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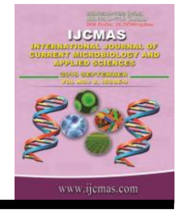

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# Effect of Organic and Inorganic fertilizers along with Azotobacter on Growth, Yield and Quality of Aonla (*Emblica officinalis gaertn.*) Cv. Na-7

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**A B S T R A C T**

An experiment was conducted to find out the effect of organic and inorganic sources of fertilizers along with bioinoculants on growth, yield and quality of aonla cv. NA-7 during 2016 and 2017. Maximum increment in vegetative parameters viz., increment in plant height (10.92%), plant spread (13.91% NS and 13.88% EW) and canopy volume (40.32%) was recorded with the application of cent per cent nitrogen through urea and *Azotobacter* with recommended dosage of SSP and MOP. Yield parameters viz., fruit length (4.52 cm), fruit diameter (5.24 cm), fruit weight (48.56 g), fruit volume (47.80 cc), pulp weight (40.49 g) number of fruits per tree (2389.57) were recorded maximum when 25 per cent of nitrogen was applied as FYM and 75 per cent was applied as urea along with *Azotobacter* application. Maximum yield per tree (116.05) was also recorded under the same treatment combination. All the fruit quality parameters improved with the integrated application of FYM along with inorganic fertilizers and biofertilizers. The total soluble solids (11.26 $^{0}$Brix), total sugars (6.72 per cent) and reducing sugars (3.42 per cent) were found maximum in fruits receiving 50 per cent nitrogen in the form of FYM and 50 percent through urea augmented with *Azotobacter*, whereas the ascorbic acid content was found maximum (625.23 mg/100g of pulp) with cent per cent nitrogen through application of FYM augmented with *Azotobacter*. The results suggested that 25 per cent nitrogen can be replaced through chemical fertilization along with FYM on N-equivalent basis plus *Azotobacter* inoculation.

## Introduction

Aonla or Indian gooseberry (*Emblica officinalis* Gaertn. Syn. *Phyllanthus emblica*) belongs to the family Euphorbiaceae, is one of the important indigenous fruits of Indian subcontinent, known for its medicinal and therapeutic properties and considered as a wonder fruit for health conscious population. It is the richest source of vitamin C (400-1300 mg/100 g from pulp) among the fruits next to Barbados cherry (Mandal *et al.*, 2013). Soil type, fertility and nutrient management play an important role in obtaining higher growth and yields of aonla. Inadequate nutrition has very often been attributed as the cause of lower yields in aonla. Therefore, balanced nutrition is important, both for young growing plants as well as grown up fruit bearing trees. However, a bearing tree requires balanced nutrient application for maintenance of vegetative growth along with fruit production. Indiscriminate use of chemical fertilizers had adversely affected the soil fertility, water quality, yield and quality of the produce and increased level of resistance in pests (Kalloo, 2003). Due to poor physical properties of soil it becomes very hard during season and crop suffers due to deficiency of major plant nutrients. Crop nutrition is one of the most essential factor, which greatly affect the yield and quality of Aonla (Mustafa *et al.*, 2013). Fruit productivity and quality can be maintained in subsequent generation by integrated nutrient management system and contribute share in input cost of production (Singh *et al.*, 2012). Therefore efficient use of integrated plant nutrient supply system is a prerequisite for achieving continuous advances in productivity of fruits crops in ecologically sustainable manner (Chundawat, 2001). This calls for moving away from chemical agriculture and embracing organic matter management, which improves all soil properties and brings nitrogen through organic manures and useful microorganisms. Since nitrogen is the main nutrient required for plant growth, the use of organic source is being encouraged for N management as nitrogen is released slowly rather than instantly as seen in water-soluble, inorganic fertilizer sources. Organic manures like farmyard manure, which is a storehouse of major nutrients apart from containing considerable amount of macro and micronutrients and have potential to improve yield to save costly chemical fertilizers. Incorporation of inoculants like *Azotobacter* either sole or in combination with inorganic and organic fertilizers have shown to improve nutrition of plants through biological nitrogen fixation and also secretion of some growth, nutrition and microbial activity in the rhizosphere. The present study, therefore, was conducted to evaluate the effect of conjoint use of organic and inorganic sources of nutrients along with biofertilizers on growth, yield and quality attributes in aonla in Jammu sub-tropics.

## Materials and Methods

The present studies were conducted at Farmers Field, Akhnoor, Jammu on ten years old aonla trees having uniform size and vigour. The experimental field has sandy loam soil and soil was acidic in reaction with pH 6.92, 0.70 dS/m electrical conductivity and 0.72% organic carbon content. A total of 12 treatments replicated thrice were executed in randomized block design *viz.*, $T_1$ (100% N as urea), $T_2$ (25% N as FYM and 75% N as urea), $T_3$ (50% N as FYM and 50% N as urea), $T_4$ (75% N as FYM and 25% N as urea), $T_5$(*Azotobacter*+$T_1$), $T_6$ (*Azotobacter*+$T_2$), $T_7$ (*Azotobacter* + $T_3$), $T_8$ (*Azotobacter*+$T_4$), $T_9$ (*Azotobacter*+100% N as FYM), $T_{10}$ (100% N as FYM), $T_{11}$ (*Azotobacter* application only) and $T_{12}$ (Control). *Azotobacter* culture was applied near active root zone @ 200 g/tree. Recommended dose of Phosphorus ($P_2O_5$) and potassium ($K_2O$) were applied in all treatments as per the recommendations in package of practices of SKUAST-J. Farmyard manure was applied to the trees around the trunk in the first week of February. *Azotobacter* with a uniform dose of 200 g plant$^{-1}$ was mixed in jaggery solution prepared separately for each tree and were fed to roots as per the treatment details after 20 days from the application of inorganic fertilizers. The urea was applied in two split doses; *viz.* first in last week of Februarys and another in August. Plant height was recorded with the help of marked bamboo stick from the ground surface to the maximum height attained by the plant before fertilizer application (BFA) and after fruit harvest (AFH). The same was recorded in meter (m) and expressed as per cent increase in plant height using the formula : Per cent increase in plant height= Plant height (AFH) - Plant height (BFA)/ Plant height (BFA) × 100. Plant spread was recorded for each tree before fertilizer application (BFA) and after fruit harvest (AFH) by putting the marked bamboo stick horizontally with the tree from east-west and north-south and mean spread was worked out in meter (m). The same was expressed as per cent increase in plant spread using the formula :

Per cent increase in plant spread= Plant spread (AFH) – Plant spread (BFA)/ Plant spread (BFA) x 100.

Canopy volume ($m^3$) of the respective trees for each treatment was calculated as per the formula given by Westwood *et al.,* (1963) and expressed as per cent increase as above. Total number of fruits was recorded at the time of harvesting and the results were expressed as number of fruits per tree. The total number of fruits harvested per tree and average fruit weight were taken into consideration to work out the yield per tree in kilograms. A random sample of 10 healthy fruits from each treatment was obtained for physical quantification of the fruits and expressed as mean values. Fruit length and fruit diameter were recorded for individual fruit using Digital Vernier's Caliper. For pulp weight, pulp of ten selected fruits was separated from the stone by using sharp stainless steel knife. Pulp and stone weights were measured separately on digital electronic balance. The mean weight of pulp and stone of each treatment was expressed in gram (g). Fruit weight was measured using electronic balance. Fruit volume was determined by displacement method. The fruit quality parameters were analyzed following standard procedure as described by AOAC (1984). The data generated during the course of study was subjected to statistical analysis as prescribed by Panse and Sukhatme (2000).

## Results and Discussions

Vegetative growth of aonla tree was significantly affected by the application of different combinations of FYM, urea and *Azotobacter*. Results revealed that maximum increase in plant height (10.92%), plant spread (13.91% NS and 13.88% EW) and canopy volume (40.32%) was recorded with the application of cent per cent nitrogen in the form of urea along with *Azotobacter* ($T_5$) whereas minimum increase in plant height (5.70%), plant spread (5.44 % NS and 5.67% EW) and canopy volume (16.73%) was recorded under control ($T_{12}$). However, treatment $T_6$ was equally effective (Table 1). The maximum increase in vegetative growth characters of aonla under these treatment combinations is supported by the fact that nitrogen through urea is readily available to the plant, which increased the vegetative growth abruptly contrary to other treatments where nitrogen was released slowly as reported by Umar *et al.,* (2009). Secondly, increased nitrogen availability is affected by higher percentage of nitrogen through urea in association with nitrogen fixing culture has been documented by Bambal *et al.,* (1998) whereas increment in plant height and spread by biofertilization with *Azotobacter* in combination with inorganic fertilizers may be due to the fact that nitrogen as fixed by *Azotobacter* and being a constituent of protein and chlorophyll, plays a vital role in photosynthesis. It enhances accumulation of carbohydrates which, in turn, increases growth of the plants (Boughalleb *et al.,* 2011). Saraf and Tiwari (2004) found that phytohormones extracted from FYM help the plant to grow more luxuriously even with reduced doses of chemical fertilizers.

Data regarding fruit length, fruit diameter and yield characteristics of aonla is presented in Table 2. From the perusal of pooled data, results reveal that the application of 25 per cent nitrogen per tree through FYM + 75 per cent nitrogen/tree was applied in the form of urea along with *Azotobacter* ($T_6$) resulted in maximum fruit length (4.52 cm), fruit diameter (5.24 cm), fruit weight (48.56 g), pulp weight (40.49 g), fruit volume (47.88 cc) number of fruits per tree (2389.56) and fruit yield (116.05 kg/tree).

However, results for these parameters were at par with treatment $T_5$ and minimum were recorded under control. Specific gravity of aonla fruits did not show any specific pattern. The increase in average fruit size are due to the optimum supply of plant nutrients in right amount during entire crop period and growth promoting hormones produced by *Azotobacter* applied with different treatment combinations (Vishwakarma *et al.,* 2017).

The increase in average fruit weight due to the integration of organic sources of nutrients occurred due to accelerated mobility of photosynthates from source to sink as influenced by the growth hormones, released or synthesized due to organic sources of nutrients. The increase in fruit volume may be attributed to the corresponding increase in length and diameter. Bio- fertilizers increased the level of plant growth regulators in plants which favoured cell enlargement (Bhatia, *et al.,* 2001 and Singh *et al.,* 2012).

The enhancement in yield mainly because of proper supply of nutrients, induction of growth hormones and better solute uptake by the plants which stimulated cell division, cell elongation, increase in number of fruit and weight, ultimately increased fruit yield.

These results are in accordance with the findings of Yadav *et al.,* (2007) and Mustafa *et al.,* (2013) in aonla.

Beneficial effect of integrated sources on yield of aonla could be attributed to the fact that FYM after proper decomposition and mineralization supplied available nutrients directly to the fruits, which had solublizing effect on fixed forms of nutrient in soil and had improved physio-chemical and microbial environment leading to better expression of response to applied chemical fertilizers these are important constituents of nucleotides, protein, chlorophyll and enzymes, taking part in various metabolic processes and having direct impact on vegetative and reproductive phases of fruits. *Azotobacter* tended to promote nitrogen fixation and biosysnthesis of plant growth regulators like IAA and $GA_3$ and hence positively influenced production of fruit trees (Venkateshwarlu and Rao, 1983). The existence of favourable nutritional environment under the influence of bio-fertilizers, FYM and inorganic fertilizers had a positive influence on vegetative and reproductive growth, which ultimately led to realization of higher yield. Manjare *et al.,* (2018) reported that application of *Azotobacter* along with full dose of chemical fertilizers with highest number of fruits per tree and yield per tree in sapota.

Table.3 reveals chemical characteristics of aonla fruits. From the perusal of pooled data, maximum TSS (11.26 $^0$Brix), TSS acid ratio total sugars (6.72%), reducing sugars (3.42%) and non reducing sugars (3.15%) respectively, with the application of 50 per cent nitrogen/tree through FYM + 50 % through urea augmented with Azotobacter ($T_7$) which was at par with $T_6$ while minimum total soluble solids and sugar content were recorded under control ($T_{12}$).

**Table.1** Effect of FYM, urea and *Azotobacter* on per cent increase in plant height, plant spread and canopy volume in aonla cv. NA-7 (Pooled mean of two years)

| Treatments | Plant height (%) | Plant spread Canopy volume (%) | | |
|---|---|---|---|---|
| | | (N-S) | (E-W) | |
| **$T_1$ (100% of N/tree through Urea)** | 9.32 | 11.66 | 11.87 | 34.51 |
| **$T_2$ (75% N through Urea+ 25% through FYM)** | 9.07 | 10.20 | 10.57 | 31.05 |
| **$T_3$ (50% N through Urea + 50% through FYM)** | 8.90 | 9.50 | 10.17 | 29.96 |
| **$T_4$ (25% N through Urea + 75% through FYM)** | 7.96 | 7.86 | 8.16 | 26.63 |
| **$T_5$ (*Azotobacter* + $T_1$)** | 10.92 | 13.91 | 13.88 | 40.32 |
| **$T_6$ (*Azotobacter* + $T_2$)** | 10.39 | 12.66 | 12.73 | 37.12 |
| **$T_7$ (*Azotobacter* + $T_3$)** | 9.09 | 11.69 | 11.83 | 32.92 |
| **$T_8$ (*Azotobacter* + $T_4$)** | 8.60 | 10.37 | 10.75 | 30.30 |
| **$T_9$ (*Azotobacter* + 100% N through FYM)** | 7.83 | 8.17 | 8.36 | 25.66 |
| **$T_{10}$ (100% N through FYM)** | 6.45 | 7.95 | 8.05 | 22.29 |
| **$T_{11}$ (*Azotobacter* @ 200g/tree)** | 6.16 | 6.87 | 7.14 | 20.48 |
| **$T_{12}$ (Control)** | 5.70 | 5.44 | 5.56 | 16.73 |
| **CD (5%)** | **1.21** | **1.57** | **1.35** | **3.35** |

**Table.2** Effect of FYM, urea and *Azotobacter* on fruit physical characters and yield of aonla cv NA-7 (Pooled mean of two years)

| Treatments | Fruit length (cm) | Fruit diameter (cm) | Pulp weight (g) | Fruit weight (g) | Fruit volume (cc) | Specific gravity | No. of fruits/tree | Fruit yield Kg/tree |
|---|---|---|---|---|---|---|---|---|
| **$T_1$ (100% of N/tree through Urea)** | 4.07 | 4.27 | 37.45 | 40.49 | 40.68 | 0.99 | 2181.22 | 88.32 |
| **$T_2$ (75% N through Urea+ 25% through FYM)** | 4.27 | 4.46 | 39.60 | 44.99 | 44.75 | 1.00 | 2255.87 | 102.55 |
| **$T_3$ (50% N through Urea + 50% through FYM)** | 4.22 | 4.34 | 38.42 | 43.13 | 42.89 | 1.00 | 2243.00 | 94.00 |
| **$T_4$ (25% N through Urea + 75% through FYM)** | 3.98 | 4.21 | 36.30 | 39.95 | 39.90 | 0.99 | 2177.65 | 82.77 |
| **$T_5$ (*Azotobacter* + $T_1$)** | 4.48 | 5.19 | 40.34 | 47.44 | 47.05 | 1.00 | 2283.74 | 108.35 |
| **$T_6$ (*Azotobacter* + $T_2$)** | 4.52 | 5.24 | 40.59 | 48.56 | 47.80 | 1.01 | 2389.57 | 116.05 |
| **$T_7$ (*Azotobacter* + $T_3$)** | 4.38 | 5.09 | 40.07 | 46.49 | 45.76 | 1.01 | 2245.78 | 103.38 |
| **$T_8$ (*Azotobacter* + $T_4$)** | 4.18 | 4.31 | 39.35 | 42.05 | 42.00 | 0.99 | 2235.65 | 96.74 |
| **$T_9$ (*Azotobacter* + 100% N through FYM)** | 4.08 | 4.20 | 35.72 | 38.14 | 38.30 | 0.98 | 2170.00 | 87.00 |
| **$T_{10}$ (100% N through FYM)** | 3.98 | 4.17 | 35.38 | 37.44 | 37.68 | 0.98 | 2137.94 | 80.04 |
| **$T_{11}$ (*Azotobacter* @ 200g/tree)** | 3.95 | 4.08 | 34.63 | 36.64 | 37.05 | 0.99 | 2133.56 | 77.11 |
| **$T_{12}$ (Control)** | 3.67 | 3.74 | 31.28 | 34.05 | 34.41 | 0.98 | 2093.38 | 71.28 |
| **CD (5%)** | **0.05** | **0.06** | **0.19** | **0.81** | **0.81** | **0.014** | **32.74** | **5.43** |

**Table.3** Effect of FYM, urea and *Azotobacter* on quality characteristics of aonla cv NA-7 (Pooled mean of two years)

| Treatments | TSS ($^0$Brix) | Titratable acidity (%) | TSS/Acid ratio | Total sugars (%) | Reducing sugars (%) | Non-reducing sugars (%) | pH | Ascorbic acid (mg/100g of pulp) |
|---|---|---|---|---|---|---|---|---|
| **$T_1$ (100% of N/tree through Urea)** | 9.23 | 1.91 | 4.81 | 5.36 | 3.12 | 2.12 | 4.75 | 582.39 |
| **$T_2$ (75% N through Urea+ 25% through FYM)** | 10.01 | 1.77 | 5.65 | 6.32 | 3.32 | 2.85 | 4.72 | 591.12 |
| **$T_3$ (50% N through Urea + 50% through FYM)** | 10.16 | 1.77 | 5.74 | 5.92 | 3.24 | 2.54 | 4.16 | 610.35 |
| **$T_4$ (25% N through Urea + 75% through FYM)** | 10.09 | 1.73 | 5.81 | 5.85 | 3.13 | 2.58 | 4.36 | 611.15 |
| **$T_5$ (*Azotobacter* + $T_1$)** | 10.63 | 1.92 | 5.52 | 6.44 | 3.37 | 2.91 | 4.94 | 588.62 |
| **$T_6$ (*Azotobacter* + $T_2$)** | 11.22 | 1.83 | 6.11 | 6.57 | 3.39 | 3.01 | 4.86 | 596.37 |
| **$T_7$ (*Azotobacter* + $T_3$)** | 11.26 | 1.83 | 6.15 | 6.72 | 3.42 | 3.13 | 4.80 | 617.63 |
| **$T_8$ (*Azotobacter* + $T_4$)** | 10.60 | 1.76 | 6.02 | 5.94 | 3.16 | 2.63 | 4.68 | 623.32 |
| **$T_9$ (*Azotobacter* + 100% N through FYM)** | 9.05 | 1.76 | 5.14 | 5.29 | 2.80 | 2.36 | 4.71 | 625.23 |
| **$T_{10}$ (100% N through FYM)** | 8.52 | 1.68 | 5.07 | 5.15 | 2.97 | 2.07 | 4.66 | 616.17 |
| **$T_{11}$ (*Azotobacter* @ 200g/tree)** | 8.22 | 1.81 | 4.53 | 5.12 | 2.95 | 2.06 | 4.01 | 578.46 |
| **$T_{12}$ (Control)** | 8.12 | 1.85 | 4.44 | 4.51 | 2.58 | 1.83 | 3.39 | 574.29 |
| **CD (5%)** | **0.14** | **0.032** | **0.05** | **0.05** | **0.03** | **0.026** | **0.05** | **1.29** |

Nitrogen stimulates the functioning of number of enzymes in the physiological processes, which might have improved the total increase in total soluble solid content of the fruits. The highest mean values for total sugars could be attributed to the involvement of nitrogen in various energy sources like amino acids and amino sugars. Improved TSS and sugar contents of guava fruit with the application of biofertilizers and organic manure was also reported by Sharma *et al.,* (2013).

The perusal of pooled data revealed that acidity of the aonla fruit juice significantly increased with the increased concentration of urea as source of nitrogen. Highest acidity (1.92) was recorded under treatment with cent per cent nitrogen applied through urea along with *Azotobacter* ($T_5$) followed by treatment $T_1$ (cent per cent application of nitrogen as urea) where 0.91 per cent titratable acidity was recorded. The increase in acidity might be due to increased synthesis and translocation of organic acids in fruits. Similar results are in consonance with Gupta *et al.,* (2019). Maximum TSS: acid ratio (6.15) was recorded in fruits of trees treated with 50 per cent nitrogen as FYM and 50 per cent nitrogen as urea augmented with *Azotobacter* ($T_7$) followed by $T_6$ and $T_8$. Minimum TSS: acid ratio was recorded under control. The pooled data estimates reveal maximum fruit pH (4.94) recorded with the application of cent per cent nitrogen as urea augmented with *Azotobacter* ($T_5$) while minimum (3.39) was recorded under control ($T_{12}$). However, there was not much variation in fruit pH during both the years of study.

The pooled data estimates also showed significant effect of various treatment combinations on ascorbic acid content of aonla fruits. Maximum ascorbic acid content (625.23 mg/ 100g 0f pulp) was recorded with the application of cent per cent nitrogen per tree as FYM along with *Azotobacter* ($T_9$) and minimum was recorded under control ($T_{12}$). The highest ascorbic acid may be due to catalytic activity of several enzymes, which participate in the biosynthesis of ascorbic acid.

These findings are in consonance with Yadav *et al.,* (2012). Singh *et al.,* (2000) who reported an increase in ascorbic acid content of sweet orange cv. Mosambi with the application of biofertilizers. Tiwari *et al.,* (2015) who also found that organic manures significantly influenced vitamin C content in aonla fruit.

On the basis of the aforesaid findings, it can be concluded that cojoint application of organic, inorganic and biofertilizers significantly improved the growth, yield and quality of aonla fruits as compared to the application of urea alone.

Integration of 25 per cent nitrogen per tree through FYM and 75 per cent nitrogen per tree through urea along with *Azotobacter* application recorded maximum increment in vegetative growth parameters which was at par with cent per cent nitrogen per tree through urea along with *Azotobacter* and has highest yield and quality parameters in aonla and was found to be best on overall basis.

Hence, such combination of integrated nutrient management can lead to reduced usage of urea thereby restoring the natural health of the soil.

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