# Forgotten science: How 1900s studies challenge the current research on sap analysis

Javier Santa-Cruz[1,2,3*], Diego Calbucheo[3,4], Samuel Valdebenito[2], Vicente Vásquez[2], Marcelo Aguilar[1], Patricia Peñaloza[2], Hernán Allendes[2,3], Kooichi Vidal[2]

(1. *Escuela de Ciencias Agrícolas y Veterinarias, Universidad Viña del Mar, Viña del Mar 2520000, Chile*;
2. *Escuela de Agronomía, Facultad de Ciencias Agronómicas y de Los Alimentos, Pontificia Universidad Católica de Valparaíso, Quillota 2260000, Chile*;
3. *R & D Department, HortiTech Analytics, Quillota 2260000, Chile*;
4. *Laboratorio de Ecoinformática, Instituto de Conservación, Biodiversidad y Territorio, Universidad Austral de Chile, Valdivia 5090000, Chile*)

**Abstract:** Plant sap analysis has emerged as a key focus in recent agricultural research, aiming to enhance fertilizer management and improve crop nutritional assessment. Despite its current recognition as an innovative technique, the origins of sap testing date back over 120 years, with early studies largely overlooked by contemporary researchers. This work revisits these foundational studies, exploring their findings and revealing their potential to challenge modern techniques. This study discusses historical methods of sap collection and how variations in pressure and extraction techniques can influence its nutrient composition. This retrospective examination suggests that integrating these early insights can significantly enhance current sap testing methods.

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## 1 Introduction

Improving fertilizer use efficiency is a key goal for achieving sustainable agriculture, as mentioned in the “Farm to Fork Strategy” adopted by the EU and in the FAO “Strategic Framework 2022-2031”. It is also indirectly considered in the 2030 Agenda of the United Nations. One proposed way to address this issue is to seek technological innovations to aid in plant nutritional diagnosis and real-time decision making, commonly known as “on-farm quick tests”.

In recent years, several research studies have focused on plant sap analysis, highlighting its relevance as a powerful tool to enhance fertilizer management[1-4]. Despite being considered an innovative technique, the genesis of the sap tests dates back more than 120 years. It is surprising that references to the first studies are virtually absent in the current scientific literature, leaving their key findings to fall into oblivion.

Diverse reasons for this can be suggested. For instance, the lack of consistency in terminology used to refer to the fluid obtained by pressing plant tissues, which has been interchangeably termed “cellular extract”, “cellular juice”, “plant juice”, “plant fluids”, “tissue fluids” and “plant solutions”. Another cause may be the limited access to this information, which has been progressively facilitated over time by digitalization and database indexing. Nevertheless, it is now possible to access those initial studies; thus, we consider it crucial to integrate their results into the current discussion on sap analysis.

## 2 Sap as a nutritional index

Although articles such as “The snappy sap test”[5] have been considered some of the first records of sap analysis, our literature search reveals that its conception extends back further in time. The oldest study we found dates from 1902, in which Fred Heald[6] evaluated the sap electrical conductivity of several vegetables.

Only four years later, André[7] measured the content of nutrients such as nitrogen and phosphorus in the sap of two flower crops. Thereafter, several authors described that sap mineral concentration was closely related to the fertilizer application rates to soil and substrate[8-10].

Following that framework, the same authors suggested that sap mineral content could be used as a fertilizer index, and critical levels for each nutrient could be established. Consequently, Carolus[11] defined the nutritional sufficiency levels for five macronutrients in the sap of potatoes, an initiative that has been carried out by several researchers up to the present.

## 3 Early methodological questions

One of the main steps in performing sap analysis is the extraction of sap from fresh plant tissues. In current studies, this

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**Biographies: Diego Calbucheo**, Agr Eng MS, research interest: ecology, Email: dgcalbucheo@gmail.com; **Samuel Valdebenito**, Agr Eng MS, research interest: plant histology, Email: samuel.valdebenito.p@mail.pucv.cl; **Vicente Vásquez**, Agr Eng, research interest: horticulture, Email: vicente.vasquez.e@mail.pucv.cl; **Marcelo Aguilar**, Agr Eng MS, research interest: plant nutrition, Email: marcelo.aguilar@uvm.cl; **Patricia Peñaloza**, Agr Eng PhD, research interest: horticulture, Email: patricia.penaloza@pucv.cl; **Hernán Allendes**, Agr Eng PhD, research interest: plant nutrition, Email: hernan.allendes@gmail.com; **Kooichi Vidal**, Agr Eng MS PhD, research interest: horticulture, Email: kooichi.vidal@pucv.cl.
***Corresponding author: Javier Santa-Cruz**, Agr Eng MS, research interest: plant nutrition, Mailing address: Calle San Francisco S/N, Sector La Palma, Quillota, Región de Valparaíso 226000, Chile, Email: santacruz.agr@hotmail.com.

fluid is obtained by crushing the selected tissue with a pencil, placing small pieces of it in a syringe, a garlic press, or a citrus squeezer, as well as in a screw or hydraulic press. However, little is known about the equivalence and representativeness of these methods, and it is assumed that the pressing device and its operation do not affect the sap nutrient content[12]. Although modern research has not addressed this, studies conducted in the past century focused their efforts on this physical factor through the question: "Do applied pressure and recovered volume alter sap composition?".

A study by Heald[13] marks the starting point for this issue, proposing the development of a special press for plant research, intended to extract small volumes of sap from plant tissues. However, the sap obtained by a single pressing is usually not enough for all the desired nutritional measurements (e.g. °Bx, pH, EC, $NO_3^-$, $K^+$, $Ca^{2+}$, $Mg^{2+}$), hence repeated or more vigorous extractions must be carried out with the same sample.

In this context, Marie & Gatin[14] and Dixon & Atkins[15] wondered if pressing a tissue sample multiple times changes the sap properties, describing that solute concentration increases in each successive sap portion. Conversely, Gortner et al.[16] provided evidence that this trend could be species-dependent; hence, sap concentration could also decrease or remain constant.

Similar findings were reported by Sayre & Morris[17], who noted that the electrical conductivity and sugar content of corn sap remained constant after several extractions. While the same trend was described for nitrate-nitrogen and inorganic phosphorus, they found a depletion of total nitrogen and phosphorus. This suggested that not all sap constituents change equally when pressed more than once.

Likewise, Gerdel[18] evaluated the nitrate-nitrogen in corn sap, but included a new factor: the use of increasing pressures to obtain each successive sap portion. Nevertheless, consistent with previous findings, he reported that nutrient concentration remained stable after six extractions. By contrast, Broyer & Hoagland[19] described that the electrical conductivity and potassium concentration increased in the first five sap portions until approximately 25% of the total shoot moisture was removed. After that, both parameters decreased close to their initial values. In this sense, some ionic species could have greater changes than others when sap portions are expressed by increasing pressures (e.g. $NO_3^-$ versus $K^+$).

The above-mentioned studies illustrate how sap nutrient concentration can be modified by the extraction of different volumes, as well as the amount of pressure exerted to obtain them. Hence, they provide crucial evidence that challenges the current belief that equal sap portions are obtained by successive extractions from the same sample. With this, we aim to highlight the need to delve into the past before working for the future – and to give an opportunity to hundreds of studies on sap analysis from the past century that are waiting to be considered.

## 4 Conclusions

The growth rates of modern science have led us to forget the genesis of some research topics, which could result in the loss of valuable information for decision-making. The first studies on plant sap were likely inaccessible for researchers until now; therefore, it is important to take their findings into account and use them to improve the current methods for sap analysis. We encourage authors, reviewers, and editors, as well as agricultural consultants and laboratories, to critically evaluate the methods used for obtaining and analyzing plant sap, while also considering early studies as a foundation for future research.

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