Study of bud break in 'Hass' avocado

Estudio del brotamiento en aguacate 'Hass'

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Abstract
The capacity to stimulate precocious bud break of 'Hass' avocado buds on excised shoots and intact trees in a commercial orchard holds much value for studying hormonal control of bud dormancy, floral development, and the effect of the ON crop in an alternate bearing orchard on floral development versus bud dormancy. This knowledge would facilitate development of strategies to increase floral and vegetative shoot development at key stages in tree phenology. For shoots excised before bud break in February, 6-benzyladenine, but not gibberellic acid, increased bud break of both swollen (active) and inactive apical and lateral buds. For 1-year-old spring shoots (with fruit) excised from ON trees, apical and lateral buds produced predominantly vegetative shoots. Apical buds on shoots without fruit excised from OFF trees produced predominantly floral shoots; lateral floral and vegetative bud break were increased by 6-benzyladenine only if the apical bud was removed. Excised shoots with fruit from ON-crop trees, with or without the apical bud removed, underwent minimal bud break and plant bioregulators (PBRs) had no effect. In a commercial orchard, 6-benzyladenine significantly increased bud break of floral apical buds, but not lateral buds, of shoots without fruit on OFF-crop trees. PBRs had no effect on apical or lateral buds on shoots with fruit on ON-crop trees. Vegetative bud break on 1-year-old spring shoots of OFF- or ON-crop 'Hass' trees and 1-year-old summer/fall shoots of OFF-crop trees increased when the apical bud was removed before the end of March and the end of April, respectively.

Resumen
La capacidad de estimular el brotamiento precoz en yemas de aguacate 'Hass' sobre brotes extraídos y en árboles de plantaciones comerciales, es de mucho valor para el estudio del control hormonal del reposo de yemas, desarrollo floral, el efecto de alta producción en años ON en una plantación en desarrollo floral versus reposo de yemas. Este conocimiento facilitaría el desarrollo de estrategias para incrementar el desarrollo de brotes florales y vegetativos en estados fenológicos claves. Para los brotes extraídos antes del brotamiento en Febrero, tratamientos con 6-benciladenina, pero no con ácido giberélico, resultaron en brotamiento de yemas hinchadas y restantes tanto laterales como apicales. En brotes (con fruta) de primavera de 1 año extraídos de árboles ON, las yemas laterales y apicales crecieron predominantemente como vegetativas. Las yemas apicales de brotes extraídos de árboles OFF produjeron mayormente inflorescencias; el crecimiento floral y vegetativo de las yemas aumentó con 6-benciladenina sólo cuando se removió la yema apical. En brotes extraídos de árboles ON, con y sin yema apical, el brotamiento fue pobre y los BRPs no tuvieron efecto. En la plantación comercial, 6-benciladenina incrementó significativamente el brotamiento de yemas florales apicales pero no laterales en brotes sobre árboles OFF. Los BRPs no tuvieron efecto en yemas apicales ni laterales en brotes con fruta sobre árboles ON. Finalmente, el brotamiento vegetativo en brotes de primavera de 1 año en árboles 'Hass' OFF u ON y en brotes de verano/otoño de 1 año en árboles OFF incrementó cuando se quitó la yema apical antes del final de Marzo y del final de Abril, respectivamente.

Key words. Alternate bearing, apical dominance, bud dormancy, floral development, plant bioregulators

Introduction

Yield of the 'Hass' avocado is proportional to the number of floral shoots and flowers at spring bloom (Garner and Lovatt 2008). Thus, to increase yield and grower income, it is important to develop strategies to increase floral shoot number. Such strategies would be especially important in the spring following the heavy ON crop, when a light OFF bloom is anticipated. Whereas a percentage of lateral buds of the 'Hass' avocado do not undergo bud break, but remain inactive and subsequently abscise (Davenport 1986), the number of buds that remain inactive is significantly greater in the OFF bloom, resulting in the OFF crop, than in the ON bloom (Lovatt 2006). Contributing factors include the possibilities (*i*) that the large number of fruit in the ON crop changes the hormone composition of the buds for next year's spring bloom, inhibiting bud break of viable floral buds or inhibiting floral

development or (*ii*) that growth of the predominantly vegetative apical buds during the OFF bloom inhibits bud break of lateral floral buds. Removal of the shoot apical bud is a long-standing practice that successfully eliminates apical dominance and increases bud break of lateral buds, floral or vegetative. In addition, earlier research with the 'Hass' avocado demonstrated that growth of the vegetative shoot apex of terminal indeterminate floral shoots inhibited bud break of lateral floral buds (Salazar-García, Lord and Lovatt 1999). Thus, prebloom foliar applications of plant bioregulators (PBRs) that overcome apical dominance or other types of dormancy might successfully increase floral intensity at bloom.

At the present time, there are no commercial practices that dramatically increase floral intensity of the 'Hass' avocado, with the exception of early fruit removal during the ON-crop year. The objective of the research presented herein was to test the capacity of foliar-applied PBRs, removal of the apical bud, and the combination of these two strategies to increase bud break of floral and vegetative buds. These strategies were also tested with 1-year-old shoots that did not set fruit (without fruit, spring, summer and fall shoots) on OFF-crop trees and 1-year-old shoots that set fruit the previous spring (with fruit, spring shoots only, summer and fall shoots did not develop) on ON-crop trees in a commercial alternate bearing 'Hass' avocado orchard. Different concentrations of 6-benzyladenine (BA), gibberellic acid (GA_3) and hydrogen cyanamide (HDC) were tested *in vitro* using excised shoots and *in vivo* using shoots on mature trees in a commercial 'Hass' avocado orchard. In both systems, the efficacy of the PBRs to increase lateral bud break was compared on shoots with the apical bud present versus shoots with the apical bud removed. The PBRs tested are each known for their capacity to stimulate precocious bud break.

Materials and Methods

Plant material. The research was conducted with shoots excised from bearing 'Hass' avocado trees at the University of California-Riverside (UCR), Riverside, California, and in a commercial orchard in Irvine, California, where the whole tree experiments were also carried out. Trees received standard grower practice; no visual symptoms of water stress, disease or nutritional disorders were observed.

Excised shoots. Starting in February, spring flush vegetative shoots from the previous year having swollen (active, more advanced) or closed (inactive, less advanced) apical buds were excised. In addition, shoots with fruit from ON-crop trees (predominantly last year's spring shoots) and shoots without fruit from OFF-crop trees (predominantly last year's summer shoots) were excised. For simplicity these shoots are referred to as shoots from On- or OFF-crop trees. All shoots were defoliated, made devoid of fruit, washed with dish detergent, sterilized in a 10% bleach solution for 10 min, and rinsed with distilled water. The cut end of the shoots was cut again before placing the shoots in a 125 mL Erlenmeyer flask containing a sufficient amount of the solutions (50-75 mL) described below to cover the cut end of the shoots for more than seven days, when the end of the shoot was cut again to remove 6-7 mm to facilitate uptake and the solutions were replaced with fresh solutions. The shoots were maintained at 22 °C, 16-h day/ 8-h night under minimal evapo-transpiration in a growth room in the Plant Transformation Research Center at UCR. At time zero, each shoot was labeled and the number of nodes with buds on each shoot was counted. Apical and lateral buds were evaluated weekly and the date of bud break and type of shoot that developed (floral or vegetative) recorded.

Experiment 1. One-year-old spring shoots collected at UCR in late winter (February) were treated with: (*i*) 0.6, 0.3, 0.15, 0.075, 0.038 or 0.019 mM 6-benzyladenine (BA); (*ii*) 10 or 5 mM gibberellic acid (GA_3); (*iii*) rinsing for 15 min with distilled water (dH_20) and then transferred to distilled water; and (*iv*) distilled water only (untreated control).

Experiment 2. One-year-old spring shoots were collected at UCR in late winter (February), the apical bud was removed, and the shoots were treated with: (*i*) 0.6, 0.15 or 0.019 mM BA; (*ii*) 10 or 5 mM $GA_{3;}$ (*iii*) rinsing for 15 min with distilled water and then transferred to distilled water; and (*iv*) distilled water only (untreated control).

Experiment 3. One-year-old spring shoots collected in Irvine in early spring (March), with and without the apical bud removed, were treated with: (*i*) 0.3, 0.15 or 0.075 mM BA; (*ii*) 5 or 2.5 mM GA; (*iii*) 0.125%, 0.063% or 0.032% (v/v) hydrogen cyanamide (HDC); (*iv*) rinsing for 15 min with distilled water and then transferred to distilled water; and (*v*) distilled water only (untreated control).

Whole trees. In the commercial 'Hass' avocado orchard in Irvine, shoots with fruit on ON-crop trees (1-year-old spring shoots with little to no summer or fall shoot growth present) and shoots without fruit on OFF-crop trees (1-year-old spring shoots with summer and some fall shoot growth present) were used in two separate experiments testing the effects of foliar-applied PBRs on apical and lateral bud break and removal of the shoot apical bud at progressively later dates on lateral bud break. All treatments were applied to individual shoots on one tree (block) and replicated on 10 or 30 ON- and 10 or 30 OFF-crop trees for *Experiments 4* and *5*, respectively. Shoots were selected randomly from shoots with fruit for ON-crop trees and from shoots without fruit for OFF-crop trees. For clarity these shoots are referred to as shoots on ON- or OFF-crop trees. For both experiments the design was randomized complete block. The number of apical and lateral buds on spring and summer/fall shoots that underwent bud break and the type of shoot that developed from each bud (floral or vegetative) was determined every 15 days.

Experiment 4. Shoots with fruit on ON-crop trees and shoots without fruit on OFF-crop trees were sprayed in late winter (February) with the following treatments: (*i*) 25, 50 or 100 mg/L BA (Maxcel®, Valent BioScience Corp.); (*ii*) 25, 50 or 100 mg/L GA_3 (Progibb®, Valent BioScience Corp.); (*iii*) 10 or 20 mg/L of HDC (Dormex®, Dormex USA); and (*iv*) water - control. Solutions contained the wetting agent L-77 at 0.05%.

Experiment 5. Shoots with fruit on ON-crop trees and shoots without fruit on OFF-crop trees were selected, tagged and the apical bud removed every 30 days from one set of shoots on both ON- and OFF-crop trees in February, March, April and May.

Results

Excised shoots. Experiment 1. Apical floral growth occurred only on shoots collected with swollen (active, more advanced development) apical buds (Table 1). Apical buds on shoots collected with closed (inactive, dormant) buds were exclusively vegetative. Supplying BA (0.038, 0.075, or 0.15 mM) to excised shoots collected with closed buds significantly increase bud break of vegetative apical buds. Similarly, lateral floral growth occurred only on shoots collected with swollen buds (Table 1). Lateral buds produced predominantly vegetative shoots for shoots collected with swollen or closed buds. Supplying BA significantly increased bud break of floral (0.038 mM) and vegetative (0.075 mM) lateral buds on shoots collected with swollen buds.

Table 1. Effect of plant bioregulators on bud break of floral and vegetative apical and lateral buds on excised 'Hass' avocado shoots collected in late winter (February) with swollen (active, more advanced development) and closed (inactive, dormant) apical buds.

	Apical buds		Lateral buds	
Treatments	Closed	Swollen	Closed	Swollen
	---------- *no. of floral buds that broke per 2 shoots* ----------			
10 mM GA_3	0 c[z]	0 a	0 a	0 c
5 mM GA_3	0 c	1 a	0 a	0 c
0.6 mM BA	0 c	1 a	0 a	0 c
0.3 mM BA	0 c	2 a	0 a	0 c
0.15 mM BA	0 c	1 a	0 a	0 c
0.075 mM BA	0 c	2 a	0 a	0 c
0.038 mM BA	0 c	1 a	0 a	3 b
0.019 mM BA	0 c	0 a	0 a	0 c
Rinsed + dH_2O	0 c	1 a	0 a	0 c
dH_2O - control	0 c	0 a	0 a	0 c
	---------- *no. of vegetative buds that broke per 2 shoots* ----------			
10 mM GA_3	0 c	0 a	0 a	0 c

5 mM GA_3	0 c	0 a	0 a	0 c
0.6 mM BA	0 c	0 a	0 a	0 c
0.3 mM BA	0 c	0 a	0 a	0 c
0.15 mM BA	2 a	1 a	4 a	1 bc
0.075 mM BA	2 a	0 a	1 a	6 a
0.038 mM BA	2 a	1 a	0 a	0 c
0.019 mM BA	2 a	2 a	2 a	0 c
Rinsed + dH_2O	1 b	1 a	2 a	2 bc
dH_2O - control	1 b	2 a	0 a	3 b
P-value	< 0.0001	0.1983	0.1248	0.0182

[z] Values in a vertical column followed by different letters are significantly different at the specified *P*-values by Fisher's Protected LSD Test.

Experiment 2. Lateral buds on shoots collected with swollen or closed apical buds at the time of apical bud removal and PBR treatment produced only vegetative shoots (Table 2). GA_3 (10 mM) inhibited lateral bud break for shoots with closed buds, Whereas GA_3 (10 and 5 mM) inhibited lateral bud break for shoots with swollen buds. BA (0.15 mM) significantly increased lateral bud break on shoots collected with closed buds. Differences in the results obtained in *Experiments 1* and *2* are likely due to the fact that 1-year-old shoots were collected indiscriminately without knowledge of the ON- or OFF-crop status of the trees, which had been harvested. In all subsequent experiments, the presence or absence of fruit on a shoot and the crop load of the trees was carefully controlled.

Table 2. Effect of plant bioregulators on bud break of floral and vegetative lateral buds on excised 'Hass' avocado shoots collected in late winter (February) with swollen (active, more advanced development) and closed (inactive, dormant) apical buds at the time of apical bud removal.

	Lateral buds	
Treatments	Closed	Swollen
	- no. of floral buds that broke per 2 shoots -	
10 mM GA_3	0 d[z]	0 c
5 mM GA_3	0 d	0 c
0.6 mM BA	0 d	0 c
0.15 mM BA	0 d	0 c
0.019 mM BA	0 d	0 c
Rinsed + dH_2O	0 d	0 c
dH_2O - control	0 d	0 c
	-no. of vegetative buds that broke per 2 shoots-	
10 mM GA_3	0 d	0 c
5 mM GA_3	1 cd	0 c
0.6 mM BA	4 b	2 bc
0.15 mM BA	7 a	0 c
0.019 mM BA	1 cd	6 a
Rinsed + dH_2O	2 bcd	3 b
dH_2O - control	3 bc	4 ab
P-value	0.0003	0.0012

[z] Values in a vertical column followed by different letters are significantly

different at the specified *P*-values by Fisher's Protected LSD Test.

Experiment 3. Apical buds on shoots from OFF-crop trees produced significantly more floral shoots than vegetative shoots, with only a few exceptions (Table 3). The PBRs tested did not increase bud break of floral or vegetative apical buds relative to the untreated control. It is noteworthy that rinsing the shoots with distilled water for 15 min before supplying the shoots with only distilled water increased bud break of apical floral buds significantly more and earlier than all other treatments, just 1 week after the initiation of the experiment (data not shown). Shoots treated with 0.032% HDC had significantly less apical floral bud break. Apical bud break on shoots with fruit from ON-crop trees was low and the PBRs tested were without effect (Table 3).

Table 3. Effect of plant bioregulators on bud break of floral and vegetative apical buds on excised 'Hass' avocado shoots without fruit collected from OFF-crop trees and with fruit collected from ON-crop trees in early spring (March).

	Apical buds	
Treatments	Shoots without fruit	Shoots with fruit
	-no. of floral buds that broke per 10 shoots -	
5 mM GA_3	6 bcd[z]	0 a
2.5 mM GA_3	7 abc	1 a
0.125% HDC	5 bcde	0 a
0.063% HDC	6 bcd	1 a
0.032% HDC	4 cdef	1 a
0.3 mM BA	6 bcd	0 a
0.15 mM BA	8 ab	1 a
0.075 mM BA	6 bcd	0 a
Rinsed + dH_2O	10 a	1 a
dH_2O - control	8 ab	0 a
	- no. of vegetative buds that broke per 10 shoots -	
5 mM GA_3	0 g	0 a
2.5 mM GA_3	0 g	0 a
0.125% HDC	2 efg	0 a
0.063% HDC	1 fg	0 a
0.032% HDC	3 defg	1 a
0.3 mM BA	2 efg	0 a
0.15 mM BA	1 fg	0 a
0.075 mM BA	4 cdef	0 a
Rinsed + dH_2O	0 g	0 a
dH_2O - control	1 fg	2 a
P-value	<0.0001	0.5704

[z] Values in a vertical column followed by different letters are significantly different at the specified *P*-values by Fisher's Protected LSD Test.

Similar to apical buds on shoots excised from ON-crop trees, lateral bud break was low and the PBRs tested were without effect even when the apical bud had been removed (Table 4). For shoots excised from OFF-crop trees, lateral floral bud break was low but significantly increased by 0.15 mM BA for shoots with the apical bud removed. BA at 0.3 mM significantly increased lateral floral bud break 3 weeks after the initiation of the experiment (data not shown), but the treatment effect was not significantly greater than the control at the end of 3 months (Table 4). Lateral bud break of vegetative buds was not increased by any PBR treatment for excised shoots from OFF-crop trees with the apical bud present. Shoots with the apical bud removed treated with 0.075 BA had the greatest number

lateral vegetative buds undergo bud break. This number was significantly greater than lateral floral bud break for all treatments. Rinsing shoots excised from OFF-crop trees with distilled water for 15 min prior to supplying only distilled water was the second best treatment, but equal to the untreated control for shoots with the apical bud present.

Table 4. Effect of the presence or absence of the apical bud and plant bioregulators on bud break of floral and vegetative lateral buds on excised 'Hass' avocado shoots without fruit collected from OFF-crop trees and with fruit collected from ON-crop trees in early spring (March).

	Lateral buds	
Treatments	Shoots without fruit	Shoots with fruit
Apical bud present		
	--- No. of floral buds that broke per 10 shoots ---	
5 mM GA_3	0 f[z]	0 a
2.5 mM GA_3	0 f	0 a
0.125 % HDC	0 f	0 a
0.063 % HDC	0 f	0 a
0.032 % HDC	0 f	0 a
0.3 mM BA	5 cde	0 a
0.15 mM BA	0 f	0 a
0.075 mM BA	0 f	0 a
Rinse + dH_2O	1 ef	0 a
dH_2O only	1 ef	0 a
	------ No. of vegetative buds per 10 shoots ------	
5 mM GA_3	0 f	0 a
2.5 mM GA_3	0 f	0 a
0.125 % HDC	2 ef	0 a
0.063 % HDC	0 f	0 a
0.032 % HDC	0 f	0 a
0.3 mM BA	0 f	0 a
0.15 mM BA	1 ef	0 a
0.075 mM BA	2 ef	0 a
Rinse + dH_2O	4 cdef	0 a
dH_2O only	8 bc	0 a
Apical bud removed		
	------ No. of floral buds per 10 shoots ------	
5 mM GA_3	0 f	0 a
2.5 mM GA_3	0 f	0 a
0.125 % HDC	0 f	0 a
0.063 % HDC	0 f	0 a
0.032 % HDC	0 f	0 a
0.3 mM BA	3 def	0 a
0.15 mM BA	7 bcd	0 a
0.075 mM BA	1 ef	0 a

Rinse + dH_2O	0 f	0 a
dH_2O only	0 f	0 a
	------ No. of vegetative buds per 10 shoots ------	
5 mM GA_3	0 f	0 a
2.5 mM GA_3	0 f	0 a
0.125 % HDC	0 f	0 a
0.063 % HDC	0 f	0 a
0.032 % HDC	0 f	0 a
0.3 mM BA	0 f	0 a
0.15 mM BA	1 ef	0 a
0.075 mM BA	15 a	0 a
Rinse + dH_2O	10 b	0 a
dH_2O only	5 cde	1 a
P-value	<0.0001	0.4746

[z] Values in a vertical column followed by different letters are significantly different at the specified *P*-values by Fisher's Protected LSD Test.

Whole trees. Experiment 4. Floral apical buds on untreated control shoots on OFF- and ON-crop trees had equal bud break (Table 5). BA (25 or 50 mg/L) significantly increased bud break for shoots on OFF-crop trees but not for shoots on ON-crop trees. Similarly, vegetative apical buds on untreated control shoots on OFF- and ON-crop trees had equal bud break (Table 5), but in this case, all PBR treatments reduced bud break of apical vegetative buds for shoots on OFF-crop trees and had no effect on bud break of apical vegetative buds for shoots on ON-crop trees. There were no significant effects due to foliar applied PBRs on lateral bud break (floral or vegetative) for spring or summer/fall shoots on OFF-crop trees or on spring shoots on ON-crop trees (summer/fall shoots did not develop on ON-crop trees). Thus, there were no significant differences in lateral bud break (floral or vegetative) related to alternate bearing, although lateral buds on spring shoots on OFF-crop trees had numerically more floral bud break than shoots on ON-crop trees (Table 5). Even though no significant differences were obtained, BA (25 and 50 mg/L) had a positive effect on lateral floral bud break on spring shoots, given the average number of buds (nodes) per shoot was 2.4. Also, GA_3 (25 mg/L) had an interesting effect on lateral vegetative bud break for summer/fall shoots, for which the average number of buds (nodes) was 5.1 (Table 5).

Table 5. Effect of plant bioregulators applied to the foliage of 'Hass' avocado shoots without fruit on OFF-crop trees and shoots with fruit on ON-crop trees in late winter (February) on bud break of floral and vegetative apical and lateral buds.

	Apical buds		Lateral buds			
			Spring shoots		Summer/fall shoots	
Treatments	Floral	Vegetative	Floral	Vegetative	Floral	Vegetative
	---------- no. of buds that broke per 10 shoots ----------					
Shoots without fruit						
25 mg/L BA	8 a[z]	1 cd	6 a	0 a	0 a	2 a
50 mg/L BA	7 a	1 cd	5 a	0 a	0 a	3 a
100 mg/L BA	5 ab	2 bcd	3 a	2 a	1 a	3 a
25 mg/L GA_3	5 ab	1 cd	3 a	0 a	0 a	8 a
50 mg/L GA_3	5 ab	0 d	2 a	1 a	1 a	0 a
100 mg/L GA_3	5 ab	1 cd	0 a	0 a	1 a	0 a
10 mg/L HDC	3 bc	1 cd	0 a	0 a	4 a	3 a

20 mg/L HDC	5 ab	1 cd	2 a	0 a	0 a	3 a
dH_2O	3 bc	4 abc	0 a	0 a	5 a	4 a
Shoots with fruit						
25 mg/L BA	3 bc	5 ab	0 a	2 a	-[y]	-
50 mg/L BA	1 c	5 ab	0 a	0 a	-	-
100 mg/L BA	1 c	6 a	0 a	0 a	-	-
25 mg/L GA_3	3 bc	2 bcd	0 a	1 a	-	-
50 mg/L GA_3	0 c	5 ab	0 a	0 a	-	-
100 mg/L GA_3	1 c	4 abc	1 a	0 a	-	-
10 mg/L HDC	1 c	2 bcd	0 a	0 a	-	-
20 mg/L HDC	0 c	2 bcd	0 a	1 a	-	-
dH_2O	3 bc	4 abc	0 a	1 a	-	-
P-value	0.0002	0.0194	0.6708	0.5581	0.4227	0.7004

[z] Values in a vertical column followed by different letters are significantly different at the specified *P*-values by Fisher's Protected LSD Test. [y] Shoots with fruit on ON-crop trees did not have summer/fall shoots.

Experiment 5. Lateral floral bud break was low overall (Table 6). Bud break of lateral floral buds was observed only on shoots on OFF-crop trees when apical buds were removed on February 20 for summer/fall shoots and March 20 for spring shoots. Lateral vegetative buds on spring shoots had equal bud break and a similar response to the time of apical bud removal independent of the presence or absence of fruit on the shoot and OFF- or ON-crop status of the trees. In both cases, removal of the apical bud before the end of March significantly increased bud break of lateral vegetative buds compared to the untreated control for each shoot type. Removal of the apical bud through April 20 significantly increased bud break of lateral vegetative buds on summer/fall shoots on OFF-crop trees. Shoots with fruit on ON-crop trees did not produce summer/fall shoots. The data revealed a high proportion of buds on all shoots that did not undergo bud break well past peak bloom (Final data were collected in June).

Table 6. Effect of removing the apical bud from 'Hass' avocado shoots without fruit on OFF-crop trees and shoots with fruit on ON-crop trees monthly from February through May on bud break of floral and vegetative lateral buds through June.

	Spring shoots			Summer/fall shoots		
Treatments	Floral	Vegetative	Nodes	Floral	Vegetative	Nodes
	---------- *No. of lateral buds per 30 shoots* ----------					
Shoots without fruit						
February 20	0 a[z]	16 bcd	85 bc	4 a	36 a	90 b
March 20	5 a	21 ab	98 b	0 b	36 a	83 b
April 20	0 a	8 cde	74 c	0 b	29 a	126 a
May 20	0 a	0 e	68 c	0 b	0 b	126 a
Control	0 a	0 e	73 c	0 b	0 b	109 ab
Shoots with fruit						
February 20	0 a	20 abc	152 a	-[y]	-	-
March 20	0 a	29 a	133 a	-	-	-
April 20	0 a	6 de	135 a	-	-	-
May 20	0 a	0 e	147 a	-	-	-
Control	0 a	0 e	147 a	-	-	-
P-value	0.1491	<0.0001	<0.0001	0.0269	<0.0001	0.0239

[z] Values in a vertical column followed by different letters are significantly different at the specified *P*-values by Fisher's Protected LSD Test. [y] Shoots with fruit on ON-crop trees did not have summer/fall shoots.

Discussion

Excised shoot experiments. Developing floral shoots on excised shoots proved very delicate. They desiccated easily, abscised early and were more sensitive to PBR treatments, exhibiting damage at lower concentrations than developing vegetative shoots, which remained alive for months. Floral apical bud break was greater on shoots collected with swollen apical buds than those collected with closed apical buds, but bud break of vegetative apical buds on shoots collected with closed buds was significantly increased with 6-benzyladenine, consistent with the capacity of this PBR to overcome dormancy. 6-Benzyladenine also increased bud break of both floral and vegetative lateral buds on shoots collected with swollen buds, suggesting a benefit to applying PBRs when the bud is active or more developmentally advanced. Moreover, BA treatments, but not other PBR treatments, produced early results, and thus, accelerated the process of bud break.

Apical buds on shoots without fruit excised from OFF-crop trees produced more floral than vegetative shoots. These shoots also produce more total floral and vegetative shoots than apical buds on shoots with fruit excised from ON-crop trees. PBR treatments did not significantly increase bud break. 6-Benzyladenine significantly increased bud break of floral and vegetative lateral buds on shoots from OFF-crop trees *only* when the apical bud was removed, consistent with reports of apical dominance in 'Hass' avocado (Thorp and Sedgley 1993). GA_3 (5 and 10 mM) and all concentrations of hydrogen cyanamide tested caused symptoms of toxicity in excised shoots and failed to stimulate bud break.

Whole tree experiments. 6-Benzyladenine (25 and 50 mg/L) increased apical floral bud break on shoots without fruit on OFF-crop trees compared to the untreated control OFF-crop trees. Removal of the apical bud in late February through late May, demonstrated that lateral bud break of vegetative buds on spring shoots without and with fruit on OFF- and ON-crop trees, respectively, was significantly increased only when the apical bud was removed on February 20 or March 20, but not later. Removing the apical bud from February 20 to April 20 increased lateral bud break of vegetative buds on summer/fall shoots without fruit on OFF-crop trees. Lateral floral shoots were observed only when the apical bud was removed in February and March on shoots on OFF-crop trees. Salazar-García et al. (1999) previously demonstrated that growth of the apical floral shoot inhibited the growth of the lateral floral (and vegetative) buds. The lack of effect from GA_3 in stimulating bud break was interesting since these same concentrations stimulated bud break of floral buds when applied earlier (November, December and January) (Salazar-García and Lovatt 1998). This result taken together with the lack of response to progressively later apical bud removal suggests that floral and vegetative buds become more inhibited or less viable from February through bloom.

Conclusions

Additional research is required to increase the efficacy of PBR treatments to dramatically increase floral bud break. Use of excised shoots for *in vitro* analysis of the capacity of different concentrations of PBRs to increase bud break did not sufficiently correspond to results obtained with whole trees in the commercial orchard to warrant pursuing this approach further. However, taken together, results obtained with the excised shoots *in vitro* and shoots of whole trees *in vivo* were consistent that apical dominance inhibits bud break of lateral floral and vegetative buds, and that 6-benzyladenine, a cytokinin, was the best PBR of those tested for overcoming the inhibition of bud break, being more effective at the concentrations tested when the apical bud was removed. Thus, excised shoots cultured *in vivo* might be an excellent controlled system for studying apical dominance in the 'Hass' avocado. The results also demonstrated that the floral bud number on shoots with fruit on ON-crop trees is lower or more strongly inhibited than on shoots without fruit on OFF-crop trees. Future research will focus on testing more powerful cytokinins and include earlier application times.

Literature

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