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Perspectives and Use of Biostimulants in Fruit Growing

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Abstract: The climatic and edaphic conditions of Southern Brazil where temperate fruits are produced affect the productivity and physiological aspects of the main species and cultivars. Physiological aspects such as vegetative growth, fruiting and physiological disturbances can be affected by environmental conditions. In Southern Brazil, one of the limiting factors to the development of temperate fruit trees is the insufficient chilling requirement for the main species and cultivars. Additionally, during the growing season, abiotic stresses are also frequent, affecting both productivity and quality of the fruits. Recently, substances called biostimulants has been gaining ground in fruit growing aiming the control of stress and, consequently, the increase of productivity and quality of fruits.

Key words: temperate fruit growing, physiological effects, abiotic stress

1. Introduction

The increasing demand for food quantity and quality associated with the concern about the preservation of the environment and the need for low levels of agrochemical residues in plants require a constant search for new products and new technologies to explore all the productive potential of the plants in an ecologically correct way.

Large field yields are lost due to several factors such as concentration of the harvesting within a certain period, low storage capacity and poor postharvest handling. Decreased quality may occur even before fruits reaching consumers. In addition, the excessive supply of a particular fruit within a certain period causes the price reduction of the fruit resulting in lower price paid to the producer.

New cultivars presenting different maturation cycles, resistance to diseases and insects, higher contents of vitamins and proteins and, of course, higher yields, have been developed. However, many of these new materials require new technologies such as irrigation, fertilization, pruning, training system and also the use of biostimulants so that they can express the full production potential.

The use of biostimulants in fruit growing, especially those based on amino acids, is recent in Brazil. The use of biostimulants has only become possible through studies to understand the physiological aspects of plants. Thereby, it is possible to stimulate and reduce plant growth, induce or inhibit flowering, control the water balance of plants by inducing the stomatal opening or closure, induce bud break, alter the sex expression of some plants and avoid stress.

High yield and quality of fruits associated with environmental preservation are the keys to achieve success in modern fruit growing, and the use of biostimulants will be crucial for the growth of this economic activity.

2. Bioestimulantes

Biostimulants act on plant physiology in different ways and by different routes to improve productivity and quality. They have several origins and leave no residues, being among the oldest products used in agriculture. Although its use in fruit growing is more

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recent (started in the late 90s), the increase has been occurring exponentially.

Biostimulants are described by several authors as non-nutritional products which can increase yield and resistance to stresses caused by temperature, water deficit and others. They act as activators of the plant cell metabolism, give vigor to the immune system, reactivate physiological processes at different developmental stages, stimulate root growth, induce the formation of new shoots and improve the quality and quantity of fruits, among others.

Biostimulants generally contain amino acids, humic substances (humic and fulvic acids), plant growth hormones, vitamins and various other elements, and may also contain organic substances from algae extract. They are rich in organic substances, phytonutrients, carbohydrates, amino acids and nutrients that act primarily as plant biostimulants. We must pay attention to two important points: high levels of carbohydrates and high levels of other substances such as amino acids, natural hormones (auxins, cytokinins and gibberellins) and alginates.

Deciduous tree species store N in the form of reserve proteins in perennial tissues such as bark and wood of aerial parts, as well as in roots. The main mechanism responsible for this storage is the redistribution of N, which begins with the leaf senescence during the fall. In this process, leaf proteins are hydrolyzed, and the resulting amino acids are transported in the phloem sap to storage tissues where they are converted into reserve proteins. Although some studies have described in detail the dynamics of this process, it is evident that in some species such as apple [1], pear [2], peach [3] and cherry [4] trees, the remobilization of N occurs before the absorption of N by the roots begin. In contrast, during the winter period, the inverse process occurs: the hydrolysis of these nitrogen reserves (remobilization), producing free amino acids, which are translocated via xylem sap and used to supply growth demands of new shoots and inflorescences in early spring.

Many studies have already observed peaks of concentration of free amino acids in the xylem sap in the phase that precedes the bud break. This is attributed to the intense remobilization of N from storage tissues in order to sustain the processes of initial growth of shoots and the flowering of the plants. The increase in the free amino acids concentration coupled to the bud break process that results from the remobilization of N stored is dependent on the occurrence of low winter temperatures during the endodormancy phase of the plants. This process induces the activity of endopeptidases enzymes, which act in the degradation of reserve proteins, producing amino acids that can then be transported in the sap xylem to growth points.

Once the bud break after dormancy often occurs prior to N uptake, since soil temperature is still low, the plant needs to remobilize the N stored in the form of proteins during the fall. In this way, the initial bud growth becomes almost completely dependent on the stored N reserves, since the root system only becomes active after the growth of new shoots. Although few studies have described in detail the dynamics of this process, it is evident that in some species such as apple tree, the N remobilization occurs before the beginning of the N uptake by the roots. In woody species of temperate climate, the xylem pathway is considered essential for the translocation of ions, nucleotides and small metabolites such as soluble sugars and organic nitrogen compounds. Biostimulants may play an important role in this process, as they enable better performance and establishment of plants, especially under unfavorable conditions, promote rapid rooting and vigorous growing and potentiate resistance to environmental stress conditions (excess temperature and/or water deficit, quite common at planting and plant development). They also improve the use of fertilizer and soil nutrients, increase the photosynthetic rate and the available energy (carbohydrates) and provide higher resistance to cold stresses, insects and diseases. In this way, biostimulants can play an important role in improving yield and quality of temperate fruit trees.

Biostimulants have been associated with agroecological fruit growing, but they can play a very important role in the conventional fruit growing as a complement to the nutrition and protection against abiotic factors. They can solve some of the most important challenges in fruit growing, such as increasing yield and quality, extreme temperatures, water deficit and other climate-related stresses, requiring control to optimize yields. Higher quality can benefit fruit growers and provide a safe food for consumers.

In Brazil, there are still few studies on biostimulants for temperate fruit trees, and the most advanced studies refer to the bud break in conditions with insufficient chilling requirements, mainly for apple and plum trees cultivation. The results show increases in the bud break and flowering, standardization of fruit maturation and increase in the fruit production (Tables 1, 2, 3 and 4). They have also been used for flowering anticipation and fruit maturation.

Table 1 Effect of bud break promoters on beginning, full and end of flowering of "Maxi Gala" and "Fuji Suprema" apple trees.

Treatment	2014/2015			2015/2016		
	Beginning	Full	End	Beginning	Full	End
	Maxi Gala					
1. Control	12/10	24/10	28/10	08/10	28/10	05/11
2. MO 3.5% + Dormex® 0.7%	28/09	03/10	12/10	21/09	25/09	28/09
3. Erger® 3.0% + $Ca(NO_3)_2$ 3%	28/09	03/10	10/10	22/09	26/09	06/10
4. MO 3.5% + Erger® 1.0%	30/09	03/10	12/10	25/09	30/09	10/10
5. MO 3.5 + Erger® 1.0% + $Ca(NO_3)_2$ 3.0%	01/10	04/10	10/10	23/09	28/90	08/10
6. MO 2.0% + Erger® 1.0%	01/10	08/10	15/10	25/09	30/09	10/10
7. MO 2.0% + Erger® 1.0% + $Ca(NO_3)_2$ 3.0%	28/09	05/10	14/10	23/09	28/09	08/10
8. Dormex® 0.7% + Erger® 1.0% + $Ca(NO_3)_2$ 3.0%	29/09	04/10	14/10	22/09	27/09	30/09
	Fuji Suprema					
1. Control	12/10	21/10	28/10	23/09	30/09	10/10
2. MO 3.5% + Dormex® 0.7%	30/09	03/10	10/10	16/09	24/09	28/09
3. Erger® 3.0% + $Ca(NO_3)_2$ 3%	29/09	03/10	10/10	19/09	26/09	29/09
4. MO 3.5% + Erger® 1.0%	30/09	03/10	08/10	16/09	26/09	29/09
5. MO 3.5 + Erger® 1.0% + $Ca(NO_3)_2$ 3.0%	28/09	01/10	08/10	16/09	26/09	29/09
6. MO 2.0% + Erger® 1.0%	29/09	06/10	12/10	16/09	26/09	29/09
7. MO 2.0% + Erger® 1.0% + $Ca(NO_3)_2$ 3.0%	27/09	02/10	10/10	16/09	26/09	30/09
8. Dormex® 0.7% + Erger® 1.0% + $Ca(NO_3)_2$ 3.0%	30/09	06/10	12/10	19/09	25/09	29/09

MO: Mineral Oil.

Table 2 Effect of bud break promoters on axillary bud break (%), terminal bud break (%) and fruit set (%) of "Maxi Gala" apple trees.

Treatment	Axillary bud break (%)		Terminal bud break (%)		Fruit set (%)	
	2012	2013	2012	2013	2012	2013
1. Control	10.1 c	1.8 b	78.4 c	18.3 d	104.3 a	150.0 a
2. $Ca(NO_3)_2$ 3.0%	10.1 c	3.5 b	90.1 b	42.0 c	81.4 a	130.0 a
3. Mineral Oil 3.5% + Dormex® 0.7%	59.7 b	24.5 a	97.0 a	86.9 a	16.8 b	14.9 b
4. Erger® 1% + $Ca(NO_3)_2$ 3%	43.2 b	15.8 a	95.5 a	65.1 b	49.8 b	68.2 a
5. Erger® 2% + $Ca(NO_3)_2$ 3%	77.1 a	11.7 b	99.5 a	83.0 a	45.3 b	26.0 b
6. Erger® 3% + $Ca(NO_3)_2$ 3%	65.4 b	26.1 a	97.3 a	84.0 a	30.8 b	15.4 b
7. Erger® 4% + $Ca(NO_3)_2$ 3%	87.6 a	33.8 a	100.0 a	93.7 a	44.3 b	8.2 b
8. Erger® 5% + $Ca(NO_3)_2$ 3%	75.2 a	29.9 a	99.3 a	94.6 a	38.4 b	6.8 b
CV (%)	20.0	56.0	9.0	16.9	43.2	122.5

Means followed by same letter do not differ by Scott-Knott test at 5% probability. CV: Coefficient of variation.

Table 3 Effect of bud break promoters on axillary bud break (%) of "Fuji Suprema" apple trees.

Treatment	Axillary bud break (%)		
	2013/2014	2014/2015	2015/2016
1. Control	12.6 b	5.2 d	4.4 c
2. Mineral Oil 3,5% + Dormex® 0,7%	60.2 a	51.9 a	50.1 a
3. Bluprins® 3% + $Ca(NO_3)_2$ 3%	43.0 a	7.5 d	5.7 c
4. Bluprins® 5% + $Ca(NO_3)_2$ 3%	59.4 a	30.3 b	7.3 c
5. Bluprins® 3% + $Ca(NO_3)_2$ 5%	58.5 a	20.3 c	7.2 c
6. Bluprins® 5% + $Ca(NO_3)_2$ 5%	62.3 a	14.2 c	4.6 c
7. Bluprins® 3%+$Ca(NO_3)_2$ 3% +$NH_4(NO_3)$ 3%	73.8 a	20.0 c	11.0 b
8. Bluprins® 5%+$Ca(NO_3)_2$ 4% +$NH_4(NO_3)$ 4%	71.3 a	14.9 c	19.9 b
CV (%)	27.9	31.0	35.4

Means followed by same letter do not differ by Scott-Knott test at 5% probability. CV: Coefficient of variation.

Table 4 Fruit production per plant (FPP, kg) and average fruit weight (AFW, g) of "Maxi Gala" and "Fuji Suprema" apple trees under the influence of compounds for bud break.

Treatment	Maxi Gala		Fuji Suprema	
	FPP (kg)	AFW (g)	FPP (kg)	AFW (g)
1. Control	25.9 b	123.6 ns	9.0 b	145.1 ns
2. Mineral Oil 3,5% + Dormex® 0,7%	35.6 a	113.9	3.9 b	137.4
3. Bluprins® 3% + $Ca(NO_3)_2$ 3%	23.4 b	116.7	9.4 b	165.3
4. Bluprins® 5% + $Ca(NO_3)_2$ 3%	34.5 a	120.3	13.9 a	141.3
5. Bluprins® 3% + $Ca(NO_3)_2$ 5%	40.6 a	118.7	16.1 a	142.6
6. Bluprins® 5% + $Ca(NO_3)_2$ 5%	42.7 a	113.6	9.6 b	149.6
7. Bluprins® 3%+$Ca(NO_3)_2$ 3% +$NH_4(NO_3)$ 3%	14.2 b	125.9	19.9 a	140.6
8. Bluprins® 5%+$Ca(NO_3)_2$ 4% +$NH_4(NO_3)$ 4%	38.0 a	111.3	16.6 a	140.0
CV (%)	31.9	118.0	33.2	11.2

Means followed by same letter do not differ by Scott-Knott test at 5% probability. ns: not significant. CV: Coefficient of variation.

Table 5 Fruit production per plant (kg) of "Royal Gala" apple trees treated with AVG and Promalin® during flowering.

Treatment	Fruit production per plant (kg)				
	2008	2009	2010	2011	Accumulated
1. Control	19,92 ns	15,08 ns	7,28 b	14,76 ns	57,0 b
2. AVG 30 ppm	40,13	33,13	10,05 b	22,90	106,2 a
3. AVG 60 ppm	27,81	29,53	17,88 a	19,82	95,0 a
4. AVG 120 ppm	35,08	28,90	10,87 b	19,15	94,0 a
5. AVG 30 ppm + Promalin® 0,5mL/L	32,91	22,56	19,52 a	15,22	90,2 a
6. AVG 60 ppm + Promalin® 0,5mL/L	41,39	24,76	20,54 a	16,80	103,5 a
7. AVG 120 ppm + Promalin® 0,5mL/L	30,84	22,15	17,06 a	16,05	86,1 a
CV (%)	31,56	45,49	47,26	36,99	25,14

Means followed by same letter do not differ by Scott-Knott test at 5% probability. ns: not significant. CV: Coefficient of variation.

An important aspect for temperate fruit trees is the fruit set. Some species and cultivars require cross-pollination, and some studies have already shown a significant increase in the fruit set by applications of biostimulants during the apple tree flowering. For "Gala" apple trees, according to Tables 5 and 6, increases of 151% in the fruit set and 186% in the fruit yield were obtained.

Recent studies have demonstrated the effect of biofertilizers on the increase of the red coloration of apple fruits (Table 7). Although some studies have already shown the importance of biostimulants for the temperate fruit growing, some points still require studies, such as stress control of low and high temperatures, increase of fruit size, induction of disease resistance, control of physiological disturbances, increase of soluble solids contents in the fruits, abiotic stresses, among others.

Table 6 Fruit production per plant (FPP, kg), number of fruits per plant (NFP) and average fruit weight (AFW, g) of apple trees treated with Stimulate®.

Treatment	FPP (kg)	NFP	AFW (g)
1. Control	34,34 b	292,33 b	118,60 bc
2. Stimulate® 0,1%	33,98 b	262,60 b	130,90 a
3. Stimulate® 0,2%	54,55 a	469,67 a	116,83 c
4. Stimulate® 0,4%	40,39 b	337,83 b	121,98 abc
5. Stimulate® 0,8%	35,42 b	281,67 b	126,82 ab

Means followed by same letter do not differ by Tukey test at 5% probability.

Table 7 Percentage of "Monalisa" and "Venice" apples with red color distribution in the skin above 80%, between 50 and 80% and below 50%.

Treatment	Monalisa			Venice		
	Red color distribution in the skin (%)					
	> 80%	50-80%	< 50%	> 80%	50-80%	< 50%
1. Control	47,3 b	32.9 a	19.8 a	31,1 c	51.6 a	17.4 a
2. Potasium-S King® (4 L ha^{-1})	37,1 b	40.0 a	22.9 a	48,5 b	42.6 a	8.9 b
3. Mover® (3 L ha^{-1}) + Hold® (2 L ha^{-1})	35,7 b	34.2 a	30.1 a	40,7 b	45.7 a	13.6 a
4. Sunred® (4 L ha^{-1})	39,7 b	38.2 a	22.1 a	29,2 c	53.1 a	17.7 a
5. KCl (20 kg ha^{-1})	33,5 b	38.3 a	28.1 a	36,6 c	49.9 a	13.5 a
6. Etefon (480 g ha^{-1})	69,0 a	20.6 b	10.4 b	67,8 a	27.3 b	4.9 b
CV (%)	16,7	17,4	22,5	10,7	13,2	33,7

Means followed by same letter do not differ by Scott-Knott test at 5% probability. CV: Coefficient of variation.

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