



Productive manifestations and sensitivity to codling moth (*Cydia (Laspeyresia) pomonella* (L.) of apple cultivars and hybrids

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(Manuscript received 18 May 2022; accepted for publication 14 November 2023)

Abstract. *The present study was conducted during the period 2019 - 2021 at the Institute of Agriculture, Kyustendil. The productivity, fruit quality, and sensitivity to codling moth of 10 apple cultivars and 9 hybrids were evaluated. Standard technology was implemented to grow the fruit-bearing trees, which were grafted on MM 106 rootstock and planted at a distance 4.5×2.5 m. The highest average yields were obtained from the cultivar Rosana (30.4 kg/tree) and hybrid 9 (28.3 kg/tree). Fruit weight ranged from 83 g (hybrid 2/4) to 248 g (Charden). Goldrush had the highest fruit flesh firmness – 10.0 kg/cm² and hybrid 1/7 the lowest – 6.7 kg/cm². No differences in the sensitivity to codling moth were observed among cultivars and hybrids. The percentage of damage ranged from 3.7% (hybrid 1/3) to 5% (Rosana) in 2020 and from 43.6% (hybrid 2/4) to 55.7% (Golden Resistan) in 2021.*

Keywords: *Malus × domestica*, fruit weight, codling moth, yield, fruit size

Introduction

The apple (*Malus × domestica* Borkh.) is one of the most widely grown species in the world. In Bulgaria, it ranks fourth in area but first in fruit production. In recent years, the selection of apples has focused on creating resistant or disease-tolerant cultivars (Sasnauskas et al., 2015; Inderbitzin et al., 2019).

The codling moth (*Cydia (Laspeyresia) pomonella*) is the most economically important pest, widespread throughout the world where apples are grown. The life cycle of *C. pomonella* is directly dependent on the ecological conditions where it is distributed and develops one to three or even more generations per year (Ricci et al.,

2009; Guermah and Medjdoub-Bensaad, 2018). In some years, the larvae can cause significant damage to the fruit - from 20% to 90%, depending on their density, cultivar, and place of cultivation. In orchards where the pest is not controlled, the damage can reach 100% (Howitt, 1993; Vossen and Devarenne, 2004). Damage to late cultivars is more significant than to earlier maturing ones (Caprile and Vossen, 2011). The different sugar content also has some effect on the degree of damage (Lombarkia and Derridj, 2002; Brahim et al., 2013; Joshi et al., 2015).

To improve the codling moth control it is important to establish its preferences for laying eggs on different apple cultivars. The results of laboratory studies conducted with 10 apple cultivars showed that it prefers to lay eggs mainly

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on Golden Delicious and Fuji and relatively less on Arlet, Pristine, Sunrise, and Honeycrisp (Joshi et al., 2015). In Golden Delicious, this is explained by the high content of sugars in the fruit, which stimulate egg laying, and poor egg production on Starking Delicious is associated with high polyphenols levels, which act as a repellent to this pest (Meni Mehzoum et al., 2018). Mahi et al. (2021) found that the degree of damage of Golden Smoothie cultivar was twice as high compared to Gala Brookfield and Granny Smith, due to differences in the nutrient content of the fruit and the period of ripening. Establishing the sensitivity of individual apple cultivars to the codling moth is an important step in the fight against this pest.

The study aimed to evaluate the productivity, fruit quality, and susceptibility of some apple cultivars and hybrids to the codling moth in the Kyustendil region.

Material and methods

The study was conducted during the period 2019-2021 in a collection plantation of the Institute of Agriculture, Kyustendil, on 10 cultivars and 9 apple hybrids. The orchard is planted with trees grafted on MM 106 rootstock at a distance of 4.5×2.5 m. The trees are formed in a free-growing crown with a central leader. The plantation was grown with standard technology and the trees were in a period of full fruiting. All cultivars and hybrids were represented by five trees. The soil in the experimental field is Chromic Luvisols, with a light sandy loamy texture, and neutral reaction. Fertilization with 18 kg nitrogen in active substance per decare was applied annually. The trees were irrigated by over-crown sprinkling. The following characteristics were evaluated: average yield per tree (kg), fruit weight (g), fruit sizes (mm), and flesh firmness (kg/cm²) on samples of 30 fruit from each experimental tree, taken at random during the harvest. Based on diameter, the fruit was classified into three classes – class 'Extra' (>65 mm), class I (55-65 mm), and class II (50-55 mm) in %, according to the Bulgarian state standard.

Pheromone traps CSALOMON, manufactured

at the Plant Protection Institute of HAS, Budapest, were used to establish the beginning of the flight of the codling moth. The traps were placed in the crowns of trees on the south side at a height of 1.50 - 1.80 m above the soil surface. The traps were inspected daily until the first butterflies were caught, and then three times a week. The fight against this pest was carried out more than the Economic Threshold Levels of Insect Pests, with permitted insecticides. At the harvest, 20 fruits from each experimental tree were examined and the fruit damage was reported.

The data were statistically analyzed using analyses of variance (ANOVA). The significance of the differences among mean values was determined using the LSD test at $p \leq 0.05$.

Results and discussion

Most of the studied cultivars and hybrids in average yield per tree exceeded the standard cultivar Golden Delicious and proved to be productive to very productive (Table 1). The highest yields, average for the period 2019-2021, were obtained from the trees of Rosana and hybrid No 9 - 30.4 and 28.3 kg, respectively. With a proven lowest yield were the trees of hybrid No 152 (10 kg), followed by those of hybrids 1/18, 1/7, and 2/4. As a result of the more significant freezing of the fruit buds of Charden and Belgolden in 2019, their yield was also lower than the standard cultivar. Relatively high productivity of the Rosana has also been reported by other authors (Jönsson and Tahir 2004; Sosna, 2014).

Charden had the highest fruit weight, followed by New Jonagold and the hybrid 8/22. The fruit of hybrid 2/4 and Rosana were the smallest and the differences compared to most of the other cultivars and hybrids were significant (Table 1). Sosna (2014) also defined Rosana as a cultivar with relatively small to medium-sized fruit.

Goldrush had relatively the highest fruit flesh firmness (10.0 kg/cm²), and the fruit of hybrid 1/7 had the lowest flesh firmness - 6.7 kg/cm². There were no significant differences in this indicator between the other cultivars and hybrids (Table 1).

Table 1. Yield and quality of fruit of apple cultivars and hybrids, on average for 2019 - 2021

Cultivar/ Hybrid	Yield (kg/tree)	Fruit weight, g	Fruit length, mm	Fruit diameter, mm	Flesh firmness, kg/cm ²
Rosana	30.4 a	112 d	56.7	64.1	8.4
New Jonagold	24.4 a-d	200 ab	67.2	79.5	7.8
Ginger Gold	26.1 abc	183 abc	65.9	75.5	8.1
Charden	15.9 e-h	248 a	67.1	86.4	7.9
Belgolden	14.2 fgh	132 cd	63.0	67.5	7.6
Golden Resistant	20.0 def	150 bc	64.1	69.2	8.3
Gold Milenium	24.2 a-d	162 bc	64.9	74.6	8.2
Goldrush	21.3 cde	161 bc	63.1	71.7	10.0
Defloga	18.6 def	141 bcd	60.6	71.3	7.6
Golden Delicious (st)	21.8 b-e	166 bc	65.7	74.3	7.0
Nº 1/3	22.2 b-e	130 cd	59.2	69.2	9.0
Nº 1/7	13.7 fgh	125 cd	54.4	66.6	6.7
Nº 1/18	12.3 gh	141 bcd	59.5	69.4	7.8
Nº 8/22	26.7 abc	196 ab	70.1	75.6	8.4
Nº 2/4	14.5 fgh	83 d	51.2	57.9	7.7
Nº 4/15	22.0 b-e	135 bc	60.2	68.8	6.9
Nº 6	23.7 b-d	125 cd	55.8	64.1	7.9
Nº 9	28.3 ab	183 abc	65.9	75.2	8.6
Nº 152	10.0 h	143 bcd	57.0	70.9	8.2

Except for hybrid 2/4, the fruit of the other cultivars and hybrids were over 60 mm in diameter and meet the requirements for first and 'Extra' quality, according to Ordinance Nº108 dated 12.09.2006 on the Requirements for the quality of fresh fruit in Bulgaria. The highest percentage of fruit of 'Extra' quality was obtained from cultivars Charden and Defloga. In 2019 and 2020 all the

production from them was 100% of this class (Table 2). The percentage of fruit in the 'Extra' class was also high in Golden Resistant, Gold Milenium, Goldrush, hybrids 8/22 and 9. The fruit of Rosana and hybrid 2/4 were mostly of class II, while the other cultivars and hybrids lacked such fruit or their percentage was insignificant.

Table 2. Percentage distribution of apple fruit by classes in different years

Cultivar / Hybrid	2019			2020			2021		
	Class ,Extra'	Class I	Class II	Class ,Extra'	Class I	Class II	Class ,Extra'	Class I	Class II
Rosana	9	30	61	5	29	66	12	25	63
New Jonagold	75	18	7	87	13	-	82	18	-
Ginger Gold	50	47	3	45	55	-	64	20	16
Charden	100	-	-	100	-	-	91	9	-
Belgolden	32	65	3	54	38	8	43	49	8
Golden Resistant	81	19	-	87	13	-	89	11	-
Gold Milenium	87	13	-	91	9	-	85	12	3
Goldrush	95	5	-	93	7	-	12	88	-
Defloga	100	-	-	87	13	-	13	78	9
Golden Delicious (st)	78	18	4	91	7	2	88	12	-
Nº 1/3	2	85	13	25	69	6	36	52	12
Nº 1/7	78	22	-	15	63	22	18	69	13
Nº 1/18	58	24	18	43	32	25	49	33	18
Nº 8/22	95	5	-	98	2	-	94	6	-
Nº 2/4	2	65	33	-	16	84	5	28	67
Nº 4/15	83	11	6	92	8	-	72	28	-
Nº 6	15	79	6	6	60	34	24	68	8
Nº 9	94	6	-	89	8	3	89	11	-
Nº 152	78	19	3	64	25	11	89	11	-

It was found that the butterflies of the 1st generation of the codling moth began to fly in early May, and the end of their flight was in the second ten days of June or the first ten days of July (Table 3). The 2nd generation usually starts flying in early July but was also observed in the second half of June (2020). In 2019 the end of the flight was registered at the end of August, and in the next two years in the second half of September. The duration of flight of moths of both generations was from 111 days (in 2019) to 133 days (in 2020), but in our other

studies, the duration of the flight was up to 197 days. Factors that affect this duration were mainly air temperature and rainfall, as well as insecticide treatments. The number of moths caught per trap ranged from 30 to 180 (Table 3). In 2019 a weak flight was observed, which is associated with a relatively low codling moth density the previous year and the lack of fruit due to freezing of flowers from late spring frosts. Over the next two years, no significant difference was found in the density of the codling moth.

Table 3. Flight of codling moth of the 1st and 2nd generation during the period 2019 - 2021, established with pheromone traps CSALOMON

Year	Generation	Start, date	End, date	Duration, days	Number of moths per trap
2019	1 st generation	05.05.	8.07.	64	30
	2 nd generation	08.07.	23.08.	47	
2020	1 st generation	02.05.	18.06.	48	170
	2 nd generation	18.06.	11.09.	85	
2021	1 st generation	10.05.	07.07.	59	180
	2 nd generation	07.07.	15.09.	71	

The dynamics of the flight of the codling moth in the individual years are presented in Figures 1, 2, and 3.

In 2019, there were no identifiable peaks in the dynamics of the flight of *C. pomonella* (Figure 1). The reason for this was the low density of the pest the previous year and the lack of fruit as a result of compromising the harvest. The following year, 4 peaks per flight for the 1st and 3 peaks in the 2nd generation were observed (Figure 2). In 2021 there were two more pronounced flying peaks for

the 1st and one for the 2nd generation (Figure 3). In years with less pronounced peaks of flight, due to the low pest density, cold and rainy, or too dry and hot weather, the caterpillars of the codling moth fall into oligopause and diapause, pupate late in the fall or next year. This reduced the density of the next generation in July and August but prolonged the flight until the end of September. Establishing the flight dynamics of *C. pomonella* is crucial for an effective fight against this pest.

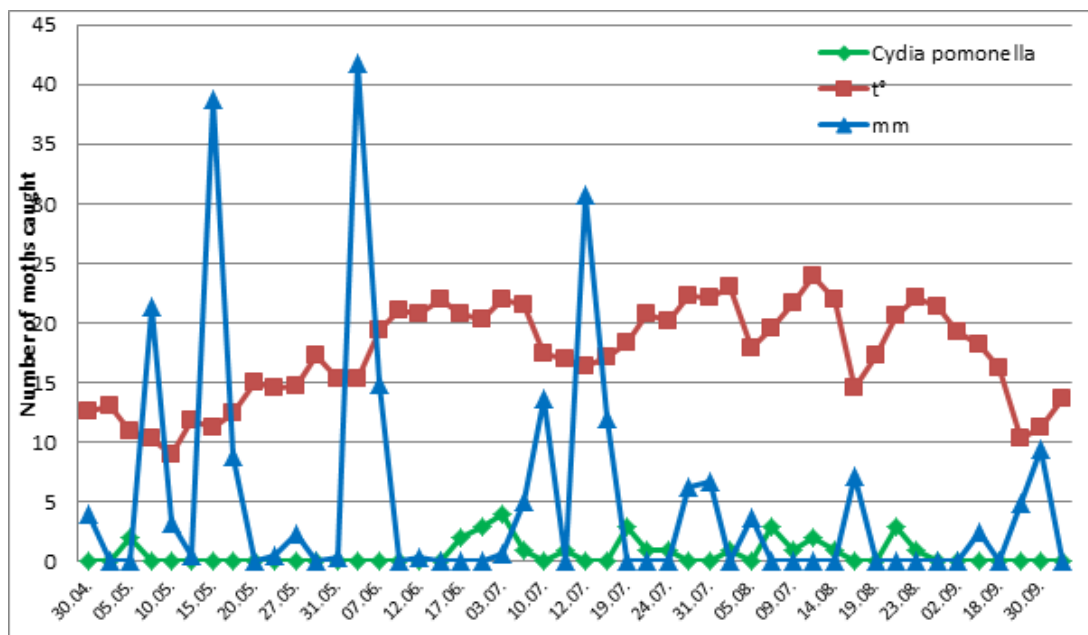


Figure 1. Dynamics of flight of codling moth, average daily air temperature and rainfall from April to September, 2019

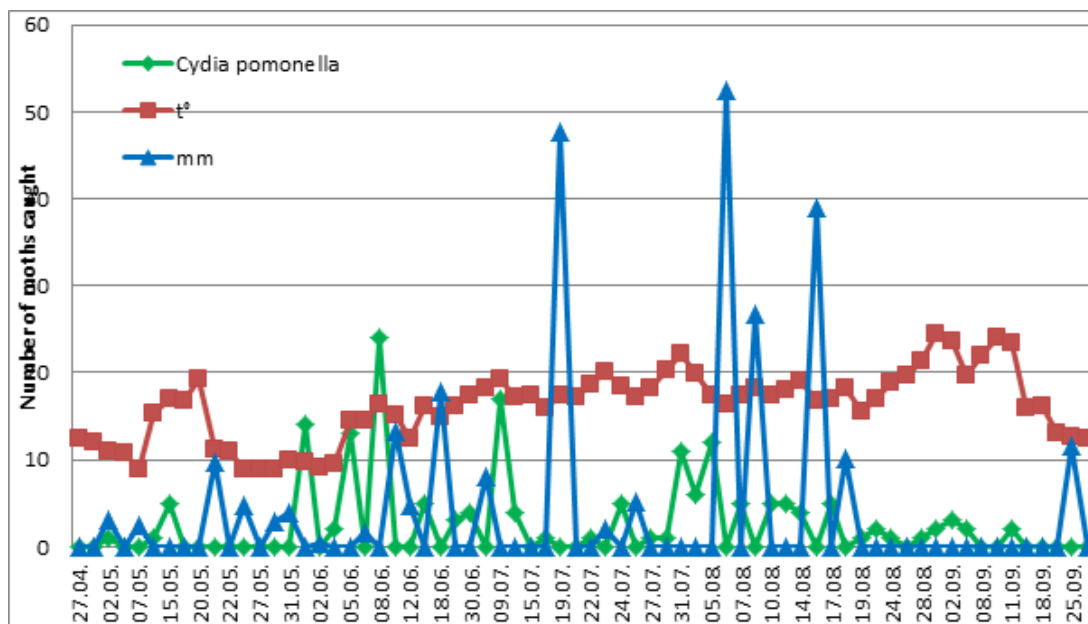


Figure 2. Dynamics of flight of codling moth, average daily air temperature and rainfall from April to September, 2020

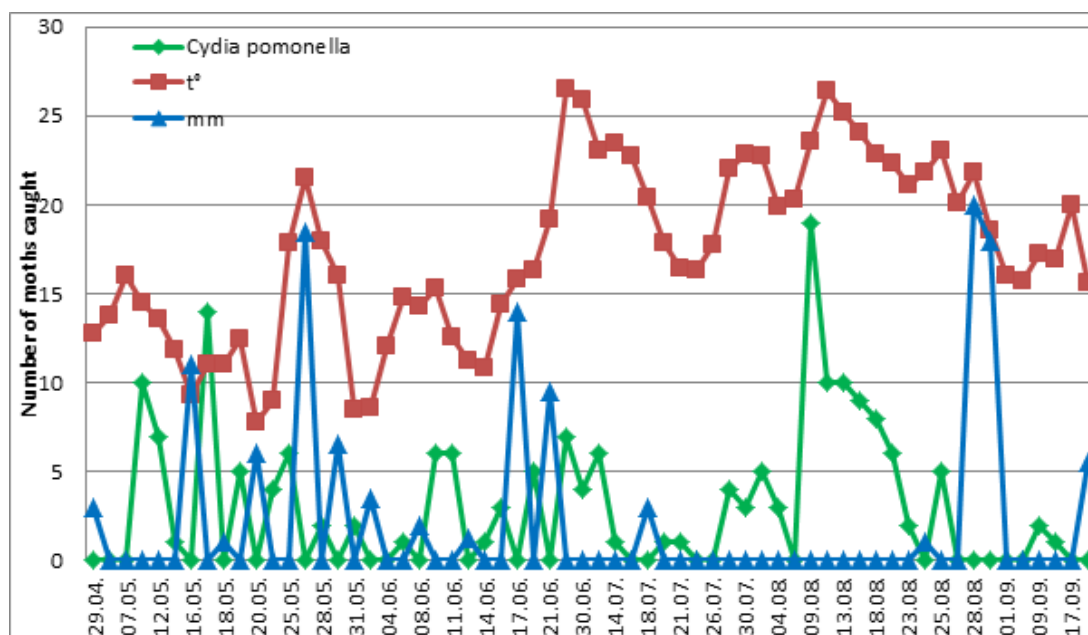


Figure 3. Dynamics of flight of codling moth, average daily air temperature and rainfall from April to September, 2021

One treatment against the 1st and up to three sprays against the 2nd generation of codling moth were carried out in the individual years. In 2019, due to poor fruiting, the number of reported wormy fruit in most cultivars and hybrids was insignificant and the data were not representative. The following year, the damage found during the harvest in the cultivars ranged from 5% (Rosana) to 19% (New Jonagold), and in hybrids - from 3.7% (1/3) to 26.95% (8/22). In 2021 the damage was significantly higher and, in the cultivars it varied from 15% (Goldrush) to 55.7% (Gold Resistant) and in the hybrids from 10% (1/18) to 43.6% (2/4) (Table 4). The higher damage rates this year were due to the high density of the pest. In untreated apple orchards, the damage in the individual years was significant and reached 46-76% in some cultivars, which was about 1.4 to 12.4 times more than in the treated orchards.

Table 4. Damage from codling moth in different cultivars and hybrids of apples, 2020 – 2021.

Cultivar / Hybrid	Damage, %	
	2020	2021
Rosana	5.0	45.3
New Jonagold	19.0	-
Ginger Gold	6.0	55.5
Charden	12.0	28.1
Belgolden	5.4	23.9
G. Resistant	10.0	55.7
Gold Milenium	11.5	18.5
Goldrush	8.0	15.0
Defloga	15.5	24.0
G. Delicious	6.0	33.1
Nº 1/3	3.7	39.3
Nº 1/7	15.0	40.9
Nº 1/18	20.0	10.0
Nº 8/22	26.9	19.5
Nº 2/4	10.0	43.6
Nº 4/15	15.5	26.1
Nº 6	9.5	35.6
Nº 9	15.0	30.5
Nº 152	4.4	22.0

Conclusion

Most of the studied cultivars and hybrids are highly productive and have good characteristics in terms of size, crunchiness, and appearance. With their inclusion in mass production, the assortment of yellow-colored apple cultivars can be diversified, which are represented mainly by Golden Delicious, as they all have a yellow color of the fruit skin. No preference of the codling moth for one or another cultivar or hybrid was found. The established flight dynamics and density of *Cydia pomonella* can be used for timely control of the pest. The prolonged flight of moths - from the beginning of May to the middle of September requires additional treatments for late-maturing apples - until the first ten days of September. In untreated apple orchards, the damage from this pest is significant and in some years it is from 1.4 to 12.4 times more than in the treated orchards.

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