSKHPKV Palampur have shown that the rain- water may either be conserved *in-situ* or harvested in poly-lined tanks and utilized judiciously through micro-irrigation systems. The conservation tillage by utilizing available weed biomass not only resulted in moderation of soil hydro-thermal regimes but also increased the biological yields and total water use in comparison to conventional tillage. Harvesting rain-water and run-off water in hills in small/ big ponds is being practiced since past. Based on experimentation for seepage control, use of UV resistant blue coloured sheet (200-250 GSM thickness) has been recommended by the CSKHPKV Palampur. The harvested rain-water should be used exclusively for vegetable based cropping system rather than for its utilization as life saving irrigation under cereal based cropping system. The average values of water use efficiency (WUE) were 7.88 kg/ha-mm under vegetable based cropping systems in comparison to 4.77 kg/ha-mm under maize-wheat cropping system(Anonymous 2012). In recent years, micro- irrigation systems comprising of drip and sprinkler have been promoted in majority of hill states keeping in view the limited water resources available. Experiments conducted by Palampur University have shown that drip based irrigation resulted in higher soil water content, water use efficiency (47.43 to 52 %) and saving in irrigation water (53.53 to 63.43 %) in comparison to conventional method of irrigation.

In Himachal Pradesh, 82 % of the total cultivated area is rainfed and in such situation, wheat is the most important *rabi* crop grown by the farmers. In spite of the increase in areas under high yielding varieties, being 84 % under wheat, there is not much increase in the average yield (Anonymous 2009). The grain yields of wheat averaged over the past 10 years, are 1248 kg/ha compared to 10 years National averages of 1972 kg/ha. The average rainfall of the state varies from 1000 mm to 2500 mm with most of the rain is received during monsoon period (mid June to mid September). About 80 % rains are received during monsoon and winter rains are meager and erratic. The ET demand estimated for wheat growing period is about 500- 600 mm. During September to December, the evaporation exceeds rainfall which coincides with sowing of wheat. Also, following rainfall, the surface soil dries out very rapidly due to its poor moisture retention characteristics. It creates problem for seeds to germinate or germinated seedlings to establish its roots downward even though the layers below seed-zone remain wet.

In-situ Moisture Conservation

Tillage immediately after harvest of maize is done by hill farmers in order to conserve and carry-over the post monsoon residual moisture for sowing of rain fed wheat. By doing so, the wet soil profile is being exposed to lose moisture in seed-zone depth, results in moisture stress conditions at sowing of wheat. If right from the time of harvest of maize (September), seed-zone moisture is conserved and carried-over then it is possible to obtain optimum seed-zone moisture at sowing of wheat. Minimum tillage for wheat may result in conservation and carry-over of residual moisture for sowing of wheat on time. It can also results in saving of energy, labour and time. Himachal Pradesh being a hill state and situated in the lap of Western Himalayas has abundance of waste materials like wild sage (*Lantana camara*), kali basuti (*Eupatorium adenophorum*) etc. These materials are growing on the bunds and in pastures nearer to the cultivated land. They have little or no value either as fuel or fodder to farming community. Hence, they can be used as mulch materials for the conservation and carryover of soil moisture without any additional cost particularly under minimum tillage practice (Sandal et al., 2009a).

Field experiments were conducted at Palampur (32^0 6' N latitude and 73^0 3' E longitude), Himachal Pradesh to study the effects of *in-situ* rain-water conservation practices, seed soaking and fertilizer management on growth and productivity of rainfed wheat grown in maize-wheat sequence (Sandal et al., 2009b). The treatments comprised of, a) moisture conservation practices viz., T_1 - conventional tillage to maize and wheat, T_2 - application of *Lantana* and *Eupatorium* etc as mulch after harvest of maize and wheat + sowing of maize with conventional tillage and sowing of wheat with conservation tillage and T_3 – application of *Lantana* and *Eupatorium* as mulch after harvest of maize and wheat + sowing of maize and wheat with conservation tillage, b) fertilizer levels viz., 50 and 100 % of recommended NPK (80 kg N, 17 kg P and 30 kg K /ha) and c) seed soaking (in water) in wheat viz., dry and pre-soaked seeding. Results indicated that *in-situ* moisture conservation (T_2 and $T_{3)}$ recharged the soil profile effectively leading to higher seedling emergence, plant height, dry matter accumulation, tiller numbers, root length & mass densities,effective tillers, grains/spike,1000 grain weight and ultimately higher grain & straw yields and nutrient uptake in comparison to no moisture conservation (T_1). Pre-soaking of wheat seeds in water significantly improved wheat seedling emergence resulting in better crop stand compared to dry seeding. Increasing the fertilizer doses from 50 to 100 % of recommended NPK (80 kg N, 17 kg P and 30 kg K /ha) significantly enhanced crop growth and yields of rainfed wheat (Table 1 to 5).

Table 1: Effect of moisture conservation practices and seed soaking on seedling emergence parameters of rainfed wheat

Treatment	Days to emergence initiation		Days to constant emergence		Emergence (%)		Emergence velocity (% per day)		Emergence rate index	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
T_1	12.5	9.0	28.2	19.0	80.8	22.2	2.9	1.1	4075	705
T_2	10.8	6.0	21.9	20.0	79.0	75.3	3.7	4.1	5252	2303
T_3	10.5	6.0	22.8	20.0	75.5	66.8	3.4	3.8	5271	1952
CD(P=0.05)	0.03	0.04	0.38	NS	0.36	0.54	0.06	0.05	62	86
Dry	11.8	7.0	20.0	78.2	53.3	2.9	2.6	4612	1654	1654
Soaked	10.7	7.0	19.0	78.6	54.2	3.8	2.7	5120	1653	1653
CD(P=0.05)	0.02	NS	NS	NS	NS	0.05	NS	51	NS	NS

Table 2: Effect of moisture conservation practices, seed soaking and fertilizer management on root growth (0-0.30 m depth) of rainfed wheat

Treatment	Root length density (x 10^4 m m^{-3})				Root mass density(kg m^{-3})			
	CRI		Heading		CRI		Heading	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
T_1	0.086	0.215	0.979	1.068	0.065	0.112	3.134	3.684
T_2	0.226	0.559	1.870	2.049	0.183	0.168	3.611	4.332
T_3	0.201	0.581	1.893	1.983	0.142	0.171	3.617	4.342
CD(P=0.05)	0.006	0.098	0.064	0.066	0.010	0.022	0.005	0.336
Dry	0.166	0.451	1.581	1.696	0.116	0.151	3.401	4.123
Soaked	0.176	0450	1.584	1.704	0149	0.150	3.550	4.120
CD(P=0.05)	0.005	NS	NS	NS	0.009	NS	NS	NS
NPK_{50}	0.162	0.451	1.581	1.696	0.116	0.151	3.401	4.123
NPK_{100}	0.180	0.452	1.582	1.704	0.143	0.150	3.505	4.120
CD(P=0.05)	0.005	NS	NS	NS	0.009	NS	NS	NS

Table 3: Effect of moisture conservation practices ,seed soaking and fertilizer management on plant growth parameters of rainfed wheat

Treatment	Dry matter accumulation (kg m^{-2}) at heading stage		Number of tillers at heading stage		Plant height (m)			
					CRI		Heading	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
T_1	0.188	0.192	193	158	0.0672	0.181	0.772	0.714
T_2	0.229	0.376	412	288	0.0971	0.219	0.864	0.932
T_3	0.228	0.348	402	317	0.0936	0.212	0.872	0.928
CD(P=0.05)	0.003	0.010	6.5	14.2	0.0017	0.0021	0.0064	0.0083
Dry	0.209	0.308	327	256	0.0811	0.203	0.831	0.867
Soaked	0.219	0.334	340	278	0.0841	0.207	0.816	0.873
CD(P=0.05)	0.002	NS	3.4	NS	0.0014	0.0016	NS	NS
NPK_{50}	0.209	0.274	329	231	0.0814	0.201	0.0082	0.841
NPK_{100}	0.219	0.334	340	278	0.0841	0.207	0.0816	0.873
CD(P=0.05)	0.002	0.007	3.4	9.4	0.0014	0.0016	0.0056	0.0061

Table 4: Effect of moisture conservation practices and fertilizer management on yield attributes of rainfed wheat

Treatment	Number of effective tillers		Grain $spike^{-1}$		1000 grain weight (x 10^3 kg)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
T_1	200.7	142.1	23.7	24.4	33.8	33.9
T_2	337.1	241.3	31.0	32.7	35.9	34.2
T_3	327.3	274.8	31.7	31.8	35.2	34.9
CD(P=0.05)	11.6	9.6	5.4	6.2	0.8	0.6
Dry	283.8	219.4	28.2	29.6	34.9	34.3
Soaked	292.9	221.7	29.3	30.1	35.0	34.7
CD(P=0.05)	6.7	NS	NS	NS	NS	NS
NPK_{50}	282.9	221.8	28.2	29.7	34.8	34.4
NPK_{100}	293.8	226.7	29.3	30.9	35.1	34.6
CD(P=0.05)	6.8	4.3	NS	NS	NS	NS

Table 5: Effect of moisture conservation practices and fertilizer management on biological yields of rainfed wheat

Treatment	Grain yields (t ha^{-1})		Straw yields (t ha^{-1})		Harvest index (%)		B:C Ratio	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
T_1	1.42	1.33	1.92	1.78	42.52	42.77	1.62	1.52
T_2	2.31	2.47	3.41	2.97	40.38	45.40	2.63	2.82
T_3	2.13	2.26	3.43	3.12	38.31	42.01	2.43	2.58
CD(P=0.05)	0.23	0.27	0.26	0.31	2.12	1.45		
Dry	1.91	2.04	2.82	2.64	40.51	43.59	2.18	2.33
Soaked	2.01	1.96	3.02	2.59	39.96	43.08	2.29	2.24
CD(P=0.05)	0.08	NS	0.07	NS	NS	NS		
NPK_{50}	1.92	2.04	2.82	2.64	40.51	43.59	4.38	4.66
NPK_{100}	2.01	2.12	3.03	2.72	39.89	43.80	2.29	2.42
CD(P=0.05)	0.08	0.05	0.07	0.06	NS	NS		

Rain-water harvesting & its utilization

The basic principal of rain water harvesting is to "*catch the water where it falls*". The rain water harvesting is the process of collecting, concentrating and improving the productive use of rain water and reducing unproductive depletion. In other words, it involves collection, storage and recycling of rain water (including all natural resources like rivers, streams, lakes, ponds, wells, water springs, ground water aquifers etc,) for agricultural, domestic or industrial purposes. Rain water harvesting may be under taken by capturing surface runoff from, local/adjoining catchments, roof tops, water springs, seasonal/perennial streams (kuhls etc) and water lifting schemes etc. The basic components of rain water harvesting are, collection and storage of rain water, effective utilization of stored water and augmentation of natural water resources (Sharma et al., 2010).

In Himachal Pradesh, about 18 % of the cultivated area has assured irrigation facilities, generally occupied by vegetable cultivation. Since, the productivity of irrigated agriculture is more than twice the rain fed agriculture, it is very essential to bring the maximum area under irrigation with judicious and economic use of harvested rain and ground water for increasing the water productivity of land. Efficient utilization of harvested rain-water either in small or big farm ponds is being emphasized upon through micro-irrigation systems especially drip system. Also, undulating topography with poor soil water retention and transmission characteristics in hills favours drip irrigation system. Field studies were conducted during the years 2008-09, 2009-10 and 2010-11 years to evaluate the efficient utilization of harvested rain-water in poly-lined tank (100 m^3 capacity) in 400 sq m area under different cropping systems. The three year study indicated that on an average, 7367 mm of stored water was applied out of which, 5269 mm (2/3) was applied in vegetable based cropping systems (Table 6). The corresponding values of total water applied for rice based and maize/ soybean based cropping systems were 1399 and 466 mm. The marketable yields and returns were highest under vegetable based cropping systems in comparison to cereal based cropping systems. The average values of water use efficiency (WUE) were 7.88 kg/ha-mm under vegetable based cropping systems, 6.65 kg/ha-mm under soybean-wheat cropping system, 5.94 kg/ha-mm under rice (SRI)-wheat cropping system, 4.77 kg/ha-mm under maize-wheat cropping system and 2.17 kg/ha-mm under rice (CTR) -wheat cropping systems (Table 7).

Table 6: Total water use of harvested rain-water in different cropping system/ activity

Cropping system/ Activity	2008-09			2009-10			2010-11			Mean		
	Water applied (mm)	Effective Rainfall (mm)	Total water use (mm)	Water applied (mm)	Effective Rainfall (mm)	Total water use (mm)	Water applied (mm)	Effective Rainfall (mm)	Total water use (mm)	Water applied (mm)	Effective Rainfall (mm)	Total water use (mm)
Maize-wheat	200	1880	2080	150	1688	1838	350	2122	2472	233	1896	2129
Soyabean – wheat	200	1880	2080	150	1688	1838	350	2024	2374	233	1896	2129
Rice (SRI) – wheat	440	2090	2530	470	1762	2232	550	2037	2587	486	1963	2449
Rice (CTR) – wheat	980	1970	2950	1110	1653	2763	650	1836	2486	913	1819	2732
Brinjal-broccoli-green onion-french bean	3300	1880	5180	3120	2054	5174	1250	2404	3654	2556	2113	4669
Okra – radish-green onion-french bean	3200	1880	5080	3840	2054	5894	1100	2319	3419	2713	2084	4797

Bio-compost unit (50 m^2)	220		220	240		240	240		240	233		233
Total	8540	11580	20120	9080	10899	19979	4490	12742	17232	7367	11739	19106

Table 7: Equivalent yield and water use efficiency in different cropping system/ activity

Cropping system/ Activity	2008-09		2009-10		2010-11		Mean	
	Maize equivalent yield (Mg ha^{-1})	WUE (kg $ha\text{-}mm^{-1}$)	Maize equivalent yield (Mg ha^{-1})	WUE (kg $ha\text{-}mm^{-1}$)	Maize equivalent yield (Mg ha^{-1})	WUE (kg $ha\text{-}mm^{-1}$)	Maize equivalent yield (Mg ha^{-1})	WUE (kg $ha\text{-}mm^{-1}$)
Maize-wheat	7.96	3.82	10.30	5.60	10.72	4.34	10.17	4.77
Soyabean – wheat	18.60	8.94	17.17	9.34	13.86	5.84	13.95	6.65
Rice (SRI) – wheat	16.36	6.47	21.08	9.44	15.27	5.90	14.54	5.94
Rice (CTR) – wheat	10.52	3.57	12.05	4.36	8.84	3.56	9.06	2.17
Brinjal- broccoli-green onion- french bean	64.92	12.53	56.04	10.83	37.61	10.29	40.54	8.68
Okra – radish- green onion- french bean	59.76	11.76	59.64	10.12	33.66	9.84	33.90	7.07
Bio-compost unit (50 m^2)	25.68		29.69		17.63		17.41	
Total	203.8		206.0		137.59		139.57	

Micro-irrigation for efficient utilization of harvested rain-water

The water and fertilizer are the two important and costly inputs for agricultural production and are interrelated in their effects on plant growth and yield. Every effort must be made to enhance water and fertilizer use efficiency by reducing their wastage. In recent years, keeping in view the limited water resources available, micro-irrigation systems comprising drip and sprinkler have been promoted in Himachal Pradesh. So far, about 116 ha area has been brought under drip irrigation system (Sankranarayanan et al., 2011).

Drip irrigation is the system for precise application of water to synchronize with the plant needs. It maintains a favorable soil water regime and restricts the fluctuation of soil water potential within narrow range. This system recharges the root –zone and maintains the uniformity of seed–zone moisture throughout the planting area for a longer period as compared to conventional methods of irrigation. Irrigation scheduling based on drip system takes into account moisture depletion pattern, infiltration, retention, transmission and redistribution pattern of soil and atmospheric demand. It is eco-friendly irrigation system saving > 60 percent water and increases the yield by 30-40 percent over conventional methods (Magar and Nandgude, 2005). Also, drip irrigation is an option wherever water availability limits conventional irrigation and further it reduces the risk of yield reduction due to terminal dry spell (Ramamurthy et al., 2009).

The regulated supply of water through drippers not only affects the plant root and shoots growth parameters but also the fertilizer use efficiency and nutrient uptake. Drip irrigation along with fertilizer (fertigation) reduces the wastage of water and chemical fertilizers, subsequently optimizes the nutrient use by applying them at critical stages and proper place and time, which finally increases the water and nutrient use efficiency.

Fertigation which combines irrigation water with fertilizer is well recognized as the most effective and convenient means of maintaining optimal nutrient levels and water supply according to specific needs of each crop and type of soil. The technique applies both water and fertilizer at a low rate to the vicinity of

plant root zone as per crop needs and according to crop developmental phase, resulting in higher yields and better quality of produce. Fertigation technology reduces the requirement of fertilizer by 40-60 per cent and enhances the yield (Kumar and Singh, 2002). The right combination of water and nutrients is the key for increasing the yield and quality of produce. The availability of N, P and K nutrient was found to be higher in root zone area of drip fertigated plots (Sathya et al., 2008).

The study was conducted at experimental farm of CSK HPKV, Palampur, during the year 2010-2011 with the objectives of evaluating the effects of drip irrigation levels applied at IW/CPE = 0.8, 1.0 and 1.2 and NPK fertigation on soil water retention and transmission, plant water and water use efficiency, growth, productivity and nutrient uptake of cauliflower (Table 8 and 9). The treatments comprised of (a) Three drip irrigation levels viz., $I_{1.2}$ (IW/CPE = 1.2) – Drip at 120 percent CPE, $I_{1.0}$ (IW/CPE = 1.0) – Drip at 100 percent CPE and $I_{0.8}$ (IW/CPE = 0.8) – Drip at 80 percent CPE, (b) Three fertigation levels viz., F_{100} – 100 percent recommended dose of fertilizer, $F_{66.6}$ – 66.6 percent recommended dose of fertilizer and $F_{33.3}$ – 33.3 percent recommended dose of fertilizer and (c) Control - flood Irrigation of 4 cm at 8-10 days interval + 100 percent recommended dose of fertilizer (Kapoor, 2012).

The results indicated that $I_{1.2}$ treatment had higher soil water content, soil water stock, profile water recharge in comparison to $I_{1.0}$, $I_{0.8}$ and I_{Rec}. The $I_{1.2}$ treatment due to favorable soil moisture regimes led to better root and shoot growth, higher relative leaf water content, marketable curd yield, NPK uptake and water use efficiency in comparison to $I_{1.0}$ and $I_{0.8}$. Likewise, F_{100} treatment had higher root and shoot growth, relative leaf water content, marketable curd yield, NPK uptake and water use efficiency in comparison to $F_{66.6}$ and $F_{33.3}$. The highest marketable curd yield, NPK uptake, water use efficiency, gross return was obtained under $I_{1.2}F_{100}$ treatment combination. The study concluded that drip based irrigation scheduling resulted in higher water use efficiency (47.43 to 52 %) and saving in irrigation water (53.53 to 63.43 %) in comparison to conventional method of irrigation.

Table 8: Effect of irrigation management on Consumptive water use (mm) during crop growth stages

Soil suction based irrigation	No of irrigations applied	Total irrigation (mm) (A)	Effective rainfall (mm) (B)	Cumulative profile water depletion (mm) (C)		Crop water use (mm) (A+B+C)		Curd yield (Mg ha^{-1})	Water Use Efficiency (kg ha^{-1} mm^{-1})	
				0-0.30 m	0.-0.60 m	0-0.30 m	0-0.60 m		0-0.30 m	0-0.60 m
$I_{0.8}$	45	219.4	246	3.09	3.29	468.49	468.69	12.11	25.9	25.8
$I_{1.0}$	45	249.5	246	0.52	0.20	496.02	495.7	12.23	24.7	24.7
$I_{1.2}$	45	278.8	246	-2.69	-4.19	522.11	520.61	13.82	26.5	26.6
I_{Rec}	15	600.0	246	3.37	1.90	849.37	847.90	14.80	17.5	17.5

Table 9: Effect of drip irrigation and fertigation on biological yield

Treatment	Curd yield (Mg ha^{-1})	Fresh weight of plant without curd (Mg ha^{-1})
Drip irrigation levels		
$I_{0.8}$	12.11	14.11
$I_{1.0}$	12.23	16.23
$I_{1.2}$	13.82	18.77
CD (P=0.05)	0.73	0.73
Fertigation levels		
F_{100}	14.26	17.87
$F_{66.6}$	13.03	16.70
$F_{33.3}$	10.87	14.54
CD (P=0.05)	0.73	0.72
Control vs Others		
Control	14.80	17.80

Others	12.72	16.37
CD (P=0.05)	0.94	0.93

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