AATCC Review

05 January 2025: Received
10 March 2025: Revised
08 April 2025: Accepted
12 April 2025: Available Online

https://aatcc.peerjournals.net/

Original Research Article

Open Access

Efficacy of pre-harvest foliar application of potassium nitrate, urea and salicylic acid on biochemical changes and yield in mango cv. Mallika (*Mangifera indica* L.)

Deepak Kumar, Kumari Karuna*, Awadhesh Kumar Pal, Abhay Mankar, Nishant and Pawan Kumar

Bihar Agricultural University, Sabour, Bhagalpur-813210 Bihar, India

ABSTRACT

The present study was carried out in two successive years in 2021 and 2022 in the experimental area of BAU Sabour, Bhagalpur, Bihar to show the efficacy of potassium nitrate, urea and salicylic acid alone and in combination to improving the biochemical and yield attributes of mango cv. Mallika. The studies revealed that the fruit quality in terms of total sugar, total soluble solids, titratable acidity, ascorbic acid, total antioxidant capacity and total phenol increased significantly in the combination treatment consist of two foliar applications, first in last week of October and second in mid November. Yield in number (38.33) fruits per plant and maximum average weight per fruit (497.62 g) was obtained in the treatment T_{15} (Potassium nitrate 3% + Urea 2% + Salicylic acid 2000 ppm).The above treatment combination also increases total sugar (17.26%), total soluble solids (24.09 °Brix), ascorbic acid (37.23 mg/100g), total antioxidant capacity (1.33 µmol. Trolox equiv.100 g -1 FW), total phenol (129.41 mg Gallic acid equiv. g-1 FW pulp) and titratable acidity (0.340 %) in comparison to control (water spray).

Keywords: *Mallika, fruit quality, yield, potassium nitrate, urea, salicylic acid, antioxidant capacity, phenol, total sugar, TSS, titratable acidity, ascorbic acid*

INTRODUCTION

Mango is the most important fruit crop among all the fruits at national as well as global level also. The production of mango is 21822 thousand MT and area 2258 thousand ha and yield 9.66 MT per ha in 2017-18 [2]. It is commercially grown in more than 111 countries but now in India it is greatly valued where about 40 per cent of area is under mango. Mango is the main commercial and popular fruit crop of our country. It is the third widely produced fruit crop of the tropics after banana and citrus. The total world production of mango is 55.85 million tonnes [3].

The mango cultivar Mallika, is a major semi-vigorous plant, a mid-season variety grown commercially with an aim to export due to its size, weight, acid blend sweetness and firm pulp. It's nature in initial stage is a shy bearing which results low productivity whereas the main objective of a mango grower is to harvest the maximum fruits per plant at low input cost every year. The production of flowers may be governed by enhancing the flowering shoot per cent and the production may be increased by enhancing the per cent of fruit-set and its fruit retention per cent up to the harvest time [38]. There is different well-established way to improve fruit quality as well as productivity of different fruit crops [50, 51]. Several experiments revealed that foliar feeding of nutrients directly to the site of the metabolism as a substitute for or supplement to soil application considerably enhanced fruit set per cent, fruit retention per cent, fruit yield, and quality attributes of mango [39, 46]. Foliar feeding of plants can effectively supplement soil fertilization. It has been found that the foliar application is more influential as compared to soil application of same level of nutrients. It was suggested that foliar feeding could be applied successfully to compensate for the shortage of those nutrients in plants [4]. Likewise, foliar spraying is an applied method for crop feeding either micro or macro nutrients in form of liquid are used [30]. The same, foliar nutrition is more effective on young leaves and a shortage of macro and micronutrients can be removed by this foliar application [21]. As well, the impact of some macro and microelements on fruit quality were reported by many investigators [14, 58].

Among different methods the foliar application of urea spray was reported to be an effective tool for increasing fruit set per cent, fruit retention per cent, producing a higher number of fruits per tree, increasing yield, and improving quality [34, 35, 40, 41, 55, 60, 61], potassium nitrate involved in numerous biochemical and physiological processes and play a pivotal and important role to plant growth and development, yield, quality and stress [8]. Hence, potassium is one of the principal plant nutrients underpinning crop productivity, yield, and quality determinations. When potassium uptake is lower than demand then foliar potassium is mobilized to the fruit, results better of plant growth, fruit set and quality [6] and salicylic acid play a crucial role in the regulation of several physiological activities in the plant such as stomata closure, plant nutrient uptake, chlorophyll synthesis and protein synthesis [22, 32, 42], also regulate plant responses to both abiotic and biotic stress factors [37] and enhances plant stress resistance and it has used widely due to its valuable role in plant stress resistance against abiotic stresses [28].

MATERIALS AND METHODS

Ten years old healthy Mallika mango plant with spacing (3.0 m × 2.5 m) was selected for the experiment.

Corresponding Author:* ***Kumari Karuna*

DOI: https://doi.org/10.21276/AATCCReview.2025.13.02.258

Urea (2%, 3%), salicylic acid (1000 ppm, 2000 ppm) and potassium nitrate (3%) were sprayed alone and in combinations to the selected plants. All the plants, used in the present study were maintained under uniform cultural management during the entire period of the experiment.

Preparation of working solution of chemicals

The chemicals used for the study were urea (2%, 3%), salicylic acid (1000 ppm, 2000 ppm), potassium nitrate (3%), and all have water-soluble. Therefore, it was first dissolved in water and then poured it in the required amount of water to prepare a fix concentration of stock solution one day before its application. On the day of spray, the working solution was prepared from these stock solutions to apply on the plant.

Spraying on experimental plants

After preparation of a working solution of urea (2%, 3%), salicylic acid (1000 ppm, 2000 ppm) and potassium nitrate (3%) at different concentrations alone and with different combinations, the solution was sprayed over the experimental Mallika mango plants only at 25th October and 15th November. The control plants were sprayed with distilled water. The experiment was continued for two consecutive years during 2021-2022. Spacing of plants in the experimental field was 3.0 m × 2.5 m and the number of treatments was eighteen with three replications.

Biochemical analyses

During both experimental years the biochemical analysis as well as yield of all the experimental plants wasrecorded. Thereafter, the biochemical analyses of ripe mango fruits were carried out.

Total sugar

Total sugar content was estimated according to [26] method. The per cent was determined by taking 50 ml of filtrate sample solution in a 100 ml volumetric flask and added 5 ml concentrated HCl and left it for 24 hours. Thereafter, added 2 drops phenolphthalein indicator in it and add 40% NaOH solution until it turns pink colour. 0.1 N HCl added slowly drop by drop for the pink colour disappearing. For this 10 g fruit pulp sample is grinded, 100 ml distilled water and 2 ml lead acetate solution was added in 250 ml volumetric flask. After that, 1.9 ml potassium oxalate solution was put in the solution and volume made up 250 ml with distilled water and then filtered the sample through filter paper. Filtrate was taken in burette and Fehling's solution A and B was taken in a conicalflask @ 5 ml each and 50 ml distilled water was added in it. Therefore, boiling of the solution was done until it becomes colour less. 2 drops of methylene blue indicator was added in it and titrate it with filtrate solution until brick red end point came.

$$\text{Total sugar (\%)} = \frac{\text{Factor} \times \text{Dilution}}{50 \times \text{Titrate value} \times \text{weight of sample}} \times 100$$

Total soluble solid

Total soluble solids content of the ripe fruit pulp was measured at room temperature with the help of hand refractometer (Atago, Tokyo, Japan) and the reading thus obtained was corrected for temperature variations to 20°C as per the International Temperature Correction Table (Hortwitz 1980) and expressed in terms of °B (degree Brix).

Titratable acidity

The titratable acidity content of ripe fruit pulp was determined by using titration method [36]. For these two grams of ripe fruit pulp sample was weighed and crushed with the help of mortar pistal and add 50 ml distilled water in it.Afterproper mixing it was filtered. In filtered sample, 2-3 drop of 1% phenolphthalein indicator was added and titrated against 0.1N sodium hydroxide. The titrated value was used for calculating the titratable acidity in per cent.

$$\text{Titratable acidity} = \frac{\text{Titre value x normality of alkali vol. made up equivalent wt. of acid x100}}{\text{Vol. of sample taken for estimation (aliquot) x wt. of sample taken x1000}}$$

Ascorbic acid content

By the help of 2, 6-dichlorophenol indophenol dye method (Jones and Hughes 1983), ascorbic acid content in the fruit pulp was determined. For this, 3 per cent metaphosphoric acid solution and 2 g of fruit pulp sample was crushed. After that volume of the extract was made up 100 ml and 10 ml of solution was titrated against the dye (2, 6-dichlorophenol indophenol) till the pink colour appeared. The ascorbic acid was expressed as mg 100 g-1 fruit pulp weight.

$$\text{Ascorbic acid} = \frac{\text{Titrate value x dye factor x volume made up}}{\text{Aliquot of extract taken for estimation x vol. of sample taken for estimation}} \text{ x100}$$

Antioxidant capacity

For estimating antioxidant capacity of fruit pulp, 1g of fruit pulp sample was crushed and homogenates at 10000 rpm for 20 min at 4°C temperature then supernatant collected. In a small tube 1 ml each of ammonium acetate, copper chloride, neocuproine were taken and added 100 µl supernatant samples into it. For blank, instead of sample 100 µl distilled water was added into it. Thereafter, absorbance was recorded in a spectrophotometer at 450 nm wavelength. The total antioxidant capacity was expressed as µmol Trolox equiv. 100 g-1 fresh pulp weight.

$$\textit{Antioxidant capacity} = \frac{\text{O.D x 4.1 x volume made up x 1000 x 100}}{\text{Weight of sample x 1.67 x 10000 x 0.1}} \text{ x100}$$

Total phenol

By the method described by [48] with some modifications the total phenolic content of fruit pulp was determined. For this 10 ml of 80% ethanol solution 1- gram fruit pulp was crushed with the help of mortar pistal. Then at 2000 rpm for20 min. at 24°C homogenate sample was centrifuged and obtained sample supernatant was used for assay of total phenol content. After that, 200 µL supernatant sample, 2.8 mL of distilled water and 0.5 mL of 2 N Folin-Ciocalteu reagents were added and left for 3 minutes, added into2 mL 20% of Na_2CO_3. After some time, prepared solution when turn into blue-black colour. Then absorbance was measuredat 750 nm using 1 cm cuvette with the help of perkin-elmer UV-VIS lambda 25 spectrophotometers and to obtaining standard calibration curve Gallic acid (0–800 mg L^{-1}) was used. The total phenol was expressed in term ofmg Gallic acid equiv. g^{-1} pulp.

$$\text{Total phenol} = \frac{\text{O.D x volume made up with 100\% ethanol}}{\text{Aliquot taken x weight of sample x 1000}} \text{ x 100}$$

Fruit weight

Weight of three fruits from each one of the three replications for a single treatment was recorded by weighing the sample on pan balance. The average weight of a fruit was calculated in each treatment and expressed in gram (g).

Yield

To calculate the yield of plant, all the harvestable fruits from each plant were harvested through mango harvester and weighing of harvested fruits in each treatment with replication and analyzed the data.

Statistical analysis

The observations were subjected to statistical analysis by using randomized block design (RBD) with three replications. Data of two consecutive years were pooled to prepare average data for each parameter. The mean difference was tested by 'F' test at 5% level of significance (LOS). Critical difference (CD) at 5% level of significance was used for comparison among treatments. Data were analyzed using statistical analysis software (R studio) and the means were compared using Duncan's multiple range test.

RESULTS AND DISCUSSION

Total sugar

It is envisaged from the data and graphical presented in (Fig. 1) that the total sugar content was increased in all the chemical-treated plants as compared to the control. From the graph the maximum total sugar (17.26 %) in T_{15} (Potassium nitrate 3 % + Urea 2 % + Salicylic acid 2000 ppm) which was statistically at par with T_{14} (17.24 %) and followed by T_{17} (16.71 %) which intern at par with T_{16}. However, the minimum total sugar (14.15 %) was in T_1 (control) followed by T_4(14.31 %) which was at par with T_2, T_3, T_6, and T_{18} (14.57 %, 14.59 %, 14.37 % and 14.50 % respectively). Rest of the treatments had an intermediary effect.

Furthermore, total sugar content of ripe mango fruit was recorded as maximum in the treatment consist of urea, potassium nitrate and salicylic acid application in all the foliar sprayed plant irrespective of concentrations with a minimum in control. The maximum total sugar (17.26 %) was recorded in T_{15} (Potassium nitrate 3% + Urea 2% + Salicylic acid 2000 ppm). This increase in total sugar content in the mango can be explained by the foliar application of the mentioned chemicals could be attributed to enhanced carbohydrate metabolism. Foliar application increases the capacity of production and translocation of sugar as potassium increases [9]. Similar results has been reported by [1] in grapes and [12] in guava, [43, 53, 59, 24, 51] in mango.

Total soluble solid

As compared to the control, the total soluble solids of ripened mango fruits of Mallika cultivar increased in all foliar chemical treated plants presented in (Fig. 2). The analysis of variance in respect of total soluble solids concluded that the treatments differed highly significantly in both the years as well as pooled analysis. From the graph, it is clearly showed that the treatment differed highly significantly and it was measured maximum (24.09 °Brix) in T_{15}in the plants that received the chemical combination with (Potassium nitrate 3 % + Urea 2 % + Salicylic acid 2000 ppm) as compared to control (T_1) i.e.19.34 °Brix.

The fruit quality parameters of mango cv. Mallika was significantly influenced by the foliar application of urea, potassium nitrate and salicylic acid on the plant. The TSS content has increased in the urea, potassium nitrate and salicylic acid treatment irrespective of its concentration.

The application of foliar feeding of chemicals increases TSS and found maximum (24.09 °Brix) in T_{15} (Potassium nitrate 3% + Urea 2% + Salicylic acid 2000 ppm) during fruit ripening could be due to hydrolysis of starch into sugar, hydrolysis of polysaccharides, conversion of organic acids into soluble sugars and enhanced solubilization of insoluble starch and pectin present in the cell wall and middle lamella [15]. The foliar potassium favors the conversion of starch into simple sugar during ripening by activating the sucrose synthase enzyme [11], salicylic acid regulates the carbohydrate metabolism in both source and sink tissue of plants, hydrolysis of sucrose by invertase [27] and potassium is also involved in phloem loading and unloading of sucrose and amino acids and storage in the form of starch in developing fruits by activating the enzyme starch synthase [29]. These results are in line with those of [7, 46, 51, 54, 59] in mango. Also, the obtained results are in harmony with those of [18] who mentioned that the application of urea, functioning on number of enzymes might be stimulated, affecting the physiological processes, which in turn hydrolyzed starch and helped in metabolic activity during the change of available starch into sugar and soluble solid content.

Titratable acidity

The graphical presentation on the effect of various concentrations of chemicals on titratable acidity is presented in (Fig. 3). The statistical analysis of data revealed that titratable acidity of fruit was highly significant in graph.The analysis of variance of pooled data reflected that the minimum titratable acidity percentage (0.340 %) recorded in T_{15} (Potassium nitrate 3 % + Urea 2 % + Salicylic acid 2000 ppm) which was statistically at par with T_{14} (0.343 %) and T_{17} (0.347 %) followed by T_{16} whereas maximum titratable acidity percentage (0.489) in T_1 followed by T_4 (0.475 %) which was statistically at par with T_5 (0.470 %).

The decreasing trend was obtained in titratable acidity per cent of the ripe fruit. The all-foliar sprayed treatment had significantly lower in titratable acidity in comparison to control and least (0.340 %) in T_{15} (Potassium nitrate 3% + Urea 2% + Salicylic acid 2000 ppm). On the other hand, reduction of titratable acidity per cent in treated treatments might be due to the rapid metabolic changes with rapidly conversion of organic acids into sugars and their derivatives by reactions involving reversal of glycolytic pathway [5].

Ascorbic acid content

A perusal of graph on ascorbic acid in mg/100 g of pulp content of mango cv. Mallika presented in (Fig. 4). The variation in ascorbic acid among the treatments was highly significant in both the years and pooled analysis also. From the analysis of variance of pooled data, it was found that maximum ascorbic acid (37.23 mg/100g) in treatment T_{14} which was statistically at par with T_{15} (37.18mg/100g) whereas minimum (29.30) in T_1.

This might be due to higher level of sugar by foliar spray of urea, potassium nitrate and salicylic acid since ascorbic acid is synthesized from sugar [17].

Total antioxidant capacity

Total antioxidant capacity of ripe mango cv. Mallika of different treatment was presented in (Fig. 5). The analysis of variance in respect of total antioxidant capacity indicated that treatment differed significantly from each other. From the figure, the highest total antioxidant capacity (1.33 µmol. Trolox equiv.100 g -1 FW) in T_{15} followed by T_{14} (1.29 µmol.

Trolox equiv. 100 g -1 FW pulp) whereas, lowest (1.04 µmol. Trolox equiv. 100 g -1 FW pulp) in T_1

The significant increase in antioxidant in treated plant is might be influenced by polyphenolic compounds which mainly contributed to increase in antioxidant capacity in mango fruits [58]. This result is also in agreement with other reports that the antioxidant capacity of fruits is due primarily to non-vitamin C phytochemicals [33, 56].

Total phenol

As compared to control, total phenol content of mango cv. Mallika was increased in all the treated fruits and graphical presented in (Fig. 6). The analysis of variance in respect of total phenol indicated that the differences among treatments were highly significant. An observation of figure revealed that maximum phenol (129.41 mg Gallic acid equiv. g-1 FW pulp) in T_{14}(Potassium nitrate 3 % + Urea 2 % + Salicylic acid 1000 ppm)

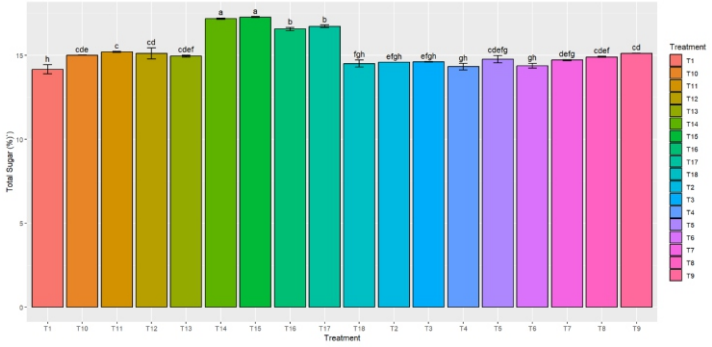
Total phenol content was positively affected by the application of potassium nitrate, urea and salicylic acid of different concentrations. Most effective treatment combination was T_{14} (Potassium nitrate 3 % + Urea 2 % + Salicylic acid 1000 ppm). This might be due to higher level of sugar by foliar spray of above nutrients. Salicylic acid showed positive result on phenol content [44] in mango cv. Kesington and [62] in ber.

Average Fruit weight and Fruit yield/plant

The analysis of variance of pooled data showed in (Fig. 7) that the maximum (497.62 g) average fruit weight was in T_{15} whereas, minimum (411.20 g) in T_1 (control). Data presented regarding the total number of fruits per plant have been shown graphical in (Fig. 8). It was highly significant in both the years and pooled analysis also. On the other hand, the statistical analysis of pooled data showed maximum (38.33) fruits per plant in T_{15} (Potassium nitrate 3 % + Urea 2 % + Salicylic acid 2000 ppm) which was at par result in T_{14}, T_{16} and T_{17} (38.00, 36.00 and 35.17 respectively) however, minimum (24.33) in T_1 (control) which was at par with T_2, T_3 and T_4. Rest of all treatment had intermediary effect on total numbers of fruit/plant.

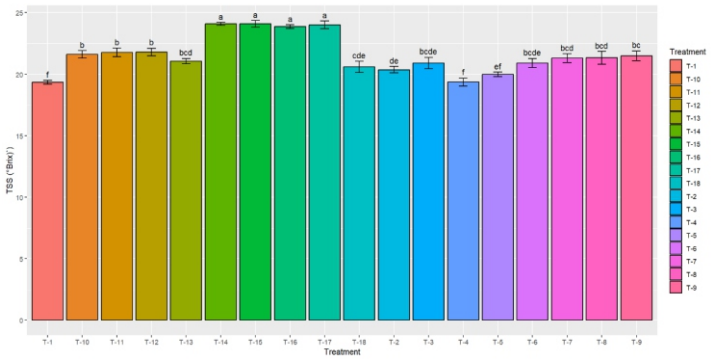
The urea has helped in more fruit retention per shoot, which resulted in increasing number of fruits per plant [52]. Similar results were found by [10] in Kinnow mandarin. The cumulative effect of nitrogen on photosynthetic as well as metabolic activities has helped to increase the fruit size and fruit weight and thereby increase the fruit yield [19]. Similar results are also found by [25]. The increase in yield parameters due to salicylic acid observed in the present investigation can be attributed to increased photosynthetic activity in leaves and translocation of more photo-assimilates to fruits [31]. The findings of [47] in mango and [13] in olive agree with the present study.

Figure 1. Effect of potassium nitrate, urea and salicylic acid on total sugar in mango cv. Mallika



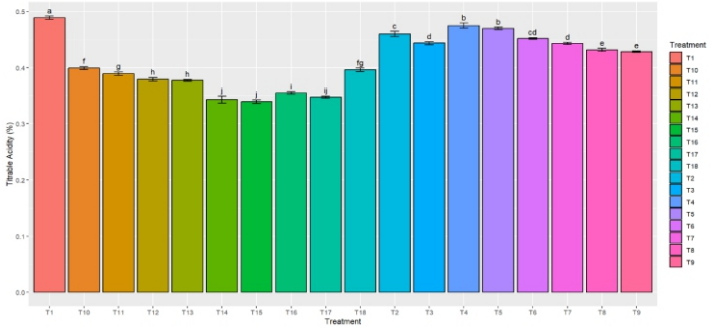
(T_1 – control; T_2 - salicylic acid 1000ppm; T_3 - salicylic acid 2000ppm; T_4 - urea 2%; T_5 - urea 3%; T_6 - urea 2% + salicylic acid 1000ppm; T_7 - urea 2% + salicylic acid 2000ppm; T_8 - urea 3% + salicylic acid 1000ppm; T_9 - urea 3% + salicylic acid 2000ppm; T_{10} - KNO_3 3% + salicylic acid 1000ppm; T_{11} - KNO_3 3% + salicylic acid 2000ppm; T_{12} - KNO_3 3% + urea 2%; T_{13} - KNO_3 3% + urea 3%; T_{14} - KNO_3 3% + urea 2% + salicylic acid 1000ppm; T_{15} - KNO_3 3% + urea 2% + salicylic acid 2000ppm; T_{16} - KNO_3 3% + urea 3% + salicylic acid 1000ppm; T_{17} - KNO_3 3% + urea 3% + salicylic acid 2000ppm; T_{18} - KNO_3 3%)

Figure 2. Effect of potassium nitrate, urea and salicylic acid on TSS in mango cv. Mallika



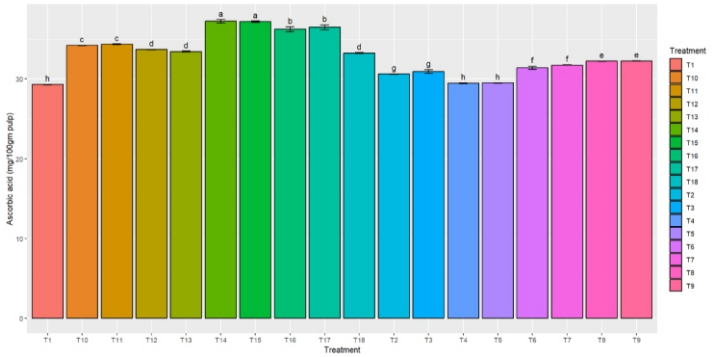
(T_1 – control; T_2 - salicylic acid 1000ppm; T_3 - salicylic acid 2000ppm; T_4 - urea 2%; T_5 - urea 3%; T_6 - urea 2% + salicylic acid 1000ppm; T_7 - urea 2% + salicylic acid 2000ppm; T_8 - urea 3% + salicylic acid 1000ppm; T_9 - urea 3% + salicylic acid 2000ppm; T_{10} - KNO_3 3% + salicylic acid 1000ppm; T_{11} - KNO_3 3% + salicylic acid 2000ppm; T_{12} - KNO_3 3% + urea 2%; T_{13} - KNO_3 3% + urea 3%; T_{14} - KNO_3 3% + urea 2% + salicylic acid 1000ppm; T_{15} - KNO_3 3% + urea 2% + salicylic acid 2000ppm; T_{16} - KNO_3 3% + urea 3% + salicylic acid 1000ppm; T_{17} - KNO_3 3% + urea 3% + salicylic acid 2000ppm; T_{18} - KNO_3 3%)

Figure 3. Effect of potassium nitrate, urea and salicylic acid on titratable acidity content in mango cv. Mallika



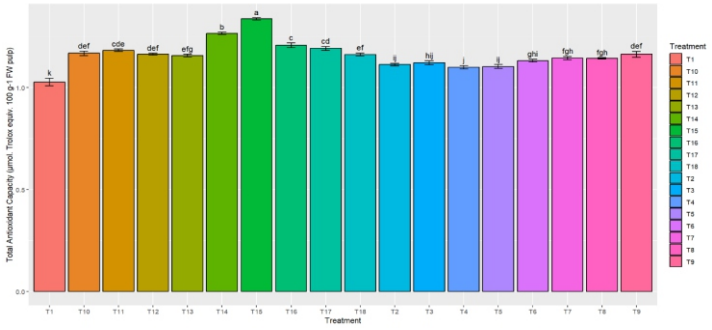
(T_1 – control; T_2 - salicylic acid 1000ppm; T_3 - salicylic acid 2000ppm; T_4 - urea 2%; T_5 - urea 3%; T_6 - urea 2% + salicylic acid 1000ppm; T_7 - urea 2% + salicylic acid 2000ppm; T_8 - urea 3% + salicylic acid 1000ppm; T_9 - urea 3% + salicylic acid 2000ppm; T_{10} - KNO_3 3% + salicylic acid 1000ppm; T_{11} - KNO_3 3% + salicylic acid 2000ppm; T_{12} - KNO_3 3% + urea 2%; T_{13} - KNO_3 3% + urea 3%; T_{14} - KNO_3 3% + urea 2% + salicylic acid 1000ppm; T_{15} - KNO_3 3% + urea 2% + salicylic acid 2000ppm; T_{16} - KNO_3 3% + urea 3% + salicylic acid 1000ppm; T_{17} - KNO_3 3% + urea 3% + salicylic acid 2000ppm; T_{18} - KNO_3 3%)

Figure 4. Effect of potassium nitrate, urea and salicylic acid on ascorbic acid content in mango cv. Mallika



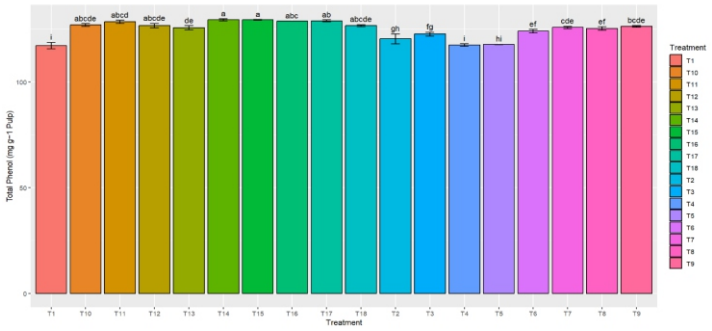
(T_1 – control; T_2 - salicylic acid 1000ppm; T_3 - salicylic acid 2000ppm; T_4 - urea 2%; T_5 - urea 3%; T_6 - urea 2% + salicylic acid 1000ppm; T_7 - urea 2% + salicylic acid 2000ppm; T_8 - urea 3% + salicylic acid 1000ppm; T_9 - urea 3% + salicylic acid 2000ppm; T_{10} - KNO_3 3% + salicylic acid 1000ppm; T_{11} - KNO_3 3% + salicylic acid 2000ppm; T_{12} - KNO_3 3% + urea 2%; T_{13} - KNO_3 3% + urea 3%; T_{14} - KNO_3 3% + urea 2% + salicylic acid 1000ppm; T_{15} - KNO_3 3% + urea 2% + salicylic acid 2000ppm; T_{16} - KNO_3 3% + urea 3% + salicylic acid 1000ppm; T_{17} - KNO_3 3% + urea 3% + salicylic acid 2000ppm; T_{18} - KNO_3 3%)

Figure 5. Effect of potassium nitrate, urea and salicylic acid on total antioxidant capacity in mango cv. Mallika



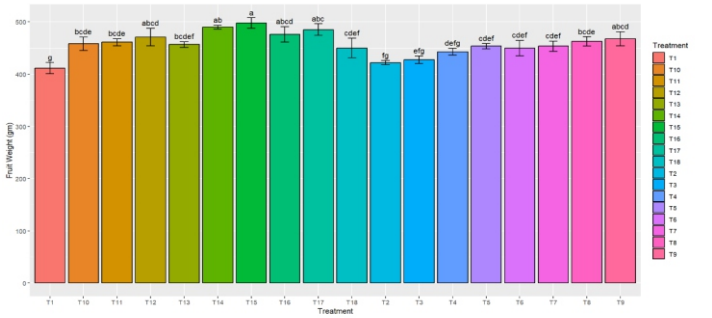
(T_1 – control; T_2 - salicylic acid 1000ppm; T_3 - salicylic acid 2000ppm; T_4 - urea 2%; T_5 - urea 3%; T_6 - urea 2% + salicylic acid 1000ppm; T_7 - urea 2% + salicylic acid 2000ppm; T_8 - urea 3% + salicylic acid 1000ppm; T_9 - urea 3% + salicylic acid 2000ppm; T_{10} - KNO_3 3% + salicylic acid 1000ppm; T_{11} - KNO_3 3% + salicylic acid 2000ppm; T_{12} - KNO_3 3% + urea 2%; T_{13} - KNO_3 3% + urea 3%; T_{14} - KNO_3 3% + urea 2% + salicylic acid 1000ppm; T_{15} - KNO_3 3% + urea 2% + salicylic acid 2000ppm; T_{16} - KNO_3 3% + urea 3% + salicylic acid 1000ppm; T_{17} - KNO_3 3% + urea 3% + salicylic acid 2000ppm; T_{18} - KNO_3 3%)

Figure 6. Effect of potassium nitrate, urea and salicylic acid on total phenol content in mango cv. Mallika



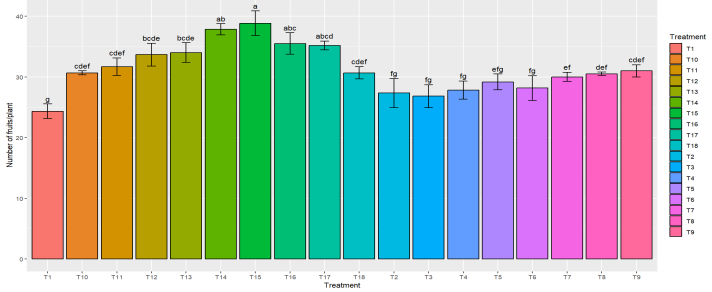
(T_1 – control; T_2 - salicylic acid 1000ppm; T_3 - salicylic acid 2000ppm; T_4 - urea 2%; T_5 - urea 3%; T_6 - urea 2% + salicylic acid 1000ppm; T_7 - urea 2% + salicylic acid 2000ppm; T_8 - urea 3% + salicylic acid 1000ppm; T_9 - urea 3% + salicylic acid 2000ppm; T_{10} - KNO_3 3% + salicylic acid 1000ppm; T_{11} - KNO_3 3% + salicylic acid 2000ppm; T_{12} - KNO_3 3% + urea 2%; T_{13} - KNO_3 3% + urea 3%; T_{14} - KNO_3 3% + urea 2% + salicylic acid 1000ppm; T_{15} - KNO_3 3% + urea 2% + salicylic acid 2000ppm; T_{16} - KNO_3 3% + urea 3% + salicylic acid 1000ppm; T_{17} - KNO_3 3% + urea 3% + salicylic acid 2000ppm; T_{18} - KNO_3 3%)

Figure 7. Effect of potassium nitrate, urea and salicylic acid on fruit weight content in mango cv. Mallika



(T_1 – control; T_2 - salicylic acid 1000ppm; T_3 - salicylic acid 2000ppm; T_4 - urea 2%; T_5 - urea 3%; T_6 - urea 2% + salicylic acid 1000ppm; T_7 - urea 2% + salicylic acid 2000ppm; T_8 - urea 3% + salicylic acid 1000ppm; T_9 - urea 3% + salicylic acid 2000ppm; T_{10} - KNO_3 3% + salicylic acid 1000ppm; T_{11} - KNO_3 3% + salicylic acid 2000ppm; T_{12} - KNO_3 3% + urea 2%; T_{13} - KNO_3 3% + urea 3%; T_{14} - KNO_3 3% + urea 2% + salicylic acid 1000ppm; T_{15} - KNO_3 3% + urea 2% + salicylic acid 2000ppm; T_{16} - KNO_3 3% + urea 3% + salicylic acid 1000ppm; T_{17} - KNO_3 3% + urea 3% + salicylic acid 2000ppm; T_{18} - KNO_3 3%)

Figure 8. Effect of potassium nitrate, urea and salicylic acid on number of fruits per tree in mango cv. Mallika



(T_1 – control; T_2 - salicylic acid 1000ppm; T_3 - salicylic acid 2000ppm; T_4 - urea 2%; T_5 - urea 3%; T_6 - urea 2% + salicylic acid 1000ppm; T_7 - urea 2% + salicylic acid 2000ppm; T_8 - urea 3% + salicylic acid 1000ppm; T_9 - urea 3% + salicylic acid 2000ppm; T_{10} - KNO_3 3% + salicylic acid 1000ppm; T_{11} - KNO_3 3% + salicylic acid 2000ppm; T_{12} - KNO_3 3% + urea 2%; T_{13} - KNO_3 3% + urea 3%; T_{14} - KNO_3 3% + urea 2% + salicylic acid 1000ppm; T_{15} - KNO_3 3% + urea 2% + salicylic acid 2000ppm; T_{16} - KNO_3 3% + urea 3% + salicylic acid 1000ppm; T_{17} - KNO_3 3% + urea 3% + salicylic acid 2000ppm; T_{18} - KNO_3 3%)

CONCLUSION

The present investigation confirms that the action of urea (2%, 3%), salicylic acid (1000 ppm, 2000 ppm), and potassium nitrate (3%) is very quick and it also degrades very quickly. Therefore, repeated applications of Urea (2%, 3%), Salicylic acid (1000 ppm, 2000 ppm) and Potassium nitrate (3%) reflected its long-lasting action for improving the physiological growth of mango cv. Mallika with increased yield of better-quality fruit in terms of higher TSS: acid ratio, reducing sugar and total phenol content. Further, among different combination treatment concentrations T_{15} (Potassium nitrate 3% + Urea 2% + Salicylic acid 2000 ppm) combination foliar spray during the month of mid-October and November showed at par results for improving all the yield and quality attributes of mango cv. Mallika.

FUTURE SCOPE OF THE EXPERIMENT

In present scenario salicylic acid helps in abiotic stress management of any crop and urea is the main component of photosynthetic activity. Potassium nitrate play an important role in flowering and fruiting in different fruit crops including mango. Thus these chemical combinations in different concentrations may be further evaluated in adverse climatic conditions to show the effect of above mentioned chemicals.

ACKNOWLEDGEMENTS

The authors are highly acknowledged to Bihar Agricultural University, Sabour, Bihar-813210 (India) for providing a good laboratory with all the facilities during the research period.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest: The authors declare that there are no conflicts of interest.

AUTHOR'S CONTRIBUTION

Deepak Kumar: Main investigator; methodology; writing-original draft. Kumari Karuna: Data curation; methodology; writing-original draft. Awadhesh Kumar Pal: Conceptualization; supervision. Abhay Mankar: Conceptualization; resources; writing-original draft. Nishant: Resources; data analyses. Pawan Kumar: Resources; writing-original draft.

ORCID

Deepak Kumar ID: https://orcid.org/0000-0002-8306-0492
K. Karuna ID: https://orcid.org/0000-0003-2718-3559
Nishant ID: https://orcid.org/0009-0003-4418-7938

REFERENCES

1. Ali W, Pathak RA, Yadav AL. (1991). Effect of foliar application of nutrients on Guava (*Psidium guajava* L.) cv. Allahabad Safeda. *Progressive Horticulture* 23 (1 - 4): 18–21.

2. Anonymous (2017). Indian horticulture database. www.nhb.gov.in.

3. Anonymous (2021). Statista.com

4. Arif M, Chohan MA, Ali S., Gul R., Khan S. (2006). Response of wheat to foliar application of nutrients. *Journal of Agricultural Biological Science* 1(4):30–34.

5. Barkule SR, Patel BN, Baghele RD. (2018). Effect of 28-Homobrassinolide, CPPU, GA3 and humic acid on quality and shelf life of Sapota (*Manilkara achras*) cv. Kalipatti harvested in winter. *International Journal of Current Microbiology and Applied Sciences* 6: 962-967.

6. Besford RT, Maw GA. (1975). Effects of potassium nutrition on tomato plant growth and fruit development. *Plant Science* 42:395–412.

7. Burondkar MM. (2005). Influence of plant growth regulator, polyamine and nutrients on post-flowering physiological behaviour in relation to yield and quality in Alphonso mango (*Mangifera indica* L.). Thesis submitted to the University of Agricultural sciences, Dharwad. (Unpublished).

8. Cakmak I. 2005. The role of potassium in alleviating detrimental effects of abiotic stresses in plants. *Journal of Plant Nutrition and Soil Science* 168(4):521–530.

9. Dsouza SB. (2007). Effect of spraying of chemical and organic compounds on fruit set, yield and quality of kokum (*Garcinia indica* Choisy). A M.Sc. (Agri.) thesis submitted to the Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli (Unpub).

10. Dudi OP, Kumar S, Singh S, Singh S. (2004). Effect of urea and FYM on fruit size and yield of kinnow mandarin. *Haryana Journal of Horticultural Sciences* 33(3&4):178-180.

11. Dutta, Ahmed PB, Kundu S. (2011). Effect of different sources of potassium on yield, quality and leaf mineral content of mango in West Bengal. *Better crops* 16-18.

12. Dutta, P. 2004. A short note on foliar potassium spray in improving the quality of Sardar guava (*Psidium guajava*). *The Orissa Journal of Horticulture* 32(1): 103-104.

13. El-Razek EA, Hasan HS, G.El–Din KM. (2013). Effect of foliar application with salicylic acid, benzyl adenine and gibberellic acid on flowering, yield and fruit quality of olive trees (*Olea europaea* L.). *Middle-East Journal of Scientific Research* 14:(11).

14. Etman, Atalla A, El-Kobbia A, El-Nawam S. (2007). Influence of flower boron sprays and soil application with some micro nutrients in calcareous soil on vegetative growth and leaf mineral content of date palm cv. Zaghloul in Egypt. In: *Proceedings of the 4th Symposium on Date Palm* in Saudi Arabia, 2007, pp 5–8

15. Gupta RK, Brahmachari VS. (2004). Effect of foliar application of Urea, Potassium nitrate and NAA on fruit retention, yield and quality of mango Cv. Bombai. *The Orissa Journal of Horticulture* 32(2): 7-9.

16. Hortwitz W. (1980). Official methods of analysis. 13th ed. Washington DC: Association of official analytical chemist.

17. Jadhav S, Salvi VG, Utkarsha D, Jadhav SC. (2019). Yield and quality of Alphonso mango as influence by foliar application of nutrients in lateritic soil. *The Pharma Innovation Journal* 8(10): 14-18.

18. Jain, PK. (2006). Fruit drop, yield and quality of mango as influenced by biozyme and urea sprays. *Indian Journal of Horticulture* 63(4): 453-454.

19. Jat G, Kacha HL. (2014). Response of guava to foliar application of urea and zinc on fruit set, yield and quality. *Journal of Agrisearch* 1(2):86-91.

20. Jones E, Hughes R, Kacha E. (1983). Foliar ascorbic acid in some angiosperms. *Phytochemistry* 22: 2493–2499.

21. Kashi AK. (1994). Vegetables. Textbook of Horticulture College. Tehran University, Tehran.

22. Khan W, Balakrishnan P, Smith DL. (2003). Photosynthetic responses of corn and soybean to foliar application of salicylate. *Journal of Plant Physiology* 160 (5): 485- 492.

23. Kumar S, Pathak RA. (1992). Effect of foliar application of nutrients on the yield and quality of grapes (*Vitis vinifera* L.) cv. Perlette *Progressive Horticulture* 24 (1 –2): 13–16.

24. Kumari K, Mankar A, Singh J. (2007). Effect of urea and growth substances on yield and quality of mango cv. Langra. *The Orissa Journal of Horticulture* 35(1): 67-70.

25. Labanauskas CK, Jones WW, Embleton TW. (1963). Effect of foliar application of Mn, Zn and urea on yield and fruit quality of orange. *In American Society of Horticultural Science Proceedings*, *Alexandria* (Vol. 82 pp. 142-153).

26. Lane JH, Eynone L. (1923). Determination of reducing sugars by means of Fehling solution with methylene blue indicator as an internal indicator. *Journal of Indian Chemical Society* 42: 32.

27. Leclere S, Scmelz EA, Chourey PS. (2003). Cell wall invertase-deficient miniature kernels have altered phytohormone levels. *Phytochem*69 (3): 692-699.

28. Martinez, Pons C, Prats V, Leon G. (2004). Salicylic acid regulates flowering time and links defense responses and reproductive development. *The Plant Journal* 37:209-217.

29. Mengel K, Kirk EA. (1987). *Principles of plant nutrition* IPI, Bern. pp. 436-437.

30. Nasiri Y, Zehtab-Salmasi S, Nasrullahzadeh S, Najafi N, Ghassemi- Golezani K. (2010). Effects of foliar application of micronutrients (Fe and Zn) on flower yield and essential oil of chamomile (*Matricaria chamomilla* L.). *Journal of Medicinal Plants Research* 4(17):1733–173.

31. Ngullie CR, Tank RV, Bhanderi RV. (2014). Effect of salicylic acid and humic acid on flowering, fruiting, yield and quality of mango (*Mangifera indica* L.) cv. KESAR. *Advance research journal crop improvement* 5(2): 136-139.

32. Piatelli M, Denicola M, Castrogiovanni V. (1969). Photo control of maranthin synthesis in Amaranthus tricolor. *Phytochem* 8:731-736.

33. Prior RL, Cao GH, Martin A, Sofic E, McEwen J, O'Brien C. (1998). Antioxidant capacity as influenced by total phenolic and anthocyanin content, maturity, and variety of Vaccinium species. *Journal of Agricultural Food Chemistry* 46:2686–2693.

34. Rajput CBS, Singh JN. (1989). Effect of urea and GA sprays on the growth, flowering and fruiting characters of mango. *Acta Horticulturae* 31: 301-305.

35. Rajput CBS, Tiwari JP. (1975). Effect of foliar sprays of urea on flowering and fruiting characters of three cultivars of mango. *Bangladesh Horticulture* 3(2): 1-5.

36. Rangana S. (2010). Handbook of Analysis and quality control for fruit and vegetable products, *Tata Mc Grow-Hill Ltd*., New Delhi.

37. Rao MV, Lee HI, Creelman RA, Mullet JA, Davis KR. (2000). Jasmonic acid signaling modulates ozone-induced hypersensitive cell death. *Plant Cell* 12:1633-1646.

38. Saha DP, Jha KK, Sengupta S, Misra S, Lal HC, Prasad K. (2017). Preliminary investigations on the effect of foliar Spray of chemicals on flowering, fruit setting and retention of fruits of mango cv. Mallika, *International Journal of Science and Environment* 6(2):1574-1580.

39. Samra JS, Thakur RS, Chadha KL. (1977). *Indian Journal of Horticulture* 34:26-29.

40. Samra NRE, Hegazi A, Abdel-Fattah MI. (2010). Effect of GA3, urea and pinching treatments on "ZEBDA" Mango trees. *Journal of Plant Production Mansoura Univ*ersity 1(10): 1399 – 1407.

41. Sarker BC, Rahim MA. (2013). Yield and quality of mango (*Mangifera indica* L.) as influenced by foliar application of potassium nitrate and urea. *Bangladesh Journal of Agricultural Research* 38(1): 145-154.

42. Shakirova FM, Sakhabutdinova AR, Bezrukova MV, Fathkutdinova RA, Fatkhutdinova DR. (2003). Changes in the hormonal status of wheat seedlings induced by salicylic acid and salinity. *Plant Science* 164:317.

43. Sharma TR, Nair MK. (1990). Influence of foliar sprays of urea, KNO3 and NAA on chemical composition of mango cv. Langra. *The Punjab Horticultural Journal* 30 (1/2): 53-56.

44. Shehzad SS, Ahmad, Jaskani MJ, Taj SUD, Shafqat W. (2016). Pre and postharvest treatment of salicylic acid to improve the fruit quality and shelf life of mango (*Mangifera indica* L.). Proceedings of Pakistan Society for Horticultural Science, 2nd International Conference on Horticultural Sciences.

45. Singh JN, Singh DK, Chakravarthy D. (1994). *Orissa Journal of Horticultural Science* 22:26-30

46. Singh K, Rathour URS, Pathak RA. (1983). Effect of foliar feeding of NPK nutrients on nutritional status of leaves, yield and quality of fruits in Dashehari mango. *South Indian Horticulture* 31(1): 229-231.

47. Singh VK, Saini JP, Mishra AK. (2001). Response of salicylic acid on flowering, floral malformation, fruit set, yield and associated bio-physical and biochemical character of mango. *Indian journal Horticulture* 58 (3):196-201.

48. Singleton VL, Orthofer R, Lamuela-Ranventos RM. (1999). Analysis of total phenols, other oxidation substrates and antioxidants by means of Folin–Ciocalteu reagent. *Methods in Enzymology* 299:152–78.

49. Souri MK, Bakhtiarizade M. (2019). Bio stimulation effects of rosemary essential oil on growth and nutrient uptake of tomato seedlings. *Scientia Horticulturae* 243:472–76..

50. Souri MK, Hatamian M. (2019). Amino chelates in plant nutrition; a review. *Journal of Plant Nutrition* 42 (1):67–78.

51. Stino RG, Sahar M, Abd EW, Habashy SA, Kelani RA. (2011). Productivity and fruit quality of three mango cultivars in relation to foliar sprays of calcium, zinc, boron and potassium. *Journal of Horticultural Science and Ornamental Plants* 3(2): 91-98.

52. Syamal MM, Singh SK, Bhattarcharya BP. (2008). Effect of urea and zinc on growth flowering fruiting and fruit quality of Kagzi lime. *Environment and Ecology* 26(3):1036-1038.

53. Vijayalakshmi D, Srinivasan PS. (2000). Improving the quality attributes of 'Off' year Alphonso mango through chemicals and growth regulators. *The Orissa Journal of Horticulture* 28(1): 31-33.

54. Vijayalakshmi D, Srinivasan PS. (1998). Effect of chemicals and growth regulators on the fruit number, fruit weight and yield in mango cv. Alphonso. *Madras Agricultural Journal* 85 (10 – 12): 701–702.

55. Wahdan MT, Habib SE, Bassal MA, Qaoud EM. (2011). Effect of some chemicals on growth, fruiting, yield and fruit quality of "Succary Abiad" cv. mango *Journal of American Science* 7(2): 651-658.

56. Wang H, Cao GH, Prior RL. (1997). Oxygen radical absorbing capacity of anthocyanins. *Journal of Agricultural and Food Chemistry* 45: 304–309.

57. Westover F, Kamas J. (2009). Investigation of spray timing of B and effects of micro-nutrient sprays on yields of 'Blanc du Bois' wine grapes. In: *Proceedings of the Texas Viticulture and Enology Research Symposium* pp 2-3

58. Xiaowei Ma, Hongxia Wu, Liqin Liu, Quansheng Yao, Songbiao Wang, Shanshan RZ, Yigang ZhouXing. (2011). Polyphenolic compounds and antioxidant properties in mango fruits. *Scientia Horticulturae* 129, 102–107.

59. Yeshitela TB (2004). Potassium nitrate and urea sprays affected flowering and yields of Tommy Atkins mango in Ethiopia. *South African Journal of Plant and oil* 154- 172.

60. Yeshitela T, Robbertse PJ, Stassen PJC. (2005). Potassium nitrate and urea sprays affect flowering and yields of 'Tommy Atkins' (*Mangifera indica* L.) mango in Ethiopia. *South African Journal of Plant and Soil* 22(1): 28-32.

61. Zaeneldeen EMA. (2014). Effect of urea, gibberellic acid foliar application and pinching early panicles on productivity of "Succary Abiad" mango trees under desert conditions. *Middle East Journal of Agriculture Research* 3(2): 135-143.

62. Zeraatgar H, Davarynejad GH, Moradinezhad F, Abedi B. (2018). Effect of salicylic acid and calcium nitrate spraying on qualitative properties and storability of fresh jujube fruit (*Ziziphus jujube* Mill.) *NotulaeBotanicae Horti Agrobotanici Cluj-Napoca* 46(1):138-147.