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Intensification of aonla (*Phyllanthus emblica*) based production systems for their stability, productivity and profitability under dryland regions of semiarid India

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Abstract

Aonla is a highly adaptable fruit crop for semi-arid regions under rainfed conditions. However, productivity and profitability are often constrained by climatic variability and unstable markets. To enhance system stability and land-use efficiency, two field experiments were conducted for three years (2009–2011) in mature Aonla orchards (9 years old) at Dryland Farming Research Station, Bhilwara, Rajasthan, India. Experiment I tested agronomical intercrops (7 treatments), while Experiment II involved cucurbitaceous crops (7 treatments). Results revealed that rainfall variability strongly influenced intercrop yield and economic performance. Under drought conditions, greengram and kachari provided maximum returns, whereas under favorable rainfall, maize + blackgram and pumpkin were superior. Across all conditions, blackgram and kachari were the most stable and profitable intercrops. Intercropping enhanced system stability and overall economic resilience without negatively impacting aonla yield.

Keywords: Aonla, intercropping systems, cucurbits, dryland agriculture, profitability, rainfall variability

Introduction

In India, dryland agriculture area includes the north western desert regions of Rajasthan, the plateau region of central India, the alluvial plains of Ganga Yamuna River basin, the central highlands of Gujarat, Maharashtra and Madhya Pradesh, the rain shadow regions of Deccan in Maharashtra, Deccan Plateau of Andhra Pradesh and Tamil Nadu highlands (Rao and Ryan, 2004 and Singh *et al.*, 2004) [6, 10]. Dry land may be improved through suitable farming technologies aiming at improving the soils fertility and productivity by development of forestry and pasture, overcoming the grazing and also promotes various farming system including Agri-Horticultural system. Among various strategies to improve or more precisely stabilize the farm productivity, agro-horti-pastoral systems have been found to be adapted resilient and remunerative under uncertainties of these regions in terms of weather variables particularly soil moisture (Awasthi *et al.*, 2009 and Gupta *et al.*, 2019) [1, 4]. Under the such systems, short duration arable crops raised in the interspaces of fruit trees providing seasonal revenues. The aonla is well suited fruit crop of this type of farming situations and farmers of rainfed semiarid regions prefer this crop. Generally, budded aonla plants starts bearing 3 year after planting and reach their maximum capacity up to 8 years of age. Aonla is a deep-rooted and deciduous tree species. Fruits are the rich source of vitamin C and tannin and have several medicinal values. Aonla is a suitable fruit crop in the dryland regions of semiarid regions and farmers also got inclined towards establishment of orchards. However, during recent years the prices of aonla have been highly fluctuating and returns from such orchards are highly unstable, thus the aonla based production systems under drylands of semiarid regions of India need to be relooked for making such systems more stable and profitable in terms of production and economic returns across varied situations born out of the behaviour of rainy season during different years. An intercropping system is an age old practices which has attracted worldwide attention for yield (Willey, 1979). In Aonla orchards growing of crops as intercrops in rainy season is profitable for fruit growers in terms of additional income (Sarkar *et al.*, 2004 and Singh *et al.*, 2013) [7, 9].

There have been some studies suggesting profitable utilization of available interspaces for raising intercrops in developing aonla orchards improving the efficiency and profitability of this type of production systems. However, possibilities of taking various intercrops in mature aonla orchard have not been explored and reported adequately. Thus, keeping all these facts in view present investigations was planned and executed for three years.

Materials and Methods

A. Description of Experimental Site: This experiment was conducted at Dryland Farming Research Station (MPUAT), Bhilwara (India), situated at 24°20'N and 74°20'E and 432 m AMSL during the *khariif* - 2009, 2010 and 2011. This aonla orchard was raised under the theme of alternate use system of land under rain fed conditions. The aonla plants were planted in pits dug out up to depth of 3 meter and filled with mixture of sand, tank silt and manures during 2001-02 at the distance of 8 meter for row and plant. The details of the physio-chemical properties of soil have been given in the table 1.

B. Prevailing Environments

This orchard was maintained under rainfed situation and all the crops taken in both the experiments were also rainfed. The annual rainfall was 353.2 mm in 2009, 792.8 mm in 2010 and 722 mm in the year 2011, while normal rainfall is 657.7 mm for Bhilwara. The details of rainfall behaviour indicating total amount and distribution of rainfall and incidence and intensity of dry spells experienced during the crop season, the all relevant information for the period of three years of experimentation has been summarized in the table 2. First year (2009) was a drought year having only 201.2 mm of rainfall during crop season against the normal of 657.7 mm with three dry spells of more than 10 days reducing the crop growing season only up to 69 days. During 2010, the growing season was better than that of year 2009 with having total rainfall of 460.6 mm during crop season of 79 days with 2 dry spells of more than 10 days. However, third year (2011) was the best in this respect receiving 610 mm of rainfall during crop season without no dry spell of more than 10 days thus enabled a crop growing season of 89 days.

C. Raising of Experiments

The experiments were conducted during 2009 to 2011 at dryland farming research station, Arjia, Bhilwara (Rajasthan) India under semi-arid dryland conditions.

Experiment I

Agronomical crop combination experiment consisted five treatments (2009), Six treatments (2010) and seven treatments (2011). Treatments included T₁ – Control (Natural fodder), T₂ – Maize, T₃ – Blackgram, T₄ – Greengram, T₅ – Sesame, T₆ – Maize + blackgram (2:2) ICS, T₇ – Aloe vera grown between interspace of aonla trees.

The aonla was planted with the geometry of 8 x 8 meter and in between two aonla plants a plot of having size of 4.8 x 8 meter was used for raising of treatment crops as per recommended geometry. The shade area of aonla tree was not included in the plot area so instead of 8 meter only 4.8 meter area was considered for the width of the plot where crops were raised. The maize (PHEM-2) was sown at a row spacing of 60 cm while blackgram (T-9) Sesame (RT 46) green gram (K 851) each were sown at row spacing of 30 cm. For aloe vera edible species was used and was planted 30 cm apart and its leaves were sold as

vegetable. In case of maize + blackgram (2:2 intercropping systems) 2 maize rows were planted as paired row at the 30cm apart and in between 2 rows of blackgram were accommodated 30 cm apart. The date of sowing and harvesting of different crops have been given in the table 2. The fertilizer to each crop was given as per the zonal recommendation. The crops were harvested threshed as per the standard procedures adopted for these purposes at research farm.

Experiment II

The second experiment consisted six treatments during 2009 and 2010 and seven treatments during 2011 viz., T₁ – Control (Natural fodder), T₂ – Bottle gourd, T₃ – Ridge gourd, T₄ – Pumpkin, T₅ – Bitter gourd, T₆ – Kachari and T₇ – Sponge gourd. Total six vegetable plants for each crop were raised in outer ring of each basin/ pits of aonla and vines were spread in the interspaces. In both the experiments the inter-crops were sown in *khariif* season just after the first rainfall. Recommended package of practices were followed during crop grown session. All the treatments were replicated four times in randomized block design with 4 replications. The data of fruit yield of aonla was recorded on the basis of per plant and per hectare basis however, these data have not been included in this manuscript for avoiding the ambiguity. The fruit yield of intercropped cucurbits was recorded for per basin of aonla plant and converted into kg/ha.

D. Economics

Experiment I

For working out the economics of the different crops and crop combinations the minimum support price (MSP) was used to calculate returns from grain and for straw/stover prevailing prices were utilized. For calculating costs standard general costs were taken in to consideration as decided by the centre as no additional cost for implying treatment was applicable in this investigation. For carrying out statistical analysis of the treatments the grain /seed and straw/ stover yields were converted in to Maize Equivalent Grain yield and Maize Equivalent Stover yield.

Experiment II

The cucurbit crops were planted in such a way that in each selected basin of aonla tree as per the randomization of the experiment, those 6 plants of each such crop are established and vines were spread in the interspaces. For this purpose, seeds of private seed companies were placed in the outer ring of aonla tree basin. These crops were not given any fertilization or any other input. The plucking of fruits was done periodically keeping in view the marketable size and stage of any crop. The vegetables were sold at the variable prices as decided by the statutory price ascertaining committee of the DFRS Arjia and returns thus obtained were used as the gross returns from every treatment separately. Net returns were calculated by subtracting cost from gross returns for each treatment.

C. Statistical Analysis

The experiments were carried out in RBD with four replications. Post-hoc comparisons were conducted using Duncan's Multiple Range Test (DMRT) which is a stepwise multiple comparison procedure applied following a significant ANOVA to determine which specific treatment means differ statistically. The method controls the experiment-wise error rate while providing greater sensitivity for detecting mean differences. In the resulting mean separation table, treatments that share at least one common letter

are considered statistically similar (at par), whereas treatments assigned distinct letters are regarded as significantly different, typically at the 5% significance level.

Results and Discussion

The results owing to performance of different intercrops in both the experiments indicate that variability of rainfall in terms of total amount and its distribution had very strong influence in two ways, firstly, the crop growing season length was variable during all three years having 69, 79 and 89 days seasons during 2009, 2010 and 2011, respectively. Secondly the incidence of dry spells of varied durations during crop growing seasons caused lasting impact on the performance of various crops in both the experiments.

The fruit yield of aonla trees was not affected by introduction of any of intercrop during any of the year of investigation therefore the details of their yields have not been reported in this study. The returns owing to intercrops are in the fashion of additional cost versus additional returns and have been reported accordingly.

Experiment I

The yield and economics data of various crop and crop combinations have been given in table 3 and 4. The grain/ seed yield data have been converted in to maize equivalent grain yield (MEqGY) and the stover /straw yield was converted into maize equivalent stover yield (MEqSY) for enabling statistical analysis. In the control plot, no crop was raised and natural vegetation grown during crop season was harvested as fodder and its value has been converted in to MEqSY.

The prevailing environment in terms of rainfall amount and its distribution was highly variable during all three years of this study as presented in table 2. Such variability of rainfall determined the performance of different crop and crop combinations. First year of experiment (year 2009) was a drought year confining to only 69 days of growing season and this shortened growing season was also affected with the malady of 3 dry spells of more than 10 days duration. Under such extreme drought situation, the greengram was the best crop giving the highest maize equivalent seed yield followed by blackgram reemphasizing the importance of kharif pulses under such unfavourable rainfall situation (Shweta *et al.*, 2022, Ezung *et al.*, 2022 and Khalid *et al.*, 2023) ^[8, 3, 14]. Sesame also gave reasonable production but under such stress of drought no grain formation in maize was there resulting in no grain yield of maize this year. The stover /straw or fodder are equally important under dryland farming systems and during this drought year it was surprising that control where no crop was grown and only naturally grown vegetation was used as fodder, gave the highest maize equivalent stover yield followed by maize and greengram and sesame. The economics of these treatments followed the pattern of yield where greengram gave the highest net returns followed by blackgram and sesame. The maize growing during this drought year was economically undesirable and even after giving the good amount of stover yield net loss of Rs 4262 was observed under maize treatment.

The year of 2010 was a moderate year and the performance of treatment was in sharp contrast to that of year of 2009. During this year, though there was incidence of two dry spells of more than 10 days duration during crop season but better amount of rainfall than that of year of 2009 facilitated a 79 days crop season. Combination of two factors namely increased amount of rainfall amount, lesser incidence of dry spells and somewhat extended crop growing season improved the performance of

maize and sesame. The sesame produced the highest maize equivalent yield during this year followed by maize + Black gram (2:2 intercropping system), however both of these treatments were statistically at par. The next performing treatments were balckgram, sole maize and greengram remaining statistically at par to each other. During this year, sole maize gave the maize equivalent grain yield at par to all other treatments except sesame and this year every treatment was at reasonably good level of production. However, the highest net returns were obtained with maize + Black gram (2:2 intercropping system) followed by sesame despite of the fact the sesame produced the highest Maize Equivalent grain yield. In this rainfed region, the fodder received in as Stover / straw or in any other forms is also possesses great economic value as live stocks are vitally integrated with the cropping systems of these regions and sesame straw has no fodder value for the livestock of the region and straw/stove obtained from maize + Black gram (2:2 intercropping system) are highly preferred causing huge difference in the economic values of the straw obtained from sesame and straw/stove obtained from maize + Black gram (2:2 intercropping system). And this variation of economic values of straw /stover altered the net returns received from these two treatments.

During the year of 2011, the environment was altogether different and abundance of rainfall was there and during 89 days of crop season a total of 610 mm rainfall was received with no dry spell and this amount of relatively excess of moisture had highly negative effect on kharif pulses particularly on greengram that resulted in the lowest seed yield and it was giving net loss of Rs 589 and the next worst treatment was the sesame. During this year the highest MEqGY and MEqSY were obtained with maize + balckgram gave the highest yield however, it was at par with sole maize indicating towards poor performance of balckgram in intercrop combination on account of luxurious growth of maize. The net returns during this year also followed the exact trend of the yield performance under various treatments.

However, it is evident from the three year data witnessing distinct and peculiar rainfall situation during these three years the performance of balckgram was moderate during every situation giving moderately stable seed yield across the variable rainfall situations observed during these three years of investigation. The performance of balckgram was consistent and gave moderate returns during diverse types of rainfall situation while other all treatments were drastically influenced either as positively or negatively with the varied rainfall situation but the across all these situations balckgram was consistent in yield performance.

Experiment II

The different cucurbit crops were raised with the perspective of additional returns against the added costs. The seeds of cucurbit crops were place in the outer ring of the aonla basin and vines were spread in the available interspaces. The yield was recorded for individual crops on the basis of each aonla basin and on the basis of hectare grown in this mode. The cost for these treatments were incurred only for two components namely seed and plucking of fruits otherwise unlike of Experiment I no other costs were involved. The data pertaining to yield and economics of different cucurbit crops have been presented in the table 5 and 6.

As it was quite evidence from the data for the performance of various crops was fashioned by the different yearly variability attributes of rainfall in terms of amount and distribution of rainfall, length of crop growing season and incidence of dry

spells of more than 10 days duration.

During drought year of 2009, the kachari performed the best by producing 1326 kg/ha fruit yield fetching net returns to the tune of Rs 6720/ha followed by ridge gourd and bottle gourd with corresponding values for fruit production and net returns of 634 kg and Rs 3651 and 478 kg and Rs 3347, however, pumpkin and control under which natural vegetation was used as fodder were the worst hit treatments incurring net loss of Rs 285 and Rs 697, respectively. The performance of kachari was not only found as the best during drought year but it was reasonably consistent in terms of fruit yield and net returns during rest of the years where rainfall pattern was bearing huge yearly variations during the years 2010 and 2011. However, the pumpkin that was fetching negative net returns during drought year of 2009 as no fruit yield was obtained, emerged as the best treatment during favourable years of 2010 and 2011 giving the highest fruit yield and net returns. Similar results were also reported by Das *et al.*, 2011^[2], Singh *et al.*, 2013^[9] and Meena *et al.*, 2017^[5] in aonla orchards. The results indicate that aonla with pumpkin had maximum yield of inter crop and minimum in sole crop. During 2010, next to pumpkin, bottle gourd recorded the highest fruit yield and net returns followed by kachari. The performance of ridge and sponge gourd was not satisfactory during any of the year across diverse rainfall situations. Since the year of 2011 was a good rainfall year even control could give net returns of Rs 2844

otherwise during initial two years of experimentation during 2009 and 2010 this was incurring net loss. The returns from cucurbitaceous crops have also been reported by earlier researcher in aonla based cropping system (Singh *et al.*, 2013, Meena *et al.*, 2017 and Yadav *et al.*, 2024)^[9, 5, 13]. Apart from giving additional returns the spreader vines of cucurbits also suppressed the weed growth, reduced the evaporation from the soil by covering the interspaces leading to more amount of moisture retention in the soil of orchard.

Table 1: Physico-chemical properties of soil of aonla orchard

Physical Properties	
Texture class	Sandy loam
Structure	Sub angular blocky
Water holding capacity (%)	27.40
Field capacity (%)	26.25
Wilting Point	7.52
Chemical Properties	
Organic carbon (%)	0.26
Available nitrogen (kg/ha)	207.40
Available phosphorus (kg/ha)	36.60
Available potash (kg/ha)	224.0
EC of saturation extract at 25°C (ds/m)	0.35
pH (1:2 soil water suspension)	8.87
Gypsum requirements (t/ha)	6.02

Table 2: Details of rainfall situation and growing period of crop during 2009-2012

Total rainfall	Experiment 1	Experiment 2	Experiment 1	Experiment 2	Experiment 1	Experiment 2
during crop season	201.2	201.2 Three 15 days (28.07.09 to 11.08-09) 16 days (14.08.09 to 29.08.09) 16 days (14.08.09 to 29.08.09) 33 days (31.08.09 to 3.10.09) 04.07.09 27.09.09 69	460.6	460.6	610	610
	Three		Two	Two	Nil	nil
Dry spells of >10 days during crop season	15 days (28.07.09 to 11.08-09) 16 days (14.08.09 to 29.08.09)		17 days (9 to 25 July 2010) 18 days (12.09. 2010 to harvest)	17 days (9 to 25 July 2010) 18 days (12. 09. 2010 to harvest)		
	28 days (31.08.09 to harvest)					
Date of sowing	20.07.09		08.07.2010	08.07.2010	30.06.2011	07.07.2011
Date of	27.09.09		24.09.2010	24.09.2010	03.10.2011	03.10.2011
Harvesting						
Effective cropping season (Days)	69		79	79	89	89

Table 3: Yield of agronomical crops as intercrops in aonla based agri-horti systems during 2009-11

Treatment	Maize equivalent grain yield (kg/ha)			Maize equivalent stover yield (kg/ha)				
	2009	2010	2011	Mean	2009	2010	2011	Mean
Control*	0d	0d	0e	0	1871 ^a	3422 ^b	2282 ^c	2525
Maize	0d	1614 ^{bc}	1726 ^a	1113	1628 ^{ab}	3807 ^b	2791 ^b	2742
Blackgram	1105 ^b	1730 ^{abc}	1046 ^b	1294	1189 ^c	2192 ^c	1667 ^d	1683
Greengram	1807 ^a	1434 ^c	350 ^d	1197	1414 ^{bc}	2303 ^c	978 ^e	1565
Sesame	817 ^c	2040 ^a	414 ^d	1090	225 ^d	616 ^d	784 ^e	542
Maize + BG (2:2) ICS	-	1960 ^{ab}	1800 ^a	1880	-	4665 ^a	4139 ^a	4402
Alovera	-	-	702 ^c	702	-	-	0f	-
S.Em.	87.6	135	78	-	105	231	107	-
C.D. (P = 0.05)	270	407	233	-	324	696	318	-

(Values followed by common letters are not significant at 5% level of significance using the DMRT test)

*Natural Fodder

Table 4: Economics from aonla orchards with intercropping of agronomical crops during 2009-11.

Treatment	Cost of cultivation (Rs/ha)				Gross return (Rs/ha)				Net returns (Rs/ha)				B:C ratio			
	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean
Control *	3000	3000	2316	2772	3835	5133	4791	4586.333	835	2133	2475	1814	1.28	1.71	2.07	1.69
Maize	7600	7600	7245	7481.667	3338	17846	26567	15917	-4262	10246	19322	8435	0.44	2.35	3.67	2.15
Blackgram	5620	5950	6912	6160.667	12936	17246	16049	15410.33	7316	11296	9137	9250	2.30	2.90	2.32	2.51
Greengram	5762	6192	6840	6264.667	20069	14783	6251	13701	14307	8591	-589	7436	3.48	2.39	0.91	2.26
Sesame	5710	6110	6576	6132	8226	18365	6619	11070	2516	12255	43	4938	1.44	3.01	1.01	1.82
Maize + BG (2:2) ICS	-	9105	8616	8860.50	-	21714	30290	26002	-	12609	21674	17142	-	2.38	3.52	2.95
Alovera	-	-	3643	3643	-	-	8424	8424	-	-	4781	4781	-	-	2.31	2.31

*Natural Fodder

Table 5: Yield parameters of cucurbitaceous crops as intercrops in Aonla based vegetable systems during 2009 -11

Treatment	Fruit yield/ plant (kg)				Average fruit yield/Aonla basin (kg)				Fruit yield (kg/ ha)/ fodder dry yield (kg/ha)*			
	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean
Control *	0	0	0		0	0	0		698	1872	2457	1676
Bottle gourd	0.68	5.12	4.11	9.91	4.06	30.73	24.66	59.46	634	4791	3847	3091
Ridge gourd	0.51	0.96	0.92	2.39	3.06	5.763	5.56	14.39	478	899	869	749
Pumpkin	-	19.33	4.91	24.25	-	116.00	29.50	145.5	0	18096	4797	7631
Bitter gourd	0.25	0.55	0.59	1.4	1.48	3.331	3.56	8.38	230	520	557	436
Kachari	1.42	4.16	3.42	9.00	8.50	25.00	20.52	54.02	1326	3900	3202	2809
Sponge gourd	-	1.11	0.74	1.85	-	6.66	4.48	59.46	-	1078	700	889

* (Natural Fodder)

Table 6: Economics analysis from aonla orchards with intercropping of cucurbitaceous vegetables during 2009-11.

Treatment	Additional cost (Rs/ha)				Additional gross income (Rs/ha)				Additional net returns (Rs/ha)				B: C ratio (on the basis of marginal costs)			
	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean
Control *	3000	3000	2316	8316	2303	2808	5160	10271	-697	-192	2844	652	0.77	0.94	2.23	1.31
Bottle gourd	1725	1725	2060	5510	5072	23956	19237	48265	3347	22231	17512	14363	2.94	13.89	9.34	8.72
Ridge gourd	2085	2085	2060	6230	5736	11686	8687	26109	3651	9601	6602	6618	2.75	5.6	4.22	4.19
Pumpkin	285	1500	1295	3080	0	72384	19188	91572	-285	70884	17688	29429	0	48.26	14.82	21.03
Bitter gourd	1536	1536	2060	5132	2760	9354	9456	21570	1224	7818	7920	5654	1.8	6.09	4.59	4.16
Kachari	1236	1236	1250	3722	7956	15600	12808	36364	6720	14364	11572	10885	6.44	12.62	10.25	9.77
Sponge gourd	-	2085	2060	4145	-	7548	5600	13148	-	5463	3515	4489	-	3.62	2.72	3.17

* (Natural Fodder)

Conclusion

On the basis of this three-year study, it may be concluded that interspaces of Aonla orchard can be utilized successfully for taking of different crops and vegetables profitably. Taking of such crops will not only ensure some additional returns but cost incurred on the orchard can efficiently be spread by taking cucurbits placing them in outer rings of Aonla basins. Further, the blackgram in agronomic crops and kachari among horticultural crops are the best suited crops under such farming situations giving stable yields at a reasonable level across the diverse and variable rainfall situations.

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