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# Nutrient availability and fruit production of Aonla (*Emblica officinalis* Gaertn.) as affected by trickle irrigation and superabsorbent polymer

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**Abstract**

An experiment was conducted to find out the effect of trickle irrigation and superabsorbent polymer (SAP) on nutrient availability and fruit production of Aonla. The two years pooled data assessed the influence of trickle irrigation intervals (3 and 6 days) and various doses of superabsorbent polymer (30, 60, 90, and 120 g) with black polyethylene mulch on soil properties, soil and leaf nutrient availability and fruit yield quality attributes of Aonla. Results showed that the combined treatment of drip/trickle irrigation intervals and SAP with mulch retained the maximum water holding capacity, with the three-day interval of drip/trickle irrigation paired with 90 g of SAP and mulch exhibiting the most positive effects on soil characteristics, and fruit yield enhancement. Plants treated with this method yielded the highest fruit production (101.43 kg/tree), followed by the same irrigation interval with 120 g of SAP and mulch (96.98 kg/tree), while control plants yield the least (66.79 kg/tree) over the two-year period (pooled data). Superabsorbent polymers not only conserve water during irrigation but also enhance soil physico-chemical and biological properties, being environmentally friendly as they naturally degrade without leaving toxic residues. Thus, the application of SAP presents a promising approach to increasing fruit production sustainably in water-stressed environments.

**Keywords**: Aonla, Superabsorbent polymer, Drip/ trickle irrigation, Yield and Rainfed condition

## Introduction

Aonla, (*Emblica officinalis* Gaertn.) commonly referred to as Indian gooseberry, is a resilient and highly productive fruit crop belonging to the *Euphorbiaceous* family. Thriving in dry sub-tropical climates, it has gained recognition as one of India's most important minor fruit crops, predicted to be the 'fruit of the 21st century even though it existed from time immemorial (Singh et al., 2009). Aonla is not only native to India but also grows naturally in various parts of the world including Sri Lanka, Cuba, Puerto Rico, China, Thailand, and Japan. Rich in both tannins and ascorbic acid, it holds a unique position as an edible material. Major aonla-growing regions within India include Uttar Pradesh, Maharashtra, Gujarat, Rajasthan, Andhra Pradesh, Tamil Nadu, Karnataka, Haryana, Punjab, Himachal Pradesh, and Jammu and Kashmir. Recognized for its high nutritional value, aonla is a potent source of vitamin C and is valued for its health benefits and medicinal properties. Its organic cultivation has seen a surge in recent years, driven by the demand for value-added products in international markets. Although fresh aonla fruit is highly acidic and astringent, its processed forms such as murabba, pickle, candy, juice, squash, jam, jelly, and powder have gained popularity. In agricultural practices, water conservation is crucial for fruit crops, with the use of soil conditioners like superabsorbent polymer (hydrogel) showing significant potential in improving water retention and enhancing fruit production. When polymers are assimilated into the soil it is assumed that they retain large quantities of water and nutrients, which are released as compulsory by the tree. Therefore, plant/tree growth might be improved with partial water supply (Islam et al., 2011). The incorporation of super absorbent polymer improved seed germination and emergence, crop growth and yield and decrease the irrigation requirement of trees. Super absorbent polymers can hold 400-1200 g of water per dry gram of hydrogel. The use of super absorbent polymers has countless significance for their role in the upsurge of water absorption capacity and retention of water scarcity circumstance and the decline of bad possessions of drought stress. Under rainfed condition, crops can better withstand drought condition without moisture stress by using hydrogel. Similarly, mulching has been recognized as a beneficial practice in fruit tree cultivation, offering advantages such as soil temperature regulation, moisture retention, weed suppression, and enhanced nutrient uptake. Drip irrigation, alongside plastic mulching, has demonstrated positive effects on plant growth, soil properties, leaf nutrients, fruit yield, and water efficiency in citrus cultivars like Kinnow mandarin, particularly in rainfed regions of Jammu. These innovative practices not only improve fruit quality and yield but also contribute to the socio-economic well-being of orchardists by increasing income per unit area.

## Materials and Methods

The field experiment took place at the Rainfed Research Substation for Subtropical Fruits, located at Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, India (latitude $32^0$ 39" N, longitude $74^0$ 53" E, elevation 332 m above mean sea level). It spanned two consecutive years (2018-19 to 2019-20) using 15-year-old Aonla 'Aonla NA-7' plants budded on desi rootstock, planted at a spacing of 10 m x 10 m in 2007. The soil, categorized as sandy loam, had a bulk density of 1.65 g/cm3 and was composed of sandstone, shales, conglomerates, and clay beds, classified as ustifluvents, ustipsamments, ustochrepts, local haplustalfs, and fluvaquents. Soil pH was nearly neutral (7.05) with mild electrical conductivity (0.12 $dSm^{-1}$), and mean available nutrient concentrations were 229.45, 15.68, 157.24, 361.40 and 378.12 kg/ha N, P, K, Ca and Mg respectively. The subtropical climate featured hot and dry summers, hot and humid rainy seasons, and cold winters. Annual rainfall averaged 750.70 mm in 2018 and 905.10 mm in 2019, with 70-80% occurring during the monsoon (July to September). The experiment was organized in a randomized block design with 15 treatments and 3 replications, utilized one plant per treatment unit. Treatments included various combinations of trickle irrigation intervals and superabsorbent polymer (SAP) applications with mulch. Water was supplied from March $15^{th}$ to July $15^{th}$ during summer and from September $15^{th}$ to October $15^{th}$ during the water stress period. Mulching involved using 200-gauge black linear low-density polyethylene sheets covering 1.0 m x 1.0 m around each tree basin. Fertilizer application followed recommendations (1600: 345; 250 g N: P: K using urea, DAP and MOP) for bearing Kinnow plants (Anonymous, 2017), with weed control and plant protection measures maintained uniformly across the experimental orchard.

Soil samples were analyzed for organic carbon, nitrogen, phosphorus, potassium, calcium, and magnesium using standard procedures (Jackson, 1973). Soil physical properties, including bulk density, porosity, and maximum water holding capacity, were determined using the Keen Roezkowski box method (Chopra and Kanwar, 1991). Leaf samples from non-fruiting branches were collected for macronutrient and secondary nutrient analysis as per the standard procedures suggested by Tandon (2005). Fruit quality parameters such as fruit weight, volume, titratable acidity, and total soluble solids were assessed according to Ranganna (2001). Statistical analysis, including analysis of variance (ANOVA) at a 5% probability level, was conducted using SPSS 16.0.

## Results and Discussion

*Variation in physico-chemical properties of soil*: The physical properties of soil showed a disparity response of trickle irrigation intervals and superabsorbent polymer (SAP) with black polyethylene mulch treatments (Table1). Amongst the amalgamation treatment of water supply through trickle irrigation and superabsorbent polymer with black polyethylene mulch materialperformed significantlysuperior, followed by different dose of superabsorbent polymer with mulch and trickle irrigations. Significantly highest soil organic carbon was recorded in $T_{12}$ (5.05 g/kg) which was numerically followed by $T_{14}$, $T_{11}$, $T_{15}$ It was also observed that control had significantly lowest soil organic carbon (4.53 g/kg). The greater availability of organic carbon in soil caused by SAP which was aptly retained in the soil with the help of plastic mulch might be attributed to higher soil organic carbon in respective treatments. These findings are in accordance with the findings of Yang *et al*., (2021) where SAP application resulted in increased total and labile organic carbon.

Table 1: Effect of trickle irrigationand superabsorbent polymeron soil physico-chemical properties of Aonla cv. NA-7 (Pooled data of 2 years)

| Treatment | Organic carbon (g/kg) | Bulk Density (g/cm$^3$) | Particle Density (g/cm$^3$) | Porosity (%) | MWHC (%) |
|---|---|---|---|---|---|
| $T_1$- Control | 4.53 | 1.710 | 2.778 | 38.44 | 25.75 |
| $T_2$- 3D TI | 4.56 | 1.696 | 2.774 | 38.86 | 27.44 |
| $T_3$- 6D TI | 4.55 | 1.701 | 2.768 | 38.56 | 26.19 |
| $T_4$- 30gSAP | 4.58 | 1.690 | 2.759 | 38.75 | 27.00 |
| $T_5$- 60gSAP | 4.68 | 1.682 | 2.753 | 38.92 | 27.70 |
| $T_6$- 90gSAP | 4.74 | 1.672 | 2.745 | 39.10 | 28.43 |
| $T_7$- 120gSAP | 4.78 | 1.658 | 2.734 | 39.37 | 29.49 |
| $T_8$- 3D TI + 30gSAP + M | 4.87 | 1.638 | 2.713 | 39.64 | 31.70 |
| $T_9$- 6D TI + 30gSAP + M | 4.82 | 1.654 | 2.719 | 39.17 | 30.22 |
| $T_{10}$- 3D TI + 60gSAP + M | 4.93 | 1.628 | 2.705 | 39.83 | 32.22 |
| $T_{11}$- 6D TI + 60gSAP + M | 4.91 | 1.634 | 2.710 | 39.72 | 31.80 |
| $T_{12}$- 3D TI + 90gSAP + M | 5.05 | 1.617 | 2.698 | 40.02 | 34.07 |
| $T_{13}$- 6D TI+ 90gSAP + M | 5.00 | 1.623 | 2.695 | 39.78 | 32.55 |
| $T_{14}$- 3D TI + 120gSAP + M | 4.97 | 1.614 | 2.685 | 39.89 | 34.22 |
| $T_{15}$- 6D TI + 120gSAP + M | 4.95 | 1.619 | 2.686 | 39.71 | 33.45 |
| CD (P=0.05) | 0.02 | 0.047 | 0.015 | 0.16 | 0.30 |

MWHC; maximum water holding capacity, D: days, TI:trickle irrigation:SAP:superabsorbent polymer, M: mulch

Bulk and particle density showed a reverse trend and as output of minimum (1.614 and 2.685 g/cm$^3$ respectively) of three days trickle irrigation intervals and 120gm superabsorbent polymer (SAP) with black polyethylene mulch in $T_{14}$which was statistically at par with $T_{12}$, $T_{13}$, and $T_{15}$. Significantly higher bulk and particle density was recorded in control (1.710 and 2.778 g/cm$^3$ respectively). Higher organic carbon concentration in the respective treatments might be attributed to lower bulk and particle density of respective treatments.

The porosity of soil was significantly highest in $T_{12}$ (40.02%)which was found statistically at par with $T_{14}$ (39.89%) on the other hand, it was found significantly lower in control (38.44%).Maximum water holding capacity (MWHC) was recorded significantly higher in $T_{14}$(34.22%) which was statistically at par with $T_{12}$ (34.07%). On the other hand, significantly lowest MWHC was recorded in control (25.75%). Use of mulch in combination with 3day trickle irrigation and SAP resulted in reduced compaction of the soil which resulted in improved physical properties of the soil. All the treated plants exhibited significantly improvement in soil organic carbon of soil as compared to control.

Table 2: Effect of trickle irrigationand superabsorbent polymeron available nutrient content of Aonla cv. NA-7 (Pooled data of 2 years)

| Treatment | Available N (kg/ha) | Available P (kg/ha) | Available K (kg/ha) | Ca (kg/ha) | Mg (kg/ha) |
|---|---|---|---|---|---|
| $T_1$- Control | 217.31 | 15.92 | 156.37 | 360.28 | 373.73 |
| $T_2$- 3D TI | 219.25 | 16.14 | 156.58 | 360.60 | 373.97 |
| $T_3$- 6D TI | 218.19 | 16.03 | 156.46 | 360.43 | 373.78 |
| $T_4$- 30gSAP | 220.27 | 16.26 | 156.65 | 360.90 | 374.99 |
| $T_5$- 60gSAP | 220.97 | 16.67 | 157.06 | 361.56 | 376.35 |
| $T_6$- 90gSAP | 222.90 | 16.95 | 157.17 | 361.76 | 377.95 |
| $T_7$- 120gSAP | 224.17 | 17.35 | 157.38 | 362.02 | 380.01 |
| $T_8$- 3D TI + 30gSAP + M | 226.19 | 17.94 | 158.80 | 363.30 | 383.25 |

| | | | | | |
|---|---|---|---|---|---|
| $T_9$- 6D TI + 30gSAP + M | 224.95 | 17.44 | 158.02 | 362.25 | 380.75 |
| $T_{10}$- 3D TI + 60gSAP + M | 227.82 | 18.41 | 159.52 | 364.22 | 385.37 |
| $T_{11}$- 6D TI + 60gSAP + M | 227.04 | 18.14 | 158.93 | 363.56 | 381.94 |
| $T_{12}$- 3D TI + 90gSAP + M | 230.24 | 19.06 | 161.35 | 365.32 | 386.77 |
| $T_{13}$- 6D TI+ 90gSAP + M | 226.05 | 18.51 | 159.08 | 364.45 | 386.39 |
| $T_{14}$- 3D TI + 120gSAP + M | 228.82 | 18.94 | 160.38 | 365.89 | 388.35 |
| $T_{15}$- 6D TI + 120gSAP + M | 227.55 | 18.53 | 159.86 | 364.35 | 387.05 |
| CD (P=0.05) | 0.60 | 0.30 | 1.01 | 0.39 | 0.49 |

D: days, TI:trickle irrigation:SAP:superabsorbent polymer, M: mulch

Available *nutrients content*: The data presented in Table 2 of available primary (N, P and K) and secondary (Ca and Mg) nutrients indicate that these parameters were significantly influenced by trickle irrigation intervals and SAP with mulch treatments. The enhanced availability of primary nutrients facilitated by $T_{12}$ likely stemmed from elevated microbial activity, leading to heightened mineralization and nutrient transformation within the root zone of the plants in this treatment, relative to other treatments. The prevalence of an optimal soil-water regime further supported this process. (Amberger, 2006).The available secondary nutrients were almost similar trend of primary nutrients.The observed increments in available calcium (Ca) and magnesium (Mg) levels in soils subjected to the $T_{14}$ treatment might be attributed to enhanced microbial mobility, accelerated decomposition, mineralization of hydrogel and mulch in conjunction with nitrogen, suppression of competitive weeds, and amelioration of soil structure. (Abobatta and Khalifa, 2019).

*Variation in leaf nutrient composition*: The major and secondary nutrients (N, P, K, Ca and Mg) concentration in leaves depicted in an inequality reply to trickle irrigation intervals and SAP with black polyethylene mulch material (Table 3). The leaf nutrients like N, P and K were found significantly highest in $T_{14}$ numerically followed by $T_{12}$, $T_{15}$, $T_{11}$ and was lowest in control. The better leaf nutrients i.e. N, P and K content of 3 days water supply through trickle irrigation intervals and SAP with mulch materials trees might have been caused by improved availability of such nutrients in soil under sole treatments. The concentration of nutrients in leaves reduced with reduction in soil moisture content. The concentration of secondary nutrients like Ca and Mg in leaves was also found significantly higher in $T_{14}$ followed by $T_{12}$ and was lowest in control. The increase in leaf nutrient concentration may be attributed to the reduced weed population under trickle irrigation intervals and the use of SAP with mulch materials, which provide increased accessibility to nutrients and soil moisture for enhanced growth and translocation to the leaves of the trees. The observed association of leaf nutrient content aligns with findings reported by Shirgure (2000) in acid lime and Panigrahi *et al*. (2012) in 'Nagpur' mandarin, suggesting that leaf nutrient composition is influenced by water stress in citrus plants. However, across all treatments, the levels of macro and secondary leaf nutrients exceeded the optimal amounts required for sustainable citrus production (Panigrahi and Srivastava, 2016).

Table 3: Effect of superabsorbent polymer and trickle irrigation on leaf nutrient content of leaves of Aonla cv. NA-7 (Pooled data of 2 years)

| Treatment | Leaf N (%) | Leaf P (%) | Leaf K (%) | Leaf Ca (%) | Leaf Mg (%) |
|---|---|---|---|---|---|
| $T_1$- Control | 2.77 | 0.14 | 2.70 | 1.53 | 0.41 |
| $T_2$- 3D TI | 2.80 | 0.17 | 2.73 | 1.56 | 0.43 |
| $T_3$- 6D TI | 2.78 | 0.15 | 2.71 | 1.54 | 0.42 |
| $T_4$- 30gSAP | 2.83 | 0.15 | 2.74 | 1.62 | 0.42 |
| $T_5$- 60gSAP | 2.85 | 0.17 | 2.76 | 1.64 | 0.44 |
| $T_6$- 90gSAP | 2.88 | 0.18 | 2.78 | 1.67 | 0.44 |
| $T_7$- 120gSAP | 2.92 | 0.19 | 2.80 | 1.70 | 0.45 |
| $T_8$- 3D TI + 30gSAP + M | 2.95 | 0.22 | 2.91 | 1.75 | 0.46 |
| $T_9$- 6D TI + 30gSAP + M | 2.93 | 0.21 | 2.83 | 1.72 | 0.45 |
| $T_{10}$- 3D TI + 60gSAP + M | 2.98 | 0.24 | 2.96 | 1.79 | 0.46 |
| $T_{11}$- 6D TI + 60gSAP + M | 2.97 | 0.22 | 2.86 | 1.77 | 0.46 |
| $T_{12}$- 3D TI + 90gSAP + M | 3.04 | 0.25 | 3.01 | 1.88 | 0.47 |
| $T_{13}$- 6D TI+ 90gSAP + M | 3.00 | 0.24 | 2.88 | 1.82 | 0.46 |
| $T_{14}$- 3D TI + 120gSAP + M | 3.07 | 0.27 | 3.09 | 1.92 | 0.48 |
| $T_{15}$- 6D TI + 120gSAP + M | 3.04 | 0.25 | 3.05 | 1.86 | 0.44 |

| | | | | | |
|---|---|---|---|---|---|
| CD (P=0.05) | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 |

D: days, TI:trickle irrigation:SAP:superabsorbent polymer, M: mulch

*Fruit yield and quality attributes*: The influence of trickle irrigation intervals and SAP with black polyethylene mulch on fruit yield and quality parameters (fruit yield, fruit weight, fruit volume, Titratable acidityand TSS) are presented in Table 4. The augment in fruit yield was mostly attributed to improvement in soil moisture for longer time and availability of nutrients. Significantly highest fruit yield was recorded with treatment $T_{12}$ (101.43 kg/tree) which was numerically followed $T_{14}$ (96.98 kg/tree) while significantly lower was recorded in control (66.79 kg/tree). Yield under different doses SAP were intermediate, but significantly superior to different trickle irrigation intervals. Similar results of increased yield due to trickle irrigation and SAP with mulch were reported in Kinnow mandarin and other citrus crops (Kumar *et al*., 2022a and Kalhapure *et al*., 2016). Significantly highest fruit weight was recorded with $T_{12}$ (44.06 g) which was statistically at par with $T_{13}$ and $T_{14}$. On the other hand, significantly lowest fruit weight was recorded in control (34.46 g). Significantly higher fruit volume was recorded with $T_{14}$ which was followed by $T_{15}$, $T_{13}$ and $T_{12}$while significantly lower fruit volume was recorded in control.Titratable aciditywas found significantly higher in control (1.95%). The TSS was significantly lower in $T_{14}$ (1.52%) which was statistically at par with $T_{12}$ and $T_{15}$. On the other hand, significantly higher total soluble solids (TSS) were recorded in $T_{14}$ (10.90) which were statistically at par with $T_{12}$, $T_{13}$ and $T_{15}$. Significantly lower value of TSS was recorded in control (9.73). The higher titratable acidity and lower TSS with the fruits in control compared to other treatments was possibly caused by improved alteration of acids to sugars in dehydrated juice sacs which is obligatory to sustain the osmotic pressure of fruit cells under mild water stress condition prevailed under trickle irrigation intervals (Kumar *et al*., 2018 and Kumar *et al*., 2022b). Previous studies also confirmed the better TSS in citrus fruits under soil water shortage condition in root zone of trees (Navarro *et al*., 2010).

Table 4: Effect of superabsorbent polymer and trickle irrigation fruit yield and quality of Aonla cv. NA-7 (Pooled data of 2 years)

| Treatment | Yield (kg/tree) | Fruit weight (g) | Fruit volume (cc) | Titratable acidity (%) | TSS ($^0$Brix) |
|---|---|---|---|---|---|
| $T_1$- Control | 66.79 | 34.46 | 28.51 | 1.95 | 9.73 |
| $T_2$- 3D TI | 69.43 | 35.18 | 28.77 | 1.87 | 9.79 |
| $T_3$- 6D TI | 68.27 | 35.06 | 28.65 | 1.91 | 9.77 |
| $T_4$- 30gSAP | 71.85 | 36.11 | 29.40 | 1.81 | 9.81 |
| $T_5$- 60gSAP | 74.88 | 36.67 | 29.89 | 1.74 | 9.92 |
| $T_6$- 90gSAP | 77.98 | 37.30 | 30.10 | 1.70 | 9.94 |
| $T_7$- 120gSAP | 83.37 | 38.15 | 30.15 | 1.66 | 9.97 |
| $T_8$- 3D TI + 30gSAP + M | 89.18 | 40.34 | 31.46 | 1.63 | 10.23 |
| $T_9$- 6D TI + 30gSAP + M | 86.11 | 39.05 | 31.07 | 1.64 | 10.13 |
| $T_{10}$- 3D TI + 60gSAP + M | 93.55 | 42.03 | 32.09 | 1.59 | 10.45 |
| $T_{11}$- 6D TI + 60gSAP + M | 91.15 | 40.76 | 32.08 | 1.61 | 10.27 |
| $T_{12}$- 3D TI + 90gSAP + M | 101.43 | 44.06 | 33.49 | 1.54 | 10.77 |
| $T_{13}$- 6D TI+ 90gSAP + M | 95.69 | 43.93 | 33.56 | 1.58 | 10.64 |
| $T_{14}$- 3D TI + 120gSAP + M | 96.98 | 43.90 | 34.09 | 1.52 | 10.90 |
| $T_{15}$- 6D TI + 120gSAP + M | 92.37 | 41.66 | 33.96 | 1.54 | 10.54 |
| CD (P=0.05) | 3.69 | 0.72 | 0.29 | 0.02 | 0.51 |

D: days, TI: trickle irrigation: SAP: superabsorbent polymer, M: mulch

**Conclusion**

Superabsorbent polymers (SAP) retain water and nutrients in the soil, releasing them under dry conditions. Additionally, black polyethylene mulch conserves soil moisture, while trickle irrigation serves as a creative and water-saving technique during periods of water stress, enhancing soil characteristics and the productivity of Aonla cv. NA-7. The elevated soil and leaf nutrient concentrations observed in plants treated with trickle irrigation and

SAP with mulch materials are attributed to the improved availability of such nutrients in the soil under this treatment. Consequently, it can be inferred that utilizing three-day trickle irrigation and 90 g of SAP with black polyethylene mulch may represent a superior option for Aonla cultivation in the Kandi belt of Jammu's subtropical region. Overall, the study supports the adoption of trickle irrigation and SAP with mulch, potentially leading to increased production and quality of Aonla fruits in the area.

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**References**

Abobatta, W.F. and Khalifa, S. M. (2019). Influence of hydrogel composites soil conditioner on navel Orange growth and productivity. *Journal of Agriculture and Horticulture Research*, 2(2), 1-6.

Amberger, A. (2006). Soil Fertility and Plant Nutrition in the Tropics and Subtropics, first ed. IFA/IPI, Paris, France/Horgen, Switzerland.

Anonnymous (2017). Package of practices for horticultural crops. Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir, India.

Chopra, S. L. and Kanwar, J. S. (1986). Analytical Agricultural Chemistry. Kalyani Publishers. Ludhiana - New Delhi.

Islam, M.R., Hu, Y., Mao, S., Jia, P., Eneji, A.E., Xue, X. (2011). Effects of water-saving superabsorbent polymer on antioxidant enzyme activities and lipid peroxidation in corn (*Zea mays* L.) under drought stress. *Journal of the Science of Food and Agriculture*, 91, 813–819.

Jackson, M.L. (1973). Soil Chemical Analysis: Advanced course. The Author. Madison, Wisconsin, USA.

Kumar, V., Singh, V. B., Sohan, P. and Khajuria, S. (2014). Effect of Various Mulches on Soil Moisture Content, Soil Properties, Growth and Yield of Kinnow under Rainfed Condition. *International Journal of Agricultural Sciences*, 10 (1), 225-229.

Kalhapure, A., Kumar, R., Singh, V. P. and Pandey D. S. (2016). Hydrogels: a boon for increasing agricultural productivity in water-stressed environment. Current Science, 111(11), 1773-79. https://doi: 10.18520/cs/v111/i11/1773-1779.

Kumar, V., Sharma, V., Bhat, A. K., Gupta, N. and Singh, V. B. (2016). Effect of Various Mulching on Soil Properties and Fruit Quality Attributes of Eureka lemon (*Citrus limon* Burm) in kandi area. *Indian Journal of Ecology*, 1, 238-241.

Kumar, V., Sharma, V., Gupta, N., Kumar, R., Singh, B., Kumar, M., Singh, V.B. (2018). Soil mulches able to mitigate soil water deficiency impacts on Eureka lemon (*Citrus limon* Burm) production in rainfed environments in the Shivaliks of Jammu. *International Journal of Chemical Studies*, 6(3),2578-2584.

Kumar, V., Kumar, R., Chand, G., Kumar, J., Singh, B., Khajuria, S., Dhotra, B., Reena, Sharma, A. and Kumar, M. (2022a). Dynamics of soil properties and fruit productivity of Kinnow mandarin (*Citrus reticulata* Blanco) as affected by drip trickle irrigation and hydrogel. *Agricultural Mechanization in Asia*, 53 (3), 6439-46.

Kumar, V., Kumar. R., Chand. G., Kumar. J., Singh. B., Dhotra, B., Khajuria, S., Gupta, S., Sharma, N., Sinha, A. K., Raina, V., Ahamad, S. (2022b). Influence of trickle irrigation and hydrogel on Kinnow mandarin (*Citrus reticulate* Blanco) under rainfed condition. *Agricultural Mechanization in Asia*, 53(7),9007-9023.

Navarro, J.M., Pnrez-Pnrez, J.G., Romero, P., Botha, P. (2010). Analysis of the changes in quality in mandarin fruit, produced by deficit irrigation treatments. *Food Chemistry*, 119, 1591–1596. https://doi:10.1016/j.foodchem.2009.09.048

Panigrahi, P. and Srivastava, A.K. (2016). Effective management of irrigation water in citrus orchards under a water scare hot sub-humid region. *Scientia Horticulturae*, 210, 6-13. https://doi.org/10.1016/j.scienta.2016.07.008

Panigrahi, P., Srivastava, A.K., Huchche, A.D. and Singh, S. (2012). Plant nutrition in response to drip versus basin irrigation in young Nagpur mandarin on Inceptisol. *Journal of Plant Nutrition*, 35, 215–224. https://doi: 10.1080/01904167.2012.636124

Ranganna, R. (2001). Handbook of Analysis and Quality Control for Fruit and Vegetable products, second ed. Tata McGraw Hill, New Delhi.

Shirgure, P.S., Marathe, R.A., Ram, L., Singh, S. (2000). Irrigation scheduling in acid lime as affected by different soil moisture regimes. *The Indian Journal of Agricultural Sciences*, 70 (3), 173–176.

Tandon, H. L. S. (2005). Methods of Analysis of Soils, Plants, Waters, Fertilizers and Organic Manures, seconded. Fertilizer Development and Consultancy Organization, New Delhi, India.

Tiwari, K. N., Kumar, M., Santosh, D. T., Singh, V. K., Maji, M. K. and Karan, A. K. (2014). Influence of drip irrigation and plastic mulch on yield of sapota (*Achras sapota*) and soil nutrients. *Irrigation and drainage systems engineering*, 3, 116.

Yang, Y., Wu, J., Zhao, S., Gao, C., Pan, X.,Tang D.W.S and van der Ploeg, M. (2021). Effects of long-term super absorbent polymer and organic manure on soil structure and organic carbon distribution in different soil layers. *Soil and tillage research*, 206,104781. https://doi.org/10.1016/j.still.2020.104781

Islam, M.R.,Hu, Y., Mao, S., Jia, P., Eneji, A.E., Xue, X. (2011). Effects of water-saving superabsorbent polymer on antioxidant enzyme activities and lipid peroxidation in corn (*Zea mays* L.) under drought stress. *Journal of the Science of Food and Agriculture*, 91, 813–819. https://doi: 10.1002/jsfa.4252.

Singh,V., Singh, P. and Singh, A. K. (2009). Physico-chemical composition and evaluation of aonla cultivars under Chhattisgarh conditions**.** *Indian Journal of Horticulture***,** 66(2), 267-270.