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Aonla-Based Hortipastoral System for Soil Nutrient Buildup and Profitability

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Abstract: Aonla-based hortipastoral system involving *Dichanthium annulatum* with four nitrogen doses viz., 0, 20, 40 and 60 kg ha^{-1} to the grass as understory forage species was studied for ten consecutive years (1996-2005). Highest dose of N (60 kg ha^{-1}) gave significantly higher dry pasture yield (4.04 t ha^{-1}) with aonla tree compared with the pure pasture condition (3.73 t ha^{-1}). The pasture production was marginally higher in association with trees (3.38 t DM ha^{-1}) as compared to pure pasture (3.07 t DM ha^{-1}). The fruit production started from 5th year of planting and over the five years of fruiting maximum fruit production of 13.25 t ha^{-1} was recorded when 60 kg N ha^{-1} was applied to the grass component. 40-60 kg N ha^{-1} applied to grass plot improved psysico-chemical composition of fruits. The mean B:C ratio over ten year of experiment was 1:1.85 for pure pasture and 1:3.70 for hortipastoral system. The employment generation was 2.07-man-days $month^{-1}$ in pure pasture and 4.74-man-days $month^{-1}$ with incorporation of aonla tree with the same pasture.

Key words: Aonla cv. N.A.-7, *Dichanthium annulatum*, nitrogen, economics, employment.

In India rainfed areas account for 97 million ha supporting more than four hundred million human population and two third of livestock population. Farmers in these areas are predominantly small, marginal and are resource poor. Livestock rearing, which provides nutrition and helps in stabilizing the farm income, is a complementary occupation in these areas. The combined pressure of human and livestock coupled with land degradation has resulted in shortage of green and dry fodder resulting in poor livestock productivity. Hortipastoral system has the potential to mitigate the shortage of dry and green fodder for feeding the fast increasing population of livestock as well as nutritive food (fruit) to the human. Hortipastoral is socially accepted, ecologically feasible and economically viable for class IV and V type of land in which fruit trees are grown in association with grasses and legumes (Singh, 1996; Sharma, 2004).

Aonla or Indian gooseberry (*Emblica officinalis* Gaertn.) is an important fruit crop of arid and semi-arid regions of India. It is grown commercially because of high economic return, therapeutic and neutraceutical value and its suitability for marginal lands without much care (Singh, 1974). Due to the development of high yielding improved cultivars, the area under this crop is increasing. Pathak *et al.* (2003) reported that aonla has spread over 50,000 ha area in this country with approximate production of 1.75 lakh tonnes. The fast increase in acreage under aonla provides an opportunity to utilize the interspaces during juvenile and bearing phases of orchard by growing suitable pasture species to mitigate the fodder shortage. *Dichanthium annulatum* (Marvel grass) is one of the most suitable grass species for forage, hay and grazing along with arresting the soil loss. In degraded lands soils are most deficient in available nitrogen. Keeping these facts in view an experiment was conducted to determine the level of applied nitrogen for optimization of fruit and forage production along with economic feasibility and soil fertility in aonla-based hortipastoral system.

Materials and Methods

A study was conducted at Central Research Farm (longitude 25°, 26', 08" N, latitude 78°, 30'21" E and msl 216 m) of Indian Grassland and Fodder Research Institute, Jhansi, during 1996 to 2005. The grafted aonla cv. NA.7 was planted during rainy season 1996 in 1 m^3 pits filled with soil + 30 kg FYM + 100 g aldrin powder. The soil of experimental site was clay loam; containing 38.5% clay, 32.5% sand and 29.0% silt. The soil was poor in available N (140-148 kg ha^{-1}), P (3.8-4.1 kg ha^{-1}) and K (110.7 kg ha^{-1}), low in organic carbon (OC, 0.42%), neutral in pH (6.54). The plot size was 18 x 18 m having 9 trees $plot^{-1}$ (6 x 6 m). The understory was transplanted with rooted slips at 50 cm row spacing and 30 cm plant to plant spacing. The same size of plot was also transplanted with pure pasture. The experiment consisted of seven treatments viz., T_1 (aonla +

natural vegetation), T_2 (aonla + *Dichanthium* + 20 kg N ha^{-1} to grass plot), T_3 (aonla + *Dichanthium* + 40 kg N ha^{-1} to grass plot), T_4 (aonla + *Dichanthium* + 60 kg N ha^{-1} to grass plot), T_5 (*Dichanthium* + 20 kg N ha^{-1}), T_6 (*Dichanthium* + 40 kg N ha), T_7 (*Dichanthium* + 60 kg N ha^{-1}). Each treatment was replicated three times in randomized block design.

Nitrogen was applied to pasture through broadcasting in 2 split doses at monthly interval during rainy season. Phosphorus (20 kg ha^{-1}) and potash (30 kg ha^{-1}) was supplied to all plots. Recommended dozes of manure and fertilizers, viz., 10 kg farmyard manure, 100 g N, 50 g P, and 100 g K $plant^{-1}$ was applied to 1-year-old aonla plant. This dose was increased every year in the same proportion up to 8 years. After eight years, each aonla tree received 80 kg farmyard manure, 800 g N, 400 g P and 800 g K every year. The N was supplied in 2 splits, mid-July and mid-September. The annual weather parameters rainfall (mm), rainy days, temperature and relative humidity were collected from meteorological observatory of Central Research Farm of IGFRI, Jhansi (Table 1). The forage (end of September) and fruit (end of December) yield data were recorded every year. After ten years of experiment the soil was analyzed for OC and available N, P, K using standard procedures. The physico-chemical characteristics like fruit weight (by physical weighing), fruit volume (by measuring flask), TSS, glucose and ascorbic acid were recorded at the time of harvest each year during 2000-2005. The total soluble solid (TSS) was recorded by hand refractometer. Glucose was estimated by anthrone method following Morris (1948). Ascorbic acid was estimated by 2,6-Dichlorophenol-Indophenol visual titration method following Johnson (1948). Economics of the system was calculated at 2005 (year) prices (labor @ 70 Rs. day^{-1}, tractor Rs. 200 hr^{-1}, 30 kg FYM pit^{-1}, FYM Rs. 250 t^{-1}, fencing cost Rs. 15000 ha^{-1}, grafted plant Rs. 15 $plant^{-1}$, 277 plants ha^{-1} i.e., 6 m apart, life saving irrigation only for first two years @ Rs. 800 $year^{-1}$ and fertilizer rate on current market price of year 2005 and produce sold as pasture @ Rs. 1800 DM t^{-1} and aonla fruit Rs. 8 kg^{-1}.

Results and Discussions

Pasture production

The nitrogen applied to grass significantly increased pasture production and highest doses of nitrogen had given significantly higher pasture yield over lower doses in all the consecutive year except first year. The average production of pasture increased up to fifth year and there after pasture production declined with tree as well as in pure pasture. This decline was 13.3%, 34.3%, 38.4% and 41.8% in seventh (2002), eighth (2003), ninth (2004) and tenth year (2005) in association with tree. Similar trend was observed in pure pasture. Average maximum forage yield of over ten year was recorded 4.55 t DM ha^{-1} with tree and 3.92 t DM ha^{-1} in pure pasture when applied with highest doses (60 kg ha^{-1}) of nitrogen. The pasture production across treatments was higher in association with tree (3.53 t DM ha^{-1}) compared with the pure pasture (3.29 t DM ha^{-1}) but this increase was not significant. The probable reason may be that manure and fertilizers applied to aonla tree were utilized by sown pasture as there was no physical barrier between the root systems of trees and pasture and thus, better availability of nutrients compensated for the area lost. Sansamma and Pillai (2000) had reported increased

Table 1. Annual meteorological observation of C.R. Farm from 1996 to 2005

Year	Temperature (°C)		Rainfall (mm)	Rainy days	Relative humidity (%)	
	Maximum	Minimum			RH (i)	RH(ii)
1996	31.7	17.3	952.7	52	82	42
1997	30.6	17.2	990.9	57	85	48
1998	32.3	18.5	905.6	45	84	45
1999	32.5	17.6	1118.2	52	81	43
2000	32.5	16.8	715.9	37	85	38
2001	32.3	16.7	1174.7	51	86	43
2002	33.1	17.5	545.7	29	81	41
2003	32.2	17.6	1193.9	39	83	48
2004	32.7	17.6	486.1	31	80	43
2005	32.8	17.1	439.8	31	79	41

Table 2. Pasture production (tDM ha^{-1}) as influenced with aonla tree and nitrogen levels

Treatment	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year	Mean
Pasture with tree											
T_1	0.9	1.7	3.0	3.1	4.7	4.0	2.6	2.3	2.2	1.5	2.60
T_2	1.5	2.5	3.3	3.7	5.1	4.2	3.0	2.7	2.5	2.2	3.07
T_3	1.9	4.1	4.0	5.1	6.9	5.2	3.0	3.2	3.1	2.7	3.92
T_4	2.1	4.8	5.0	5.6	5.8	6.5	4.6	4.1	4.0	3.0	4.55
Mean	1.6	3.3	3.8	4.4	5.6	4.9	3.3	3.0	2.9	2.4	3.53
Pure pasture											
T_5	1.2	2.0	2.5	3.2	5.5	4.0	2.7	2.4	2.3	2.0	2.78
T_6	1.3	2.3	3.1	4.3	6.0	4.4	3.0	2.7	2.5	2.1	3.17
T_7	1.8	3.9	4.8	5.2	5.1	5.4	3.8	3.4	3.2	2.6	3.92
Mean	1.4	2.7	3.5	4.2	5.5	4.6	3.2	2.8	2.7	2.2	3.29
CD (P=0.05)	NS	0.2	0.3	0.4	0.5	0.6	1.0	0.7	0.7	0.4	

forage production in Guinea grass cultivated beneath of coconut trees and Sharma (2004) in jujube-based hortipasture system.

Fruit production

The fruiting of aonla started after fifth year of plantation. Average fruit yield was 2.64 t ha^{-1} in the first year (2000), 7.5 t ha^{-1} in second year (2001), 15.72 t ha^{-1} in the third year (2002), 17.40 t ha^{-1} in fourth year (2003). In the fifth year (2004) due to poor rainfall (486.1 mm in 31 rainy days) it reduced to 16.63 t ha^{-1}, while in the sixth year (2005) due to regular drought (439.8 mm rainfall in 31 rainy days) it declined to 6.67 t ha^{-1}. The N doses applied to grass plots showed significant effect as compared to control. In the sixth year due to poor rainfall nitrogen effects were not significant. Newaj *et al.* (2006) reported that grafted aonla start fruiting after 4th year of plantation and after 6 year it might produce 60-80 kg tree^{-1} with highest production in 8th year (9.58 t ha^{-1}) under agri-horti system (aonla + blackgram/ greengram). The fruit yield was not influenced with sown pasture *D. annulatum* as it only gave supplementary effect as compared with natural vegetation grown beneath the tree canopy (T_1).

Physico-chemical composition of aonla (cv. NA-7)

Average of 6 years data on physico-chemical parameters of fruit, revealed no significant differences in weight and volume of aonla fruits due to treatments (Table 4), with highest fruit weight (42.1 g) and fruit volume (42.3 cc) in T_3. The glucose content in fruit was highest in T_1 (108.7 mg g^{-1} dry weight), however, T_2 and T_4 were at par. The ascorbic acid content increased over T_1. There was not much variation in ascorbic acid content in T_3 and T_4 indicating residual nitrogen applied to the pasture plots did not influence ascorbic acid content.

Soil improvement

Significant improvement in the chemical composition of soil (30 cm depth) was observed after 10 years of aonla-based hortipastoral system with different doses of nitrogen applied to the pasture. The improvement in OC (about 92%), available N (20.8%), P (9.0%) and K (58%) were higher in hortipastoral plots as compared to sown

Table 3. Aonla fruit production (t ha^{-1}) as influenced by nitrogen application to grass

Treatment	5th year	6th year	7th year	8th year	9th year	10th year	Mean
T_1	2.20	6.54	11.86	12.77	12.10	6.53	8.66
T_2	2.75	7.32	13.93	15.34	14.37	6.70	10.06
T_3	2.49	7.71	18.10	19.97	19.48	6.73	12.41
T_4	3.12	8.52	19.00	21.54	20.59	6.75	13.25
Mean	2.64	7.50	15.72	17.40	16.63	6.67	
CD (P=0.05)	0.60	0.67	1.02	3.02	2.96	NS	

Table 4. Physico-chemical composition of aonla (cv.NA-7) over 6 years with different nitrogen levels to grass

Treatment	Fruit weight (g)	Fruit volume (cc)	TSS (°Brix)	Glucose (mg/g DW)	Ascorbic acid (mg/100g pulp)
T_1	37.1	39.2	11.9	108.7	961.9
T_2	39.4	39.5	10.9	105.6	969.4
T_3	42.1	42.3	11.2	100.2	991.7
T_4	39.4	40.0	11.5	105.4	987.3
Mean	39.5	40.1	11.4	105.0	977.6

pure pasture (Table 5). This might be due to the fact that aonla, being a deciduous tree, the litter decomposes during monsoon season adding nutrients to the soil. Organic acids present in the aonla leaves lowered the soil pH, marginally (0.2). Similarly Newej *et al.* (2006) reported soil improvement in aonla-based agri-horti system. They noticed that after 9 years of aonla plantation OC increased by 28% in black soil and 62.5% in intermixed red-black soil. It was also reported that intercrop blackgram/greengram enriched the soil with available N by nitrogen fixation.

Economics of the system

The economics of the system was calculated on 2005 market price. It was found that the pasture production with aonla tree was beneficial as compared to pure pasture. Aonla with natural vegetation and nitrogen applied to pasture production increased the net profit. The mean B:C ratio over ten year of experiment for pure pasture was 1:1.85 where as in association with aonla tree it was 1:3.70. Newaj *et al.* (2006) also reported that at the age of 13 years, the B:C ratio from aonla + blackgram was 1:3.28 and pure crop of blackgram was 1:1.23 and pure aonla was 1:1.97.

Employment generation

Due to application of nitrogen to sown pasture (*Dichanthuium annulatum*) the production increased significantly resulting in increased man-days required for harvesting of pasture (Table 6). However, through incorporating the aonla trees in sown pasture of *Dichanthium* the employment generation could be doubled from 2.07 month^{-1} to 4.15 man-days month^{-1} because of increased number of operations in orchard. Similarly Sandhu *et al.* (2000) reported growing wheat and maize annually generate only 143 man days ha^{-1}, whereas, the fruit crops such as mango, grapes and papaya annually generate 800, 2500 and 350 man days ha^{-1}, respectively. Kinnow and other mandarins generate 760, malta, limes and lemon generate 560 and guava and sapota generate 460 man days ha^{-1} year^{-1}. He also reported that a shift of 5% of irrigated area from cereal crops to horticulture can create 50% more productive employment in agriculture.

Thus, it could be concluded that aonla is a suitable fruit species for semi-arid and arid degraded lands. Under semi-arid region the interspaces of aonla plantation could be utilized by *Dichanthium annulatum* (Marvel grass) by supplying with 40-60 kg N ha^{-1} to grass with recommended dose of FYM and fertilizers to aonla tree which gave forage (3-4 t DM ha^{-1}) and fruit 10-13.25 t ha^{-1}. It is an economically viable (cost benefit ratio 1:3.70), ecologically feasible (improved soil fertility) and socially accepted i.e. generate employment (4.15 man days month^{-1}) to minimize migration from rural areas.

Table 5. Soil Changes (30 cm depth) after 10-year under aonla-based hortipastoral system

Composition	1996	2005	
	Initial soil	Tree + pasture	Pure pasture
Organic C (%)	0.23-0.27	0.41-0.55	0.38-0.42
Available N (kg ha^{-1})	140-148	159.9-188.2	150-152.6
Available P (kg ha^{-1})	3.8-4.1	4.3-4.9	3.9-4.0
Available K (kg ha^{-1})	110.7-124.3	174.9-196.4	164.2-168.1
pH	6.54	6.34	6.51

Table 6. Employment generation in pure pasture and aonla-based hortipasture

Treatment	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year	Total (man days month^{-1})
T_1	102	31	31	28	37	45	54	52	50	46	476 (3.9 month^{-1})
T_2	125	35	38	35	47	55	64	61	56	48	564 (4.7 month^{-1})
T_3	122	38	40	37	52	60	70	67	58	52	597 (4.96 month^{-1})
T_4	124	40	43	43	60	68	77	74	63	57	649 (5.4 month^{-1})
T_5	36	17	21	23	26	26	23	21	19	13	225 . (1.87 month^{-1})
T_6	38	19	23	25	28	28	25	23	21	15	249 (2.04 month^{-1})
T_7	39	19	26	35	33	32	28	26	22	16	276 (2.3 month^{-1})

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