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ROMANIAN AGRICULTURAL RESEARCH, NO. 38, 2021
First Online: January, 2021. DII 2067-5720 RAR 2021-56

THE RELATION BETWEEN TECHNOLOGIES FOR LATE BLIGHT (*Phytophthora infestans*) AND THE YIELD COMPONENTS (BIOMASS) OF DIFFERENT POTATO VARIETIES

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ABSTRACT

***Phytophthora infestans*, the causal agent of late blight, is a major threat to potato crop all over the world. Fungicides play a crucial role in the integrated control of late blight. Variety choice is dictated by end users who demand cultivars with specific agronomic characters and these are difficult to combine with late blight resistance.**

The main aim of this research was to test the influence of two different densities (53300 plants/ha and 44400 plants/ha) and two different late blight control technologies (using only contact fungicides - TECH1 and alternative systemic and contact fungicides - TECH2) on the biomass of three heighly cultivated varieties (Riviera, Christian and Roclas).

The potato canopy of different varieties present large difference regarding stem length and leaf number, shoot and tubers weight in response to the applied technologies.

In 2014 conditions, the total biomass of the varieties and combinations of treatments studied did not differ significantly. In 2015 and 2016 conditions, the varieties were differentiated both by the amount of biomass accumulate on July 1-4 and by the statistical differentiation of the variants within the varieties. The studied densities had significant effects on plant biomass accumulations at the beginning of July.

In all years, at the beginning of July, due to the earlyness and sensitivity to late blight, the green mass in Riviera variety was significantly lower, compared to the green mass in the middle early varieties Roclas and Christian.

Keywords: potato, late blight (*Phytophthora infestana*), fungicides, technology, densities.

INTRODUCTION

The potato crop, according to FAO statistics (2017), is of global importance, occupying 4th position after the three "giant" grain (wheat, corn, rice). Potato crop is graded as a high potential food security and cash crop because of its ability to provide a high yield of high quality product per unit input with a shorter crop cycle (mostly <120 days) compared to major cereal crops like maize (Struik and Wiersema, 1999; Arega et al., 2018).

In terms of energy is of great importance for human consumption in a variety of ways of preparation and industrialization.

Currently potato is cultivated in different production systems in 140 countries in an area of 19 million hectares, with a total yearly production of 322 million tons and an average yield of 40 t/ha. Compared to the average yield of 30-40 t/ha obtained in Western countries in our country's production was 2.5-3.0 times less, this being determined by a number of limiting factors (Hermeziu, 2017).

Potato late blight, caused by *Phytophthora infestansis* one of the most destructive diseases of potato globally, including Romania (Zadoks, 2008; Hanukkalla, 2013). Potato late blight fast development when conditions are suitable causes massive disease spread which is called disease epifitoty. Disease spread depends to meteorological conditions, high infection, and potato growing period at disease attack time (Razukas, 2008).

It is known that the application of limited number of fungicides repeatedly in a specific area increases the insensitivity of the

Received 3 November 2020; accepted 7 January 2021.

pathogen and decreases the efficacy of the fungicides due to the pathogen strain shifting to resist the fungicides. Standard recommendations for delaying the development of insensitivity to fungicides in fungal pathogens include rotating classes of fungicides (Brent and Hollomon, 2007; Mekonen and Tadesse, 2018).

The optimization of plant density is one of the most important subjects of potato production management, because it affect seed cost, plant development, yield and quality of the crop (Bussan et al., 2007).

More than 160 years after the first appearance of *P. infestans*, late blight continues to pose a major threat to potato production, and its control today is possible only through frequent application of fungicides (Cooke et al., 2011; Fry and Goodwin, 1997). Nevertheless, yield loss caused by this plant pathogen is estimated to be approximately 16% of the world potato production (Haverkort et al., 2009), in spite of these efforts (Axel et al., 2012).

MATERIAL AND METHODS

The experiment was carried out for three consecutive years (2014-2016) to the National Institute of Research and Development for Potato and Sugar Beet - Braşov and included three factors: potato varieties, fungicides control and two different densities. It was used a complete randomized block design with four replicates and the following factors: A factor represented by Riviera, Roclas and Christian varieties, B factor represent by the two densities (0.75 m x 0.25 m and 0.75 m x 0.30 m), and C factor represent the late blight control with different fungicides (2 variants of treatment: TECH1 - only contact fungicides and TECH2 - contact and systemic fungicides).

Disease severity was scored using 1-9 scale. 1: None or very few lesions on the leaflets (0% foliage affected); 2: 3% foliage affected; 3: 10% foliage affected; 4: 25% foliage affected; 5: 50% foliage affected; 6: More than 50% but less than 75% stem and foliage affected; 7: More than 75% but less than 90% affected; 8: Only very few green areas of stem and leaf (much less 10%); 9: 100% foliage completely destroyed (Anonymous, 1947; Cruiskshank et al., 1982). The assessment used a key on the whole plant.

All the others aspects regarding cultivation and maintenance was in line with current good agricultural practice.

Two plants were randomly selected at the centre of each plot and their heights, number of main strains, the lenght of the middle leaf, aerial part weight, underground part weight, number of tubers and their weight in hill were measured.

The data obtained were statistically processed using the MSTAT-C program (test Duncan and analysis of variance).

RESULTS AND DISCUSSION

The climatic conditions during the vegetation period (Table 1) determined decisively the growth and development of the potato plants and the evolution of late blight attack in the years 2014-2016.

Table 1. Air temperature and rainfalls during the experiment

	Month					
	April	May	June	July	August	
Year	**Air temperature (°C)**					**Average**
2014	9.1	13.9	16.4	19.3	18.7	14.3
2015	7.9	15.1	17.3	20.7	19.9	16.7
2016	11.3	12.4	19.0	19.7	18.4	15.0
MMA	8.5	13.6	16.5	18.1	17.5	13.6
	Amount of rainfall (mm)					**Amount**
2014	118.5	100.2	76.0	115.4	60.6	34.4
2015	28.0	44.8	175.6	42.4	22.6	111.0
2016	98.4	100.4	121.2	28.8	85.8	38.0
MMA	50.0	82.0	96.7	99.8	76.4	52.5

In 2014, the first appearance of late blight was recorded on June 17, 35 days after emergence of plants for Riviera and 28 days after for Roclas and Christian varieties.

In 2015, favorable climatic conditions for late blight during June led to its appearance on July 1st, 41 days after emergence for Riviera and 39 days after for Roclas and Christian varieties.

The earliest appearance of late blight in the last 24 years was recorded in 2016. The appearance of the first late blight outbreaks was reported in the experimental field on May 31, 2016, the earliest appearance in the last 24 years. Late blight appeared to Riviera variety 18 days after emergence and to Roclas and Christian varieties at 15 days after.

Table 2. Late blight attack degree in early July (2014-2016)

No.	Variety	Density plants/ha	Late blight control technology	Late blight mark (1-9)		
				July, 2nd 2014	July, 1st 2015	June, 27th 2016
1	Riviera	44.4	TECH1	5.0 a	0.9 ab	6.5 a
2			TECH2	4.0 b	0.1 d	3.8 b
3		53.3	TECH1	5.0 a	1.3 a	7.1 a
4			TECH2	3.8 b	0.5 bc	4.1 b
Mean				4.4 a	0.7 a	5.4 a
5	Roclas	44.4	TECH1	1.4 cd	0.8 b	3.7 b
6			TECH2	0.9 def	0.3 cd	2.0 c
7		53.3	TECH1	1.5 c	0.6 bc	3.3 b
8			TECH2	0.8 ef	0.3 cd	2.1 c
Mean				1.1 b	0.5 a	2.8 b
9	Christian	44.4	TECH1	1.3 cde	0.3 cd	3.4 b
10			TECH2	0.5 f	0.1 d	2.0 c
11		53.3	TECH1	1.3 cde	0.3 cd	3.4 b
12			TECH2	0.4 f	0.1 d	2.0 c
Mean				0.9 b	0.2 a	2.7 b
LDS 5% (Variety)				0.4	0.4	0.6
LDS 5% (Variety*Density*TECH)				0.5	0.4	0.9

Maximum degree of attack on the Riviera variety were registered in 2014 (5.0) and 2016 (7.1) to the variants with TECH1 control technology. For Roclas and Christian varieties, in similar combinations, the recorded values varied between 1.3-1.5 in 2014 and 3.4-3.7 in 2016, respectively emergence (Table 2).

To Riviera variety, applying TECH2 technology, the late blight marks were significantly lower up to 3.8-4 in 2014 and 2016, and in 2015 up to 0.1-0.5, given that in the years with stronger attack in the Roclas and Christian varieties the maximum value of late blight was 2.1.

The total biomass accumulated in different years for the studied variants and shown in Table 2, reflects the different conditions of vegetation period. The experimental average of the total biomass was 1041 g mv./plant (CV = 23.2%) in 2014, 842 g mv./plant (CV = 24.0%) in 2015, and 1107 g mv./plant (CV = 24.1%) (Table 3).

Table 3. Effects of interaction between variety and late blight control technology on the tubers yield formed in early July

No.	Variety	Density thousands hills/ha	Late blight control technology	Total biomass (g gt/plant)		
				July, 4th 2014	July, 2nd 2015	July, 1st 2016
1	Riviera	44.4	TECH1	1064 abc	719 cd	1140 bcd
2			TECH2	1233 ab	913 abcd	1075 bcd
3		53.3	TECH1	1158 abc	652 d	979 bcd
4			TECH2	778 c	739 cd	827 cd
Mean				1058 a	756 b	1005 b
5	Roclas	44.4	TECH1	1228 ab	1183 a	1721 a
6			TECH2	1320 a	1027 abc	1241 bc
7		53.3	TECH1	1082 abc	670 d	1243 bc
8			TECH2	931 abc	822 bcd	902 bcd
Mean				1140 a	956 a	1277 a
9	Christian	44.4	TECH1	1061 abc	935 abcd	1128 bcd
10			TECH2	921 abc	1141 ab	1349 ab
11		53.3	TECH1	855 bc	598 d	714 d
12			TECH2	871 bc	710 cd	969 bcd
Mean				927 a	846 a	1040 b
Experimental mean (CV)				1041 (23.2%)	842 (24.0%)	1107 (24.1%)
LDS 5% (Variety)				274 g/plant	158 g/plant	164 g/plant
LDS 5% (Variety*Distance*Treatment)				358 g/plant	300 g/plant	396 g/plant

In 2014, the total biomass of the varieties and combinations studied did not differ significantly.

In 2015 and 2016, the varieties were differentiated both by the amount of biomass on July 1-4 and by the statistical differentiation of the variants within the varieties.

To the Riviera variety, in both years, the determined biomass was significantly lower (756 g mv./plant and 1005 g mv./plant), compared to the total biomass determined for Roclas variety (956 g mv./ plant and 1277 g mv./plant). Also the total biomass of Christian variety (846 g mv./plant and 1040 g mv./plant) was significantly lower than Roclas biomass but only in 2016 (Table 3).

Table 4. The interaction between variety and density on total biomass in early July

Variety	Density thousands hills/ha	Total biomass (g gt/plant)		
		July, 4th 2014	July, 2nd 2015	July, 1st 2016
Riviera	44.4	1148 a	816 abc	1008 bc
	53.3	968 a	696 c	03 cd
Roclas	44.4	1274 a	1105 a	1481 a
	53.3	1006 a	746 bc	1073 bcd
Christian	44.4	991 a	1038 ab	1238 b
	53.3	863 a	653 c	841 d
Mean	44.4	1137	986	1275
	53.3	945 O	698 O	939 O
Dl 5% (Distance)		72 g/plant	118 g/plant	282 g/plant
LDS (Variety*Distance)		595 g/plant	289 g/plant	231 g/plant

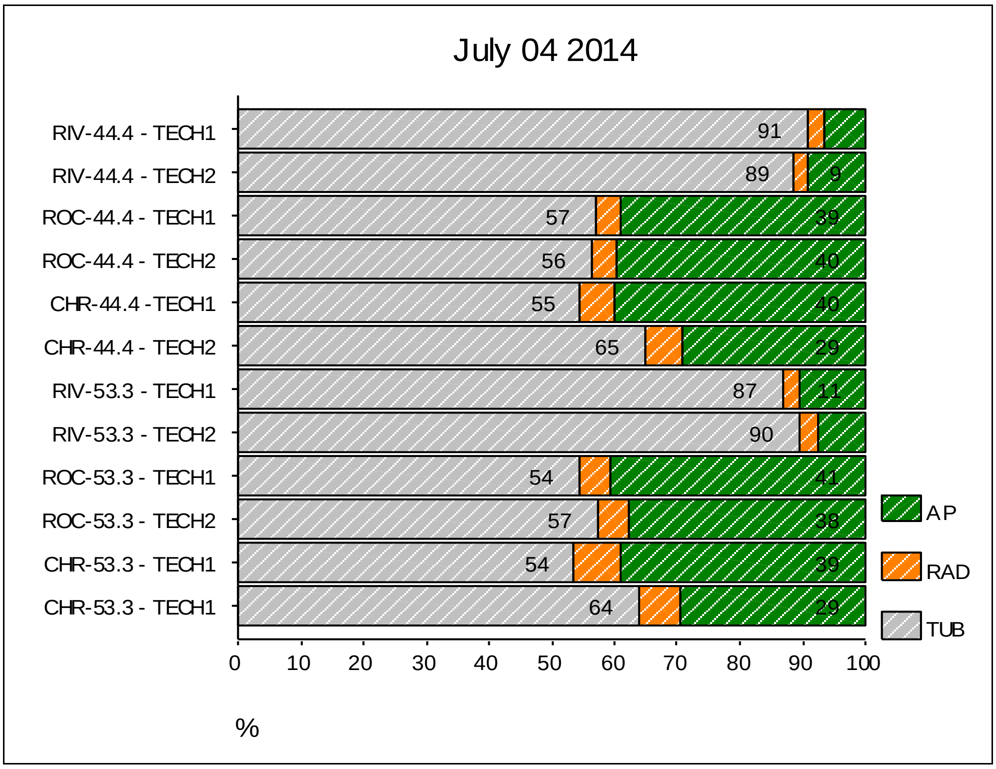
The studied densities had significant effects on plant biomass at the beginning of July. Compared to the average biomass quantities obtained in the variants with planting density 44.4 thousand hills/ha of 1137 g gt./plant in 2014, of 986 g gt./plant in 2015 and 1275 g gt./plant in 2016 at the density of 53.3 thousand hills/ha, the total fresh biomass in the respective years was 945 g gt./plant, 698 g gt./plant and 939 g gt./plant.

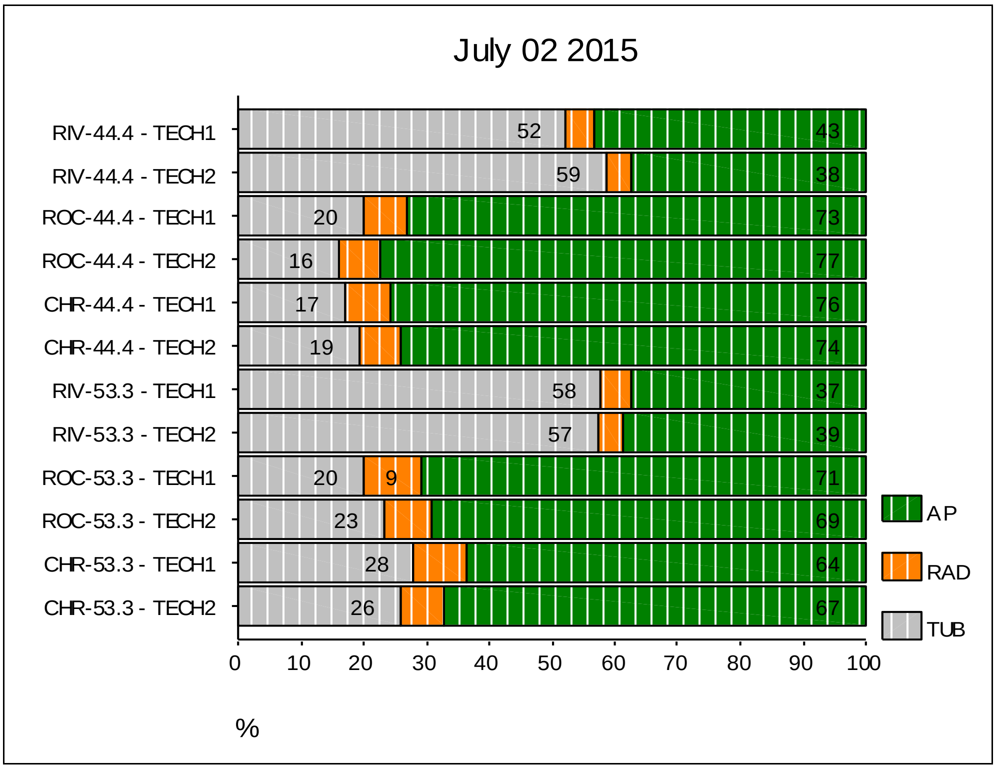
In two years out of the three studied, the differences in biomass due to densities were significant for Roclas and Christian varieties (Table 4).

Table 5. The interaction between variety and late blight control technology on total biomass in early July

Variety	Late blight control technology	Total biomass (g gt/plant)		
		July, 4th 2014	July, 2nd 2015	July, 1st 2016
Riviera	TECH1	1111 a	686 b	1060 b
	TECH2	1006 a	826 ab	951 b
Roclas	TECH1	1155 a	926 a	1482 a
	TECH2	1125 a	924 a	1072 b
Christian	TECH1	958 a	766 ab	921 b
	TECH2	896 a	925 a	1159 b
Mean	TECH1	1075	793	1154
	TECH2	1008 ns	891 *	1061 ns
Dl 5% (Treatment)		103 g/plant	87 g/plant	301 g/plant
LDS (Variety*Treatment)		254 g/plant	212 g/plant	280 g/plant

In just one year, TECH2 treatments provided on average a higher amount of biomass (891 g gt./plant) than TECH1 (793 g gt./plant) without significant differences between varieties (Table 5).





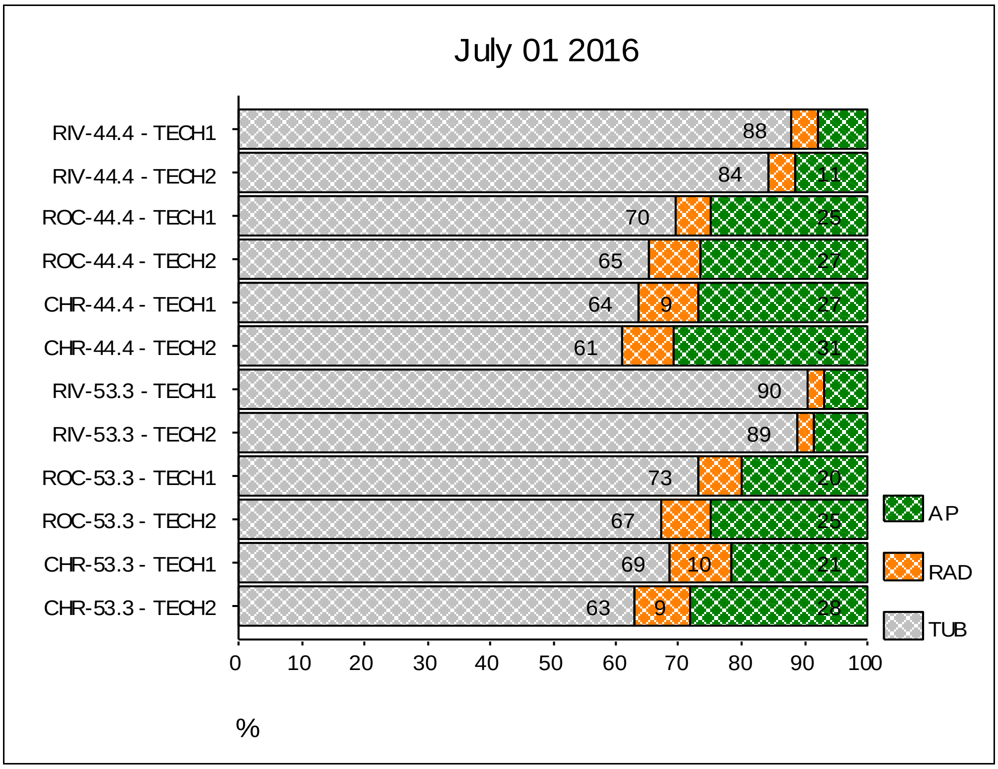


Figure 1. Percentage structure of plant biomass at the beginning of July

In 2014 and 2016, the climatic conditions between the emergence of the plants and the measurements at the beginning of July were characterized by higher rainfall, moderate temperatures, shorter sunlight and higher relative air humidity. These conditions determined in the early planted crops the massive growth of the tubers due to the foliage, simultaneously with the loss of the foliage due to late blight attack, especially for Riviera variety.

In 2014, at the time of the measurements, the percentage of green foliage in the total biomass for the Riviera variety was between

6.7 and 39.5%, for Roclas between 10.6 and 39.9%, and for Christian between 29.5 and 40.8%.

The production of tubers was between 56.3 and 90.9% at Riviera, 54.6 and 89.6% at Roclas, and at Christian between 53.6 and 63.9%.

In 2016, the percentages determined for the active foliage of the plants varied between 7.9 and 26.7% in Riviera, 7.0 and 27.0% in Roclas and between 20.1 and 28.1% in Christian and for the accumulated production between 65.2 and 88.0% were determined in Riviera, between 61.1 and 90.4% in Roclas, and in Christian between 63.1 and 73.30%.

In 2015, the late blight attack began only after measurements were taken. At the beginning of July, the aerial part of the plants represented from the total biomass between 37.5 and 77.3% at Riviera, 37.2 and 75.6% at Roclas and at Christian variety between 60.6 and 70.8%. This year, due to the short period of production accumulation, the percentages of biomass production were lower, between 16.1 and 58.6% in the Riviera and between 17.1 and 57.8% in Roclas. For the Christian variety to which the accumulation of production was later, the percentage of biomass production varied depending on the variant between 20.1 and 28.0%.

At the beginning of July, the percentages of fresh biomass components per plant did not differ significantly between the densities of 44.4 and 53.3 thousand plants per hectare. Also, the differences were not statistically assured for the TECH1 and TECH2 control technology (Figure 1).

CONCLUSIONS

In the years with favorable conditions for late blight the Riviera variety, sensitive one, the degree of attack was significantly higher than to Roclas and Christian varieties, with average score by 4.4 on July 2, 2014 and 5.4 on June 27, 2016, compared to the scores determined for the less sensitive varieties, Roclas (1.1-2.8) and Christian (0.9-2.7).

In 2015, favorable from the thermohydric point of view to the growth of the foliage and with reduced late blight attack, the foliage of the plants of the early variety Riviera was three times more developed compared to 2014 and 2016, in which the late blight attack was very strong.

For the middle early varieties Roclas and Christian, more resistant to late blight, with significantly richer foliage, at the beginning of July, when the registrations were made, the mass of the foliage practically doubled.

According to the results of this study, an adequate planting density accompanied by an optimal number of treatments, depending on climatic conditions, are solutions for managing an efficient potato crop. By developing a proper canopy the late blight attack is properly managed and there is an increase in productivity. It also contributes to the rational application of fungicides, reducing costs and environmental pollution.

REFERENCES

Anonymous, 1947. *The measurement of potato blight*. Trans. Brit. Mycol. Soc., 31: 140-141.

Arega, A., Tekalign, A., Solomon, T., Tekile, B., 2018. *Effect of inter and intra row spacing on tuber yield and yield components of potato (Solanum tuberosum L.) in Guji zone, Southern Ethiopia*. J. Adv. Plant. Sci., 1: 102.

Axel, C., Zannini, E., Coffey, A., Guo, J., Waters Deborah, K., Arendt, E.K., 2012. *Ecofriendly control of potato late blight causative agent and the potential role of lactic acid bacteria: a review*. Appl. Microbiol. Biotechnol., 96: 37-48. DOI 10.1007/s00253-012-4282-y

Brent, K.J., and Hollomon, D.W., 2007. *Fungicide resistance in crop pathogens: How can it be managed?* FRAC Monograph 1, 2nd Ed. CropLife International, Brussels: 55.

Bussan, A.J., Mitchell, P.D., Copas, M.E., Drilias, M.J., 2007. *Evaluation of the effect of density on potato yield and tuber size distribution*. J. Crop. Sci., 47: 2462-2472.

Cooke, L.R., Schepers, H., Hermansen, A., Bain, R.A., Bradshaw, N.J., Ritchie, F., Shaw, D.S., Evenhuis, A., Kessel, G.J.T., Wander, J.G.N., Andersson, B., Hansen, J.G., Hannukkala, A., Naerstad, R., Nielsen, B.J., 2011. *Epidemiology and integrated control of potato late blight in Europe*. Potato Res. 54(2): 183-222. DOI:10.1007/s11540-011-9187-0

Cruiskshank, G., Stewart, H.E., Wastie, R.E., 1982. *An illustrated assessment key for foliage blight of potatoes*. Potato Research, 25: 213-214.

FAOSTAT - Food and Agriculture Organization of the United Nations, 2017. *Database-Agricultural Production*. Retrieved from: http://apps.fao.org; consulted: April, 2020.

Fry, W.E., and Goodwin, S.B., 1997. *Resurgence of the Irish potato famine fungus*. Bioscience, 47(6): 363-371. DOI:10.2307/1313151

Hanukkalla, A.O., 2013. *Changes in epidemiology and population structure of P. infestans in Finland 1847-2011*. Proceedings of the fourteenth workshop of EuroBlight workshop. In: Schepers H.T.A.M. (eds.), PPO Special Report, 16: 123-135.

Haverkort, A., Struik, P., Visser, R., Jacobsen, E., 2009. *Applied biotechnology to combat late blight in potato caused by Phytophthora infestans*. Potato Res., 52(3): 249-264. DOI:10.1007/s11540-009-9136-3

Hermeziu, M., 2017. *Research on the influence of some technological meaures of late blight (Phytophthora infestans) on production and quality*. Ph. D. Thesis, UASVM Cluj-Napoca.

Mekonen, S., and Tadesse, T., 2018. *Effect of varieties and fungicides on potato late blight [Phytophthora infestans, (Mont.) de Bary]*. Management Agrotechnology, 7: 182. DOI: 10.4172/2168-9881.1000182

Razukas, A., Jundulas, J., Asakaviciute, R., 2008. *Potato cultivars susceptibility to potato late blight (Phytopthtora infestans)*. Applied Ecology and Environmental Research: 95-106.

Struik, P.C., and Wiersema, S.G., 1999. *Seed potato technology*. Wageningen Pers, Wageningen, The Netherlands: 383.

Zadoks, J.C., 2008. *The potato murrain on the Europe Continent and the Revolutions of 1848*. Potato Research, 51: 5-45.