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Efficient utilization of interspaces of aonla (*Emblica officinalis* G.) orchard through intercropping under rainfed condition

Sunil Kumar*, A. K. Shukla and H. V. Singh
ICAR-Indian Grassland and Fodder Research Institute, Jhansi-284 003, India
*Corresponding author e-mail: sunilhort66@yahoo.co.in
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Abstract

An experiment was conducted to utilize interspaces of 13 years old established aonla plantation with pearl millet + cowpea combinations to optimize forage and fruit production. The aonla growth and fruit production was not influenced with intercropping of pearl millet + cowpea (2:2 ratios) under rainfed condition and produced fruit yield of 13.65 t/ha in the month of December. Pearl millet (multicut) + cowpea in association with tree produced 14.4 and 30.4 t green fodder and crude protein (265.74 and 556.4 kg/ha) in 1st and 2nd year, respectively. But pearl millet (multicut) + cowpea without tree produced 12.7 and 28.4 t/ha green fodder and 239.5 and 494.7 kg/ha crude protein, respectively. However, single cut pearl millet + cowpea with and without tree produced green fodder (11.1, 27.1 and 8.3, 27.0 t /ha) and crude protein (226.7, 530.8 and 171.3, 471.0 kg/ha) during 1st and 2nd year, respectively. Higher net profit of Rs. 95,000 and 94,570 was received from pearl millet (multicut) + cowpea in association with tree in 1st and 2nd year, respectively which were higher than sole tree (Rs. 73,000 and 56,090) and sole crop of pearl millet single cut + cowpea (Rs. 2,625 and 17,625) and pearl millet (multicut) + cowpea (Rs. 6,900 and 18,760) in 1st and 2nd year, respectively. The positive soil nutrient build up was also noticed when fodder crop was intercropped with aonla tree. Higher fungi population (3.64 cfu x10^5 per gram) of rhizosphere soil was recorded in pearl millet (multicut) intercropped with cowpea and lowest fungal population 3.12 x 10^5 cfu per gram rhizosphere soil was recorded where aonla was grown exclusively.

Keywords: Agri-horti system, Aonla, Cowpea, Intercropping, Pearl millet

Introduction

Pearl millet is considered as an important dual purpose crop for arid and semi regions and its fodder quality can considerably be increased through intercropping with cowpea. Inter cropping of pearl millet with legumes like cowpea, green gram and cluster bean was found beneficial and recorded higher production (Ram *et al.*, 2005; Sharma, 2008). Agri-horti system is considered as the most ideal strategy to provide food, nutrition, income security and mitigate the fodder shortage by utilizing the interspaces of fruit plant orchards (Sharma, 2014). Aonla (*Emblica officinalis* Gaertn.) is an important fruit crop of semi-arid region of India. It is grown commercially because of its high economic returns, therapeutic and nutraceutical value and its suitability for marginal lands. The tree canopy of aonla allows intercepting light and permits intercropping even after it has made full growth. Hence, it is one of the most suitable fruit species for hortipasure system in semi-arid region. Its deep root system and deciduous nature, sparse foliage makes an ideal plant amenable for intercropping. Previous studies have indicated beneficial effects of intercropping of vegetables (Verma *et al.*, 2005), arid crops (Awasthi *et al.*, 2009), grass (Kumar and Chaubey, 2008) and perennial pigeon pea (Prasad *et al.*, 2007) in pre and post bearing stage of orchards. Hence, an experiment was conducted to assess the feasibility and economics of intercropping with pearl millet and cowpea under thirteen years old aonla plantation through agri-horti based fodder production system under rainfed condition.

Materials and Methods

The experiment was conducted during *Kharif* seasons of 2009-10 under 13 years old fully established aonla (cv. NA-7) orchard at Central Research Farm (longitude 25^0 26' 08" N, latitude 78^0, 30' 21" E and altitude 216 m above mean sea level) of the institute. The soil was clay loam; contains 38.55% clay, 32.5% sand and 29.5% silt with 2 m depth. The soil was poor in available N (169.3 kg/ha), P (4.1 kg/ha) and K (172.7 kg/ha), low in organic carbon (0.39 %), and neutral in pH (6.4). The understorey was intercropped with pearl millet fodder single and multicut with cowpea. The pearl millet fodder (single cut cv. Gujrat Bajra-1 and multicut cv. Rajasthan Bajra Chari-

2) and cowpea (Bundel Lobia-2) were sown in lines at 30 cm apart row in the ratio of 2:2 in the month of July during both the years (2009 and 2010) of study. The experiment consisted of 5 treatments viz., T_1 (Aonla sole), T_2 (Aonla + pearl millet single cut + cowpea), T_3 (Aonla + pearl millet multicut + cowpea), T_4 (sole pearl millet single cut + cow pea) and T_5 (sole pearl millet multicut + cowpea). Plot size of each treatment was 12 m x 24 m with 8 trees/plot planted at 6 m apart was maintained. Experiment was replicated four times in randomized block design. The recommended agronomic practices were followed to the aonla tree and fodder crops each year to ensure good crop. The weather parameters viz., rainfall (mm) and rainy days were collected from meteorological observatory of Central Research Farm of the institute (Fig 1).

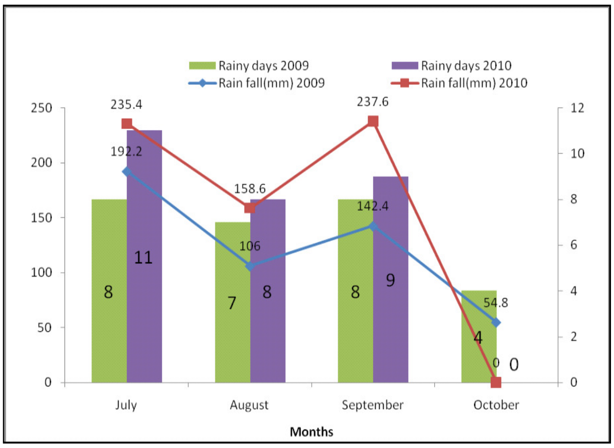

Fig 1. Rainfall and rainy days distribution during the experiment

For estimation of dry matter and crude protein in fodder crops, fresh samples (500 g) were collected randomly from each plot at 50% flowering and dried in hot-air oven at 70°C till constant weight. Microbial count in term of colony forming unit (cfu) per gram of fungi and bacteria in rhizosphere soil of each fodder was done at 50% flowering and in aonla in the month of November at fruiting stage following standard dilution plating and culture count methods. Soil nutrient buildup in terms of available nitrogen, phosphorus, potassium and organic carbon was measured from each treatment after the harvest of fodder crops at end of experiment following standard procedures. Economics of the system were calculated on present price of inputs and outputs.

Results and Discussion

***Tree growth and fruit yield*:** The understorey intercrop combination did not affect the growth canopy and fruit yield of aonla trees (Table 1). The highest fruit yield of aonla 13.3 t/ha and 13.43 t/ha was recorded through intercropping with multicut pearl millet and cowpea during first and second years, respectively. Sharma (2004) and Kumar and Shukla (2011) also reported that understorey forage crop combinations did not influence the fruit yields of established ber and aonla tree species due to differential rooting behaviour of crops. Singh (1997) observed that intercropping of rainfed legume crops in ber orchard at Pali in Rajasthan gave 3 times higher yield as compared to sole crops. Under rainfed situation, fruit tree based framing system resulted in reduced risk. It was observed that in 2009 only 499.4 mm rainfall within 27 rainy days yielded 14.36 t/ha fruits, where as in 2010, 631.6 mm rainfall in 28 rainy days yielded 12.18 t/ha fruits. Total rainfall was more rainfall in the year 2010 than 2009, but it was delayed which affected the fruit yields. Indeed, in aonla early or pre-monsoon plays a major role in production.

Table 1. Performance of 13 years old Aonla trees as influenced by associated fodders

Treatment	Tree height (m)		Canopy Spread (m)		Fruit (t/ha)	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
T_1	5.9	4.9	5.3	4.3	13.3	10.87
T_2	5.3	4.6	4.9	4.8	14.5	12.24
T_3	5.4	4.6	5.8	4.7	15.3	13.43
T_4	—	--	—	--	—	—
T_5	—	--	—	--	—	—
Mean	5.3	4.7	5.3	4.6	14.36	12.18
CD at 5%	NS	NS	NS	NS	NS	NS

T_1: Sole Aonla; T_2: Aonla + pearl millet single cut + cowpea; T_3: Aonla + pearl millet multicut + cowpea; T_4: Pearl millet single cut + cowpea sole; T_5: Pearl millet multicut + cowpea sole

Fodder yield and quality: Under rainfed situation the production of intercrop fodder depends on rainfall distribution. In first year, due to below normal rainfall only one cut was taken resulting in lower yield (11.62 t green fodder or 2.25 t DM/ha), whereas normal rainfall was received during 2nd year it produced good crop with average yield of 28.2 t green fodder or 5.25 t DM/ha as two cuts were taken from multicut pearl millet. Both years the multicut pearl millet + cowpea produced higher yield in association with aonla tree. In 1st year it produced 28.6 percent and in 2nd year 12.2 percent higher green fodder as compared to pearl millet single cut + cowpea. Intercropping of multicut pearl millet with cowpea also gave maximum yield without affecting Aonla fruit crops. Similarly sole fodder production (Table 2) of pearl millet multi cut + cowpea produced higher yield as compared to pearl millet single cut + cowpea during both the years. Kumar and Shukla (2011) reported utilization of interspaces of 10 years old Aonla orchard through *Panicum maximum* + *Stylosanthes hamata* which produced 5.1 t DM/ha in association with tree 4.5 t DM/ha as sole pasture. Similarly, Ram *et al.* (2005) reported that interspaces of old ber orchard can be utilized for forage production through perennial pasture species. They found that intercropping of guinea grass with caribbean stylo produced significantly higher dry forage (5.87 t/ha) and crude protein (441.6 kg/ha) as compared to guinea grass + caribbean stylo + dinanath grass (5.10 t DM/ha and 389.3kg/ha crude protein) and dinanath grass + caribbean stylo (3.84 t DM/ha and 330.9 kg/ha crude protein). Ram *et al.* (2006) also reported that utilization of interspaces of 6 years old orchard of *Annona* can be intercropped with bufell grass (*Cenchrus ciliaris*) and *Stylosanhes* species. They found that bufell grass + *S. hamata* produced 5.95 t DM/ha and bufell grass + *S. scabra* produced 5.15 t DM/ha without affecting the *Annona* plant growth and fruit yield. Intercropping of pearl miller (multicut) + cowpea influenced the crude protein yield. Both years the pearl millet (multicut) + cowpea produced higher crude protein (265.7 and 546.4 kg/ha) as compared to pearl millet (single cut) + cowpea (226.7 and 530.8 kg/ha) in association with aonla. Similarly, sole fodder production (Table 3) of pearl millet (multicut) + cowpea produced higher crude protein as compared to pearl millet (single cut) + cowpea during both the years. In general the crude protein content of forage derived from cereal fodder is low. However, it improves when intercropped with legumes which are rich in protein. Contribution of pearl millet in green fodder with different treatment combination was also estimated. It was found that highest green fodder yield of pearl millet (22.1 t/ha) was recorded when aonla intercropped with pearl millet (multicut) + cowpea and it was lowest (19.1 t/ha) when pearl millet (single cut) + cowpea was sown as sole crop. Similarly cowpea as green fodder had higher yield (8.3 t/ha) in the treatment where it was intercropped with aonla. Sole fodder crops yielded lower quantity of fodder. The probable reason was that manure and fertilizers applied to aonla tree were also utilized by sown crop component. Dry fodder yield of pearl millet and cowpea was also higher in the treatment intercropped with aonla (3.47 t/ha) of pearl millet (multicut) and 4.51 t/ha of cowpea than intercropping without aonla. Higher dry matter yield obtained from cowpea combinations also provided nutritious fodder as cowpea contained higher protein than exclusive pearl millet.

Table 2. Fodder production under aonla based agri-horti system

Treatment	Green fodder production (t/ha)						Dry matter (t /ha)						Crude protein (kg/ha)					
	1st year			2nd year			1st year			2nd year			1st year			2nd year		
	Pearl millet	Cow pea	total	Pearl millet	Cow pea	total	Pearl millet	Cow pea	total	Pearl millet	Cow pea	total	Pearl millet	Cow pea	total	Pearl millet	Cow pea	total
T_1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
T_2	6.34	4.76	11.1	19.6	7.5	27.1	1.42	0.82	2.24	5.19	1.06	6.25	98.0	128.7	226.74	363.3	167.5	530.8
T_3	8.63	5.79	14.4	22.1	8.3	30.4	1.81	0.88	2.69	5.14	1.19	6.33	126.7	139.0	265.74	359.8	186.8	546.4
T_4	4.85	3.45	8.3	19.1	7.9	27.0	1.09	0.61	1.70	4.22	1.14	5.36	77.39	93.9	171.33	295.4	175.6	471.0
T_5	7.18	5.52	12.7	21.6	6.8	28.4	1.55	0.84	2.39	4.92	0.95	5.87	108.5	131.0	239.5	349.3	145.4	494.7
Mean	6.75	4.88	11.62	20.6	7.6	28.2	1.47	0.79	2.25	4.87	1.08	5.95	102.6	123.7	225.8	332.9	168.8	500.9
CD at 5%	1.07	0.81	1.76	0.73	0.08	0.83	0.32	0.12	0.43	0.67	0.03	0.05	10.24	13.8	11.3	36.08	9.96	18.3

Table 3. Soil nutrient build up for intercropping of fodder with aonla

Treatment	Soil nutrient build up (%) after experiment			
	OC	Available nutrient (kg/ha)		
		N	P	K
Initial	0.39	169.3	4.1	172.7
T_1	0.433 (11.2)	185.58 (9.62)	4.225 (3.04)	181.66 (5.19)
T_2	0.436 (11.87)	186.53 (10.18)	4.228 (3.13)	179.79 (4.06)
T_3	0.438 (12.33)	188.14 (11.13)	4.235 (3.31)	180.00 (4.23)
T_4	0.436 (11.81)	184.07 (8.73)	4.212 (2.75)	179.60 (4.00)
T_5	0.434 (11.31)	186.0 (9.87)	4.282 (3.63)	179.61(4.00)
CD >0.05	NS	0.13	0.03	0.05

Values in parentheses are build up (%) after experiment; OC: Organic carbon

Microbial count in rhizospheric soil: Microbial count in terms of fungi and bacteria in the rhizospheric soil of crops in different treatment combination clearly indicated that higher fungi population (3.64 cfu x10^5 per gram) was recorded in pearl millet (multicut) intercropped with cowpea. Lowest fungal population 3.12 x 10^5 cfu per gram rhizosphere soil was recorded in the aonla alone (Fig 2). However, higher bacterial population 68.75 cfu/g rhizosphere soils were recorded with multicut as well as single cut pearl millet when grown along with aonla. Crops grown without aonla had lowest bacterial population. The rhizo deposition of nutrients by plant roots support increased microbial growth. Plant species and seasonal changes affect the indigenous bacterial soil communities and function of fungal communities. Mougel *et al.* (2006) observed that the dynamics of the genetic structure of bacterial and fungal communities were characterized during the developmental stage of *M. truncatula*. Hossain *et al.* (2010) reported that changes in the composition of both bacterial and fungal communities were closely related to the rate of litter decomposition and it was influenced by its chemical composition and activities of soil decomposers. They used leaf litter from fifteen plant species collected from semi-natural and improved grasslands and found that plant species influenced litter decomposition not only through influencing the quality of substrate but also through changing the composition of soil microbial communities.

Soil nutrient buildup: Microbial activity during litter decomposition changed the soil nutrient status. About 8.73 to 11.13 per cent increase in available nitrogen (kg/ha) and 3 percent in phosphorus and 4 to 5 per cent in potassium were recorded (Table 3). Per cent improvement in organic carbon was non-significant in respect of different treatments. However, available N was slightly higher in aonla tree based treatments. It was probably due to aonla leaf fall which added some nitrogen in soil or application of additional fertilizer in aonla basin. Soil buildup due to litter fall and their decomposition in aonla was also reported earlier (Kumar *et al.,* 2009). Similarly available P and K were also higher in soil with aonla based treatment combinations. Another reason was probably higher bacterial population with treatment of fodder crops when intercropped with aonla, since microbial biomass plays a key role in soil nutrient cycling (McLaughlin *et al*., 1988; Frossard *et al*., 2000). In agricultural soils, microbial activity in the form of phosphate-solubilizing bacteria improved P transfer from soil to plants (Adhya *et al*., 2015).

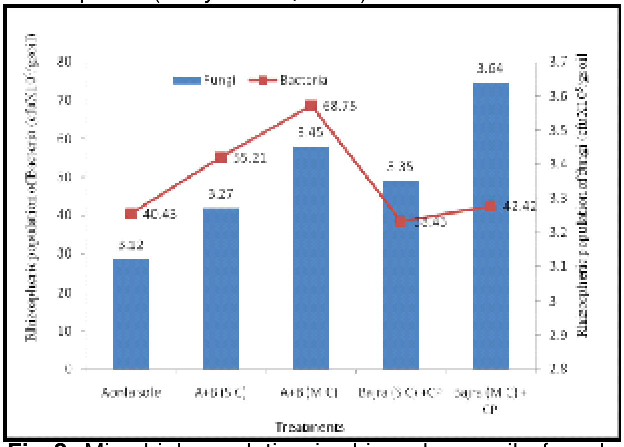

Fig 2. Microbial population in rhizosphere soil of aonla and intercropped fodder

Economics: Fruit crops are deep rooted, hardy and tolerant to abnormal monsoon e.g. early or late onset, intermittent dry spell, early withdrawal, uneven distribution of rainfall etc. when compared to short duration field crops. Thus it brings stability in farm income. Despite variable rainfall during experimental period, higher net profit of Rs. 95,000 and 94,570 was received from pearl millet (multicut) + cowpea in association with tree in 1st and 2nd year, respectively (Table 4), which was higher than sole tree (Rs. 73,000 and 56,090) and sole crop of pearl millet (single cut) + cowpea (Rs. 2,625 and 17,625) and pearl millet (multicut) +

Table 4. Economics of fruit and under storey fodder crops

Treatment	1st year (tree)		Net profit	2nd year (tree)		Net profit
	Input	Output		Input	Output	
T_1	20000	93100	73000	20000	76090	56090
T_2	25675	112600	86925	26675	110070	83395
T_3	25800	121500	95000	26800	121370	94570
T_4	5675	8300	2625	6675	24300	17625
T_5	5800	12700	6900	6800	25560	18760

cowpea (Rs.6,900 and 18,760) in 1st and 2nd year, respectively. Kumar and Ram (2010) also observed maximum cost: benefit ratio (1:1.99) of pasture when 10 years old ber orchard intercropped with guinea grass + *S. hamata*.

Conclusion

It was concluded that in semi-arid region of central India, the interspaces in established aonla orchards can efficiently be utilized through pearl millet (multicut) + cowpea combinations resulting in higher total productivity, positive rhizosphere colonization, improved soil fertility and higher profitability without affecting aonla yields.

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