Article

Cold compensators in apple tree 'Golden Glory': development and production

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Abstract

The apple tree (*Malus domestica* Borkh) is a temperate zone fruit tree that requires the application of sprouting promoters. The objective of this research was to study the efficiency of cold compensators: Erger, potassium nitrate, Thidiazuron (Revent), BroStart, Tecno Oil 100 EW and hydrogen peroxide, in the Golden Glory/MM 111 variety, the trees were planted in 2009, at 4 m between streets and 2 m between trees, (1 250 trees per ha), a factorial arrangement 56 bounded to 25 treatments with different concentrations was used using a Taguchi L25 structure generated by the Minitab 16.1.0.0 statistical package, in so much so that the statistical analysis was by means of response surface, weighing the effect of the factors to select those with the best effect in the production and development set. The variables evaluated were vegetative growth, node density, sprouting of one and two-year-old branches and production. The results obtained indicate that the treatments with Revent, potassium nitrate and Tecno Oil 100 EW oil had a positive effect on the variables of vegetative growth and production, the latter favored the increase with 90.7%. In knot density, Erger presented the best effect and in sprouting branches a year was BroStart in synergy with Revent and Erger. Finally, it is concluded that the compensators evaluated proved to be an alternative in dormancy breaking apple 'Golden Glory'.

Keywords: BroStart, Erger, hydrogen peroxide, potassium nitrate, Tecno Oil 100 EW, yield.

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Introduction

Apple tree (*Malus domstica* Borkh) is grown all over the world. Mexico is among the first twenty apple-producing countries, with a total production of 659 thousand 451 tons and a value of 7 779 million pesos, in a harvested area of 60 thousand 328 hectares, contributing Chihuahua 86.4% of the national volume for 2018 (SIAP-SIACON-NG, 2019). The apple tree is a fruit-bearing deciduous temperate climate, which requires a certain amount of winter cold to overcome its lethargy, a physiological condition that occurs annually to survive cold winters (Petri and Leite, 2010; Seif El-Yazal *et al*., 2012).

However, it is difficult to determine the precise amount of cold that is required to get out of lethargy (Carvajal-Millan *et al*., 2000). This deficiency of cold affects a late sprouting in terminal buds, a poor and irregular flowering, large number of buds without sprouting, low fruit tie, low production and poor quality, as well as an increased risk of fire blight (Quintana, 2006). A management strategy to reduce problems of insufficient cooling is the application of cold compensators.

Among the compensators mentioned in the literature and that have been applied are: mineral oils, dormex (hydrogenated cyanamide), aminoburts, semitrol, break trhu, Tecno Oil 100EW, calcium nitrate, revent, potassium nitrate, promalin, biozyme, thidiazuron (TDZ) and erger. Mineral oil was the first sprouting promoter used commercially; it is a winter insecticide oil, with low unsulfonated residue and high level of unsaturated compounds. Applied in combination with the Dinitro Orto Cresol (DNOC) on the buds produces an anaerobic effect; since a low level of oxygen causes budding, probably due to the accumulation of anaerobic compounds such as ethanol and acetaldehyde (Quintana, 2006).

According to Mohamed *et al*. (2018) mineral oil (DNOC), is the most useful rest treatment for apples, which has been used effectively to complement the cold temperature, and achieve a satisfactory breaking of the bud, improving the crop, because they can spread within the plant. It is worth mentioning that the applications of this product at the end of the 70’s of the last century are not used in Mexico. However, they are returning to retake. Nañez (2013) mentions that Tecno Oil 100 EW is an emulsifying oil that remains in the plant long enough, a product that is demanded in Chihuahua's apple producers’ areas.

Thidiazuron has cytokinetic activity capable of stimulating sprouting, because it acts as a precursor in the formation of cytokinins exerting a direct effect on the site of action of growth promoting hormones (Talamini *et al*., 2002). Cyanamide tends to be very toxic to humans, suggesting using promoters with the same efficiency, but with less risk of toxicity. Another product such as Dinitro Orto Sec Butil Phenol (DNOSBP) ceased to be used in the 80’s and was replaced by Erger, Syncro and Vorax mixed with calcium nitrate or mineral oil, which showed effects on axillary and terminal sprouting in apple trees (Petri *et al*., 2014).

Erger works on the physiology of the buds providing nutrients to the dormant tissues, producing a change in the balance of promoters/growth inhibitors, develops a signal of initiation of metabolic activity that leads to bud sprouting (Hawerroth *et al*., 2010). Despite the large number of effective substances to induce sprouting, few are accepted due to the toxicity they generate in plants and the environment, as well as a high cost. Therefore, the identification of new more effective compounds to break the latency and that adequately replace toxic products such as cyanamide that is listed as the most potent chemical compound in sprouting. Being relevant today, without losing efficiency and safety for man and plants.

Taking into account the above, the objective of this work was to evaluate the effect of alternatives of cold compensators: Erger, potassium nitrate (KNO_3), Revent, BroStart, Tecno Oil 100 EW and hydrogen peroxide, in the apple tree variety Golden Glory on development and production.

Materials and methods

The research work was carried out during the crop development cycle in 2015, in the 'La Semilla' orchard of the Faculty of Agrotechnological Sciences of the Autonomous University of Chihuahua, in 'Golden Glory'/MM111 trees planted in 2009 to a distance of 4∗2 m (1 250 trees per hectare). The soil properties at the experimental site under study correspond to a pH of 6.28, electrical conductivity of 0.14 dS m^{-1}, organic matter 0.94%, CIC 7.39 cmol kg^{-1}, organic nitrogen 10.7 mg kg^{-1}, P 34.9 mg kg^{-1}, K 268.2 mg kg^{-1}, Ca 1362.6 mg kg^{-1}, Mg 246.8 mg kg^{-1}, S 10.9 mg kg^{-1}, Fe 17.2 mg kg^{-1}, Mn 25.8 mg kg^{-1}, Zn 0.4 mg kg^{-1}, Cu 0.4 mg kg^{-1}, Bo 1 mg kg^{-1}.

A factorial arrangement 5^6 limited to 25 treatments generated by the statistical package Minitab 16.1.0.0 was used, 5 repetitions were used per treatment, so the number of trees used was 125 experimental units (each experimental unit consisted of a tree). The application date was March 7, 2015, the cold and concentration compensators used are shown in Table 1.

Table 1. Factors and levels used as cold compensators.

	Factors					
	Erger	Potassium nitrate	Thidiazuron (Revent)	BroStart	Tecno Oil 100 EW	Hydrogen peroxide
Levels (%)	0	0	0	0	0	0
	0.4	1	0.025	0.75	0.5	1
	0.8	2	0.05	1.5	1	2
	1.2	3	0.075	2.25	1.5	3
	2.4	6	0.15	4.5	3	6
Simple $mean^{W}$	1.2	3	0.075	2.25	1.5	3

Erger, nitrogen 15%, calcium 4.7% density 1.14 g cc pH 5.9; potassium nitrate, 13% nitrogen, 45% K_2O; Thidiazuron, N-Phenyl-N'-1,2,3 thiadazol-5-il-urea 42.4%; Brostart, 8% nitrogen, 11% calcium, carboxy® 0.50% acids; Tecno Oil 100 EW imported emulsified oil, pesticide and cold compensator, non-sulphonable residues pH 6-8, hydrogen peroxide 50% H_2O_2. ^{W}= the maximum or minimum response surface is obtained from the simple average.

The treatment framework of the Taguchi L25 factorial experiment was five repetitions, where the experimental unit was a tree with 125 experimental units in total, the treatments are shown in Table 2 and were applied on March 7, 2015.

Table 2. Distribution of treatments factorial experiment Taguchi L25.

Treatment	Cold compensators (%)					
	Erger	Potassium nitrate	Thidiazurón (Revent)	BroStart	Tecno Oil 100 EW	Hydrogen peroxide
1	0	0	0	0	0	0
2	0	1	0.025	0.75	0.5	1
3	0	2	0.05	1.5	1	2
4	0	3	0.075	2.25	1.5	3
5	0	6	0.15	4.5	3	6
6	0.4	0	0.025	1.5	1.5	6
7	0.4	1	0.05	2.25	3	0
8	0.4	2	0.075	4.5	0	1
9	0.4	3	0.15	0	0.5	2
10	0.4	6	0	0.75	1	3
11	0.8	0	0.05	4.5	0.5	3
12	0.8	1	0.075	0	1	6
13	0.8	2	0.15	0.75	1.5	0
14	0.8	3	0	1.5	3	1
15	0.8	6	0.025	2.25	0	2
16	1.2	0	0.075	0.75	3	2
17	1.2	1	0.15	1.5	0	3
18	1.2	2	0	2.25	0.5	6
19	1.2	3	0.025	4.5	1	0
20	1.2	6	0.05	0	1.5	1
21	2.4	0	0.15	2.25	1	1
22	2.4	1	0.00	4.5	1.5	2
23	2.4	2	0.025	0	3	3
24	2.4	3	0.05	0.75	0	6
25	2.4	6	0.075	1.5	0.5	0

The cold units (UF) calculated according to the method of Richardson *et al*. (1974) accumulated in the Namiquipa Alto 'El Terrero' weather station (location of La Semilla orchard) for 2015 was 922, the average of accumulated cold units for this region was 772 with a standard deviation of 143 UF, the maximum accumulation during the period 2002-2018 was 1036 UF for the year 2010, while the year with the lowest accumulation of UF was 549 in 2006, in 2015 the year of study 922 UF accumulated, it was the third year with greater cold accumulation Network of Meteorological Stations of UNIFRUT (2019).

The variety 'Golden Glory' was introduced in the Northwest of the State of Chihuahua in the mid-1990s of the last century as an alternative to the main cultivar 'Golden Delicious', since this variety is highly susceptible to the rosette of the fruit (scabs in different forms, intensity and location in the epidermis) which substantially decreases its sale price but is destined for industrial use at a minimum price; nevertheless, 'Golden Glory' is of high cold requirement, around 1 300 to 1 400 units cold, 30% to 40% more than 'Golden Delicious', hence the need to use cold compensators to achieve a more sprouting early, uniform and dense to ensure commercially profitable production.

Vegetative material

'Golden Glory' trees grafted on MM 111 pattern were used, with an age of 7 years at the beginning of the investigation; 125 trees with healthy appearance and uniform vigor were selected from the central rows of the plantation frame. The management of the garden was carried out with a medium technological level, with micro sprinkler irrigation.

Variables evaluated

From each experimental unit, five tertiary branches were randomly selected, at least three years of age in which the terminal vegetative growths and number of nodes (where the leaves originate) were measured by growth that together will constitute branching (bracing) and will provide mostly foliar coverage, when the nodes mature and natural defoliation occurs (beginning of endodormance) they will become buds.

These buds the following year (one-year-old shoots) if they sprout they will be transformed into vegetative spurs, simple toasts and crowned toasts that in addition to contributing to the foliar cover (and therefore elaboration of photosynthes) constitute to a lesser extent the current production (crowned toasts) and future production (vegetative spurs and simple toasts that will be transformed respectively into fruiting spurs and crowned towers, respectively) as long as winter cold requirements are met.

Vegetative growth

Of the five random branches by means of a fluxometer, the length of the current vegetative growth of each branch, expressed in cm, was measured.

Density of vegetative growth nodes

The number of knots was measured by current growth and with this the node density (growth length between the number of knots) was obtained and expressed as the number of knots per centimeter of length.

Sprouting in branches of one year

From the selected branches, immediately below the current growth and up to the growth scar of the previous year, the total number of buds were counted, how many of them sprouted (emit clusters of spur leaves) and lateral growths (future simple toasts and crowned toasts) and how many remained dormant (without sprouting), with this the percentage of sprouting in branches of one year of age was obtained, when there is not enough cold only the terminal bud (apical and two or three lateral buds) usually sprout forming only weak vegetative growth and with very closed angles, which in turn will hinder the formation of fruitful buds, a normal sprouting in branches of one year of age is considered to be around 70% or greater.

Sprouting in two-year shoots

In the same way as in the one-year-old shoots, the number of buds was counted from the terminal scar of the one-year-old growth to the base of the two-year growth, the number of sprouted and non-sprouted buds were counted and with them the percentage of sprouting in branches of two years of age was calculated, it is considered that this should be greater than 50%. When the cold requirements are not satisfied, then one to three buds will sprout, which causes long shoots with low foliation and fruiting with rather vertical growths and closed angles that will hinder the induction and floral differentiation giving an appearance of irregular tufts.

Production

In production, each tree was fully harvested, and the corresponding weight was obtained, this weight was extrapolated to the number of trees per hectare and the production in tons per hectare was this.

Statistical analysis

For the statistical analysis, given the Taguchi L25 factor structure, a complete quadratic response surface analysis was performed, adjusting the surface to determine the levels of the factors for optimal response (SAS, 2015). This technique is used when each factor is studied for three or more levels, a quadratic response surface is estimated by regression with the method of least squares (Vargas *et al*., 1991).

The analysis of all the response variables is finally summarized in Table 4, which specifies the factors and the simple mean for each of them (average between the minimum and the maximum concentration used for each factor, it is precisely from this value that the maximum or minimum response surface is obtained according to the variable), the resulting eigenvalues expressed as percentages of the mean, positive or negative are taken as the case may be, then the eigenvectors are expressed with rounded signs from 0.25 or higher, such that 0.2501 ≤ + ≤ 0.3749, 0.3750 ≤ + +≤ 0.6249, 0.6250 ≤ +++ ≤ 0.8749 ++++> 0.875, the same would be the case for negative eigenvectors.

In this way, we consider which factors are the ones that are most influencing that variable; then the frequency of signs for each eigenvalue was obtained and the total for the eigenvalues present, this total was multiplied by 20%, then selecting those factors whose frequency is greater than 20% of the observed signs either indistinctly positive or negative, then the total positive and negative signs, generally the eigenvectors with positive signs are considerably greater than those negative, those factors and response variables of greater weight will be selected, whose frequency of signs (coefficients of eigenvectors) is greater than 20%, in this way those factors and variables of greater weight were obtained in a general way; of the selected factors and variables the maximum observed dose was obtained, obtained from the simple average of the factor levels.

A subsequent discussion will consist of the graphical response surface for those factors of greater weight and interactions between them and in this way it was calculated if the factors are independent or present synergism or antagonism and with this the most critical factor or factors were obtained for the response variables considered.

Results and discussion

Apple trees require a high percentage of vegetative sprouting, to develop a balanced structure and start their productive stage in less time. Table 3 shows the maximum response surface for the vegetative growth variable in which a growth range of 8.7 to 50.5 cm is observed with an increase of 478%, with the combination of potassium nitrate, Revent and Tecno Oil 100EW , with an increase of 33.3%, 10.7% and 90.7% respectively. To obtain the highest plant growth response by 50.5%, it is required to reduce the amount of Erger BroStart and H_2O_2 by 1.03 1.83 from 5%, respectively. This synergy favors the vegetative growth on the apple tree 'Golden Glory'.

Table 3. Maximum^{U} response surface for current vegetative growth in 'Golden Glory' apple trees treated with sprouting stimulators 2015.

Regression		Factors					
		Erger	Potassium nitrate	Revent	BroStart	Tecno Oil 100 EW	Hydrogen peroxide
		0.0638^{V}	0.0578	0.1230	0.062	0.0395	0.7584
Linear (L)^{X}	<0.0001^{V}	C^{X}		L	L	L	
Quadratic (C)	0.0041		Tecno Oil^{Y}	Brostart			
Products	0.0996						
Model	<0.0001						
			μ= 26.8	R^2= 0.4983		CV= 20.98	
cm	Error est.				(%)		
8.7	11.686	1.2	3	0.075	2.25	1.5	3
10.7	11.101	1.16	3.07	0.073	2.18	1.62	2.99
13	10.462	1.12	3.16	0.073	2.12	1.76	2.98
15.8	9.784	1.1	3.26	0.074	2.08	1.89	2.97
19.2	9.147	1.08	3.37	0.075	2.04	2.03	2.95
23	8.69	1.06	3.47	0.075	2	2.17	2.94
27.4	8.603	1.05	3.58	0.077	1.97	2.3	2.92
32.4	9.072	1.05	3.68	0.078	1.93	2.45	2.9
37.8	10.197	1.04	3.79	0.08	1.9	2.58	2.89
43.9	11.959	1.03	3.89	0.081	1.87	2.72	2.87
50.5	14.277	1.03	4	0.083	1.83	2.86	2.85
Increments (+) decrements (-)with respect to the simple mean							
+478.2		-14.2	+33.3	+10.7	-18.7	+90.7	-5
Canonical response surface analysis							
Predicted at stationary point		Decoded critical values					
7.2708		1.5252	2.9059	0.0771	0.9205	0.9024	0.6129

Regression	Factors					
	Erger	Potassium nitrate	Revent	BroStart	Tecno Oil 100 EW	Hydrogen peroxide
	0.0638[V]	0.0578	0.1230	0.062	0.0395	0.7584
Eigenvalores	Eigenvectores					
27.952	0.0339	0.3461	0.2128	-0.1423	0.9001	-0.0578
19.2201	0.649	0.4517	-0.5113	0.3162	-0.0343	-0.1098
-7.2831	0.042	-0.5525	0.0519	0.6951	0.2857	-0.3543
-18.3785	-0.0213	0.4682	0.6801	0.4882	-0.2552	0.119

[U]= mountain range analysis (Ridge); μ= general mean; CV= coefficient of variation; R^2= coefficient of determination. [V]= probability of F = Pr≥ 0.05 not significant, significant 0.05≤ Pr≤ 0.01, highly significant Pr≤ 0.01; [X]= response (Pr> │t│) significant linear (L), quadratic (C); [Y]= significant products of that factor with the rest; [W]= decoded values; [Z]= those eigenvalues whose cumulative variability was greater than 70% are selected.

Table 4 shows an analysis of all the response variables, where the factors and the simple mean for each of them are specified. It is shown that the factors that had the greatest impact on the vegetative growth variable were potassium nitrate, Brostart and Tecno Oil 100 EW, in the density of nodes influenced Erger, Revent and BroStart; in sprouting of branches of one year the ones of greater impact were potassium nitrate, Revent and Tecno Oil 100 EW, for sprouting in branches of two years the ones of greater influence were Erger, potassium nitrate Revent, Tecn Oil 100 EW and in production Tecno Oil 100 EW was the one with the greatest impact. However, the cold compensators that most influenced according to the frequency presented were potassium nitrate, Revent and Tecno Oil 100 EW.

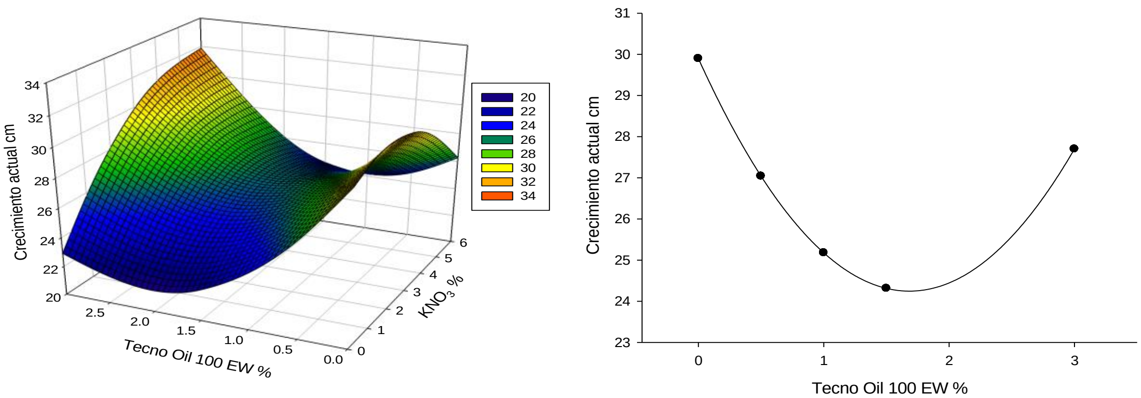
Table 4. Components of apple 'Golden Glory' development treated with dormancy breakers 2015 vegetative cycle.

	(%)						Eigenvectors	
	Erger 1.2[T]	KNO_3 3	Revent 0.075	BroStart 2.25	Tecno Oil 1.5	H_2O_2 3		
	Current vegetative growth[V] μ= 26.8 (8.7-50.5 cm)						Total	Prop. +/-
+104.3[U]		+[W]			++++		5	5/0
+71.7	+++	++	--	+			8	6/2
-27.2		--		+++	-	-	7	3/4
-68.6		++	+++	++	-		8	7/1
Frequency	3	7	5	6	6	1	28[Y]	
Dose	1.03	4	0.083	1.83	2.86	2.85		
	Knot density μ= 2.2 (2.4-1.2 knots cm^{-1})							
+47.2	++		+		+++		6	6 / 0
+16.6			--	+++			5	3 / 2
-38.5	--	++	++	+			7	5 / 2
Frequency	4	2	5	4	3	0	18	
Dose	1.2	3	0.075	2.25	1.5	3		

	(%)						Eigenvectors	
	Erger 1.2[T]	KNO_3 3	Revent 0.075	BroStart 2.25	Tecno Oil 1.5	H_2O_2 3		
	Sprouting in branches of one-year μ= 86.3 (44.9-100%)							
+51.2		+++	++	+	+	+	8	8/0
-47.1	+	++	--	+		+	7	5/2
-74.5			++		++++		6	6/0
Frequency	1	5	6	2	5	2	21	
Dose	1.07	2.9	0.083	2.16	2.21	2.93		
	Sprouting in branches of two years μ= 71.3 (15.2-100%)							
134.2		+++	+			++	6	6/0
-93.3	+	--	++			++	7	5/2
-107.8	+++						3	3/0
-170.5			++		++++		6	6/0
Frequency	4	5	5	0	4	4	22	
Dose	1.09	2.71	0.087	2.32	2.18	2.92		
	Production μ= 48 (26.8-91.2 t ha^{-1})							
+47.4	++		++		+++		7	7/0
+42.3	++	++	-			-	6	4/2
+28.6	-			--	+++	++	8	5/3
-45.7		+++	++	+		++	8	8/0
Frequency	5	5	5	3	6	5	29	
Dose	1.19	2.22	0.1	2.84	2.73	3.57		
	Abstract						Total	
Subtotal	17	24	26	15	24	12	118	118
Selection	5/2	5/3	5/3	5/2	5/4	5/1	Proportion +/-	
Prop. +/-	14/3	20/4	19/7	13/2	22/2	10/2	98[Z] / 20	
Maximum		4	0.087		2.86			

[T]= means simple levels factors; [U]= eigenvalues expressed as a percentage of the average; [V]= range in parentheses corresponds to the predicted values, from the simple mean, μ= general mean of the variable; [W]= each sign corresponds to multiples of 0.25 rounded to the nearest room; [Y]= frequency observed for that variable, those factors ≥ 20% (bold) are selected; [Z]= total frequency for the set of variables, those factors ≥20% are selected. Type of response, L= linear; C= quadratic and interaction of factors according to their symbology; Response for factors *= significant (0.05 ≤ probability ≤ 0.01); **= highly significant (probability <0.01).

Figure 1a shows the current growth variable showing the interaction of potassium nitrate with Tecno Oil 100 EW, which showed an increase of 33.3%. In relation to the quadratic response Figure 1B, although the vegetative growth decreased as the concentration of Tecno Oil 100 EW increased, the range observed from 30 to 24.5 cm from which an inflection was observed that retakes the unreached growth of heading, can be considered appropriate to promote a reasonable formation of knots (usually 20 to 30 cm) from which the leaves that contribute to the vigor of the plant and maintenance (development of photosynthes) of the current crop emerge; formation of buds for the following year which in turn will result in the third cycle in vegetative and fruitful spurs.



a) b)

Figure 1. Influence of the response curves that show the interactions for the current growth variable; a) interaction of Tecno Oil 100 EW and KNO3, and b) quadratic response of Tecno Oil 100 EW in current growth.

That is, an optimal vegetative growth, ensures the preponderance of the productive cycle as long as the use of dormancy breakers is continued, otherwise, it could result in vegetative growth greater than those observed here that increases the apical dominance in impairment of sprouting of buds in shoots of the second and third year. According to what Medina-García *et al*. (2011) that if cold compensators were not applied, sprouting would be delayed and crop phenology would be affected.

Some authors have conducted studies with cold compensators such as Pineda (2005), who used Tecno Oil 90 oil in apple trees, and obtained 26.2% in sprouting, being one of the most important treatments applied. The use of oils has resurfaced in the interest of horticulture, in the latent period especially in apple trees. The oils when applied on the buds produce an anaerobic effect; a low level of oxygen causes buds to sprout, probably due to the accumulation of anaerobic compounds such as ethanol and acetaldehyde (Quintana, 2006).

Likewise, Maldonado (1997), reports that Thidiazuron (Revent) has a good behavior of vegetative sprouting in apple trees, due to the similar effect of the cytokinin plant hormone, since it stimulates cell division and activates metabolic pathways for the production of Energy. Comparing to what was obtained in this study, Revent (Thidiazuron) had a positive effect, since the oil accentuated the effect of Thidiazuron (Quintana, 2006).

Sprouting of buds of one year

In Figure 2a, the interaction between Tecno Oil 100 EW and Revent is observed with a one-year increase in budding of 92%, presenting a synergistic effect with different mode of action, on the permeability of the bud scales. Also, in Figure 2b Tecno oil 100 EW presents a quadratic response where the maximum point was 90% with a 3% application of Tecno oil. These data agree with Campoy *et al*. (2010) who mention that the application with thidiazuron and winter oil managed to flourish significantly earlier and more uniformly.

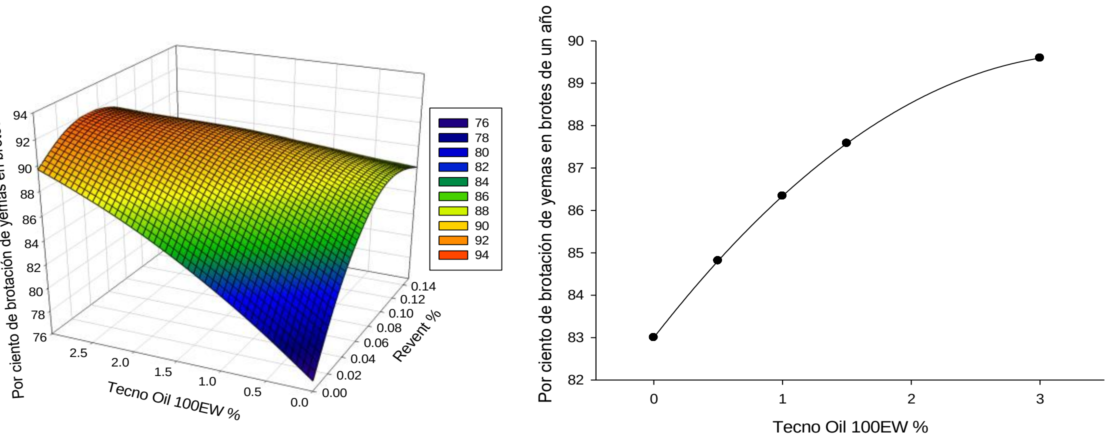


Figure 2. Influence of the response curves that show the interactions for the bud budding variable of one year; a) interaction of Tecno oil 100 EW and Revent; and b) quadratic response of Tecno Oil 100 EW in one-year sprouting.

Promoting sprouting will only have the expected result if the application is performed when the cell membranes are in a state receptive to the presence of exogenous hormones; this occurs once the permeability of the membranes and the communication between the bud and the underlying tissues has been established, that is, during the last stage of the endodorming phase and during the ecodoring period (Llamas *et al*., 2002). After having received 1 281 cold hours, we can deduce that the buds were in a sensitive state to the application of sprouting promoters and in a period of time sufficient for a uniform and compact sprouting, which began 20 days after applications.

Sprouting of two-year-old buds

The results obtained for sprouting buds of two years are observed in Figure 3a with an interaction between Tecno Oil 100 EW and potassium nitrate, which presented a greater increase in this variable of 80%. In the same way, in Figure 3b Tecno Oil 100 EW presents a quadratic response with a maximum point of 77% and a 3% application of Tecno Oil 100 EW. In an article published by INTAGRI (2017), they mention that potassium nitrate acts on sprouting with a lighter effect, which can be combined with mineral oil in a concentration of 5%.

On the other hand Nutrecology (2003), mentions that Erger works on the physiology of the buds providing nutrients to the dormant tissues, which produces a change in the balance promoters/growth inhibitors, to develop a signal of initiation of metabolic activity that leads to the sprouting of buds. It has been investigated that the application of KNO_3 can partially replace the cooling requirement, increasing the number of flowers and inflorescences because it increases the amount of solutes inside the tree cells triggering cell expansion through the change of osmotic potential causing the tree flourishes causing the required hormonal imbalance (Khayat *et al*., 2010).

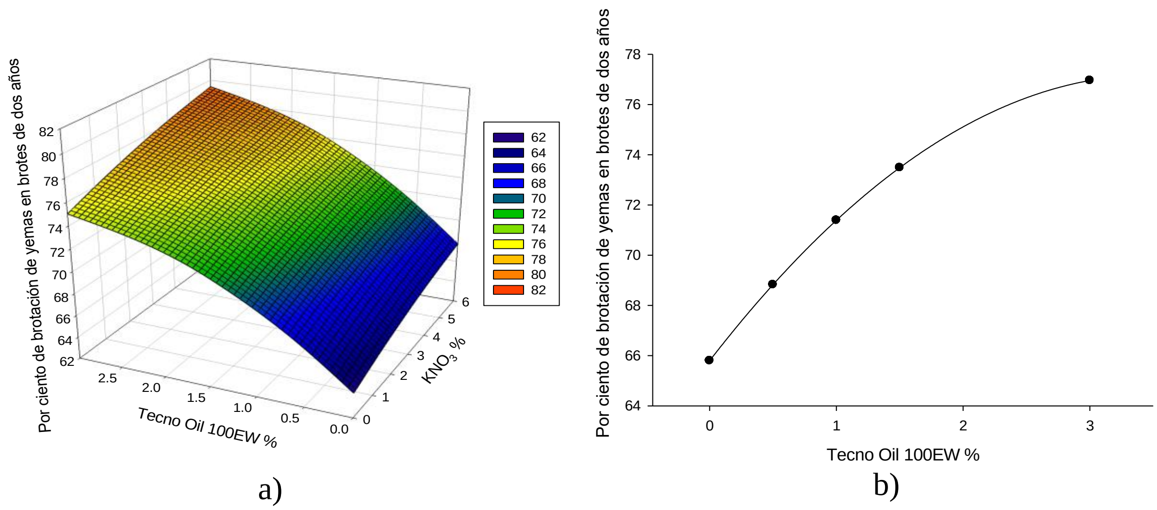


Figure 3. Influence of the response curves that show the interactions for the bud budding variable of two years; a) interaction of Tecno Oil 100 EW and KNO3; and b) quadratic response of Tecno Oil 100 EW in sprouting buds of two years.

Production

In relation to the results obtained in Production, Figure 4a shows the quadratic response where an optimum is achieved with the range explored for Revent with the highest production (49.5 t ha^{-1}) when using 800 milliliters per 1 000 L water, point where an inflection was recorded from which the yield decreased; it is worth mentioning that when the dose exceeded the inflection point, a type of rosette of the leaves was observed without these being able to extend completely, likewise, the flower petals did not open completely (precisely the appearance of rose flowers) and in harvest the fruit presented a larger than normal opening in the calyx area with an atypical appearance for this variety.

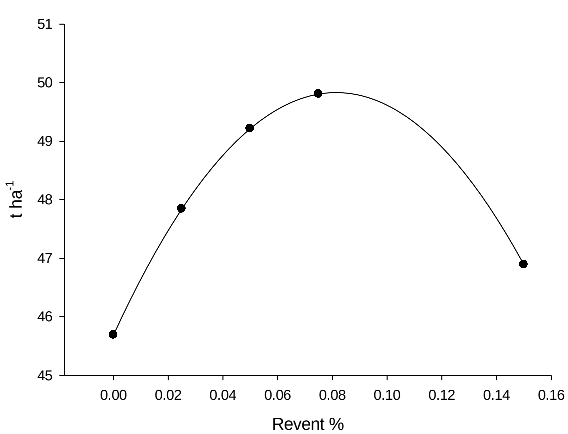


Figure 4. a) quadratic response of Tecno Oil 100 EW in the production variable.

Petri *et al*. (2014), tested Erger, Syncron and Vorax mixed with calcium nitrate and mineral oil and obtained an effective effect with a higher yield, unlike the control, indicating that with the increase in productivity the fruit had an average weight of 11%, emphasizing the association with mineral oil. In the same way Seif El-Yazal *et al*. (2011) used 6% mineral oil and 8% potassium nitrate obtaining a higher yield to the control, in this study 4% potassium nitrate and Tecno oil 100 EW 3.86% was used, said author mentions that the effect of the oil It generates the opening of the button due to its stimulating effect on natural gibberellins.

It is important to mention that the use of cold compensators must be accompanied by a series of cultural practices in order to stimulate the sprouting of fruit trees and even their relationship with climate change (Ramírez *et al*., 2011).

Conclusions

The cold compensators Revent concentration 0.087%, KNO_3 with 4% and Tecno Oil 100 EW Oil with 2.86% application, had a positive effect on the variables of vegetative growth and production, being Tecno Oil 100 EW who favored the increase with 90.7%. In the variables of sprouting nodes of one year and two years, the interactions of potassium nitrate and Tecno Oil100 EW had the greatest impact, contributing to the increase of these parameters. In addition, according to the frequency presented, potassium nitrate, Revent and Tecno Oil 100 EW were the most influential. So in this study the application of cold compensators, showed to be an alternative of cold compensators in apple tree 'Golden Glory'.

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