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Chemical interventions for advancing the fruiting season of sugar apple (*Annona squamosa* L.) cv. balanagar

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Abstract
Fruits of 'Balanagar', the most commonly grown cultivar of sugar apple (*Annona squamosa*) in India, come to harvest during the rainy months of September-October. Advancing its fruiting to early summer would be advantageous for better fruit quality. Since flowering in sugar apple occurs on current season growth arising naturally after leaf fall during late winter, attempt was made to advance the fruiting season by defoliating the trees using chemicals, well before the natural leaf fall during December - January. The chemical defoliants urea (5%, 10% & 15%) and ethrel (2000ppm, 3000ppm & 4000ppm) and bud sprout promoter KNO_3 (5%, 10% and 15%) were sprayed during first week of October for two consecutive years (2016-17 and 2017-18). Maximum defoliation (97%, 96.5%) was recorded for ethrel @ 4000ppm during both the years. Early sprouting (26 days, 16.1days) and flower initiation (35 days, 23.03 days) were recorded in trees sprayed with urea @ 15% for both the years, respectively. Earliest harvest was from trees treated with urea @ 15% (290 days) and ethrel @ 4000ppm (285 days). Fruit yield per tree was not affected by any of the treatments. Defoliation with different chemicals significantly influenced vegetative and reproductive growth of sugar apple cv. Balanagar leading to early fruit harvest by 5-6 weeks.

Keywords: sugar apple; chemical defoliation; off season crop; fruit quality

1. Introduction
Sugar apple (*A. squamosa* L.) is cultivated in arid and semi-arid regions of India, mainly in the states of Andhra Pradesh, Maharashtra, Karnataka, Bihar, Orissa, Assam, Tamil Nadu and Rajasthan. Its fruits are generally used fresh, while some products like custard powders and ice-creams are prepared from the fruit pulp. It is high in energy, an excellent source of vitamin C and manganese, rich in thiamine, vitamin B6 and good provider of iron, magnesium, phosphorus and potassium in fair quantities. Among all the sugar apple cultivars in different parts of India namely Balanagar, Mammoth, Mahaboobnagar, Washington, Red Sitaphal, British Guinea, Kakarlapahad, *etc.*, Balanagar is the most common. Under natural conditions, its fruits mature and come to harvest during September-October, which coincides with monsoon rains resulting in poor fruit quality coupled with high incidence of anthracnose disease and fruit fly. It is a deciduous fruit crop and flowers on current season growth during March-April after leaf fall during previous winter. Crop regulation practices to advance fruiting could be beneficial for getting high quality fruits during summer. In annona, flower bud formation is extra-axillary which is borne opposite the leaves, restricted to early shoot development (George and Nissen, 1987) [11]. As sugar apple cv. Balanagar possesses short branches with subpetiolar lateral buds, defoliating trees or promoting bud break with application of chemicals could be easier and economical than pruning to induce flowering. Different chemicals *viz.* urea, dormex, ethrel, potassium iodide (KI), naphthalene acetic acid (NAA), *etc.* can be used effectively to defoliate the tree. During the later part of stress period, application of fertilizer, manure and irrigation promotes new growth and plants come into flowering and fruiting followed by spraying with these chemical defoliants. Several studies have been conducted in different fruit crops for induction of flowering by using defoliants. Singh *et al.* (1994) [37] found that with increase of urea concentration, the rate of defoliation increases and 15 per cent urea spray was optimum for regulating crop growth in guava cv. Allahabad Safeda. Kobayashi (1986) [21] recorded that with the increase of ethephon concentration (600-1800ppm), there was increase in defoliation from 26 to 94 per cent in guava cv. Beaumont. Nanra *et al.* (2001) [24] studied that the maximum defoliation is caused

due to KI spray followed by urea spray in guava. In guava cv. Allahabad Safeda, 250ppm NAA spray caused maximum defoliation and produced maximum yield (Dubey *et al.*, 2002) [8]. The chemical defoliants have significant effect on inducing vegetative growth and flowering in fruit trees. Ethrel, thiourea and dormex have been used to increase bud break in grapevine (Shikhamany and Reddy, 1989) [36]. Watson and Casper (1984) [43] and Watson (1986) [42] reported that the defoliation resulted in interruption of flowering response as a result of manipulations in partitioning of assimilates within the tree. There is competency for assimilates, which depend on the extent of branch autonomy for reproductive as well as vegetative growth. The defoliation practices cause physical injury, which may trigger hormonal stimulation that in turn initiates the metabolic processes needed for bud break (Kato & Ito, 1962) [18]. Potassium nitrate (KNO_3) is effective in increasing bud break (Erez and Lavee, 1974) [10]. Also, foliar application of K enhanced carbohydrate reserves, which ensured better flowering, fruit set and yields in fruit crops. Maloba *et al.* (2017) [22] reported that spraying mango cvs. 'Apple' and 'Ngowe' with 4% KNO_3 was effective for improved flowering. Though the information on endogenous regulation of bud break and sprouting is insufficient, the axillary buds in sugar apple are hidden at the base of the leaf petiole, which acts as physical barrier for their sprouting. Thus, manipulating the defoliation time would influence the flowering time and fruit harvest. As information on crop regulation in sugar apple are lacking, attempt is made to manipulate fruiting season of sugar apple following foliar treatments with chemical defoliants like urea, ethrel and bud break inducing KNO_3.

2. Materials and Methods

2.1 Experimental site and plant material

The investigation was carried out on 12-year old healthy trees of sugar apple cv. Balanagar maintained at orchard of ICAR-IIHR, Bengaluru (India) during two consecutive years *i.e.* 2016-17 and 2017-18. Sixty uniform and healthy trees were selected for the present study.

2.2 Treatment application

Foliar spray of chemicals was undertaken during first week of October for both the years with urea @ 5% (T1); urea @ 10% (T2), urea @ 15% (T3), ethrel @ 2000ppm (T4), ethrel @ 3000ppm (T5), ethrel @ 4000ppm (T6), KNO_3 @ 5% (T7); KNO_3 @ 10% (T8); KNO_3 @ 15% (T9) and water (control) (T10). These treatments were replicated three times randomly. Standard package of practices were adopted for maintenance of trees during the experimentation.

2.3 Defoliation per cent

Extent of defoliation was recorded by counting the number of leaves before and after three weeks of chemical applications on randomly selected branches and expressed as per cent defoliation per tree.

2.4 Vegetative and reproductive growth

The number of days required for sprouting and flowering was assessed by recording the days taken for the emergence of first sprout and flower respectively after the treatment imposition. The durations of the first and last harvest were calculated from the date of imposing the treatments to the first fruit harvest and the last fruit harvest respectively.

2.5 Fruit yield and fruit quality attributes

The total fruit yield per tree was recorded at harvest by measuring weight of fruit harvested and values were expressed in kilogram. Fruit weight (g) was recorded using electronic balance. Number of seeds was counted and seed index calculated as the number of seeds per 100 g of fruit weight (Richardson and Anderson, 1996) [32]. The total soluble solids (TSS) were measured using digital refractometer and expressed as degree Brix. Titrable acidity was estimated by adopting the titrametric method of A.O.A.C (1975) [2] using phenolphthalein indicators and values were expressed in terms of percentage tartaric acid equivalent. Pulp content (%) of fruit was determined using the following formula:

$$\text{Pulp (\%)} = \frac{\text{Pulp weight}}{\text{Fruit weight}} \times 100$$

2.6 Leaf gas exchange characteristics

Gas exchange parameters such as net photosynthesis (P_N, μmol m^{-2} s^{-1}), transpiration rate (E, mmolm^{-2} s^{-1}) and stomatal conductance (gs, mmol $m^{-2}s^{-1}$) were recorded in three fully expanded leaves of each plant using portable photosynthesis system (LCpro+, ADC BioScientific limited, UK) during morning hours of clear and sunny conditions between 09:30 h and11:30 h at two stages *viz.* fruit set (March, 2018) and rapid fruit growth (May, 2018) stage in second year (2017-18).

2.7 Light interception: Photosynthetically active radiation (PAR) below the tree canopy was measured using the LI-191SA Line Quantum Sensor (Li-Cor, Lincoln, NE) uniformly overcast days between 12:00 h and 13:00h at two stages (fruit set and rapid fruit growth stages) during the second year of study (2017-18).

2.8 Total leaf chlorophyll content

The total leaf chlorophyll content was measured at fruit set stage (FSS) and rapid fruit growth stage (RFGS) during second year. The leaf sample weighing 100 mg was kept into a test tube and 10 mL of dimethyl sulphoxide (DMSO) was added. The tubes were incubated in an oven at 65°C for 3½ hours and the contents filtered. The chlorophyll content was determined using spectrophotometer (UV 1650PC, Shimadzu, Japan) at wave lengths of 663 and 645 nm. The total chlorophyll (mg g^{-1}fresh weight) was estimated according to Hiscox and Isrealstam (1979) [15].

2.9 Shoot biochemical composition

The total carbohydrates and hormones (abscisic acid and gibberellin) were estimated from shoots of uniform size (10 cm, 3 cm) after six weeks of spraying the chemicals. Phytohormones like gibberellic acid (GA_3) and abscisic acid (ABA) contents in shoots (proximal end) were determined in a HPLC (Prominence, Shimadzu, Japan), using a Photo Diode Array (PDA) (Shimadzu, Japan, model:SPD-M20A) detector and 4 µm-Fusion RP-C18 column (Phenomenex, USA, 250 × 4.6 mm) according to Kelen *et al.* (2004) [19] with modifications. A solvent mixture of acetonitrile: water (pH 4.0) (30:70 v/v) at 0.8 ml min^{-1} was used as the mobile phase. The GA_3 and ABA were detected at 200 and 260 nm, at retention times of 13.2 and 16.2 min, respectively. The $GA_3$and ABA contents were quantified using external standards (Sigma-Aldrich, MO, USA). The total carbohydrates content was estimated spectrophotometrically (UV 1650PC, Shimadzu, Japan) using anthrone reagent as

described by Hedge and Hofreiter (1962) [14] and values expressed in mg/g dry weight. Total phenol content in shoot was estimated by spectrophotometric procedure of Singleton and Rossi (1965) [39]. Shoot sample (2 g) was extracted in 80% ethanol by boiling for 3 minutes and after cooling and filtering, the filtrate was extracted thrice with petroleum ether (b. p. 40–60 °C). The aqueous ethanolic extract collected was used for total phenol content estimations using Foiln-Ciocalteu reagent and measurement of absorption at 660 nm. The quantification of phenols was done using chlorogenic acid (Sigma make) as standard.

2.10 Statistical analysis
The experimental design adopted was randomized block design (RBD) with three replications. All the data were analysed using OPSTAT (Sheoran *et al.*, 1998) [35]. Statistical analysis for each individual year was done separately for the parameters studied and discussed at $P < 0.05$ for significance of difference between their mean values.

3. Results and Discussion
3.1 Vegetative and reproductive growth parameters
The maximum defoliation to an extent of 96.5-97.0% and 93.3-95.9% was recorded under ethrel @ 4000 and urea 15%, respectively while the control trees showed 4.3-5.0% defoliation during both the years (Table 1). This is in agreement with Sheikh (2013) [34], who observed that foliar spray of ethrel was more effective than other defoliants like metacid, profenosphos or urea phosphate for defoliating pomegranate cv. Kesar. Also, Chandra *et al.* (2011) [4] in pomegranate and Kobayashi (1986) [21] reported the similar results with ethrel in guava cv. Beaumont. De la Obra (2006) [6] also found that urea is effective in causing defoliation in cherimoya. Ethylene is well documented for its regulatory role for abscission (Reid, 1985) [30], thus increased ethylene formation elicited by ethrel could account for induced defoliation evident in the present investigation. Physiological mechanism by which high concentrations of urea cause defoliation is meagrely understood. It is possible that the the increased nitrogen in the leaves leading to lowering of carbon to nitrogen ratios could be facilitative of defoliation. Trees sprayed with urea@15%, started early sprouting, while the latest to sprout was control trees during both the years (Table 1). Bud sprouting was advanced by 6 weeks in first year and by 9 weeks in second year. Nanra *et al*. (2001) [24] and Boora *et al.* (2016) [3] reported early sprout initiation for urea sprays at 10% and 15% in guava. Earliest flower initiation was evident in trees sprayed with urea @ 15% while control trees took maximum days for flower initiation during both the years (Table 1). Early sprouting as well as flower initiation of plants treated with urea @ 15% could be related to the early defoliation. Olesen and Muldoon (2012) [25] and Rajput *et al.* (1986) [28] also reported similar findings in anona and guava, respectively.

3.2 Fruit quality parameters
Larger fruits (329.5g, 294.9g) were harvested from trees sprayed with ethrel@4000ppm in 2016-17 and ethrel@3000ppm in 2017-18 (Table 2). However, fruit weight for treatments with urea (10% & 15%) and ethrel (2000ppm & 3000ppm) were *on par* with fruits obtained from trees treated with ethrel @ 4000ppm. Smaller fruits (179.2, 194.9g) were harvested from control trees in both the years. Similarly, Sahay *et al*. (2001) [33] found that application of urea at 15% followed by hand de-blossoming increased the fruit size over control guava plants. The results are in conformity with findings of Dubey *et al.* (2001) [7] in guava. Minimum peel weight was recorded (74.9, 55.1 g) for fruits harvested from control and trees sprayed with KNO_3 @ 5% during first and second year, respectively (Table 2). During first year, maximum pulp (54.7%) was recorded in trees sprayed with KNO_3 @ 10% while no significant effect of treatments was observed during second year (Table 2). More pulp recovery from fruit in KNO_3 treated trees was due to lesser peel weight than other treatments (Table 2).

Comparatively, lesser number of seeds per fruit was observed in fruits obtained from trees sprayed with ethrel @ 3000ppm in first year and ethrel @ 4000ppm in second year, while KNO_3 @ 10% and water sprayed trees recorded more number of seeds per fruits, in 2016-17 and 2017-18, respectively (Table 2). Similar, result was observed by Gonzalez *et al*. (2013) [13] in cherimoya. Fruits with lower seed index ratio were harvested from trees sprayed with ethrel @ 3000ppm in first year and ethrel @ 4000ppm in the second year (Table 2) while an upper limit of seed index ratio was recorded for fruits obtained from control trees during both the years. Higher value of seed index implies greater fertilization success and more number of seeds per fruit (Gonzalez and Cuevas, 2008) [12].

3.3 Yield characters
No significant effect of treatments was observed on total soluble solids (TSS) during 2016-17 while during 2017-18 maximum value of 27.37 °B was recorded for fruits harvested from control trees (Table 3). Similar result was reported by Singh *et al*, (1992) [38] in guava, when none of the treatments (urea, ethephon, NAA and KI) affected the TSS. In contrast, Rajput *et al*. (1986) [28] and Dwivedi *et al*. (1990) [9] obtained the higher TSS content with 15% urea in guava. Significant effect of treatments was observed on acidity in first year and maximum value was recorded for trees sprayed with KNO_3 @ 15% and control while no treatment effect on acidity was observed during 2017-18 (Table 3).

Treatments significantly influenced the number of days taken for first harvest in both the years (Table 4). During 2016-17, trees sprayed with urea @ 15% were harvest at the earliest (290 days) after imposing treatments while control trees were harvested 6-7 weeks later to this treatment (337 days). While in second year, urea @ 10% and 15%, ethrel @ 2000ppm, 3000ppm and 4000ppm, and KNO_3 @ 15% treated trees were harvested at the same time (285 days) while fruits in control trees comes to harvest after 5 weeks (320 days). Khan *et al*. (2013) [20] reported that defoliation in guava advance the harvest by 30 days. Control trees were harvested at last at the end of season in first year (358 days) after imposing the treatments while, trees treated with ethrel @ 3000ppm, KNO_3 @ 5%, KNO_3 @ 15% and control have harvested at the same time (349 days) in the second year (Table 4). Gonzalez *et al*. (2013) [13] reported that urea treated cherimoya trees had come early to harvest than control trees and more than 50% of the yield was harvested in the first harvest. They also observed non-significant effect of treatments on fruit quality. Also, spraying urea @ 12% advanced the harvesting period as well as yield in guava (Amador *et al.*, 1992) [1]. No significant effect of treatments was recorded on fruit yield per tree in either year. However, higher values of yield (9.6 kg, 11.1 kg) were recorded from trees sprayed with KNO_3 @ 15% in both the years (Table 4). Higher yield in KNO_3 can be attributed to occurrence of more number of fruits on the tree compared to other treatments. The result was in conformity with the

findings of Khan *et al.* (2013) [20] in guava, where no significant effect of defoliation treatments was seen on fruit yield.

3.3.1 Leaf gas exchange characteristics

Significant effect of treatments was observed on photosynthetic rate and stomatal conductance and transpiration rate in trees treated with different chemicals (Table 5). Comparatively, higher photosynthetic rate (13.8 µmol CO_2 m^{-2} s^{-1}) and stomatal conductance (0.3 mol m^{-2} s^{-1}) was recorded in trees sprayed with urea @ 10% than the control trees (9.6 µmol CO_2 m^{-2} s^{-1}). However, stomatal conductance was recorded similar (0.2 mol m^{-2} s^{-1}) for rest of the treatments. Trees sprayed with urea @ 15 % recorded higher transpiration rate (7.3 mmol m^{-2} s^{-1}) than the other treatments and lowest in control (5.18 mmol m^{-2} s^{-1}). The higher photosynthesis rate in trees sprayed with urea 15% could be due to higher leaf chlorophyll content (Reed *et al.*, 2012) [29]. The light interception by tree canopy was greater (58.7%) for trees sprayed with urea @ 10% at fruit set stage (March, 2018) while lesser (45.9%) light was intercepted by trees sprayed with KNO_3 @ 5%. At rapid fruit growth stage also higher value of light interception was recorded from trees treated with urea @ 10% however minimum light was intercepted by the canopy of control trees (Table 5). Higher intercept of light could be attributed to dense canopy of these trees and also more number of leaf as well as leaf area per shoot (data not shown). As reported by Pilau and Angelocci (2015) [26] in orange, reduction in leaf area and sparse canopy caused reduction of solar radiation interception.

3.4 Biochemical parameters

The amount of carbohydrate in shoot varied with different treatments during both the years of observation (Table 6). In first year, more amount of stored carbohydrate (19.1%) was recorded in shoots of trees sprayed with urea @ 5% while it was lesser (9.5%) in shoots of trees sprayed with urea @15%. During second year (2017-18), total carbohydrate (17.30%) was estimated maximum in shoot of control trees, while it was minimum (7.94%) in trees sprayed with ethrel @ 3000ppm. Carbohydrate is required for bud sprouting, early shoot and flower development (Reig *et al.*, 2006) [31]. As the carbohydrate was estimated after six weeks of treatment impostion, there was no sprout emergence in this treatment (urea @ 5%), which shows little or no utilization of stored carbohydrates of the shoot while minimum amount of carbohydrate in treatment (urea @ 15%) might be due to utilization of stored reserve for sprouting. The amount of carbohydrate is generally fluctuating in the shoot as it is declining to maximum during the spring season (sprouting and new leaf emergence) to minimum during winter season. Mohamed (2010) [23] suggested that increased bud break showed faster degradation of stored carbohydrates in grapevine, where the reducing sugar acts as carbon source to the cells for the synthesis of biochemical compounds needed for bud break. Also, these soluble sugar acts as signal which regulate the development of bud (Chao and Serpe, 2010) [5]. Trees sprayed with ethrel @ 4000ppm recorded maximum total phenol content (1.95 mg/g and 1.26 mg/g) while it was recorded minimum in shoots of trees sprayed with urea @ 5% during both the years (Table 6). Since ethrel application (4000ppm) had detrimental effect on defoliation which could have resulted in higher amount of phenol in shoots of these trees. Shoot damage practices in trees such as defoliation can increase the level of defenses like secondary metabolites like phenols and terpenoids, (Tellamy and Raupp, 1991) [41]. A higher level of ABA was recorded in shoots of trees sprayed with urea @ 15% (1294 ng/g Fw) while it was found lowest (523 ng/g Fw) in shoots of control trees (Figure 1). Stress stimulus due to defoliation might have increased the level of ABA in the shoot of these treated trees. A higher amount of GA_3 was noted in shoots of trees sprayed with KNO_3 @ 15% (867 ng/g Fw) while lowest level of GA_3 (291 ng/g Fw) was recorded for control trees (Figure 1). As KNO_3 contains nitrogen, this may have elevated the endogenous nitrogen levels in the shoot which, in turn increased the endogenous gibberellin level. Also, increased level of GA_3 can increase the number of sprouts by promoting physiological processes of trees as reported by Iqbal *et al.* (2011) [16] that application of gibberellin promotes photosynthesis and nitrogen utilization in plants. Similar results were reported by Rajagopal and Rao (1974) [27] in tomato and Jang *et al.* (2008) [17] in rice. Hormones have major role in various developmental processes in the shoot such as bud break, sprouting, shoot development as well as flowering. Different hormones have their own role; also their interactions with each other affect the various growth processes. Gibberellin mainly overcome bud dormancy and allows them to grow while abscisic acid (ABA) is antagonistic to this function (Weiss and Ori, 2007) [44]. The leaf 'chlorophyll content' is considered as an important index of the metabolic efficiency of plants. Significant treatment effects were recorded on leaf chlorophyll content. At fruit set, the maximum total leaf chlorophyll content (2.68 mg/g) was recorded in trees sprayed with urea @ 15%, on par with treatments urea @ 10% and KNO_3 @ 15% (Table 6). Minimum value of chlorophyll content (0.78 mg/g) was recorded for trees sprayed with KNO_3 @ 5%. Similarly, at rapid fruit growth stage, the maximum total leaf chlorophyll content (2.52 mg/g) was in leaves where urea @ 15% was sprayed trees, while minimum (1.74 mg/g) was recorded in trees sprayed with KNO_3 @ 5%. The decline in chlorophyll content in the other treatments may be attributed to limited chlorophyll synthesis for want of conducible environmental conditions (Sritharan *et al.*, 2010) [40].

Table 1: Effect of chemical defoliants and KNO_3 spray on defoliation per cent and days for sprout initiation and flower initiation in Sugar Apple cv. Balanagar

Treatments	Defoliation (%)		Sprout initiation (days)		Flower initiation (days)	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1- Urea@5%	10.7^{c}	14.1^{c}	60.1^{b}	60.6^{bc}	70.3^{b}	70.2^{bc}
T_2- Urea@10%	90.0^{b}	95.2^{a}	28.2^{e}	18.4^{e}	36.5^{gh}	27.4^{f}
T_3- Urea@15%	93.3^{ab}	95.8^{a}	26.0^{e}	16.1^{e}	35.0^{h}	23.0^{g}
T_4- Ethrel@2000 ppm	91.0^{b}	87.2^{b}	28.3^{e}	25.4^{d}	38.8^{g}	32.7^{e}
T_5- Ethrel@3000 ppm	94.0^{ab}	94.7^{a}	30.7^{e}	25.1^{d}	38.7^{gh}	31.3^{ef}
T_6- Ethrel@4000 ppm	97.0^{a}	96.5^{a}	36.8^{d}	26.0^{d}	43.5^{f}	30.3^{ef}
T_7- KNO_3@5%	8.7^{cd}	7.3^{ef}	58.5^{b}	62.3^{b}	64.8^{c}	72.3^{b}

T_8- KNO_3@10%	5.3^{de}	9.0^{de}	47.1^{c}	59.0^{bc}	59.0^{d}	65.9^{cd}
T_9- KNO_3@15%	12.3^{c}	11.7^{cd}	40.8^{d}	56.0^{c}	51.6^{e}	62.2^{d}
T_{10}- Control (water spray)	4.3^{e}	5.0^{f}	71.0^{a}	82.1^{a}	86.8^{a}	95.7^{a}
F- test (P=0.05)	S	S	S	S	S	S
SE (m)±	1.37	1.13	1.67	1.87	1.25	1.47
$CD_{5\%}$	4.06	3.35	4.96	5.54	3.71	4.35
C.V. (%)	4.67	3.78	6.78	7.50	4.12	4.96
S- Significant at p =0.05						

Table 2: Effect of chemical defoliants and KNO_3 spray on fruit weight, peel weight, pulp content, seeds per fruit and seed index in Sugar Apple cv. Balanagar

Treatments	Fruit weight (gm)		Peel weight (g)		Pulp (%)		Seeds per fruit		Seed index	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1- Urea@5%	244.8^{bcde}	243.8^{b}	115.5^{bc}	79.7^{bc}	48.3^{bcd}	60.5	42.5^{bc}	54.0^{abc}	17.7^{cde}	22.2^{cd}
T_2- Urea@10%	306.3^{ab}	266.6^{ab}	126.7^{ab}	80.3^{bc}	52.7^{ab}	62.9	43.7^{bc}	45.7^{bc}	14.3^{cde}	17.2^{def}
T_3- Urea@15%	309.3^{ab}	264.8^{ab}	152.9^{a}	80.1^{bc}	43.4^{d}	61.9	54.5^{ab}	56.0^{abc}	17.7^{cde}	21.3^{cd}
T_4- Ethrel@2000 ppm	281.9^{abc}	258.9^{b}	135.1^{ab}	88.9^{ab}	46.8^{cd}	58.0	38.8^{bc}	54.0^{abc}	13.7^{cde}	21.0^{cde}
T_5- Ethrel@3000 ppm	268.4^{abcd}	294.9^{a}	131.1^{ab}	107.0^{a}	47.3^{bcd}	57.8	22.7^{c}	45.0^{cd}	8.7^{e}	15.2^{ef}
T_6- Ethrel@4000 ppm	329.5^{a}	222.2^{cd}	154.5^{a}	71.5^{bcd}	48.6^{bcd}	62.3	37.0^{bc}	31.3^{d}	11.7^{de}	14.1^{f}
T_7- KNO_3@5%	200.1^{de}	205.7^{d}	83.1^{cd}	55.1^{d}	50.9^{abc}	65.5	40.2^{bc}	49.7^{abc}	20.3^{cd}	24.2^{bc}
T_8- KNO_3@10%	231.4^{cde}	205.6^{d}	79.8^{d}	62.0^{cd}	54.7^{a}	60.3	69.0^{a}	59.2^{ab}	30.0^{ab}	28.7^{ab}
T_9- KNO_3@15%	233.0^{cde}	212.3^{cd}	103.1^{bcd}	66.7^{bcd}	47.4^{bcd}	60.1	49.8^{ab}	45.3^{c}	22.0^{bc}	21.7^{cd}
T_{10}- Control (water spray)	179.2^{e}	194.9^{d}	74.9^{d}	68.4^{bcd}	47.4^{bcd}	54.6	57.2^{ab}	61.2^{a}	32.0^{a}	31.4^{a}
F- test (P=0.05)	S	S	S	S	S	NS	S	S	S	S
SE (m)±	23.4	12.0	11.7	7.6	1.9	2.7	7.4	4.6	3.1	2.0
$CD_{5\%}$	70.2	35.9	35.1	22.8	5.7	-	22.2	13.8	9.2	6.1
C.V. (%)	15.7	8.8	17.5	17.4	6.8	7.7	28.2	15.9	28.4	16.3
S- Significant; NS- Non significant at p =0.05										

Table 3: Effect of chemical defoliants and KNO_3 spray on total soluble solids (TSS) and acidity in Sugar Apple cv. Balanagar

Treatments	TSS (°B)		Acidity (%)	
	2016-17	2017-18	2016-17	2017-18
T_1- Urea@5%	30.0	23.8^{bcd}	0.19^{b}	0.19
T_2- Urea@10%	30.0	22.7^{d}	0.18^{b}	0.16
T_3- Urea@15%	32.0	22.3^{d}	0.26^{ab}	0.15
T_4- Ethrel@2000 ppm	27.8	24.7^{abcd}	0.23^{b}	0.18
T_5- Ethrel@3000 ppm	24.9	24.7^{abcd}	0.19^{b}	0.25
T_6- Ethrel@4000 ppm	25.8	23.6^{cd}	0.19^{b}	0.17
T_7- KNO_3@5%	26.9	26.5^{ab}	0.16^{b}	0.17
T_8- KNO_3@10%	31.5	25.5^{abc}	0.22^{b}	0.16
T_9- KNO_3@15%	31.1	23.1^{cd}	0.29^{a}	0.17
T_{10}- Control (water spray)	33.0	27.4^{a}	0.34^{a}	0.18
F- test (P=0.05)	NS	S	S	NS
SE (m)±	2.4	0.9	0.02	0.02
$CD_{5\%}$	-	2.7	0.09	-
C.V. (%)	14.1	6.5	23.92	19.83
S- Significant; NS- Non significant at p =0.05				

Table 4: Effect of chemical defoliants and KNO_3 spray on harvest duration (first harvest and last harvest) and fruit yield in Sugar Apple cv. Balanagar

Treatments	First harvest (days)		Last harvest (days)		Fruit yield/tree (kg)	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1- Urea@5%	297.3^{bc}	308.3^{ab}	340.0^{b}	340.3	7.4	7.6
T_2- Urea@10%	293.3^{c}	285.0^{c}	331.7^{bc}	340.3	8.1	9.1
T_3- Urea@15%	290.0^{c}	285.0^{c}	323.3^{c}	344.7	8.5	8.5
T_4- Ethrel@2000 ppm	293.3^{c}	285.0^{c}	340.0^{b}	340.3	5.7	7.9
T_5- Ethrel@3000 ppm	305.7^{b}	285.0^{c}	331.7^{bc}	349.0	6.6	8.4
T_6- Ethrel@4000 ppm	298.3^{bc}	285.0^{c}	340.0^{b}	335.7	7.7	10.2
T_7- KNO_3@5%	298.3^{bc}	308.3^{ab}	344.0^{ab}	349.0	8.2	8.4
T_8- KNO_3@10%	296.7^{c}	296.7^{bc}	340.0^{b}	344.7	8.3	9.1
T_9- KNO_3@15%	291.7^{c}	285.0^{c}	344.0^{ab}	349.0	9.6	11.1
T_{10}- Control (water spray)	337.0^{a}	320.0^{a}	358.7^{a}	349.0	6.7	8.3
F- test (P=0.05)	S	S	S	NS	NS	NS
SE (m)±	2.84	6.62	5.15	3.96	0.93	0.84
$CD_{5\%}$	8.50	19.68	15.29	-	-	-
C.V. (%)	1.64	3.89	2.63	1.99	21.02	16.40
S- Significant; NS- Non significant						

Table 5: Effect of chemical defoliants and KNO_3 spray on photosynthetic rate, stomatal conductance, transpiration rate and light interception in Sugar Apple cv. Balanagar

Treatments	Photosynthetic rate ($\mu mol\ CO_2 \cdot m^{-2} s^{-1}$)	Stomatal conductance ($mol\ m^{-2}\ s^{-1}$)	Transpiration rate ($mmol\ m^{-2}\ s^{-1}$)	Light interception (%) (2017-18)	
	2017-18	2017-18	2017-18	FSS	RFGS
T_1- Urea@5%	13.63^{a}	0.29^{a}	4.80^{c}	49.55^{cd}	66.38^{d}
T_2- Urea@10%	13.75^{a}	0.29^{a}	7.00^{a}	58.68^{a}	73.70^{a}
T_3- Urea@15%	12.99^{abc}	0.24^{ab}	7.29^{a}	57.90^{a}	73.38^{a}
T_4- Ethrel@2000 ppm	12.64^{ab}	0.24^{ab}	5.03^{c}	53.38^{abc}	71.00^{abc}
T_5- Ethrel@3000 ppm	11.37^{abc}	0.18^{bc}	5.51^{bc}	56.86^{a}	72.65^{ab}
T_6- Ethrel@4000 ppm	10.34^{bc}	0.17^{bc}	6.07^{abc}	56.35^{a}	67.80^{cd}
T_7- KNO_3@5%	10.48^{bc}	0.21^{bc}	5.45^{bc}	45.87^{d}	64.68^{d}
T_8- KNO_3@10%	10.73^{bc}	0.20^{bc}	6.03^{abc}	56.68^{a}	65.63^{d}
T_9- KNO_3@15%	10.87^{bc}	0.21^{bc}	6.82^{ab}	55.06^{ab}	68.58^{bcd}
T_{10}- Control (water spray)	9.58^{c}	0.17^{c}	5.18^{c}	49.87^{bcd}	46.83^{e}
F- test (P=0.05)	**S**	**S**	**S**	**S**	**S**
SE (m)±	0.83	0.03	0.49	1.89	1.58
$CD_{5\%}$	2.46	0.07	1.47	5.49	4.58
C.V. (%)	12.40	19.62	14.47	7.00	4.71
S- Significant at p =0.05; FSS- Fruit set stage; RFGS- Rapid fruit growth stage					

Table 6: Effect of chemical defoliants and KNO_3 spray on carbohydrate, phenol content of shoot and total leaf chlorophyll in Sugar Apple cv. Balanagar

Treatments	Carbohydrate (%)		Phenol (mg/g)		Total leaf chlorophyll (mg/g)	
	2016-17	2017-18	2016-17	2017-18	FSS*	RFGS**
T_1- Urea@5%	19.10^{a}	16.26^{b}	0.91^{g}	0.66^{g}	1.20^{g}	2.27^{d}
T_2- Urea@10%	11.48^{f}	14.72^{c}	1.15^{e}	1.21^{ab}	2.65^{a}	2.31^{cd}
T_3- Urea@15%	9.50^{g}	10.12^{e}	1.24^{d}	1.25^{a}	2.68^{a}	2.52^{a}
T_4- Ethrel@2000 ppm	14.48^{d}	11.20^{d}	1.21^{d}	1.99^{d}	2.02^{c}	2.13^{e}
T_5- Ethrel@3000 ppm	13.72^{e}	7.94^{f}	1.72^{b}	1.11^{c}	1.72^{f}	2.38^{bc}
T_6- Ethrel@4000 ppm	14.40^{d}	8.30^{f}	1.95^{a}	1.26^{a}	1.85^{e}	1.74^{g}
T_7- KNO_3@5%	18.20^{b}	17.18^{a}	0.94^{g}	0.69^{fg}	0.87^{h}	2.09^{e}
T_8- KNO_3@10%	15.78^{c}	16.82^{ab}	1.42^{c}	1.17^{b}	1.91^{d}	1.91^{f}
T_9- KNO_3@15%	15.44^{c}	16.48^{ab}	1.07^{f}	0.81^{e}	2.66^{a}	2.36^{bc}
T_{10}- Control (water spray)	18.76^{ab}	17.30^{a}	0.94^{g}	0.72^{f}	2.09^{b}	2.40^{b}
F- test (P=0.05)	S	S	S	S	**S**	**S**
SE (m)	0.22	0.28	0.02	0.02	0.02	0.03
$CD_{5\%}$	0.64	0.85	0.05	0.05	0.05	0.08
C.V. (%)	2.49	3.61	2.13	3.14	1.54	2.17
S- Significant at p =0.05; FSS- Fruit set stage; RFGS- Rapid fruit growth stage						

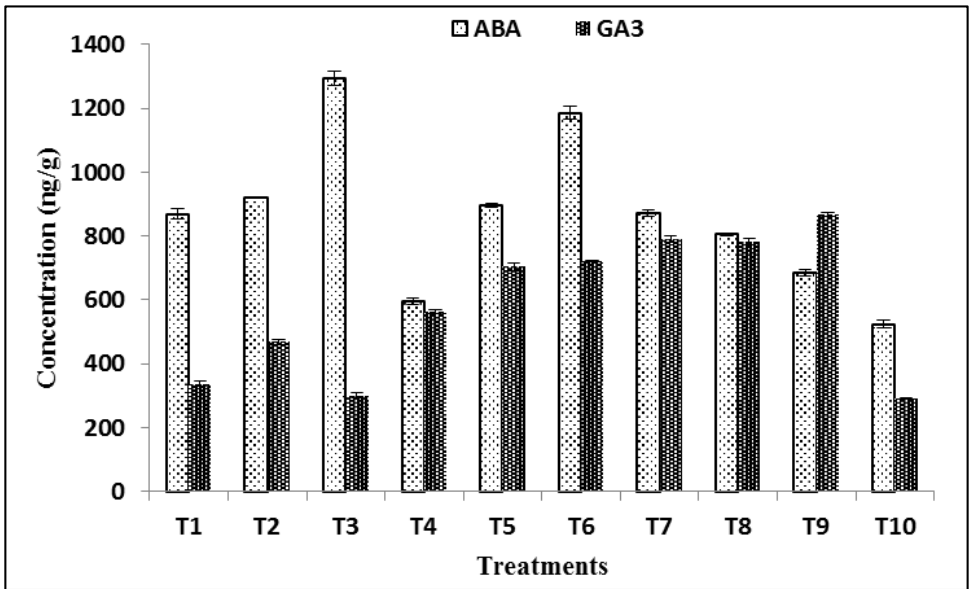

Fig 1: Effect of chemical defoliants and KNO_3 spray on ABA and GA_3 content of shoots in Sugar Apple cv. Balanagar. Values are mean of three replicates ± SE (Standard error)

4. Conclusion

The present study showed that different chemicals with varying concentrations had significant influence on defoliation, vegetative growth, flowering, fruit quality and harvest period in sugar apple cv. Balanagar. There was significant influence on the biochemical constituent of the

shoots *viz.* total carbohydrate, total phenol, hormones (ABA and GA_3), which influenced the various growth parameters. Thus, from the present investigation, it can be concluded that urea@ 10% and 15% as well as all concentration of ethrel (2000ppm, 3000ppm and 4000ppm) are effective for advancing fruiting by 5-6 weeks in sugar apple cv. Balanagar. Application of potassium nitrate (5%, 10% and 15%), did not cause defoliation but its application improved the sprouting, number of flowers and fruits in the treated trees. Therefore, further studies to standardize best combination of defoliant and KNO_3 for getting early harvest with maximum fruit yield could be attempted.

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