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Short communication

Reaction to late blight in response to nitrogen management in Argentine potato cultivars

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ABSTRACT

The objective of this study was to evaluate the reaction to late blight of two potato cultivars in response to nitrogen (N) management under field and *in Vitro* conditions. In Balcarce trial a reduction in phenols with the addition of excess N was found. Despite the reduction of the concentration of phenols no differences in the relative area under disease progress curve (rAUDPC) were observed between N levels. In Tafí del Valle, the rAUDPC denoted an interaction between cultivar and N level. In Frital, the N0 showed lower rAUDPC than N optimal (Opt) and N excessive (Exc) treatments. In contrast, no differences in rAUDPC between N levels on Pampeana were found. In the detached leaf test, no significant differences between N levels were observed in the threshold of severity of disease and the lesion growth rate. In conclusion, excessive N fertilization did not increase the susceptibility to late blight in this study.

1. Introduction

Late blight disease, caused by the oomycete *Phytophthora infestans* (Mont.) de Bary, is one of the main production constraints of the potato crop (Haverkort et al., 2008). To control foliar infections, the usual strategy is fungicide application, which increases production costs and environmental risk (Huarte and Capezio, 2003). Cultural control measures can be used to reduce the pathogen populations by reducing its survival, dispersal and reproduction by means of: clean seed, removal of volunteer potato plants, hilling with adequate amount of soil, adequate storage and management of plant nutrition (Garrett and Dendy, 2001).

Nitrogen (N) supply not only results in enhanced growth but is also simultaneously accompanied by lower levels of resistance to different pathogens (Ros et al., 2008). Changes in the carbon (C)/N in the plant that cause the decrease of phenolic compounds related to defense mechanisms has been reported as responsible for this lower resistance level (Herms and Mattson, 1992).

In Vitro studies have shown that N application produces an increase in susceptibility of potato to *P. infestans* (Carnegie and Colhoun, 1983; Mittelstraß et al., 2006; Ros et al., 2008) although with differences among cultivars (Ros et al., 2008). In contrast, under field conditions, crop nutrition influence on late blight development can be inconsistent (Colon et al., 2002 cited by Mittelstraß et al., 2006; Juárez et al., 2001; Rubio-Covarrubias et al., 2005) because climate, N rate, growth stage, cultivar resistance, and natural inoculum confound N effects. Rubio-Covarrubias et al. (2005) found that the effect of N fertilization on late blight severity depends on the growth stage at which infection by late blight first occurs. In addition, increased growth caused by higher N supply results in denser canopies and more intercepted light early in the season. Changes in canopy size may affect microclimate and hence late blight because *P. infestans* is sensitive to temperature and humidity (Juárez et al., 2001).

In Argentina, growers of Tucumán and South East Buenos Aires, two important potato-producing areas in Argentina, apply large amounts of N fertilizer and often exceed the requirements of the crop (Giletto et al., 2003; Hernández et al., 2008). Furthermore, these areas suffer significant losses due to late blight. However, it is not clear if N excess increases late blight infection. The quantification of losses due to late blight under different regimes of N fertilization is necessary to guide the selection of the most appropriate management practices to optimize the use of resources in a specific location.

Hence, the objective of this work was to evaluate the reaction to late blight of Argentine potato cultivars with contrasting levels of

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resistance, under different regimes of N fertilization (optimal and excessive) in this two potato production areas of Argentina and in *In Vitro* experiments.

2. Materials and methods

2.1. Field experiments

In Balcarce, Buenos Aires, Argentina (37° 45′ S; 58° 18′ W) the trial was carried out in the 2008/2009 growing season. The experimental design used was a split–split plot in randomized complete block with three replicates. The main plot comprised potato cultivars [Pampeana INTA (MPI 59.789/12 × Huinkul MAG, moderately resistant to late blight) and Frital INTA (Serrana INTA × Katahdin, susceptible to late blight)], the sub-plots were fungicide regimes [with fungicide (CF) and without fungicide (WF)] and the sub-subplot was the N level [optimal (N Opt) and excessive (N Exc)]. The trial was planted on November 17, 2008; each plot had four rows, 5 m long and 85 cm apart. Prior to planting the crop 96 kg ha^{-1} of P was applied. Weed control, insect control and sprinkler irrigation were conducted according to standard recommended practices for the region. In the treatment CF, funguicide Mancoceb (2 kg a.i. ha^{-1}) was applied weekly after the 72 days after planting (DAP). In the treatment N Opt, 70 kg of N ha^{-1} was applied at planting. In the treatment N Exc, 50 and 80 kg of N ha^{-1} were applied at planting and at the beginning of the tuber-filling stage, respectively.

Fifteen petiole samples were collected from each plot 60 and 85 DAP to estimate the nutritional state. As diagnosis method petiole dry matter N–NO_3^- concentration was used. Photosynthetically active radiation was determined using a radiation sensor bar Li-Cor 1914 SB (LICOR, USA) at 35, 51, 60, 79 and 116 DAP. Intercepted radiation percentage (IRP) was established according to the formula: (1-A/A0)(100), where A is the radiation value reaching the soil and A0 the value registered above the crop. At 65 DAP five plants per plot were cut at ground level to measure N and C concentration by dry combustion with a LECO TruSpec CNS (LECO, St. Joseph, MI; LECO, 2008). The concentration of phenols was determined in leaves of five plants randomly selected at 65, 82, 101 DAP with Folin–Ciocalteau reagent (Bray and Thorpe, 1954). In each plot, readings were made of the leaf area percentage affected (Henfling, 1987) by *P. infestans* starting from symptoms manifestation (86, 97, 106, 113 and 121 DAP). With these infection percentage values, the area under disease progress curve (AUDPC) was estimated as established by Shaner and Finney (1977). An additional variable, relative AUDPC (rAUDPC), was estimated for each cultivar, by dividing AUDPC by the maximum potential AUDPC. The maximum potential AUDPC is calculated by multiplying the total number of days between the first and last readings by 100 (Bonierbale et al., 2008). Potato plants were harvested at maturity and marketable tuber yield per plot was converted to Mg ha^{-1}.

In Tafí del Valle, Tucumán, Argentina (26° 52′ S; 65° 40′ W) the trial was conducted in the 2008/2009 growing season. The treatments were deployed in a factorial arrangement of two cultivars (Pampeana and Frital) and three N levels [without N (N0), N Opt and N Exc] in randomized complete block with three replicates. Seed tubers were planted on November 25, 2008; each plot had three rows, 5 m long and 70 cm apart. Prior to planting the crop 96 kg ha^{-1} of P was applied. In the treatments N Opt and N Exc were applied 70 and 140 kg N ha^{-1} respectively. In each plot, the percentage of leaf area infected was visually estimated 64, 71, 78, and 84 DAP. The rAUDPC were estimated. Potato plants were harvested at maturity and total tuber yield per plot was converted to Mg ha^{-1}.

The field experiments were carried out under natural conditions for late blight development.

2.2. Detached leaf in Vitro test

This assay had a factorial arrangement of two cultivars (Pampeana and Frital) and two N levels (N Opt and N Exc). Four plants of each cultivar were planted in the greenhouse. At 10 DAP 0.4 and 0.8 g N per pot were applied N Opt and N Exc respectively. Forty-five DAP at each plot two leaves per plant from the upper portion of the foliage were cut. The detached leaflets were placed in Petri dishes on 2% water–agar and inoculated with *P. infestans* sporangial suspension (race 2, 3, 6, 7, 8, 9; mating type A2) by placing a 50 μl droplet on the abaxial side. The concentration of sporangia was adjusted to 40,000 sporangia mL^{-1}. The Petri dishes were then placed in a growth chamber at 18–20 °C and 80% relative humidity. Each leaflet was photographed every 12 h. Lesion growth rate (LGR) was estimated as the ratio between the percentage of damaged area, calculated with the American Phytopathological Society (APS) program Asses 2.0, and the time in hours after the first necrotic lesions were observed. The number of hours after inoculation to reach a 5% leaf area affected [disease severity threshold (DT_5)] (Dorrance et al., 2001) was estimated by simple linear regression with the values of LGR of each plot.

2.3. Environmental characterization of field experiments

At Balcarce, 195 mm of rain fell during the growing season but long periods between rain events early in the season, low humidity and temperatures resulted in unfavorable pathogen development. From the 105 to 120 DAP rainfall and relative humidity increased promoting the progress of the disease at the end of the crop cycle (data not shown). At Tafí del Valle, mean temperatures ranged between 20.5 and 8.4 °C, average relative humidity was 81.5% and rainfall totaled 465 mm distributed over the growing season (data not shown). Thus, at this site, weather conditions were favorable for disease development throughout growing season.

2.4. Statistical analyses

Analyses of variance (ANOVA) for all three experiments were made using GLM procedures (SAS, SAS Institute Inc., 2004). When in Tafí del Valle experiment significant treatment differences were found, the least significant differences (LSD) test were used. Simple regression analysis was made using REG procedure (SAS, SAS Institute Inc., 2004). Correlation analysis was done to determine if there were relationships between DT_5, LGR, and rAUDPC using the PROC CORR procedure in SAS (SAS, SAS Institute Inc., 2004). Correlation analysis was done using two cultivars: Pampeana and Frital, and two N levels: N Opt and N Exc.

3. Results

3.1. Balcarce

There were significant differences in N–NO_3^- concentrations between N levels in both sampling dates. At 60 DAP the average petiole N–NO_3^- were 16.4 and 21.1 g kg^{-1} for N Opt and N Exc treatments respectively and at 85 DAP the average petiole N–NO_3^- concentrations were 5.7 and 12.8 g kg^{-1} for N Opt and N Exc treatments, respectively (Table 1).

Table 2 shows the concentrations of C, N and the C/N ratio at 65 DAP. C concentration was not significantly affected by N treatment. As expected, the C/N ratio was significantly lower in the N Exc treatment ($p \leq 0.01$). Additionally, significant differences

Table 1
Petiole nitrate concentrations ($N-NO_3^-$) (measured 60 and 85 DAP) in the 2008/2009 growing season at Balcarce for two cultivars: Pampeana (P) and Frital (F), two fungicide regimes: with fungicide (CF) and without fungicide (WF), and two N levels: optimal (N Opt) and excessive (N Exc).

			$N-NO_3^-$ (g kg^{-1})	
			DAP	
			60	85
P	CF	N Opt	10.0	6.0
		N Exc	19.0	11.9
	WF	N Opt	19.1	5.3
		N Exc	19.3	13.0
F	CF	N Opt	18.1	6.1
		N Exc	24.4	12.5
	WF	N Opt	18.7	5.6
		N Exc	21.9	13.8
Averages and standards error	P		16.8 ± 4.9	9.0 ± 4.2
	F		20.8 ± 4.8	9.5 ± 4.8
	CF		17.9 ± 6.6	9.1 ± 4.6
	WF		19.7 ± 3.4	9.4 ± 4.5
	N Opt		16.4 ± 5.4	5.7 ± 2.9
	N Exc		21.1 ± 3.7	12.8 ± 2.3
CV (%)			22.1	25.5

CV (%): Perceptual variation coefficient.
In the treatments N Opt and N Exc were applied 70 and 130 kg N ha^{-1} respectively.

between cultivars were observed in C/N ratio and N concentration ($p \leq 0.05$).

No interactions among the three factors were observed on any sampling date for IRP. Fungicide regime had a significant effect at 116 DAP (Fig. 1a). Significant differences between cultivars were found at 51 and 116 DAP (Fig. 1b). Significant differences between N levels, at 116 DAP were observed because in N Exc the intercepted radiation was 16.8% more than in the N Opt treatment (Fig. 1c).

For phenol content significant differences between cultivars, at 82 and 101 DAP, were observed ($p \leq 0.05$) (Table 2). At 65 DAP there were no significant differences. However, Pampeana showed 13.4% more concentration of phenols than Frital (Table 2). N regime had a significant effect in the third sampling date ($p \leq 0.05$) where phenol concentration was higher with N Opt than with N Exc (730.0 and 666.4 ug g^{-1}, respectively). At first and second sampling dates the differences between N levels were not significant. However, N Opt showed the highest phenol concentrations in comparison to N Exc (Table 2). At 65 DAP C/N ratio was positively associated with phenol concentration (Fig. 2).

For rAUDPC there were significant differences ($p \leq 0.05$) between cultivars (0.18 and 0.23 for Pampeana and Frital, respectively) and fungicide regime ($p \leq 0.05$) (0.15 and 0.26 for the CF and WF treatments, respectively). On the contrary, no significant differences among N levels (Table 2).

Fungicide treatments significantly affected marketable tuber yield ($p \leq 0.10$) (36.1 and 29.0 Mg ha^{-1} for the CF and WF treatments respectively). However, no significant differences between N levels were observed. No significant cultivar – fungicide regime interaction was observed. Although, in Frital the CF treatment showed a higher tuber yield than the WF treatment (31%). Instead, in Pampeana a much smaller difference was detected (17%) (Table 2).

3.2. Tafí del Valle (Tucumán)

An interaction between cultivar and N regime was found for rAUDPC ($p \leq 0.01$) (Table 3). On the Frital cultivar, the N0 treatment showed a significantly lower rAUDPC than N Opt and N Exc treatments (0.36, 0.42 and 0.43 respectively). Despite the increase in rAUDPC, due to the addition of N, no significant differences between N Opt and N Exc were found in this cultivar (Table 3). However, no differences were detected on the Pampeana cultivar (0.25, 0.23 and 0.23 for N0, N Opt and N Exc treatments respectively). In yield a significant difference between cultivars was detected ($p \leq 0.01$). Yields for Pampeana were 132% more than Frital (17.2 and 7.4 Mg ha^{-1} respectively). Additionally, significant differences between N0 and the other two N levels were observed ($p \leq 0.10$) (Table 3).

3.3. Detached leaf in Vitro test

In the detached leaf test DT_5 was significantly affected by cultivar ($p \leq 0.01$) (86.8 and 72.4 h for Pampeana and Frital cultivars respectively), but no significant differences between cultivars were observed for LGR. Additionally, no significant differences between N levels were found in DT_5 and LGR (Table 4).

Table 2
Nitrogen (N) content, carbon (C) content, C/N ratio (measured 65 DAP), total phenols (measured 65, 82 and 101 DAP), Relative Area Under Disease Progress Curve (rAUDPC) and marketable tuber yield in the 2008/2009 growing season at Balcarce for two cultivars: Pampeana (P) and Frital (F), two fungicide regimes: with fungicide (CF) and without fungicide (WF), and two N levels: optimal (N Opt) and excessive (N Exc).

			N (%)	C (%)	C/N ratio	Phenols (ug g^{-1})			rAUDPC	Marketable tuber yield (Mg ha^{-1})
						DAP				
						65	82	101		
P	CF	N Opt	5.4	41.4	7.7	779.5	514.5	766.7	0.14	34.6
		N Exc	5.8	40.7	7.1	637.9	473.0	816.1	0.13	30.9
	WF	N Opt	5.5	40.9	7.4	883.0	854.5	810.2	0.23	30.0
		N Exc	5.5	39.9	7.3	679.5	769.8	711.3	0.21	26.0
F	CF	N Opt	5.6	40.5	7.2	586.7	625.3	653.5	0.17	38.9
		N Exc	6.2	40.3	6.5	549.4	563.3	571.7	0.15	39.8
	WF	N Opt	5.6	41.0	7.4	733.3	1088.5	689.7	0.29	28.6
		N Exc	6.2	40.5	6.6	475.7	1141.3	566.4	0.31	31.6
Averages and standards error	P		5.5 ± 0.3	40.7 ± 1.2	7.4 ± 0.3	745.0 ± 166.1	677.7 ± 163.2	776.1 ± 127.8	0.18 ± 0.05	30.4 ± 7.7
	F		5.9 ± 0.3	40.6 ± 0.7	6.9 ± 0.5	586.3 ± 150.8	597.8 ± 116.3	620.3 ± 83.4	0.23 ± 0.05	34.7 ± 5.9
	CF		5.7 ± 0.3	40.7 ± 0.7	7.1 ± 0.5	638.4 ± 132.5	640.7 ± 170.7	702.0 ± 156.9	0.15 ± 0.04	36.1 ± 7.4
	WF		5.7 ± 0.4	40.6 ± 1.2	7.2 ± 0.4	692.9 ± 212.0	634.7 ± 120.4	694.4 ± 108.9	0.26 ± 0.07	29.0 ± 4.7
	N Opt		5.5 ± 0.2	41.0 ± 0.5	7.4 ± 0.3	745.6 ± 192.1	700.8 ± 138.3	730.0 ± 133.2	0.21 ± 0.08	33.0 ± 8.1
	N Exc		5.9 ± 0.4	40.3 ± 1.8	6.8 ± 0.4	585.6 ± 115.0	574.6 ± 125.9	666.4 ± 128.6	0.20 ± 0.08	32.1 ± 6.2
CV (%)			4.3	2.5	3.4	26.6	17.2	14.8	12.9	17.6

CV (%): Perceptual variation coefficient.
In the treatments N Opt and N Exc were applied 70 and 130 kg N ha^{-1} respectively.

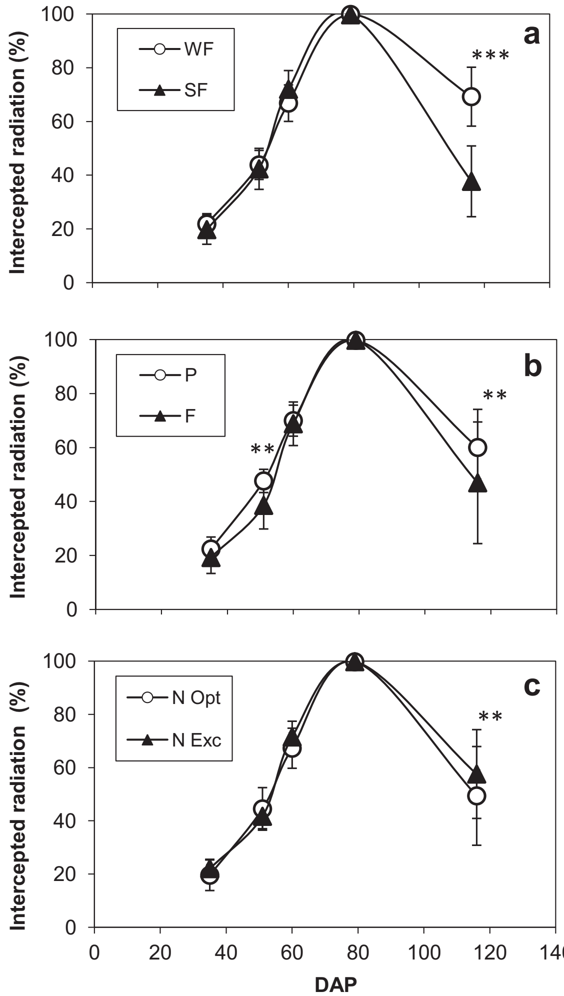

Fig. 1. Intercepted radiation (%) as a function of time, expressed as days after planting (DAP), in the 2008/2009 growing season at Balcarce for (a) two fungicide regimes: with fungicide (CF) and without fungicide (WF), (b) two cultivars: Pampeana (P) and Frita (F), and (c) two N levels: optimal (N Opt) and excessive (N Exc). *Significant at $p \leq 0.10$; **Significant at $p \leq 0.05$; ***Significant at $p \leq 0.01$. In the treatments N Opt and N Exc were applied 70 and 130 kg N ha^{-1} respectively.

3.4. Correlation of experiments

The data showed that significant and negative correlation coefficients were found between DT_5 and rAUDPC at Balcarce and rAUDPC at Tafí del Valle (−0.59 and −0.78 respectively) (Table 5). In contrast, the correlation between LGR and rAUDPC was very low and not significant (Table 5).

4. Discussion

If the petiole $N{-}NO_3^-$ concentration is between 12 y 17 g kg^{-1} at 60 DAP and between 9 y 12 g kg^{-1} at 85 DAP then the N levels are optimized for reaching maximum yield (Vitosh and Silva, 1996 cited by Giletto et al., 2006). Therefore, in Balcarce trial, petiole $N{-}NO_3^-$ concentration up to 65 DAP brought the crop nutritional state to adequate in N Opt and to excess in N Exc levels, respectively. However, at 85 DAP the crop nutritional states were insufficient for N Opt and excessive for N Exc (Vitosh and Silva, 1996 cited by Giletto et al., 2006). C/N ratio was significantly lower in N Exc treatment because of higher N levels within plant tissue (Table 2). Herms and Mattson (1992) explained that changes in the C/N ratio decreases secondary metabolism (defense mechanisms) but

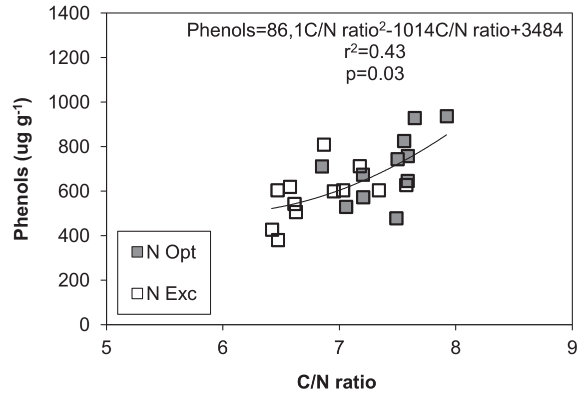

Fig. 2. Relation between total phenols concentration (ug g^{-1}) and C/N ratio (measured 65 DAP) of leaves of potato plants at Balcarce for two N levels: optimal (N Opt) (closed symbols) and excessive (N Exc) (open symbols). In the treatments N Opt and N Exc were applied 70 and 130 kg N ha^{-1} respectively.

stimulates foliage production, which may, in the end, increase susceptibility to pathogens (Walters and Bingham, 2007). However, in this experiment, the lower C/N ratio, caused by the application of N in excess (Table 2) did not increase foliage, since the intercepted radiation percentage did not increase during the first four samplings dates (Fig. 1c). These results would be explained by the fact that the availability of N was sufficient to meet crop requirements. Therefore, N was accumulated in excess in vegetative tissues (Table 2). In contrast, at 116 DAP N Exc treatments intercepted more radiation than the N Opt treatment (Fig. 1c). This behavior was due to the inadequate crop nutritional status in the N Opt treatment at the end of the cycle (Table 1). Thus, the remobilization of N from leaves to tubers caused early senescence in this treatment which is reflected in decreased leaf area and therefore in the intercepted radiation (Fig. 1c).

The concentration of phenols decreased with the increase of the N dose. Thus, a positive association was observed between C/N ratio and phenols concentration as reported by Herms and Mattson (1992). In the N Exc treatment, a smaller C/N ratio was determined (Table 2) that can be explained by a competition of protein biosynthesis and phenylpropanoid biosynthesis for the amino acid phenylalanine (Jones and Hartley, 1999; Mittelstraß et al., 2006). Pampeana showed a higher concentration of phenols than Frital (Table 2). These results agree with those reported by Andreu et al. (2001).

Table 3
Relative area under disease progress curve (rAUDPC) and tuber yield in the 2008/2009 growing season at Tafí del Valle (Tucumán) for two cultivars: Pampeana (P) and Frital (F), and three N levels: without N (N0), optimal (N Opt) and excessive (N Exc).

		Tuber yield (Mg ha^{-1})	rAUDPC
P	N0	13.3	0.25
	N Opt	17.9	0.23
	N Exc	20.3	0.23
F	N0	4.7	0.36
	N Opt	7.4	0.42
	N Exc	9.9	0.43
Averages and standards error	N0	9.0 ± 4.9	0.30 ± 0.06
	N Opt	12.7 ± 6.5	0.32 ± 0.08
	N Exc	15.1 ± 8.1	0.33 ± 0.07
	P	17.2 ± 6.0	0.23 ± 0.02
	F	7.4 ± 2.6	0.40 ± 0.04
CV (%)		33.6	6.4

CV (%): Perceptual variation coefficient.
In the treatments N0, N Opt and N Exc were applied 0, 70 and 140 kg N ha^{-1} respectively.

Table 4
Lesion growth rate (LGR) and number of hours after inoculation to reach a 5% leaf area affected [disease severity threshold (DT_5)] in detached leaf test for two cultivars: Pampeana (P) and Frital (F), and two N levels: optimal (N Opt) and excessive (N Exc).

		LGR (% $hour^{-1}$)	DT_5 (hours)
P	N Opt	0.66	87.90
	N Exc	0.63	85.78
F	N Opt	0.74	73.07
	N Exc	0.67	71.69
Averages and standards error	P	0.64 ± 0.10	86.80 ± 7.11
	F	0.70 ± 0.16	72.38 ± 2.38
	N Opt	0.70 ± 0.08	80.48 ± 9.98
	N Exc	0.65 ± 0.17	78.73 ± 8.95
CV (%)		24.5	8.1

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An increase of C/N ratio and smaller phenol content possibly increased the susceptibility to *P. infestans* (Mittelstraß et al., 2006). However, in Balcarce no increase in the rAUDPC was associated with a higher C/N ratio (Table 2). In Tafí del Valle, the rAUDPC was greater in N Exc but the difference between treatments was not statistically significant (Table 3). This may be due to the fact that excessive doses of N would not increase the rAUDPC unless the infection is initiated early in the crop cycle and the disease pressure is high (Rubio-Covarrubias et al., 2005). In the Toluca Valley, Mexico, changes in the reaction to *P. infestans* due to application of N in excess were found (Rubio-Covarrubias et al., 2005). At this site, the weather conditions are favorable for the development of the disease and the disease pressure is higher than in Balcarce and Tafí del Valle.

At Tafí del Valle trial the N0 treatment had a significantly lower rAUDPC than N Opt and N Exc treatments in Frital (Table 3). In this case, the application of N likely promoted the development of the plant foliage creating a microclimate favorable for pathogen development. However, no differences were detected among N treatments on the Pampeana cultivar (Table 3). Ros et al. (2008) also found that the effect of N fertilization on late blight severity was more pronounced in the susceptible cultivar.

In the detached leaf test the DT_5 and LGR were not affected by fertilization regime (Table 4). The detached leaf test was consistent with the results observed under field conditions in Balcarce (Table 2) and Tafí del Valle (Table 3). Our results differ from those observed by Mittelstraß et al. (2006). However, these authors compared the reaction to late blight infection with and without the addition of N and determined the effect of N fertilization over the infected leaf area but not on LGR. In this sense, Carnegie and Colhoun (1983) found also, in the detached leaf tests, that with high N dose the size of lesions but not their growth rate was influenced and Juárez (2001) found that high N dose did not produce an increase in LGR.

Table 5
Correlation coefficients for the relationships between relative area under the disease progress curve (rAUDPC) measured in the field in Balcarce and Tafí del Valle, and lesion growth rate (LGR) and number of hours after inoculation to reach a 5% leaf area affected [disease severity threshold (DT_5)] using two cultivars: Pampeana (P) and Frital (F), and two N levels: optimal (N Opt) and excessive (N Exc).

		LGR	DT_5	rAUDPC Balcarce	rAUDPC Tafí del Valle
LGR			ns	ns	ns
DT_5		−0.09		**	***
rAUDPC	Balcarce	0.13	−0.59		**
rAUDPC	Tafí del Valle	0.28	−0.78	0.65	

ns = not significant; * = $p \leq 0.10$; ** = $p \leq 0.05$; *** = $p \leq 0.01$.

In Argentina, growers apply large amounts of N fertilizer and often exceed the requirements of the crop. Our experiments provide evidence that excessive N fertilization did not increase the susceptibility to late blight. Hence, N does not seem to be an important factor for management of late blight in Argentina. However, further experimentation is warranted to confirm these findings.

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