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Harnessing digital innovations to transform production and value chains in the spice industry

Digitalization is transforming the spice industry, offering innovative solutions for production, supply chain optimization, and marketing. India, the largest producer and exporter of spices, is at the forefront of integrating emerging digital technologies such as sensors, drones, and mobile applications to enhance sustainability and precision in spice cultivation. Technologies like the Spice Var database, decision support tools, and AI-driven quality assessments are improving farming practices, boosting productivity, and ensuring food safety. Additionally, blockchain technology and e-auction platforms like eSpice Bazaar and SPIISRY are streamlining trade and traceability, providing transparency in the spice supply chain. The adoption of these digital tools not only improves efficiency but also promotes eco-friendly and sustainable farming practices, benefiting producers, consumers, and the environment. As the industry continues to evolve, digital innovation will play a crucial role in maintaining the heritage of spices while adapting to modern market demands.

Digitalization has become an integral part of our daily lives worldwide, and it is increasingly crucial in production and supply chain of spices. Emerging trends involve the use of sensors, digital tools, and online platforms to enhance transparency and sustainability of the spices production.

Spices are high value and low volume, export-oriented commodities, commonly used for flavouring and seasoning of food and beverages. India is the world's largest producer, consumer, and exporter of spices; the country produces about 75 of the 109 varieties listed by the International Organization for Standardization (ISO) and accounts for half of the global trading in spices. Growing demand from the emerging segment of nutraceuticals is driving the global consumption of Indian spices further at a time when the country is straining to meet the needs of the traditional food sector. The cultivation of spices in India is in an area of 4.76 million ha with a production of 11.80 million tonnes during 2023-24. India's share in spices export at global level is 1.42 million metric tonnes, accounting for US $ 4.46 billion (Spices Board, 2024).

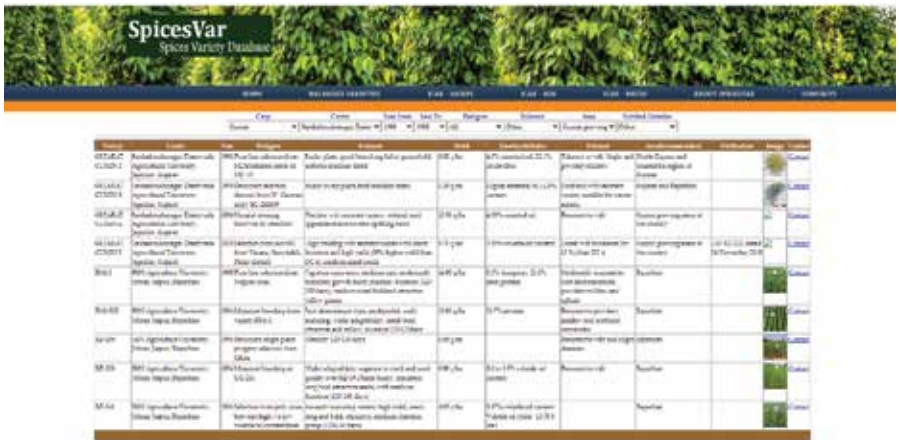
Precision in production

Precise methods are employed for fertilisation more efficiently and to reduce the use of pesticides and irrigation. Advisory services such as digital support tools and automatic weather stations are increasingly being adopted. As many advanced technologies require small producers to make large investments, low-cost smartphone applications are being developed in spices- and herb-producing countries.

Application of drones

To promote drone technology for spraying purposes and precision agriculture, demonstrations have been conducted at both the ICAR-Indian Institute of Spices Research and the ICAR-National Research Centre on Seed Spices. These demonstrations highlighted how drones improve efficiency, reduce labour costs, and enhance crop management through precise application of inputs (plant protection chemicals, nutrients etc).

The unmanned aerial vehicle (UAV) platform is a



SpicesVar database

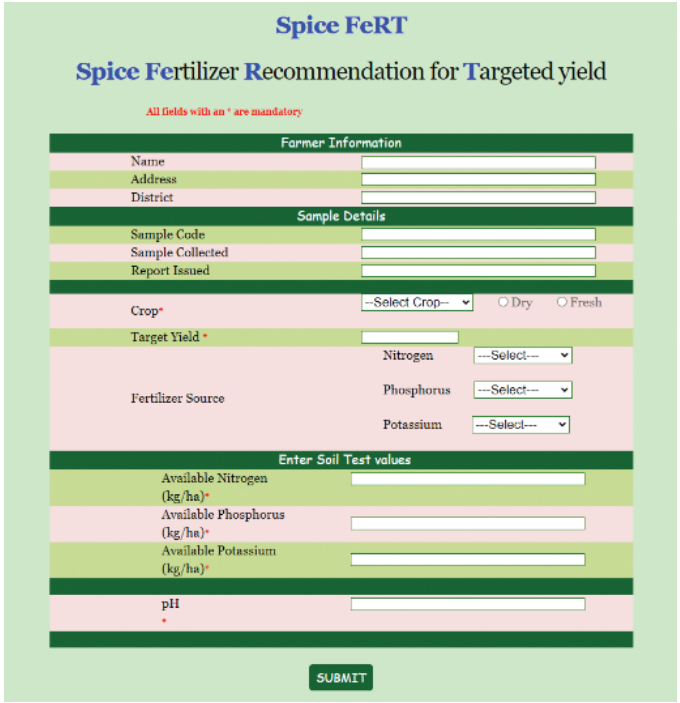
high throughput phenotyping technology that successfully estimates the growth performance, physiological changes, and yield. A study conducted at Thailand, successfully developed an approach to estimate the above and below ground traits of turmeric plants using the UAV platforms and also verified the superior accession by curcuminoids yield.

Digital tools promote sustainable farming practices and educate farmers about the eco-friendly technologies.

SpicesVar

SpicesVar is ICAR-AICRPS's database on the performance of spice varieties in India. Spices Var is also a platform for the exchange of know-how and a tool to safeguard, retrieve, and exchange information related to spices. Information can be retrieved regarding three groups of spice crops: major, tree and seed spices. The database has a primary function, which is data retrieval. Access to and use of the database are free. It is a powerful search engine for easy retrieval and comparison of information. It is also a template for educational purposes and a gateway to spice knowledge and statistics.

SpicesVar addresses the needs of producers, the public, and spice research centres for information management related to spice crop cultivars in different agro-climatic environments and allows users to identify cultivars adapted to their specific requirements and environment. Scientists from spices research institutes and universities reviewed the database and provided valuable comments and suggestions for its design and improvement. (http://14.139.189.29/SpicesVar).



Spice FeRT software

Smartphone applications

ICAR-Indian Institute of Spices Research has developed and launched a mobile app (black pepper, cardamom, ginger and turmeric) for the benefit of farmers who is interested in spices cultivation. It is a simple, user-friendly application providing authentic and scientific information on spices cultivation. It is available in Google Play Store and can be freely downloaded in any android devices. Currently it is available in English and Hindi and soon other versions will be made available.

Decision support tools

The range of decision support tools is extensive and includes software solutions for farmers (such as bookkeeping, planning and agricultural science), software connected to weather stations used to plan plant protection, determination of the best time to harvest, and many others.

Spice FeRT

ICAR-IISR has developed a soil test-based fertilizer recommendation for targeted yield of spices (Spice FeRT). For obtaining a particular yield, the plant takes up a definite amount of major nutrients. Once this requirement is known, the fertilizer requirement can be estimated taking into consideration the contribution from soil available nutrients and fertilizer use efficiency levels. This software is for getting fertilizer recommendations for the targeted yield based on the factors like initial soil fertility, nutrient required per unit yield (NR), contribution of nutrient from soil (CS) and contribution from fertilizer (CF) that were standardized, validated and recommended for major spice crops, viz. black pepper, ginger, turmeric and cardamom. Through this targeted nutrient supply, one can avoid imbalance of nutrients in soil, improve fertilizer use-efficiency and increase yield as compared to the blanket recommendation (http://14.139.189.27/soil/turmeric.html).

Card SiS and CardSApp

Indian Cardamom Research Institute (ICRI), Spices Board developed a GIS based spatial interpolation of soil nutrients of cardamom in collaboration with Rubber Research Institute of India (CardSiS, https://www.indianspices.com/research/slides.html). The web based fertiliser recommendation was developed based on interpolated soil fertility data in collaboration with Digital University, Kerala, overlaying different soil fertility parameters and soil depth following the guidelines of soil test-based fertiliser recommendations by ICRI.

Presently, the CardSApp (https://cardsapp.spicesboard.org.in) is applicable to cardamom growing

areas in ten villages for Idukki, Kerala. In the second phase of the project, CardSApp will cover the other cardamom growing regions of Idukki, Tamil Nadu and Karnataka.

Geostatistical analyst of ArcGIS software was used for generating soil nutrient maps using Inverse Distance Weighted Algorithm. Spatial interpolation maps were prepared for 12 nutrients like organic carbon (OC), soil pH, available potassium (K), available calcium (Ca), available magnesium (Mg), available boron(B), available copper (Cu), available iron (Fe), available manganese (Mn), available phosphorous (P), available sulphur (S) and available zinc (Zn). Further, village-wise spatial variability of soil nutrient maps was prepared in the Geotiff format with cell size of 30 m.

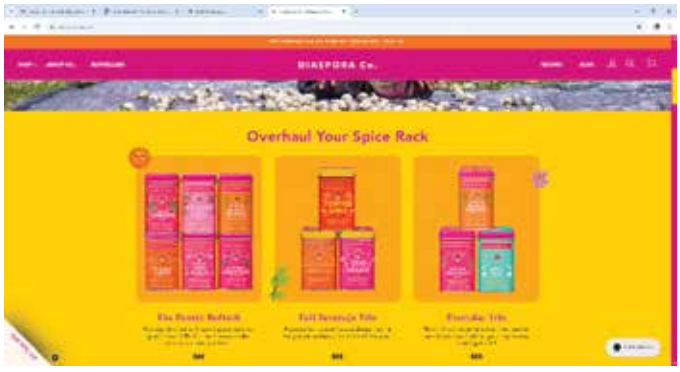
Processing and digital innovations

New technologies, equipment and databases enable precise measurement of the main quality parameters for certain products. This improves transparency and control over quality and food safety issues. In the spices and herbs sector, this involves monitoring parameters such as moisture, density and seed size, as well as controlling contamination with foreign bodies. Process automation and artificial intelligence are also key trends. Advanced quality assessment can be performed by an electronic nose – a sensing device that detects odours and flavours. For example, the leading spice company uses artificial intelligence to develop new flavours. A leading laboratory testing companies use next generation sequencing to establish the authenticity of products. This DNA fingerprint database contains unique identifying characteristics (the "fingerprints") of foodstuffs and makes it possible to obtain proof of authenticity, which was not previously available.

The European Union has developed a tool to ensure the flow of information and a quick response when risks to public health are detected in the food chain. This tool is called the Rapid Alert System for Food and Feed (RASFF). Food inspectors in all EU member states collect information about the reasons why different food products have been rejected by the market and send those data to RASFF (https://webgate.ec.europa.eu/rasff-window/screen/search).

Blockchain technology and traceability

The blockchain technology is increasingly being used to reduce the costs of intermediaries. Blockchain systems allow each stakeholder in the supply chain to view the progress of goods throughout the supply chain, monitor the container movement in real time, and see the status of the customs documents. In addition to tracking the goods, blockchain technology can be used to encrypt important documentation (e.g. regarding quantities or prices and contracts). An example of a successful use of blockchain technology is for the sourcing of spices and herbs (https://www.verstegen.co.uk/verstegen-sustainability/blockchain). By scanning the QR code on a package of nutmeg it is possible to learn more about the place of origin and to see which farmer has grown that particular packaged spice.



Recently, the Indian Spice Board has signed a memorandum of understanding with the United Nations Development Programme (UNDP) Accelerator Labs to build a blockchain-based traceability interface for Indian spices. The project will be piloted with more than three thousand chilli and turmeric farmers in select districts of Andhra Pradesh.

Digital innovations in marketing

e-Auction Centres of Cardamom: E-auction of cardamom plays a key role in the primary sale of the small cardamom in India under the provisions of the Cardamom Licensing & Marketing Rules 1987 framed in accordance with Spices Board Act 1986. In order to bring the transparency and functional convenience in trading operations of cardamom, Spices Board had introduced E-auction facility at its auction centres in Bodinayakanur, Tamil Nadu and Puttady, Kerala in 2007, replacing the traditional outcry system. Spices Board has upgraded the e-auction system to Cloud based live E-auction in 2021 to conduct e-auction of Cardamom (small) simultaneously from the two auction centres. Similarly, the Spices Board of India has also developed a specific spice trade platform – eSpice Bazaar (http://espicebazaar.in/). This platform serves not only as a simple trade tool, but it includes many support functions for different spices in the supply chain. Stakeholders Agricultural and Processed Food Products Export Development Authority (APEDA) has launched the Agri Exchange platform (https://agriexchange.apeda.gov.in/) where suppliers and buyers can search for offers in specific spice categories.

Market research

Several marketing research companies regularly collect extremely large data sets related to retail sales of food items to identify consumer behaviour and trends. These companies sell data to commercial companies to help them innovate and make better marketing decisions. However, for most small and medium-sized companies, the large data sets of leading data providers are too expensive for daily use. The commodity market is fast becoming one of the most popular segments of the financial market. Commodity trading involves purchasing and selling derivative contracts such as futures and options. The primary commodity exchange in spices is NCDEX. National Commodity & Derivatives Exchange Limited (NCDEX / the Exchange) is a professionally managed on-line, commodity Exchange, with diverse product offerings setting a benchmark for both agriculture and non-agri commodities derivatives segment. Currently,

the exchange offers derivative contracts in spices for black turmeric, coriander, cumin and cumin mini.

SPIISRY (https://spiisry.in/), the online sales outlet of ICAR-Indian Institute of Spices Research, gives fresh hope to farmers and start-ups. SPIISRY' works as a linkage point for farmers, startups, and customers to ensure mutual benefits to all stakeholders. Small spice processors can also leverage e-commerce solutions in various ways. A startup entrepreneur, backed by ICAR-IISR, successfully utilizes web-based marketing for spices and spices blends (https://www.diasporaco.com/?view=sl-7C27D6AC).

SUMMARY

Digital innovation in the spice industry is transforming the traditional practices, enhancing efficiency, and opening new avenues for growth. From precision farming techniques and supply chain optimization to e-commerce platforms, technology is enabling producers to meet the evolving demands of the market. As data analytics and AI continue to shape the landscape, stakeholders can leverage insights to improve quality, reduce waste, and ensure sustainability. Ultimately, embracing digital innovation not only benefits businesses but also enriches the consumer experience, fostering a deeper appreciation for spices in a rapidly changing world. The future of spices is not just about flavour; it's about smart, sustainable, and connected practices that celebrate heritage while embracing modernity.

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