Mieux suivre et prévoir les récoltes maraîchères grâce aux drones et à la vision artificielle

Une présentation de:

Philippe Vigneault, AAC

Jean-Christophe Ruel, Innoptech

Philippe Vigneault, AAC	Jean-Christophe Ruel, Innoptech
Contexte et défis de la recherche	Vegforecast
10-15 minutes.	30-35 minutes.

Association des producteurs maraîchers du Québec

Agriculture et Agroalimentaire Canada

Agriculture and Agri-Food Canada

Innoptech

Canada

Partie 1 (Contexte et défis de la recherche)

Exploiter les données différemment pour s'ouvrir à la transformation numérique de l'agriculture

<2004

≈2008

2009

≈ 2010

2018

2017

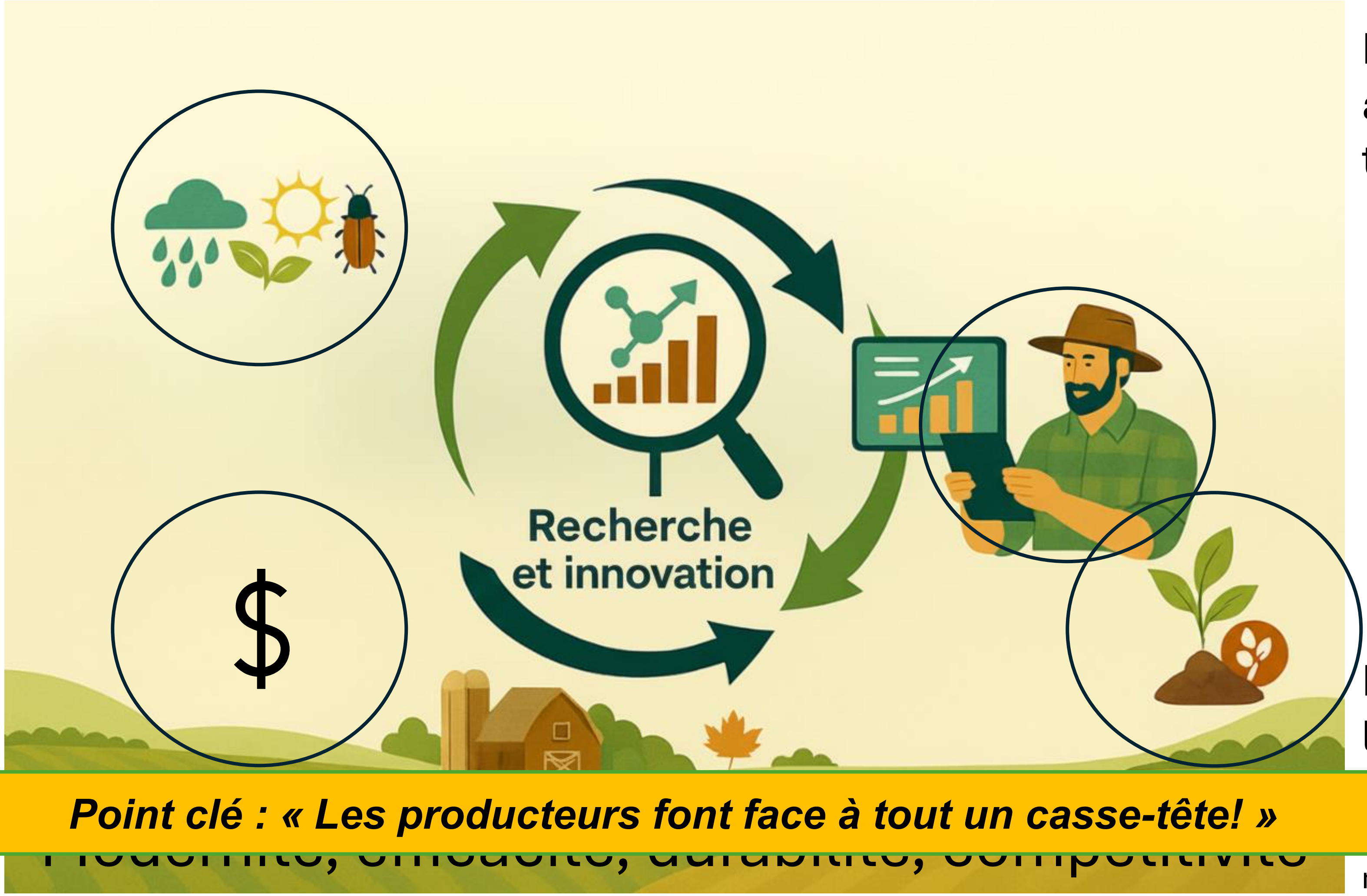
2016

≈ 2014

Les défis et solutions de la recherche

Menaces évolutives
Changements climatiques, nouveaux ravageurs et pathogènes

Prise de décisions agronomiques en temps réel



Enjeux économiques

exportation

Réduction de l'empreinte

réduction des pesticides

Point clé : « Les producteurs font face à tout un casse-tête! »

Les solutions simples ne suffisent plus.

- Solutions adaptées pour faire face aux problèmes complexes et dynamiques

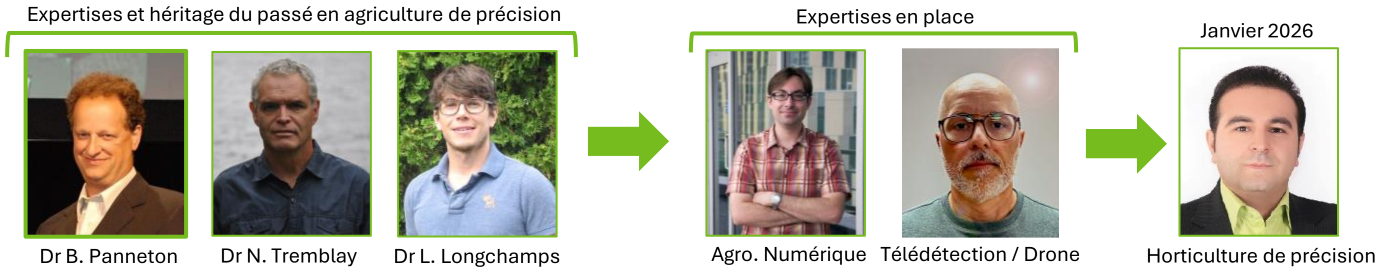
- La recherche scientifique comme levier pour:
  - Le développement d'outils
  - S'adapter aux conditions changeantes.

Progrès et intégration des technologies comme levier

- S’inspirer du continuum de la biovigilance (*Carisse, Fall et al.*) et de l’agriculture de précision
- S’appuyer sur des méthodes pilotées par:
  - Les nouvelles technologies
  - Les données massives

Expérience et expertise du CRD de Saint-Jean-sur-Richelieu (AAC)

- Plus de 25 ans d'expérience en agriculture de précision
- Projets phares : Géophyte (**Dr Panneton**), SCAN (**Dr Tremblay**)
- Reconnu pour son expertise en agriculture numérique (**Dr Lord**), dronautique, traitement de données massives
- Embauche prochaine d'un chercheur en horticulture de précision



Miser sur un nouveau continuum de recherche au CDR de Saint-Jean-sur-Richelieu

Projets de recherche basés sur les besoins complexes du secteur

Expertises scientifiques

Approche basée sur la socialisation des expertises

Groupes de spécialités technologiques

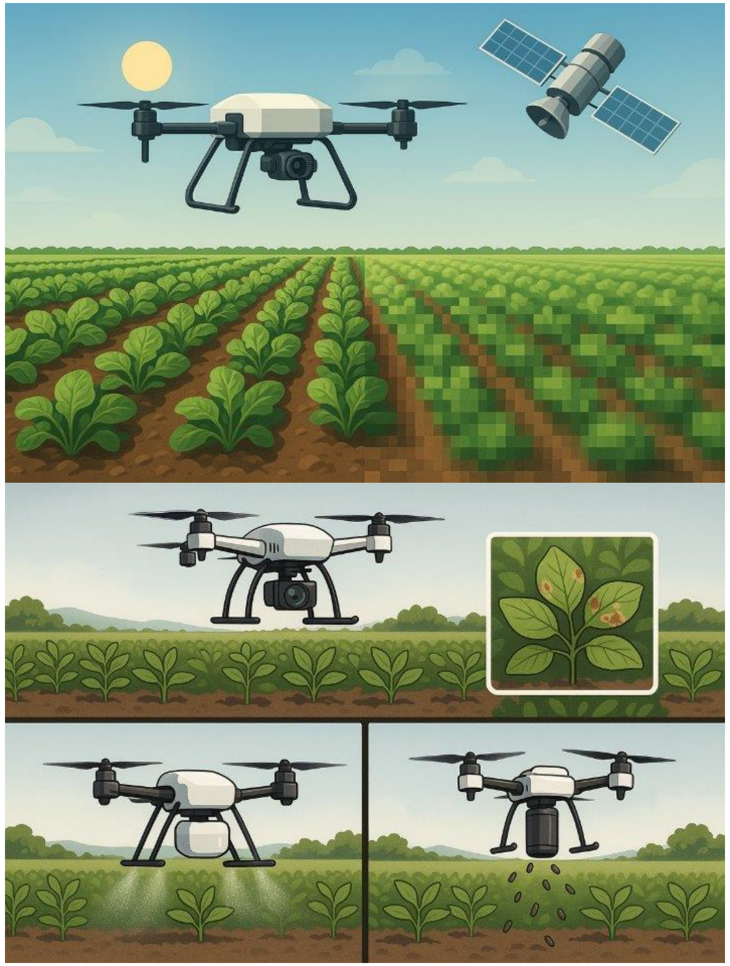
Synergie intellectuelle & Rehaussement de l’efficacité de la recherche

Résultats

Point clé : « Une approche multidisciplinaire est essentielle pour résoudre des problèmes complexes! »

L'exemple de l'utilisation du **Drone** comme outil de la transformation numérique de l'agriculture

- Drones comme technologie incontournable
- Se situe entre les satellites et capteurs sur le terrain
- Intéressant ratio $$$/efficacité
- Acquisition de données à très haute résolution
- Capacité accrue de revisite



Miser sur les drones pour exploiter l'imagerie à **très haute résolution**

+

Oblique view RGB

LiDAR

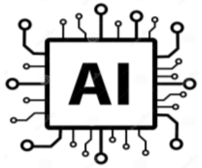
Multispectral

IR Thermique

Superspectral

+

Outils de traitnement et d'analyses



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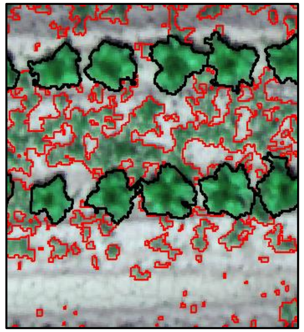
Extraction et détection de caractéristiques

Crop

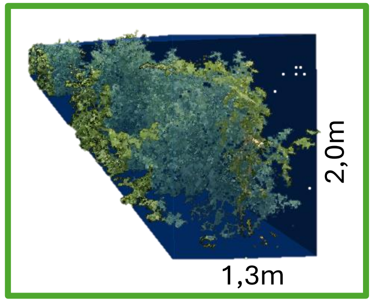
Weed

Pests

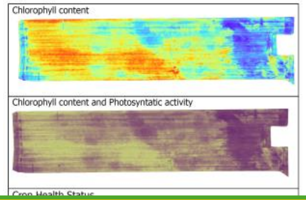
Diseases



Structure 3D de la canopée



Cartes de stress des cultures basées sur des informations spectrales



Fournir des données traitées pour une analyse plus approfondie

Point clé : « Le drone est outil d'observation formidable! »

Usages et bénéfices des capteurs et des drones

2022

Computers and Electronics in Agriculture 198 (2022) 107017
Contents lists available at ScienceDirect
Computers and Electronics in Agriculture
journal homepage: www.elsevier.com/locate/compag

Review

Drones in agriculture: A review and bibliometric analysis

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ARTICLE INFO

Keywords:
Drones
UAV
Precision agriculture
Internet of Things
Bibliometrics

ABSTRACT

Drones, also called Unmanned Aerial Vehicles (UAV), have witnessed a remarkable development in recent decades. In agriculture, they have changed farming practices by offering farmers substantial cost savings, increased operational efficiency, and better profitability. Over the past decades, the topic of agricultural drones has attracted remarkable academic attention. We therefore conduct a comprehensive review based on bibliometrics to summarize and structure existing academic literature and reveal current research trends and hotspots. We apply bibliometric techniques and analyze the literature surrounding agricultural drones to summarize and assess previous research. Our analysis indicates that remote sensing, precision agriculture, deep learning, machine learning, and the Internet of Things are critical topics related to agricultural drones. The co-citation analysis reveals six broad research clusters in the literature. This study is one of the first attempts to summarize drone research in agriculture and suggest future research directions.

1. Introduction

Agriculture represents the primary food source of the world (Friha et al., 2021), and it has been facing severe challenges due to the increasing demand for food products, food safety, and security concerns as well as calls for environmental protection, water preservation, and sustainability (Inoue, 2020). This development is predicted to continue since the world population is estimated to reach 9.7 billion by 2050 (2019). Since agriculture constitutes the most prominent example of water consumption globally, it is expected that food demand and water consumption will dramatically increase in the foreseeable future. Furthermore, the increasing consumption of fertilizers and pesticides coupled with the intensification of farming activities could lead to future environmental challenges. Similarly, arable land is limited, and the number of farmers is decreasing worldwide. These challenges accentuate the need for innovative and sustainable farming solutions (Elijah et al., 2018; Friha et al., 2021; Inoue, 2020; Tzounis et al., 2017).

Incorporating novel technologies has been identified as a promising solution to address these challenges. Smart farming (Brewster et al., 2017; Tang et al., 2021) and precision agriculture (Feng et al., 2019; Khanna & Kaur, 2019) have emerged as a result of such debates. The former is a general notion for adopting information communication technologies (ICT) and other cutting-edge innovations in farming activities to increase efficiency and efficacy (Haque et al., 2021). The latter focuses on site-specific management in which the land is divided into homogeneous parts, and each part gets the exact amount of agricultural input for crop yield optimization by means of novel technologies (Feng et al., 2019; Khanna & Kaur, 2019). Prominent technologies that have attracted scholars' attention in this field include Wireless Sensor Networks (WSNs) (J. Zheng & Yang, 2018; Y. Zhou et al., 2016), the Internet of Things (IoT) (Gill et al., 2017; He et al., 2021; Liu et al., 2019), artificial intelligence (AI) techniques, including machine learning and deep learning (Liakos et al., 2018; Parsaeian et al., 2020; Shadrin et al., 2019), computing technologies (Hsu et al., 2020; Jinbo et al., 2019; Zamora-Izquierdo et al., 2019), big data (Gill et al., 2017; Tantalaki et al., 2019), and blockchain (P. W. Khan et al., 2020; Pincheira et al., 2021).

In addition to the abovementioned technologies, remote sensing has been considered a technological tool with high potential to improve smart and precision agriculture. Satellites, human-crewed aircraft, and drones are popular remote-sensing technologies (Tsouros et al., 2019). Drones, popularly known as Unmanned Aerial Vehicles (UAVs),

* Corresponding author.

2023

remote sensing
MDPI

Review

Remote Sensing in Field Crop Monitoring: A Comprehensive Review of Sensor Systems, Data Analyses and Recent Advances

Emmanuel Omia [1], Hyungjin Bae [1], Eunsung Park [2], Moon Sung Kim [3], Insuck Baek [3], Isa Kabenge [4] and Byoung-Kwan Cho [1,2,*]

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2 Department of Smart Agricultural Systems, Chungnam National University, Daejeon 34134, Republic of Korea
3 Environmental Microbial and Food Safety Laboratory, Agricultural Research Service, United States Department of Agriculture, Powder Mill Road, BARC-East, Bldg 303, Beltsville, MD 20705, USA
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* Correspondence: chobk@cnu.ac.kr

Abstract: The key elements that underpin food security require the adaptation of agricultural systems to support productivity increases while minimizing inputs and the adverse effects of climate change. The advances in precision agriculture over the past few years have substantially enhanced the efficiency of applying spatially variable agronomic inputs for irrigation, such as fertilizers, pesticides, seeds, and water, and we can attribute them to the increasing number of innovations that utilize new technologies that are capable of monitoring field crops for varying spatial and temporal changes. Remote sensing technology is the primary driver of success in precision agriculture, along with other technologies, such as the Internet of Things (IoT), robotic systems, weather forecasting technology, and global positioning systems (GPSs). More specifically, multispectral imaging (MSI) and hyperspectral imaging (HSI) have made the monitoring of the field crop health to aid decision making and the application of spatially and temporally variable agronomic inputs possible. Furthermore, the fusion of remotely sensed multisource data—for instance, HSI and LiDAR (light detection and ranging) data fusion—has even made it possible to monitor the changes in different parts of an individual plant. To the best of our knowledge, in most reviews on this topic, the authors focus on specific methods and/or technologies, with few or no comprehensive reviews that expose researchers, and especially students, to the vast possible range of remote sensing technologies used in agriculture. In this article, we describe/evaluate the remote sensing (RS) technologies for field crop monitoring using spectral imaging, and we provide a thorough and discipline-specific starting point for researchers of different levels by supplying sufficient details and references. We also high light strengths and drawbacks of each technology, which will help readers select the most appropriate method for their intended uses.

Keywords: remote sensing; crop monitoring; precision agriculture; data fusion; artificial intelligence; hyperspectral imaging; multi-spectral imaging

check for updates

Citation: Omia, E.; Bae, H.; Park, E.; Kim, M.S.; Baek, I.; Kabenge, I.; Cho, B.-K. Remote Sensing in Field Crop Monitoring: A Comprehensive Review of Sensor Systems, Data Analyses and Recent Advances. Remote Sens. 2023, 15, 354. https://doi.org/10.3390/rs15020354

Academic Editor: Jochem Verrelst

Received: 31 October 2022
Revised: 31 December 2022
Accepted: 1 January 2023

information on the spatial variation of key agronomic parameters. The world's population is growing at its fastest speed, and researchers have estimated that it will reach over 9 billion people by 2050 [1]; however, all humankind still relies on agriculture to provide its most basic needs of food and fiber [2]. As has been reported by the Natural Environment Research Council [3], the adverse effects of climate change have also begun to substantially deteriorate agricultural productivity. Therefore, following an earlier remark

2024

Phytopathology® 2024 • 114:1733-1741 • https://doi.org/10.1094/PHYTO-01-24-0009-PER
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PERSPECTIVES

From Detection to Protection: The Role of Optical Sensors, Robots, and Artificial Intelligence in Modern Plant Disease Management

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2 Embrapa Agricultural Digital, Campinas, SP 13083-886, Brazil
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Accepted for publication 22 May 2024.

Abstract

In the past decade, there has been a recognized need for innovative methods to monitor and manage plant diseases, aiming to meet the precision demands of modern agriculture. Over the last 15 years, significant advances in the detection, monitoring, and management of plant diseases have been made, largely propelled by cutting-edge technologies. Recent advances in precision agriculture have been driven by sophisticated tools such as optical sensors, artificial intelligence, microsensor networks, and autonomous driving vehicles. These technologies have enabled the development of novel cropping systems, allowing for targeted management of crops, contrasting with the traditional, homogeneous treatment of large crop areas. The research in this field is usually a highly collaborative and interdisciplinary endeavor. It brings together experts from diverse fields such as plant pathology, computer science, statistics, engineering, and agronomy to forge comprehensive solutions. Despite the progress, translating the advancements in the precision of decision-making or automation into agricultural practice remains a challenge. The knowledge transfer to agricultural practice and extension has been particularly challenging. Enhancing the accuracy and timeliness of disease detection continues to be a priority, with data-driven artificial intelligence systems poised to play a pivotal role. This perspective article addresses critical questions and challenges faced in the implementation of digital technologies for plant disease management. It underscores the urgency of integrating innovative technological advances with traditional integrated pest management. It highlights unresolved issues regarding the establishment of control thresholds for site-specific treatments and the necessary alignment of digital technology use with regulatory frameworks. Importantly, the paper calls for intensified research efforts, widespread knowledge transfer, and education to optimize the application of digital tools for plant disease management, recognizing the intersection of technology's potential with its current practical limitations.

Keywords: accuracy, artificial intelligence, optical sensors, plant disease detection, robotics

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The article reports the results of the research only. Mention of a trademark or proprietary product is solely for the purpose of providing specific information and does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

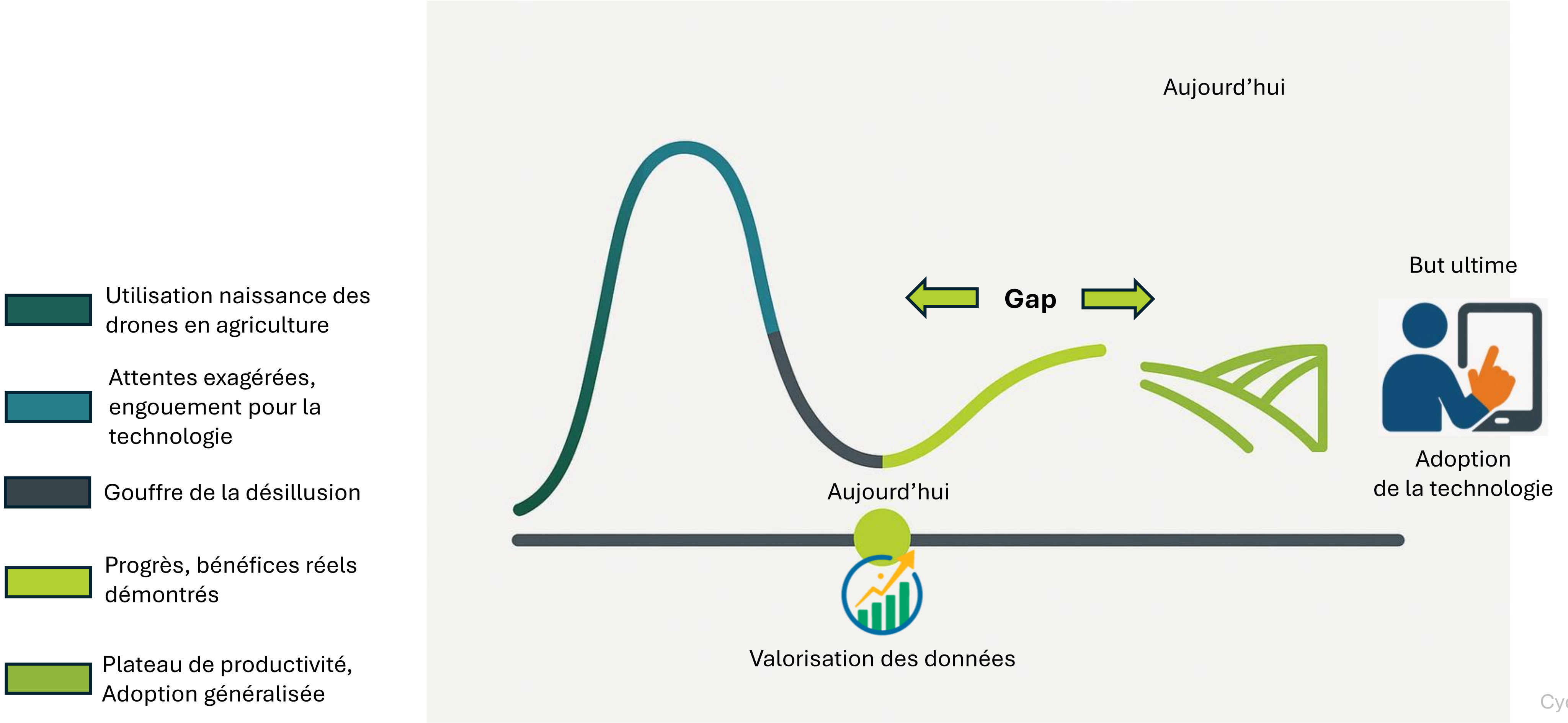
Funding: A.-K. Mahlein was partially funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy (EXC 2070-390732324) and by the German Federal Ministry of Food and Agriculture (BMEL) under project FarmerSpace based on a decision of the Parliament of the Federal Republic of Germany. The Federal Office for Agriculture and Food (BLE) provided coordinating support for digitalization in agriculture as a funding organization (grant number FZK 28DE104A18). C. H. Bock was supported by the U.S. Department of Agriculture-Agricultural Research Service CRIS Project 6042-21220-014-00. E. M. Del Ponte was supported by the Brazilian National Council for Scien-

Driving Motivation

Agricultural crop production, including the production of food, feed, and fiber, faces multiple challenges. Crop science and agricultural practice are caught between sustainable productivity increases, challenging and changing environmental conditions, increased biotic and abiotic stresses, and shifting policy frameworks. Digital agriculture is a burgeoning approach that can meet the challenge of creating a sustainable global agricultural production system (Basso and Antle 2020). Plant diseases reduce the quality and quantity of crop yield, and integrated crop protection strategies need to be implemented while addressing environmental concerns and being sensitive to regulatory practices. Regulations continue to tighten conventional plant protection products to mitigate environmental

Point clé : «le transfert des connaissances vers les pratiques agricoles est plutôt ardu »

Défis et limites pour les agriculteurs



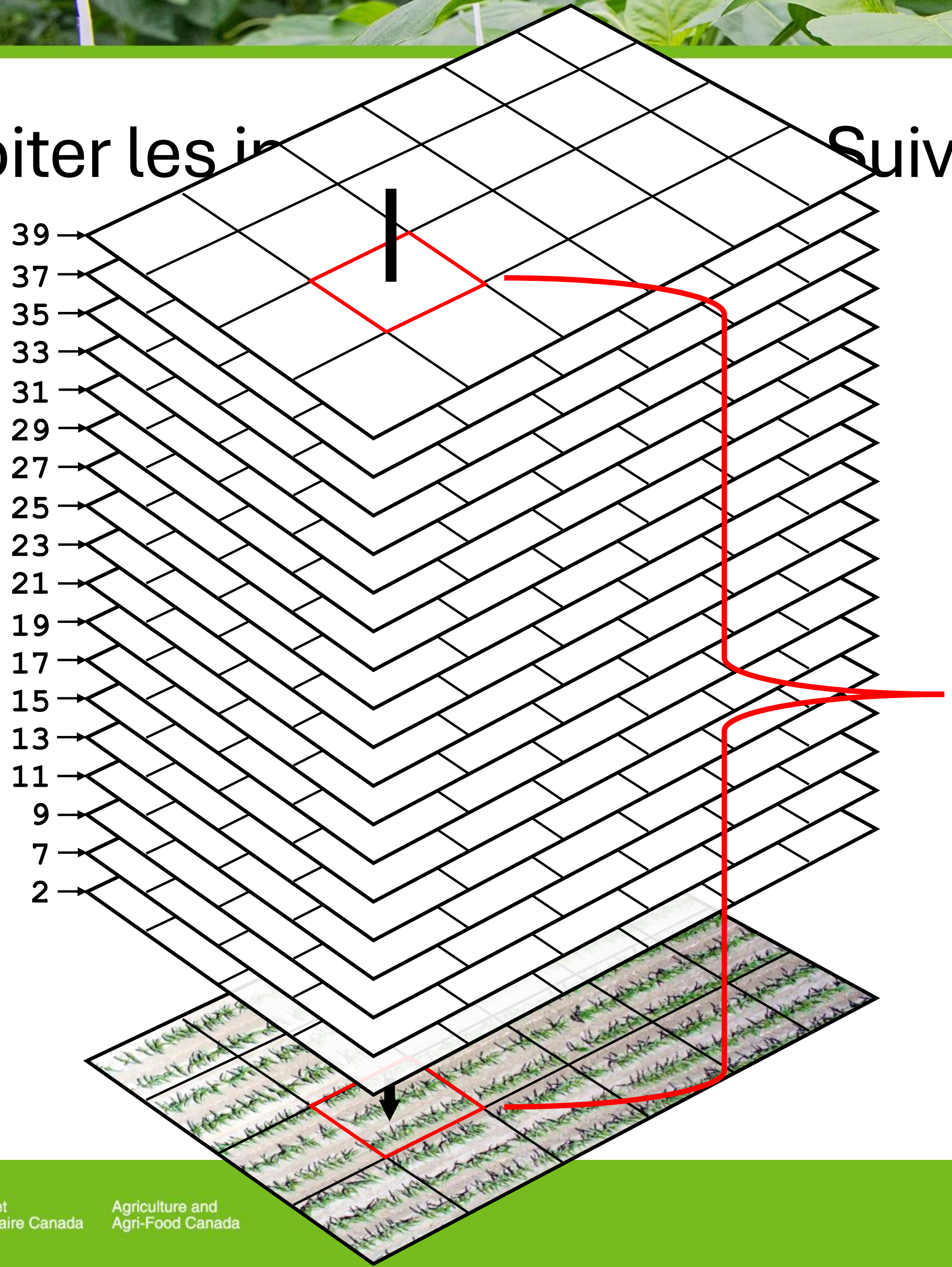
Cycle de l'engouement de Gartner

Défis et limites pour les agriculteurs

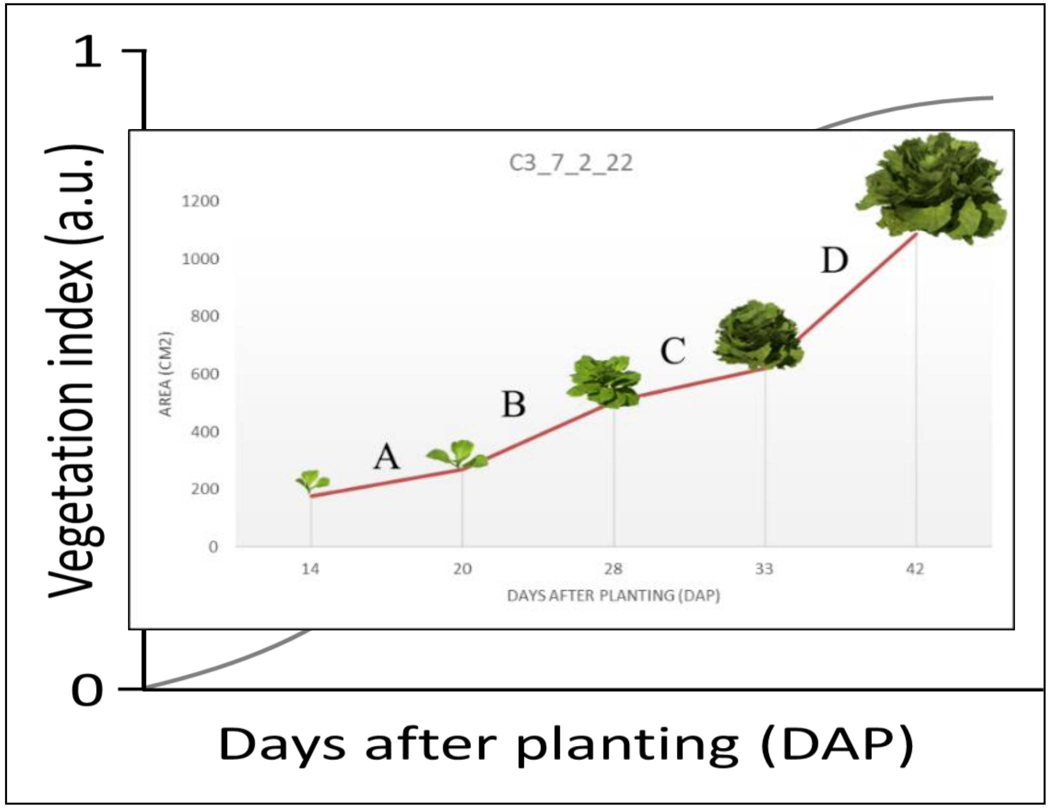
- Valorisation et interprétation des images complexes
- Compétences multidisciplinaires nécessaires
- Intégration à d’autres sources de données agricoles
- **Importance de la science appliquée des données**

Point clé: « Le drone n’est pas la finalité. Le défi est de produire des outils d’aide à la décision! »

Exploiter les i… Suivi temporel des cultures par drone

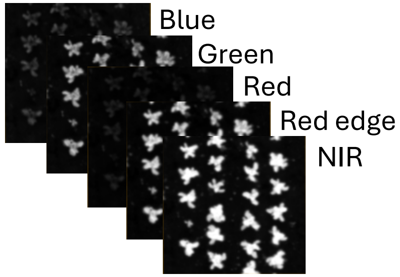


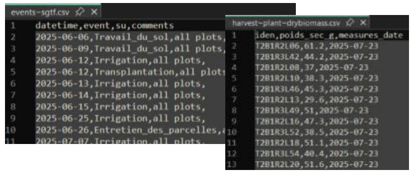
Growth curve for pixel/zone X_i, Y_i



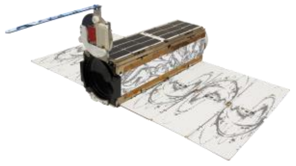
Plant.DynaSTI : Une approche d'observation avancée pour la recherche

• Outil scientifique développé pour analyser la croissance de chaque objet (e.g. laitue) • Génère des données morphologiques des plants (taille, volume, hauteur)
• Évalue précisément les impacts de traitements et intrants expérimentaux



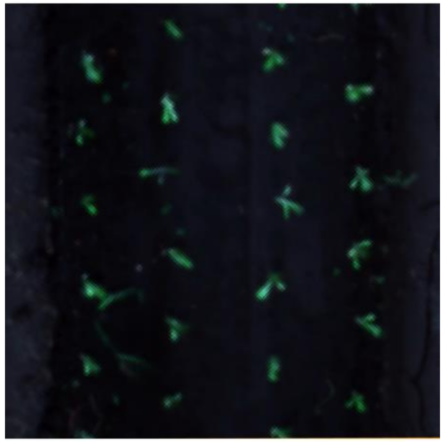


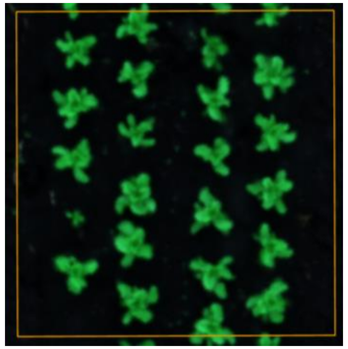
Multi-source



Multi-platforme

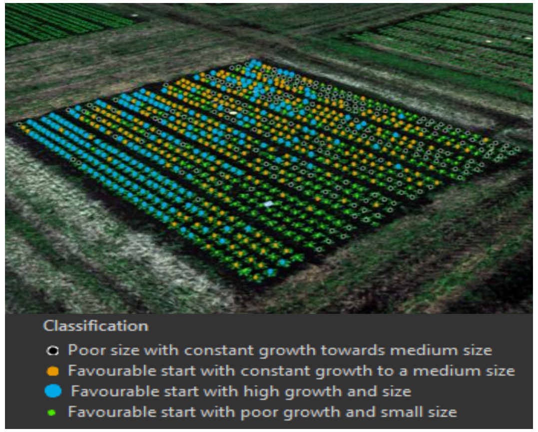
Beaucoup de données

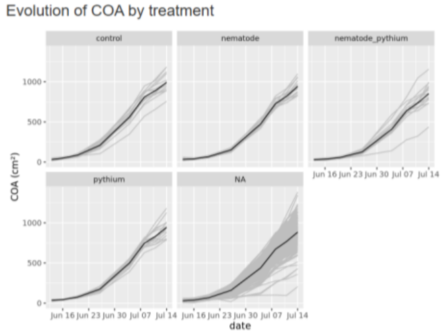




Multi-temporelle

Multi-échelle





Intégration multidimensionnelle des données Avantages clés de Plant.DynaSTI

- Analyse spatio-temporelle pour détecter subtilités invisibles
- Intégration avec d'autres sources : microbiome, maladies, nutrition
- Comparaison entre plants et traitements
- Échantillonnage fréquent et interprétation fine
- Valeur individuelle pour chaque plant
- Accessibilité à toutes les données pour une puissance statistique supérieure

De plus:

- **Grande visibilité** au sein du ministère
- **Positionnement avantageux** pour la transformation numérique de l'agriculture, l'un des grands piliers de la recherche à AAC
- **Deux publications scientifiques qui se base sur cette approche**
- **Mais…**

ISPRS Open Journal of Photogrammetry and Remote Sensing 11 (2024) 100052

Contents lists available at ScienceDirect

ISPRS Open Journal of Photogrammetry and Remote Sensing

journal homepage: www.journals.elsevier.com/isprs-open-journal-of-photogrammetry-and-remote-sensing

An integrated data-driven approach to monitor and estimate plant-scale growth using UAV

Philippe Vigneault[a,*], Joël Lafond-Lapalme[a], Arianne Deshaies[a], Kosal Khun[a], Samuel de la Sablonnière[a], Martin Filion[a], Louis Longchamps[b], Benjamin Mimee[a]

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ARTICLE INFO

Keywords:
UAV
Crop monitoring
Plant scale growth model
Logistic growth curve
Growth characteristics
Maturity estimation
Lettuce

ABSTRACT

UAV-mounted sensors can be used to estimate crop biophysical traits, offering an alternative to traditional field scouting. However, the high temporal resolution offered by UAV platforms, critical for identifying small differences in crop conditions, is rarely exploited throughout the entire growing season. This limits growers' ability to obtain timely information for real-time interventions. New findings support that it is possible to parametrize an entire crop growth cycle under different conditions by accumulating sufficient data over time and using logistic growth models to highlight growth patterns. A step forward would be to model crop growth cycle at the plant-level in order to anticipate the optimal harvest dates in each plot or quickly identify growth problematics. Individual plant monitoring can be achieved by combining high spatial resolution images with accurate segmentation algorithms. The main objective of the study was therefore to develop and validate an integrated pipeline based on multidimensional data to extract predictive growth metrics for crop monitoring at the plant-level under various field conditions. The plant growth monitoring workflow was based on a three-step design ultimately leading to decision-making and reporting. Lettuce (*Lactuca sativa* L.) was chosen as a model plant due to its simple geometry, rapid growth and simple cultivation method. Treatments were composed of contrasting cover crops. Overall, correlation analysis showed that UAV-derived morphological metrics are reliable proxies for harvested biomass throughout the growing season, especially in later stages (Spearman's $\rho > 0.9$) and can be used as growth indicators. Therefore, Logistic Growth Curves (LGCs) were fitted to Crop Object Area (COA) values for each individual lettuce, using data up to 26 (generating G_{26} LGCs), 30 (G_{30}) and 37 (G_{37}) Days After Transplant (DAT). To assess the quality of their projections, G_{26} and G_{30} were compared to the reference LGC G_{37}. The results indicated that Mean Absolute Percentage Error (MAPE) of projected COA was 9.6% and 6.8% for G_{26} and G_{30} respectively. Overall, the LGC parameters were close to the reference and highly correlated with the harvested biomass. The study also demonstrated the potential of having very good insight on plant maturity level by modeling the LGC 13 days before harvest. Furthermore, a dashboard was proposed to monitor current and projected maturity level, highlighting areas for further investigation. This novel integrated pipeline has the potential to become a valuable tool for research, on-farm decision making, and field interventions by providing data on plant biomass, maturity, and growth stages under different conditions, used as crop growth indicators.

1. Introduction

Precision agriculture is a discipline that aims at incorporating temporal and spatial variation into crop management decisions to improve sustainability in agricultural production and ultimately reduce environmental impacts on soils, water and biodiversity (Bongiovanni and Lowenberg-Deboer, 2004; ISPA, 2021). In precision agriculture, several site-specific technologies are used to improve decision making based on real-time crop/plant data acquisition (Kayad et al., 2022; Saiz-Rubio and Rovira-Más, 2020; Dhanaraju et al., 2022). These allow to identify plant growth problems related to biotic or abiotic stresses, to estimate input requirements (e.g., fertilizer, irrigation), and effectively control diseases and pests through improved field interventions.

Reliable and robust remote sensing platforms, such as UAVs or

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Plant Soil
https://doi.org/10.1007/s11104-025-07742-7

RESEARCH ARTICLE

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Interplay between nitrogen fertilization and plant growth-promoting rhizobacteria impacts lettuce growth under field conditions

Adrien Biessy · Marie Ciotola · Mélanie Cadieux · Arianne Deshaies · Antoine Zboralski · Kosal Khun · Joël Lafond-Lapalme · Philippe Vigneault · Martin Filion

Received: 5 February 2025 / Accepted: 15 July 2025

Abstract

Background and aims In the global context of reducing the use of synthetic fertilizers, it is crucial to explore solutions that may help minimizing yield losses associated with lower nitrogen fertilizer application regimes. In this study, we explored the potential of using two plant-beneficial rhizobacteria, *Pseudomonas protegens* B21-024 and *Bacillus pumilus* LBUM494, alone and in combination, to promote the growth of field-grown lettuce plants under varying nitrogen fertilization conditions.

Methods We carried out a field experiment exploring the plant growth promotion ability of these two bacterial strains, alone and in combination, under three nitrogen fertilizer application regimes (recommended application dose, 50% reduction and 75% reduction). Lettuce growth and aboveground biomass accumulation were monitored weekly throughout the growing season using manual harvesting and unmanned aerial vehicle imaging. Leaf macronutrients content was also analyzed at harvest.

Results *P. protegens* B21-024 and *B. pumilus* LBUM494, alone and in combination, promoted plant growth under all three nitrogen fertilization regimes. However, inoculation with *P. protegens* B21-024 was the only treatment able to compensate for yield losses associated with lower nitrogen fertilizer applications. The microbial consortium composed of the two bacterial strains was less effective than the two strains inoculated alone under the lowest nitrogen fertilizer application regime.

Conclusion This study demonstrates the potential of using *P. protegens* B21-024 to promote lettuce growth under field conditions, especially under reduced nitrogen fertilizer regimes.

Keywords Plant growth-promoting rhizobacteria · *Pseudomonas protegens* · *Bacillus pumilus* · Nitrogen fertilizer · Field experiment · Nitrogen leaf content

Responsible Editor: Michel-Pierre Faucon.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11104-025-07742-7.

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Saint-Jean-Sur-Richelieu Research and Development Centre, Agriculture and Agri-Food Canada, Saint-Jean-Sur-Richelieu, QC, Canada

Point clé « est-ce que Plant.DynaSTI serait un outil bénéfique pour les producteurs? »

Published online: 29 July 2025

Springer

Partenariat Innoptech – Projet Agri-Science

• Collaboration pour créer un système d'aide à la décision • Chaîne intégrée de traitement de données drones + IA • Automatisation du suivi, prédiction du nombre de plants sains et de la maturité

Objectif : optimiser productivité, durabilité, résilience • Aucune solution équivalente existante

Conclusion

Présentation de Vegforecast par M. Jean-Christophe Ruel