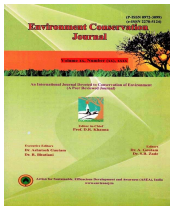
Environment Conservation Journal 23 (3):439-449, 2022

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Growth, yield and economics of amla (*Emblica officinalis* L.) based agri-horticultural system in Alfisols of semi-arid tropic

M. N. Thimmegowda ✉
AICRP on Agrometeorology, University of Agricultural Sciences, GKVK, Bengalur.
Mudalagiriyappa
AICRP for Dry land Agriculture, University of Agricultural Sciences, GKVK, Bengaluru.
B.K. Ramachandrappa
University of Agricultural Sciences, GKVK, Bengaluru- 560 065.
B. G. Vasanti
AICRP for Dry land Agriculture, University of Agricultural Sciences, GKVK, Bengaluru.
M. S. Savitha
AICRP for Dry land Agriculture, University of Agricultural Sciences, GKVK, Bengaluru.
Santosh Nagappa Ningoji
AICRP for Dry land Agriculture, University of Agricultural Sciences, GKVK, Bengaluru.
M. Madan Kumar
AICRP for Dry land Agriculture, University of Agricultural Sciences, GKVK, Bengaluru.
K.M. Puneetha
AICRP for Dry land Agriculture, University of Agricultural Sciences, GKVK, Bengaluru.

ARTICLE INFO

Received : 01 December 2021
Revised : 21 April 2022
Accepted : 29 May 2022

Available online: 18 September 2022

Key Words:
Amla
Crop equivalent yield
Collar diameter
Canopy spread
Profitability

ABSTRACT

An intercropping trial conducted during 2011 to 2017 using five year old amla (*Emblica officinalis* L.) orchard planted at 4 X 4 m spacing and grown under rainfed condition to identify the suitable and profitable intercrops. The intercrops *viz,* finger millet, fodder maize, field bean, grain amaranth, cowpea, horsegram were considered in the study besides their pure stand. Growth parameter of amla such as plant height (369 cm), number of branches/tree (2.73), stem diameter (35.31 cm), canopy spread (279 cm) and biomass yield (296 kg/ha) was found to be statistically significant with Amla intercropped with field bean compared with sole amla. The higher amla equivalent yield was recorded in intercropping with finger millet (1517 kg/ha) and was at par with cowpea (1298 kg/ha). Finger millet proved to be better intercrop in amla and registered 57.11 per cent higher net returns and Benefit cost ratio than sole amla. Overall, Amla + finger millet cropping system was found to be more sustainable both interms of benefit cost ratio (2.43) and improving system productivity (104.44 %) followed by pulse crop such as cowpea and field bean. The higher sustainable yield index (0.83) was with amla + finger millet intercropping system while Land Equivalent Ratio and Area Time Equivalent Ratio were higher with amla + field bean intercropping system.

Introduction

Climate change induced an unsustainable production system under rainfed situation, demands climate smart crops (Ramachandrappa *et al*., 2016a; Bhutiani and Ahamad, 2018) combating climate change demands enhancing forest ecosystem, which is difficult to increase under populated India. Alternate land use involving Agri- horti systems seems to the long term operation for sustainability. Amla or Indian goose berry (*Emblica officinalis* L.) based agri-horticultural system has enormous potential to use and conserve rainfall particularly under dryland condition for betterment of poor farmers (Thimmegowda *el al.,* 2019). Amla is an

Corresponding author E-mail: mnthimmegowda@gmail.com
Doi: https://doi.org/10.36953/ECJ.9962236

deep rooted deciduous tree species, which has a wide adaptability in wider range of soil. It is potential fruit species suitable for growing under dryland condition. Sole amla orchards provides gives higher gross returns with lesser investments for planting and its management, but taking agricultural crops as intercrops along with amla provides an opportunity for better land utilization also reduction in the risk due to aberrant climate condition.

Agri horticulture systems in rainfed conditions are the ideal systems for controlling runoff, soil erosion and land degration. The major problem in rainfed area is increased competition between trees and crops for water. But the varied nature of crops in agri-horti system, utilize the water as well as other resource efficiently with added seasonal revenue. Intercropping has been proved as potential crop production systems and it will provide substantial yield advantage over sole cropping system (Willey, 1979).

Intercropping systems have ability to cover land surface very efficiently, which check soil erosion and helps to check soil erosion through sufficient ground coverage and also improve the soil physico-chemical condition. Traditionally, intercropping in the interspaces of fruit orchards is practiced (Adiveppa Mallappa Asangi *et al*, 2019), but only a few results are available for amla based horticultural system. Hence, the present study was undertaken to know the suitability and profitability aspects of different intercrops under *rain-fed* conditions in *Alfisols* of semiarid tropic.

Material and Methods

Study area: The field study was carried out at the AICRP for Dryland Agriculture, University of Agricultural Sciences, Bengaluru. The centre is situated in Eastern Dry Zone of Karnataka at 12^0 58' North latitude and 77^0 35' East longitude with altitude of 930 m above mean sea level. The site experiences climate with bimodal distribution of rainfall *i.e.* the rainfall during 2014 and 2015 was positive normal with 8.6 and 15.9 per cent excess higher values. The deviation during *kharif* 2013 and 2016 was -7.4 and -24.5 %, respectively compared to normal and the impact on crop production activities under conventional farming practices was more pronounced during 2016 (Table 1).

Plate1: Geotagged image of experimental site

The intercropping trial was carried out in well-established five year old amla orchards for seven years from 2011-12 to 2017-18.

Treatment details: The intercrops considered in the study are finger millet, cowpea, horsegram, field bean, fodder maize and grain amaranth besides their sole crop and compared with amla. The intercrops were sown one meter away from the trunk. The experiment was laid out in a Randomized Block design with three replications. Well decomposed compost 15 t ha^{-1} was applied well before 15 days prior to sowing of the intercrops. Nitrogen, phosphorus and potassium were applied as basal doses @ 50:40:25 kg ha^{-1} for finger millet, 25:50:25 kg ha^{-1} for cowpea and field bean, 25:38:25 kg ha^{-1} for horsegram, 100:50:25 kg ha^{-1} for fodder maize and 40:20:20 kg ha^{-1} for grain amaranth. In case of finger millet, fodder maize and grain amaranth. Nitrogen was applied in two equal splits one as basal dose and at 30 DAS. The soil of the experimental site was acidic in reaction [pH(1:2.50): 5.4], deficient in organic carbon (0.32 %), medium in available N (372.8 kg ha^{-1}), P_2O_5 (49 kg ha^{-1}) and K_2O (169.9 kg ha^{-1}).Observations on growth parameters of amla in terms of plant

height, number of branches per plant and crown diameter were recorded. The data on fruit yield per plant were recorded at harvest during all four years and were statistically analyzed, similarly the intercrops yield was also recorded. The yield of intercrop was converted into amla equivalent yield considering the yield and prevailing price of the produce (Thimmegowda *et al.,* 2016).

$$\text{Crop equivalent yield (kg/h)} = \text{Yield of main crop (kg/ha)} + \left\{ \frac{\text{Yield of inter crop (kg/ha)} \times \text{Price of inter crop (Rs./kg)}}{\text{Price of main crop (Rs/kg)}} \right\}$$

Land Equivalent Ratio (LER) along with Area Time Equivalent Ratio (ATER) were calculated as intercropping efficiency with below given formula (Willey, 1979):

$$\text{Land equivalent ratio} = \frac{(Y_{ab})}{Y_{aa}} + \frac{(Y_{ba})}{Y_{bb}}$$

Where,
Y_{aa}: Sole yield of crop a
Y_{bb}: Sole yield of crop b
Y_{ab}: Intercropping yield of crop a
Y_{ba}: Intercropping yield of crop b

Area Time Equivalent Ratio of different cropping systems are calculated by formula given by Hiebsch and Mc Collum (1987).

$$\text{Area time equivalent ratio} = \frac{(R_{ya} X_{ta}) + (R_{yb} X_{tb})}{T}$$

Where,
Rya: Relative yield of the crop 'a'
Ryb: Relative yield of the crop 'b'
ta: Duration (days) for crop 'a'
tb: Duration (days) for crop 'b'
T: is the total duration (days) of the intercropping system.

The Sustainable yield index of amla based intercropping systems was calculated with the formula given by Ramachandrappa *et al.* (2016b).

$$\text{Sustainability yield index (SYI)} = \frac{A - SD}{Y_{max}}$$

Where,
A = Average yield over the years for a particular treatment;
SD = Standard deviation for the treatment;
Y_{max} = Maximum yield obtained in any of the treatments over the years.

The economics was calculated for individual treatments for all the years by respective price of inputs and produce. The net return received during study was worked out by subtracting cost of cultivation (Rs/ha) from the gross return (Rs/ha) of respective years.

Statistical analysis: The data from 7 years were analyzed to check the significant difference between the treatments and to draw valid conclusions with Analysis of Variance technique (Gomez and Gomez, 1984. The level of significance used in 'F' and 't' test was p=0.05. Critical difference (CD) values were calculated, wherever 'F' test was found significant.

Results and Discussion

Growth Parameters of amla

Plant height, Number of branches and Collar diameter: Inter crops grown in association with amla varied significantly for different parameters. The plant height, branches and collar growth are the important attributes, which greatly influenced by supply of water and nutrient. The increased plant population per unit area due to addition of intercrops resulted in higher competition for soil moisture, nutrients and light, which influenced the vertical/ horizontal growth and intern growth parameters. Amla + field bean recorded significantly higher plant height (369 cm), number of branches (2.66) and collar diameter (35.31 cm) followed by amla + cowpea, amla+ horsegram compared to amla sole (309, 2.26, 31.03 cm, respectively) (Table 2). The higher growth parameters are mainly attributed due to enhanced availability of nitrogen through symbiotic nitrogen fixation and increased organic matter addition in the form of leaf litter by the legume crops. Due to higher biomass production, incorporation and further decomposition has led to higher availability of nutrients for uptake (Adiveppa Mallappa Asangi *et al.,* 2019). The increase in stem collar diameter could also be due to increase in leaf canopy spread, number of leaves and number of branches. These results are in conformity with the findings of Chauhan *et al.* (2013), Ramulu *et al.* (2015) and Swain *et al.* (2014).

Table 1: Meteorological data of the experimental area during 2011-2017 at UAS, GKVK, Bengaluru

	2011	2012	2013	2014	2015	2016	2017
Normal rainfall (mm)	923.1	925.2	915.4	913.8	917.2	920.4	915.7
Actual rainfall (mm)	804.5	571.9	847.5	992.3	1061.2	694.9	1115.8
Number of rainy days	61	34	58	54	71	43	64
Number of dry spells	3	6	6	3	2	4	2
Excess / deficit rainfall (%)	-12.8	-38.2	-7.4	8.6	15.9	-24.5	17.93

*** Normal rainfall was calculated taking average annual rainfall from 1978 to previous year**

Canopy spread/plant and biomass (kg/tree): At harvest, the canopy spread of amla differed significantly due to intercropping. Amla + field bean recorded higher canopy spread/plant (279 cm) followed by amla + cowpea (250 cm). Significantly lower canopy was recorded by amla +fodder maize (197.2cm) (Table 3). Higher biomass (kg/tree) was noticed in amla + field bean (296 kg/tree) followed by amla +horse gram (286 kg/tree) as compared to other intercrops (Table 3). Enhanced growth of amla plants in with intercrops might have attributed to the improved soil porosity and aeration from frequent soil management practices and also due to the better response for applied inputs by intercrops than in sole plantation. Interspaces of sole crops were left uncultivated and not received additional inputs like manure, fertilizer *etc.,* Awasthi and Saroj (2004) reported positive effect of intercrops on growth and vigour of amla and mango. The finding also supports the views of Saroj *et al.* (2003) in ber.

Yield of Amla as influenced by intercrops

Amla yield: Among the different intercrops, higher amla fruit yield (749 kg/ha) was recorded from the amla trees inter cropped with field bean, while it was minimum in fodder yield (535 kg/ha) followed by 721 kg/ha in amla + cowpea, 655 kg/ha in Amla + horse gram and 604 kg/ha in amla + finger millet than amla + fodder maize (535 kg/ha) and sole amla (655 kg/ha) (Table 5). Growing of pulse crop helped in building up of soil fertility and better utilization of applied nutrients which resulted in improved growth and yield of main crop (Meena *et al.,* 2011). Maize being an exhaustive crop removed much nutrients for its growth and yield and there by resulted in reduced yield of amla (Chaturvedi and Jha, 1998). The other reason for increase in fruit production under agri-horticultural system may be also due to application of fertilizers and manure to intercrops and its utilization by amla trees as there was no physical barrier between root systems of intercrops and trees (Korwar *et al.,* 2006).

Amla equivalent yield: Significantly higher amla equivalent yield was observed in intercropping with finger millet (1517 kg/ha) followed by cowpea (1298 kg/ha) and field bean (1235 kg/ha) compared to other intercrops in amla based agri-horti system (Table 6). Better performance of small millet even under drought and erratic rainfall both as sole and intercrop during the different growing period over the years was due to their drought tolerance (Shashidhar *et al.,* 2000). With respect to legume as intercrops which act as good cover crop and helps in better moisture conservation helped in yield enhancement

Intercropping efficiency

On the basis of mean data among different intercrops, maximum land equivalent ratio was recorded with amla+ field bean (1.69) followed by amla + finger millet (1.61) intercropping system, indicating more efficient use of land than sole amla and among the intercrop less land equivalent ratio was recorded in amla + fodder maize (1.46) (Figure 1). Intercropping efficiency analysis using the ATER approach has also shown differences among different associations (Figure 1). The higher mean values of ATER were recorded by the Amla + field bean (1.67) intercropping system. While, the lowest ATER value was recorded by the alma + finger millet (1.06). The higher yield were recorded in intercrops was mainly due to complementary effects among component crops and also due to efficient use of resources when compared to sole cropping systems (Mudalagiriyappa *et al.*, 2011). The inherent capacity of crops will efficiently utilize natural resources and complementary interaction plays vital role in resource utilization (Maitra *et al*., 2019). Further, higher yield of both the crops in maize-cowpea intercroppingombination was noted than pure stands (Kimou *et al*., 2017).

Table 2: Plant height (cm), No of branches and stem diameter (cm) of amla as influenced by amla based Agri-horti system

Treatment	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	Pooled
Plant height (cm)								
Amla+ Finger millet	163	236	240	304	357	350	345	285
Amla+Fodder maize	174	254	248	334	355	365	359	299
Amla+Field bean	204	289	341	357	388	506	500	369
Amla+Grain amaranth	188	255	239	301	320	328	329	280
Amla+Cowpea	164	253	313	342	381	444	439	334
Amla+Horsegram	190	263	341	349	376	482	476	354
Amla sole	151	172	207	342	380	457	452	309
S. Em. ±	5.89	15.76	15.14	20.24	22.60	34.47	34.07	29.59
C. D. (p=0.05)	18.14	48.56	46.64	NS	NS	106.23	104.99	83.07
No. branches								
Amla+Finger millet	1.77	2.20	2.11	2.83	2.83	2.33	2.67	2.39
Amla+Fodder maize	2.10	2.30	2.58	3.00	3.00	3.00	2.67	2.66
Amla+Field bean	3.30	2.77	2.83	3.10	3.10	2.00	2.00	2.73
Amla+Grain amaranth	2.80	2.90	2.33	3.00	3.00	2.33	2.33	2.67
Amla+Cowpea	1.90	2.20	2.57	3.07	3.07	2.67	3.33	2.69
Amla+Horsegram	2.40	2.77	2.58	3.00	3.00	1.67	2.33	2.54
Amla sole	1.60	1.43	1.98	3.07	3.07	2.33	2.33	2.26
S. Em. ±	0.12	0.17	0.13	0.08	0.08	0.56	0.36	0.28
C. D. (p=0.05)	0.37	0.52	0.41	NS	NS	NS	NS	0.77
Stem diameter (cm)								
Amla + Finger millet	12.6	21.0	21.8	31.5	32.3	43.8	44.7	29.66
Amla + Fodder maize	12.8	24.2	25.9	37.8	38.2	43.7	42.7	32.19
Amla +Field bean	15.2	26.9	32.3	38.5	42.1	45.5	46.7	35.31
Amla + Grain amaranth	15.0	25.4	22.6	32.0	35.1	43.3	42.0	30.79
Amla + Cowpea	12.8	24.2	28.9	38.3	42.0	41.8	43.0	33.02
Amla + Horsegram	14.8	24.4	28.2	38.2	40.2	46.3	47.3	34.22
Amla sole	10.7	19.5	20.9	38.8	40.8	43.7	43.0	31.03
S. Em. ±	0.62	1.18	1.26	2.09	4.08	2.73	2.67	2.34
C. D. (p=0.05)	1.92	3.64	3.87	NS	NS	NS	NS	6.58

***NS: Non-significant at p=0.05**

Table 3: Canopy spread and biomass of amla as influenced by amla based Agri-horti system

Treatment	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	Pooled
Canopy spread (cm)								
Amla + Finger millet	90	153	146	179	302	346	349	223
Amla + Fodder maize	106	152	156	207	282	307	307	217
Amla + Field bean	118	192	199	302	338	402	404	279
Amla + Grain amaranth	109	189	152	185	290	318	318	223
Amla + Cowpea	101	153	190	265	313	365	362	250
Amla + Horsegram	108	155	182	243	306	343	346	240
Amla sole	78	131	106	304	308	404	396	247
SEm±	3.50	15.86	6.62	9.57	22.20	14.98	12.56	13.43
CD (0.05)	10.79	NS	20.40	29.50	NS	46.15	38.69	37.70
Amla biomass (kg/ha)								
Amla+Finger millet	78	150	158	386	264	386	395	259
Amla+Fodder maize	80	180	197	384	323	384	367	273
Amla+Field bean	99	206	261	326	366	405	409	296
Amla+Grain amaranth	97	192	165	258	291	380	362	249
Amla+Cowpea	80	180	226	325	365	363	373	273
Amla+Horsegram	96	182	219	323	348	415	419	286
Amla sole	63	136	149	329	353	385	380	256
S. Em. ±	5.1	11.1	12.4	22.0	43.5	30.8	29.8	25.2
C. D. (p=0.05)	15.6	34.3	38.1	67.7	NS	NS	NS	70.8

***NS: Non-significant at p=0.05**

Table 4: Intercrop yield as influenced by amla based Agri-horti system

Treatment	Intercrop yield (kg/ha)						
	2011	2012	2013	2014	2015	2017	Mean
Amla + Finger millet	2610	1843	2187	2296	1746	1324	1620
Amla+Fodder maize	17989	12332	9840	7691	18057	13902	7825
Amla + Field bean	887	725	953	595	334	308	490
Amla + Grain amaranth	1287	1106	948	783	267	261	555
Amla+Cowpea	810	737	856	498	473	398	450
Amla + Horsegram	653	587	831	526	247	221	421
Finger millet	2576	1872	2424	2679	2167	2033	2292
Fodder maize	27683	13846	10758	17727	23070	18974	18676
Field bean	947	769	970	776	587	557	768
Grain amaranthus	1413	1295	1152	958	412	349	930
Cowpea	877	795	924	727	935	808	844
Horsegram	703	615	1030	697	424	405	646

***In 2016 due to scanty rainfall intercrop was not recorded.**

Table 5: Amla yield as influenced by amla based Agri-horti system

Treatment	Amla yield (kg/ha)					
	2013	2014	2015	2016	2017	Pooled
Amla+Finger millet	407	411	776	728	699	604
Amla+Fodder maize	379	399	577	591	730	535
Amla+Field bean	449	470	1045	914	867	749
Amla+Grain amaranth	338	386	711	699	716	570
Amla+Cowpea	422	453	1012	861	858	721
Amla+Horsegram	458	425	816	838	739	655
Amla sole	476	509	999	846	879	742
S. Em. ±	16.90	25.39	60.22	78.92	51.49	49.16
C. D. (p=0.05)	52.07	NS	185.55	NS	NS	138.72

***NS: Non-significant at p=0.05**

Table 6: Amla equivalent yield as influenced by amla based Agri-horti system

Treatment	Amla Equivalent yield (kg/ha)						SYI
	2013	2014	2015	2016	2017	Pooled	
Amla+Finger millet	1849	1845	1736	728	1427	1517	0.83
Amla+Fodder maize	858	591	1254	591	1251	912	0.43
Amla+Field bean	1255	1214	1504	914	1290	1235	0.64
Amla+Grain amaranth	825	1561	1112	699	1108	1061	0.53
Amla+Cowpea	1903	1076	1604	861	1355	1298	0.68
Amla+Horsegram	1264	846	1032	838	932	982	0.48
Amla sole	476	509	999	846	879	742	0.32
S. Em. ±	51.88	97.68	57.81	56.34	60.35	67.22	
C. D. (p=0.05)	151.42	285.10	168.73	164.43	176.16	188.00	

***NS: Non-significant at p=0.05**

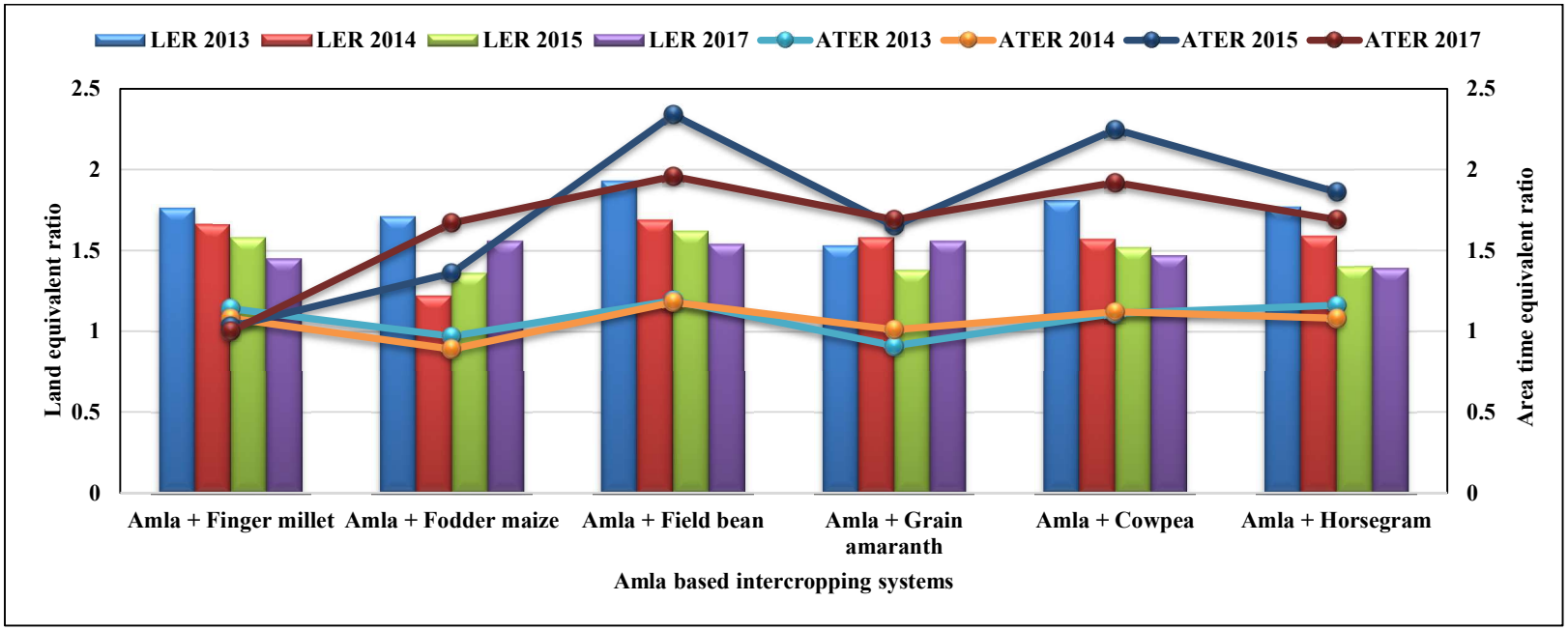


Figure 1. Land equivalent ratio and Area time equivalent ratio of amla as influenced by amla based Agri-horti system.

Table 7: Net returns and B: C ratio of amla as influenced by amla based Agri-horti system

Treatment	Net returns (Rs./ha)								B:C ratio							
	2011	2012	2013	2014	2015	2016	2017	Mean	2011	2012	2013	2014	2015	2016	2017	Mean
Amla + Finger millet	18400	20618	29831	51632	43110	10824	29446	29123	2.38	2.27	2.74	3.33	2.64	1.59	2.07	2.43
Amla + Fodder maize	13300	9321	-2726	2573	28499	5591	28737	12185	2.21	1.73	0.90	1.12	2.31	1.31	2.13	1.67
Amla + Field bean	3300	1310	9210	23570	34548	19037	24332	16472	1.51	1.17	1.32	1.94	2.35	2.09	2.88	1.89
Amla + Grain amaranth	14300	8939	-2687	38665	18736	13635	25212	16686	2.16	1.70	0.90	2.63	1.73	1.95	1.96	1.86
Amla + Cowpea	1628	1197	29548	18867	39917	16794	27824	19396	1.10	1.07	2.07	1.78	2.65	1.95	2.25	1.84
Amla + Horsegram	5650	2590	11994	11513	28876	17914	18501	13863	1.41	1.19	1.46	1.52	3.33	2.15	1.72	1.83
Amla sole	-	-	6537	9958	29094	23039	24053	18536	-	-	1.79	3.68	2.82	3.14	3.16	2.91

Sustainable yield index (SYI)

The data given in Table 6 revealed that amla + finger millet intercropping system recorded the higher sustainable yield index (0.83) followed by amla + cowpea (0.68) and amla + amla + field bean (0.64) as compared to sole amla (0.32) which indicated that at least 159 per cent of the maximum observed yield over years is assured with high probability in intercropping system as against 159 per cent in sole cropping system. Hence, higher sustainable yield index shows that the intercropping helps in providing yield stability (Henry and Kumar, 2005). Similar findings were reported by Koli *et al*. (2004). Finger millet was found to be a compatible intercrop with amla for efficient use of resources and sustainability under dryland situations.

Economics

Economic analysis of different inter cropping system showed that higher returns were obtained when the intercrops were grown in association with amla compared to sole cropping. Finger millet intercropping in amla earned maximum net returns (Rs. 29,123/ha) followed by amla + cowpea (Rs. 19,396/ha). These two intercrops estimated an additional income of Rs. 10,587/ha and 860/ha, respectively over sole amla. Lower returns obtained from other intercropping system was due to lower prevailing market price and increased cost on amla in all other treatments. Similar was the trend in B:C ratio with 2.13 in amla + finger millet with 104.44 % improvement in system productivity compared to other inter crops (Table 7). The increased returns from tree- crop combination have been reported by Nath *et al*. (2007) in perennial fruit based multi storied production system

Conclusion

Agri-horticulture system is an essential approach to have higher farm income and for maintaining better soil fertility. Even though the yield of individual crops including amla was higher under sole crops but the additional yield from component crops is an added advantage under intercropping system. Amla trees inter cropped with finger millet was better cropping system, since it has recorded 104.47 per cent higher finger equivalent yield, higher net returns, inter cropping efficiency and sustainable yield index when compared to sole amla. Besides finger millet, pulses like cowpea and field bean are also best intercrops in amla to get higher yield, profit and sustainability.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Adiveppa Mallappa Asangi, Krishna Murthy., R.., Chamegowda,, T. C., Sathish., A.,. Thimmegowda, M. N., & Devakumar. A. S. (2019). Influence of custard apple (*Annonasquamosa* L.) based agri-horticulture system on intercrop yield and soil properties. *Int. J. Pure App. Bio. Sci, 7*(2), 79-85.

Awasthi, O. P., & Saroj. P. L. (2004). Economic analysis of mango multistrate intercropping. *Tropical Sci, 44*(1), 43-47.

Bhutiani, R., & Ahamad, F. (2019). A case study on changing pattern of agriculture and related factors at Najibabad region of Bijnor, India. *Contaminants in Agriculture and Environment: Health Risks and Remediation*, *1*, 236.

Chaturvedi, O. P., & Jha. M. K. (1998). Crop production and economics under *Litchi chinensis*Sonn. Plantation across 1 to 9 year age series in north Bihar, India. *Int. Tree Crop J, 9*, 159-168.

Chauhan, S. K, W. S., Dhillon., N., Singhand, R., & Sharma. (2013). Physiological ehaviour and yield evaluation of agronomic crops under agri -horti-silviculture system. *Int. J. Plantation Res, 3*, 1-8.

Gomez, K. A., & Gomez. A. A. (1984). Statistical Procedures for Agricultural Research, 2nd Edition, A Wiley Inter Science Publication, New York.

Henry, A., & Kumar. D. (2005). Arid legumes for sustainable agriculture and trade, *Scientific publishers*,1-199.

Hiebsch, C. K., & Mc Collum. R. I. (1987). Area-x-time equivalency ratio: a method for evaluating the productivity of intercrops. *Agron. J, 79*: 15-22.

Kimou, S. H., Coulibaly., L. F., Koffi., B. Y., Toure., Y., Dede K. J., & Kone. M. (2017). Effect of row spatial arrangements on agromorphological responses of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.). *African J. Agric. Res. 12*(34), 2633-2641.

Koli, B. D., Deshpande., A. N., Kate, R. N., & Banga., A. R. (2004). Inter and Intra cropping of vegetables in castor on inceptisols of dryland conditions. *Indian J. Agron, 49*(3), 154-156.

Korwar, G. R., Pratibha., G., Ravi, V., & Palanikumar. D. (2006). Influence of organics and inorganics on growth, yield of anola (*Emblica officinalis*) and soil quality in semi arid tropics. *Indian J. Agric. Sci, 76*, 457-461.

Maitra, S., Palai., J. B., Manasa P., & Kumar. D. P. (2019). Potential of intercropping system in sustaining crop productivity. International Journal of Agriculture. *Environ. Biotechno, 12*(1), 39-45.

Meena L. R., Mann J. S., & Meena Ram Kesh. (2011). Performance evaluation of cowpea and Cenchrus setigerus intercropping and nitrogen supplementation through organic and inorganic sources in Aonla (*Emblica officinalis* Gaertn) based horti- pasture system. *Range Manage. Agrofor, 32*(1), 33-39.

Mudalagiriyappa, Nanjappa., H. V., Ramachandrappa B. K., & Sharath Kumar. H. C. (2011). Productivity and Economics of Castor (*Ricinus communis* L.) based Intercropping Systems in Vertisols under Rainfed Conditions. *Indian J. Dryland Agric. Res. Dev*, *26*(2), 77-81.

Nath, V., Das., B., Yadav., M. S., Kumar., S., & Sikka., A. K. (2007). Guava suitable crop for second floor in multi-storied cropping system in upland plateau of eastern India. *Acta Horti. 735*: 277–295.

Ramachandrappa, B. K., Thimmegowda., M. N., Sathish., A., Dhanapal G. N., & Ravi Kumar. H. S. (2016a). Effect of intercropping in nipped castor (*Ricinus communis* L.) under rainfed conditions. *Indian J. Dryland Agric. Res. Dev*, *31*(1): 30-36.

Ramachandrappa, B. K., Thimmegowda., M. N., Sathish., A., Jagadeesh., B. N., Devaraja., K., Srikanth Babu., P. N., and Savitha. M. S. (2016b). Real time contingency measures to cope with rainfall variability in southern Karnataka. *Indian J. Dryland Agric. Res. Dev, 31*(1), 37-43.

Ramulu, Ramachandrappa., B. K., Sathish., A., Mudalagiriyappa & Nanjappa. H. V. (2015). Growth and yield of custard apple (*Annona squamosa* L.) in agri-horti system. *Res. Crops.,* **16**(3): 531-536.

Saroj, P. L., Dhandar., D. G., Sharma., B. D., Bhargava, R., & Purohit. C. K. (2003). Ber (*Zizfphus mauritiana* Lamk.) based agri-horti system: A sustainable land use for arid ecosystem. *Indian J. Agroforestry, 5*: 30–50.

Shashidhar, G. B., Basavaraja, R., & Nadagouda, B. (2000). Studies on pigeonpea intercropping systems in small millets under shallow red soils. *Karnataka J. Agric. Sci, 13* (1): 7-10

Swain, S. C., Sahooand, S. C., & Mishra. P. J. (2014). Effect of intercropping systems on growth, yield, fruit quality and leaf nutrient status of mango under rainfed situation. *Int. J. Agric. Sci, 8*: 174-78.

Thimmegowda, M. N., Devaraja, K., Savitha, M. S., & Puneetha. K. M. (2019). Studies on different intercrops in amla based Agri-Horti system. National conference on Arid Fruits: Away forward for Sustainable production and nutritional security, Souvenir cum abstract compendium, Pp: 169. 28th to 30th November-2019. UAS, Raichur.

Thimmegowda, M. N., Ramachandrappa, B. K., Devaraja, K., Savitha, M. S., Srikanth Babu, P. N., Gopinath., K. A., Ravindra Chary, G., & Ch. Srinivasa Rao. (2016). Climate resilient intercropping systems for rainfed red soils of Karnataka. *Indian J. Dryland Agric. Res. Dev*, 31 (2): 39-44.

Willey, R. W. (1979). Intercropping- Its importance and research needs. *Field Crop Abstract, 32*(2):73-85.