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EFFECTS OF FUNGICIDES, ROW SPACING AND CULTIVAR ON POTATO BIOMASS AND YIELD

Manuela Hermeziu[1*], Gavrilă Morar[2], Floriana Maria Ştefan[1], Radu Hermeziu[1]

[1]National Institute of Research and Development for Potato and Sugar Beet Braşov, 2 Fundăturii str., 500470 Braşov, Braşov County, Romania
[2]University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Mănăştur str., 400372 Cluj-Napoca, Cluj County, Romania
[*]Corresponding author. E-mail: hermezium@gmail.com

ABSTRACT

Trials were performed to the National Institute of Research and Development for Potato and Sugar Beet between 2014-2016. Experimental design was completely randomized with four replicates, two planting densities (53,300 plants/ha, respectively 44,400 plants/ha) and two programs of fungicides application (only contact products - TECH 1; contact, translaminar and systemic product - TECH 2). Analysed varieties were Riviera (very early and very sensitive to late blight variety), Christian and Roclas (medium early and moderately susceptible to late blight varieties). The highest yields were obtained in variety Roclas (between 877 and 1048 g/plant), compared with yields that were recorded in late July in Riviera (between 698 and 732 g/plant) and Christian (between 668 and 820 g/plant) varieties.

Keywords: potato, *Phytophthora infestans*, fungicides, technology.

INTRODUCTION

Late blight is the most destructive of all potato diseases and was responsible for the Irish Famine in the middle of the 19th century. It affects both potato foliage in the field and tuber in the storage, which can absolutely destroy a crop, producing a 100% crop loss (Tsedaley, 2014). Cultural control measures such as eliminating cull piles and volunteer potatoes, using proper harvesting and storage practices, can be used to reduce the pathogen populations by reducing its survival, dispersal and reproduction (Garrett and Dendy, 2001).

Recent research undertaken in United Kingdom by Bain et al. (2013) have shown that in the presence of more aggressive genotypes of *Phytophthora* the difference between varieties tended to be smaller in the untreated variants compared to those treated with fungicides. The use of fungicides allows a better differentiation between varieties.

Reducing the number of primary outbreaks is equivalent to a saving of 1-3 chemical treatments, by delaying the installation of epidemic disease phase (Cupsa, 1987).

Between the yield of tubers and number of stolons, tubers number and principal strains there is a close correlation with the density and size of planted tubers (Bretan and Simionescu, 1972; Diaconu, 1995). The main stems density per hectare strongly influences the average number of stems at hill and the average weight of a tuber (Morar, 1979). According to some authors (Burdon and Chilvers, 1982) high planting density determines a higher intensity of the disease. The reason that sometimes the results can be in contradiction is the fact that differences in plant density can be higher at the beginning of the season, but become less important as the season progresses and the plants grow to compensate the lower density (Pfleeger and Mundt, 1998).

MATERIAL AND METHODS

The research was carried out to the National Institute of Research and Development for Potato and Sugar Beet - Braşov between 2014-2016 on a chernozem soil.

Each year the field experiments were set up in random blocks, 4 replicate plots with 4

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rows each with 20 plants. The size of elementary plot was 18 m^2.

Planting was made on 1st April 2014, 27th April 2015 and 31 March 2016. In all cases, cultivation and maintenance was in line with current good agricultural practice.

Potato cultivars: Riviera (Dutch potato variety) very susceptible to late blight, Christian and Roclas (Romanian potato varieties) moderately susceptible to late blight.

First symptom of late blight observed: 2014, June 17th, 2015, July 1st and 2016, May 31st.

Fungicides application (product, active ingredient, dose):

2014 – TECH 1: June, 17th - Dithane M-45 2,5 kg/ha (mancozeb 80%); June, 25th - Bravo 500 SC 2,0 l/ha (clorotalonil 500 g/l); July, 2nd - Electis 75 WG 1,8 kg/ha (mancozeb 68,5% + zoxamide 8,8%); July 8th - Bravo 500 SC 2,0 l/ha (clorotalonil 500 g/l); July, 15th - Folpan 80 WG 2,0 kg/ha (folpet 80%); July, 24th - Shirlan 500 SC0,4 l/ha (fluazinam 500 g/l); July, 31st - Shirlan 500 SC 0,4 l/ha (fluazinam 500 g/l);

2014 – TECH 2: June, 17th - Ridomil Gold Mz 68 WG2,5 kg/ha (mefenoxam 4% + mancozeb 64%); June, 26^{5h} - Consent 450 SC 2,0 kg/ha (fenamidon 75 g/l + propamocarb 375 g/l); July, 2nd - Drago 76 WP2,0 kg/ha (cymoxanil 6% + mancozeb 70%); July 8th - Revus 250 SC 0,6 l/ha (mandipropamid 250 g/l); July, 15th - Acrobat Mz 90/600 WP 2,0 kg/ha (dimetonorf 9% + mancozeb 60%); July, 24th - Bravo 500 SC 2,0 l/ha (clorotalonil 500 g/l l); July, 31st - Shirlan 500 SC 0,4 l/ha (fluazinam 500 g/l);

2015 – TECH 1: July, 1st - Dithane M-45 2.5 kg/ha (mancozeb 80%); July, 8th - Electis 75 WG 1.8 kg/ha (mancozeb 68.5% + zoxamide 8.8%); July 15th - Bravo 500 SC 2.0 l/ha (clorotalonil 500 g/l); July, 22nd - Folpan 80 WG 2.0 kg/ha (folpet 80%); July 27th - Bravo 500 SC 2.0 l/ha (clorotalonil 500 g/l); August 3rd - Shirlan 500 SC 0.4 l/ha (fluazinam 500 g/l);

2015 – TECH 2: July, 1st - Ridomil Gold Mz 68 WG 2.5 kg/ha (mefenoxam 4% + mancozeb 64%); July, 15th - Drago 76 WP 2.0 kg/ha (cymoxanil 6% + mancozeb 70%); July 27th - Consento 450 SC 2.0 kg/ha (fenamidon 75 g/l + propamocarb 375 g/l); August 3rd - Shirlan 500 SC 0.4 l/ha (fluazinam 500 g/l);

2016 – TECH 1: May, 30 - Dithane M-45 2.5 kg/ha (mancozeb 80%); June, 7th - Bravo 500 SC 2.0 l/ha (clorotalonil 500 g/l); June 16th - Folpan 80 WG 2.0 kg/ha (folpet 80%); June, 27th - Bravo 500 SC 2.0 l/ha (clorotalonil 500 g/l); July 8th - Electis 75 WG 1.8 kg/ha (mancozeb 68.5% + zoxamide 8.8%); July 15th - Shirlan 500 SC 0.4 l/ha (fluazinam 500 g/l); July 24th - Shirlan 500 SC 0.4 l/ha (fluazinam 500 g/l);

2016 – TECH 2: May, 30 - Ridomil Gold Mz 68 WG 2.5 kg/ha (mefenoxam 4% + mancozeb 64%); June, 7th - Consento 450 SC 2.0 kg/ha (fenamidon 75 g/l + propamocarb 375 g/l); June, 16th - Infinito 687,5 SC 1.4 l/ha (fluopicolid 62,5 g/l + propamocarb 625 g/l); June 27th - Consento 450 SC 2.0 kg/ha (fenamidon 75 g/l + propamocarb 375 g/l); July 8th - Revus 250 SC 0.6 l/ha (mandipropamid 250 g/l); July 15th - Bravo 500 SC 2.0 l/ha (clorotalonil 500 g/l); July 24th - Shirlan 500 SC 0.4 l/ha (fluazinam 500 g/l).

Late blight assessment: plots are assessed for the extent of blight spots on the leaves. Each plot was assessed as a whole for percentage disease severity using a standard accepted severity key (Anonymous, 1947; Cruickshank et. al., 1982).

Yield assessment: two rows in the centre of each plot were harvested mentioned the number and the weight of tubers with blight.

RESULTS AND DISCUSSION

Years 2014-2016 in Braşov area were warmer and with less rainfalls amount than normal. In the period of vegetation on the whole annual average air temperature was higher with 1.2°C and the amount of rainfall was below the annual amount with 26.6 mm in 2014, 11 mm in 2015 and 33 mm in 2016 (Table 1).

Table 1. Air temperature and rainfall during the experiment

Year	Month					Average
	May	June	July	August	September	
	Air temperature (°C)					
2014	13.4	16.4	19.3	18.7	14.3	16.4
2015	15.1	17.3	20.7	19.9	16.7	17.9
2016	12.4	19.0	19.7	18.4	15.0	16.9
MMA	13.6	16.5	18.1	17.5	13.6	15.9
	Amount of rainfall (mm)					Total
2014	94.4	76.0	115.4	60.6	34.4	380.8
2015	44.8	175.6	42.4	22.6	111.0	396.4
2016	100.4	121.4	28.8	85.8	38.0	374.4
MMA	82.0	96.7	99.8	76.4	52.5	407.4

As can be observed (Table 2) the average number of tubers/hill at the beginning of July was 14.5 (26.0%) in 2014, 7.5 (27.4%) in 2015 and 16.9 (19.2%) in 2016.

In 2014 Roclas variety was noted by the highest number of tubers to the hill (17.7), while to Riviera and Christian varieties were determined an average of 12.0, respectively 13.7 tubers/hill. The number of tubers to the hill has not been significantly modified by the combined effect of plants density and differentiated late blight control technology. In 2015, in which were formed the lowest number of tubers at hill, the varieties have not differed significantly, Riviera having 8.3 tubers/plant, Roclas 6.8 tubers/plant and Christian 7.5 tubers/plant. In 2016, Roclas and Christian varieties had a significantly higher number of tubers to the hill (18.4 and 19.9 tubers/hill) compared with the average number of Riviera variety (12.2 tubers/hill). Although the number of tubers to the hill has not significantly different, it can be seen in Roclas and Riviera varieties a tendency to decrease the number of tubers to TECH 2 variants towards TECH 1, especially at high planting density of 53.3 thousand hills/ha (Table 2).

Table 2. Effects of interaction between variety, density and late blight control technology on the number of tubers formed in early July

No.	Variety	Density (thousand hills/ha)	Late blight control technology	Number of tubers/plant		
				July 4th, 2014	July 2nd, 2015	July 1st, 2016
1	Riviera	44.4	TECH 1	10.6 c	7.5 abc	16.0 bcd
2			TECH 2	15.4 abc	9.3 ab	11.1 de
3		53.3	TECH 1	12.6 bc	8.4 abc	13.3 cde
4			TECH 2	9.3 c	8.1 abc	8.5 e
Mean				**12.0 b**	**8.3 a**	**12.2 b**
5	Roclas	44.4	TECH 1	19.0 a	7.4 abc	22.4 a
6			TECH 2	19.5 a	8.1 abc	19.8 ab
7		53.3	TECH 1	18.3 ab	5.3 c	21.8 a
8			TECH 2	14.1 abc	6.3 c	15.8 bcd
Mean				**17.7 a**	**6.8 a**	**19.9 a**
9	Christian	44.4	TECH 1	13.8 abc	7.8 abc	21.4 a
10			TECH 2	11.6 c	9.8 a	20.3 ab
11		53.3	TECH 1	14.8 abc	6.9 abc	15.0 bcd
12			TECH 2	14.6 abc	5.8 bc	17.1 abc
Mean				**13.7 b**	**7.5 a**	**18.4 a**
Experimental mean (CV)				**14.5** (26.0%)	**7.5** (27.4%)	**16.9** (19.2%)
LSD 5% (Variety)				3.4 tub./plant	4.1 tub./plant	3.1 tub./plant
LSD 5% (Variety * Density * Treatment)				5.6 tub./plant	3.1 tub./plant	4.8 tub./plant

In 2014, the total biomass of the varieties and studied combinations was not significantly differentiated.

In the years 2015 and 2016, the varieties were distinguished both by the quantity of biomass at the beginning of July and statistical differentiation of variants within varieties.

For Riviera variety, in both years, biomass determined at beginning of July was significantly lower (756 g/plant and 1058 g/plant), compared to the total biomass determined in Roclas variety (956 g/plant and 1277 g/plant). Also, total biomass of Christian variety was significantly lower than the Roclas variety biomass in the year 2016 (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/plant)		
				July 4th, 2014	July 2nd, 2015	July 1st, 2016
1	Riviera	44.4	TECH 1	1064 abc	719 cd	1140 bcd
2			TECH 2	1233 ab	913 abcd	1075 bcd
3		53.3	TECH 1	1158 abc	652 d	979 bcd
4			TECH 2	778 c	739 cd	827 cd
Mean				**1058 a**	**756 b**	**1005 b**
5	Roclas	44.4	TECH 1	1228 ab	1183 a	1721 a
6			TECH 2	1320 a	1027 abc	1241 bc
7		53.3	TECH 1	1082 abc	670 d	1243 bc
8			TECH 2	931 abc	822 bcd	902 bcd
Mean				**1140 a**	**956 a**	**1277 a**
9	Christian	44.4	TECH 1	1061 abc	935 abcd	1128 bcd
10			TECH 2	921 abc	1141 ab	1349 ab
11		53.3	TECH 1	855 bc	598 d	714 d
12			TECH 2	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%)
LSD 5% (Variety)				274 g/plant	158 g/plant	164 g/plant
LSD 5% (Variety * Density * Treatment)				358 g/plant	300 g/plant	396 g/plant

Date of planting had strong effects on the number of tubers formed on the hill.

In the years in which the crop was planted early (2014, April 1st and 2016, March 31), due to temperature and humidity conditions favourable to tuberization, the number of tubers per plant was significantly higher (15.6 tubers/plant in 2014 and 18.5 tubers/plant in 2016), compared with 12.1 tubers/plant in 2015, a year when after planting (April 27th), less favourable conditions followed (Table 4). Average number of tubers per plant varied between 9.6 and 11.8 in Riviera variety, between 15.1 and 22.8 in Roclas variety and between 21.0 and 11.6 in Christian variety. To the end of July experimental average for the yield of tubers to the hill was 770 g/plant in 2014, 781 g/plant in 2015 and 861 g/plant in 2016. In all years the highest yields were obtained to Roclas variety (between 877 and 1048 g/plant), compared with yields that were recorded to Riviera (between 689 and 715 g/plant) and Christian varieties (between 668 and 820 g/plant).

The highest yield at the end of July (between 1001 g/plant and 1283 g/plant) was obtained to Roclas variety at the density of 44.4 thousand hills/ha when was applied late blight treatments TECH 1. It should be mentioned that the difference compared to the rest of the variants was significant only in 2014, year with strong attack of blight (Table 5).

Table 4. Effects of interaction between variety, density and late blight control technology on number of tubers formed at the end of July

No.	Variety	Density (thousands plant/ha)	Late blight control technology	Number of tubers/plant		
				August 1st, 2014	July 30, 2015	July 27th, 2016
1	Riviera	44.4	TECH 1	11.3 c	9.0 c	14.0 cd
2			TECH 2	12.8 bc	10.9 abc	11.4 d
3		53.3	TECH 1	12.3 bc	8.5 c	10.8 d
4			TECH 2	10.5 c	10.1 bc	10.9 d
Mean				**11.7 b**	**9.6 b**	**11.8 b**
5	Roclas	44.4	TECH 1	20.0 a	14.3 abc	26.4 a
6			TECH 2	16.4 abc	13.4 abc	20.0 abc
7		53.3	TECH 1	15.6 abc	16.8 a	20.8 abc
8			TECH 2	18.9 a	15.9 ab	24.3 ab
Mean				**17.7 a**	**15.1 a**	**22.8 a**
9	Christian	44.4	TECH 1	18.6 a	13.6 abc	25.1 ab
10			TECH 2	19.1 a	11.0 abc	20.4 abc
11		53.3	TECH 1	17.6 ab	10.5 abc	18.8 bc
12			TECH 2	14.3 abc	11.1 abc	19.8 abc
Mean				**17.4 a**	**11.6 b**	**21.0 a**
Experimental mean (CV)				**15.6** (22.5%)	**12.1** (31.3%)	**18.5** (23.3%)
LSD 5% (Variety)				3.2 tub./plant	2.8 tub./plant	4.0 tub./plant
LSD 5% (Variety * Density * TECH)				5.2 tub./plant	5.6 tub./plant	6.4 tub./plant

Table 5. Effects of interaction between variety, density and late blight control technology on yield at the end of July

No.	Variety	Density (thousands hill/ha)	Late blight control technology	Yield (g/hill)		
				August 1st, 2014	July 30, 2015	July 27th, 2016
1	Riviera	44.4	TECH 1	708 cd	747 bcde	962 abc
2			TECH 2	791 bc	903 abc	679 bc
3		53.3	TECH 1	644 cd	614 e	559 c
4			TECH 2	648 cd	665 de	658 bc
Mean				**698 b**	**732 b**	**715 b**
5	Roclas	44.4	TECH 1	1283 a	1001 a	1223 a
6			TECH 2	986 b	915 ab	1013 ab
7		53.3	TECH 1	744 cd	857 abcd	938 abc
8			TECH 2	769 bc	733 bcde	1020 ab
Mean				**946 a**	**877 a**	**1048 a**
9	Christian	44.4	TECH 1	836 bc	774 abcde	992 ab
10			TECH 2	676 cd	685 bcde	955 abc
11		53.3	TECH 1	651 cd	809 abcde	663 bc
12			TECH 2	510 d	676 bcde	668 bc
Mean				**668 b**	**735 b**	**820 b**
Experimental mean (CV)				**770** (19.1%)	**781** (28.4%)	**861** (28.1%)
LSD 5% (Variety)					104 g/plant	213 g/plant
LSD 5% (Variety *Density * TECH)					205 g/plant	360 g/plant

A similar trend in favour of the combination low planting density (44.4 thousand plants/ha) with late blight treatments TECH 1 has been found to Christian variety, but without statistics significance.

The status of plant vegetation and climatic conditions in July had a decisive role in the accumulation of potato production. The highest accumulation values were recorded in the year 2015 in the Christian (23-26 g/plant/day) and Roclas varieties

(17-22 g/plant/day) compared with Riviera variety, to which due to the maturity of plants the accumulation of production occurred at a rate of 11 g/plant/day.

In the years 2014 and 2016 when planting was done early, following the attack of blight and the maturity of the plant, at the end of July, Riviera variety yields were close to those determined at the beginning of the month, some variants registering a loss of 3-12 g/day at hill. During these years, also to Roclas and Christian varieties, daily accumulations were generally below 10 g/plant/day.

Daily rate of accumulation at the hill level between harvest at the beginning and the end of July for each year is presented in Figure 1.

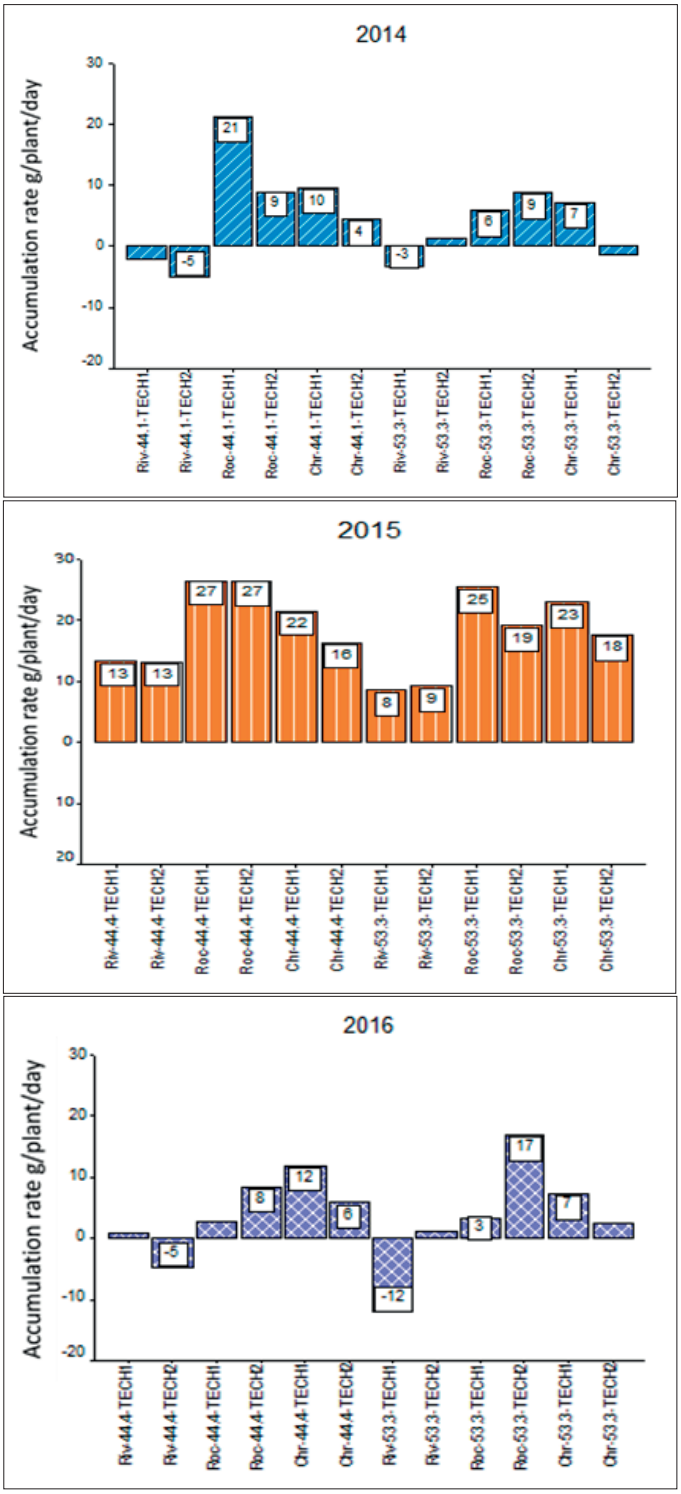

Figure 1. Daily production rate of accumulation to hill (2014-2016)

CONCLUSIONS

Due to the different growing conditions the effects on yield of variants resulting from the combinations of factors variety-density-late blight control technology was of different intensity. In 2014 and 2016 the late blight attack was strong until early July and TECH 2 treatments had superior efficacy to TECH 1 in all varieties. In 2015, with reduced late blight attack in July, the statistically significant superiority of TECH 2 treatments to TECH 1 manifested only in the earliest varieties Riviera and Roclas.

In 2014, a year with unfavourable conditions and high late blight attack only partially controlled, significant differences between variants were established. In 2015, favourable growing conditions and low late blight attack allowed a higher yield, the difference between Roclas and Christian variants remained on the threshold of statistical significance or insignificant compared to Riviera variety. In 2016, the experimental average was the same as in 2014.

The yield of Riviera (29.0 t/ha) and Christian (34.5 t/ha) varieties were equal with yields obtained in the previous year. The yield of Roclas variety (41.5 t/ha) significantly exceeded the yields achieved in previous years.

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