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Dynamics of vegetative morphomatrix, productivity and economics of NA 7 aonla (*Emblica officinalis*) in different planting systems under rainfed conditions

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ABSTRACT

A field experiment was conducted to determine the effects of different planting systems and densities on plant growth and their relation to yield and quality attributes of NA 7 aonla (*Emblica officinalis* Gaertn) during the years 2011-2013 under rainfed hot semi- arid ecosystem of western India. The present study contained 5 planting systems as treatments namely, square, hedgerow, double hedge row, cluster and paired system. Different planting systems significantly influenced the vegetative growth, yield and quality of fruits during both the years of experimentation. The highest plant height was noted in double hedgerow system (7.80 m) and the lowest in paired system (7.08 m). Consequently, the rootstock (59.82cm), scion girth (58.38 cm) and plant spread (6.99 cm) was measured maximum in square system of planting. However, these parameters were measured the lowest in double hedgerow followed by hedgerow and cluster planting systems. Result of study revealed that the mean yield/plant (110.24 kg) was recorded the highest in square but the yield/ha were recorded maximum in double hedgerow (225.90 q) followed by hedgerow (202.65 q) and cluster (170.37 q). During the experimentation, a considerable difference in yield over previous year was observed among the different planting systems. An increase in yield over square system by the rest of the system ranged between 83.8% - 132.39% being highest in double hedgerow and lowest in paired system, whereas per cent increase in yield in double hedgerow over other systems ranged between 26.44-132.39 being the maximum and minimum upon square and hedgerow systems of planting, respectively. There were significant differences amongst different planting system with regards to fruit physical and quality attributes. Among the different planting systems, the square system exhibited better values for physical qualities, whereas chemical attributes like TSS, total sugar, vitamin C and total phenols were observed maximum in double hedgerow planting system. The net economic return was computed with double hedgerow (₹ 192 270.00 and 243 035.00) followed by hedgerow (₹ 150 800.00 and ₹ 195 650) and it was minimum in square (₹ 83 950.00 and ₹ 107 605.00) system of planting.

Key words: Aonla, Double hedgerow, Economics, Planting systems and Yield

Aonla or Indian gooseberry (*Emblica officinalis* Gaertn) is an important and remunerative fruit crop for dry tract of country. In addition to its therapeutical and nutraceutical uses, it has better scope of value added products. Aonla has been bestowed with some special characters by the nature like the hardiness and adaptability to varied agro-climatic conditions, intensive and deeper root system, summer dormancy of zygote, synchronization of fruit growth and development with maximum soil moisture availability which enable it to grow in aberrant agro-climatic conditions particularly in arid and semi-arid ecosystem (Pathak and Pathak 2001, Korwar *et al.* 2006, Singh *et al.* 2012). The NA 7 aonla is a precocious in bearing, upright semi spreading growth habit, early maturing and prolific bearer and therefore, prompts the growers to go far its cultivation to harness more benefits by maximizing the productivity under rainfed conditions. During recent years, owing to the dwindling in per capita land holdings, for attaining high orchard productivity, high density plantings has become the need of hour which also ensures better utilization of biotic and abiotic resources which ultimately leads to higher productivity.

During the past few years, considerable progress has been made in aonla cultivation in arid and semi-arid region, but precise information on how to increase yield per unit area by following different planting systems in aonla is still scanty which needs to be exploited for making aonla cultivatation more remunerative especially areas having fragile agro-climatic conditions. High density planting with combination of various planting systems has been successfully demonstrated in mango (Singh *et al.* 2001, Gunjate *et al.* 2002, Mistry and Patel 2006), litchi (Rathore *et al.* 2003) and guava (Mahajan *et al.* 2005). Considering these reports, it appears that planting geometry and manipulation in the spacing acts as an important tool to obtain higher production and productivity (Bose *et al.*1992). There is dearth of information on suitable planting systems

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for enhancing the productivity with quality produce on the economical potential of aonla under rainfed conditions, previously Singh *et al.* (2007 and 2011) has reported the effect of different planting systems during the initial 7 years of orchard life under the present experiment in which plant have not attained age to assess their economic yield. In the present study, an attempt was made to critically analyze the vegetative morphomatrix, productive potential and quality attributes of aonla plants attained economic stage in different planting systems under rainfed hot semi-arid ecosystem. This would help orchardist in formulating a planting plan for aonla to bridge the productivity gap for sustaining production over long period.

MATERIALS AND METHODS

A trial on different planting systems was conducted on 11 and 12 years old NA-7 aonla, established through *in-situ* patch budding during 2001, at the Experimental Farm of Central Horticultural Experiment Station (CIAH), Vejalpur, Panchmahals (Godhra), Gujarat (22^0 41'' 38'' N and 73^0 33' 38'' and 113 to 115 m above mean sea level) during two consecutive years of 2011-2013. The area is characterized by semi-arid hot climate. The actual annual water needed or potential evapotranspiration of the area ranges between 1500 to 1600 mm, whereas actual mean usual precipitation is about 831 mm. The mean monthly maximum temperature ranges from 26 and 41°C, while the minimum monthly temperature varies between 10°C and 26°C. The soil type was clay-to-clay loam in texture with available N 151.00, P 7.53 and K 170.50 kg/ha, slightly alkaline (pH 7.90) in reaction while EC of the experiment soils was 0.13 ds/m. The soil depths range from 0.75 to 1.0 meter, derived from mixed alluvial basalts, quartzite, granite, and having layers of limestone just below the soil depth. Uniform cultural practices were followed during the course of study in different planting system. Experiment comprised five treatments of planting systems, viz. T_1, square (9 plants/ plot); T_2, hedgerow (15 plants /plot); T_3, double hedgerow (20 plants / plot); T_4, cluster system (16 plants/ ha) and T_5, paired (12 plants/plot) planting systems which were replicated four in randomized block design considering each planting system as treatment. For commercial exploitation of various planting geometries, the actual plant population was 100, 130, 200, 169 and 260 in square, paired, hedgerow, cluster and double hedgerow planting system respectively in one ha area. Net area of plot of the each treatment was 900 m^2 (30 m × 30 m) and total area of the experimental field was18000 m^2, i.e. 1.8 ha. The plot size was 30 m × 30 m for one treatment (planting system). Prevailing planting distance 10 m × 10 m apart and its half distance 5m × 5m apart was followed in plot in trial. Normal planting distance was maintained in square system of planting (10 m × 10 m). In hedgerow planting system, distance between row-to-row and plant-to-plant was kept 10 m and 5m, respectively, while in double hedgerow system, two rows of hedge were planted at half of distance (5m × 5m). In case of paired planting system, pair of two plants at the distance of 5m × 5m in between the rows and 10 m within row and 6 pair per plot were maintained, whereas in cluster planting system a cluster of 4 plants at 5m × 5m apart were accommodated, hence 4 clusters per plot (30m × 30m) were adjusted.

Data on growth parameters like plant height, rootstock girth, scion girth, plant spread were recorded in October during both the years. Fruits of uniform physiological age were selected randomly from each treatment from all directions of the plant and were subjected to various quantitative and qualitative characters. Quality attributes such as total soluble solids (TSS) was measure through hand refrectmeter. Sugar, acidity, total phenols and vitamin C were estimated as per standard methods described by AOAC (1990).

RESULTS AND DISSCUSSION

A thoughtful perception of the data revealed that different planting systems influenced significantly on various aspects studied on commercial variety NA 7 aonla under rainfed conditions of hot semi-arid ecosystems.

Growth

The data on effect of different planting systems on plant growth presented in Table 1 revealed that the plants of double hedgerow system (T_3) attained maximum plant height (7 .63 m and 7.98 m) followed by T_2 and T_4 whereas the same was minimum in square system (7.10 m and 7.25 m) closely followed by paired system (T_5) during 2011-12 and

Table 1 Effect of high density planting systems on the vegetative growth parameters of aonla

Treatment	Plant height (m)			Root stock girth (cm)			Scion girth (cm)			Plant spread (m)		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean
Square	7.10	7.25	7.17	59.35	60.29	59.82	58.12	58.97	58.38	6.87	7.12	6.99
Hedge row	7.47	7.67	7.57	54.67	55.84	55.25	51.73	52.41	52.07	6.12	6.25	6.18
Double hedgerow	7.63	7.98	7.80	53.49	54.85	54.17	51.00	52.05	51.52	5.89	6.00	5.94
Cluster	7.40	7.61	7.50	56.00	57.70	56.85	55.00	56.82	55.91	6.12	6.29	6.20
Paired	7.16	7.00	7.08	57.94	58.17	58.05	57.33	57.75	57.54	6.75	6.97	6.80
CD(P=0.05)	0.30	0.37		2.86	3.44		4.93	4.78		0.48	0.80	

T_1- Square system, T_2-Hedgerow system, T_3-Double hedgerow system, T_4-Cluster system and T_5-Paired system

2012-13. Ram and Sirohi (1996) had reported that the plants under high density planting attained more height than that of normal density after 8th year in mango var. Dashehari. Continuous increases in rootstock and scion girth were observed in the plants at all the stages under various planting systems. Rootstock girth was recorded the maximum (59.35 cm and 60.29cm) in T_1 (square system) followed by T_5 and T_4 whereas the same was found the minimum in T_3 (53.49 cm and 54.85 cm) followed by T_2 and T_4 during both the years of experimentation. The scion girth of the plants of all the planting systems ranged between 51.00 cm - 58.12 cm and 52.05 cm - 58.97 cm being highest in T_1 (58.97 cm) followed by T_5 and T_4 while it was noted the lowest in T_3 (51.52 cm) followed by T_2. Conspicuous reduction in the rate of plant spread was observed after 10^{th} year in double hedgerow planting system which exhibited lowest spread under rainfed semi-arid environment of central Gujarat. The maximum plant spread (6.99 m) was obtained in T_1 followed by T_5 and T_4 whereas minimum values for the same was recorded in T_3 (5.94 m) followed by T_2 and T_4. A sharp increase in the height was noticed in case of T_3 and T_2 planted at closer spacing (double hedgerow). In general, the plant had tendency to grow vertically in quest of light and due to insufficient space at lateral side between plant to plant and row to row, whereas the plants at wider spacing has plenty space to spread their canopy laterally in comparison to closer spacing. Availability of nutrient and more exposure of plant to sun might have increased the photosynthesis resulting into better development of plant stem in square and paired system of plantings. These results are in accordance with the findings reported by Stamper *et al. (*1996), Tachibana (1990), Bal and Dhaliwal (2003) and Ram and Sirohi (1991) in different fruit crops.

Yield

With advancement of age, the productivity rose significantly in all the systems of planting and interacted with age indicating independent variation in each system with age. Data on yield parameters have been presented in Table 2 clearly revealed that the productivity as a function of individual tree is higher in square system but by accommodating higher plant population in double hedgerow led to almost more than double the production. Under semi-arid ecosystem of Godhra conditions, during the initial years of orchard life, significant differences for yield/tree was not observed among the different planting systems. However, in later stages the yield/tree increased in square system than rest of the systems. The yield/tree was obtained maximum from square system (98.00 and 122.48 kg) followed by paired and cluster system, whereas the same was minimum in double hedgerow system (88.50 and 108.35 kg) followed by hedgerow which showed reduction in yield in comparison to square system after 10 years. This may be due to unavailability of space for lateral growth for fruiting due to overcrowding state of orchard life prevailing in double hedgerow planting system whereas in wider spacing, more effective leaf space, higher leaf to fruit ratio and bigger vegetative dimension of the plant might have resulted to produce large number of bigger size fruits/tree. Pandey and Majumdar (1998) also reported a decline in yield /plant of Amrapali mango in high density planting after 11 years under Delhi conditions. However, the maximum mean yield/ ha was recorded in T_3 (255.90 q) followed by T_2 and T_4. The minimum yield/plot and yield /ha (9.92 q/plot and 110.24 q/ha) was observed in T_1 followed by T_5. However, if productivity per unit area basis is considered, it is obvious that double hedgerow had given significantly higher yield than square and paired systems of planting.

This effect is due to huge differences in number of tree per unit area under different planting systems. Such an increase in production through high plant population per unit area has been achieved by Anbu *et al.* (2001) in mango, Chadha *et al.* (1973) in pine apple, Bal and Dhaliwal (2003) and Chundawat *et al.*(1992) in guava, Gupta and Bist (2005) in pear, Sharma *et al.* (1992) in mandarin and Rathore *et al.* (2003) in litchi. An increase in yield in different planting systems over square system varied between 25.26% and 132.39% and it was highest in double hedgerow and the lowest in paired system of planting whereas the per cent increase in yield in double hedgerow system over rest of the planting system ranged between 26.44 -132.39. The maximum increment in yield was computed in double hedgerow which was more than double over square system, whereas the minimum of the same was recorded with hedgerow planning system.

Quality

Results of study on various quality attributes revealed that the physical and chemical attributes had significant differences among the different planting systems.

Physical attributes

The close look at the data presented in Table 3 revealed that different planting systems influenced physical attributes of aonla in terms of weight, fruit size, pulp weight, seed weight and specific gravity under various planting systems. The fruit weight ranged between 45.19- 48.00 g and 45.05-46.86 g during both the years. The highest fruit weight, fruit diameter and fruit length was recorded 47.43 g, 4.24 cm and 4.12 cm respectively in T_1 (square system) followed by T_5 and T_4, whereas the lowest fruit weight, fruit length and fruit diameter were recorded in T_3 (45.12 g, 3.99 cm and 4.14 cm) followed by T_4 and T_2. The maximum fruit pulp and seed weight (45.37 and 2.06 g) were also recorded in T_1 followed by T_2 and T_4 in regards to fruit pulp and seed weight respectively, while the minimum values for the same were recorded in T_3 (43.63 and 1.99 g) followed by T_2 and T_4.

The specific gravity of the fruits under different planting systems in both the years ranged between 1.01-1.03 and 1.01-1.04 being highest in double hedgerow planting system, but differences among the treatment could not reach the level of significance. The difference in physical attributes of fruit of different planting systems might be due to

Table 2 Dynamics of yield in high density planting systems of aonla under rainfed conditions

Treatment	Yield/plant (kg)			Yield/plot (q)			Yield/ha (q)			Increase in yield over square system (%)			Increase in yield in DHR over other systems (%)		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean
Square	98.00	122.48	110.24	8.82	11.02	9.92	98.00	122.48	110.24			134.79	130.00	132.39	
Hedge row	89.95	112.70	101.32	13.49	16.90	15.19	179.90	225.40	202.65	83.57	84.03	83.8	27.90	24.98	26.44
Double hedgerow	88.50	108.35	98.42	17.70	21.67	19.68	230.10	281.71	255.90	134.79	130.00	132.39			
Cluster	91.00	110.63	100.81	14.56	17.70	16.13	153.79	186.96	170.37	56.92	52.64	54.78	49.61	50.06	49.83
Paired	93.47	119.24	106.35	11.21	14.30	12.75	121.51	155.01	138.26	23.97	26.55	25.26	89.36	81.73	85.54
CD(P=0.05)	3.50	05.13		3.88	04.65		54.99	120.23							

DHR-Double hedge row

Table 3 Effect of high density planting systems on physical quality attributes of aonla

Treatment	Fruit weight (g)			Fruit diameter (cm)			Fruit length (cm)			Pulp weight(g)			Seed weight (g)			Specific gravity		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean
Square	48.00	46.86	47.43	4.27	4.22	4.24	4.15	4.10	4.12	45.93	44.81	45.37	2.07	2.05	2.06	1.01	1.01	1.010
Hedge row	46.47	46.13	46.30	4.22	4.18	4.20	4.10	3.94	4.02	44.97	45.00	44.98	2.03	2.00	2.01	1.02	1.03	1.025
Double hedgerow	45.19	45.05	45.12	4.17	4.12	4.14	4.00	3.98	3.99	44.19	43.07	43.63	2.00	1.98	1.99	1.03	1.04	1.035
Cluster	47.00	46.05	46.52	4.23	4.17	4.20	4.12	3.94	4.03	44.44	44.10	44.27	2.03	2.03	2.03	1.01	1.03	1.020
Paired	47.10	46.42	46.76	4.25	4.20	4.22	4.10	4.05	4.07	45.06	44.39	44.72	2.04	2.03	2.03	1.02	1.02	1.020
CD(P=0.05)	1.81	1.75		0.06	0.08		0.09	0.26		0.64	0.83		0.04	0.03		NS	NS	

Table 4 Effect of high density planting systems on chemical quality attributes of aonla fruits

Treatment	TSS (^{0}brix)			Total sugar (%)			Reducing sugar (%)			Non-reducing sugar (%)			Acidity (%)			Vitamin C (mg/100g)			Total phenols Mg/100g		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean
Square	9.50	8.45	8.97	5.24	5.28	5.26	3.23	3.21	3.22	2.01	2.07	2.04	2.21	2.20	2.20	494.15	498.20	496.17	171.51	169.05	170.28
Hedge row	9.25	9.30	9.27	5.82	5.80	5.81	3.25	3.10	3.17	2.57	2.56	2.56	1.98	2.10	2.04	502.15	505.27	503.71	169.59	168.80	169.19
Double hedgerow	9.50	9.50	9.50	5.97	5.98	5.97	3.42	3.30	3.37	2.60	2.58	2.56	2.05	2.00	2.02	508.00	510.73	509.36	174.16	171.29	172.72
Cluster	9.30	9.40	9.35	5.45	5.52	5.48	3.21	3.21	3.21	2.24	2.31	2.27	2.20	2.05	2.12	504.24	504.40	504.32	172.13	170.4	171.17
Paired	8.75	8.70	8.72	5.20	5.24	5.22	3.06	3.04	3.05	2.14	2.20	2.17	2.18	2.15	2.18	491.15	496.33	493.74	172.98	170.56	171.77
CD(P=0.05)	0.31	0.41		0.32	0.44		0.15	0.20		0.27	0.30		NS	NS		06.85	08.40		1.617	1.39	

Table 5 Dynamics of economics in various planting systems of aonla under rainfed conditions

Treatment	Gross income/ha (₹)			Input cost/ha (₹)			Net income/ha (₹)		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean
Square	98000.00	122480.00	110240.00	14550.00	14875.00	14712.50	83450.00	107605.00	95527.50
Hedge row	179900.00	225400.00	202650.00	29100.00	29750.00	29425.00	150800.00	195650.00	173225.00
Double hedgerow	230100.00	281710.00	255905.00	37830.00	38675.00	38252.50	192270.00	243035.00	217652.50
Cluster	153790.00	186960.00	170375.00	24589.50	25138.75	24864.13	129200.50	161821.30	145510.90
Paired	121510.00	155010.00	138260.00	18915.00	19337.50	19126.25	102595.00	135672.50	119133.80

availability of nutrients in wider spaced plants and competition for nutrients and less exposure to sunlight among closer spaced plant under various planting systems. More or less similar findings have been reported by Chundawat *et al. (*1992), Pandey *et al.* (1997), Mahajan *et al.* (2005) and Kumar and Singh (2000) in guava under different agro-climatic conditions of India.

Chemical attributes

It is evident from the data in Table 4 that the fruits from trees in double hedgerow tended to show higher values for TSS, total sugar, vitamin C and total phenols and exhibited significant differences for their quality attributes and lower values for acidity under rainfed conditions of western India. The mean value of TSS (9.50%), total sugar (5.97%), non-reducing sugar (2.56%), reducing sugar (4.37%) and vitamin C content (509.36 mg/100g) were recorded maximum in the treatment T_3 (double hedgerow system) closely followed by T_2 and T_4, whereas TSS (8.72%), total sugar (5.22%), reducing sugar (3.05%) and vitamin C (493.74 mg/100g) were observed the minimum in paired system followed by T_1 (square system). The highest acidity (2.18%) was observed in T_5 while total phenols was found maximum in T_3 (172.72 mg) followed by T_5 and T_4. However, per cent acidity of fruit pulp among the treatments were found to be non-significant. Higher acidity of the fruits harvested from the trees planted at wider spacing may be ascribed to the higher nitrogen content which might be led to the increased synthesis of organic acids. Similarly the reduction in vitamin C in paired and square systems could be due to increased oxidation and degradation along with dilution processes (Vig and Kelly 1982, Ajitpal and Dhaliwal 2004, Nath *et al.* 2007).

Economics

A perusal of data in the Table 5 revealed that the all the planting systems exhibited wide differences in their net profit during both the years of experimentation. The maximum net return was computed in double hedgerow (₹ 192 270 and ₹ 243 035) followed by hedgerow and cluster, whereas it was computed the lowest in square system (₹ 83 450 and ₹ 107 605) followed by paired system of planting. Similar observation were reported Singh *et al.* (2011) in aonla, Chadha *et al.* (1973) in pine apple and Chundawat *et al.* (1992) in guava under different agro-climatic conditions of India.

Based on the observations on various aspects, it may be deduced that owing to reduced crop weed competition and better utilization of resources like space, moisture, light, nutrients, the double hedgerow planting system in aonla demonstrated exclusively better results in terms of yield and quality which assure the benefit for the farmers of semi-arid region and can be adopted by aonla growers for getting better productivity per unit area under rainfed conditions.

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