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Camelina sativa GENOTYPES RESPONSE TO DOWNY MILDEW AND WEED SUPRRESION IN ORGANIC AGRICULTURE

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ABSTRACT

Camelina (*Camelina sativa* L. Crantz), has gained considerable attention in Europe as a potential oil seed feedstock for biofuels and bioproducts, although as cultivated surfaces it remains a marginal crop. As well in Romania progress has been made towards camelina's yield potential but this under organic agriculture conditions has not been studied enough. Given this increased interest in camelina, six genotypes were compared to characterize camelina's production potential in organic farming.

Field experiments were conducted out in a randomized complete block design (RCBD) with four replications, six genotypes in three growing seasons (2016-2019). Plant population, frequency (F%) of downy mildew attack, weeds infestation and yield were evaluated.

The higher amount of spring rainfall (in 2017 and 2019) and cooler temperatures favoured a significant downy mildew plant infection, with some variations among genotypes. GP 202 proved to be most sensitive to downy mildew attack followed by Lena. The most resistant genotype was Calena, which recorded, for the three different years, the lowest degree of attack.

In weeds suppression the variation due to year was higher than that due to the genotype and interactions of the factors.

Results identify, in relation to climatic conditions, the most suitable genotypes for the tested environment, in terms of resistance to downy mildew and weed infestation. Calena, Camelia and Lindo genotypes were more less affected by downy mildew, weed infestation was less and the yield was higher as compared to the other genotypes studied.

Keywords: *Camelina sativa,* genotypes, plant population, downy mildew *(Peronospora parasitica)* weed infestation, organic agriculture, yield.

INTRODUCTION

Camelina *(Camelina sativa* L. Crantz), also known as false or wild flax, is an annual oilseed species. It is grown as a forage and biofuel crop in Europe and North America (Moose et al., 2012; Leclere et al., 2018). Camelina was cultivated in Romania for centuries, but now occupies a small area, due to the higher prevalence of growing more productive rapeseed crop. There are two cultivated forms such as winter and summer, but the winter forms yielding higher than summer forms in Romania.

Several studies have addressed the effect of cultivar camelina on seed yield and oil content. So, the yield in organic farming of some camelina cultivars vary from 270 to 1268 kg/ha depending by year and sowing time (Toncea et al., 2013; Toncea, 2014). Among 30 camelina accessions evaluated by Vollmann et al. (2007) across three environments in Austria, seed yield was found to range from 1574 to 2248 kg ha^{-1} and oil content ranged from 40.5 to 46.7% depending on cultivar. In a study evaluating 19 camelina accessions across three field sites in western Canada, Gugel and Falk (2006) reported that yields ranged from 962 to 3320 kg ha^{-1} and oil content ranged from 38 to 43%.

Downy mildew on *C. sativa* caused by *Peronospora parasitica* (synonym *Peronospora camelinae* Gäum.), represents a serious threat to the cultivation of *Camelina*

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sativa in US (Florida) because of the humid climate favouring disease development (Abaye et al., 2019).

Diseased plants may reduce yield while disease management would increase production costs (Srivastava et al., 2012; Gesch, 2014). Relative few studies have been conducted in different environments, the performance of multiple camelina cultivars under Romanian conditions has not been fully explored. Different symptoms typical of downy mildew were observed in different genotypes and trial plots from Romania (Toncea et al., 2013, 2015).

Although camellia is a relatively weed-resistant plant by the ability to generate chemical compounds that suppress weed growth and many weeds are suppressed until leaf drop occurs in the crop, managing weeds is a major economic constraint to the organic farms.

In Romania, especially as perennial dicotyledonous weeds predominate and lately the infestation with common ragweed (*Artemisia artemisiifolia*) is more and more frequent and very difficult to control in organic crops.

Establishing best management practices, including the most productive genotypes for a given region or environment will aid in optimizing camelina productivity. To date, no extensive evaluation of camelina germplasm has been made for organic production under the Romanian conditions.

Therefore, the present study was designed to determine the suitable cultivars for camelina cultivation in organic agriculture from Romania. Consequently, six camelina genotypes were compared for three consecutive growing seasons through a field experiment carried out in organic agriculture conditions (Fundulea area, south eastern part of Romania). The environmental and genotypic effects were assessed on plant stand establishment, downy mildew attack, weed infestation, and as well as the yield.

MATERIAL AND METHODS

The studies were carried out in the period 2016-2019 at the organic fields of Innovation and Technical Assistance Centre for Ecological Agriculture, part of The National Agricultural Research and Development Institute (NARDI) Fundulea, Romania (44°26'N latitude, 68 m altitude). The climate is typical of temperate continental area, characterized by annual rainfall of 571 mm and an average annual temperature of 10.5°C. The area is characterized by chernozem loam soil with 6.3-6.8 pH in aqueous solution. Daily air temperature and rainfall during the period of the study were collected from a meteorological station close to the experimental field (less than 250 m, Table 1).

The experiment had a randomized complete block design (RCBD) with four replications in each year of the study. Plot size was 12 m^2 each.

The tested genotypes were: Camelia, Lindo, Calena, Avio, GP 202 and Lena.

Camelina seeds were sown with a plot seeder to a depth of 1.5-2.0 cm, in a stand of 600 germinating seeds per 1 m^2 with 15 cm row spacing, on 14 October 2016, 16 October 2017 and 15 October in 2018.

It were determined the plant population, frequency of downy mildew attack (F%) and weed infestation.

F% referred to the number of plants showing disease symptoms/total number of evaluated plants. The samples for those determinations were taken from 4 points randomly by 0.25 m^2 of area.

The interpretation of the statistical analysis was done according to the guides elaborated by Stefanic (2010) and Gupta et al. (2020).

RESULTS AND DISCUSSION

The experimental period (2016-2019) was characterized by varied weather conditions in different stages of camelina genotypes development. Total rainfall in October was lower in 2016 and 2018 than in 2017. During growing season of 2017 and 2019 were registered high precipitation from April to June and low temperatures in April, whereas the growing season of 2018 was characterized by very low precipitation (in April and May) and temperatures close to the long-term average (Table 1).

In 2017 and 2019, the cumulated rainfall during April-May exceeded with 32.9 mm, respectively, 69.3 the normal of the zone (106.3 mm) cumulated with low temperatures, while in 2018 registered a moisture deficit of 69.9 mm and high temperature (Table 1), which explains the downy mildew infestation in 2017 and 2019 (Table 3).

Table 1. The rainfall and average of temperature during experimental years, compared to multiannual average (1970-2019)

	I	II	III	IV	V	VI	VII	VIII	IX	**X**	XI	XII
Rainfall (mm)												
2016										**74.4**	48.8	0.0
2017	35.4	50.5	47.6	***73.4***	***65.8***	***96.4***	***113.6***	94.4	12.2	**116.6**	49.2	27.8
2018	36.0	58.6	40.6	**2.4**	**34.0**	*120.6*	85.0	2.8	28.6	**10.8**	23.0	43.0
2019	53.8	21.4	22.4	**51.4**	**124.2**	74.6	87.4	12.6	6.2	38.0	33.2	0.0
MMA	34.9	32.1	38.8	45.0	61.3	74.3	69.2	50.3	49.2	42.7	42.2	48.5
Temperature (°C)												
2016	-4.3	6.2	7.7	**13.7**	16.1	22.9	24.1	23.4	19.1	**10.3**	5.7	-0.13
2017	**-5.5**	**-0.3**	8.6	**10.6**	16.8	22.4	23.3	23.9	19.0	11.7	7.0	3.6
2018	0.8	1.6	3.3	15.8	19.4	22.6	22.8	25	19.1	13.4	5.2	-0.1
2019	-1.2	3.8	9.3	**11.2**	17.2	23.6	23.0	24.7	19.3	12.8	10.2	4.0
MMA	-2.4	-0.2	4.9	11.2	16.9	20.8	22.8	22.3	17.4	11.3	5.3	-0.1

It has been noticed that, in field conditions, camelina is frequently affected by some diseases, the most frequent being the downy mildew produced by *Peronospora parasitiaca*.

The analysis of variance for plant infestation with downy mildew indicated a significant effect of year, genotype and interaction between factors at the 0.1% level of significance.

The effect of year was significantly higher than those of the genotype ones (97% vs. 1.57%) (Table 2).

Table 2. Analysis of variance for plant infestation with downy mildew

Source of variance	DF	Mean square	F value
A Factor: Year	2	1173437 (97%)	3534***
Error A	6	332 (0.02%)	
B Factor: Genotype	5	18860 (1.57%)	63***
Interaction AxB	10	7762 (0.64%)	25***
Error B	45	299 (0.02%)	

Under 2017 conditions the frequency of infestation with downy mildew (*Peronospora parasitiaca*) of studied genotypes was from 0% (Calena genotype) up to 55.3% (GP 202 genotype), in 2018 the infestation with this disease was insignificant and in 2019 the average was 11.1% (Table 3).

Table 3. The frequency of attack with downy mildew (%) for studied genotypes

Genotype	2017	2018	2019
Camelia	18.0	0.0	4.2
Lindo	27.0	0.0	8.3
Calena	0.0	0.0	3.6
Avio	36.3	0.9	16.3
GP 202	55.3	1.0	18.9
Lena	44.7	0.0	15.2
Average	*30.2*	*0.4*	*11.1*

The differences can be explained by high moisture and low temperatures in April 2017 and 2019, which determined good conditions for this disease as compared with the same period in 2018 when was dryness and the temperatures were higher. Our research is consistent with studies conducted by Elad et al. (2014) that show that the infestation with downy mildew in camelina tending to be associated with cool weather.

GP 202 proved to be most sensitive to downy mildew attack followed by Lena. The most resistant cultivar was Calena, which recorded, for the three different years, the lowest degree of attack (Table 3).

The analysis of variance for the plant population indicated a significant effect of year and genotype at the 0.1% level of significance. The variation due to year was higher (97.51%) than that due to the genotype (1.87%) and interactions of the factors (0.57%) (Table 4).

Table 4. Analysis of variance for plant population of studied camelina genotypes

Source of variance	DF	Mean square	F value
A Factor: Year	2	1265809 (97.51%)	4435.19***
Error A	6	285.401 (0.02%)	
B Factor: Genotype	5	24304.68 (1.87%)	82.57***
Interaction AxB	10	7403.28 (0.57%)	25.15**
Error B	45	294.32 (0.0.02%)	

The different plant population of the culture in experimental years could explain also the difference between the frequency of the downy mildew attack in the two years favourable to the appearance of this disease (Figure 1). The low density of plants in 2017 is explained by excessive precipitation in autumn (116.6 mm in October, Table 1) which produced water stagnation and soil compaction, a phenomenon that has not been found in the other two years. Other study shown that incidence and severity of downy mildew infection at harvest were affected by weather conditions and especially cumulative rainfall and mean air temperatures (Desai et al., 2004; Vellios et al., 2017), but also by the amount of (i) camelina biomass (as indicator for the dispersion potential of the disease, Fitt et al., 2006), (ii) intercrop species biomass (as indicator for blocking effect, Boudreau, 2013), and (iii) weeds biomass (as an indicator of the development of the vegetative cover, Wisler and Norris, 2005) (quoted by Leclere et al. 2021).

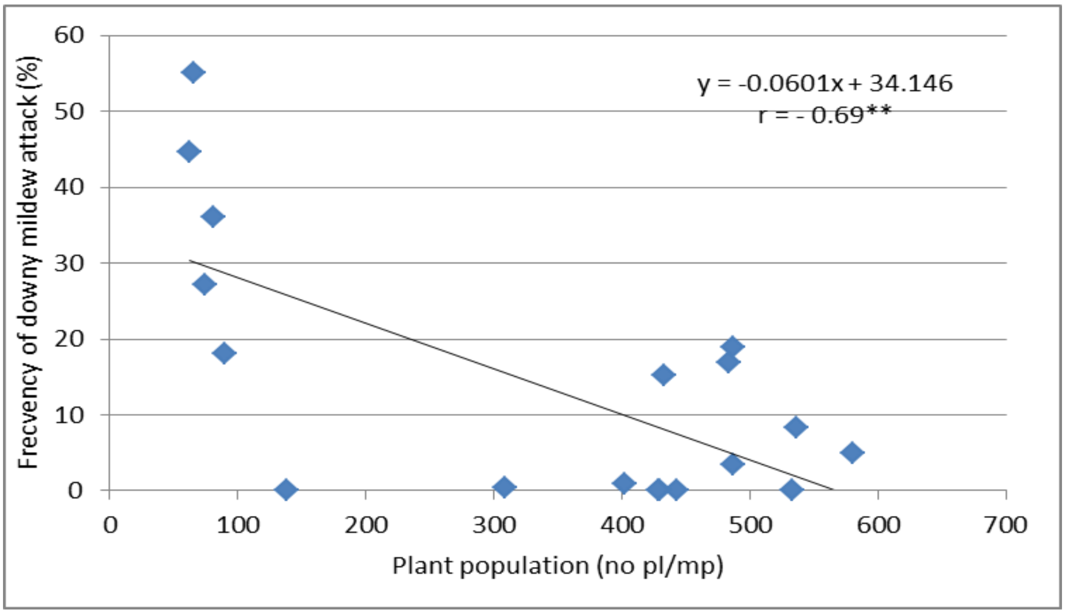

Figure 1. Relationship between plant population and frequency of downy mildew attack

Camelina cultivars were reported to differ in their response to temperature (Allen et al., 2014) and nutrient assimilation (Jiang et al., 2013) and also, interactions with environmental factors, (Podgoreanu et al., 2015). It would therefore be beneficial for growers (and for ecological farms even more) to identify camelina cultivars that will perform well in their specific conditions.

The analysis of variance for infestation with weeds indicated a significant effect of year, genotype and their interaction at the 0.1% level of significance. The variation due to year was higher (79%) than that due to the genotype (12%) and interactions of the factors (8.57%) (Table 5).

Table 5. Analysis of variance for infestation with weeds

Source of variance	DF	Infestation with weeds (ws/m^2)	
		Mean square	F value
A Factor: Year	2	2697 (79%)	1340.47***
Error A	6	2.01 (0.06%)	
B Factor: Genotype	5	409 (12%)	50.49***
Interaction AxB	10	292.31 (8.57%)	36.08***
Error B	45	8.10 (0.24%)	

The weed infestation was relatively high in 2017, the average was up 48 weeds/m^2. The higher weed infestation was in plot with Avio genotype (48 ws/m^2) and lower in plot with Lena genotype (12 ws/m^2) (Table 6).

Table 6. The weed infestation in experimental plots

Genotype	Number of weeds/m^2										
	CIRAR	VERPE	POLCO	AMBAR	CHEAL	MATCH	GALAP	CONAR	SETVI	POLAV	Total
	2017										
Camelia	9	4	0	13	0	0	0	0	0	0	26
Lindo	15	6	0	15	0	1	0	0	0	0	37
Calena	5	4	2	18	1	0	0	0	2	1	33
Avio	7	4	3	20	1	1	2	4	2	4	**48**
GP 202	6	6	5	15	0	0	0	0	0	0	32
Lena	3	1	1	7	0	0	0	0	0	0	**12**
	2018										
Camelia	4	3	0	6	1	0	0	0	0	0	14
Lindo	0	1	0	4	0	1	0	0	0	0	6
Calena	0	0	0	4	0	0	0	0	0	0	4
Avio	3	2	1	10	0	1	1	1	1	1	21
GP 202	6	0	0	12	0	0	0	1	0	0	19
Lena	3	3	1	8	1	1	0	0	0	0	17
	2019										
Camelia	2	1	0	7	0	0	0	0	0	0	10
Lindo	5	4	0	15	0		3	0	0	0	27
Calena	3	2	1	20		2	0	0	2	1	31
Avio	10	3	0	16	0	0	2	1	2	5	39
GP 202	3	2	0	17	0	0	0	0	0	0	22
Lena	6	3	2	20	1	2	0	0	0	0	34

CIRAR: *Cirsium arvense* (Thristle); VERPE: *Veronica persica* (Speedwell); POLCO: *Polygonum convolvulus* (Wild buckwheat); AMBAR: *Ambrosia artemisiifolia* (Common ragweed); CHEAL: *Chenopodium album* (Lamb's quarters); MATCH: *Matricaria chamomilla;* GALAP: *Galium aparine;* CONAR: *Convolvulus arvensis* (Field bindweed); SETVI: *Setaria viridis* (Foxtail millet); POLAV: *Polygonum aviculare.*

The most abundant weed was *Ambrosia artemisiifolia* in all years of experimentation (Table 6).

Table 7 shows the F-test results of experimental weather conditions (year), genotype, and their reciprocal interaction effects on camelina seed yield. The interaction of the two variables was very significant for seed yield. This evidentiate the important influence of the seasonal variation on the different responses of camelina genotypes due to variability in the amount and distribution of rainfall and to temperature fluctuations.

Table 7. Analysis of variance for yield

Source of variance	DF	Yield (kg/ha)	
		Mean square	F value
A Factor: Year	2	1182806 (96.82%)	908.03***
Error A	6	1302 (0.11%)	
B Factor: Genotype	5	22727 (1.86%)	6.54***
Interaction AxB	10	11330 (0.93%)	3.26***
Error B	45	3473(0.28%)	

Camelina yield from experimental plots varied from 250 kg/ha to 825 kg/ha with higher yelds in 2019. The lowest yields were recorded in 2017 due to the downy mildew attack and the strong weed infestations. It can be seen that there is a correlation between yeld and precipitation because in 2019 (with a large amount of precipitation in April and May) the highest productions were obtained compared to 2018 in which there was a deficit of precipitation in the same period. This is especially evident for Camelia and GP 202 cultivars (Figure 2).

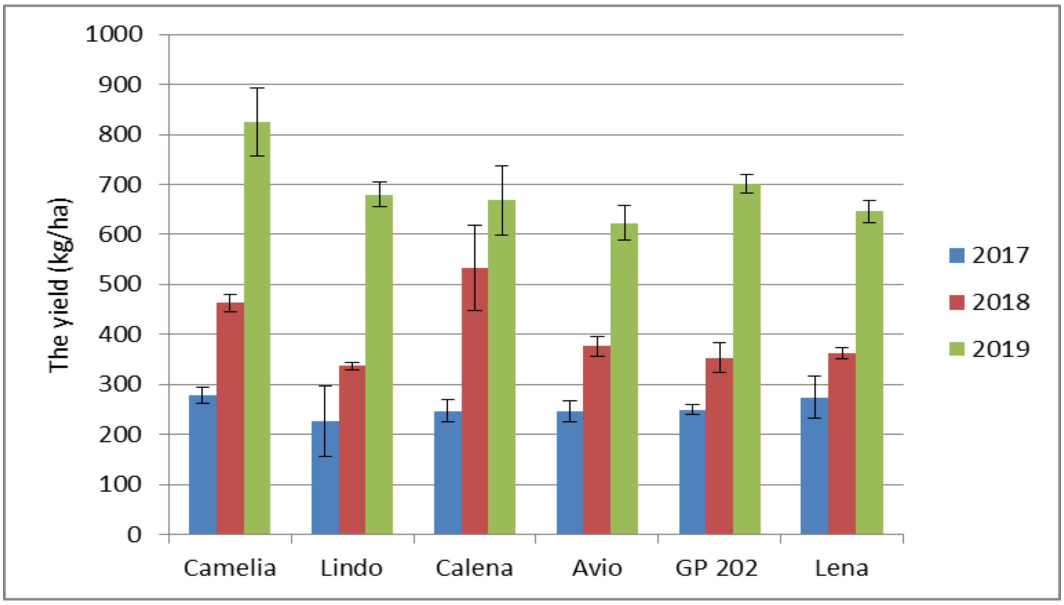

Figure 2. The seed yield of studied camelina cultivars

It is obvious that also the degree of infestation with weeds significantly reduced the yield. Negative correlations were obtained between yield and weed infestation (r = -0.68**), respectively between weed infestation and plant population (r = -0.75***) and significant for 1% probability, since the coefficients of correlation between yield and plant population was positive (r = 0.84***) and significant for 0.1% probability. Also a negative and significant correlation for 5% probability was between yield and downy mildew infestation, without taking into account the year 2018 when there were no conditions for the appearance of this disease (Table 8).

Table 8. The correlation coefficients among studied traits

Specification	Plant population	Downy mildew infestation	Weed infestation
Yield	r = 0.84***	r = 0.24 (all year) r = -0.59* (only 2017 and 2019)	r = -0.68**
Downy mildew infestation	r = -69**	1	
Weed infestation	r = -0.75***	r = -0.50	1

*, significant for 5% probability; **, significant for 1% probability; ***, significant for 0.1% probability.

Under Mediterranean region temperature and soil water are the most important environmental conditions affecting camelina seed yield and quality (Angelini et al., 2020). Our results shown that, in Temperate Continental region the camelina seed yield can by limited by water storage and low temperature during the vegetative phase in spring which led a low plant populations, increased downy mildew attack and a high weed infestation.

CONCLUSIONS

Our results illustrate that in experimental organic conditions, the plant population of camelina crop, infestation with downy mildew *(Plasmopara paradisiaca)* and weeds vary between years, but among the genotypes, too. The differences concerning the plant population resulted from seedbed conditions (rainfall or drought in autumn), unfavourable environmental conditions (water stagnation, soil compactation and frost in spring) and adaptability of genotype. The differences concerning weed infestation were observed in all varieties throughout the trial. The most abundant weed was *Ambrosia artemisiifolia*. Our results have shown that frequency of downy mildew attack was positive influenced by low temperature and high amount of precipitation in spring as well as by plant population and weed infestation. However, these results are of great interest since some varieties seem to be better adapted to organic conditions and, on the other hand, they could be used as valuable genitors in creating new camelina varieties adapted to organic control of downy mildew.

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