

Vegetative growth, flowering pattern and yield of mango (*Mangifera indica* L.) as affected by exogenous application of paclobutrazol and KNO₃

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Summary

Studied the response of different flowering regulatory agro-chemicals had a significantly positive impact on vegetative growth, flowering pattern and yield attributes of mango, during 2015-16 and 2016-17. Paclobutrazol is associated with a shorter internodal length and the highest flowering intensity. The study was laid out with 7 treatments in randomized block design and replicated thrice were applied on north Indian mango cultivars "Dashehari" and "Kesar" under the Banswara condition of Rajasthan. The results revealed that most of the flowering parameters were better performed with paclobutrazol @ 3.0 ml m⁻² soil drench application mid-September (number of flowers/10 tagged panicle, per cent hermaphrodite flowers, per cent fruit set, least length and width of panicle) and foliar application of potassium nitrate 25 g l⁻¹ observed maximum height and width of panicle, fruit weight, yield kg tree⁻¹, yield t/ha.

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Introduction

Mango (*Mangifera indica* L.) is the choicest fruit among the tropical and sub-tropical regions and belongs to the family Anacardiaceae in the order Sapindales. India is the world's largest mango producer, with an annual production of 18.67 MT from 2.55 MH area and a productivity level of 7.3 tonnes per hectare Anonymous (2). In India, poor mango crop productivity is crucial for farmers due to alternate or biennial-bearing habits. One of the most important elements in mango orchard management is growth control. This crop has faced a long-standing problem of alternate bearing behaviour of most of the north Indian mango cultivars viz. Dashehari, Langra, Chausa, Bombay Green that denotes variation in low yield potential Pandey and Dinesh, (13) Excessive vigour implies a diminution in light penetration thus it improves flowering pattern quality attributes and ultimately results at higher yield Miller (11).

Before 2001, Cycocel was a key element for growth control in mango orchards. At that time the perceived benefits of using cycocel were great effectiveness in growth control Luis et al. (9). In 2001 Paclobutrazol and potassium nitrate were permitted phytochemicals had been widely reported as inhibitor of shoot growth in pear and mango. Like chlormequat and daminozide, paclobutrazol is an inhibitor of GA₃ biosynthesis. All of these compounds inhibit stem elongation and promote flowering but they also have the disadvantages of extended persistence in apple trees and troubling

toxicological properties Steffens and Wang (23). Paclobutrazol is a sterol inhibitor, which blocks the oxidation of kaurene to kaurenic acid Dalziel and Lawrence (4). It inhibits gibberellins biosynthesis in the sub-apical meristem and causes vegetative growth retardation Dheim & Browning (7). Growth-regulating properties of paclobutrazol are mediated by changes in the levels of important plant hormones including the gibberellins, and abscisic acid cytokinins. Paclobutrazol affects the isoprenoid pathway and alters the levels of plant hormones by inhibiting gibberellins synthesis and increasing cytokinins levels. When gibberellins biosynthesis is inhibited, more precursors in the terpenoids pathway accumulate and that results in the production of abscisic acid. Paclobutrazol acts as stress protectant by maintaining relative water content, membrane stability index, photosynthetic activity, photosynthetic pigments and protects the photosynthetic machinery by enhancing the level of osmolytes, antioxidant activities and level of endogenous hormones and thereby enhances the flowering and yield Soumya et al. (21). Excessive vegetative growth and high gibberellins synthesis at the time of flower bud differentiation is one of the reasons for the erratic bearing of mango. Thus, for increasing the reproductive growth of the tree there is a need to retard vegetative growth and to reduce the gibberellins biosynthesis during flowering. Certain growth regulators have been identified to induce the flowering in mango during "Off-year" Pandey and Dinesh (13). Dheeraj et al. (6) soil drench application of paclobutrazol 3 ml m⁻² at 120 days before at fruit bud differentiation stage was found to better improve on flowering aspect as well as yield (23.7 %) over control in mango cv. Banganpalli. NAA @ 80 ppm spray 30 days before flowering was found to improve flowering in mango Davenport (5). This study aimed to analyze the performance of different strategies

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used to reduce vegetative growth in mango cultivars "Dashehari" and "Kesar".

Materials and Methods

The experiment was carried out on seventeen-year-old uniform mango trees planted at 10 x 10 metre spacing. The climate of the experimental site is humid climate with an average annual rainfall range of 511 to 1043 mm precipitating mainly between the first week of July and to middle of August. The two agro-chemicals used in the first experiment were applied at three different concentrations, viz. paclobutrazol (2.5, 3.0 and 3.5 ml m⁻² plant canopy as soil drench) and potassium nitrate (25, 37.5 and 50 g litre⁻¹ as foliar application) during mid-September to mid-October along with the spray of water as control treatment. The study was laid out with 7 treatments in involved a factorial randomised block design with replicated thrice. There were three homogenous trees per elemental plot. The variables evaluated were the number of flowers/ ten tagged panicles, flowering intensity, per cent hermaphrodite flowers, per cent fruit set, least length and width of panicle, fruit weight, yield kg/tree, yield t/ha in the year after treatment application. The final shoot length was evaluated in winter. A randomly selected sample was recorded on 100 tagged shoots (25 shoots in each direction) and the average was calculated at 90 and 180 days after treatment application. *Correlation and*

regression of different independent variables of with respect to yield dependent variables to flowering attributes.

Results and Discussion

All the paclobutrazol concentrations were also able to reduce vegetative shoot length as compared to potassium nitrate and control (Table 1). Scrutiny of pooled data indicated that the cultivar Dashehari showed a significant effect and more plant height (7.11 m) as compared to Kesar. In the case of agro-chemicals application, the maximum height (7.32 m) was registered in treatment T₆ (Potassium Nitrate 50 g l⁻¹) as foliar application and a minimum (6.79 m) was assigned in control. The interaction effect of paclobutrazol and potassium nitrate had not significant effect on plant height during both years. The particular effect of paclobutrazol and potassium nitrate on vegetative shoot emergence at 90 and 180 days after treatment application was significantly higher during both years of studies. A careful analysis of the pooled data indicated that the maximum shoot length was (23.05 and 26.46 cm) in cv. Dashehari at 90 and 180 days after treatment application and the minimum was (21.11 and 25.21 cm) in cv. Kesar. With regards to agrochemicals at 90 and 180 days after treatment application, the maximum shoot length (24.68 cm and 27.70 cm) was recorded in treatment T₆ (potassium nitrate foliar application).

Table 1. Response of mango varieties to agrochemicals on vegetative growth parameters

Treatments/ Varieties	Plant height (m)	Shoot length (cm)		Canopy volume (m ³)	Leaf area (cm ²)
		90 DAT	180 DAT		
V ₁ : (Dashehari)	7.11	23.05	26.46	182.70	72.03
V ₂ : (Kesar)	6.52	21.11	25.21	137.07	70.01
SEm±	0.13	0.42	0.50	3.11	0.88
C.D.5%	0.37	1.18	NS	8.83	NS
Agro- chemicals					
T ₁ (PBZ @ 2.5 ml m ⁻²)	6.68	20.90	25.38	156.49	69.46
T ₂ (PBZ @ 3.0 ml m ⁻²)	6.51	19.42	24.36	144.11	68.29
T ₃ (PBZ @ 3.5 ml m ⁻²)	6.47	19.27	23.94	135.67	67.81
T ₄ (KNO ₃ @ 25 g l ⁻¹)	6.82	23.71	26.27	165.02	72.13
T ₅ (KNO ₃ @ 37.5g l ⁻¹)	7.11	24.17	27.29	172.96	73.77
T ₆ (KNO ₃ @ 50 g l ⁻¹)	7.32	24.68	27.70	182.13	76.10
T ₇ (Control)	6.79	22.39	25.92	162.81	69.59
SEm±	0.25	0.78	0.93	5.82	1.65
C.D. at 5%	NS	2.21	2.63	16.52	4.69
CV %	12.46	12.23	12.44	12.61	8.06

All concentrations of paclobutrazol were also able to reduce canopy volume as compared to potassium nitrate and control (Table 1). Significant variation in canopy volume among different treatments. The maximum canopy volume was recorded in cv. Dashehari (182.70 m³) followed by Kesar (137.07 m³). The data furnished on the response of agro-chemicals also showed significant variation and cited the maximum value of canopy volume (182.13 m³) in treatment T₆ (potassium nitrate 50 g/litre as foliar application), which was statistically at par with T₅. The minimum canopy volume (135.67 m³) was assigned in paclobutrazol 3.5 ml m⁻² plant canopy as a soil drench (T₃). Non-significant

differences were observed in leaf area (cm²) among both the cultivars (Table 1). Among both the cultivars "Dashehari" showed higher leaf area (72.03 cm²) as compared to Kesar (70.01 cm²). The data revealed that different concentrations of agrochemicals showed non-significant effects on leaf area during both the years as well as in pooled analysis. The highest leaf area was obtained with T₆ (76.10 cm²) during individual years, respectively and the minimum leaf area in T₃. The interaction effect of cultivars and agrochemicals application on vegetative growth parameters had a non-significant response with plant height, shoot length, canopy volume and leaf area respectively (Table 2).

Table 2. Interaction effect of mango varieties to agrochemicals on vegetative growth parameters

Treatments	Plant height (cm)	Shoot length (cm)		Canopy volume (m ³)	Leaf area (cm ²)
		90 DAT	180 DAT		
	Pooled	Pooled	Pooled	Pooled	Pooled
V ₁ T ₁	7.04	21.82	25.48	179.49	70.59
V ₁ T ₂	6.79	20.43	24.57	161.71	69.09
V ₁ T ₃	6.74	20.36	24.98	155.55	68.70
V ₁ T ₄	7.18	24.85	26.89	191.81	72.78
V ₁ T ₅	7.40	25.23	28.32	193.64	74.91
V ₁ T ₆	7.48	25.32	28.55	208.29	77.36
V ₁ T ₇	7.16	23.32	26.44	188.41	70.77
V ₂ T ₁	6.33	19.97	25.27	133.50	68.33
V ₂ T ₂	6.24	18.42	24.16	126.51	67.50
V ₂ T ₃	6.20	18.18	22.91	115.79	66.92
V ₂ T ₄	6.47	22.58	25.65	138.22	71.47
V ₂ T ₅	6.82	23.12	26.26	152.29	72.63
V ₂ T ₆	7.16	24.04	26.84	155.98	74.83
V ₂ T ₇	6.42	21.46	25.39	137.22	68.40
SEm±	0.35	1.10	1.31	8.23	2.34
C. D. (P=0.05)	NS	NS	NS	NS	NS

The Maximum number of flowers (2865.24) were registered in cv. Dashehari as compared to Kesar (2748.07) in Table 3. Significant differences among both the cultivars were observed. The highest number of flowers was obtained with T₂ (3026.67) and the minimum flowers in T₇ (control). The maximum hermaphrodite flower was recorded in cv. Dashehari (32.08 %) and minimum in cv. Kesar (30.40%) (Table 3). The data furnished on the response of agrochemicals also showed significant variation and cited the maximum value of

hermaphrodite flower (31.98 %) in treatment T₄ (potassium nitrate 25 g l⁻¹ as foliar application). Whereas, the minimum hermaphrodite flower (29.42 %) was in control. The Maximum sex ratio (0.47) was registered in cv. Dashehari as compared to Kesar (0.44). The data revealed that different concentrations of agrochemicals show a significant effect on sex ratio in pooled analysis (Table 3). The highest sex ratio obtains with T₁ and T₄ (0.47) and the minimum value of sex ratio in T₇ (0.42).

Table 3. Response of mango varieties to agrochemicals on flowering attributes

Treatments/ Varieties	Number of flowers/ panicles	Hermaphrodite flowers (%)	Sex ratio	Fruit set (%)	Length of panicle (cm)	Width of panicle (at maximum span cm)	Flowering intensity (%)
V ₁ : (Dashehari)	2865.24	32.08	0.47	1.53	41.43	27.71	69.04
V ₂ : (Kesar)	2748.07	30.40	0.44	1.22	33.21	32.14	66.99
SEm±	13.11	0.19	0.004	0.02	0.42	0.59	0.38
C.D.5%	37.21	0.54	0.012	0.05	1.20	1.68	1.08
Agro-chemicals							
T ₁ (PBZ @ 2.5 ml m ⁻²)	2835.58	31.85	0.47	1.59	35.59	29.44	69.20
T ₂ (PBZ @ 3.0 ml m ⁻²)	3026.67	31.62	0.46	1.60	34.55	29.12	70.60
T ₃ (PBZ @ 3.5 ml m ⁻²)	2755.67	31.21	0.45	1.49	32.20	27.80	69.22
T ₄ (KNO ₃ @ 25 g l ⁻¹)	2896.33	31.98	0.47	1.50	40.51	31.59	70.60
T ₅ (KNO ₃ @ 37.5g l ⁻¹)	2806.25	31.37	0.46	1.24	39.94	31.00	65.29
T ₆ (KNO ₃ @ 50 g l ⁻¹)	2696.08	31.24	0.46	1.21	39.54	30.32	65.67
T ₇ (Control)	2630.00	29.42	0.42	0.97	38.89	30.21	65.52
SEm±	24.534	0.356	0.008	0.03	0.79	1.10	0.712
C.D. at 5%	69.62	1.01	0.022	0.09	2.24	NS	2.02
CV %	3.03	3.95	5.80	7.57	7.32	12.79	3.63

The maximum per cent fruit set was assigned in cv. Dashehari (1.53%) followed by Kesar (1.22%). It is evident from the data that foliar application of paclobutrazol 3 ml m⁻¹ canopy volume had a significant influence on fruit set in both the mango cultivars (Table 3). The maximum fruit set per panicle (1.60 %) was observed in treatment T₁ (Paclobutrazol 2.5 ml m⁻² plant canopy as soil drench) as compared to rest of the treatments. However, minimum fruit set (0.97%) was recorded in treatment T₇ (control). The maximum panicle length (41.43 cm) was recorded in cv. Dashehari, whereas, the minimum length (33.21 cm) in Kesar. The data revealed that different concentrations of agrochemicals were showing a significant effect on panicle length (Table 4). Maximum panicle length was obtained with T₄ (40.51 cm), which was statistically at par with T₅, T₆ and T₇. Minimum (32.20 cm) panicle length in T₃ (Paclobutrazol 3.5 ml m⁻² plant canopy as a soil drench). The maximum panicle width was registered in cv. Kesar (32.14 cm) followed by Dashehari (27.71 cm). The agro-chemicals effect on panicle width was found non-significant (Table 2). Maximum panicle width was assigned in T₄ (Potassium nitrate 25 g l⁻¹ as foliar application) and minimum in T₃ (Paclobutrazol 3.5 ml m⁻² plant canopy as soil drench).

The maximum flowering intensity was recorded in cv. Dashehari (69.04 %) and followed by cultivar Kesar (66.99 %) (Table 4). The response of agro-chemicals on flowering intensity was also found significant and maximum flowering intensity (70.60 %) was observed in treatment T₂ (Paclobutrazol 3.0 ml m⁻² plant canopy as soil drench) and T₄ (Potassium nitrate 25 g l⁻¹ foliar application), which was statistically at par with T₃ and minimum flowering intensity (65.52 %) was registered in control. Paclobutrazol was found to effectively inhibit plant height and leaf expansion. Reduction in vegetative growth may be attributed to the inhibiting effect of paclobutrazol on gibberelline biosynthesis. These results are in accordance with Singh and Rajput (17) in mango; and Kulkarni (8) in mango cv. Banganapalli; Burondkar et al. (3) in Alphonso mango; Uperti et al. (24) in mango cv.

Totapuri. Abolfazl et al. (1) in strawberry cv. Selva; Ramina et al. (18) in strawberry; Yeshitela et al. (25) in mango cv. Tommy Atkins Srilatha et al. (22) in mango; Rahim et al. (16) in mango. It might be due to an increase in vegetative growth with the maximum harvest of solar light. Further, per cent fruit set and per cent fruit retention were maximum recorded in cv. Dashehari therefore number of fruits plant⁻¹ ultimately increased in this treatment. Further, bigger size fruits, higher fruit weight and a maximum number of fruits plant⁻¹ were observed in Dashehari, which was, one of the reasons for achieving a higher yield of mango cv. Dashehari.

The highest number of fruits harvested tree⁻¹ was recorded in the Dashehari cultivar (242.90), while the minimum value was noted in cv. Kesar (Table 5). The treatment incorporated a significant effect on the number of final fruits harvested per tree maximum number of fruits was recorded (235.42) in T₁ which was the highest as compared to the rest of the treatments. The interaction effect of cultivars and agrochemicals application on flowering-fruiting parameters had a significant response with fruit set and fruit retention (Table 5). Maximum per cent fruit set and fruit retention per cent were recorded in the combination of V₁T₂ (Dashehari + Paclobutrazol 3.0 ml m⁻² plant canopy; a soil drench). This might be due to varietal response with agrochemicals combination. This view is strengthened due to the existence of a highly significant and positive correlation between yield and flowering attributes. In case of both the cultivars (Dashehari and Kesar) respectively, highly positive significant correlation association of number of flowers ($r = 0.88$ and 0.83), hermaphrodite flowers (%) ($r = 0.83$ and 0.88), flowering intensity (%) ($r = 0.82$ and 0.42), fruit retention (%) ($r = 0.89$ and 0.73) with yield (kg/tree) and negative highly significant correlation between length of panicles ($r = -0.15$ and 0.09) and titratable acidity (%) ($r = -0.59$ and -0.60) with yield. A number of fruits showed a non-significant correlation with dependent variable (y) yield. These findings are strongly supported and in accordance with Yadav et al., (2017).

Table 4. Response of mango varieties to agrochemicals on yield attributes

Treatment/ Variety	Number of fruits tree ⁻¹ at harvest	Fruit weight (g)	Yield tree ⁻¹ (Kg)	Yield tonnes hectare ⁻¹
V ₁ : (Dashehari)	242.90	203.67	49.02	4.90
V ₂ : (Kesar)	217.69	217.90	46.92	4.69
SEm±	0.60	0.457	0.17	0.02
C.D.5%	1.71	1.298	0.47	0.05
Agro- chemicals				
T ₁ (PBZ @ 2.5 ml m ⁻²)	235.42	212.58	49.38	4.94
T ₂ (PBZ @ 3.0 ml m ⁻²)	234.08	217.92	50.29	5.03
T ₃ (PBZ @ 3.5 ml m ⁻²)	228.00	208.25	46.90	4.69
T ₄ (KNO ₃ @ 25 g l ⁻¹)	230.08	227.75	51.90	5.19
T ₅ (KNO ₃ @ 37.5g l ⁻¹)	226.58	220.58	49.50	4.95

T ₆ (KNO ₃ @ 50 g l ⁻¹)	233.17	197.25	45.48	4.55
T ₇ (Control)	224.75	191.17	42.34	4.23
SEm±	1.13	0.86	0.310	0.03
C.D. at 5%	3.20	2.43	0.88	0.09
CV %	1.69	1.41	2.24	2.24

Table 5. Interaction effect of mango varieties to agrochemicals on flowering and fruiting parameters

Treatments	Number of Flowers / panicle	Hermaphrodite flowers (%)	Sex ratio	Fruit set (%)	Length of panicle (cm)	Width of panicle (at maximum span cm)	Flowering intensity (%)	Fruits/tree at harvest	Fruit weight (g)	Yield (kg tree ⁻¹)	Yield (tonnes ha ⁻¹)
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
V ₁ T ₁	2900.67	32.57	0.48	1.73	39.08	27.69	70.25	247.67	207.00	50.63	5.06
V ₁ T ₂	3095.83	32.78	0.49	1.75	38.92	27.25	71.75	246.67	211.50	51.44	5.14
V ₁ T ₃	2837.17	32.19	0.48	1.60	35.66	25.75	70.42	240.67	200.83	47.86	4.79
V ₁ T ₄	2956.83	32.54	0.48	1.61	45.47	28.88	71.95	242.83	218.33	52.70	5.27
V ₁ T ₅	2860.33	32.17	0.47	1.44	44.47	28.25	67.63	239.17	210.33	50.12	5.01
V ₁ T ₆	2734.67	32.02	0.47	1.45	43.81	28.14	65.58	245.50	191.17	46.54	4.65
V ₁ T ₇	2671.17	30.31	0.44	1.08	42.58	28.00	65.72	237.83	186.50	43.83	4.38
V ₂ T ₁	2770.50	31.13	0.45	1.45	32.11	31.20	68.15	223.17	218.17	48.13	4.81
V ₂ T ₂	2957.50	30.46	0.44	1.44	30.18	31.00	69.46	221.50	224.33	49.13	4.91
V ₂ T ₃	2674.17	30.22	0.43	1.37	28.74	29.86	68.02	215.33	215.67	45.94	4.59
V ₂ T ₄	2835.83	31.42	0.46	1.39	35.54	34.29	69.26	217.33	237.17	51.10	5.11
V ₂ T ₅	2752.17	30.57	0.44	1.04	35.41	33.74	62.96	214.00	230.83	48.88	4.89
V ₂ T ₆	2657.50	30.47	0.44	0.97	35.28	32.50	65.75	220.83	203.33	44.42	4.44
V ₂ T ₇	2588.83	28.54	0.40	0.86	35.21	32.41	65.33	211.67	195.83	40.86	4.09
SEm±	34.70	0.50	0.011	0.04	1.12	1.56	1.01	1.59	1.21	0.44	0.04
C. D. (P=0.05)	NS	NS	NS	0.12	NS	NS	NS	4.52	3.43	1.24	0.12

The maximum yield tree⁻¹ (Off year: 41.75 kg; On year: 56.28 kg and pooled 49.02 kg) and yield tonnes hectare⁻¹ (Off year: 4.18; On year: 5.63 and pooled 4.90 tonnes) was observed in cv. Dashehari, which was higher as compared to Kesar during the years 2015-16 and 2016-17 and pooled, respectively (Table 3). The data pertaining to the yield tree⁻¹ and yield tonnes hectare⁻¹ were significantly highest (51.90 kg and 5.19 tonnes) under treatment T₄ and minimum yield was recorded in T₇ (42.34 kg and 4.23 tonnes/ha). The higher yields in the PBZ-treated trees are ascribed due to high flowering intensity which resulted in higher fruit numbers. Paclobutrazol has been found to accelerate stomatal response, enhance water retention and increase survival under drought in jack pine (Marshall et al. (10); Kumar et al. (27); Anusuya et al. (28)). Paclobutrazol application

significantly reduced water consumption as estimated in strawberry plants Parvin et al. (14). The lower water consumption in paclobutrazol treated *Arbutus unedo* seedling was the result of combination of means which reduced transpiration loss and increased resistance against adverse climatic condition. Navarro et al. (12). These findings are in agreement with the findings of Upreti et al. (24) on Totapuri mango; Sankar et al. (19) on Alphonso mango; Sarker and Rahim (20) on mango; and Patel et al. (15) in Alphonso mango different mango varieties.

The interaction effect between cultivars and agrochemicals levels was found significant for yield parameters. The interaction level V₁T₄ (Dashehari + Potassium nitrate 25 g per litre; foliar application) resulted in maximum yield plant⁻¹ (52.70 kg) and

estimated yield ha^{-1} (5.27 tonnes). However, combinations V_1T_2 and V_1T_4 were found to be statistically at par with each other. Where minimum values were obtained V_2T_7 for a number of fruit harvest plant⁻¹ (211.67), yield plant⁻¹ (40.86 kg) and estimated yield ha^{-1} (4.09 tonnes). The interaction level V_1T_2 (Dashehari +

Paclobutrazol 3.0 ml m^{-2} canopy soil drench application) and V_1T_4 (Dashehari + Potassium nitrate 25 g per litre; foliar application) recorded significantly higher yield attributing characters, which might be due to their individual effect.



Potassium Nitrate 25 g l^{-1} Foliar



Paclobutrazol 3.0 ml m^{-2} canopy (soil drench)



Paclobutrazol 3.0 ml m^{-2} plant canopy (soil drench application) in cv. Dashehari



Paclobutrazol 3.0 ml m^{-2} plant canopy (soil drench application) in cv. Kesar



Control in cv. Dashehari

Plate 2. Effect of Paclobutrazol (PBZ) application on flower intensity of mango



Paclobutrazol (PBZ) 3.0 ml m⁻² plant canopy (soil drench application) in cv. Dashehari



Paclobutrazol (PBZ) 3.0 ml m⁻² plant canopy (soil drench application) in cv. Kesar

Plate 3. Response of mango cultivars to application of Paclobutrazol (PBZ) on fruit size

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