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Effect of PGRs and micronutrients on granulation disorder of citrus cv. Rangpur lime (*Citrus limon*)

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Rangpur lime [*Citrus limon* (L.) Burm. fil.] is most likely a lemon (*Citrus limon*) × mandarin (*Citrus reticulata*) hybrid originating in India. The fruit whose peel is reddish-orange, with large oil glands, thin and easily removed, resembles mandarin orange. It is a prolific variety of citrus with well flavoured and highly acidic fruits. The variety has worldwide usage as a rootstock on account of its high resistance to *tristeza* virus and more tolerant to salts than others. It is an important rootstock for mandarin and sweet orange. Its juice is used locally in food and beverages as a substitute for lemon juice because of the high acidity of the fruit. Granulation is a serious pre-harvest disorder of citrus fruit in which juice sacs become hard, dry and enlarged, begin to have a grayish colour and have little free juice. Although the granulation problem has been found in many citrus growing countries of the world, its exact cause is not yet fully known. Factors like frequent irrigation, high application rates of nitrogenous fertilizers, luxuriant growth following heavy pruning or fertilization and delayed harvesting are reported to be causal factors of granulation. Further it is also associated by climatic factors, tree aspect, fruit size and tree age in all citrus species, but sweet oranges and mandarins are more severely affected as compared to other (Singh 2001). This disorder is associated with lower acid, sugar levels, total phenolics content, antioxidants and phenyl ammonia lyase activity within the fruit and increased content of senescent related enzymes like lipoxigenase (LOX) and pectin methyl esterase (PME) activity and respiration or ethylene evolution rate. Reduced internal sugar and acid content is associated with late bloom fruit, large fruit, high temperatures, increased fruit water content through irrigation or rain, shaded conditions etc. (Sinha 2017). However, Rangpur lime an important rootstock, which required seeds for raising rootstock for mandarin and sweet orange has severely affected with granulation disorder under the foot hill of Arunachal Pradesh resulting few viable seeds from the mature ripe fruit. Keeping the view and considering the need, the present experiment was initiated with the objectives to study the effect of different growth regulators and micronutrients in minimizing granulation and to increase yield of citrus cv. Rangpur lime.

Experimental site and treatment details: A field experiment was conducted during 2019–20, at research Farm of College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh on Rangpur Lime trees of 9 year old planted at 6 m × 6 m. The investigation was laid out in a randomized block design (RBD) with 9 treatments and 4 replications with 1 plant in each replication in which all the selected plants were having granulation disorder and uniform size tree as test tree of the experiment. The details of the treatments are T_1, NAA @250 ppm + $ZnSO_4$ @0.5% + $CuSO_4$ @0.5%; T_2, GA_3 @10 ppm + $ZnSO_4$ @0.5% + $CuSO_4$ @0.5%; T_3, NAA @300 ppm + $ZnSO_4$ @0.5% + $CuSO_4$ @0.5%; T_4, GA_3 @15 ppm + $ZnSO_4$ @0.5% + $CuSO_4$ @0.5%); T_5, NAA @250 ppm + GA_3 @10 ppm + $ZnSO_4$ @0.5% + $CuSO_4$ @0.5%; T_6, NAA @300 ppm + GA_3 @15 ppm + $ZnSO_4$ @0.5% + $CuSO_4$ @0.5%; T_7, NAA @250 ppm + GA_3 @10 ppm; T_8, NAA @300 ppm + GA_3 @15 ppm and T_9, Control. The recommended dose of fertilizer (RDF) of lime 900:250:500 g NPK/plant/year was applied to all the plants under experiment in two splits dose. Plant growth regulators NAA @250 ppm and 300 ppm and GA_3 @10 ppm and 15 ppm were applied along with micronutrient $ZnSO_4$ and $CuSO_4$ @0.5% as per the treatment requirement at specific intervals in which micronutrient were spray 1 week prior to growth regulator application @300 ml/tree uniformly. The first split dose of fertilizers was applied before flowering during January along with foliar spray of micronutrient $ZnSO_4$and $CuSO_4$ @0.5% and the remaining half after flowering during July. PGRs and micronutrients were applied during August, second spray in September

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and the third spray when it attained colour breaking stage in October month in which micronutrients foliar spray was applied one week prior to PGRs spray.

Viable seed count and fruit quality: The viable seeds for each treatment from fully matured fruit and granulation percentage (%) were evaluated by taking average mean of viable seeds per fruit and granulation percentage (%) by taking 300 fruits for each treatment. The quality parameters of the harvested fruits were analyzed in the laboratory with standard methods (AOAC 2006) and data were subjected to the statistical analysis of variance for RBD according to the method described by Gomez and Gomez (2010).

Present investigation revealed that the maximum number of fruit per tree (799.25 fruits/tree) and fruit yield (129.06 kg/tree) was found in the treatment NAA @300 ppm + GA_3 @15 ppm + $ZnSO_4$ @0.5% + $CuSO_4$ @0.5% (T_6). Foliar spray of NAA has role in auxin synthesis and it might have inhibited the formation of abscission layer and thereby increased the fruit retention. Zinc activates enzymes in protein synthesis and which might also help in prevention of abscission layer formation in plants. Besides, the copper is a main component of many enzymes in the plant and also plays an important role in energy metabolism, the deficiency of copper directly affects in the formation of grain, seed, and fruit much more than plant vegetative growth (Marschner 2002). As a result, application of GA_3 and NAA along with micronutrients significantly minimized the fruit drop and increased fruit retention resulting, maximum number of fruits per tree.

Imposition of the treatment recorded significantly minimum (17.80%) granulation with application of NAA @300 ppm + GA_3 @15 ppm + $ZnSO_4$ @0.5% + $CuSO_4$ @0.5% (T_6) (17.80%) and maximum (35%) granulation were recorded under control. Although granulation disorder was not completely controlled after the imposition of treatments however, it minimize the granulation disorders significantly in the treated plants and severe granulation occurred in control. The response to NAA obtained in the earlier studies leads to the conclusion that under granulation the auxin balance has been upset. Awasthi and Nauriyal (1972) have also reported that low zinc content in granulated fruits may be due to low auxin content and high peroxidase activity, which help the formation of lignin. Besides, zinc is involved in the biosynthesis of auxin, indole-3-acetic acid (IAA) and it's deficiency resulted in reduction of auxin content resulting in increase of peroxidase activity, helping accumulation of polysaccharides. As a result, zinc application may have overcome the ill-effects of auxin deficiency. The maximum fruit weight (161.48 g) resulting fruit yield per tree was recorded with the foliar application of NAA @300 ppm + GA_3 @15 ppm + $ZnSO_4$ @0.5% + $CuSO_4$ @0.5% (T_6) while minimum fruit weight (105.84 g) were noted under control. The significant effect of zinc and auxin in increasing the number of fruits might be due to synthesis of tryptophan which serves as precursor for auxin synthesis (Modise *et al.* 2009). Increase number of fruits per tree might be due to auxin suppresses the formation of abscission layer and thereby increases the fruit retention of the fruit. In addition, it also increases the average weight of the fruit. There was significant increase in yield per tree due to increased number of fruits per tree and fruit weight individuals than the control treatment. Similar results were also reported by Kachave and Bhosale (2009) in which gibberellic acid promotes cell elongation, cell enlargement, increase in number of cells and also helps in increasing fruit volume, diameter and weight ultimately maximum yield per tree as compared to control.

Further, physical yield parameters of the fruits were also significantly increased (Table 1) in which maximum fruit length (6.75 cm) and breadth (6.75 cm) were recorded with the foliar application of NAA @300 ppm + GA_3 @15 ppm + $ZnSO_4$ @0.5% + $CuSO_4$ @0.5% (T_6) and minimum fruit length (5.82 cm) and breadth (5.86 cm) were recorded under control resulting maximum juice content (70.00 ml) in treatment T_6 and minimum juice content (29.20 ml) was noted with the control. The increase in juice percentage due to zinc can be attributed because it might have regulated the water relations in plant metabolism. The increase in juice content of the fruit might be due to role of zinc in plant metabolism which improved tree health by better sugar metabolism and translocation of assimilates and this could be the main reason for increase in juice content. The effect of PGR and micronutrient significantly increase the viable seeds by minimizing the granulation disorder intensity in which maximum viable seeds/fruit were noted in T_6 (12 viable seeds/fruit) which was found at par with NAA @250 ppm + GA_3 @10 ppm + $ZnSO_4$ @0.5% + $CuSO_4$ @0.5% and minimum number of viable seeds per fruit in control (4 viable seeds/fruit) (Table 2). The quality improvement in viable seeds per fruit may be due to proper supply of nutrients and better translocation of water and deposition of nutrients. Significant influence of PGRs and micronutrients

Table 1 Effect of PGRs and micronutrients on yield parameters of Rangpur lime

Treatment	Fruit length (cm)	Fruit breadth (cm)	Average weight of fruit (g)	Number of fruits per tree	Fruit yield (kg/tree)
T_1	6.22	6.23	126.74	591.75	74.99
T_2	5.94	6.23	121.08	435.25	52.70
T_3	6.36	5.93	123.68	646.25	79.92
T_4	6.04	6.10	113.40	611.25	69.31
T_5	6.37	6.26	130.82	567.75	74.27
T_6	6.75	6.75	161.48	799.25	129.06
T_7	6.06	6.18	126.06	478.75	60.35
T_8	6.24	6.14	130.18	613.25	79.82
T_9 (control)	5.82	5.86	105.84	407.50	43.12
Mean	6.20	6.19	126.58	572.33	73.72
CD @5%	0.35	0.17	9.24	145.97	17.12
SE(m)±	0.11	0.05	3.19	49.71	5.83

Refer to methodology for treatment details.

Table 2 Effect of PGRs and micronutrients on granulation (%) and seed parameters of Rangpur lime

Treatment	Granulation percentage (%)	Average number of seeds per fruit	Average number of viable seeds per fruit	Seed breadth (cm)	Seed length (cm)	Seed weight (g)
T_1	31.80	11.00	09.00	0.38	1.07	0.67
T_2	33.00	11.00	10.00	0.38	0.95	0.71
T_3	24.00	13.00	08.00	0.38	1.17	0.77
T_4	29.00	12.00	09.00	0.36	1.07	0.73
T_5	23.00	14.00	12.00	0.37	1.11	0.74
T_6	17.80	14.00	12.00	0.56	1.20	0.88
T_7	28.10	11.00	08.00	0.35	1.06	0.71
T_8	18.10	09.00	06.00	0.55	1.14	0.85
T_9 (control)	35.00	08.00	03.00	0.32	0.95	0.63
Mean(s)	26.64	11.44	8.55	0.41	1.08	0.74
CD @5%	4.214	1.78	1.74	0.019	0.04	0.26
SE(m)±	1.435	0.61	0.60	0.007	0.01	0.09

Refer to methodology for treatment details.

on fruit quality was also reported by Kachave and Bhosale (2009) on kagzi lime.

Hence, it can be concluded from the study that, the application of NAA @300 ppm + GA_3 @15 ppm + $ZnSO_4$ @0.5% + $CuSO_4$ @0.5% as foliar spray thrice during August, September and October along with half recommended dose of fertilizer before flowering with $ZnSO_4$ @0.5% + $CuSO_4$ @0.5% as foliar spray and the remaining half recommended dose of fertilizer after fruit setting significantly reduced fruit granulation and showed improvement in fruit yield and quality of seed of this important rootstock of citrus.

SUMMARY

Present study was carried out at research Farm of College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh during 2019–20 to find out effect of PGRs and micronutrients on granulation disorder of citrus cv. Rangpur lime. Results observed significant effect of PGRs and micronutrient on minimizing granulation and increasing the yield of fruits. Among all the treatments NAA @300 ppm + GA_3 @15 ppm + $ZnSO_4$ @0.5% + $CuSO_4$ @0.5% (T_6) showed maximum improvement in yield and reducing the granulation disorder in which maximum increase in number of fruits/tree (799.25 fruits/tree), fruit weight (161.48 g), yield (129.06 kg/tree) and minimum granulation (17.80%) was recorded as compared to control (35%). Maximum viable seeds/fruit (12) were also attributes from the treatment T_6 which was at par with NAA @250 ppm + GA_3 @10 ppm + $ZnSO_4$ @0.5% + $CuSO_4$ @0.5% (T_5) as compared to control (4).

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