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Performance of fruit trees (drip irrigation) and intercrops(Rainfed) under Agri-horti system in arid Western Rajasthan

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Abstract

Moth bean (*Vigna aconitifolia* L.), cluster bean (*Cyamopsis tetragonoloba* L.Taub.) and sonamukhi (*Cassia angustifolia* Vahl.) were grown as intercrops under agri-horti-silvi system with 7-year-old plantations of citrus [*Citrus aurantifolia* (Cristm.) Swinglel, bael [Aegle marmelos (L.) Correa] and gonda (*Cordia myxa* L.) at research farm of Central Arid Zone Research Institute, Regional Research Station, Bikaner, during two consecutive years of 2008 and 2009. Highest seed and stover yield of moth bean (460 & 1881 $kgha^{-1}$ in 2008 and 320 & 1304 kg/ha in 2009) and cluster bean (623 & 2146 $kgha^{-1}$in 2008 and 533 & 1838 $kgha^{-1}$ in 2009) as well as, the leaf and seed yield of sonamukhi (323 & 53 $kgha^{-1}$ in 2008 and 415 & 80 $kgha^{-1}$ in 2009) was recorded in intercropping with citrus. Among the different levels of irrigation applied to fruit trees, irrigation at 80% of potential crop evapotranspiration (ETc) gave the highest yield and water use efficiency in all the crops, while the lowest was recorded at 40% ETc. It was also observed that cluster bean intercropped with citrus recorded the highest WUE (3.76 ($kgha^{-1}mm^{-1}$).

Key words: *Agri-horti system, drip irrigation, inter cropping, western Rajasthan*

Introduction

The Indian arid zone which covers around 12% of country's geographical area is characterized by low and erratic rainfall with extremes of temperature (1-48°C), high wind velocity and structure less sandy soil with low water holding capacity and poor nutrient status (Kaushik *et al.*, 2014). These are compounded by unsustainable use of land and increasing human population, placing unprecedented demand for food and natural resources, challenging most of the arid and semi-arid regions with the task of producing more per unit land with the innate limitations associated with them. Arable cropping in the arid region is often risky and crop yields are meagre and unstable; and consequently the income from existing cropping alone is insufficient to sustain the farmers' family. Therefore, to mitigate the risk and uncertainty of the income from conventional cropping, it is crucial to integrate various agricultural enterprises in the production programme and develop location specific land use management systems which can improve total land productivity and give sustainable agricultural production and provide economic stability to the farmers throughout the whole year.

An integrated approach of land management in arid areas is essential for efficient utilization of natural resources, to meet the requirements of farmers without deteriorating the land productivity and also to stabilize the income. With their modest rainfall, arid regions are characterized by relatively fewer species than the better-watered biomes but are endowed with appreciable agro-ecological diversity and hence various components viz. crop, animal, tree, grass, fruit tree can be integrated in production system for livelihood security. Perennials-based production systems: agri-horticulture and agro-forestry are considered effective strategy for improving productivity, employment opportunities, economic condition and nutritional security (Pareek, 1999; Chadha, 2002). They are essential for meeting the requirements of the ever-increasing population and managing natural resources. Agroforestry systems can enhance the total production by improving soil fertility (Singh, 2010), controlling erosion and replenishing nutrients removed through biomass harvest (Ilany *et al.*, 2010), improving microbial population (Yadav *et al.*, 2008; Vallejo *et al.*, 2012), economic benefits (Jianbo 2006; Fadl & Sheikh 2010), and nutrient and water-use efficiency (Anderson *et al.* 2009; Pinho *et al.*, 2011). The objective of introducing woody perennials in farming system is not only to cover the risk of crop failures but also to meet the demand for fuel, food, fruit, fodder and small timber. Traditional tree-integrated farming systems are adopted since time immemorial for security of food, fodder and fuel wood in drought-prone arid regions (Ndayambaje and Mohren, 2011; FAO, 2013), but are unable to meet the requirement of the ever increasing biotic pressure. Also, in most of the regions, people are unenthusiastic to adopt agroforestry because of lesser short term benefits from tree species.

Agri-horticultural systems which integrate horticultural species with arable crops ensure income to the farmers much earlier. Integration of horticultural species provides income at regular intervals to the farmers, in addition to production obtained from

agricultural crops during the early stages of tree establishment (Kaushik and Kumar, 2003). Agri-horticultural systems can provide increased income throughout the year and minimize the risk of total failure of the system productivity as in traditional agriculture. Keeping in view these findings, an experiment was conducted at research farm of ICAR-Central Arid Zone Research Institute, Regional Research Station, Bikaner during 2008 and 2009 with the objectives of assessing the performance of different trees and crops in agri-horti system in arid part of western Rajasthan at the higher age of trees even (up to 8 years).

Material and methods

The present investigation was carried out at the Research Farm of Central Arid Zone Research Institute, Regional Research Station, Bikaner (latitude 28.03°N, longitude 73.19°E), India during kharif 2008 and 2009 with the existing 7 year old plantation of citrus [Citrus aurantifolia (Cristm.) Swingle], bael [Aegle marmelos (L.) Correa] and gonda (*Cordia myxa* L.) maintained under drip irrigation system. The total rainfall during the year was 273.1mm & was 352.5mm (Jan-Dec) in 2008 and 2009, respectively . It was 7.05 and 62.74% higher than normal average rainfall (255 mm)during 2008 & 2009 ,respectively. During the cropping season (July-October) the total rainfall was 97.5mm in 2008 256.4 mm in 2009 (Fig. 1). The soil of the experimental site was alkaline (pH 8.3), non-saline (EC_2 0.22 dS m^{-1}), loamy sand with organic carbon 1.0 g/ kg, available N 89.7 kg/ha, available P 8.0 kg/ha and available K 234.1 kg/ha and can store moisture 112 mm m^{-1} soil profile. The plants were grown at three irrigation levels *i.e.* I_1 (40%ETc), I_2 (60%ETc) and I_3 (80%ETc) on the basis of evapotranspiration. Mothbean (*Vigna aconitifolia* L.), clusterbean (*Cyamopsis tetragonoloba* L.Taub.) and sonamukhi (*Cassia angustifolia* Vahl.) were grown as intercrops under rain-fed condition during kharif season. Recommended agronomic practices and plant protection measures were followed for individual crops and trees. The trees viz. citrus, bael and gonad were planted at 6 m x 5 m distance in which the intercrops were grown in the tree row spacing of 6 m. Fertilizers were applied as per the recommendations of tree species and inter crops. Experiment was taken under strip plot design with three replications. All growth parameter of fruit trees were taken during the month of November. Data was statistically analyzed by the procedure described by Gomez and Gomez (1984).

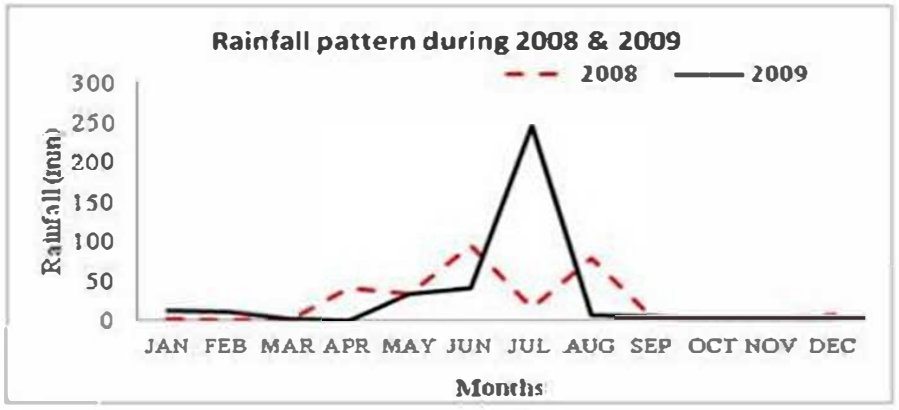

Fig 1: Rainfall pattern during crop season

Results and Discussion

Growth of fruit trees

Different irrigation levels significantly affected the growth parameters (plant height, stem girth and tree canopy) of fruit trees (Table 1). The highest plant height for all the trees was recorded at 80% ETc irrigation level, which was higher by 2.1 and 13.69 % in citrus; 5.14 and 9.29 % in *bael* and 1.37 and 4.43 % in *gonda* compared to the other two treatments ie. 60% and 40% ETc irrigation levels, respectively. The same trend was observed in case of stem girth and tree canopy which was highest in 80% ETc irrigation level but was at par with 60 % ETc irrigation level (Table 1).

Rainfed intercropping significantly affected the growth of all the fruit trees. Highest tree height of citrus and bael was recorded in intercropping with moth bean whereas highest tree height of gonda was recorded in intercropping with cluster bean. The stem girth and tree canopy of all the fruit trees were at par under intercropping with moth bean and cluster bean, but it was significantly higher compared to trees which were grown with no intercropping (Table 1).

Fruit yield

About 40 % plants were in fruiting and mean highest fruit yield of citrus (235.0 kg/ha and 248.28 kg/ha in 2008 and 2009, respectively) was recorded in citrus intercropped with moth bean giving maximum fruit yield (350.0 kg/ha in 2008 and 387.75 kg/ha in 2009) at 80% ETc irrigation level. This was 8.6 and 16.0 percent and 89.2 and 124.3 per cent higher compared to intercropping with cluster bean and sonamukhi, in the years 2008 and 2009, respectively (Table 2).

Yield of intercrops

In 2008, moth bean and cluster bean did not perform well and plant population as well as grain formation was improper and unsatisfactory, due to poor rainfall and long dry spell after sowing. During the crop season of 2009, even though total rainfall was normal, its distribution was skewed resulting in poor yield of rainfed mothbean and clusterbean. The highest seed and stover yield of both moth bean and cluster bean was recorded with citrus which was significantly higher than that with bael and gonda. Sonamukhi gave satisfactory yields and during both the years, the highest dry leaf yield (323 kgha^{-1} in 2008 and 415 kgha^{-1} in 2009) was recorded with citrus which was 7.3 and 28.9 % higher over intercropping with bael and 68.2 and 48.2 % higher over intercropping with gonda in 2008 and 2009 respectively (Table 3). At different irrigation levels, irrigation at 80% ETc of fruit trees gave the highest leaf and seed yield and lowest was at the level of 40% ETc (Table 3).

The better performance of all the intercrops associated with citrus might be due to less competition from citrus trees for moisture and nutrients in comparison to bael and gonda. Along similar lines, Yadava *et al.* (2013) reported that the highest total biological yield and seed yield of mung bean and clusterbean was recorded in intercropping with citrus compared to that with mopane (*Colophospermum mopane*) and shisham (*Dalbergia sissoo*) in Bikaner. Further, Dwivedi *et al.* (2007) also reported the highest wheat yield under citrus plantation followed by aonla and minimum crop yield under guava plantation.

Water use efficiency

Water use efficiency (WUE) of different crops varied from 0.62 to 3.76 kgha^{-1}mm^{-1} (Table 3). Among the different levels of irrigation, irrigation at 80%ETc gave the highest water use efficiency in all the intercrops. This suggests that WUE increased with the increase in levels of irrigation. This might be due to the fact that biomass produced by crops increased proportionately with the total water used by the crops. The WUE was highest with cluster bean followed by moth bean, while sonamukhi recorded the lowest WUE. The highest WUE in all the intercrops was recorded in intercropping with citrus followed by bael and the lowest was observed with gonda. In contrast, Kaushik *et al.* (2011) reported that irrigation at 40% ETc for tree species (shisham + aonla, shisham + guava, khejri + guava, khejri + aonla) gave the highest WUE in intercropped tomato. Irrigation water use efficiency (IWUE) in an agri-silvi-horti production system of semi-arid ecosystems in Haryana was found to increase with the use of drip irrigation, without any loss of yield in the different crop components (Kaushik *et al.*, 2014).

It is evident from the data that the highest yield and WUE of all the intercrops was observed in intercropping with citrus. This might be due to less competitive effect of citrus on intercrops compared to bael and gonda. Beniwal *et al.* (2008) observed that the root biomass density of citrus at a radial distance of 1.0-2.5 meter was very less (16.7 g m^{-3}) compared to shisham (74.7 g m^{-3}) and mopane (134.8 g m^{-3}). They further reported that as the root biomass and soil moisture extraction by citrus in the cropping zone (i.e. 2.5 m radial distance) was less, it could perform well in agri-horti system with minimum effect on crop growth and yield.

The study revealed that intercropping of cluster bean, moth bean and sonamukhi in agri-horti system can successfully be done in drip irrigated 7-year old citrus plantations without any reduction in productivity of intercrops as well as the growth and yield of citrus trees. Selection of horticultural and agricultural crops is very crucial for the success of the integrated system. Hence, location specific agroforestry system models have to be developed for increased yield, water use efficiency and subsequently higher total income.

Table 1. Growth of fruit trees as affected by intercrops & irrigation levels under drip irrigation system (Mean of two years, 2008 & 2009)

Trees	Tree height (cm)						
	Irrigation levels (%ETc)			Intercrops			
	80	60	40	Moth bean	Cluster bean	Sonamukhi	No crop
Citrus	275.61	257.52	231.54	322.45	237.07	207.87	214.75
Bael	333.92	297.48	278.35	406.89	283.19	263.85	237.20
Gonda	204.28	211.90	172.57	176.45	199.38	256.71	190.40
Mean	271.29	255.62	227.37	302.80	266.34	242.81	214.12
CD 5%	Irri=19.8	Irri x tree=34.31		Trees= 19.8		Tree x crop=39.62	
	Stem girth (cm)						
Citrus	34.5	31.83	30.17	34.78	30.78	28.78	24.33
Bael	31.17	29.25	25.83	28.22	30.89	28.33	27.56
Gonda	25.67	30.75	23.25	28.89	30.78	22.56	24.0
Mean	30.45	30.61	26.42	30.63	30.82	26.56	25.3
CD 5%	Irri= 2.52	Irri x tree=4.37		Trees= 2.52		Tree x crop=5.05	
	Tree canopy (m^2)						
Citrus	7.39	6.27	6.04	7.96	6.49	5.31	5.45

Bael	8.01	6.12	5.50	7.03	7.33	5.65	5.76
Gonda	6.09	6.23	4.46	6.03	4.90	4.43	4.59
Mean	7.17	6.17	5.32	6.99	6.24	5.11	5.02
CD 5%	Ini= 0.90	Irri x tree=1.56		Trees= 0.90		Tree x crop=1.81	

Table 2. Mean fruit yield (kg ha $^{-1}$) under drip irrigation system during 2008 & 2009

Agri-horti system (drip irrigation)	Irrigation levels (% ETc) 2008				Irrigation levels (% ETc) 2009			
	80	60	40	Mean	80	60	40	Mean
Citrus +Moth	350	253	102	235.00	387.75	263.87	93.24	248.29
Citrus+ Guar	322.4	235.8	90.5	216.23	334.33	258.27	53.28	215.29
Citrus + Sonamukhi	185	199.5	86.33	156.94	172.89	125.87	79.92	126.23
Mean	285.80	229.43	92.94	--	298.32	216.00	75.48	--
CD 5%	30.64				28.63			

Table 3. Yield and water use efficiency of rainfed intercrops under agri-horti system (fruit trees in drip irrigation system) during 2008 & 2009

Fruit trees	Yield of rainfed intercrops (q/ha) with fruit trees(drip irrigation)						WUE (kgha^{-1}mm^{-1}) of crops intercrop with fruit trees grown at different irrigation levels (%ETc)								
	Moth bean		Cluster bean		Sonamukhi		Mothbean			Clusterbean			Sonamukhi		
	Seed	Stover	Seed	Stover	Leaf yield	Seed yield	80	60	40	80	60	40	80	60	40
2008															
Citrus	4.60	18.81	6.23	21.46	3.23	0.53	2.87	2.50	1.83	3.76	3.39	2.61	1.37	1.26	1.01
Bael	3.63	14.85	4.87	16.76	3.00	0.65	2.19	2.03	1.46	2.92	2.50	2.19	1.33	1.20	1.13
Gonda	2.93	11.97	3.60	12.39	1.92	0.53	1.72	1.56	1.30	2.24	2.09	1.30	0.90	0.84	0.82
CD 5%	0.80	2.40	0.80	2.60	2.72	0.57									
2009															
Citrus	3.20	13.04	5.33	18.38	4.15	0.80	1.37	1.25	1.13	2.54	2.15	1.56	1.40	1.36	1.32
Bael	2.78	11.37	3.32	11.41	3.22	0.68	1.25	1.11	0.90	1.38	1.17	1.33	1.11	0.98	0.89
Gonda	2.49	10.16	2.10	7.19	2.80	0.54	1.13	1.00	0.78	0.78	0.98	0.70	0.95	0.95	0.62
CD 5%	0.18	3.42	0.32	4.20	2.93	0.55									

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