



# Decision support system for controlling Late Blight: Field trials and digital tool development in the Peruvian highlands -Preliminary results

## Introduction

Late blight is considered as one of the most important constraints to potato production worldwide (Haverkort et al. 2009). Severe yield losses, ranging from 50% to 100% were reported in native potatoes at 4090 m.a.s.l. in Peru (W. Perez et al. 2015) posing a risk to potato biodiversity in areas that were previously free from the disease (Lindqvist-Kreuze et al. 2020). This disease can be particularly difficult to manage in Peru, due to high disease pressure throughout the growing season which occurs from the time of emergence (Kromann et al. 2008). A major problem with late blight control in the Andes is the farmers' lack of knowledge about several aspects of disease management, including disease diagnosis and differences in the efficacies of available fungicides (Ortiz, Thiele, and Forbes 2003) and no use of protective clothing to apply pesticides (Kromann et al. 2014). Under to Peruvian conditions, Bustamante (2007) reported until 12 fungicide sprays to control LB and Perez et al. (2022) reported between 11 to 11 and 20 sprays per season. In developing countries, farmers commonly use fungicides to control LB, but the cost of these products can represent 10 to 25 percent the total value of a farmer's potato harvest, their use significantly reduces family incomes, and their application poses risks to humans and the environment. Given the significant challenges posed by late blight in the Andes, there is an urgent need for advanced technological solutions to aid farmers in effective disease management. While computerized decision support systems (DSS) have

been successful in more developed regions, their adaptation in areas like the Andes remains limited. The objectives of this study are i) to evaluate of late blight management strategies across varied cultivars and ii) to develop of a universal digital decision support tool for late blight management.

## Materials and Methods

### 1. Comprehensive evaluation of late blight management strategies across varied cultivars

This objective involves conducting designed field trials spanning multiple growing seasons, specifically tailored to assess and compare the effectiveness of varied late blight management strategies under realistic field conditions. The trials will encompass a diverse array of potato cultivars, from highly susceptible to resistant strains, to understand the disease's impact across different genetic backgrounds. The aim is to provide a broad understanding of disease dynamics and effective management practices in diverse environmental and crop conditions, thereby contributing to improved agricultural resilience and sustainability.

During two growing seasons (2021-2022 and 2022-2023) four field trials were carried out in the district of Paucartambo, department of Pasco in Central Peruvian Highlands. In growing season 2019-2020, two experiments were carried out in Cacara (S10°46' 25.52"; W 75°48'46") and Aco (S10°45'55"; W75°44'15"). Plots with basic seed tubers of susceptible [Canchan (CIP 380389.1) and Yungay (CIP

720064), moderately resistant [UNICA (CIP 392797.22)] and resistant cultivars [Poderosa (CIP 399049.22)] were evaluated every 7, 9 and 11 days, respectively. In growing season 2022 – 2023, two field trials were carried out in Cacara and Yarhuay ( 2880 masl). Plots with susceptible (Canchan and Yungay), moderately resistant [UNICA and Amarilis (CIP384866.5)] and resistant cultivars (Poderosa) were evaluated every 7, 9 and 11 days, respectively. In both growing season, field trials were carried out from November to April during rainy season, and plants were exposed to LB epidemics occurred naturally. The plot size was 55.44 m<sup>2</sup> (4.55m x 11.9 m) with 100 plants per plot. Fertilization was adjusted based on results of soil analysis. Other agronomic practices were conducted following recommendations from a local agronomist.

Field trial of growing season 2021-2022 had three treatments: 1) weekly sprays, 2) Sim Cast Modified by CIP, and 3) control (without fungicides). In growing season 2022-2023, four treatments were carried out: 1) weekly sprays, 2) Hand held decision Support tool 'HH-DST' (Pérez et al. 2020), 3) Sim Cast Modified by CIP, and 4) control (without fungicides). For all treatments, including the control, an initial fungicide application was made at 80% plant emergence and from that date on, all following fungicide applications were based on recommendations provided by the spray regime (e.g., HH-DST, Sim Cast modified, weekly sprays according to local practices). With susceptible varieties, the first fungicide application was made with either a systemic or translaminar fungicide, and in moderate resistant or resistant varieties was made with contact fungicide. Pesticides were applied until run-off with a 20-L lever-operated knapsack sprayer. Constant flow valves (CFValve R11–16SY; G.A.T.E, Sebastian, FL) were used with hollow cone nozzles with exit holes of either 0.8 or 1.2 mm.

Disease severity readings (%) were registered since 80% plant emergence every 7 days in all treatments, and furtherly Relative Area Under Disease Progress Curve (rAUDPC) were calculated by each treatment in all experiments as described by Forbes, Perez, and Andrade Piedra (2014). For growing season 2022-2023, commercial and noncommercial tubers were selected and weighed at the harvest. The number of

applications, dose, concentration, and the environmental impact quotient (EIQ) for each active ingredient were registered to estimate the environmental impact (EI) (Kovach et al. 1992) per treatment.

## 2. Development of a digital decision support tool for late blight management:

The goal was to create a user-friendly, Shiny App-based decision support system (DSS), designed for accessibility to farmers of varying technological expertise levels.

This Shiny App-based tool was engineered for ease of use, ensuring accessibility to researchers and farmers. It provided dynamic, real-time guidance, integrating extensive meteorological data and algorithms within the DSS framework. The SIMCAST system (Fry et al., 1983) was incorporated into our DSS, considering its demonstrated efficacy in various field conditions. SIMCAST, along with other systems showed effectiveness in reducing late blight severity. Although originally developed for temperate regions, SIMCAST's principles were adapted and validated to suit the Andean conditions. This adaptation aimed to optimize fungicide application schedules, thereby reducing unnecessary applications, and minimizing environmental impact. The implementation of SIMCAST within the DSS provided tailored recommendations for fungicide application based on updated weather forecasts and disease risk assessments, thus contributing to more efficient and sustainable disease management practices.

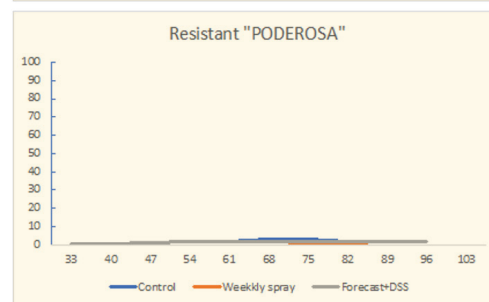
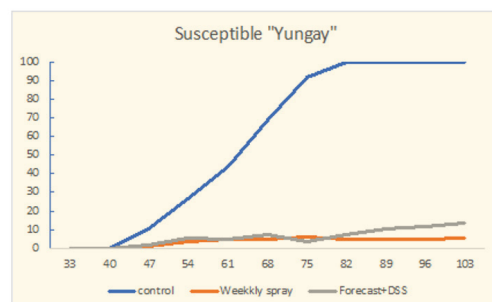
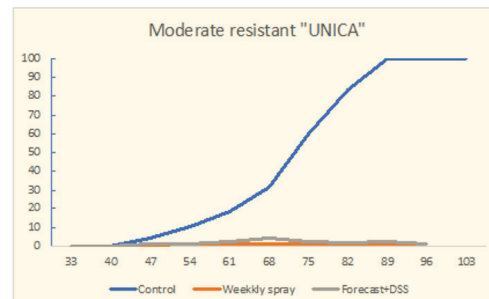
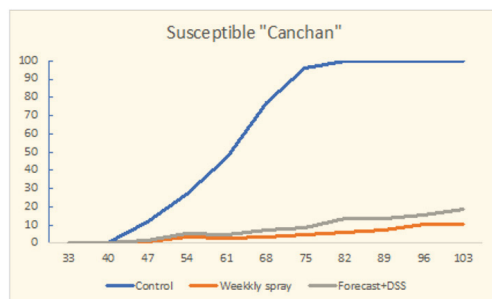
## Regional Late Blight Risk Estimation

A thorough analysis was conducted to assess the progression and risk of late blight across the Andes. Utilizing meteorological forecasts over 5x5 km grids, the system calculated late blight risk for each grid point within key potato-producing areas.

## Results

In both experiments carried out in growing season 2021-2022, control of LB achieved with weekly sprays and SimCast modified were similar (Figure 1).

**Experiment Cacara (Paucartambo/Pasco)**  
10°46'25.52" S;  
75°48'46"W



**Experiment Aco**  
**(Paucartambo/Pasco)**  
**10°45'55" S;**  
**75°44'15" W**

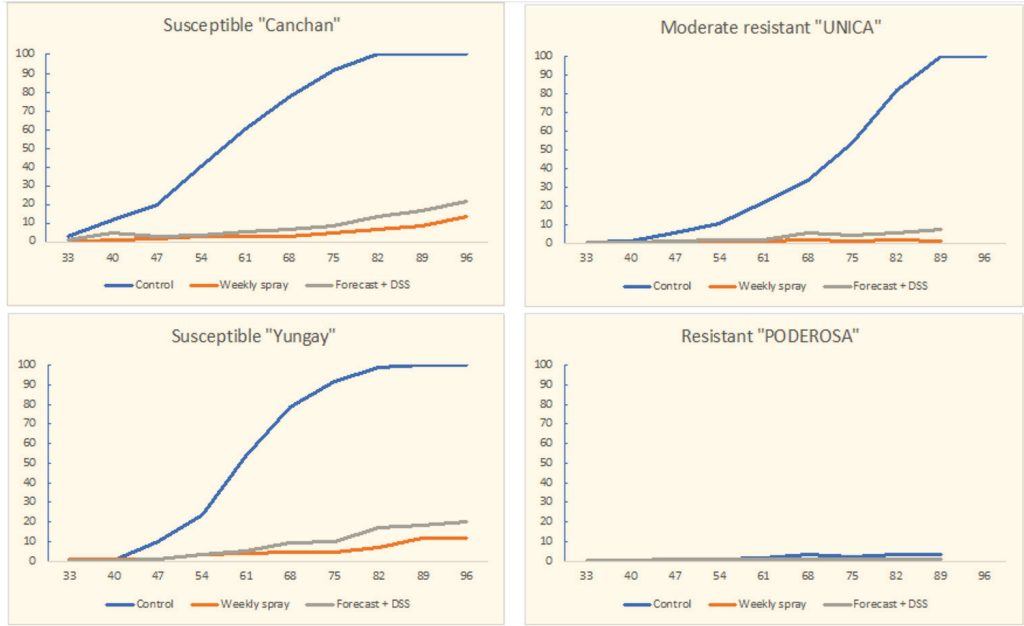


Figure 1. Potato Late Blight progress curves showing the proportion of leaf area infected after fungicide sprays according to SimCast modified criteria and weekly sprays compared with control (without fungicides). In both experiments carried out in growing season 2022-2023,

control of late blight was statistically similar among three treatments: weekly sprays, HH-DST (Handheld decision Support tool), and Sim Cast modified, however, with SimCast modified was reduction of number of fungicide sprays and Environmental Impact compared with other treatments (Table 1 and 2).

**Table 1.** Comparison of treatments to control late Blight in Cacara (Paucartambo, Pasco) during growing season 2022-2023.

Variety	Treatments	rAUDPC	Sprays number	Commercial weight	EI/Ha
Amarilis	Without fungicides	0.50 a**	0	5.5 a	0.00
	Weekly sprays	0.06 b	9	35.15 a	272.73
	HH-DST*	0.05 b	7	32.45 a	223.72
	SimCast	0.04 b	7	38.15 a	103.71
Canchan	Without fungicides	0.51 a	0	3.55 b	0.00
	Weekly sprays	0.05 b	9	53.6 a	181.46
	HH-DST	0.02 b	9	46.75 a	186.32
	SimCast	0.04 b	7	35.8 a	103.71
Poderosa	Without fungicides	0.00 a	0	35.75 a	0.00
	Weekly sprays	0.01 a	9	31.1 a	272.73
	HH-DST	0.00 a	6	25 a	209.68
	SimCast	0.00 a	4	29.45 a	90.46
UNICA	Without fungicides	0.22 a	0	34.5 a	0.00
	Weekly sprays	0.04 b	9	41.05 a	272.73
	HH-DST	0.03 b	7	36.85 a	223.72
	SimCast	0.02 b	5	47.5 a	99.97
Yungay	Without fungicides	0.41 a	0	3.4 b	0.00
	Weekly sprays	0.04 b	9	41.9 a	181.46
	HH-DST	0.02 b	9	33.35 a	186.32
	SimCast	0.02 b	7	46.8 a	103.71

\*HH-DST= Hand held decision Support tool (Pérez et al. 2020).  
 \*\*Values followed by the same letter are not statistically significant. Tukey's Honest Significant Difference (HSD) test (0.05).

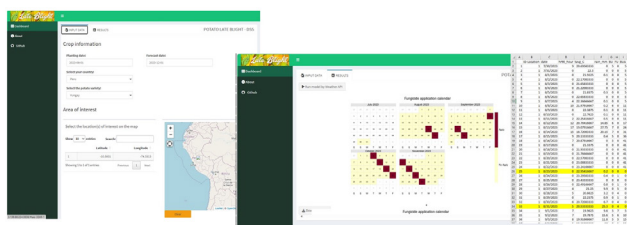
**Table 2.** Comparison of treatments to control late Blight in Yarhuay (Paucartambo, Pasco) during growing season 2022-2023.

Variety	Treatments	rAUDPC	Sprays number	Commercial weight	EI/Ha
Amarilis	Without fungicides	0.35 a**	0	5.47 b	0.00
	Weekly sprays	0.04 b	9	29.73 a	193.42
	HH-DST*	0.04 b	7	25.13 a	155.65
	SimCast	0.03 b	7	31.30 a	113.56
Canchan	Without fungicides	0.37 a	0	2.83 c	0.00
	Weekly sprays	0.02 b	9	33.57 a	124.23
	HH-DST	0.02 b	9	41.53 a	175.79
	SimCast	0.02 b	7	29.30 b	113.56
Poderosa	Without fungicides	0.00 a	0	14.60 a	0.00
	Weekly sprays	0.00 a	9	21.80 ab	193.42
	HH-DST	0.00 a	7	23.17 a	173.59
	SimCast	0.00 a	4	17.83 ab	77.47
UNICA	Without fungicides	0.25 a	0	17.93 b	0.00
	Weekly sprays	0.03 b	9	34.97 a	193.42
	HH-DST	0.03 b	7	38.13 a	155.65
	SimCast	0.02 b	5	33.73 a	93.71
Yungay	Without fungicides	0.32 a	0	9.20 b	0.00
	Weekly sprays	0.02 b	9	41.07 a	124.23
	HH-DST	0.01 b	9	45.67 a	175.79
	SimCast	0.04 b	7	29.73 a	113.56

\*HH-DST= Hand held decision Support tool (Pérez et al. 2020).  
 \*\*Values followed by the same letter are not statistically significant. Tukey's Honest Significant Difference (HSD) test (0.05).

## Development of a digital decision support tool for late blight management:

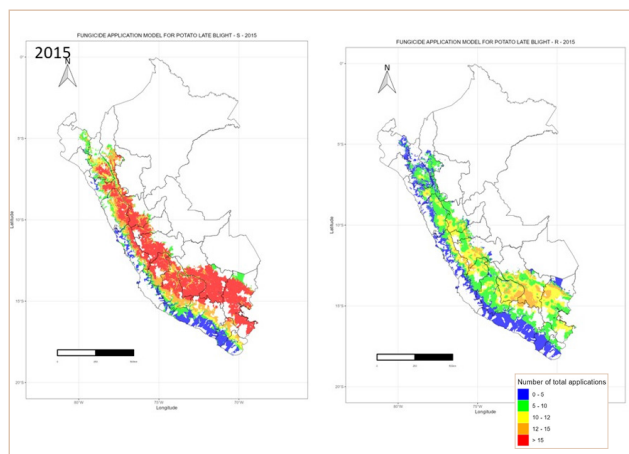
The tool was designed to promote efficient and sustainable pesticide use, while also providing educational resources and adaptive management strategies. This tool aimed to not only monitor and predict late blight outbreaks but also to offer actionable, real-time advice to farmers. Figure 1 shows the interface of the developed tool, highlighting its features and user-friendly design. The tool can be accessed through <http://lateblight.cipotato.org/> & <http://3.139.88.224:3838>



**Figure 1.** Interface of the decision support tool for late blight management

## Regional Late Blight Risk Estimation

This pixel-level implementation of the DSS generated real-time updated risk maps. This not only assisted farmers in immediate decision-making but also aided in long-term agricultural planning and adaptation strategies against late blight. Figure 2 illustrates a map showcasing the late blight risk estimation for a resistant and a susceptible variety for the year 2015, providing a visual representation of the disease's potential impact in different scenarios.



**Figure 2** Late blight risk estimation for a resistant and a susceptible variety for the year 2015 (left susceptible variety, right resistant variety).

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