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Productivity and economics of different agri-silvi-horti systems under drip irrigation

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ABSTRACT

A field experiment was conducted in two years old fruit and tree species namely shisham (*Dalbergia sissoo*) + aonla (*Embilica officinalis*), shisham (*D. sissoo*) + guava (*Psidium guajava*), khejri (*Prosopis cineraria*) + aonla (*E. officinalis*) and khejri (*P. cineraria*) + *guava* (*P. guajava*) during 2007-08 and 2008-09 planted at a spacing of 6m×6m. The crop sequences, viz. ridgegourd (*Lifa acutangula*) - tomato (*Solanum lycopersicum*), moongbean (*Vigna radiata*) - fallow and cluster bean (*Cyamopsis tetragonoloba*) - fallow were raised in the interspaces of the trees. Ridgegourd and tomato were raised with drip irrigation, while moongbean and cluster bean were raised as rainfed. The trees and crops were subjected to three drip irrigation treatments, viz. T_1 (100% ETc), T_2 (70% ETc) and T_3 (40% ETc) with three replications per treatment. Yield of intercrops was not affected by the different silvi-horti systems. The irrigation treatments influenced the yield of crops and growth of trees. Maximum yield (39323 kg/ha) of tomato and growth of trees was recorded under 100% replenishment of water except in case of shisham, where maximum height (803.0 cm), diameter (15.4 cm) and crown spread (550 cm^2) was recorded under 70% replenishment of water after 48 months of plantation. Maximum irrigation water use efficiency (19.34 g/l) was recorded for ridgegourd under 40% replenishment of water when grown in association with khejri + aonla. Intercropping of tomato and ridgegourd with khejri + guava was found most remunerative with maximum NPV, BC ratio and net returns after sole cropping.

Key words: Agri-silvi-horti, Drip irrigation, ETc, Irrigation water use efficiency

The Indian arid and semi-arid regions are characterized by immature, structure less, coarse textured soils with low water holding capacity and poor nutrient status. The moisture deficit conditions dominate for a long time through out the year, which acts as the major limiting factor for establishment and growth of woody plant. Most of the cropping systems operating in the limited irrigated area of arid ecosystems have very high water requirement and are highly unsustainable, hence location specific models have to be developed involving fruit crops, multipurpose tree species and arable crops in an agri-silvi-horti production system for increasing irrigation water use efficiency (IWUE), productivity, profitability and sustainability of the system. The prevailing soil and climate conditions of the arid and semi-arid ecosystem are not congenial for the surface irrigation. Drip irrigation not only optimize the water use efficiency but also play a significant role in regulation of the harvest depending upon the time and is more appropriate for tree crops in arid and semi-arid ecosystem. Drip irrigation discharges the water in root zone of the plant and results in efficient utilization of water. The present studies were therefore, conducted to develop a location specific agri-silvi-horti system with drip irrigation.

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MATERIALS AND METHODS

The experiment was conducted at Chaudhary Charan Singh Haryana Agricultural University Regional Research Station, Bawal, located in the low rainfall zone of the southern Haryana (28.1° N, 76.5° E and 266 m above mean sea level). In general, May-June are the hottest (21-46^0 C temp.), while December-January are the coldest (0–15^0 C temp.) months of the year. The site is characterized by inadequate precipitation (350-550 mm) during monsoon (July–September) and is also quite erratic. Between October and March, weather remains almost dry except occasional light showers. Thereafter, it is quite dry till June. High temperature along with peak evapotranspiration rate of 5.3 mm/day is observed from July to October and 2.7 mm/day from November to February. The maximum evapotranspiration rate of 14 mm/day is recorded in the month of June. The soil of the experimental site was sandy loam in texture, low in organic carbon (0.17%), medium in available phosphorus (16.0 kg/ha), high in available potassium (190.0 kg/ha). The pH (1:2) of experimental field was 8.2 and EC (1:2) 0.78 dS/m.

Two years old combinations of fruit and tree species namely shisham (*Dalbergia sissoo* L.) + aonla (*Embilica* *officinalis* Gaertn.), shisham (*D. sissoo*) + guava (*Psidium guajava* L.), khejri (*Prosopis cineraria* (L.) Druce) + aonla (*E. officinalis*) and khejri (*P. cineraria*) + guava (*P. guajava*) planted at a spacing of 6m×6m following cultural practices recommended for the region were used for this study. Grafted saplings were used for fruit trees and seedlings were used for forest trees. Plants were protected against termite by applying chlorpyriphos (2 ml/L) with irrigation water. After establishment of trees the crop sequences, viz. ridgegourd (*Luffa acutangula* Roxb.) - tomato (*Solanum lycopersicum* L.), moongbean (*Vigna radiata* L.) - fallow and cluster bean (*Cyamopsis tetragonoloba* (L.) Taub) - fallow was raised in the interspaces of the trees for four years. The crops were also raised as sole. The data is presented for two years (during 3rd and 4th year), i.e. 2007-08 and 2008-09 in the present paper. Ridgegourd and tomato were raised with drip irrigation, while moongbean and cluster bean were raised as rainfed.

Single lateral drip line was placed on the soil surface in each tree row. Each tree was provided by two drippers (emitters) having discharge rate of 4.01/h. During the first 6 months after planting, all trees were irrigated equally to ensure the uniformity of plant growth. The trees were subjected to three drip irrigation treatments viz. T_1 (100% ETc), T_2 (70% ETc) and T_3 (40% ETc) with three replications. The water applied in T_1 was considered sufficient to fully satisfy the needs of the crop (100% ETc). Irrigation treatments were based on crop evapotranspiration (ETc, mm), considering rainfall and was derived from class A Pan Evaporimeter (Doorenbos and Purit 1977) placed in the proximity of a standard meteorological station adjacent to the experimental field. The total amount of irrigation (liter/plant) applied in T_1 was calculated as:

Water requirement = $K_P \times K_C \times E_{PAN} \times$ canopy area (Dorrenbos and Pruit 1977).

Where K_P is the pan coefficient, K_C the crop coefficient and E_{PAN} is pan evaporation.

Similarly, the water requirement for tomato and ridgegourd was also computed for three treatments, viz. T_1 (100% ETc), T_2 (70% ETc) and T_3 (40% ETc). Single lateral drip line was placed on the soil surface in each crop row of tomato and ridgegourd. Each plant was provided by one emitter having discharge rate of 4.01/h. The spacing for tomato was 1.0×0.50 m and for ridgegourd it was 1.0×1.0 m. The trees and crops were irrigated on every alternate day. The drip irrigation system was operated during evening hours to avoid evaporation losses. Total amount of irrigation applied in different treatments is given in Table 3 and 4. The growth performance was recorded in terms of height and collar diameter. In each treatment of 24×12 m plot size, observations were recorded on nine plants after excluding the border. Biomass of trees was estimated from the formula: Biomass = 0.0026G 2.76, Where, G is girt in cm. The yield of different crops was also recorded. Irrigation Water Use Efficiency (IWUE) was calculated by dividing the biomass increment (fresh weight basis) with the quantity of water applied.

For economic evaluation of the system, the cost items included the cost of plants, labour charges for digging pits, planting and training of trees, charges for ploughing the field, field preparation and for cultivation of crops, material inputs such as seed and fertilizer, labour cost for different field operations, harvesting and threshing charges of crops, interest on working capital and rental value of land was calculated on the basis of prevailing market prices in nearby villages. The life of drip system was considered as 10 years and cost was also divided into ten years. For returns prevailing market rates of fruits, grain and straw were taken

Table 1 Plant height (cm), diameter (cm) and crown spread (cm^2) of different tree species under drip irrigation system after 24 and 48 months of planting

Tree species	Height				Diameter				Crown spread			
	100%	70%	40%	Mean	100%	70%	40%	Mean	100%	70%	40%	Mean
Shisham	430	441	413	428	9.2	9.8	8.8	9.3	200	210	190	200
Aonla	262	260	253	259	4.8	5.1	4.4	4.8	190	180	160	177
Khejri	175	172	189	179	4.2	3.9	3.5	3.9	150	130	110	130
Guava	187	180	164	177	4.4	4.3	3.9	4.2	140	120	100	120
Mean	264	264	255		5.7	5.8	5.2		170	160	140	
48 months												
Shisham	728	803	688	740	15.3	15.4	12.8	14.5	530	550	520	533
Aonla	450	477	298	408	9.8	8.6	7.9	8.8	440	410	390	413
Khejri	381	228	297	302	7.0	6.0	5.2	6.1	420	390	360	390
Guava	284	233	210	242	6.2	5.9	5.0	5.7	403	410	380	398
Mean	461	435	373		9.6	9.0	7.7		448	440	412	

CD=0.05	Height		Diameter		Crown spread	
	24	48	24	48	24	48
Tree	14.3	16.5	0.46	0.44	22	28
Irrigation	NS	10.2	0.35	0.27	NS	89
Interaction	NS	NS	NS	NS	NS	NS

as the sale rates and net returns, NPV, BC ratios at discounted rate (@ 12%) BC was calculated. The data were subjected to ANOVA and statistically analysed using split-plot design with three replications after Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

Growth performance of trees

The growth of fruit and forest tree species increased with increase in time and irrigation levels. *D. sissoo* showed significantly more growth (height and diameter) as compared to other tree species, irrespective of irrigation levels (Table1). Maximum growth was under 100% ETc replenishment by all the tree species except *D. sissoo* in which maximum growth (height and diameter) was recorded under 70% ETc replenishment of water at both stages of observation, i.e. 24 and 48 months of age. Minimum growth was observed in *Psidium guajava* with 40% ETc replenishment of water. In general, the amount of water supplied by different irrigation treatments affected the different vegetative parameters. The irrigation treatments influenced the growth in terms of diameter and crown spread. It may be due to the fact that the moisture is a critical factor responsible for growth of woody plant species. Increase in trunk and crown diameter with the increase in evaporation-replenishment rates have also been observed by Kaya *et al.* (2011) in apricot and Ramniwas *et al.* (2012) in guava. Positive effects of increased water have been reported in one of our earlier studies (Kaushik *et al.* 2011) for diameter. The tree species varied significantly for plant height and diameter at both the stages of observations and *D. sissoo* showed maximum growth followed by *E. officinalis* irrespective of irrigation treatments.

Yield of intercrops

Irrigation treatments influenced the yield of tomato and ridgegourd significantly. Maximum tomato yield (39 350 kg/ha) was obtained from sole cropping of tomato closely followed by (39 323 kg/ha) under khejri + guava when the plants were irrigated on the basis of 100% ETc. Increase in tomato yield with increased quantity of irrigation water has already been reported by Panigrahi *et al.* (2010) and Dunage *et al*. (2009). The yield of moongbean and clusterbean was non-significant under all the irrigation levels (irrigation applied only to trees) as these crops were grown as rainfed. Maximum yield (1 025 kg/ha) was obtained from clusterbean when raised in the interspaces of khejri + guava. Moongbean showed minimum yield (425 kg/ha) under shisham + guava (Table 2).

The yields of different field crops grown in the interspaces of different tree species were at par with their sole cropping, indicating that the silvi-horti system (different tree combinations) of 4-years age did not affect the yield of inter crops. This might be due to less crown area and low interception of light by trees in the initial years. Green matter yield of dhaincha, grain yield of wheat and barley and fodder yield of berseem remained unaffected due to *Melia azedarach* during the first four years of plantation

Table 2 Yield (kg/ha) of intercrops as affected by different trees and irrigation scheduling under drip irrigation system (average of 2 years)

Tree/intercrops	Moong bean			Mean	Cluster bean			Mean	Tomato			Mean	Ridge gourd			Mean
	100%	70%	40%		100%	70%	40%		100%	70%	40%		100%	70%	40%	
Shisham + aonla	810	825	822	819	1005	975	990	990	39100	37020	29001	35040	9700	9480	9150	9443
Shisham + guava	760	785	806	784	975	892	960	942	39200	34150	27880	33743	9650	9000	9000	9217
Khejri + guava	763	780	803	782	1025	875	950	950	39323	35000	27000	33774	9850	9265	8773	9296
Khejri + aonla	814	825.5	808	816	998	990	1000	996	39130	36640	28848	34873	9890	9250	9000	9380
Sole	750	751	748	750	1020	1000	1002	1007	39350	37200	30000	35517	9895	9700	9400	9665
Mean	779	793	797		1005	946	980		39221	36002	28546		9797	9480	9065	

CD =0.05	Moong bean	Cluster bean	Ridge gourd	Tomato
Trees	NS	NS	NS	NS
Irrigation	NS	NS	215	1153
Tree × Irrigation	NS	NS	NS	NS

Table 3 Water applied (l/ha) and irrigation water use efficiency (g/l) of tomato and ridgegourd under different tree species under drip irrigation system

Tree species	Water applied					
	100%		70%		40%	
	Ridge gourd	Tomato	Ridge gourd	Tomato	Ridge gourd	Tomato
Shisham + guava	2621622	18575029	1995789	13002579	1345588	7430029
Shisham + aonla	2665746	18335029	2022472	12834529	1525424	7334029
Khejri + guava	954457.4	7620029	732411.1	5334029	487389	3048029
Khejri + aonla	886995.5	7400029	637931	5180029	465357	2960029
Sole	1011759	9302600	800330	6526316	544928	3750000
	Irrigation water use efficiency (IWUE)					
Shisham + guava	3.70	2.11	4.75	2.82	6.80	3.92
Shisham + aonla	3.62	2.13	4.45	2.66	5.90	3.95
Khejri + guava	10.32	5.16	12.65	6.56	18.00	9.65
Khejri + aonla	11.15	5.28	14.50	7.14	19.34	9.86
Sole	9.78	4.23	12.12	5.70	17.25	8.00

(Nandal and Kumar 2010). The average grain and straw yields of arable crops were more under sole cropping, but were statistically at par to those obtained from interspaces of various silvi-horticultural systems during initial four years of establishment (Kaushik *et al.* 2011).

Irrigation water use efficiency (IWUE)

Maximum irrigation water use efficiency (4.66 g/l) was recorded in shisham under 40% ETc (Table 4). Irrigation water use efficiency ranged from 2.11 to 19.34 g/l. Irrigation water use efficiency increased with decrease in water application in sole well as in agri-silvi-horti systems. This may be due to less water requirement under 70 and 40% irrigation levels and comparatively less reduction in yield under these levels of irrigation as compared to 100% irrigation level. Increased WUE with decreased application of water in tomato has also been reported by Dunage *et al.* (2009). In general, ridgegourd showed more IWUE than tomato irrespective of irrigation treatments (Table 3).This might be due to rains during *kharif* season (rainy season) and less water application to ridgegourd. Maximum IWUE was recorded under 40% ETc for both the crops, i.e. tomato and ridgegourd. These results are in agreement with our earlier findings (Kaushik *et al*. 2011).

Yield of fruit crops

The fruit yield of aonla and guava was recorded during the 4th year. The fruit yield was not affected by different crops; therefore, average yield is given. Maximum fruit yield (1010 kg/ha) was recorded in aonla under100% replenishment of water in association with Khejri (Table 5). Increase in fruit yield and quality with the increase in evaporation-replenishment rates have also been observed by Verma *et al.* (2007) in peach. Minimum yield was observed in guava when irrigation was applied on 40% replenishment of water in association with *Dalbergia sissoo*. In general the yield of aonla was higher than guava irrespective of irrigation treatments.

Table 4 Water applied (l/ha) and irrigation water use efficiency (g/l) of different tree species under drip irrigation system

Tree species	100%		70%		40%	
	Water applied	IWUE	Water applied	IWUE	Water applied	IWUE
Shisham	5585	2.38	3793	2.98	2130	4.66
Aonla	3332	1.58	2193	1.82	1248	2.15
Khejri	2300	1.30	1574	1.36	907	1.59
Guava	3000	1.31	2052	1.48	1170	1.53

Economics

Two years mean data revealed that agri-silvi-horti (ridgegourd – tomato + khejri + guava) system gave higher net return (₹ 70 334) and NPV (₹ 100 869) under 100% replenishment of water, which was slightly less from sole cropping of tomato may be due to no expenditure on tree

Table 5 Yield of aonla and guava (kg/ha) at different irrigation levels during 4th year

Treatment	Irrigation levels (ETc)							
	Aonla				Guava			
	100%	70%	40%	Mean	100%	70%	40%	Mean
Shisham + aonla	1000.0	887.0	709.0	865				
Khejri + aonla	1010.0	900.0	722.0	877.0				
Shisham + guava					900.0	778.0	600.0	759.0
Khejri + guava					930.0	812.0	605.0	782.0
Mean	1005.0	894.0	716.0		915.0	795.0	603.0	

Table 6 Economic analysis of the agri-sivli-horti system developed under drip irrigation

	100% ETc					70% ETc					40% ETc				
	S+A	S+G	K+G	K+A	Sole	S+A	S+G	K+G	K+A	Sole	S+A	S+G	K+G	K+A	Sole
Ridgegourd - Tomato															
Cost of cultivation	58920	58920	58920	58920	49900	50097	50097	50097	50097	45175	45581	45581	45581	45581	39600
Gross returns	127000	128425	129254	127600	123112	120685	113321	116347	119225	117250	98923	96400	93668	98230	98500
Net returns	68080	69505	70334	68680	73212	70588	63224	66250	69128	72075	53342	50819	48086	52649	58900
NPV (12%)	97053	99465	100869	98069	119945	100108	91642	96765	101637	108138	76301	72029	67405	75127	87546
B:C	2.15	2.27	2.19	2.17	2.46	2.4	2.26	2.32	2.37	2.59	2.17	2.11	2.05	2.15	2.48
B:C (Discounted @12%)	2.62	2.58	2.63	2.60	2.05	2.41	2.47	2.48	2.35	2.17	2.59	2.68	2.78	2.62	2.25
Clusterbean - Fallow															
Cost of cultivation	24690	24690	24690	24690	15620	24617	24617	24617	24617	15620	24617	24617	24617	24617	15620
Gross returns	36150	36525	36320	35988	31620	34660	33966	33635	35190	30620	35467	33906	34960	34944	30620
Net returns	11460	11835	11630	11298	16000	10043	9349	9018	10573	15000	10850	9289	10343	10327	15000
NPV (12%)	41727	41727	41725	41720	26398	41603	41603	41600	41601	26398	41603	41599	41600	41603	26398
B:C	1.46	1.47	1.46	1.47	2.08	1.41	1.38	1.36	1.43	1.96	1.44	1.38	1.42	1.41	1.97
B:C (Discounted @12%)	1.73	1.75	1.74	1.72	2.4	1.67	1.63	1.62	1.69	2.32	1.7	1.63	1.68	1.67	2.32
Moongbean - Fallow															
Cost of cultivation	23940	23940	23940	23940	15000	23762	23762	23762	23762	15000	23000	23000	23000	23000	15000
Gross returns	29300	29100	29400	29470	22500	29185	28996	29084	29265	22600	28205	28380	28325	27850	22550
Net returns	5360	5160	5460	5530	7500	5423	5234	5322	5503	7600	5205	5380	5325	4850	7550
NPV (12%)	40459	40459	40459	40459	25350	40158	40158	40158	40158	25350	38871	38871	38871	38871	25350
B:C	1.22	1.21	1.23	1.23	1.5	1.22	1.22	1.23	1.23	1.5	1.22	1.23	1.23	1.21	1.5
B:C (Discounted @12%)	1.45	1.44	1.45	1.45	1.78	1.45	1.44	1.45	1.46	1.78	1.45	1.46	1.46	1.43	1.78

plantation in sole cropping (Table 6). Whereas, maximum discounted BC ratio (2.78) was recorded with the same rotation under 40% replenishment of water. Less return from moongbean - fallow rotation may be due single cropping under rainfed conditions (Table 5). The economic viability of a system is the most important consideration for adoption of any technology at the farmer's field. Among various crops ridgegourd-tomato rotation under all the tree species gave maximum NPV, BC and discounted BC ratio followed by cluster bean-fallow rotation. This might be due to higher yield of these crops. Economic evaluation of different agri-silvi-horti system during the course of investigation showed that the ridge gourd - tomato associated with all the tree species fetched highest returns. These results are in agreement with the findings of Kaushik *et al*. (2006 and 2011)

CONCLUSION

It is concluded that different silvi-horti systems did not affected the yield of arable and vegetable crops up to four years. Seventy percent replenishment of water (70%ETc) was found optimum for shisham. Intercropping of tomato and ridgegourd with khejri +guava was found most remunerative as maximum net returns, NPV and BC ratios were observed with this rotation fuel wood, timber, fodder from silvicultural species and fruit from horticultural species will compensate the reduction of crop yield in subsequent years and will result in higher returns in association with arable crops.

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