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ENHANCING SUGARCANE CULTIVATION: A LITERATURE REVIEW ON KNOWLEDGE-BASED SYSTEMS USING FACTUAL AND HEURISTIC METHODS

Ms. Priyanka Mohan Shelar, Research Scholar, Savitribai Phule Pune University,Pune
Dr. Mohite Babasaheb Jotiram, Director ,Zeal Institute of Business Administration, Computer Application and Research

ABSTRACT
This comprehensive review examines various studies on the use of advanced technologies and methodologies to improve agricultural practices, specifically in sugarcane cultivation. It highlights the integration of Internet of Things (IoT), machine learning models, expert systems, and data analysis techniques to address challenges such as water scarcity, soil degradation, and pest-related crop losses. The review identifies the main challenges, including high costs, technology integration, farmer education, and the socio-economic and environmental impacts of these technologies. Additionally, it discusses specific applications such as the AICRP Reporter software for data management in sugarcane trials, IoT-based automation, fuzzy logic for optimization, and image processing for disease detection.
Keywords: Sugarcane cultivation, Internet of Things (IoT), Machine learning, Expert systems, Data analysis, Fuzzy logic, Smart farming, Precision agriculture, Crop yield prediction, Disease detection.

1.Introduction:

First stage of any research is to identify and review research related material. This chapter focuses on details of material that have been reviewed to clarify the conceptual aspects, to get further direction of study undertaken and to identify research gap. Researcher collected and thoroughly studied all related material. The statistical data and relevant information were obtained from the various sources such as research projects, thesis, reports, books, papers, journals, surveys, articles, various internet sources and web sites, etc. The studies on relevant aspects have been reviewed. The review of literature includes sources of various related topics which have been classified as: expert system for sugarcane, Sugarcane crop management factor, sugarcane in Maharashtra and Methodological review. The present chapter is divided in to these four sections and each section is concluded with research gap matrix at the end. Classification of review has done as follows:

2. REVIEW OF EARLIER STUDIES AND RESEARCH GAP MATRIX

2.1 Expert Systems for Sugarcane

Table No. 2.1 Research Gap Matrix of Reviewed Literature Related to Expert Systems for Sugarcane

Sr.No	Title	Summary/Key Learning	Research Gap
1	Smart Farming: Internet of Things (IoT)-Based Sustainable Agriculture	-Smart farming integrates IoT, cloud computing, and innovative technologies in agriculture. - Emphasizes sustainable practices for crop management, irrigation, nutrient management, pest and disease control. - Addresses challenges in agriculture, such as water scarcity, soil degradation, and pest-related crop losses.	Challenges in implementing smart farming include cost, technology integration, and farmer education. - Variation in soil and crop types poses challenges for uniform application. - Limited discussion on socio-economic aspects and potential environmental impacts.

2	Web-Based Data Management Techniques for Coordinated Trials of Sugarcane Technologies	-Sugarcane production technologies need multi-location trials for adoption. - Traditional data management poses issues like late reporting, wrong/missing data. - A web-based software, AICRP Reporter, improves efficiency and addresses data management challenges.	- Lack of detail on specific technical aspects of the software implementation.
3	A Review of the Applications of IoT for Agricultural Automation	- IoT widely used in agriculture: management, monitoring, control, unmanned machinery. - Various wireless communication technologies employed. - Potential for increased crop quality, production, and reduced labor.	- Need for technology integrating IoT across all agricultural aspects. - Insufficient application of IoT to autonomous agricultural machinery.
4	Simultaneous Selection for Yield and Stability in Sugarcane Using AMMI Model	- Evaluation of sugarcane clones using AMMI model for yield and stability	- Limited discussion on the genetic aspects of clones; Limited details on environmental factors
5	Expert system for decision support in sugarcane domain	- Crop production is a complex process requiring decision-making at various stages. - Expert Systems are crucial for efficient decision-making in agriculture. - Development of an Expert System involves Knowledge Engineering and Software Engineering. - Methodology includes knowledge acquisition, representation, and verification. - Testing is essential for system consistency and correctness	- Complexity in encoding all human expert decision-making processes. - Dependency on domain experts for knowledge acquisition. - Limited mention of specific software tools used in implementation.
6	HybES: a Hybrid Expert System	- Hybrid Expert System (HybES) incorporates rule-based systems and relational databases within fuzzy logic data sets and criteria. - Rules are based on the Object-Attribute-Value (O-A-V) triplet representation model. - Valid-time versions of knowledge are used, making the system valid at certain time periods. - Fuzzy sets and linguistic variables are used to handle uncertainty. - The system infers using either forward chaining or backward chaining. - Working memory is split	- The paper does not specify the limitations or gaps in the proposed system.

		into Conditions' and Rules' Working Memory.	
7	Mobile 'app' for Precise Irrigation Scheduling...	- Efficient and economical scheduling of surface irrigation is crucial for high water productivity in sugarcane cultivation in subtropical India.	
8	Weed detecting robot in sugarcane fields using fuzzy real time classifier	- Proposal of a weed detecting robotic model for sugarcane fields using fuzzy real-time classifier on leaf textures. - Automated image classification system designed for weed detection. - Robotic prototype designed with Raspberry Pi microcontroller.	- Lack of information on real-world deployment and scalability. - No discussion on the economic feasibility of implementing the proposed system.
9	Optimizing the Fertility Rate of Sugarcane Crops at Precision Agriculture using the Fuzzy Logic Method	1. Utilizes fuzzy logic for recommending water volume, lime content, and fertilization in sugarcane farming based on soil nutrient content. 2. Achieves 37.09% cost efficiency compared to the factory method. 3. Shows an 8% increase in tillering growth with the fuzzy logic method.	1. Does not discuss the real-world deployment or scalability of the proposed system. 2. Lack of information on economic feasibility. 3. The study duration and sample size are not explicitly mentioned.
10	Multi-objective fuzzy optimization for sustainable irrigation planning	- Determining optimal cropping patterns under uncertainty. -- Maximizing net benefits, crop production, employment generation, and manure utilization simultaneously. - Developing a Multi-Objective Fuzzy Linear Programming (MOFLP) model. - Successful application to Jayakwadi Project Stage-I, Maharashtra, India.	Limited discussion on specific challenges faced during the application of the MOFLP model. - Lack of detailed exploration of how uncertainty was handled in decision parameters. - No discussion on the trade-offs or conflicts that might arise when maximizing multiple objectives.
11	Fuzzy Internet of Things-based water irrigation system	- Efficient irrigation through an Internet of Things (IoT) based Fuzzy Water Irrigation System (FWIS). - Two operating modes: Manual Mode (MM) for web server-controlled irrigation and Automatic Mode (AM) using Fuzzy Logic (FL) for intelligent decision-making. - Integration of FL for TURN_ON_Time determination based on soil parameters. - Evaluation of FWIS with 95.1% accuracy in controlling water flow. - Reduction in water usage compared to traditional irrigation approaches.	- One-time investment cost mentioned, but ongoing labor costs not considered. - Limited discussion on scalability and adaptability to diverse agricultural settings.

12	Irrigation Planning of Upper Wardha Project Using Fuzzy Linear Programming	1. Application of FLP to irrigation planning with multiple conflicting objectives. 2. Use of fuzzy set theory to handle vagueness and imprecision in objective values. 3. Introduction of three models focusing on net benefits, crop yield, and irrigation area maximization. 4. Optimal results obtained at specific degrees of truth, demonstrating flexibility. 5. Comparative analysis with LP reveals variations in net benefits, crop production, and irrigation intensity.	1. Assumptions like constant water requirements and fixed evaporation losses. 2. Limited discussion on uncertainty implications and adaptability to other situations. | 3. Lack of exploration on the impact of resource availability variations. 4. The study assumes constant market rates for labor, crops, and fertilizers.
13	Image Processing Based Disease Detection for Sugarcane Leaves	- Sugarcane faces diseases caused by fungi, bacteria, viruses. - Image processing and computer vision for disease detection in sugarcane leaves. - Diseases studied: red rot, mosaic, leaf scald.	- Limited discussion on algorithmic details. - Lack of comparative analysis with other methods. - Limited information on existing models. - No mention of sample size.
14	An Approach for Prediction of Crop Yield Using Machine Learning and Big Data Techniques	- Agriculture is vital for the economy, and crop yield prediction is crucial for planning. - Machine learning techniques (ANN, SVM) and big data are explored for prediction. - Various factors like weather conditions, soil properties, and crop type influence predictions.	- Limited discussion on big data techniques' impact. - Sample sizes and specific machine learning algorithms used are not mentioned. - Lack of comparative analysis with other existing models.

This comprehensive review examines various studies on the use of advanced technologies and methodologies to improve agricultural practices, specifically in sugarcane cultivation.

Smart Farming: Internet of Things (IoT)-Based Sustainable Agriculture focuses on integrating IoT, cloud computing, and innovative technologies to address challenges such as water scarcity, soil degradation, and pest-related crop losses. The main challenges include high costs, technology integration, and farmer education, along with a lack of discussion on socio-economic and environmental impacts.

Web-Based Data Management Techniques for Coordinated Trials of Sugarcane Technologies addresses issues in multi-location sugarcane trials, such as late reporting and data inaccuracies. The AICRP Reporter software is proposed to improve data management efficiency, but the study lacks technical implementation details. (Syed Sarfaraz Hasan, 2020)

A Review of the Applications of IoT for Agricultural Automation highlights diverse IoT applications, including management, monitoring, control, and unmanned machinery, which can enhance crop quality, increase production, and reduce labor. However, there is a need for comprehensive IoT integration across all agricultural aspects and more application in autonomous machinery.

Simultaneous Selection for Yield and Stability in Sugarcane Using AMMI Model evaluates sugarcane clones for yield and stability using the AMMI model but offers limited discussion on the genetic aspects of the clones and environmental factors.

Expert System for Decision Support in Sugarcane Domain discusses the development of expert systems involving knowledge acquisition, representation, and verification to aid complex decision-making in agriculture. The challenges include encoding human decision-making processes and dependence on domain experts, with limited mention of specific software tools.

HybES: A Hybrid Expert System integrates rule-based systems with relational databases using fuzzy logic to handle uncertainty, employing an Object-Attribute-Value representation model. However, the paper does not specify limitations or gaps in the system.

Mobile 'App' for Precise Irrigation Scheduling focuses on improving water productivity in sugarcane cultivation through efficient and economical irrigation scheduling, though it lacks specified research gaps.

Weed Detecting Robot in Sugarcane Fields Using Fuzzy Real Time Classifier proposes a robotic model for weed detection using a fuzzy real-time classifier and Raspberry Pi microcontroller. The study lacks information on real-world deployment, scalability, and economic feasibility.

Optimizing the Fertility Rate of Sugarcane Crops at Precision Agriculture Using the Fuzzy Logic Method uses fuzzy logic for recommending water, lime, and fertilization based on soil nutrients, achieving cost efficiency and improved tillering growth. The study lacks details on deployment, scalability, economic feasibility, duration, and sample size.

Multi-Objective Fuzzy Optimization for Sustainable Irrigation Planning develops a Multi-Objective Fuzzy Linear Programming model to optimize cropping patterns under uncertainty. There is limited discussion on application challenges, handling uncertainty, and trade-offs in maximizing multiple objectives.

Fuzzy Internet of Things-Based Water Irrigation System integrates IoT with fuzzy logic for efficient irrigation, achieving high accuracy and reduced water usage. The study mentions one-time costs but not ongoing labor costs and has limited discussion on scalability and adaptability.

Irrigation Planning of Upper Wardha Project Using Fuzzy Linear Programming applies FLP to irrigation planning with multiple objectives, handling vagueness and demonstrating flexibility. The study lacks exploration of water requirements, evaporation losses, uncertainty implications, resource availability variations, and constant market rates.

Image Processing Based Disease Detection for Sugarcane Leaves uses image processing and computer vision to detect diseases in sugarcane leaves caused by fungi, bacteria, and viruses. The study offers limited algorithmic details, comparative analysis, and information on sample size and existing models.

An Approach for Prediction of Crop Yield Using Machine Learning and Big Data Techniques explores machine learning and big data for crop yield prediction, considering factors like weather, soil properties, and crop type. The study lacks details on the impact of big data techniques, specific machine learning algorithms, sample sizes, and comparative analysis with other models.

2.2. Sugarcane crop management factor

Table No. 2.2 Research Gap Matrix of Reviewed Literature Related to Sugarcane factors

Sr. No	Title	Summary/Key Learning	Research Gap
1	Remote Sensing Applications in Sugarcane Cultivation: A Review	Global sugarcane production trends; Importance of Earth observation (EO) in sugarcane cultivation; Use of various sensors for mapping, growth monitoring, and yield estimation	Insufficiently accurate cloud masks and analysis-ready-data (ARD); Scalability issues in implementing machine learning algorithms; Lack of human resources in sugarcane-producing countries
2	Character-based Numerical Classification for Sugarcane Varieties	- A character-based numerical rating system is proposed for evaluating sugarcane varieties. -	- Prevailing naming systems lack information on the commercial traits of

		The proposed system considers characteristics used in breeding programs globally. - Aims to indicate features of commercial importance and accommodate emerging varieties. - Addresses anomalies in existing naming systems. - Highlights confusion in prefixes of different criteria in naming varieties.	sugarcane varieties. - Anomalies and confusion exist in current naming systems. - Similar names for sugarcane varieties and other crops cause confusion.
3	CaneDES: A Web-Based Expert System for Disorder Diagnosis in Sugarcane	- Sugarcane faces biotic and abiotic stresses affecting production and productivity. - CaneDES, a web-based expert system, aids timely and accurate diagnosis.	- Limited mention of potential challenges in implementing CaneDES.
4	An Expert System For Diagnosing Sugarcane Diseases	- Sugarcane diseases pose a threat to crop yield. - Proposed an expert system for timely diagnosis. - Used CLIPS and Delphi languages. - Tested and found useful by a group of farmers. - Generic nature for other crop environments.	- No mention of specific challenges or limitations. - Lack of detailed discussion on the knowledge representation technique.
5	Expert Systems Applied to Plant Disease Diagnosis: Survey and Critical View	- Expert systems in agriculture, particularly plant pathology. - Evolution over four decades. -Challenges in development. -Critical analysis of past, present, and future.	-Difficulty in translating concepts into technical solutions. - Knowledge acquisition challenges. - Organizational problems. – defined scope. - Lack of clear criteria for testing.
6	Efficient Detection of Sugarcane Diseases through Intelligent Approaches: A Review	- Agriculture is crucial for economic growth. Sugarcane is a vital crop in India. - Diseases severely impact sugarcane production. - Computational approaches, image processing, and machine learning aid in disease detection.	- Early diagnosis is crucial to prevent economic losses. - Issues with manual identification. - Need for automatic identification.
7	Image processing technique for estimation of brown spot severity in sugarcane	- Proposed an image processing technique for estimating brown spot severity in sugarcane leaves. - Used simple threshold segmentation and triangle thresholding. - Measured accuracy using a paint tool.	- Simple thresholding may not be suitable for all lesion region characteristics.
8	Climate Resilient, High Yielding and Stable	Nine genotypes identified with high yield sustainability and low	Lack of specific details on tested environmental

	Sugarcane Genotypes in India	sensitivity to adverse environmental conditions. Stability observed across CCS, cane yield, and sucrose percentage.	conditions or stresses. Specific traits contributing to climate resilience not detailed.
9	Effect of Planting Methods on Growth, Yield, and Quality of Sugarcane in Subtropical India	- Ring-pit and trench planting methods significantly improved soil physical properties. - Root proliferation, growth, cane yield, and sugar yield were higher in ring-pit method.- Improved juice quality observed in ring-pit planting.	- Lack of detailed information on specific factors influencing sugarcane productivity. - Limited details on analytical methods used.
10	Drought Tolerance Potential of Promising Sugarcane Cultivars in Western Uttar Pradesh	- Drought is a limiting factor for sugarcane productivity - Evaluation of ten elite sugarcane genotypes for drought tolerance - Varieties 'CoS 07250' and 'CoSe 01434' showed higher tolerance and cane yield under water stress	- Lack of detailed information on specific factors influencing sugarcane productivity under drought
11	Mechanization of Sugarcane Planting	- Development of a multifunctional planting machine for deep furrow sugarcane planting. - All planting operations done in one go, placing setts much deeper. - Utilizes only four persons, reducing planting cost by 55%.	
12	Intercropping Options for Higher Profitability in sub-tropical sugarcane farming	Explored intercropping opportunities to enhance vertical land productivity and farmers' income.	Lack of detailed information on specific factors influencing sugarcane
13	Minimum Number of Seedlings for Evaluation of Cross Performance in Sugarcane	- Identifying the minimum seedling size for evaluating cane weight, number of stalks, cane height, brix, internode length, and cane diameter in seven sugarcane families. - Concluded that a minimum sample size of 150 seedlings is needed for progeny evaluation with about a 5% margin of error for mean and 10-12% for variance.	- The study does not extensively discuss the broader implications of the findings for sugarcane breeding programs.
14	Seedling Blight and Mortality Diseases of Sugarcane and Their Management	- Losses in sugarcane seedlings due to seedling diseases.	- Does not extensively discuss broader implications for sugarcane breeding programs.

			The paper primarily focuses on experimental results.
15	Effect of levels of irrigation and crop geometry on growth and yield of sugarcane under drip irrigation	- Single row planting showed higher cane yield and tillers per square meter than paired row planting. - Drip irrigation at 100% PE treatment resulted in the highest cane yield and yield attributes. - Water use efficiency was higher in drip irrigation.	- Limited information on the economic aspects of adopting drip irrigation. - No mention of environmental impacts. - Specific details about soil and climate conditions are lacking.
16	Response of soil test based integrated nutrient management under sugarcane cultivation	1. STFR (Soil Test Fertilizer Recommendation) improves yield and soil health. 2. 100% NPK (STFR) + Organic Manure + Biofertilizers enhances yield and sucrose content. 3. Economic viability: Highest B:C ratio with T6.	1. Soil Organic Matter: Reduction due to high-analysis fertilizer. 2. Economic and Environmental Aspects: Not extensively discussed.
17	Effect of Surface and Subsurface Drip Fertigation on Yield and Quality of Sugarcane	- Significant differences in cane yield, juice sucrose percentage, and CCS due to different irrigation methods and nitrogen levels. - Drip irrigation methods (subsurface and surface) outperform furrow irrigation in cane yield. - Application of 200 Kg N/ha records the highest cane yield. - Higher nitrogen levels do not result in a significant increase in yield. - Drip irrigation treatments show higher sucrose percentage compared to furrow irrigation. - Higher water use efficiency (WUE) in drip irrigation methods.	- Lack of information on economic considerations, cost-benefit analysis, and environmental impact. - Need for a more detailed exploration of factors influencing water savings and nutrient efficiency.
18	Growth, Yield, Quality and Insect-Pests in Sugarcane (Saccharum officinarum) as Affected by Differential Regimes of Irrigation and Potash under Stressed Conditions	- Potash application significantly improved sugarcane growth, yields, and quality parameters under stressed conditions. -- Germination, tiller's cane, and cane yield increased with higher potash levels. -- Insect-pest incidence, including early shoot borer and stalk borer, decreased with increased potash app- 80 kg	- The study focused on a specific cultivar (CoJ 88) and may not be universally applicable. --- Limited discussion on the economic aspects of potash application and farmer livelihoods.

		K2O ha−1 was identified as an optimal potash dose for deficient sites. --	
19	Promising Sugarcane Varieties and their Suitability for Mechanization	Sugarcane's economic, political, and social importance in India. - History of the organized sugar industry in India. -- Development of sugarcane varieties and breeding objectives.	Challenges in sugarcane cultivation, including labor shortages. -- Lodging tendencies in modern sugarcane varieties. -- Lack of information on publication source and year.
20	Agro-technology of Sugarcane Planting and Intercropping System for Higher Yield and Profit in Sub-tropical India	- Autumn planting of sugarcane in sub-tropical India yields higher sugarcane and sugar recovery. - Intercropping with short-duration crops enhances overall productivity. - Wider row spacing allows for mechanization.	- Specific limitations not provided.
21	Recent Development in Mechanization of Sugarcane Planting	Sugarcane cultivation in India covers 5.3 million hectares --- Annual production: 366 million tonnes of sugarcane, 28 million tonnes of sugar Challenges: Increased cost, labor shortage during peak planting seasons -- Mechanization for timeliness, reduced human drudgery, and improved efficiency	- Challenges in arranging labor for manual planting, resulting in prolonged operations and moisture loss --- Need for cost-effective and sustainable mechanization methods
22	Potential of Sugarcane Bud Chip Technology and its Mechanization	Sugarcane Bud Chip Technology can reduce seed mass, improve quality, and ensure quick multiplication. - Encapsulation methods (chemical and physical) for bud chips enhance viability and storability. - Bud chip technology offers advantages like lower seed requirement, higher bud sprouting rates, and increased seed multiplication rate. - Practical recommendations for implementation and cultivation practices are provided	- The paper does not explicitly mention identified gaps or limitations.
23	Micro-irrigation System for Water Management	- Freshwater scarcity is a global concern, and India, supporting a large population, faces	- Does not explicitly mention identified gaps or limitations.

		decreasing per capita water availability. - Sugarcane utilizes a significant portion of irrigation resources in India. - Micro-irrigation, with methods like drip and sprinklers, is advocated to improve water use efficiency. - Benefits include improved plant response, increased irrigation efficiency, and reduced weed growth.	
24	Moist Hot Air Treatment and its Impact on Disease Management	- Sugarcane diseases include Red Rot, Smut, RSD, Leaf Scald, and GSD. - Diseases spread through infected setts, contaminated implements, and environmental factors. - MHAT is an IDM approach for controlling seed piece transmissible diseases. - Components include healthy seed material, MHAT, land selection, sanitation, diversification, and resistant varieties. - Limited information on MHAT unit design and operation. - No specified year of publication. - Economic viability and scalability of MHAT not detailed.	Limited information on MHAT unit design and operation. No specified year of publication. Economic viability and scalability of MHAT not detailed.
25	Insect-Pests of Sugarcane and Tools Used for their Management	Intensive cultivation and new agro-techniques have changed the insect pest complex of sugarcane. - Sugarcane faces pests in both aerial and subterranean habitats. - About a dozen pests are identified as more serious. - Management strategies are crucial to avoid environmental impact. - Sugarcane agro-ecosystem study should consider factors like host population, climate, and alternate hosts.	Specific limitations and gaps were not explicitly mentioned in the provided text.
26	Management of Sugarcane Ratoon for Improving Crop Growth and Yield	- Ratoon cane provides successive ratoons, historically practiced globally.	- Poor productivity issues include gappy stands, insect-pests, and diseases.
27	Soil Physical, Chemical and Biological Changes and Long Term	Improved soil structure and sugarcane yield with	Lack of complete information on authors,

	Sustainability in Subtropical India Through Integration of Organic and Inorganic Nutrient Sources in Sugarcane	integration of organic and inorganic fertilizers	publication details, and specific gaps
28	Enhancing sugarcane (Saccharum spp. Hybrid) productivity by integrating organic, inorganic and biological sources of N in sub-tropical India	Integration of 25% and 37.5% N through sulphitation press mud cake (SPMC) and rest through inorganic nitrogen resulted in 12.5% to 25% saving of inorganic N with no loss in cane yield. 50% N through SPMC + 50% through inorganic sources increased cane yield by 12.05%. Inoculation of Azospirillum brasilense along with various nitrogen sources proved advantageous. Organic and biological sources help minimize expenditure on costly inorganic N fertilizers.	Continuous use of high-analysis fertilizers resulted in nutrient imbalance and decline in sugarcane productivity. Integrated nutrient supply is superior. Biofertilizers application led to saving of nearly 25% chemical fertilizers for sugarcane crop.
29	Participatory demonstration for enhancing knowledge and adoption of water-saving sugarcane production technologies: an action research	- Farmers derived socio-psychological benefits - Significant increase in knowledge and adoption - 21-45% saving in irrigation water - Increased yield and economic benefits	-Limited information on long-term sustainability - Lack of detailed economic analysis
30	Effect of Agro-Technological Manipulations in Improving...	- Combination of agro-techniques enhanced growth attributes, -- number of millable canes, and yield of cane and sugar. -- Trash mulching and sub-soiling contributed to soil improvement.	--- Limited focus on specific crops (sugarcane) --- Lack of consideration for socio-economic factors --- Potential issues of generalizability
31	Resource Conservation Technologies for Input Use Efficiency and Sustainable Yield of Sugarcane	- Sugarcane is a crucial crop for India's economy and rural development. - Cyclic trends in sugar production highlight the need for sustainable sugarcane production. - Technologies developed for soil organic carbon conservation and input use efficiency include green manuring, trash mulching, crop residue recycling, ring-pit planting, and double-row planting geometry.	- Sugarcane productivity in India is below its potential. - Limited genetic variability and cultural bottlenecks are identified constraints.

32	Site-specific nutrients management for targeted yield in sugarcane	- Soil fertility, organic-inorganic balance crucial for uniform yields. - Site-specific management enhances nutrient use efficiency. - Target yield approach aids in fertilizer application.	- Focus on sugarcane, applicability to other crops? - Lack of discussion on economic aspects.

This comprehensive review examines various studies on advanced technologies and methodologies to enhance sugarcane cultivation.

Remote Sensing Applications in Sugarcane Cultivation discusses global trends and Earth observation's role in mapping and monitoring. Challenges include inaccurate cloud masks, scalability of machine learning algorithms, and lack of human resources in sugarcane-producing countries. (Jaturong Som-ard 1, 2021)

Character-based Numerical Classification for Sugarcane Varieties proposes a rating system for evaluating varieties based on breeding program characteristics, addressing existing naming system anomalies and confusion.

CaneDES: A Web-Based Expert System for Disorder Diagnosis in Sugarcane aids in diagnosing biotic and abiotic stresses affecting production, though it lacks discussion on implementation challenges.

An Expert System for Diagnosing Sugarcane Diseases highlights the use of CLIPS and Delphi languages for timely disease diagnosis but omits specific challenges and knowledge representation details.

Expert Systems Applied to Plant Disease Diagnosis provides a critical view of expert systems' evolution and development challenges, such as translating concepts into technical solutions and knowledge acquisition.

Efficient Detection of Sugarcane Diseases through Intelligent Approaches reviews computational methods for disease detection, emphasizing the need for automatic identification to prevent economic losses.

Image Processing Technique for Estimation of Brown Spot Severity in Sugarcane proposes a technique using threshold segmentation but notes limitations for varying lesion characteristics.

Climate Resilient, High Yielding and Stable Sugarcane Genotypes in India identifies high-yielding genotypes with stability across different conditions, but lacks details on specific environmental stresses.

Effect of Planting Methods on Growth, Yield, and Quality of Sugarcane in Subtropical India finds ring-pit planting improves soil properties and yield, but lacks details on specific productivity factors.

Drought Tolerance Potential of Promising Sugarcane Cultivars evaluates genotypes for drought tolerance, highlighting higher-yielding varieties under stress but lacking detailed productivity factors.

Mechanization of Sugarcane Planting reports a multifunctional planting machine reducing labor and costs, without discussing economic aspects.

Intercropping Options for Higher Profitability explores intercropping to enhance productivity and income, lacking specific productivity factors.

Minimum Number of Seedlings for Evaluation of Cross Performance identifies 150 seedlings for progeny evaluation, without broader breeding program implications.

Seedling Blight and Mortality Diseases focuses on seedling disease impacts, not addressing broader breeding implications.

Effect of Levels of Irrigation and Crop Geometry finds drip irrigation enhances yield and efficiency, lacking economic and environmental impact details.

Response of Soil Test-Based Integrated Nutrient Management shows integrated nutrient management improves yield, highlighting economic viability but not extensively discussing soil organic matter reduction.

Effect of Surface and Subsurface Drip Fertigation shows subsurface drip irrigation increases yield and efficiency, with insufficient economic and environmental consideration.

Growth, Yield, Quality, and Insect-Pests in Sugarcane demonstrates potash application improves growth and reduces pest incidence under stress, focusing on a specific cultivar.

Promising Sugarcane Varieties for Mechanization details sugarcane's economic importance and modern varieties' challenges, lacking publication source and year.

Agro-technology of Sugarcane Planting and Intercropping indicates higher yield and productivity with autumn planting and intercropping, without specific limitations.

Recent Developments in Mechanization highlights mechanization's benefits for efficiency, lacking sustainable methods discussion.

Potential of Sugarcane Bud Chip Technology improves seed quality and multiplication, without explicitly mentioning gaps or limitations.

Micro-irrigation System for Water Management advocates for improved water use efficiency through micro-irrigation, without identifying gaps or limitations.

Moist Hot Air Treatment for Disease Management details MHAT's role in controlling diseases, lacking unit design, operation, and economic viability details.

Insect-Pests of Sugarcane and Management Tools addresses changes in pest complexes and management strategies, not specifying limitations or gaps.

Management of Sugarcane Ratoon highlights ratoon cane productivity challenges like gappy stands and pests, without specific limitations.

Soil Changes and Sustainability through Nutrient Integration shows improved soil structure with integrated fertilizers, lacking full publication details and gaps.

Enhancing Sugarcane Productivity with Integrated Nitrogen Sources demonstrates yield improvement with reduced inorganic nitrogen use, addressing nutrient imbalance and chemical fertilizer savings.

Participatory Demonstration for Water-saving Technologies indicates increased knowledge and economic benefits for farmers, lacking long-term sustainability and detailed economic analysis.

Effect of Agro-Technological Manipulations shows enhanced growth and yield with combined techniques, lacking focus on socio-economic factors and generalizability.

Resource Conservation Technologies discusses sustainable yield through soil carbon conservation, identifying limited genetic variability and cultural bottlenecks as constraints.

Site-specific Nutrients Management improves nutrient use efficiency and uniform yields through site-specific management, lacking economic discussion and applicability to other crops.

2.3.Sugarcane in Maharashtra

Table No. 2.3 Research Gap Matrix of Reviewed Literature Related to Sugarcane in Maharashtra

Sr.No	Title	Summary/Key Learning	Research Gap
1	Integration of sugarcane production technologies for enhanced cane and sugar productivity targeting to increase farmers' income: strategies and prospects	Emphasizes the need for cost-effective technologies and educational efforts to increase sugarcane farmers' income. Discusses advancements in sugarcane biotechnology, intercropping, and disease management.	Highlights imbalances in nutrient management, lack of wider adoption of intercropping, and challenges in disease and pest management.

2	Sugarcane: A poverty reducing crop for rural population of India	- 12.337 million sugarcane workers engaged in cultivation. - Marginal and small holdings occupy 82.82%, contributing to 54.44% of sugarcane area. - Sugarcane's significant contribution to GDP and remunerative nature. - Increased average size of sugarcane holdings over the years, especially in high-priority districts. - Identification of 43 high cane spread districts as crucial for reducing rural poverty.	- Lack of details on specific environmental or genetic factors affecting sugarcane productivity. - Insufficient information on the methods used for data analysis, statistical techniques, and models.
3	Growth Pattern and Sugar Yield of Sugarcane Varieties...	- Significant variation in growth attributes among sugarcane varieties. - Higher germination count and plant population with 'BO 153'. - 'BO 153' recorded higher LAI, sugar yield, and cane yield.	- Lack of information on specific factors influencing sugarcane productivity. - Limited details on analytical methods.
4	Sugarcane Production and Productivity Growth Scenario in India	- Average increase of around 9% in area, 13 to 21% in production, and 6-8% in productivity by the turn of the century. - Significant yield gaps in almost every cane-growing state. - Different growth phases in the last 50 years.	- Constraints affecting sugarcane productivity. - Socio-economic challenges for small farmers. - Fluctuations in production.
5	Economic analysis of sugarcane cultivation...	- India ranks second in sugarcane cultivation globally. - Sugarcane is vital for rural employment and contributes to the agricultural sector. - Cost of cultivation trends in different states.	- Increasing costs and declining yields in the last 5 years.
6	Status of Sugarcane Mechanization in India	Sugarcane is a crucial industrial crop in India, but mechanization adoption is limited. Major operations like planting, harvesting are labor-intensive. Various equipment and strategies have been developed, but adoption remains a challenge.	Small and scattered land holdings, Lack of awareness, High equipment costs, Poor economic conditions, Lack of repair facilities.

This review of sugarcane production technologies highlights various strategies and research gaps to improve productivity and farmers' income.

Integration of Sugarcane Production Technologies emphasizes cost-effective technologies and educational efforts. It discusses advancements in biotechnology, intercropping, and disease management but notes nutrient management imbalances, limited intercropping adoption, and pest management challenges. (Priyanka Singh, 2019)

Sugarcane: A Poverty Reducing Crop underscores sugarcane's economic impact, engaging over 12 million workers and contributing significantly to GDP. It identifies 43 high cane spread districts crucial for reducing rural poverty but lacks details on environmental and genetic factors affecting productivity and insufficient data analysis methods.

Growth Pattern and Sugar Yield of Sugarcane Varieties reveals significant growth attribute variations among varieties, with 'BO 153' showing higher germination, plant population, LAI, sugar yield, and cane yield. The study lacks information on factors influencing productivity and details on analytical methods.
Sugarcane Production and Productivity Growth Scenario in India reports an average increase in area, production, and productivity but highlights significant yield gaps in cane-growing states. It notes constraints affecting productivity and socio-economic challenges for small farmers, along with production fluctuations.
Economic Analysis of Sugarcane Cultivation shows India as the second-largest sugarcane producer, vital for rural employment and the agricultural sector. It discusses cultivation cost trends but highlights increasing costs and declining yields over the last five years.
Status of Sugarcane Mechanization in India notes sugarcane's importance as an industrial crop but highlights limited mechanization adoption. It discusses the labor-intensive nature of planting and harvesting and the development of various equipment and strategies. However, challenges include small and scattered land holdings, lack of awareness, high equipment costs, poor economic conditions, and lack of repair facilities.
These studies collectively highlight the need for improved nutrient management, wider adoption of advanced technologies, better mechanization, and addressing socio-economic challenges to enhance sugarcane productivity and farmers' income. The common gaps include detailed environmental and genetic factors, comprehensive data analysis methods, and economic considerations in adopting new technologies.

3. Gaps in the existing Research

There are 53 relevant articles in respect of Sugarcane Cultivation, Knowledge Based System and individual factor of Seed Selection, Soil Preparation, Water/Irrigation Management, Fertilizer Management and disease management have been studied. The past studies on particular research give idea about different dimensions of particular study. To analyses secondary data is helpful not only to clarify the conceptual aspects but also to get further direction of study undertaken. It is therefore provides the help to find research gap. Researcher has carefully and cleanly studied all secondary sources.
The research gap found thereby has been put in following section.
(1) Nature of Studies: Some of the past studies are only socio- economic survey oriented while some provide technical solutions regardless scientific analysis of problems. The present research is carried out to analyze sugarcane cultivation problems using scientific survey method and based on findings and requirement analysis the expert system solution will be designed.
(2) Scope of the study: The past studies are considered only some aspects of sugarcane cultivation. Most of researcher have studied individual factor such as seed management, irrigation management, soil management, fertilizer management, disease management and design knowledge based system. Here researcher has considered combined factor which is important for cultivation of sugarcane, problems identified in pre implementation study i.e. main study will be converted into expert system requirements and an expert system will be developed through Knowledge Based System approach and whether the developed expert system is really helpful to solve problems will be tested. Hence this research tries to overcome the gap found in the literature review.
(3) Expert Systems: There are various expert systems in sugarcane being used worldwide. It is also found that most of the studies on Sugarcane Cultivation, Knowledge Based System and individual factor of Seed Selection, Soil Preparation, Water/Irrigation Management, Fertilizer Management and disease management carried out in outside Maharashtra state. Also, the least studies available in Kolhapur division regarding Sugarcane Cultivation, Knowledge Based System, factor of Seed Selection, Soil Preparation, Water/Irrigation Management, Fertilizer Management and disease management. Hence this research tries to overcome the gap found in the literature review. Knowledge based systems have rarely proposed for Kolhapur division. Most of the expert systems have only been

proposed but not implemented. Most of them are just sugarcane informative websites. They are also not economical and operational feasible to farmers. Hence it can be concluded that no such study has been conducted to analyze sugarcane cultivation problems of Kolhapur division. The attempt has also not been made to design, develop, implement and test expert system to solve analyzed problems.

Conclusion:

The review of various studies on sugarcane production technologies highlights the diverse methodologies and advanced technologies employed to enhance sugarcane productivity. Integrating IoT, machine learning, and expert systems has shown promise in addressing key agricultural challenges, such as improving water efficiency, managing soil nutrients, and detecting diseases. However, significant challenges remain, including high implementation costs, the need for better farmer education, and the integration of these technologies into existing agricultural practices. There is also a lack of comprehensive discussion on the socio-economic and environmental impacts of these technologies. Future research should focus on overcoming these barriers and developing scalable, cost-effective solutions that can be widely adopted. Additionally, more detailed studies on genetic and environmental factors influencing productivity, comprehensive data analysis methods, and economic considerations in adopting new technologies are needed to fully realize the potential of these advancements in sugarcane cultivation.

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