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# Studies on the effect of drip irrigation and mulching on leaf nutrient status, yield and quality of aonla

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**Abstract**

The experiment was conducted to study the effect of drip irrigation and mulches on water use efficiency and productivity of aonla cv. Narendra Aonla-10 (NA-10). There were four irrigation regimes in terms of IW/CPE ratios of 1.0, 0.8, 0.6 and 0.4 and three types of mulches, namely black polythene, paddy straw and control (no mulch). The results indicated that aonla plants drip irrigated at 0.6 IW/CPE had higher leaf nitrogen status as compared to higher and lower levels of irrigation. Leaf nitrogen, potassium, calcium and magnesium were higher in paddy straw mulched trees, while phosphorus content was higher under polythene mulching. Fruits attained significantly higher fruit length, diameter, weight and volume at 1.0 IW/CPE. The higher levels of irrigation, viz., 0.8 and 1.0 IW/CPE improved fruit size but drip irrigation at 0.6 IW/CPE coupled with black polythene mulching resulted in optimum fruit yield and quality parameters such as total sugar content, ascorbic acid and acidity contents of aonla cv. NA-10. Thus, it helps in cutting down the water requirement of aonla to 0.6 IW/CPE (60% evaporation replenishment) with drip irrigation and black polythene mulching for optimum fruit yield and quality.

**Key words:** *aonla, leaf nutrient status, drip irrigation, mulching, yield and quality*

## Introduction

Aonla (*Emblica officinalis* Gaertn) is a hardy, prolific bearer and medicinally valuable fruit, which grows successfully in a variety of degraded lands, viz., saline, sodic, coastal ares and ravines, etc. (Pathak *et al.*, 2003). It also seems a tree suitable for fruit tree based agroforestry systems especially in degraded lands of arid and semiarid regions (Pathak and Saroj, 1999; Ram Newaj *et al.*, 2006). During last few decades, the area under aonla has increased in various parts of India in general, and waste and marginal lands in particular. In such lands, paucity of irrigation water and poor fertility ststus of the soil are the major constraints limiting crop production. Besides, water has become a scarce resource with increasing urbanization, burgeoning population pressure and input-intensive crop production. Attempts made in India on drip irrigation have shown 40-60 per cent economy in water use (Agarwal and Agarwal, 2005). Similarly, mulching imparts manifold advantages viz., moisture conservation, suppression of weed growth, maintenance of soil fertility and regulation of soil temperature. In the present investigation, attempts were been made to study the effect of different drip irrigation levels and mulches on leaf nutrient status, fruit yield and quality of aonla.

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## Materials and methods

The experiment was conducted at the experimental farm of Department of Horticulture, Narendra Deva University of Agriculture and Technology, Kumarganj for two consecutive years, using eight year old uniform growing plantation of aonla cultivar Narendra Aonla-10. There were four irrigation regimes in terms of IW/CPE ratio, viz., IW/CPE value of 1.0 ($I_1$), 0.8 ($I_2$), 0.6 ($I_3$) and 0.4 ($I_4$)and three types of mulches, namely, black polythene ($M_1$), paddy straw ($M_2$) and control/no mulch ($M_3$), thus making twelve treatment combinations. The experiment was laid out in randomized block design. The soil of the experimental plot was silty loam and sodic with pH 8.86, ESP 30.49, EC 3.7 dS $m^{-1}$ and organic carbon content of 0.21%. Initial leaf nutrient status of aonla was 2.07% nitrogen (N), 0.28% phosphorus (P), 1.43% potassium (K), 2.19% calcium (Ca) and 0.17% magnesium (Mg). The irrigation water was applied through drip method and scheduling of irrigation was done based on pan evaporation. Pan evaporation was recorded daily with the help of class 'A' pan evaporimeter. Rainfall less than or equal to the pan evaporation loss during the day was considered effective. The amount of water required for irrigation was computed as the ratio of Irrigation Water (IW) over Cumulative Pan Evaporation (CPE) at third day interval. Black polythene sheet of 400 gauge of 4.0 m x 4.0 m size was unrolled on the surface of tree basin with its corners and sides stitched by stacking pins and their outer side tagged in soil to avoid rolling and splitting due to strong winds. A 10-cm thick layer of paddy straw @ 20 kg paddy straw plant$^{-1}$ was spread in the tree basin for mulching. Tree basins were left unmulched under control. The mulches were placed after fertilizer application, irrigation and weeding of the experimental plots to ensure the uniform moisture content. Trees were supplied with uniform doses of manures and fertilizers in two split doses i.e., half at the time of mulching and rest half in the last week of August.

The observations were recorded on leaf nutrient status with respect to nitrogen, phosphorus, potassium, calcium and magnesium, fruit yield and fruit quality parameters, viz., fruit length, diameter, weight, volume, total sugars, ascorbic acid and acidity. As regards leaf nutrient analysis, aonla leaves were randomly taken from mid portion of shoots at termination of experiment. Nitrogen was determined by micro-Kjeldahl method as advocated by Peach and Tracey (1956). Phosphorus was estimated by wet digestion method developing vanadomoybdo colour as suggested by Richards (1954). Potassium content was analysed by wet digestion using flame photometer as suggested by Jackson (1973), while calcium and magnesium contents were estimated by the methods suggested by Chang and Bray (1951). Fruit length and diameter were recorded using Vernier calliper, while fruit volume was recorded by water displacement method. Total sugar contents were analysed by Fehling solution method as advocated by Lane and Eynon (1943). Titrable acidity was recorded by titration against NaOH solution, while ascorbic acid content was estimated as per procedure given in AOAC (1970). Data for two years were pooled and analysed statistically as per methods given by Panse *et al.* (1985).

## Results and discussion

### *Leaf nutrient status of aonla*

Data pertaining to leaf nutrient status (Table 1) indicate that aonla plants irrigated at $I_3$ (0.6 IW/CPE) level recorded highest nitrogen content (2.52%) followed by $I_2$, $I_4$ and $I_1$. The minimum nitrogen content (2.11%) was noted in $I_1$. However, treatment pairs $I_2$ and $I_4$ ; $I_1$ and $I_4$ were statistically akin. Mulching showed significant effect on nitrogen content of aonla leaves. The maximum nitrogen (2.35%) was recorded in response to paddy straw mulch followed by black polythene (2.31%) and control (2.18%). However, $M_1$ and $M_2$ were statistically at par. The interaction between two factors was found significant in respect of leaf nitrogen content, varying from 2.08 to 2.81 per cent with the maximum nitrogen in $I_3M_2$ followed by $I_2M_2$, $I_3M_1$, $I_4M_1$, $I_3M_3$. Phosphorus content of aonla leaves was significantly affected by irrigation regimes and mulching. Highest phosphorus content (0.38%) was recorded at $I_2$ irrigation level followed by $I_3$ (0.37%), $I_4$ (0.36%) and $I_1$ (0.35%) irrigation regime. However, treatment pairs $I_2$ and $I_3$; $I_1$ and $I_4$ did not differ significantly. Mulching also significantly influenced the phosphorus content of leaves with significantly maximum phosphorus content (0.43 %) under black polythene mulched trees followed by paddy straw mulching and control. There is non-significant effect of interaction of these two factors on phosphorus content of aonla leaves. The significantly highest leaf potassium content (1.98%) was obtained under $I_2$ irrigation regime and the lowest was recorded in $I_4$ (1.74%). Mulching materials had significant effect on potassium content of aonla leaves. Mulching with paddy straw ($M_2$) had highest potassium (2.15%) content in leaves followed by trees under black polythene mulching and control (no mulching). The interaction of irrigation regimes and mulching had significantly influenced the potassium content in leaves. The maximum potassium (2.26%) was recorded in $I_2M_2$ followed by $I_3M_2$, $I_1M_2$, $I_4M_2$, $I_2M_1$ and so on.

**Table 1.** Leaf nutrient status in aonla leaves in response to drip irrigation and mulching

| Mulches | Leaf nutrient status in aonla at different irrigation levels | | | | |
|---|---|---|---|---|---|
| | **Nitrogen (%)** | | | | |
| | $I_1$ | $I_2$ | $I_3$ | $I_4$ | Mean |
| $M_1$ | 2.15 | 2.32 | 2.39 | 2.39 | 2.31 |
| $M_2$ | 2.11 | 2.39 | 2.81 | 2.10 | 2.35 |
| $M_3$ | 2.08 | 2.18 | 2.36 | 2.11 | 2.18 |
| Mean | 2.11 | 2.30 | 2.52 | 2.20 | |
| C D at 5% | Irrigation (I)–0.108; Mulching (M) – 0.093; I X M-0.186 | | | | |
| | **Phosphorus (%)** | | | | |
| $M_1$ | 0.41 | 0.45 | 0.44 | 0.42 | 0.43 |
| $M_2$ | 0.30 | 0.34 | 0.32 | 0.31 | 0.32 |
| $M_3$ | 0.34 | 0.35 | 0.34 | 0.34 | 0.34 |
| Mean | 0.35 | 0.38 | 0.37 | 0.36 | |
| C D at 5% | Irrigation (I) - 0.013; Mulching (M) –0.011; I X M - NS | | | | |
| | **Potassium (%)** | | | | |
| $M_1$ | 1.88 | 2.00 | 1.89 | 1.59 | 1.84 |
| $M_2$ | 2.10 | 2.26 | 2.15 | 2.13 | 2.16 |
| $M_3$ | 1.50 | 1.69 | 1.64 | 1.51 | 1.59 |
| Mean | 1.83 | 1.98 | 1.89 | 1.74 | |
| C D at 5% | Irrigation (I) - 0.038; Mulching (M) - 0.032; I X M – 0.065 | | | | |
| | **Calcium (%)** | | | | |
| $M_1$ | 2.11 | 2.30 | 2.17 | 1.66 | 2.06 |
| $M_2$ | 2.42 | 2.20 | 2.17 | 1.79 | 2.15 |
| $M_3$ | 2.04 | 2.05 | 1.65 | 1.60 | 1.84 |
| Mean | 2.19 | 2.18 | 2.00 | 1.68 | |
| CD (at 5%) | Irrigation (I) – 0.034; Mulching (M) – 0.035; I X M – 0.550 | | | | |
| | **Magnesium (%)** | | | | |
| $M_1$ | 0.27 | 0.29 | 0.28 | 0.24 | 0.27 |
| $M_2$ | 0.33 | 0.35 | 0.32 | 0.31 | 0.33 |
| $M_3$ | 0.21 | 0.24 | 0.23 | 0.21 | 0.22 |
| Mean | 0.27 | 0.29 | 0.28 | 0.25 | |
| C D at 5% | Irrigation (I) – 0.015; Mulching (M) – 0.013; I X M - NS | | | | |

Maximum calcium content (2.19%) was recorded under $I_1$ irrigation regime followed by $I_2$ and $I_3$ (Table 1), while the minimum content was in trees irrigated at 0.4 IW/CPE ($I_4$). However, $I_1$ and $I_2$ irrigation regimes were statistically at par in respect of leaf calcium content. Among different mulches used in the experiment, maximum calcium content (2.15%) in aonla leaves was recorded with paddy straw mulched aonla trees followed by black polythene mulching (2.06%) and control (1.84%). The interaction effects of irrigation regimes and mulches were also significant in respect of calcium content, varying from 1.60 to 2.42 per cent in different treatment combinations. The significantly maximum calcium content (2.42%) was recorded under $I_1M_2$ followed by $I_2M_1$, $I_2M_2$, $I_3M_1$, $I_1M_2$ and minimum (1.60%) was recorded in $I_4M_3$. Drip irrigation regimes and mulching significantly influenced magnesium content in aonla leaves. Maximum magnesium content (0.29%) was observed under $I_2$ irrigation level followed by $I_3$, $I_1$ and $I_4$. However, $I_2$ and $I_3$ ; and $I_1$ and $I_3$ irrigation regimes were found statistically at par. Among mulching treatments, the magnesium content (0.33%) was significantly highest under paddy straw mulching followed by black polythene and control.

Higher leaf nitrogen status in aonla leaves at $I_3$ (0.6 IW/CPE) may be attributed to restricted application of water which reduces leaching of nutrients from root zone (Purser, 1993). The findings are in agreement with Hegde and Srinivas (1989), and Ahmed (1994). The concentration of P, K and Mg was significantly higher with $I_2$ (0.8 IW/CPE). This may be due to leaching of salts from the root zone at this irrigation level resulting in increased availability of these plant nutrients. The results are in agreement with the findings of Elfving (1982) who also reported that trickle irrigation increased plant concentration nutrients because of better movement of nutrients in the soil solution and thereby ensured adequate nutrient availability to the plant. The findings are also in line with Neilsen (1995) in apple, Strabbioli and Turci (1995) in peach.

The assimilation and accumulation of Ca in aonla leaves was maximum (2.19%) at highest level ($I_1$) of irrigation, which decreased with reduced supply of irrigation water. It was due to the fact that the movement of Ca in plant was facilitated by higher amount of available soil water. It indicates that accumulation of Ca is unlike from that of N, P, K and Mg in leaves. The maximum accumulation of Ca recorded at higher level of irrigation ($I_1$) in the experiment is also supported by Duncan *et al.* (1992) and Bondok *et al.* (1995).

Among different mulches, paddy straw had beneficial effect on uptake of N, K, Ca and Mg followed by black polythene and control (no mulching). It might be due to higher moisture conservation better aeration and more soil nutrient concentrations obtained from partial decomposition of paddy straw. The findings are in conformity with Gupta and Gupta (1987), Mustaffa (1988) and Pinamonti *et al.* (1995). Phosphorus content in leaves was significantly higher in black polythene mulched aonla trees followed by control and paddy straw mulching. It may be ascribed to microbial imobilisation of P under the paddy straw mulch which lowered the absorption and translocation of phosphorus in plants. The results are in agreement with those of Mustaffa (1988) and Marumata *et al.* (1991). The interaction effects between irrigation and mulching with respect to leaf nutrient status had indicated that combination of both favourable factors i.e., drip irrigation and paddy straw mulching further increased concentration of N, K, Mg and Ca in leaves. The maximum nitrogen (2.81%) was under $I_3M_2$ while K and Mg contents were maximum in $I_2M_2$. Ca was maximum in $I_1M_2$ and maximum P was observed in $I_2M_1$. Bolding (1988) reported that leaf N content was lowest and leaf Ca content was highest with drip irrigation + potting compost in pear.

***Physical fruit characters and yield***

The physical fruit characters such as fruit length, diameter, weight and volume were significantly influenced by drip irrigation levels (Table 2). Maximum fruit length (3.91 cm), fruit diameter (4.66 cm), fruit weight (49.19 g) and fruit volume (48.29 $cm^3$) were observed at 1.0 IW/CPE followed by $I_2$, $I_3$ and $I_4$. This increase might be due to higher water application leading to larger fruit size. These results are in agreement with Hegde and Srinivas (1989) in banana. Since fruit weight is directly related to fruit yield, the highest fruit yield observed under 0.6 IW/CPE coincided with the reduced fruit size and weight. Higher yield with reduced fruit size was also recorded by Sepaskhah and Kashefipour (1994). Increased fruit volume with increasing water application was also recorded by Kumar and Bhojappa (1994). The physical fruit characters, viz. fruit length, weight and volume did not show any significant variations in response to different mulches. The interaction effect between irrigation levels and mulches with respect

**Table 2.** Effect of drip irrigation regimes and mulching on physical attributes of aonla

| Treatments | Physical attributes of aonla fruit in response to drip irrigation and mulching | | | |
|---|---|---|---|---|
| | Fruit length (cm) | Fruit diameter (cm) | Fruit weight (g) | Fruit volume ($cm^3$) |
| **Irrigation levels** | | | | |
| 1.0 IW/CPE ($I_1$) | 3.91 | 4.66 | 49.19 | 48.29 |
| 0.8 IW/CPE ($I_2$) | 3.82 | 4.46 | 47.89 | 47.46 |
| 0.6 IW/CPE $I_3$) | 3.69 | 4.43 | 47.00 | 46.28 |
| 0.4 IW/CPE ($I_4$) | 3.60 | 4.42 | 46.48 | 45.11 |
| C D at 5 % | 0.142 | 0.051 | 2.645 | 1.73 |
| **Mulches** | | | | |
| Black polythene ($M_1$) | 3.79 | 4.58 | 48.48 | 47.29 |
| Paddy Straw ($M_2$) | 3.79 | 4.48 | 47.31 | 46.78 |
| Control ($M_3$) | 3.69 | 4.43 | 47.13 | 46.29 |
| C D at 5% | NS | 0.058 | NS | NS |

to these parameters was also non-significant. Contrary to this, fruit diameter was significantly higher with black polythene mulch (4.58 cm) as compared to paddy straw and control. It may be due to reduced competition of grass, better conservation and utilization of soil moisture. Similar results were recorded by Mannini and Gallina (1987) in cucumber, Saini (1994) in ber and Chattopadhyay and Sarad Gurung (1996) in banana. The interaction effect with respect to fruit diameter exhibited significant variations with maximum fruit diameter with $I_1M_1$ (4.84 cm) followed by $I_2M_1$ (4.57 cm), $I_1M_3$ (4.52 cm) and $I_2M_2$ (4.48 cm). These findings are also in line with Welbaum *et al.* (1994).

As regards fruit yield, aonla plants irrigated at $I_3$ (IW/CPE = 0.6) recorded significantly higher fruit yield (43.96 kg/tree) followed by $I_4$, $I_2$ and $I_1$ (Table 3). Among mulch materials, use of black polythene resulted in significantly higher yield (44.53 kg/tree) followed by paddy straw mulching (39.50 kg/tree), while minimum yield (25.66 kg/tree) was obtained in control ($M_3$). Interaction between irrigation regimes and mulching showed significant influence with respect to fruit yield varying from 22.50 to 56.20 kg/tree. Maximum fruit yield (56.20 kg) was recorded under $I_4$ mulched with black polythene followed by $I_3M_1$, $I_3M_2$ and $I_2M_1$.

The higher yield at 0.6 IW/CPE might be due to efficient utilization of water and better nutrient uptake. The yield reduction both at higher irrigation levels (0.8 and 1.0 IW/CPE) and lower irrigation level (0.4 IW/CPE) might be due to unfavourable soil conditions in the root zone. At higher levels, plants get continued higher level which favours vegetative growth. In this case the poor fruit yield may be attributed to nutrient wash out from the feeding root zone. Furthermore, higher water application might lead to flower senescence and consequently lower fruit yield. However, poor yield at lower irrigation level (0.4 IW/CPE) might have resulted from water deficit leading to unavailability of water and nutrients (Sepaskhah and Kashefipour, 1994). Agarwal and Agarwal (2005) recorded 82.88% yield increase over control with 60% water application through drip coupled with plastic mulching.

**Table 3.** Fruit yield in aonla as influenced by drip irrigation and mulching

| Treatments | Fruit yield (kg/tree) | | | | |
|---|---|---|---|---|---|
| | $I_1$ | $I_2$ | $I_3$ | $I_4$ | Mean |
| M1 | 22.75 | 46.29 | 52.88 | 56.20 | 44.53 |
| M2 | 32.45 | 35.50 | 47.38 | 42.67 | 39.50 |
| M3 | 22.50 | 26.13 | 31.63 | 22.38 | 25.66 |
| Mean | 25.90 | 35.97 | 43.96 | 40.42 | |
| C D at 5% | I-2.362 | M-2.050 | I X M-4.090 | | |

Among mulching treatments, black polythene was found best for enhancing fruit yield followed by paddy straw. Better fruit yield with black polythene may be attributed to maintenance of optimum soil moisture (Agarwal and Agarwal, 2005), soil temperature (Wilhelm, 1979) and enhanced flowering duration (Hegde and Srinivas, 1990). These findings are in agreement with Pemovski *et al.* (1973) in grapes, Chadha and Pareek (1991) in mango, Agarwal and Agarwal (2005) in banana.

***Chemical fruit characters***

The fruit quality attributes, such as total sugars, ascorbic acid and acidity were significantly influenced by drip irrigation regimes and mulching (Table 4). Irrigation at 0.6 IW/CPE significantly improved the total sugar level of fruits followed by $I_2$, $I_1$ and $I_4$. However, treatment pairs, viz., $I_1$ and $I_2$; $I_1$ and $I_4$ were statistically at par. It might be due to fruit soluble sugar being negatively related to water availability, with a mild deficit showing highest percentage of total sugars. These results are in agreement with Goodwin and Jeric (1988), Coloptera (1989), Madrid *et al.* (1995). Among different mulches used in the experiment, total sugar was significantly highest with black polythene mulch (8.87 %) followed by paddy straw and control. The combined effect of drip irrigation and mulching did not cause significant variation amongst different treatment combinations. The higher total sugar content in response to black polythene mulch is attributed to better conservation and maintenance of soil moisture during fruit growth and development.

**Table 4.** Chemical attributes of aonla as influenced by drip irrigation and mulching

| Treatments | $I_1$ | $I_2$ | $I_3$ | $I_4$ | Mean |
|---|---|---|---|---|---|
| | | Total sugar (%) | | | |
| M1 | 8.90 | 9.08 | 9.14 | 8.36 | 8.87 |
| M2 | 8.37 | 8.69 | 8.96 | 7.98 | 8.50 |
| M3 | 7.54 | 7.78 | 8.18 | 7.86 | 7.84 |
| Mean | 8.27 | 8.52 | 8.76 | 8.07 | |
| C D at 5% | I - 0.34 | M – 0.30 | I X M - NS | | |
| | | Ascorbic acid (mg/100 g pulp) | | | |
| M1 | 614.00 | 658.00 | 666.50 | 703.00 | 660.38 |
| M2 | 712.00 | 726.00 | 756.00 | 767.00 | 740.25 |
| M3 | 611.50 | 622.00 | 675.00 | 694.00 | 650.63 |
| Mean | 645.83 | 668.67 | 699.17 | 721.33 | |
| C D at 5% | I - 14.3 | M - 12.39 | I X M - 24.78 | | |
| | | Acidity (%) | | | |
| M1 | 3.69 | 3.94 | 3.93 | 3.99 | 3.89 |
| M2 | 3.87 | 4.02 | 4.03 | 4.25 | 4.04 |
| M3 | 3.59 | 3.45 | 3.89 | 3.91 | 3.71 |
| Mean | 3.72 | 3.80 | 3.95 | 4.05 | |
| C D at 5% | I - 0.14 | M - 0.12 | I X M - 0.24 | | |

Variations in ascorbic acid (vitamin C) and acidity contents were noted in response to various irrigation and mulching treatments (Table 4). Maximum ascorbic acid (721.33 mg/100 g pulp) was recorded at the irrigation regime $I_4$ (IW/CPE=0.4) followed by $I_3$ (699.17 mg/100g), $I_2$ and $I_1$. Among mulch materials, paddy straw mulch gave highest vitamin C content in fruits. Significant interaction effects were also recorded with in $I_4M_2$ (767 mg/100g) followed by $I_3M_2$ and $I_2M_2$.

Fruit acidity also varied significantly with different treatments. Maximum acidity was recorded under $I_4$ (4.05%) followed by $I_3$, $I_2$ and $I_1$. As regards mulching, paddy straw mulch resulted in highest fruit acidity (4.04 %) followed by $M_1$ and $M_3$. The interaction between irrigation and mulching was also significant with respect to fruit acidity. Maximum acidity was recorded with $I_4M_2$ (4.25%) followed by $I_1M_2$, $I_2M_2$, $I_4M_1$, $I_3M_1$.

The reduction in ascorbic acid and acidity content of fruits was recorded with increasing level of irrigation as it cause dilution of fruit juice with water. On the other hand, deficit in water increases electrical conductivity of soil leading to increase in fruit acidity. These findings are in agreement with Cruse *et al.* (1982) and Madrid *et al.* (1995).

The analysis indicates that aonla plants drip irrigated at 0.6 IW/CPE had higher leaf nitrogen status as compared to higher and lower levels of irrigation. Leaf nitrogen, potassium, calcium and magnesium were higher in paddy straw mulched trees, while phosphorus content was higher under polythene mulching. Fruits attained significantly higher fruit length, diameter, weight and volume at 1.0 IW/CPE. The higher levels of irrigation, viz., 0.8 and 1.0 IW/CPE improved fruit size but drip irrigation at 0.6 IW/CPE coupled with black polythene mulching resulted in optimum fruit yield and quality parameters such as total sugar content, ascorbic acid and acidity contents of aonla cv. NA-10. Thus, it helps in curtailing the water requirement of aonla to 0.6 IW/CPE (60 % evaporation replenishment) with drip irrigation and black polythene mulching for optimum fruit yield and quality.

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