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Influence of plant growth regulators and nutrients on morpho-physiological, yield and quality attributes of mango (*Mangifera indica* L.) cv Amrapali

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Abstract
Studies were carried-out at fruit research station, Department of Horticulture, JNKVV, Jabalpur during the season of 2015-16 on 5 years old orchard of mango, to evaluate the positive effect of foliar sprays of PGR' and nutrients on flowering, fruiting, quality and physiological characteristics in Amrapali mango. Flowering parameters like panicle length, Number of panicle lets per panicle, Ratio of Hermaphrodite and male flower and Percentage of healthy and malformed panicles were increased significantly by the application of NAA 50 ppm + KNO_3 2%. Higher number of fruits at initial stage and more fruit retention percentage at harvest stage were recorded with GA_3 30 ppm + KNO_3 2%, followed by GA_3 20 ppm + KNO_3 2% treatment. Quality parameters such as fruit weight (g), fruit size, peel weight and Fruit yield (kg/ tree) were also significantly improved by the application of GA_3 30 ppm + KNO_3 2%. Under the treatment T_6 (NAA 50 ppm + KNO_3 2%) was recorded significantly maximum pulp weight which were at par with T_2. However, it was noted minimum in control (T_{17}) and reverse trend was noted in case of stone weight. Significantly minimum stone weight was recorded in treatment T_6 (NAA 50 ppm + KNO_3 2%).
Physiological parameters such as Energy interception (cal.cm-2min-1), PAR interception (µmol m-2sec-1) were significantly improved by the application of GA_3 30 ppm + KNO_3 2%. Although, reverse trend was noted in case of light transmission ratio. Foliar feeding of growth regulator and nutrients directly to the metabolite sites considerably enhanced fruit yield and other physiological characters.

Keywords: NAA, GA_3, KNO_3, flowering, fruiting, quality, yield and physiological parameters, mango

Introduction
Mango (*Mangifera indica* L.) is the premier fruit among the tropical fruits and has been in cultivation in the Indian subcontinent since several centuries. Mango is the king of fruit, is a member of Anacardiaceae family. Mangoes are most famous for it's exotic flavours, taste, and attractive colour. Mango is a delicious fruit and holds a great degree of nutritive value. Modulation of flowering and fruit set by spraying of various hormones and nutrients is the best alternative to mitigate or reduce the climate changes effect on mango. Various chemicals and plant growth regulators application have been standardized for enhancing and uniform flowering in mango. Spraying of NAA @ of 50-100 ppm has shown the effect in early flowering (Davenport, 2007) [10] in mango. Naphthalene acetic acid (NAA), an auxin group of plant growth regulator was found to have an effect on the flower promoting activity in mango (Beyer, 1976) [7]. There is need to study the effect of foliar application of growth regulator, macro and micro nutrients on bearing, yield and physiological quality of mango. Foliar sprays of plant growth regulators and nutrients not only improves the size but also enhance qualitative parameters of fruit. The foliar application of macro-nutrients and plant growth regulators have very important role in improving the productivity and quality of fruits. It has also beneficial role in recovery of nutritional and physiological disorders in fruit trees grown under sodic soil condition. Various trials have earlier conducted on foliar sprays of macro-nutrients and PGR's in different fruit species and shown significant response to improving yield and quality of fruits. (Singh and Singh, 1992; Singh and Vashishtha 1999; Brahmachari and Rani, 2000) [33].
Potassium is known for development of fruit, movement of sugars and indirectly photosynthesis. Since potassium enhances internal fruit quality while gibberellic acid is known for its anti senescing properties, promotes cell elongation and improve quality of fruit.

Agricultural systems are basically photosynthetic systems and hence must be assessed for their efficiency in conversion of solar irradiance in terms of both primary productivity and useful end products. energy interception and its utilization have a great influence on productivity which is an interaction between plants and environment through the modification and interception of fluxes of radiation, heat, CO_2 etc. Consequently, the canopy structure is obviously determinant of the photosynthetic productivity of plant communities.

Light transmission shows the ratio of the light reaching the ground surface to the incident energy. Light transmission and energy interception are related to each other. In the orchard, light penetration and distribution within the canopy is affected by arrangement, reflectance and indirect shading of leaves, fruit and branches. The sunlight use efficiency (i.e. converting light energy to dry matter) has long been the main research focus to obtain sustainable fruit production and quality in orchard systems. Some hormones regulate the phytochrome mediated reactions. Exposure to red light leads to a rapid increase in endogenous gibberellins. Hence light is also responsible directly for fruit set and yield.

In this study an attempt has been made to see the "Influence of plant growth regulators and nutrients on morpho-physiological, yield and quality attributes of mango (*Mangifera indica* L.) cv Amrapali." keeping this in view, the present study was undertaken with the following objectives;

1. To study the effect of PGR's in combination with macro and micro nutrients on flowering, fruit retention, yield and fruit quality of mango.
2. To find out the effectiveness of PGR's, macro and micro nutrients on physiological parameters of fruits.

Material and Methods

The present investigation was conducted at the fruit research station, Department of Horticulture, College of Agriculture, JNKVV Jabalpur, during the year 2015-16 on 5-years-old trees of mango cv. Amrapali. The experiment was laid out in Randomized Block design in three replications and treatments replicated thrice by using single tree as a units. Each treatment was carried out one tree for each replication. Spraying of combination of nutrients viz., KNO_3 (2%), urea (2%), $ZnSO_4$ (0.8%) and $FeSO_4$ (0.4%) and growth regulators viz., NAA (50 & 25 ppm) and GA_3 (30 & 20 ppm) was compared with control (no spray). The randomized block design was adopted with 17 treatments as shown in table (1):

Table 1: Treatment combinations – Seventeen

Symbols	Treatments
T1	NAA 25 ppm + Urea 2%
T2	NAA 25 ppm + KNO_3 2%
T3	NAA 25 ppm + $ZnSO_4$ 0.8%
T4	NAA 25 ppm + $FeSO_4$ 0.4%
T5	NAA 50 ppm + Urea 2%
T6	NAA 50 ppm + KNO_3 2%
T7	NAA 50 ppm + $ZnSO_4$ 0.8%
T8	NAA 50 ppm + $FeSO_4$ 0.4%
T9	GA_3 20 ppm + Urea 2%
T10	GA_3 20 ppm + KNO_3 2%
T11	GA_3 20 ppm + $ZnSO_4$ 0.8%
T12	GA_3 20 ppm + $FeSO_4$ 0.4%
T13	GA_3 30 ppm + Urea 2%
T14	GA_3 30 ppm + KNO_3 2%
T15	GA_3 30 ppm + $ZnSO_4$ 0.8%
T16	GA_3 30 ppm + $FeSO_4$ 0.4%
T17	Control

Determinations

- Ten panicles from all directions of tree were randomly selected for recording the length after the cessation of growth.
- Sex ratio was worked out from the data recorded for percentage of male and hermaphrodite flowers at full bloom stage.
- Fruit retention (%) was worked out by subtracting total number of fruits harvested from the initial fruit set on the selected panicles.
- Fruits from each treatment were harvested at maturity and their length and width was measured in centimeters with the help of Vernier callipers. Average length was worked out under each treatment.
- The volume of fruit was recorded in ml by displacement method.
- Weight of the fresh harvested fruits was taken on electronic balance and average weight of fruit was calculated under different treatments.
- After removal of peel from ripe selected fruits, the pulp was also removed from the stone with the help of steel knife and weighed.
- After removal of peel from ripe selected fruits, it was weighed by electronic balance.
- After removal of peel from ripe selected fruits pulp was also removed from the stone with the help of steel knife and weighed.
- Fruit yield of each treatment was recorded in kg/tree with the help of weighing balance.
- The light intensity, incident on crop canopy surface and infiltration profile within the canopy at the ground level was recorded by Lux-meter (Model- LX- 105). The PAR interception (photosynthetically active radiation) was determined by using canopy analyzer (Model - Teccagon). The chlorophyll content of leaf was measured with the help of chlorophyll content meter (Model CCM-200).

Results and Discussion

Effect of foliar spray's of plant growth regulators and nutrients on flowering characteristics

The result in table 2 indicate that panicle length was significantly increased with the foliar spray's of PGR's and nutrients as compared to control. Maximum increment in panicle length and number of panicle lets was observed with the application of NAA 50 ppm + KNO_3 2% (T_6). Similarly Ratio of Hermaphrodite and male flower and Percentage of healthy and malformed panicles were increased significantly by the application of NAA 50 ppm + KNO_3 2% over the control. Increase in panicle length with the combine application of NAA and KNO3 in the present investigation might be due to the exogenous foliar application of NAA and KNO3 which are responsible for cell division and cell enlargements. The faster cell division due to NAA (auxin) might be supported by the essential nutrients like nitrogen and potash. Nitrogen is a constituent of protein and on the other hand potash believed to be associated with synthesis of protein may be resulted higher length of panicles. Improvement in the sex ratio with the application of NAA was mainly due to increased number of hermaphrodite flowers. NAA may also have exerted its effect on sex expression by manipulating endogenous auxin corresponding to a reduction in staminate flowers. The findings are in close harmony with the result of Baghel and Tiwari (2003) [2], Birendra *et al*. (2011) [8], Singh and Banik (2011) [36], Prasad *et al*. (2011) [30].

Effect of foliar spray's of plant growth regulators and nutrients on yield and fruit quality attributes of mango

During 2015-16, table 3 show the significantly higher fruit set was recorded in trees sprayed with treatment T_{14} (GA3 30 ppm + KNO3 2%) as compared to the other treatments and minimum was registerded under the control and also the highest fruit retention (%) at harvest stage was recorded with GA3 30 ppm + KNO3 2%. The optimum supply of nutrients to the bearing mango trees help in retaining more number of fruits. The treatments exerted profound significant influences on number of fruit set per panicle. The application of gibberellic acid in the present investigation has increased the intensity of flowering, better fruit set, better fruit retention, which might have resulted in increase in the number of fruits per tree. These findings are in agreement with the findings of Kumar *et al*. (2003) [21], Baghel and Tiwari (2003) [2], Ruby and Brahmachari (2004) [33]

Data of table 3 shows that maximum fruit weight (183.25 g), fruit length (10.01 cm), fruit width (7.16 cm), fruit volume (179.84 ml) and peel weight (31.45g) observed under T_{14}(GA3 30 ppm + KNO3 2%), whereas the minimum result noted with T17(control).

Application of growth regulators and nutrients improve the qualitative parameters of fruit. The results obtained from the study revealed that all the quality parameters were found significant This may be because of contribution of potassium nitrate along with growth regulator. The quality improvement in fruits may be due to proper supply of nutrients and induction of growth hormones, which stimulates cell division, cell elongation, increase in weight of fruits, better translocation of water uptake and deposition of nutrients. These findings are in close conformity with the findings of Ray *et al*.(1991) [32].

In foliar feeding the nutrients are applied directly to the site of metabolism. This increase could be attributed to enhanced carbohydrate metabolism. This is in agreement with Vijayalakshmi and Srinivasan (2000) [42], Yeshitela (2004) [43], Kumari *et al*. (2007) [20] and Stino *et al*. (2011) [38] in mango.

Under the treatment T_6 (NAA 50 ppm + KNO_3 2%) was recorded significantly maximum (105.71g) pulp weight which were at par with T_2 (NAA 25 ppm + KNO_3 2%) (104.68g). However, it was noted minimum (86.89g) in control (T_{17}). Treatment T_6 (NAA 50 ppm + KNO_3 2%) was recorded significantly minimum (22.34g) stone weight followed by T_2 (NAA 25 ppm + KNO_3 2%) (24.22g) and T_5 (NAA 50 ppm + Urea 2%) (24.30g) as compared to other treatments. While, it was noted maximum (31.23g) in control (T_{17}). Increase in the pulp weight of fruit, all treatments affected differently and showed significant difference for fruit pulp weight, it is due to increase of fruit weight. Increased sink demand by induced application of auxin is closely related to the activation of invertase cell wall-bound in the core and invertase neutral and NAD-dependent sorbitol dehydrogenase in the pulp during rapid fruit growth. These findings are in agreement with the findings of Malik *et al*. (2000) [24], Ram and Bose (2000) [31], Hammam *et al*. (2001) [16], Ruby and Brahmachari (2004) [33], Saxena (2004) [35], Debaje *et al*. (2011) [11], Moazzam *et al*. (2011) [26], Singh and Banik (2011) [36] and Yadav *et al*. (2011) [40].

The highest yield per tree (15.26kg/tree) was found under T_{14}(GA3 30 ppm + KNO3 2%) treatment, whereas lowest yield ()was found in T17(control). The trees sprayed with GA_3 and potassium nitrate has recorded maximum yield may be due to the prolonged duration of flowering, fruit set, increase in fruit set per panicle, prevention of abscission of young fruit lets, increase in the number of fruits per tree, better fruit retention and better utilization of nutritional resources with in the trees would have resulted in the increase in fruit yield. These findings are in agreement with the findings of Bhowmick and Banik (2011) [3], Wahdan *et al*. (2011) [39], Yadav *et al*. (2011) [40], Nkansah *et al*. (2012) [27], Sarker and Rahim (2013) [34], Oosthuyse (2013) [28], Golla (2014) [14] and Dheeraj *et al* (2016) [12].

Effect of foliar spray's of plant growth regulators and nutrients on physiological characteristics of mango:

The data for various treatments with respect to the light transmission ratio**,** energy interception, PAR interception and chlorophyll content index are summarized in Table 4.

The results revealed that minimum light transmission ratio (12.31) was found under treatment T_{14} and maximum (22.36) light transmission ratio in the untreated plant (T_{17}). This suggests that the treatment T_{17} had higher LTR which was associated with the lower Ei (0.34). Treatment T_4 recorded significantly minimum (0.32) energy interception followed by T_{17} (0.34) and T_8 (0.36) as compared to other treatments. While, maximum (0.77) was recorded under the treatment T_{14}.

Hesketh and Baker (1967) [17] defined the crop stand as the product of amount of light interception and the efficiency intercepting tissues. Although the upper limit of orchard dry matter production is set by light interception, crop composition is determined by sunlight distribution within the canopy, with shade reducing fruit quality. This is a general phenomenon among perennial fruit crops and has been reported for apple, citrus, peach, cherry, kiwifruit and red raspberry. Horticultural crops, however, can rarely achieve 100% interception of sunlight because physical access is required year round for routine management operations such as spraying, pruning and picking. The sunlight use efficiency (i.e. converting light. The sunlight use efficiency (i.e. converting light energy to dry matter) has long been the main research focus to obtain sustainable fruit production and quality in orchard systems. In the recent years, however, more technological innovations are required for adequate light management in fruit trees, due to changes of paradigm of efficiency in orchard systems, which must include other factors, such as climate change, energy cost, and need of reduction of environmental impact Palmer (2011) [29] and Blanke (2011) [4]. These findings are in agreement with the findings of Blanke (2009) [5], Solomakhin *et al*. (2011) [37], Lechaudel *et al*. (2013) [22] and Yano *et al*. (2013) [41].

Treatment T_{14} recorded significantly maximum (1033.75) PAR interception followed by T_{10} (978.80) and T_6 (956.43) as compared to other treatments. While, minimum was recorded (405.18) in the treatment control (T_{17}). PAR interception was significantly influenced by the different treatments. Significantly maximum (1033.75) PAR interception was recorded in T_{14} (GA_3 30 ppm + KNO_3 2%) which had reflected in its highest economic productivity. Higher PAR interception and its subsequently utilization by the photosynthetic apparatus are the key factors for achieving the higher productivity. While, minimum (405.18) was noted in untreated plant (T_{17}). These findings are in agreement with the findings of Blanke (2009) [5], Solomakhin *et al*. (2011) [37] and Bastias and Corelli (2012) [6]. Some hormones regulate the phytochrome mediated reactions. Exposure to red light leads to a rapid increase in endogenous gibberellins. Hence light is also responsible directly for fruit set and yield. Mineral nutrition impinges on all phases of plant growth and development and adequate supplies of essential elements are required to sustain normal growth and development apart from adequate light in the community. Nutrient deficiency reduces growth in general and leaf area expansion in particular. These findings are in agreement with the findings of Blanke (2009) [5] and Solomakhin *et al*. (2011) [37].

Treatment T_{14} recorded significantly maximum (55.26) chlorophyll content index followed by T_{10} (51.68) and T_6 (49.80) as compared to other treatments, while, minimum (30.18) was recorded in control (T_{17}). The chlorophyll content index was significantly influenced by the different treatments. Treatment T_{14} (GA_3 30 ppm + KNO_3 2%) had the maximum chlorophyll content index, which also had reflected in its higher PAR interception and subsequently economic productivity. The higher chlorophyll content index indicated by T_{14} (GA_3 30 ppm + KNO_3 2%) suggests the role of components of T_{14} in increasing the chlorophyll content index which is desirable for the solar energy interception and its subsequent utilization. T_{17} (30.18) registered the lowest value for this character. Results are in agreement with the finding reported by Araujo *et al*. (2004) [1], Lu ZhiGuo *et al*. (2011) [23], Dantas *et al*. (2012) [9] and Bastias and Corelli (2012) [6].

Table 2: Influence of plant growth regulators and nutrients on flowering parameters of mango (*Mangifera indica* L.) cv Amrapali.

Treatments	Panicle lenth (cm)	Number of panicle lets per panicle	Ratio of Hermaph-Rodite and male flowers	Percentage of healthy panicle	Percentage of malformed panicles
NAA 25 ppm + Urea 2%	35.90	39.12	1: 3.63	82.86	17.14
NAA 25 ppm + KNO_3 2%	37.85	41.73	1: 3.88	89.84	10.16
NAA 25ppm+$ZnSO_4$ 0.8%	34.01	37.67	1: 3.30	79.30	20.70
NAA 25ppm+$FeSO_4$ 0.4%	26.19	32.97	1: 2.42	77.68	22.32
NAA 50 ppm + Urea 2%	36.11	39.49	1: 3.63	82.21	17.79
NAA 50 ppm + KNO_3 2%	41.12	42.10	1: 3.97	91.34	8.66
NAA 50 ppm+$ZnSO_4$ 0.8%	34.04	37.92	1: 3.62	79.57	20.43
NAA 50ppm+$FeSO_4$ 0.4%	27.94	33.46	1: 2.65	75.68	24.32
GA_3 20 ppm + Urea 2%	30.19	35.85	1: 3.10	82.29	17.71
GA_3 20 ppm + KNO_3 2%	32.13	36.17	1: 3.25	87.92	12.08
GA_3 20 ppm +$ZnSO_4$ 0.8%	24.86	32.14	1: 2.14	86.30	13.70
GA_3 20 ppm +$FeSO_4$ 0.4%	23.94	30.25	1: 1.95	80.63	19.37
GA_3 30 ppm + Urea 2%	27.92	33.67	1: 2.91	85.71	14.29
GA_3 30 ppm + KNO_3 2%	28.97	33.99	1: 2.87	88.93	11.07
GA_3 30 ppm +$ZnSO_4$ 0.8%	24.69	31.71	1: 2.09	86.87	13.13
GA_3 30 ppm +$FeSO_4$ 0.4%	23.67	29.29	1: 1.95	81.10	18.90
Control	22.91	28.30	1: 1.87	71.89	28.11
SEm ±	0.60	0.22	0.04	0.09	0.06
CD 5%	1.73	0.62	0.12	0.26	0.17

Table 3: Influence of plant growth regulators and nutrients on fruiting, yield and quality attributes of mango(*Mangifera indica* L.) cv Amrapali.

Treatments	Number of fruits at initial stage	Fruit retention percentage at harvest stage	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Fruit volume (ml)	Pulp weight (g)	Peel weight (g)	Stone weight (g)	Fruit yield (kg/ tree
NAA 25ppm+Urea 2%	59.70	1.10	170.34	8.90	6.01	125.98	102.87	26.05	24.80	12.10
NAA 25ppm +KNO_3 2%	63.85	1.45	172.78	9.81	6.72	161.02	104.68	26.96	24.22	13.61
NAA25ppm+$ZnSO_4$ 0.8%	59.37	0.79	149.57	8.54	5.89	107.97	101.10	24.57	27.59	10.59
NAA25ppm+$FeSO_4$ 0.4%	59.33	0.48	146.75	7.52	5.36	90.16	100.50	24.13	30.03	8.51
NAA 50 ppm +Urea 2%	60.57	1.14	169.48	9.14	6.14	139.00	103.64	26.42	24.30	12.64
NAA50 ppm+KNO_3 2%	64.51	1.57	179.92	9.82	6.81	165.07	105.71	28.69	22.34	14.22
NAA50ppm+$ZnSO_4$ 0.8%	59.89	0.82	151.55	8.76	5.93	110.65	100.94	24.70	28.30	11.47
NAA50ppm+$FeSO_4$ 0.4%	60.10	0.54	148.44	7.83	5.53	93.72	100.55	24.26	29.30	9.43
GA_3 20 ppm + Urea 2%	61.93	1.35	177.63	9.61	6.35	147.74	101.52	29.50	26.98	12.98
GA_3 20 ppm +KNO_3 2%	64.40	1.80	182.65	9.93	7.03	170.79	101.82	30.86	26.40	14.60
$GA_3$20ppm +$ZnSO_4$ 0.8%	55.21	1.03	158.29	8.22	5.61	121.65	98.64	26.00	30.80	10.95
$GA_3$20ppm +$FeSO_4$ 0.4%	55.54	0.71	152.03	7.83	4.83	93.98	94.99	25.02	31.16	9.97
GA_3 30 ppm + Urea 2%	61.94	1.45	176.79	9.66	6.36	151.94	101.61	29.96	26.51	13.21
GA_3 30 ppm +KNO_3 2%	65.21	1.99	183.25	10.01	7.16	179.84	102.27	31.45	26.06	15.26
$GA_3$30ppm +$ZnSO_4$ 0.8%	55.02	1.15	159.62	8.26	5.73	120.86	100.27	25.72	30.73	11.21
$GA_3$30ppm +$FeSO_4$ 0.4%	56.70	0.75	156.48	8.05	5.20	100.68	95.47	25.34	30.99	10.37
Control	54.43	0.40	140.51	7.22	4.54	79.10	86.89	23.53	31.23	8.20
SEm ±	0.19	0.03	1.20	0.07	0.07	2.32	0.56	0.22	0.27	0.24
CD 5%	0.55	0.09	3.47	0.21	0.20	6.70	1.61	0.63	0.78	0.69

Table 4: Influence of plant growth regulators and nutrients on physiological attributes of mango (*Mangifera indica* L.) cv Amrapali.

Treatments	Light transmission ratio (%)	Energy interception (cal.cm-2min-1)	PAR interception (μmol m-2sec-1)	Chlorophyll content index
NAA 25 ppm + Urea 2%	17.46	0.53	732.77	41.42
NAA 25 ppm + KNO_3 2%	15.21	0.64	916.11	48.75
NAA 25ppm+$ZnSO_4$ 0.8%	18.63	0.46	629.30	37.46
NAA 25ppm+$FeSO_4$ 0.4%	21.87	0.32	464.77	32.32

NAA 50 ppm + Urea 2%	17.15	0.55	786.47	41.70
NAA 50 ppm + KNO_3 2%	14.47	0.67	956.43	49.80
NAA 50 ppm+$ZnSO_4$ 0.8%	17.85	0.49	693.87	40.26
NAA 50ppm+$FeSO_4$ 0.4%	19.33	0.36	519.50	34.07
GA_3 20 ppm + Urea 2%	17.18	0.58	833.20	44.83
GA_3 20 ppm + KNO_3 2%	12.94	0.72	978.80	51.68
GA_3 20 ppm +$ZnSO_4$ 0.8%	18.06	0.48	655.41	37.92
GA_3 20 ppm +$FeSO_4$ 0.4%	18.94	0.41	566.88	36.18
GA_3 30 ppm + Urea 2%	16.69	0.65	867.93	46.01
GA_3 30 ppm + KNO_3 2%	12.31	0.77	1033.75	55.26
GA_3 30 ppm +$ZnSO_4$ 0.8%	17.71	0.51	692.28	37.91
GA_3 30 ppm +$FeSO_4$ 0.4%	18.89	0.43	582.45	37.11
Control	22.36	0.34	405.18	30.18
SEm ±	0.18	0.01	17.38	0.38
CD 5%	0.53	0.04	50.18	1.11

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