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Agronomic Practices and Performances of *Stevia rebaudiana bertoni* under Field Conditions: A Systematic Review †

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Abstract: *Stevia (Stevia Rebauiana Bertoni)* is one of the most renowned medicinal plants for its low calorific value. Stevia's active components are steviol glycosides (SGs), which include Rebaudioside A, B, C, D, E, F, M, Stevioside, Steviolbioside, Dulcoside A, and Dulcoside C. These steviol glycosides are 150–300 times sweeter than sugar. The sweetening molecules stevioside and rebaudioside A are the most common. In this work, we performed a systematic review combined with a bibliometric analysis of stevia farming techniques in the field. The study is based on published literature data for the years 2000–2021. A sum of 54 articles was found, indicating that scientific study on stevia's agronomic techniques and productivity in the field is currently insufficient. Asia, Europe, and South America were the major research production sites in this domain, accounting for more than 90% of the research output. The number of articles dealing with density and planting that were examined was quite restricted. The principal themes covered in the scientific literature were the effects of "fertilization" and "irrigation", followed by plant growth-promoting rhizobacteria "PGPR" and fungi "PGPF", "salinity", and "harvest" on stevia yield and quality. The results of this research will allow us to highlight insufficient available research works and knowledge gaps and the agronomic treatments that had the greatest impact on productive response were fertilization, irrigation, and salinity.

Keywords: stevia; systematic review; bibliometric analysis; stevioside; rebaudioside-A; agronomic techniques

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1. Introduction

Stevia rebaudiana Bertoni is a sweet plant that belongs to the *Asteraceae* family and is a natural non-calorie bio-sweetener that can help people with diabetes and obesity. In the next years, global demand for high bio-sweeteners is likely to increase significantly [1]. Stevia leaves contain approximately ten steviol glycosides, the most significant of which are stevioside (3–10%), rebaudioside-A (13%), rebaudioside-B, rebaudioside-C, and rebaudioside-D [2].

Before the beginning of the 21st century, most stevia research was detailed in the so-called unpublished literature; numerous experimental trials were carried out in stevia's countries of origin, but not found in the worldwide database. Little research has been undertaken on stevia's performance and quality in field conditions when various agronomic management systems were applied, despite its global relevance, resilience to unfavorable environments, sweetening qualities, and pharmacological capabilities. To answer the question, "What are the knowledge gaps in agronomic management and the performance of stevia under field conditions?" a systematic review incorporating bibliometric analysis is required. In this study, a systematic review which is a high-level summary of fundamental research with the goal of discovering, selecting, synthesizing, and evaluating all high-quality data records was used [3]. The systematic review consisting of literature searching was combined with a bibliometric analysis of stevia farming techniques in field conditions as reflected in the worldwide database over the previous two decades (2000–2021).

2. Material and Methods

We used an approach based on a literature search, inclusion and exclusion criteria, bibliometric screening, and conceptual network analysis in this study, according to Sellami et al. [4], and other researchers [5–7].

2.1. Literature Research

Literature searching linked to the agronomic techniques of stevia (*Stevia rebaudiana bertoni*) production throughout the world was performed through a systematic review of two bibliographic databases: Web of Science and Scopus. The findings were published in English-language journals between 2000 and 2021. Academic database searches were carried out on 20 October 2021. The following search terms were used in bibliographic databases to search for "subject terms" coupled with Boolean operators: ((fertilization OR irrigation* OR harvest* OR salinity* OR PGPR/PGPF* OR planting) AND (yield OR quality OR stevioside* OR rebaudioside-A*) AND (stevia or (stevia and *rebaudiana*)). Any amount of characters can be represented using the wildcards.

2.2. Inclusion and Exclusion Criteria

To synthesize evidence from a variety of sources, we employed a highly robust and reasonable systematic review process. We limited the systematic review in this analysis by specifying boundaries that included: (I) studies conducted solely in the field, excluding glasshouse and pot studies; and (II) crop productivity studies, excluding forestry, fisheries, domestic animals, and other non-food farming. According to the systematic review evaluation criteria, search keywords were based on four PICO components: population, intervention, comparison, and outcome.

2.3. Bibliometric Screening

After deduplication, the data of the accepted articles were loaded into Endnote (online bibliographic management software; Clarivate Analytics, London, UK). All references were evaluated and were used to find and analyze all references based on the following methodology: The title, abstract, and complete text of each item were pre-selected three times each. At each level, files holding or possibly carrying critical information were identified and sent to the next level.

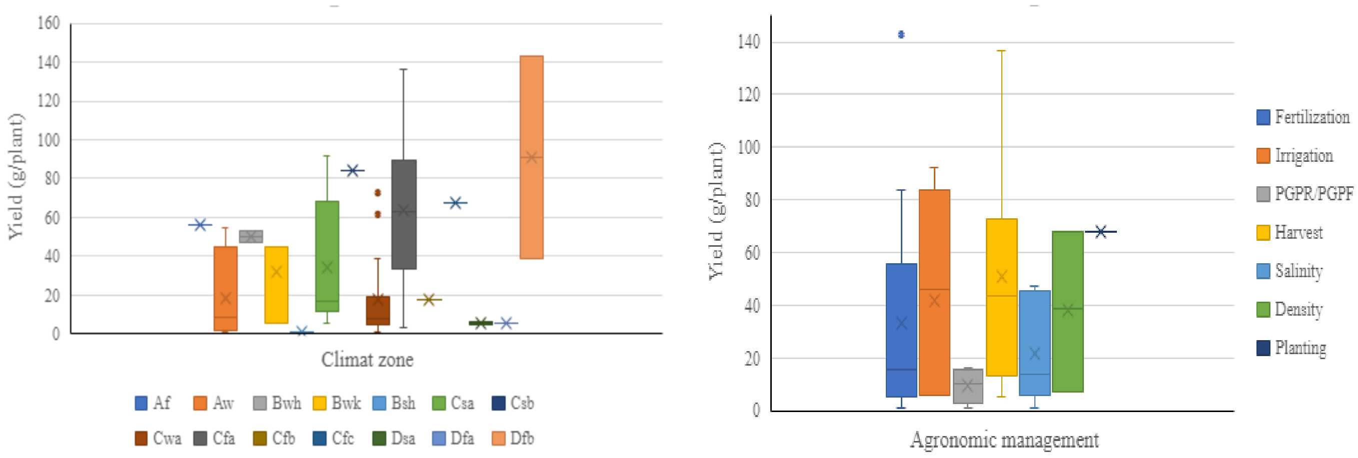
2.4. Bibliometric Analysis and Concept Network Analysis

The year of publishing, the journal, and the frequency with which authors utilized phrases and keywords were all evaluated in the systematic review meta-data. The box plots were created with MS-Excel software.

3. Results

Overall Yield across Factors of Variation

Results were obtained by the above-mentioned literature research methods, and variance was analyzed by MS-Excel software. Owing to the Köppen–Geiger climatic zone [8], the variance was extremely substantial, as shown in Figure 1a. The lowest yield response was 0.79 g/plant in the dry-humid subtropical climate (Cwa), whereas the maximum yield response was 142.8 g/plant in the warm-humid continental climate (Dfb). The highest yield was recorded in the warm-humid continental climate (Dfb), whereas the lowest was reported in the hot semi-arid climate (Bsh) with 142.8 g/plant and 0.79 g/plant respectively.



(**a**) (**b**)

Figure 1. Box plot showing yield (g/plant) trends for all articles (n = 54) across: (**a**) diverse climatic zones; (**b**) diverse agronomic practice groups. X: the average's representation. (-Köppen–Geiger climate zone are: Af: Equatorial climate Aw: tropical wet-dry climate; BSh: hot semi-arid climate; BWh: hot desert climate; BWk: cold desert climate; Cfa: humid subtropical; Cfb: maritime; Cfc: oceanic climate; Csa: interior Mediterranean; Csb: coastal Mediterranean; Cwa: dry-humid subtropical climate; Dsa: dry-hot continental climate; Dfa: hot-humid continental climate and Dfb: warm-humid continental climate. PGPR: plant growth promoting rhizobacteria, PGPF: plant growth promoting fungi-).

The yield variance between different agronomic management practices is shown in Figure 1b. The highest yield value above 80 g/plant was attained by the fertilization followed by the harvest with a yield value above 75 g/plant. The agronomic interventions that had the most influence on productive response were irrigation and harvesting time; PGPR/PGPF had less impact, with a yield value of 16.5 g/plant.

4. Discussion

The systematic review combined with the bibliometric analysis revealed that stevia can grow and ensure a high yield of leaves under different climatic zones in the world. Additionally, the reviewed studies have shown that climate zones like a warm-humid continental climate (Dfb) and humid subtropical climate (Cfa) produce the highest yield. However, a hot semi-arid climate (Bsh), dry-hot continental climate (Dsa), and hot-humid continental climate are much less productive. According to Ramesh et al. [9], stevia can be cultivated in a variety of climates, including semi-humid, subtropical, and temperate zones. Therefore, stevia yield has increased in temperate zones of Central and South Europe [10]. According to research conducted in Egypt, meteorological parameters such as temperature, as well as the length and intensity of the photoperiod, have a significant impact on stevia production, as seen by the considerable increase in yield during the summer compared to the winter [11].

The reviewed studies also have shown that agronomic methods like fertilization results in the highest yield. In addition to fertilization, irrigation is also a critical element that impacts stevia yield. Harvest and density are also important techniques to be considered. Biofertilizers by PGPR/PGPF are unfortunately less efficient.

The determination of the optimal type of fertilizer and/or irrigation regime is critical in the case of stevia introduction to new locations. Furthermore, in its native country (Paraguay), stevia yield under unirrigated conditions is 1500–2500 kg/ha, whereas the yield with irrigation is 4300 kg/ha [12]. According to Karimi et al. [13], the application rate of nitrogen (N) was raised from 30 to 90 kg/ha to boost stevia yield.

5. Conclusions

The investigation found an increased interest in research on fertilization, irrigation, and optimal harvest periods as long-term strategies to assure high yields even in disadvantaged locations like coastal and desert countries or those characterized by different biotic or abiotic stress. According to the geographical dispersion of the study, a stevia crop can adapt to a variety of climatic conditions. This systematic review may also be used by researchers to discover weaknesses and the best methodologies in a research procedure, improve cooperation, particularly among researchers from different countries, increase field studies, and maximize the application of research results. It would contribute significantly to the spread of stevia in many conditions all over the globe.

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