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Physiological Effects of Iprodione Fungicide on the Yield and Some Chemical Constituents of Strawberry

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Abstract: The present investigation was undertaken in field experiment during the two successive growing seasons of 2016/2017 and 2017/2018 to study the effect of foliar spraying with iprodione fungicide (Rovral® 50%WP) at recommended dose (1RD), recommended & half dose (1½ RD) and double dose (2RD) on "Festival" strawberry plants during the bloom and fruit stage with the beginning of fruit rots infection (3% severity) to control disease. The twice applications with RD decreased the severity % into (0.60 and 0.79) while 1½ RD decreased severity % into (0.28 and 0.33) without any significant differences between them at the first season. The same trend in decreasing fruit rots severity % was recorded during the second season as (0.71 and 0.81) for 1RD and (0.43 and 0.48) for 1½ RD. The maximum control of fruit rots infection was recorded with the double dose. The physiological adverse effects of iprodione in strawberry plants were investigated. Leaves and fruits were collected at initial time (2 hours after application) and at 21-days after application (21-DAA). The obtained results revealed that there were insignificant differences in all growth parameters recorded at the initial time. Usage of the 1RD or 1½ RD of iprodione did not detect any significant reduction in recorded traits of vegetative growth characteristics but enhanced the marketable fruit yield despite of the relatively increase in flowers abscission. The highest rate of iprodione treatment had a negative effect on leaf area, leaf dry mass and flowers abscission %. Chlorophylls a & b and carotenoids concentrations decreased gradually in the leaves with increasing the rate of iprodione, on the other hand, there were significant increase in total soluble phenols and anthocyanin concentrations with the three doses of iprodione at the initial time, while a relative decrease occurred at 21- DAA when 2RD was used. It was not expected that ascorbic acid and titratable acidity of fruits increased with the 1RD and 1½ RD treatments then reduced significantly with the 2RD of iprodione compared to control. In contrast, total soluble solids and total sugars concentration decreased in response of iprodione applications. Finally, using of the recommended rate of iprodione decreased the loss of marketable strawberry yield and maximized the cost / benefit.

Key words: Strawberry ((*Fragaria×ananassa*) · Iprodione fungicide · Growth · Yield · Fruits biochemical constituents

INTRODUCTION

Strawberry (*Fragaria × ananassa* Duch.) is a species of berry fruits that has a great nutritional values and health benefits [1]. Strawberry is low in calories with highly desirable sources of vitamins, simple sugars, L-ascorbic acid and fibers [2]. High levels of ascorbic acid and anthocyanins in fruits as antioxidants play important role against environmental stresses [3]. The chemical composition of strawberry can be modified according to the changeable in weather conditions, cultivation, agricultural practices and control plant diseases [4]. In Egypt, the cultivation of strawberry as a vegetable crop is widely spread with area of 5, 416.67 hectares and total production about 44.44 ton/ha [5]. The growth and development of strawberry plants occurred as a series of

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linear growth flushes with formations of new crowns, roots, leaves and inflorescences [6]. Menzel and Smith [7] reported that both leaf area and dry mass partitioning affected the productivity of "Festival" strawberry plants.

Strawberry fruit rot diseases are great problem for producers in the world and are particularly severe in Egypt where fruit rot is often activated by warm temperature during the harvest. *Colletotrichum* spp., *Botrytis cinerea*, *Phytophthora cactorum* and *Gnomonia comari* are the main fungal pathogens that infect strawberry causing fruit rots [8-10]. So far, chemical plant protection methods are often used in strawberry production. Chemical control with effective fungicides has played the main role in protection and curative plant against these pathogens but their use should not exceed permissible limits as recommended, otherwise led to harmful effects on human health [8].

Iprodione is a synthetic dicarboximide contact fungicide that prevents germination and inhibits mycelium growth of various fungal spores on different crops. Iprodione used as foliar fungicide or seed protector to control a wide range of root and stem rots, mildews and can also be used as a post-harvest fungicide on vegetable and fruit crops including peaches, grapes, strawberries, potatoes, lettuce, onions, rice and peanuts [11]. Eating appropriate amounts of vegetables prevent many chronic diseases but increase the pesticide exposure that may be of health concern [11].

All types of fungicides control a wide range of fungi infections at relatively low rates of application. It has been reported that applications of fungicides may strike the plant physiology by several distributions appeared as growth reduction, delay the reproductive organs development and alter the ratios of nitrogen and carbon metabolism resulting in a lower availability of nutrient for growth and development [12]. The adversity of the stress motivated by fungicides applications and the adversity of plant response subsequently have an impact on plant growth if the plants overcome this stress [13]. As stress increased due to high rates of pesticides, several photosynthetic processes may be destroyed, causing a decrease in the net photosynthesis equivalent to CO_2 assimilation [12]. Stomatal closure considered as the first physiological response resulting in limited CO_2 availability in mesophyll and decreased net photosynthesis [14]. They added that there is a strong evidence that pesticide application may limited the activity of ribulose 1, 5- bisphosphate carboxylase/oxygenase (Rubisco), essential enzyme for CO_2 fixation and accelerates the carboxylation process of ribulose 1, 5- bisphosphate. The excessive of fungicides has a strong phytotoxic effect for crop resulted in reducing their commercial value and consumer acceptance [15]. The time elapsed between fruit harvest and storing in fridges is also an important factor, as delayed refrigeration causes the loss of nutritional value in strawberry [16]. The sensitive stages to the treatments of fungicides in plant species are represented in the young and reproduction stages according to the type of used pesticide [12].

The present study aimed to study the effect of twice foliar spraying with iprodione at (1RD), (1½ RD) and (2RD) on strawberry plants during the bloom and fruit stage with the beginning of fruit rots infection (3% severity) to control disease and determine the exogenous spraying effect on vegetative growth characters, yield and biochemical constituents of strawberry leaves and fruits.

MATRIALS AND METHODS

Fresh strawberry transplants (*Fragaria×ananassa cv.* Festival) were obtained from Arid Land Agriculture Research Institute, Faculty of Agriculture, Ain Shams University. Transplants were planted on 15th and 19th of September 2016/2017 and 2017/2018 successive winter seasons, respectively, in the open field of farm located in El-Nobaria district, Abo-Elmatamer, El-Behaira Governorate, Egypt to investigate the effect of foliar spraying with three different doses of iprodione on strawberry plants during the bloom and fruit stage, when the fruit rots severity reached to 3%, to control disease and also, on growth, yield, some biochemical components and fruit quality of Festival strawberry plants.

Pesticides Selected for this Study: Iprodione (Rovral® 50%WP), (N- (3, 5- dichlorophenyl) -3- isopropyl-2, 4- dioxoimidazolidine -1- carboxamidis) was obtained from Agrimatco company. Iprodione used extensively in Egypt for controlling target key fungus attacking strawberry crop and Egyptian cultivations. Rates of iprodione application were chosen on the basis of recommended dose (90 g 100 l^{-1}water), recommended & half dose (135 g 100 l^{-1}water) and double dose (180 g 100 l^{-1}water) on strawberry.

Treatments and Experimental Design: The field experimental area with sandy loam soil (Table 1) was divided into 12 main plots (four treatments with three

Table 1: Mechanical and chemical analyses of the experimental soil

%							Soluble anions (meq $^{-1}$)			Soluble cations (meq $^{-1}$)			
Coarse sand	Fine sand	Silt	Clay	Soil texture	EC dS m^{-1}	pH	HCO_3^-	SO_4^{--}	Cl^-	K^+	Na^+	Ca^{++}	Mg^{++}
15.45	39.65	26.30	18.60	Sandy loam	0.86	6.86	2.72	2.95	2.73	1.53	2.85	2.21	2.01

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replicates); each plot covered 42 m^2 with 12 adjacent rows of 6 m in length. The distance between each row was 50 cm. Transplants were cultivated in each row with 30 cm between plants. Fertilization was applied with standard recommendations of the Egyptian Ministry of Agriculture and Land Reclamation based on the analysis of the chemical composition of the soil. Three different doses of iprodione were sprayed twice on foliage at the blooming and fruiting stage, 15th of January and 25th of March, with the beginning of the fruit rots infection appeared (3% severity) by using snake sprayer fitted with one nozzle and compared with untreated plants as follows:

- Control (sprayed with tap water)
- Iprodione 90 g 100 l^{-1}water (recommended dose)
- Iprodione 135 g 100 l^{-1}water (recommended and half dose)
- Iprodione 180 g 100 l^{-1} water (double recommended dose)

Each target plot was sprayed with one of the previous treatments separately. Plots were arranged in a complete randomized block design. The experiment was performed in three replicates for each treatment. There were three sections in each plot, one for plant growth records (at initial time; 2 hours after application; and 21-DAA) and the second for yield measurements. Samples of Strawberry leaves and fruits were taken randomly from the third section of each plot in triplicates after initial time and 21 -DAA. Samples of leaves and fruits were transported immediately in ice box to the laboratory and kept in freezer at -20°C till leaves and fruits quality analyses.

Disease Severity Percent: Fruit rot severity percent was recorded, 15 days after the two foliar applications (30th of January and 10th of April) during the two seasons as described by Townsend and Heuberger [17].

Vegetative Growth Parameters: Three plant samples were collected randomly from each treatment after initial time and 21-DAA with three replicates to measure plant fresh mass (g), number of leaves / plant, the leaf area (cm^2) of the second full expanded leaf from crown. One side leaves area were measured by Image-pro plus software (version number 6.2, Media Cybernetics Inc., USA) by using the digital images of leaf surface. After drying of these leaves until constant weight at 70°C its corresponding leaf dry mass was recorded. Specific leaf area (SLA) was calculated as the equation of Kimball *et al.* [18] "Specific leaf area = Leaf area /leaf dry mass" and expressed as $cm^2 g^{-1}$.

Yield Measurements: Another three plants with three replicates were taken to record the number of inflorescences/plant and number of flowers/florescence at both initial time and at 21-DAA. Flowers abscission % was calculated by the equation as following:

Flowers abscission % = [(total flowers number-total number of fruits) / total flowers number)] x 100.

Yield of marketable fruits (g plant^{-1}) in January, February, March, April and May was recorded and the total yield (g plant^{-1}) was calculated at the end of the season.

Biochemical Analyses in Leaves: The second leaf from crown was taken, at the initial time and at 21-DAA, from each treatment with three replicates to determine some biochemical components, *i.e.* Chlorophyll a, chlorophyll b, carotenoids, total soluble phenols and anthocyanins concentrations.

Determination of Pigments: For determining of chlorophyll a&b and carotenoids, 0.2 g of fresh leaves was weighed and grinded in 10 ml of pure acetone as presented by Costache [19], the resulting extracts were incubated in fridge for 24 hours. The next day, the absorbance was recorded at 662nm for chl. a, 645nm for chl. b and 470 nm for carotenoids. Then the concentrations was calculated and expressed as mg g^{-1}f.wt. of leaves by the following equations:

"Chlorophyll a = 11.75 A662 – 2.350 A645"
"Chlorophyll b = 18.61 A645 – 3.960 A662"
"Carotenoids = 1000 A470 – 2.270 Chl a – 81.4 Chl b/227"

Determination of Total Soluble Phenols: The concentration of total soluble phenols in the ethanolic extract was estimated by the portrayed method of Jayaprakasha *et al.* [20]. Half ml of ethanolic extract was mixed with 0.1 ml diluted Folin-Ciocalteu then added 0.8 ml solution of sodium carbonate (7.5 %) and the tubes were left in 40°C for 30 min. The absorbance was determined at 765 nm and results were estimated as mg gallic acid equivalents per 100 g f.wt.

Determination of Anthocyanins: Total anthocyanins concentration was determined according to the steps of Connor *et al.* [21]. The ethanolic extract was diluted to 1:95 (v/v) in acidified methanol (HCl 1% v/v) to obtain at wave length of 530 nm an absorbance between 0.500 - 1.000. The results are recorded as mg of cyanidin-3-glucoside 100 g^{-1} f.wt using a molar extinction coefficient of 27 900.

Evaluation of Biochemical Fruit Quality: Marketable fruit samples without any visible symptoms of infection were collected (at full ripe stage) from each treatment at initial time and after 21-DAA to determine L- ascorbic acid, titratable acidity, total soluble solids and total sugars concentrations.

The L- ascorbic acid concentration (mg 100 g^{-1} f.wt.) in fresh juice was estimated by using 2, 6 - dichloroindophenol titrimetric method with 3% oxalic acid as described in AOAC [22].

Titratable acidity (as g citric acid 100 g^{-1} f.wt.) of fruit juice was determined immediately after squeezing. Five milliliters fruit juice were diluted up to 50 ml with distilled water, then manual titration with NaOH solution (0.1N) after dropping 2 drops of phenolphthalein (1 % w/v), as an indicator, was performed according to the method portrayed by AOAC [22].

Total soluble solids % was measured by using hand-held refractometer (Atago Co, Ltd., Model N1, Tokyo, Jaban) as the methodology of AOAC [22].

Total sugars were extracted as the strategy described by AOAC [22] and measured as g 100 g^{-1} f.wt. by the phenol sulphoric acid method as portrayed by Chow and Landhausser [23].

All spectrophotometric determinations were measured by CT 200 spectrophotometer.

Statistical Analysis: Three replications from each record were subjected to analysis of variance (ANOVA) by the standard procedures using Statistix 8th version of Steel *et al*. [24]. Means were compared to significance by Duncan's multiple range tests, used for the determination of significant differences of P value lower or equal 0.05 among the results [25].

RESULTS AND DISCUSSION

Fruit Rot Severity Percent: Table (2) showed that treatment with the different rates of iprodione significantly decreased the severity of strawberry fruit rots in comparing to control during the two growing seasons. The maximum decrease was shown when the iprodione fungicide was applied with the 2 RD although this rate had negative impacts on plant growth and productivity as described below, as well as on some determined biochemical components inside the leaves or in the fruits.

Vegetative Growth Characteristics: There are insignificant differences between plants sprayed with the three different concentrations of iprodione in plant fresh mass, number of leaves/plant, leaf dry mass, corresponding leaf area and specific leaf area (SLA) at initial time (2 hours after application) in comparing with control at both seasons (Table 3). All tested parameters were increased at 21-days after application (21- DAA). The usage of iprodione with the recommended dose (RD; 90 g 100 l^{-1}) showed insignificant differences in all record traits at 21- DAA at both seasons in comparing with untreated plants. These traits were decreased with one and half of the recommended dose (1½ RD; 135 g 100 l^{-1}) or the double dose (2RD; 180 g 100 l^{-1}) of iprodione in comparison with plants treated with RD or untreated plants. Insignificant reduction in plant fresh mass, number of leaves/plant was noticed in plants exogenously sprayed with the 1½ RD of iprodione, while plant fresh mass and number of leaves/plant decreased significantly when iprodione was applied with the double dose. Both of leaf area and leaf dry mass were reduced with increasing the rate of application, with note that the reduction in leaf dry mass was more than the reduction in leaf area. This difference in the reduction resulted in increasing the specific leaf area (SLA) gradually with increasing the rate of iprodione treatment at 21-DAA in the two growing seasons. The specific leaf area became progressively less in control plants followed with plants treated with the RD without any significant difference between them.

In these current, Legard *et al.* [26] indicated that fungicide treatment did not have any positive influence on strawberry biomass, canopy diameter, leaves number / plant, leaf length and leaf width. They added

Table 2: The severity percent of strawberry fruit rots, 15 days after spraying with

	Fruits rot severity %		Fruits rot severity %	
	1st season		2nd season	
Treatments	At 30 of January	At 10 of April	At 30 of January	At 10 of April
Control	7.16[a]	11.85[a]	8.24[a]	12.82[a]
Recommended dose	0.60[b]	0.79[b]	0.71[b]	0.81[b]
Recommended dose and half	0.28[bc]	0.33[bc]	0.43[b]	0.48[b]
Double recommended dose	0.00[c]	0.12[c]	0.00[c]	0.20[c]

Values within the same column, in each season, with a different superscript letter significantly differ at P ≤ 0.05 according to Duncan's multiple range test

Table 3: Effect of foliar spraying with different doses of iprodione fungicide on strawberry growth parameters at initial time and 21 days of application (21- DAA) during 2016/2017 and 2017/2018 growing seasons

		Pl. fresh biomass (g)		No. of leaves/pl.		Leaf area (cm^2)		Leaf dry mass (g)		Specific leaf area ($cm^2\ g^{-1}$)	
Seasons	Treatments	Initial time	21- DAA	Initial time	21- DAA	Initial time	21- DAA	Initial time	21- DAA	Initial time	21- DAA
1st season	Control	78.17[a]	108.55[a]	9.33[a]	13.67[ab]	54.60[a]	56.70[ab]	0.62[a]	0.85[a]	87.75a	66.95[c]
	1RD	79.30[a]	104.63[a]	9.33[a]	14.33[a]	53.73[a]	57.00[a]	0.62[a]	0.83[a]	86.82a	68.45[c]
	1½ RD	80.73[a]	104.40[a]	9.00[a]	13.33[ab]	56.07[a]	55.87[ab]	0.63[a]	0.77[b]	89.46a	72.28[b]
	2RD	80.93[a]	86.40[b]	9.33[a]	11.33[b]	54.67[a]	54.57[b]	0.62[a]	0.61[c]	87.99a	90.34[a]
2nd season	Control	80.57[a]	112.00[a]	9.00[a]	15.33[a]	54.97[a]	57.33[a]	0.60[a]	0.71[a]	91.72a	81.77[a]
	1RD	80.53[a]	117.53[a]	9.67[a]	15.67[a]	54.73[a]	56.63[ab]	0.60[a]	0.69[a]	99.99a	82.83[a]
	1½ RD	82.23[a]	109.80[a]	8.67[a]	15.67[a]	55.30[a]	55.00[b]	0.58[a]	0.66[a]	92.75a	83.22[a]
	2RD	80.87[a]	86.17[b]	9.00[a]	12.00[b]	54.73[a]	56.47[ab]	0.55[a]	0.58[b]	93.99a	96.75[a]

1RD (Recommended dose), 1½ RD (Recommended dose and half), 2RD (Double recommended dose)
Values within the same column, in each season, with a different superscript letter significantly differ at P ≤ 0.05 according to Duncan's multiple range test

that fungicide can restrict growth and yield. Fungicide treatment reduced the growth of strawberry plants comparing with other treatments [27]. This reduction caused as a reason of the hazard effect of fungicide on targeting specific cellular processes such as respiration and sterol biosynthesis [27]. The intensity of the stress induced by the application of pesticide caused growth reduction after the agrochemical exposure [13]. Van Iersel and Bugbee [28] reported that fungicides caused plant damage which called phytotoxicity that appeared in a form of growth reduction and visual damage in plant, in addition to decrease photosynthesis and caused an interveinal chlorosis. The plant biomass and number of leaves per plant naturally increased over time [7]. The decrease in the number of leaves/plant when plants treated with the high dose of fungicide was an indicator for an increase in the percentage of leaf abscission. The highest specific leaf area (SLA) produced from higher leaf area expansion or lower leaf dry mass [7]. In this experiment, insignificant reduction in leaf area expansion with significant reduction in leaf dry mass was recorded in the double dose treatment of fungicide in comparing with control plants. The slight decrease in the leaf area to the significant decrease in leaf dry mass may be an indicator to the increasing in respiration process with normal cell division and cell expansion while the decline in leaf dry mass is related by the reduction in carbon assimilation in photosynthesis process [7, 29]. Untiedt and Blanke [30] attributed the negative effect of pesticides on photosynthesis to disturbance in CO_2-independent Hill reaction or to the uncoupling of photosynthetic electron that flow from phosphorylation and inhibit energy by prevent ATP formation or render the dissociation of ATP into ADP+ Pi.

Approximate the same record values of inflorescences number/plant and flowers number / florescence were noticed at initial time of treatments (Table 3). Also, there was an increment in these two lateral parameters at 21-DAA. Significant reduction in number of inflorescences/plant and number of flowers/florescence was shown with the double dose treatment (Table 4). In this context, Saladin and Clément [13] stated that relatively low application rate of fungicides can control a wide range of fungi. Nevertheless, application with fungicides may restrict growth and development of the reproductive organs by alternating the carbon or/and nitrogen metabolism [12]. They added that the plant sensitivity against high application rates of fungicides may increase during the critical reproduction state. There was a positive link between leaf expansion and high leaf dry mass in the recommended dose treatment which reflected in high potential yield of flowers and fruits [7].

Table 4: Effect of foliar spraying with different doses of iprodione fungicide on number of inflorescences and flowers and strawberry plants at initial time and 21 days of application (21- DAA) during 2016/2017 and 2017/2018 growing seasons

	No. of inflorescences/plant		No. of flowers/inflorescence		No. of inflorescences/plant		No. of flowers/inflorescence	
	1st season				2nd season			
Treatments	Initial time	21- DAA	Initial time	21- DAA	Initial time	21- DAA	Initial time	21- DAA
Control	3.33[a]	6.00[a]	4.67[a]	5.33[a]	3.67[a]	6.66[a]	4.67[a]	5.67[a]
1RD	3.00[a]	5.00[ab]	4.33[a]	5.33[a]	3.67[a]	5.33[a]	4.33[a]	5.33[a]
1½ RD	3.67[a]	4.00[b]	4.00[a]	5.00[a]	3.00[a]	4.00[ab]	4.67[a]	4.33[a]
2RD	3.33[a]	2.67[c]	4.00[a]	4.00[b]	3.67[a]	2.66[b]	4.00[a]	2.33[b]

1RD (Recommended dose), 1½ RD (Recommended dose and half), 2RD (Double recommended dose)

Values within the same column, in each season, with a different superscript letter significantly differ at $P \leq 0.05$ according to Duncan's multiple range test.

Table 5: Effect of foliar spraying with different doses of iprodione fungicide on flowers abscission (%) at initial time and 21 days of application (21- DAA) and the average of marketable yield of strawberry during 2016/2017 and 2017/2018 growing seasons

		Flowers abscission %		Marketable yield / plant (g)					
Seasons	Treatments	Initial time	21- DAA	January	February	March	April	May	Total
1st season	Control	6.67[a]	17.78[c]	91.41[a]	80.00[b]	50.00[c]	40.33[b]	35.37[b]	297.03[b]
	1RD	6.67[a]	23.33[bc]	88.33[a]	99.00[a]	133.00[a]	91.38[a]	54.77[a]	466.48[a]
	1½ RD	6.67[a]	46.67[ab]	79.67[b]	101.33[a]	127.33[a]	89.33[a]	55.00[a]	452.66[a]
	2RD	8.33[a]	56.67[a]	74.67[b]	39.73[c]	70.00[b]	49.00[b]	52.00[a]	285.00[b]
2nd season	Control	6.67[a]	12.22[c]	92.20[a]	82.95[b]	52.23[c]	35.40[c]	44.98[b]	307.76[b]
	1RD	6.67[a]	12.22[c]	89.57[a]	103.67[a]	110.13[a]	93.53[a]	55.07[a]	451.97[a]
	1½ RD	6.33[a]	26.67[b]	82.20[b]	98.48[a]	117.80[a]	88.50[a]	52.03[a]	439.01[a]
	2RD	6.67[a]	46.67[a]	75.23[c]	47.67[c]	73.33[b]	56.17[b]	53.90[a]	306.30[b]

1RD (Recommended dose), 1½ RD (Recommended dose and half), 2RD (Double recommended dose)

Values within the same column, in each season, with a different superscript letter significantly differ at $P \leq 0.05$ according to Duncan's multiple range test.

After the initial time of iprodione application, the percentage of flowers abscission did not exceed the percent of the normal plant (Table 5). Subsequently, after 21- DAA, the percent of flowers abscission was increased with increasing the rates of application at both seasons. The maximum percent of flowers abscission was recorded when 2RD of iprodione was applied in both seasons. Fruit harvest started in January and lasted until end of May. The amount of yield when iprodione was applied with the RD and 1½ RD was more than the 2RD treatment during January. In February, there was a clear enhanced in yield production with 1½ RD (101.33 g plant^{-1}) and RD (99.00 g plant^{-1}), respectively, comparing with control. In the same time, there was a significant reduction in yield/plant with the application of 2RD (39.73 g plant^{-1}). As for the different rates of iprodione applications during March, the yield was increased in plants sprayed with the three different doses of iprodione in comparing with the plant production, while there was a significant reduction in control. A relative decline in yield was observed during April and this decline may be natural with the plant growth curve or may be due to the spraying treatment of the iprodione that conducted at the end of March. There was an insignificant increase in yield at April in the 2RD treatment compared by control, but when the plants sprayed with the double dose of iprodione, the yield enhanced significantly in May in comparing with control until the differences between the three different doses were disappeared. The maximum total yield of marketable strawberry fruits was obtained when iprodione was used by the 1RD followed by the 1½ RD applications. This increase may be due to the increase of marketable fruits that non-infected with any fruit rots. Whereas, insignificant difference in yield was shown between the 2RD and control at both seasons. These results were agreed with that obtained by several investigators. Plants treated with the recommended dose of fungicide exhibited significantly higher marketable yield than untreated plants [31]. Van Iersel and Bugbee [28] recorded that to avoid toxicity of fungicide do not use the over dose due to its effect on reducing yield and enhanced the phytotoxicity symptoms. Moreover, sulfur containing fungicide induced high loss of apple fruits and delay harvesting stage when used with high rates [32]. Holb *et al*. [33] reported that lime sulfur applied to apple trees caused leaf toxicity, appeared as necrosis and reduction in fruit yield.

Table 6: Effect of foliar spraying with different doses of iprodione fungicide on some biochemical constituent

		Chlorophyll (a) (mg g^{-1}f.wt.)		Chlorophyll (b) (mg g^{-1}f.wt.)		Carotenoids (mg g^{-1}f.wt.)		Total soluble phenols (mg $100g^{-1}$ f.wt.)		Anthocyanins (mg $100g^{-1}$ f.wt.)	
Seasons	Treatments	Initial time	21- DAA	Initial time	21- DAA	Initial time	21- DAA	Initial time	21- DAA	Initial time	21- DAA
1st season	Control	0.44^{a}	0.45^{a}	0.25^{a}	0.27^{a}	0.20^{b}	0.21^{b}	64.86^{d}	88.04^{d}	26.384^{d}	29.000^{c}
	1RD	0.42^{b}	0.42^{a}	0.23^{b}	0.24^{b}	0.21^{a}	0.22^{a}	76.04^{c}	114.30^{b}	34.372^{c}	45.310^{a}
	1½ RD	0.28^{c}	0.34^{b}	0.18^{c}	0.23^{b}	0.22^{a}	0.19^{c}	80.60^{b}	126.97^{a}	35.819^{b}	47.787^{a}
	2RD	0.20^{d}	0.24^{c}	0.15^{d}	0.18^{c}	0.19^{c}	0.16^{d}	113.10^{a}	96.95^{c}	38.296^{a}	38.293^{b}
2nd season	Control	0.44^{a}	0.45^{a}	0.29^{a}	0.27^{a}	0.21^{b}	0.21^{a}	72.23^{c}	77.12^{d}	26.440^{d}	26.718^{d}
	1RD	0.43^{a}	0.43^{a}	0.24^{b}	0.26^{ab}	0.22^{a}	0.22^{a}	77.39^{b}	114.77^{b}	35.179^{c}	44.252^{b}
	1½ RD	0.34^{b}	0.37^{b}	0.20^{bc}	0.22^{b}	0.21^{b}	0.20^{b}	79.26^{b}	129.44^{a}	38.240^{b}	47.425^{a}
	2RD	0.21^{c}	0.21^{c}	0.18^{c}	0.18^{c}	0.19^{c}	0.15^{c}	107.35^{a}	95.81^{c}	39.103^{a}	39.883^{c}

1RD (Recommended dose), 1½ RD (Recommended dose and half), 2RD (Double recommended dose)
Values within the same column, in each season, with a different superscript letter significantly differ at $P \leq 0.05$ according to Duncan's multiple range test.

Table 7: Effect of foliar spraying with different doses of iprodione fungicide on some fruits

		Ascorbic acid (mg $100g^{-1}$ f.wt.)		Titratable acidity (g 100 g^{-1}f.wt.)		Total soluble solids (g $100g^{-1}$ f.wt.)		Total sugars (g 100 g^{-1}f.wt.)	
Seasons	Treatments	Initial time	21- DAA	Initial time	21- DAA	Initial time	21- DAA	Initial time	21- DAA
1st season	Control	73.52^{a}	78.67^{c}	0.33^{a}	0.37^{c}	8.33^{a}	10.23^{a}	6.46^{a}	8.55^{a}
	1RD	74.09^{a}	82.08^{b}	0.32^{a}	0.43^{b}	8.43^{a}	9.58^{ab}	6.15^{a}	7.40^{b}
	1½ RD	74.31^{a}	85.79^{a}	0.34^{a}	0.50^{a}	8.40^{a}	9.28^{ab}	6.14^{a}	7.22^{b}
	2RD	73.52^{a}	72.30^{d}	0.35^{a}	0.29^{d}	8.33^{a}	8.62^{b}	6.16^{a}	6.17^{c}
2nd season	Control	75.55^{a}	80.37^{c}	0.35^{a}	0.39^{b}	8.40^{a}	11.12^{a}	6.16^{a}	8.72^{a}
	1RD	75.70^{a}	83.75^{b}	0.33^{a}	0.45^{a}	8.56^{a}	10.34^{b}	6.16^{a}	8.22^{b}
	1½ RD	74.64^{a}	87.91^{a}	0.34^{a}	0.51^{a}	8.58^{a}	9.59^{c}	6.15^{a}	7.48^{c}
	2RD	75.71^{a}	71.90^{d}	0.34^{a}	0.29^{c}	8.51^{a}	9.34^{c}	6.14^{a}	6.52^{d}

1RD (Recommended dose), 1½ RD (Recommended dose and half), 2RD (Double recommended dose)
Values within the same column, in each season, with a different superscript letter significantly differ at $P \leq 0.05$ according to Duncan's multiple range test.

Table (6) showed the alteration in the concentrations of different components in the leaves of "Festival" strawberry plants according to the changing in the rates of the iprodione. It was noticed that there were decreases in chl. a, chl. b and carotenoids concentrations gradually with increasing the rates of iprodione at both tested times during the two growing seasons. These foundings recently documented by Sun *et al.* [34] who mentioned that cellular pigments, primarily chlorophylls, are the main central component in the plant cell used as an indicator of biomass. According also to these finding, fungicides containing copper inhibits both of the synthesis of chlorophyll and protochlorophyllide reductase activity "an enzyme catalyzes the formation of chlorophyllide from protochlorophyllide during the biosynthesis of chlorophyll [35].Carotenoids concentration is often provided a useful insight to the cellular physiological state. Carotenoids have central roles in photosynthesis and photoprotection [36]. At this point, the decrease in the carotenoids concentration in this current study may be attributed to the slow biosynthesis or fast degradation of carotenoids under the high levels of reactive oxygen species production or due to its converting into abscisic acid (ABA) under stress produced from fungicide applications [37], where ABA could be synthesized *via* indirect pathway from carotenoids [38]. ABA is a key plant hormone response for regulating of fruit ripening and plant senescence [39]. On the other hand, the increase of iprodione rates increased the total soluble phenols and anthocyanins concentrations at the initial time, whereas, phenols and anthocyanins concentrations decreased with the highest rate of iprodione in comparing with the other doses. Also, higher concentrations of the previous determinations were increased periodically as shown in Table 6. High capacity of phenols and anthocyanins in strawberry seemed to be the main contributor in the protective effect against stress attributed from fungicide treatment [40].

Data in Table (7) revealed that the determined fruit quality attributes changed in fruits produced from plants treated with the different rates of iprodione. Ascorbic acid concentration of "Festival" strawberries increased significantly in treatments applied with 1RD and 1½ RD of iprodione then these concentrations decreased significantly with the higher rate application. The same sequence was detected in titratable acidity percent with the three doses of iprodione. Despite of the increased concentration in ascorbic acid with the treatment of 1½ RD, TSS was significantly reduced with the 1½ and 2 RD rates of iprodione and this reduction continued in total sugar concentration in response to iprodione application during the two seasons. These results were in agreement with Wysocki and Banaszkiewicz [27] who mentioned that there was a clear increase in ascorbic acid concentration responded by Kent cultivar of strawberry treated with different fungicides protection levels. On the other hand, Rochalska *et al.* [41] recorded low accumulation of ascorbic acid in "Senga sengana" cultivar with the same treatments. Given [42] reported that fungicide application affected the accumulation of various organic compounds in the fruit to a degree less than other factors as noticed in our findings with the excess rate of iprodione

application. Chemical plant protection agents exerted a less significant impact on the chemical components and strawberry fruit quality than other environmental factors [42].

Smith [43] mentioned that the reduction in biological active organic compounds in strawberry attributed to reducing the acidity in strawberry fruits. Fungicide treatment resulted in significant decrease in total sugars concentration [27]. Petit *et al.* [12] reported that the inhibition of photosynthesis process in the leaves of plants exposed to stress is in the true as a consequence of alterations in the source sink relationship. In this connection, Vinit- Dunant *et al.* [15] stated that growth inhibition resulted from copper pesticide application reduced carbohydrates translocation from leaves which causing accumulation of starch and sucrose in leaves with low levels of sugars in sink.

In Conclusion, using of high rates of iprodione at the beginning of fruit rots infection appeared (3% severity) controlled fruit rot diseases but induced negative effects on leaf area, leaf dry mass and inflorescences abscission percent, whereas, using of the recommended rate of iprodione decreased the loss of marketable strawberry yield and maximized the cost / benefit.

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