Effect of Plant Biostimulants on Fruit Set, Yield, and Quality Attributes of "*Farbaly*" Apricot Cultivar

A. Tarantino, F. Lops, G. Disciglio, E. Tarantino

***Abstract*—**Apulia region (southern Italy) is excellent for heavy production of apricot (*Prunus armeniaca* L.). Fruit quality is a combination of physical, chemical and nutritional characteristics. The present experiment was laid in the commercial orchard in Cerignola (Foggia district, Apulia region, 41°15'49''N; 15°53'59''E; 126 a.s.l.) during the 2014-2015 season. The experiment consisted of the use of three biostimulant treatments (Hendophyt®, Ergostim® and Radicon®) compared with untreated control on 'Farbaly' apricot cultivar, in order to evaluate the vegeto-productive and fruit qualitative attributes. Foliar spray of biostimulants was applied at different times during the growth season (at red ball, fruit setting and fruit development stages). Experimental data showed some specific differences among the biostimulant treatments, which fruit set, growth and productivity were affected. Moderate influences were found regarding the qualitative attributes of fruits. The soluble solid content was positively affected by Hendophyt® treatment. Antioxidant capacity was significantly higher in Hendophyt® and Radicon® treatments respect to the untreated control.

Keywords*—Prunus Armeniaca* L., biostimulants, fruit set, fruit quality.

I. Introduction

THE apricot (*Prunus armeniaca* L.) is one of the most important fruit species in the world as the fruit highly appreciated by consumers. It was imported in Italy from Greece and from Armenia. Italy is the most important producer in Europe with 244,000 tons annually (24% of continental production), a number which has been slowly but constantly increasing. Apulia region (Southern Italy) is an excellent area for heavy production, estimated to be 10,922 tons in 2015 [1].

The apricot is considered to be among the most delectable and consumable of all fruit, which are in fresh and dry form, canned or preserved as cam, marmalade or pulp [2].

This species is particularly prone to erratic fruit set and flower bud drop as has been reported in different cultivars and growing conditions [3]. Furthermore, this species is also frequently exposed to various abiotic stress during the growth cycle that limit crop yield. Numerous pomological traits determine apricot fruit quality, that was defined by Kramer and Twiggy (1966) [4] as the conjunction of physical and chemical properties which give good appearance and acceptability to the consumable products. Fruit apricot dimensions, weight, size and shape are the most commonly measured pomological properties. These physical attributes impact market and are important in sorting, siring, packaging and transportation of fruit and designing relevant equipment [5]. Among the quality parameters that define the eating quality of apricot, the important traits such as texture and flavor influence final acceptance [6]. Apricot fruits can be considered as a good source of phytochemicals such as polyphenols, carotenoids and vitamins, which significantly contribute to their taste, colour and nutritional and functional values. Currently there is a considerable interest in these biologically active components because of their antioxidant properties and ability to alleviate chronic disease [7], [8]. In addition, the growing demand for healthy and nutritive foods in the world today has made nutrient analyses a major area in quality control studies. Therefore, fruit shape, colour intensity, aroma, sweetness, sourness, flesh firmness and juiciness and nutrition analysis are all basic sensory descriptors for apricots [9]. In recent years, the use of biostimulant compounds has encountered increasing in agriculture because they play roles in various soil and plant functions such as to improving crop resistance, controlling nutrient availability and improving quanti-qualitative crop yield [10], [11]. Plant biostimulants are organic products, consisting in different categories of substances: microbial inoculants, humic acids, fulvic acids, protein hydrolisates, aminoacids and seaweed extracts. Studied with annual plants and model species suggested that biostimulants could enhances growth, development and tolerance to abiotic stress [12], [13]. Availability of this information is relative limited for fruit crops probably due to the fact that the studies with fruit three have many disadvantages, such as the long juvenility, the large body size (require large, cultivation space), the abiotic and biotic stress conditions experiencing throughout the year. However, some studies have shown that soil or foliar application of humic acid leads to positive effect on growth, yield and fruit quality of peach and apple [14]. and "Canino" apricot cultivar [15], [16].

Other studies have shown that foliar application of seaweed extract leads to enhanced root development in grape [17], [18]. and strawberry [19]. Considering the very few researches carried on the use of biostimulants on apricot crop, this trial aims to study the effect of tree commercial plant biostimulants, applied in different time through the growing season, on fruit set, yield and quality of 'Farbaly' apricot cultivar.

II. Material and Methods

The field experimental trial was conducted during 2015 season in a commercial orchard located in the countryside of Cerignola (Foggia district, Apulian region, Southern Italy), on

Tarantino A., Lops F., Disciglio G., Tarantino E. are with the Department of Science of Agriculture, Food and Environment, University of Foggia, 71122 Foggia, Italy e-mail: emanuele.tarantino@unifg.it).

eight years old apricot trees of Farbaly® (Carmingo® group, publisher: IPS-France worldwide distributor Vivai F. Zanzi) cultivar. This cultivar, considered as one of the most successful new cultivar grown in Apulia conditions, is characterized by trees high vigor and by late blooming and repining time. The fruit ripens on July, it's medium large, orange with 30% red blush, sweet, tasty, firm flesh and semi-cling.

Apricot trees were planted 6 x 6 meter apart with rows North-South oriented, grown in a sandy-loam soil, under drip irrigation system and received the common cultural practices, including fruit thinning at the time of pit hardening, performed by hand from the growers to guarantee fruit of adequate caliber and uniformity.

Trees used in the experiment were selected to be healthy and as uniform as possible. The application of three commercial biostimulants: Hendophyt® PS (Iko-Hydro), Ergostim® XL (Isagro) and Radicon® (Fertek,) compared with untreated control were tested. In Table I, the description and the dose of the biostimulant products used in the trials are reported.

TABLE I
COMMERCIAL FORMULATIONS AND DOSE OF BIOSTIMULANTS USED IN THE TRIAL

BIOSTIMULANTS PRODUCTS
ERGOSTIM® XL (Isagro). A concentrated liquid soluble in water of N-acetiltiazolidin-4-carboxylic acid (AATC) at 2.5%, and of triazolidine-carboxylic acid (ATC) at 2%, applied at the dose of 200 ml 100 L^{-1} of water.
HENDOPHYT® PS (Iko-Hydro) Compound completely soluble powder, containing polysaccharide polymers (poliglucosammine), applied at dose of 1,5 Kg ha^{-1}.
RADICON® (Fertek) A suspension–solution containing humic and fulvic acids, obtained from compost of worm (night crawled). Total organic matter: 4%, humified organic substance = 90% of total organic matter; ratio C/N =4, applied at dose of 500 g 100 L^{-1} of water.

The biostimulants were applied by foliar spraying, three times during the growing season (at red ball, fruit setting and fruit development stages). The experiment was laid out in a randomized block design with three replicates per treatment. One buffer row were located between replicates and blocks and two or more buffer rows around the perimeter of the experimental field. Each replicate had 15 plants and tree centrally located plants per plot were used to collect vegetative and reproductive parameters.

During the experimental periodic, from October 2014 to July 2015, daily main climatic parameters (maximum, minimum and mean temperatures, total rainfall and total "Class A" Pan evaporation) were recorded at the nearest meteorological station, few kilometers from the experimental area and supplied by Consorzio per la Bonifica della Capitanata of Foggia.

Percentage of fruit set was estimated in each tree on four branches selected randomly from the four spatial directions of the three central plants of each plot. Flower buds on each branch were counted distinctly for the three types of shoot: mixed branches, darts and twigs. Approximately 50-80 flower buds were counted and recorded at the pre-blossom phase each of these selected branches. Thus, 200-300 flower buds were found on each tree. Percentage of flowers to flower buds was calculate. Percentage of initial and final fruit set were also determined respect to the number of total flowers.

The apricot fruits were harvested at the commercial maturity stage ('ready-to-eat' stage) for each treatment in three picking dates (on 13, 20 and 27 July 2015). Yield per tree (kg $tree^{-1}$) was determined by the sum of the weight of the fruit harvested, measured at each picking date. The fruits were sorted to remove overripe and bruised fruits. After sorting, samples of 25 fruits were randomly collected, placed into shallow wood crates and stored at 4 °C until the analysis that were done immediately on their arrival to the laboratory. For each picking date, 25 fruits, one by one, were weighed, measured in length, width and thickness, subjected to other physical analysis (firmness and color of the epicarp), than destoned to measure the stone weight.

A sample of thin slice of the pulp were used for the extraction of the juice of the replicate to determine soluble solid content (SSC), pH and titratable acidity (TA). The analysis on pulps and juices were performed in triplicate.

Fruit firmness was recorded by a Italy type penetrometer pressure tester and reading were recorded in kg cm^{-2}. The color of the epicarp (CIELab coordinates) was measured by Minolta Chroma Meter CR-400 Colorimeter (Minolta Corp., Osaka, Japan), both on the two opposite equatorial sides of each fruit. Color was represented by L* (lightness), a* (green-red) and b* (blue-yellow) scale [20]. The pH of apricot juice was measured with an inoLab Level 3 pH –meter. Juice soluble solids content (SSC) was determined as °Brix at 20 °C by using a digital refractometer DBR35 (*XS* Instruments, Carpi, Italy). A semi-automatic titrator was used for titratable acidity (TA) determination. In particular, 10 mL juice was diluted to 50 mL distilled water and titrated with 0.1 N NaOH to the phenolphthalein end point (pH 8.3). Titratable acidity was expressed as % of malic acid (A.O.A.C.) moreover SSC/TA ratio was calculated.

For the total phenols (TP) fruit extracts were obtained by homogenizing 15 g of apricots in a digital high-speed *homogenizer* system mod. Ultra-Turrax T18 Basic (IKA, Wilmington, NC, USA) for 1 min with 20 ml of extraction medium (2 mM Naf methanol: water solution (8:2, v/v); the homogenate was filtered and then centrifuged at 5 °C at 9,000 rpm for 5 min. Total phenols were determined according to the method of Singleton and Rossi (1965) [21]. The content of total phenols was expressed as milligrams of gallic acid per 100 grams of fresh weight (mg GA 100 g^{-1} fw). Antioxidant assay was performed following the procedure described by Brand-Williams *et al.* (1995) with minor modifications [22]. The diluted sample, 50 μL, was pipette into 0.950 mL of DPPH solution to initiate the reaction. The absorbance was read at 515 nm after overnight incubation. Trolox was used a standard and the antioxidant activity was reported in mg of Trolox equivalents per 100 g of fresh weight (mg TE 100 g^{-1} fw). The analysis was performed in triplicate.

Results were evaluated with one-way ANOVA using JMP® software (SAS Institute Inc., Cary, NC, USA) and average values were compared with Tukey test. Standard deviations were calculated using Excel software of the Office 2007® suite (Microsoft Corporation, Redmond, WA, USA).

III. Results and Discussion

A. Climate Conditions of the Experimental Site

The seasonal course of climatic conditions was quite ordinary one. The mean monthly climate parameters recorded during the experimental period, from October 2014 to July 2015, are reported in Table II.

TABLE II
MONTHLY MAXIMUM AND MINIMUM TEMPERATURE, TOTAL RAINFALL AND CLASS "A" PAN EVAPORATION DURING THE PERIOD OCTOBER 2014-JULY 2015 IN THE EXPERIMENTAL SITE

Monthly	Tmax	Tmin	Rainfall	Class "A" pan evaporation
	(°C)	(°C)	(mm)	(mm)
October 2014	24.5	12.0	62.8	50.2
November 2014	21.2	7.7	14.6	30.9
December 2014	15.0	4.5	24.2	18.5
January 2015	13.6	3.6	86.6	29.8
February 2015	13.2	3.2	45.0	28.5
March 2015	16.2	5.6	67.2	48.0
April 2015	21.8	7.4	23.6	91.6
May 2015	28.6	13.0	49.6	137.4
June 2015	31.3	15.5	60.1	154.3
July 2015	37.8	18.6	1.20	198.8
Mean	**22.32**	**9.11**		
Total			**434.9**	**788.1**

The mean minimum temperature decreased from 12.0 °C to 3.2 °C and increased from 3.6°C to 18.6 °C. The total Class "A pan" evaporation decreased from October (62.8 mm) to February (45.0 mm) and increased successively till July (198.8 mm). The monthly rainfall was unevenly distributed through the experimental period which values ranged from 1.2 to 86.6 mm.

The mean maximum temperature decreased from October (24.5 °C) to February (13.2 °C) and increased through the season till July (37.8 °C), whereas in the same periods the mean minimum temperature decreased from 12.0 °C to 3.2 °C and increased from 3.6°C to 18.6 °C. The total Class "A pan" evaporation decreased from October (62.8 mm) to February (45.0 mm) and increased successively till July (198.8 mm). The monthly rainfall was unevenly distributed through the experimental period which values ranged from 1.2 to 86.6 mm.

B. Fruit Set and Yield

Considering the results collectively of blossoming, initial and final fruit set percentages not statistically differences among mixed branches, dart and twig were noted (data not shown).

In Table III, data of effect of biostimulant treatments on the blossoming, initial and final fruit set percentage, and total yield per tree are reported. Blossom percentage showed the highest value for Radicon® (89.5%), significantly different from others biostimulant treatments and the control (values ranging from 71.2 to 77.1%, not different among them). As for the fruit set and yield per tree some differences among treatments were obtained. The highest initial fruit set percentage was obtained by using Ergostim® (53.6%), significantly different from Endophyt® (37.6%) and Radicon® (36%). The control shows, the significantly lowest value (26.8%). Also for the final fruit set the highest percentage was obtained in Ergostim® (15.0%), followed by Radicon® (14.5%); the last two treatments were significantly different from Endophyt® (11.9%) and the control (11.7%). Similar results were found in a previous research [16], using foliar biostimulant product containing humic acid (as for Radicon®), showing increased of retained fruit percentage per tree.

As for the yield, the picking fruits percentage were on average 48, 43 and 9% at first, second and three harvest respectively, which any differences among biostimulant treatments were noted (data not shown). The total marketable fruit yield per tree, reported in the same Table 3, conversely to the fruit set percentage, showed data no significant differences among all biostimulant treatments. However, the fruit yield per tree tended to be higher for Ergostim® treatment (79.8 kg $tree^{-1}$) results to other ones (values ranging from 58.8 to 69.8 kg $tree^{-1}$). The non-close correspondence between the percentage of fruit set and yield obtained in this study may be ascribed to high variability among yield per tree.

In Table IV, data of carpological parameters of fruit are reported. The fruit weight was on average significantly different among biostimulant treatments. The best results were obtained in Radicon® (84.92 g), which value was not different from the control (83.20 g) and Ergostim® (80.34 g). The significantly lowest value were obtained in Endophyt® (65, 48 g). Table IV shows considering the results collectively of blossoming, initial and final fruit set percentages not statistically differences among mixed branches, dart and twig were noted (data not shown). Stone weight, as expected, was pretty fixed to a certain value (5.01 g) and unaffected by biostimulants application. Considering the dimensional attributes of the fruit from slight the shape depends, that is great part of their attractiveness, length, width and thickness were lower in Hendophyt® (51.10 mm, 48.96 mm and 43.95 mm respectively), compared with others treatment and the control (Table IV).

Regarding the physical parameters of fruit (Table V), only slight or no significant differences among treatments were noted. The fruit firmness parameter shows no significant differences among all treatments, which values ranged from 3.69 to 5.00 kg. Regarding the color space coordinates, brightness as L* (bright to dark) was lower in Hendophyt® (61.94) respect to others treatments (values on average 65.47). The a* (green to red) was unaffected by treatments (values on average 4.50), and only slight differences were observed for b* (blue to yellow), which Hendophyt® (50.75) gave less yellowish than others biostimulant treatments and the control value (values on average 54.45).

In Table VI, where data of chemical parameters of fruit are reported, only slight and not significant difference were observed for pH, while Hendophyt® application determined a significantly positive effect on SSC (16.57 °Brix) in confront to all other treatments and the control (on average 13.08 Brix). Our range of SCC values are in agreement with previous papers on apricot [23], [24], which reported by the way that this parameter is a very important quality attribute, influencing notably the fruit taste. Some authors reported that apricot cultivars with SSC content higher than 12 °Brix were characterized by excellent gustative quality [25], [26].

As for titratrable acidity (TA), with malic acid predominant in apricot [27] no significantly differences among treatments were noted, which values ranged from 1.32 to 1.48% TA acid malic fw. To determine the eating quality of apricot fruits, the index SCC/TA ratio is also used, which lower values express strong apricot aroma [24], [28]. In Table VI, the SCC/TA ratios were tendentially higher in Hendophyt® (11.90) and in Ergostim® (10.25) than Radicon® (8.91) and the control (8.99), even though any significant differences among them were observed. The fruit maturity stage at the harvest date is the key factor affecting both fruit TA and SSC. The organic acids play an important role in fruit taste through sugar/acid ratio [29]. It may be concluded that the knowledge of the qualitative and quantitative compositions of acids and sugars in apricot fruit may prove to be a powerful tool in evaluating fruit maturity and quality [30]. Some authors reported that fruit with a SSC/TA ratio between 10 and 15 had well balanced eating quality, while fruits with lower ratio showed higher acidity values [31]. Finally, in Table VII total phenols content and antioxidant activity of fruit were reported. The phenolic content shows the highest values in the control, Radicon® and Hendophyt® treatments (108.77, 101.09 and 99.71 mg GA 100 g^{-1} fw respectively), which were not different among them, but significantly different from Ergostim® treatment (88.90 mg GA 100 g^{-1} fw). Antioxidant activity was significantly higher in Hendophyt® and Radicon® (251.99 and 247.40 mg TE 100 g^{-1} fw, respectively) respect to Ergostim® and the untreated control (173.27 and 180.15 mg TE 100 g^{-1} fw respectively).

VI. Conclusion

In this first year, finding of this study show that apricot initial and final fruits set of 'Farbaly' apricot cultivar were positively responded to foliar application of biostimulants as Ergostim® (containing of N-acetiltiazolidin-4-carboxylic and of N-acetiltiazolidine-carboxylic acids) and Radicon® (containing humic and fulvic acids).

TABLE III
Effects of Biostimulants on Blossoming Initial and Final Set of Fruits Ratios and Total Yield of 'Farbaly' Apricot Cultivar Trees

Treatment	Blossoming (%)	Inizial fruit set (%)	Final fruit set (%)	Yield (Kg $tree^{-1}$)
Control	77.1±6.8 b	26.8±4.4 c	11.7±2.6 b	68.43±5.1 a
Ergostim®	71.2±9.9 b	53.6±8.0 a	15.0±4.0 a	79.8±10.1 a
Hendophyt®	71.4±9.0 b	37.0±6.0 b	11.9±2.8 b	59.8±4.0 a
Radicon®	89.5±6.4 a	36.0±4.8 b	14.5±2.3 ab	69.8±7.2 a

*Average value ± std. dev. within a column followed by different lowercase letters are significantly at 5% Tukey test

TABLE IV
Effects of Biostimulants on carpological parameters of Fruits

Treatment	Fruit weight (g)	Stone weight (g)	Fruit length (mm)	Fruit width (mm)	Fruit thickness (mm)
Control	83.20±6.25 ab	5.04±0.33 a	57.76±2.15 a	53.73±1.62 a	47.96±1.02 ab
Ergostim®	80.34±10.69 ab	5.03±0.61 a	56.71±1.45 a	53.78±2.25 a	46.71±343 ab.
Hendophyt®	65.37±6.96 b	4.88±0.35 a	51.10±1.19 b	48.96±1.31 b	43.93±0.42 b
Radicon®	84.92±10.21 a	5.13±0.34 a	58.62±1.89	55.49±1.36 a	48.49±0.54 a

*Average value ± std. dev. within a column followed by different lowercase letters are significantly at 5% Tukey test)

TABLE V
Effects of Biostimulants on Physical parameters of Fruits

Treatment	Firmness (kg)	L*	a*	b*
Control	4.14±0.48 a	65.13±1.63 a	4.49±0.85 b	53.81±2.04 ab
Ergostim®	3.69±0.88 a	65.71±0.66 a	4.38±1.27 b	54.60±1.33 a
Hendophyt®	3.97±0.95 a	61.94±0.42 b	5.52±1.39 b	50.75±2.59 ab
Radicon®	5.00±0.84 a	65.12±0.56 a	3.62±2.26 b	54.94±2.13 a

*Average value ± std. dev. within a column followed by different lowercase letters are significantly at 5% Tukey test)

TABLE VI
Effects of Biostimulants on Chemical parameters of Fruit

Treatment	pH	SSC (°Brix)	TA (% malic ac.)	SCC/TA
Control	3.37±0.09 ab	12.67±0.21 c	1.42±0.15 a	8.99±0.79 b
Ergostim®	3.39±0.88 ab	13.53±0.55 b	1.32±0.05 a	10.25±0.79 a
Hendophyt®	3.32±0.13 ab	16.57±0.40 b	1.44±0.31 a	11.90±2.58 a
Radicon®	3.23±0.22 b	13.03±1.66 b	1.48±2.26 a	8.91±1.71 b

*Average value ± std. dev. within a column followed by different lowercase letters are significantly at 5% Tukey test.

TABLE VII
EFFECTS OF BIOSTIMULANTS ON CHEMICAL PARAMETERS OF FRUIT

Treatment	Phenolic content (mg GA/100 g fw)	Antioxidant capacity (mg TE/100 g fw)
Control	108.77±9.36 a	180.15±11.98 b
Ergostim®	88.90±2.98 b	173.27±14.85 b
Hendophyt®	99.71±2.86 ab	251.99±23.21 a
Radicon®	101.09±1.90 a	247.40±4.86 a

*Average value ± std. dev. within a column followed by different lowercase letters are significantly at 5% Tukey test.

Meanwhile biostimulants application did not give appreciable effects on many physical and chemical properties of the fruit, unless of Hendophyt® biostimulant treatment that gave increase of soluble solids content indicating better fruit quality. At the same time, beneficial effects of both in Hendophyt® and Radicon® biostimulant treatments, on nutritional properties as total phenol content and antioxidant activity were observed. However, as for biostimulant treatments the results of this study were not clearly high hit on apricot trees and fruit. Therefore, more investigation should be carried out on the use of biostimulant substances to clarify their effects. We are continuing this trial and deeply investigating biostimulant effects on various grown seasons.

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