Comparative Performance of Dryland Cropping Systems under Reduced Runoff Farming in Alfisols of Karnataka

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ABSTRACT

Cropping systems are important tool to tackle runoff, erosion and soil loss. The kind and sequence of crops will decide the kind and amount of vegetative cover, the nature of tillage operations performed on the physical and chemical properties of the soil. The field experiment was conducted during *kharif* 2019-20 and 2020-21 at AICRP for Dryland Agriculture, GKVK, UAS, Bangalore to study 'Comparative performance of dryland cropping systems under reduced runoff farming in alfisols of Karnataka'. Significantly better growth parameters *viz.*, plant height, number of leaves, number of branches, leaf area, leaf area index, leaf area duration and SPAD, yield parameters *viz.*, grain/pod yield, straw/stover yield and economics were recorded in cropping systems with one sensor based micro irrigation of 25 mm during dry spell from farm pond as compared to their respective checks. Significantly higher finger millet equivalent yield was recorded in french bean with one protective irrigation (9627 kg ha^{-1}) when compared to non-irrigated (7732 kg ha^{-1}) and other cropping systems. It was followed by pigeonpea + field bean (1:1) (5624 kg ha^{-1}). Similarly, french bean sole with one sensor based micro irrigation resulted in higher gross return (Rs.303706 ha^{-1}), net return (Rs.24556 ha^{-1}) and B:C ratio (5.22) as compared to non-irrigated and other cropping systems. However, the runoff, soil loss and nutrient losses were higher with french bean sole as compared to other cropping systems.

Keywords : Cropping systems, Dry spells, Economics, Finger millet equivalent yield, Runoff farming

IN India, rainfed agriculture accounts for two-thirds of the total cropped area (66 %) and contributes 40 per cent to the national food basket. The importance of rainfed agriculture is obvious in the country considering its contribution in the production of coarse cereals (91 %), pulses (90 %), oilseeds (85 %), cotton (65 %) and rice (55 %). The mean annual rainfall in rainfed region ranging from 400 mm to 1000 mm, which is uncertain, erratic and unevenly distributed. In India, ensuring the sustainability of rainfed agriculture is more critical for population living in these areas (Anonymous, 2010). Karnataka is a rainfed agrarian state having nearly 66 per cent of the cultivated area under rainfed agriculture. Since Karnataka is an upper riparian state, the possibility of the increasing area under irrigation is limited. 55 per cent of food grain and 75 per cent of oilseed production comes from rainfed areas in the state (Ramachandrappa *et al.,* 2016). According to rainfall pattern analysis in the state, three to four years out of ten years face severe drought, sometimes even in alternate years also. Among 18 years during 2001 to 2018, 14 years were declared as drought in the state of Karnataka (Thimmegowda *et al.,* 2018).

Among 400 M ha-m of rainfall received, 150 M ha-m flows as surface runoff, subsurface runoff and will not available to any type of production in India (Mathur *et al.,* 1997). To mitigate the runoff caused by uneven, erratic and heavy rains, *in-situ* and *ex-situ* water harvesting techniques can be used efficiently. During the rainy season when water is not required for irrigation, the excess water can be stored in a ancillary reservoir or farm ponds and used effectively during crucial periods of crop growth (Ramachandrappa *et al.,* 2017). The *in-situ* water harvesting can be attained through selection of proper cropping systems. Cropping systems are commonly recognized to affect runoff, erosion and crop yields. The kind and sequence of crops will decide the kind and amount of vegetative cover, the nature of tillage operations performed and the physical and chemical properties of the soil.

Harnessing small water sources and integrating with affordable technologies, information and access to markets makes a significant improvement in rural livelihoods. Reduced runoff farming could be an option in improving the livelihood security of the rainfed farmers. With these objectives the field experiment was carried out in *kharif* 2019-20 and 2020-21 to assess the comparative performance of different cropping system to reduce runoff, soil loss and obtain higher productivity in Eastern Dry Zone of Karnataka.

Material and Methods

Experiment Location

Experiment was carried out to study 'Comparative performance of dryland cropping systems under reduced runoff farming in alfisols of Karnataka' at the All India Co-ordinated Research Project on Dry Land Agriculture, University of Agricultural Sciences, Gandhi Krishi Vignan Kendra, Bengaluru in the Eastern Dry Zone of Karnataka at 12^0 58' N latitude and 75^0 35' E longitude at an altitude of 930 meter above mean sea level during 2019-20 and 2020-21. The soil of experimental site was slightly acidic in reaction (5.60), medium in average available nitrogen (253.87 kg ha^{-1}), medium in average available phosphorous (32.00 kg ha^{-1}) and medium in average available potassium (155.83 kg ha^{-1}).

Treatment Details

The experiment was conducted using RCRD design with factorial concept with two factors consisting of cropping systems for harvesting of runoff water from the micro watershed in the farm ponds and water productivity enhancement strategies through sensor based protective irrigation having three replications. The factor one titled 'Cropping system for harvesting of runoff water from the micro watershed in farm ponds' consist of cropping system *viz.,* T_1: french bean sole T_2: Finger millet sole, T_3: Pigeonpea + field bean (1:1), T_4: Finger millet + Pigeonpea (8:2), Perennial mixed fruit (Pomelo + Guava) orchard and Kitchen garden (Ladies finger, capsicum, tomato, french bean, brinjal, leafy vegetables, green chilli, knol khol, cluster bean, ridge guard, cabbage) and factor two titled 'Water productivity enhancement strategies' consist of I_1: Protective advanced irrigation (sensor based micro irrigation during dry spell) and I_2: Control. The respective recommended dose of fertilizers of crops were given along with 7.5 t ha^{-1} FYM during experiment.

Collection of Hydrological Data

The water harvested from five different micro water shed during runoff events are facilitated to store in respective farm ponds constructed at the end of plots. The weekly soil moisture during crop growth period from the depth of 0-15 cm and 15-30 cm were taken with Moisture probe meter (MPM-160-B), manufactured by ICT international limited, Australia. Based on soil moisture percentage and dry spell during the crop growth period the protective irrigation was given at vegetative stage in both years. The protective irrigation was given through sprinkler using diesel pump. The quantity of irrigation for different crops is indicated below.

Methods/ Seasons	*Kharif* 2019 (mm)	Date	*Kharif* 2020 (mm)	Date
Pigeonpea+ field bean (1:1)	25	05-07-2019	25	21-06-2020
Finger millet sole	25	11-09-2019	25	28-08-2020
Finger millet+ pigeonpea (8:2)	25	11-09-2019	25	28-08-2020
French bean	25	14-09-2019	25	01-11-2020
Pumelo	25	04-11-2019	25	01-11-2020

Biometric Observations

The plant height of five randomly selected plants were measured from base of plant to tip of the panicle in finger millet, perpendicular distance from ground level to the tip of main stem in pigeonpea, ground to tip of plants in field bean and french bean were taken, averaged and expressed in centimeters. Number of leaves was recorded from the randomly selected five hills of finger millet and fully opened trifoliate leaves in pigeonpea, field bean and french bean was counted and averaged to get leaves per hill/plant. Total numbers of tillers produced by five random tagged hills in finger millet and number of branches emerging directly from main stem was counted and the average of the five plants was expressed as number of branches per plant in pigeonpea, field bean and french bean. The SPAD observation was taken by using SPAD meter at at 90 DAS in finger millet, 60 DAS in field bean and french bean, 150 DAS in pigeon pea.

The fresh green leaves from five hills/plant were collected and passed through a leaf area meter INC/ LI-COR Ltd., Nebraska, USA to measure the leaf area. Then it is expressed in square centimeter. Leaf area index was worked out by dividing the leaf area $hill^{-1}$ / plant from land area covered by the plants as per the formulae given by Watson (1952). Leaf area duration was calculated between 60 - 90 DAS in field bean & french bean, 90 DAS - harvest in finger millet and 150-180 DAS in pigeonpea by using the formula given by Power *et al.* (1967).

$$LAD = \frac{LAI_1 + LAI_2}{2} \times (t_2 - t_1)$$

Where, LAD = Leaf area duration, expressed in days

LAI_1= Leaf area index of hill at time t_1

LAI_2 = Leaf area index of hill at time t_2

During each picking, pods in field bean and french bean were harvested from net plots according to treatments, weighed and expressed as kg ha^{-1}. The grain yield of finger millet and pigeon pea obtained from each net plot area was harvested, threshed, sun dried to 10-12 per cent moisture and later yield was converted to kg ha^{-1}. The straw and stalk from net plot area was cut close to the ground level and was left for air drying in the for one week. Later it was weighed and computed as straw yield in kg ha^{-1}. The respective grain and pod yield of different crops were converted into finger millet equivalent yield (kg ha^{-1}). The formula to calculate FMYE is given below.

$$\text{Finger millet equivalent yield (FMEY)} = \frac{\text{Yield of crop (kg ha}^{-1}\text{)} \times \text{Price of crop (Rs. kg}^{-1}\text{)}}{\text{Price of finger millet (Rs. kg}^{-1}\text{)}}$$

Statistical Analysis

The experimental data collected on various growth components of plant were subjected to student's 't' test. Whenever table 't' test value is more than calculated 't' test value of two means, significant difference exists between the treatments means. Otherwise values abbreviation 'NS' (Non-Significant) was indicated. Finger millet equivalent yield were subjected to Fisher's method of 'Analysis of variance' (ANOVA). Whenever F-test was significant for comparison amongst the treatments means, an appropriate value of critical differences (CD) was worked out. Otherwise against CD values abbreviation 'NS' (Non-Significant) was indicated. All the data were analyzed and the results are presented and discussed at a probability level of 5 per cent (Gomez and Gomez, 1984).

Results and Discussion

Experiment 'Comparative performance of dryland cropping system under reduced runoff farming in alfisols of Karnataka' was conducted during *kharif* 2019-20 and 2020-21. The data pertaining to different growth and yield parameters of both years and pooled are given in respective tables. The pooled data of the both years is presented and discussed below.

Effect of Water Productivity Enhancement Strategies on Plant Height, Number of Leaves and Number of Branches

Plant growth is a function of several physiological and biological processes which is measured in terms of rate of dry matter production and their partitioning into various plant parts which finally reflected on economic yield. With regarded to this vegetative plant parts serve as a source for dry matter production and the grains as sink for dry matter accumulation. The plant height was significantly higher with application of one protective sensor based micro irrigation during dry spell from runoff water stored in farm ponds of micro catchment area in french bean (57.9 cm), finger millet (120.6 cm), pigeonpea (231.5 cm) and field bean (71.7 cm) in pigeonpea + field bean (1:1) cropping system, finger millet (119.2 cm) and pigeonpea (165.3 cm) in finger millet + pigeonpea (8:2) cropping system when compared to their respective control (54.3, 111.7 , 214.6 & 62.9 and 110.9 & 156 cm, respectively) (Table 1). The increase in plant height was due to the amount of rainfall and irrigation applied to meet the water required by the crop for its metabolism. When the water extracted from the soil is less, causes a negative effect on the development of tissues and the parts of the crop such as stem. The plant heights recorded under protectively irrigated cropping systems are higher as compared to non-irrigated crops. Eric Manzi (2013) also observed higher plant height in mustard and chickpea with supplemental irrigation in rainfed condition as compared to non-irrigated.

Significantly higher number of leaves were recorded with one protective irrigation during dry spell in french bean (23.2), finger millet (83.1), pigeonpea (381.8) & field bean (26.6) in pigeonpea + field bean (1:1) cropping system, finger millet (81.6) & pigeonpea (159.6) in finger millet+ pigeonpea (8:2) cropping system as compared to their respective control (20,

TABLE 1

Growth parameters as influenced by water productivity enhancement strategies in different cropping systems under open field reduced runoff farming

Treatments	Plant height (cm)			No. of leaves***			Number of branches / tillers		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1: French bean sole *									
T_1I_1: French bean	59.5	56.3	57.9	23.8	22.6	23.2	8.5	8.1	8.3
T_1I_2: French bean	55.4	53.1	54.3	20.5	19.4	20.0	7.7	7.4	7.6
't' test	S	S	S	S	S	S	S	S	S
T_2: Finger millet sole **									
T_2I_1: Finger millet	123.3	118.0	120.6	84.1	82.1	83.1	11.2	10.5	10.9
T_2I_2: Finger millet	114.3	109.0	111.7	74.8	69.9	72.3	9.9	9.5	9.7
't' test	S	S	S	S	S	S	S	S	S
T_3: Pigeonpea * + Field bean * (1:1)									
T_3I_1: Pigeonpea	233.5	229.5	231.5	390.4	373.1	381.8	23.5	22.8	23.1
T_3I_2: Pigeonpea	217.9	211.2	214.6	360.6	350.4	355.5	21.7	19.3	20.5
't' test	S	S	S	S	S	S	S	S	S
T_3I_1: Field bean	70.5	72.9	71.7	26.2	26.9	26.6	6.0	6.8	6.4
T_3I_2: Field bean	59.3	66.4	62.9	19.7	23.1	21.4	4.9	6.2	5.5
't' test	S	S	S	S	S	S	S	S	S
T_4: Finger millet ** + Pigeonpea* (8:2)									
T_4I_1: Finger millet	120.7	117.7	119.2	83.0	80.3	81.6	11.4	10.9	11.2
T_4I_2: Finger millet	109.9	111.9	110.9	73.6	73.4	73.5	10.9	10.0	10.4
't' test	S	S	S	S	S	S	S	S	S
T_4I_1: Pigeonpea	167.7	162.9	165.3	161.4	157.7	159.6	12.7	12.4	12.5
T_4I_2: Pigeonpea	159.2	152.9	156.0	153.1	139.5	146.3	11.3	10.7	11.0
't' test	S	S	S	S	S	S	S	S	S

Water productivity enhancement strategies

I_1: Sensor based micro irrigation during dry spell I_2: Control

Note : * Trifoliate leaves per plant; ** Leaves per hill

*** No. of leaves were taken at 90 DAS in finger millet, 60 DAS in field bean and french bean, 150 DAS in pigeon pea

72.3, 355.5 & 21.4 and 73.5 & 146.3, respectively). Similarly, higher number of branches/tillers were recorded in french bean (8.3), finger millet (10.9), pigeonpea (23.1) & field bean (6.4) in pigeonpea + field bean (1:1) cropping system, finger millet (11.2) & pigeonpea (12.5) in finger millet+ pigeonpea (8:2) cropping system as compared to their respective control (7.6, 9.7, 20.5 & 5.5 and 10.4 & 11, respectively). The moisture played a major role in physiology of the plant. Hence, availability of moisture around optimum level during the period of growth due to life saving irrigation lead to higher number of leaves and branches in all crops as compared to without irrigation.

Effect of Water Productivity Enhancement Strategies on Leaf Area, Leaf Area Index, Leaf Area Duration and SPAD

Application of one protective irrigation during dry spell has significantly increased the leaf area of french bean (726 cm^2), finger millet (2143 cm^2), pigeonpea (6769 cm^2) & field bean (2032 cm^2) in pigeonpea + field bean (1:1) cropping system, finger millet (2227 cm^2) & pigeonpea (2808 cm^2) in finger millet+ pigeonpea (8:2) cropping system as compared to their respective control (653, 2048, 5367 & 1890 and 2090 & 2560 cm^2, respectively) (Table 1). The higher leaf area was a result of higher number of leaves and tiller/branch production (Table 1). Due to higher leaf area, there was marked increase in the leaf area index with one supplemental irrigation was observed in french bean (1.08), finger millet (7.14), pigeonpea (1.88) & field bean (2.26) in pigeonpea + field bean (1:1) cropping system, finger millet (7.42) & pigeonpea (1.56) in finger millet+ pigeonpea (8:2) cropping system (Table 2). The leaf area index showed a curvilinear trend of increase up to grain formation stage in finger millet & pigeon pea and pod formation in french bean & field bean and later declined marginally due to senescence. Application of irrigation during dry spell might increase metabolic activities like increase in turgidity, cell division and elongation of leaves resulting in higher biomass. Further, this has been resulted in increased leaf area and LAI which is an indicative of higher mobilizable protein pools available at the beginning of the reproductive phase and later on greater plant bearing capacity. Similar findings were also reported by Eric Manzi (2013) in mustard and chickpea.

Significantly higher leaf area duration was recorded in french bean (26.6), finger millet (165.2), pigeonpea (52.7) & field bean (52.3) in pigeonpea + field bean (1:1) cropping system, finger millet (173.5) & pigeonpea (44.4) in finger millet+ pigeonpea (8:2) cropping system as compared to their respective control (23.8, 153.6, 42.5 & 47 and 158.2 & 40.2, respectively). This higher LAD improved the crop growth parameters and resulted in higher grain and straw yield. The yield of any crop is directly proportional to its duration. As the duration increases, there will be more availability of opportunity time for photosynthesis and resulting in more dry matter production and its distribution to economic parts. Similar findings were also reported by Eric Manzi (2013).

Application of one irrigation at dry spell to different cropping system has lead to increased uptake of nutrients and resulted in significantly higher SPAD readings, which is the index of chlorophyll content in french bean (47.6), finger millet (38.9), pigeonpea (48) & field bean (47.9) in pigeonpea + field bean (1:1) cropping system, finger millet (41.2) & pigeonpea (46) in finger millet+ pigeonpea (8:2) cropping system as compared to their respective control (44.4, 36.9, 44.7 & 44.4 and 38.5 & 43.3, respectively).

Influence of Water Productivity Enhancement Strategies on Grain or Pod Yield, Stover or Straw Yield and Finger Millet Equivalent Yield in Different Crops

Yield is the resultant of different metabolic activities taking place in different stages of the growth of the plants. A sound source in terms of plant height and number of tillers to support and hold the leaves are logically able to increase the total dry matter and later lead to higher grain yield. Significantly higher grain/pod yield was recorded with application of one sensor based micro irrigation during dry spell in french bean (10097 kg ha^{-1}), finger millet (4126 kg ha^{-1}), pigeonpea (887 kg ha^{-1}) & field bean (3258 kg ha^{-1}) in pigeonpea + field bean (1:1) cropping system, finger millet

TABLE 2

Leaf area (cm^2), Leaf area index Leaf area duration and SPAD as influenced by water productivity enhancement strategies in different cropping systems under open field reduced runoff farming

Treatments	Leaf area (cm 2) ***			Leaf area index ***			Leaf area duration (Days)			SPAD***		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1: French bean sole *												
T_1I_1: French bean	753	700	726	1.12	1.04	1.08	27.7	25.5	26.6	49.0	46.3	47.6
T_1I_2: French bean	686	620	653	1.02	0.92	0.97	24.6	23.0	23.8	45.1	43.7	44.4
't' test	S	S	S	S	S	S	S	S	S	S	S	S
T_2: Finger millet sole **												
T_2I_1: Finger millet	2273	2014	2143	7.58	6.71	7.14	176.2	154.3	165.2	39.0	38.7	38.9
T_2I_2: Finger millet	2146	1949	2048	7.15	6.50	6.83	162.0	145.1	153.6	37.1	36.8	36.9
't' test	S	S	S	S	S	S	S	S	S	S	S	S
T_3: Pigeonpea* + Field bean* (1:1)												
T_3I_1: Pigeonpea	6980	6557	6769	1.94	1.82	1.88	54.6	50.7	52.7	48.8	47.3	48.0
T_3I_2: Pigeonpea	5503	5230	5367	1.53	1.45	1.49	44.2	40.8	42.5	45.2	44.2	44.7
't' test	S	S	S	S	S	S	S	S	S	S	S	S
T_3I_1: Field bean	1824	2240	2032	2.03	2.49	2.26	47.8	56.7	52.3	49.7	46.0	47.9
T_3I_2: Field bean	1684	2097	1890	1.87	2.33	2.10	43.8	50.1	47.0	45.9	42.8	44.4
't' test	S	S	S	S	S	S	S	S	S	S	S	S
T_4: Finger millet+ Pigeonpea* (8:2)**												
T_4I_1: Finger millet	2293	2161	2227	7.64	7.20	7.42	181.2	165.8	173.5	41.7	40.8	41.2
T_4I_2: Finger millet	2163	2017	2090	7.21	6.72	6.97	165.0	151.4	158.2	39.2	37.7	38.5
't' test	S	S	S	S	S	S	S	S	S	S	S	S
T_4I_1: Pigeonpea	2834	2782	2808	1.57	1.55	1.56	44.8	43.9	44.4	47.0	45.1	46.0
T_4I_2: Pigeonpea	2593	2528	2560	1.44	1.40	1.42	40.8	39.6	40.2	44.3	42.3	43.3
't' test	S	S	S	S	S	S	S	S	S	S	S	S

Water productivity enhancement strategies

I_1: Sensor based micro irrigation during dry spell I_2: Control

Note : * Leaf area per plant; ** Leaf area per hill

* Leaf area, leaf area index and SPAD were taken at 90 DAS in finger millet, 60 DAS in field bean and french bean, 150 DAS in pigeon pea

TABLE 3

Grain or pod yield (kg ha^{-1}), stover or straw yield (kg ha^{-1}) and finger millet equivalent yield as influenced by water productivity enhancement strategies in different cropping systems under open field of reduced runoff farming

Treatments	2019-20					2020-21					Pooled				
	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})	
	MC	IC	FMEY	MC	IC	MC	IC	FMEY	MC	IC	MC	IC	FMEY	MC	IC
T_1I_1: French bean	10623		10280	3808		9572		8973	4126		10097		9627	3967	
T_1I_2: French bean	8416		8144	3208		7808		7320	3553		8112		7732	3380	
T_2I_1: Finger millet	4502		4502	5221		3751		3751	5144		4126		4126	5182	
T_2I_2: Finger millet	3695		3695	4493		3114		3114	4465		3405		3405	4479	
T_3I_1: Pigeonpea + Field bean (1:1)	954	2826	5277	3896	3301	820	3690	5970	3147	4553	887	3258	5624	3521	3927
T_3I_2: Pigeonpea + Field bean (1:1)	803	2018	3976	3369	3129	612	2722	4416	2549	3718	707	2370	4196	2959	3423
T_4I_1: Finger millet + Pigeonpea (8:2)	4119	172	4413	4941	694	3416	161	3682	4553	596	3768	166	4048	4747	645
T_4I_2: Finger millet + Pigeonpea (8:2)	3277	126	3493	3129	623	2734	118	2929	3971	539	3005	122	3211	3550	581
T_5I_1: Pumelo	16252		2621			14606		2282			15429		2452		
T_5I_2: Pumelo	13732		2215			11691		1827			12712		2021		
T_6: Kitchen Garden	10491		8850			9473		8209			9982		8529		

Statistical analysis of FMEY (2019)

	T_1	T_2	T_3	T_4	T_5	Mean	T_6		T	I	T X I
I_1	10280	4502	5277	4413	2621	5419	8850	S.Em±	116.48	73.67	167.25
I_2	8144	3695	3976	3493	2215	4305		CD @ 5%	346.09	218.89	493.40

Statistical analysis of FMEY (2020)

T_1	T_2	T_3	T_4	T_5	Mean	T_6			T I	T X I	
I_1	8973	3751	5970	3682	2282	4932	8209	S.Em±	102.85	65.05	149.15
I_2	7320	3114	4416	2929	1827	3921		CD @ 5%	305.59	193.27	439.99

Statistical analysis of FMEY (Pooled)

T_1	T_2	T_3	T_4	T_5	Mean	T_6			T I	T X I	
I_1	9627	4126	5624	4048	2452	5175	8529	S.Em±	109.60	69.31	158.10
I_2	7732	3405	4196	3211	2021	4113		CD @ 5%	325.62	205.94	466.39

Note: MC : Main crop, IC: Inter crop, FMEY: Finger millet equivalent yield

TABLE 4

Economics as influenced by water productivity enhancement strategies in different cropping systems under open field of reduced runoff farming

Treatments	Gross return (Rs. ha^{-1})			Net return (Rs. ha^{-1})			B:C ratio		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1I_1: French bean sole	319437	287975	303706	261227	229886	245556	5.49	4.96	5.22
T_1I_2: French bean sole	253117	234936	244026	197547	179086	188317	4.55	4.21	4.38
T_2I_1: Finger millet sole	133878	127743	130810	105625	98880	102252	4.74	4.43	4.58
T_2I_2: Finger millet sole	110200	106350	108275	84187	79727	81957	4.24	3.99	4.12
T_3I_1: Pigeonpea + Field bean (1:1)	163598	191049	177323	128470	150881	139675	4.66	4.76	4.71
T_3I_2: Pigeonpea + Field bean (1:1)	123268	141315	132292	90380	103387	96883	3.75	3.73	3.74
T_4I_1: Finger millet + Pigeonpea (8:2)	136815	125558	131186	107076	95534	101305	4.60	4.18	4.39
T_4I, : Finger millet +Pigeonpea (8:2)	108273	100495	104384	80774	72711	76742	3.94	3.62	3.78
T_5I_1: Pumelo	81260	73030	77145	51971	44021	47996	2.77	2.52	2.65
T_5I_2: Pumelo	68660	58455	63558	41891	31686	36788	2.56	2.18	2.37
T_6: Kitchen Garden	314727	284190	299459	215539	186008	200774	3.17	2.89	3.03

Water productivity enhancement strategies

I_1: Sensor based micro irrigation during dry spell I_2: Control

French bean pods – Rs. 30 kg^{-1} ; Pigeonpea- Rs. 5300 qt^{-1} ; Finger millet- Rs. 3100 qt^{-1} ; Field bean pods- Rs. 40 kg^{-1}

Pumelo- Rs. 5 kg^{-1}

(3768 kg ha^{-1}) & pigeonpea (166 kg ha^{-1}) in finger millet+ pigeonpea (8:2) cropping system, pumelo fruit yield (15429 kg ha^{-1}) as compared to their respective control (8112, 3405, 707 & 2370, 3005 & 112 and 12712 kg ha^{-1} respectively) (Table 3).

The crops *viz.,* ladies finger, capsicum, tomato, french bean, brinjal, leafy vegetables, green chilli, knol khol, cluster bean, ridge guard, cabbage were grown using water harvested through runoff in farm ponds in kitchen garden, which is one of sustainable component of dryland ecosystem to meet house hold requirement of the farm family. Hence, it recorded a total of 9982 kg ha^{-1} yield from various crops grown during the study in kitchen garden. The results are in line with Bhandarkar and Reddy (2010), where they noticed twofold increase in yield of soybean, chickpea, rice and wheat with application of irrigation from farm pond. Samindre and More (2012), reported 100.64 per cent higher grain yield of safflowers with one protective irrigation as compared to no protective irrigation. Ramachandrappa *et al.* (2017) reported higher yield with protective irrigation from farm pond in field bean, aerobic rice and finger millet.

Similarly, application of one irrigation during dry spell also increased stover/straw yield in french bean (3967 kg ha^{-1}), finger millet (5182 kg ha^{-1}), pigeonpea (3521 kg ha^{-1}) & field bean (3927 kg ha^{-1}) in pigeonpea + field bean (1:1) cropping system and finger millet (4747 kg ha^{-1}) & pigeonpea (645 kg ha^{-1}) in finger millet+ pigeonpea (8:2) cropping system as compared to their respective control (3380, 4479, 2959 & 3423 and 645 & 581 kg ha^{-1}, respectively).

The grain yield and pod yield of different crops in different cropping systems are converted into finger millet equivalent yield to analyze and compare the productivity. Significantly higher finger millet equivalent yield was noticed with one sensor based micro irrigation during dry spell from farm pond water in french bean sole (9627 kg ha^{-1}), finger millet sole (4126 kg ha^{-1}), pigeonpea + field bean (1:1) cropping system (5624 kg ha^{-1}), finger millet+ pigeonpea (8:2) cropping system (4048 kg ha^{-1}) and pumelo (2452 kg ha^{-1}) as compared to their respective control (7732, 3405, 4196, 3211 and 2021, respectively) (Table 3). Finger millet equivalent of crops grown in kitchen garden was 8529 kg ha^{-1}. Among different cropping systems french bean with one protective irrigation has recorded higher finger millet equivalent yield (9627 kg ha^{-1}) as compared to other cropping systems.

Economics

French bean with one protective irrigation during dry spell recorded higher gross returns (Rs.303706 ha^{-1}), net returns (Rs.24556 ha^{-1}) and B:C ratio (5.22) as compared to finger millet sole (Rs.130810 ha^{-1}, Rs.102252 ha^{-1} and 4.58, respectively), pigeonpea + field bean (1:1) (Rs.177323 ha^{-1}, Rs.139675 ha^{-1} and 4.71, respectively), finger millet+ pigeonpea (8:2) (Rs.131186 ha^{-1}, Rs.101305 ha^{-1} and 4.39, respectively) and pumelo (Rs.77145 ha^{-1}, Rs.47996 ha^{-1} and 3.78, respectively) (Table 4 and Fig. 1). Among water productivity enhancement strategies irrespective of cropping systems, sensor based micro irrigation during dry spell has recorded higher gross returns, net returns and B:C ratio as compared to treatments without irrigation. Pandey *et al.* (2005) also recorded higher economics in rice with protective irrigation from lined reservoir under rainfed conditions. Anonymous (2018) also reported higher returns with supplemental irrigation with rain gun in cotton and sorghum.

It can be concluded from two years of experiment that application of sensor based micro irrigation during dry spell by using runoff water stored in the farm pond has resulted in higher yield in french bean (24.46 %), finger millet (21.17 %), pigeonpea (25.45 %) & field bean (37.4 %) in pigeonpea + field bean (1:1) cropping system, finger millet (25.39 %) & pigeonpea (36.06 %) in finger millet + pigeonpea (8:2) cropping system, pumelo fruit yield (21.37 %) as compared to treatments without irrigation during dry spells.

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