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Smart Sericulture and IoT: A Review

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ABSTRACT: Sericulture is the process of nurturing silkworm to produce silk. Many biotic and abiotic factors are responsible for growth and development of silkworm and successful crop harvest. Modernization with introduction of new technologies is the only alternative to mitigate the limitations of traditional labour intensive sericulture practices and to enhance silk production. Artificial intelligence with IoT will benefit the progress of silkworm and host plant sector by maintaining temperature, humidity and other related factors. Remote sensing technique is arising as a suitable tool for identification of favourable sites for plantation. Automatic sericulture aided with image processing might be useful in preventing disease occurrence and pest infestation by regulating climatic factors with frequent observation of silkworm and host plant. Inevitably, the application of automatic technologies in this field will work wonders, through collective efforts of the people and the government in future.

Keywords: Artificial intelligence, internet of things, photoperiod, temperature, remote sensing.

INTRODUCTION

Modernization is the key to development. The world today is undoubtedly digital and the technologies are driving more swiftly than any other revolution in our history. The application of farm technologies is still evolving in India and intended to bring positive changes in farmer's lives. The impact of technology shall act as a door to begin a new era of sericulture.

Indian sericulture is highly traditional, remained obscure for ages, practiced for many generations with a little advent of technology. India occupies second position in silk production after China. In the year 2020-21, India produced 23,896 MT, 6946 MT, 2689 MT and 239 MT of mulberry, eri, tasar and muga silk respectively (Anon., 2021). Sericulture involves many diverse activities including both on-farm and off-farm with huge employment opportunities. The chain of activities requires skilled labour and frequent observation. A successful cocoon crop is dependent on both abiotic and biotic factors namely temperature, humidity, seasons, leaf quality, silkworm race, hygiene. All these factors altogether mainly temperature and humidity decide the fate of the cocoon crop. The seasonal variations in the environmental factors like temperature and humidity affect the genotypic constitution which is expressed in commercial characters in terms of cocoon weight, shell weight, shell ratio percentage (Rahmathulla, 2012). According to Kant *et al*. (2022), climatic factors have significant influence on disease incidence in silkworm which leads to crop loss. The vagaries of nature can be controlled in mulberry and eri silkworm because of its indoor nature but unmanageable in case of tasar and muga. The production can be further increased and the gap can be reduced with the adoption of digital technologies. The use of right combination of technology with intervention of computer-based technologies such as Artificial Intelligence (AI), Internet of Things (IoT), Image Processing Systems etc. will surely enhance quality of the produce. Geographical Information System (GIS) is another branch of computer information system utilized in sericulture to create database, maps and develop models where data is the basic component (Chaturvedi, 2018).

Artificial Intelligence: It is the sophisticated branch of computer science that create machines to do intelligent things the way humans do or even better with the ability of sensing, actuation, data storage, processing and decision making. Artificial intelligence uses data from various sensor networks to determine what action to be performed for a specific location resembling human brain.

IoT and its applications in sericulture: Internet of things (IoT) is a broad term which describes physical objects with sensors, processing ability, software and other data technologies that interchange data over internet or other communication networks. IoT in sericulture will help in maintaining temperature and other factors automatically with the help of sensors and microcontroller. The mapping of the plantation, infestation of diseases and pests, surveying, etc. can be monitored regularly. Sericulture is a labour-intensive venture thereby requires sufficient skilled workers in grainage operations, rearing of silkworms, bed cleaning, harvesting of leaves, mounting and many more. The adoption of artificial intelligence (AI) with internet of things (IoT) simultaneously and utilization will save both time and money of the rearers leading to sustainable sericulture. IoT is widely popular in many fields of agriculture and even in case of animals. Karim *et al*. (2021) designed a smart fish farming aquaculture monitoring system that measure water quality (pH, temperature, turbidity, motion detection) with the help of wireless sensors to monitor aquaculture in real time.

Applications of AI and IoT in Sericulture. This includes a wide range of applications starting from soil to the growth of silkworm and post cocoon sector. The following researches in this field are as follows:

Remote sensing in sericulture: Rao *et al*. (1991) suggested the use of satellite remote sensing techniques for sericulture development to provide accurate estimate of mulberry acreage, access mulberry garden condition for cocoon production and to identify new suitable areas for mulberry cultivation. Sharma *et al*. (2012) carried out a pilot project using remote sensing and geographic information system to identify suitable sites for mulberry cultivation on the basis of soil depth, texture, soil pH, drainage, slope, ground water availability, temperature and rainfall in two districts of Jharkhand. They also added that the cultivation of mulberry and conversion of non-suitable land to suitable category would generate employment opportunities throughout the year. A portal entitled 'Sericulture Information Linkages and Knowledge System'(SILKS) has been developed by Central Silk Board (CSB) using open-source GIS for providing information to 108 districts of India and has information regarding silkworm rearing, disease management, cocoon processing, marketing and advisory services for farmers in 16 modules. Additionally, it has made notable impact mainly in North-Eastern region and initiated a number of sericulture activities (Singh *et al*., 2016). Central Silk Board has funded projects for identification and mapping of potential areas for mulberry development on 1:50000 scale by application of remote sensing and GIS in Chhattisgarh (Raigarh and Bastar) by developing SILKS (Anon., 2022a). Giora *et al*. (2022) investigated the possibility of using remote sensing satellite imaging to monitor leaf harvesting in mulberry cultivation by utilizing satellite images and proposed the use of precision agriculture to improve sericultural practice and increase silk yield.

Smart sericulture using image processing: Silkworm growth monitoring system based on Internet of Things and image processing by employing arduino software and sensors with all possible arrangements to maintain temperature and humidity by capturing photographs of silkworm was proposed by Nivaashini *et al*. (2018). A real time sericulture monitoring and disinfection system (IPv6 over low power wireless personal area network) with image processing was designed to check temperature and humidity including status of silkworm by capturing images (Divya Darshini *et al*., 2016). Raste *et al*. (2014) designed a system comprised of data acquisition unit, computation unit and actuation unit which detect the environmental factors with the help of sensors. The data gathered was compared to existing ideal parameters and actuators were turned on when needed. Similar prototype was introduced by Gunasheela *et al*. (2018); Srinivas *et al*. (2019) that sensed (by sensors) the fluctuations in weather parameters (temperature, humidity, light, CO_2 etc.) of the rearing house and showed in OLED which will automatically sent to mobile application of agriculturist followed by activation or deactivation of fan, heater, light and sprayer when required. Arun *et al*. (2019) developed a prototype operated in real time which was capable to monitor and control all the parameters of the rearing environment. In addition to that, the colour change of the larval body was identified which indicated the different stages of larval growth up to cocoon stage. A system about forecasting predictions for seven days was demonstrated by Jambukar and Dawande (2020), based on IoT which recorded the temperature, humidity and transferred the values to oracle database (UART) that helped in machine learning of change in parameters via python. Moinuddin *et al*. (2020) prepared an automated sericulture system by utilizing broadband/Wi-Fi and IoT incorporated with microcontroller, temperature sensor, light dependent register, humidity sensor and LCD to control the climatic conditions of rearing room along with necessary actions. Similar technology was developed by Yashaswini *et al*. (2020) by employing microcontroller (ARM7), moisture sensor to check soil moisture, rain sensor to sense the rainfall, LCD etc. The system checked over irrigation and top soil erosion and reduced water wastage. Moreover, it controlled the temperature of rearing room within the fixed temperature range. Reddy and Bhaskar (2022) designed a system to monitor the parameters like humidity, temperature, accumulation of harmful gases in the rearing room. The data collected was utilized to control the parameters in that closed area. Automatic images of the silkworms were captured with the help of cameras and compared, followed by application of medicine in case of diseased worms. The system was intended to help the rearers my minimizing physical labour involved in the whole process and to increase the silk yield. A system of automatic temperature detection was put forwarded by Eathamakula *et al*. (2020), where two thermostats were employed from remote location, one inside the silkworm shed and other one outside the shed. The readings were automatically sent in every fifteen minutes for monitoring the temperature in day, week, month and year, thereby reducing manual observation. Manoj (2020) proposed a system where raw data was gathered and subjected to imputation methods and further subjected to tree regression technique and linear regression technique to find optimum temperature and humidity required for successful cocoon yield. Jegadeesan *et al*. (2021) proposed a 'IoT based automated sericulture system' that detected variations in natural parameters, displayed on the webpage and send messages to sericulturist who was responsible to make pre-programmed basic moves (whenever temperature rise or fall, the fan was directed to switched on or off automatically) thereby controlling the environmental conditions of silkworm rearing house. Artificial intelligence along with terahertz imaging technology (THz) was integrated by Xiong *et al*. (2021) to monitor internal morphology of silkworm egg with 98.5% recognition accuracy of egg development stage in less time. Deepthi and Sastry (2021) created a real time prototype that controlled the installed environment (temperature, humidity) along with classification of healthy and diseased worms based on colour change and texture analysis. Further, the diseased silkworm could be differentiated into flacherie or pebrine by adopting suitable mask and histogram of the worms. An automated smart sericulture plant based on IoT and AI was developed by Nithin *et al*. (2021) comprised of digital sensors to observe temperature, humidity, vibration etc. and timer based automatic disinfectant and lime water sprayer to check disease occurrence with fire alarm system. In addition to that, the system used IR sensor, vibration, gas sensor to prevent entry of unwanted things and chopper blade buttons for selection of blades for mulberry leaves chopping. Choudhary and Kaur (2022) also developed an efficient wireless sensor network technology which combined microcontroller and GSM module to track and regulate humidity, temperature and light intensity in silkworm rearing room which will save both time and money. A deep learning Convolutional Neural Networks (CNN) was proposed by Yogeshraj *et al.* (2022) to distinguish healthy and unhealthy silkworms with high accuracy and low complexity by employing image processing algorithms. Environmental factors like temperature, rain was monitored using sensors and controlled with the help of fans and heaters.

Application on mulberry cultivation: Ramya *et al*. (2015) proposed an automated system of soil testing by collecting soil from different region of Karnataka for mulberry plantation with the help of classifier algorithm and approved through mathematical formulas. Decisions were taken by using J48 (C4.5) decision tree from data mining tool WEKA and predicted whether the soil is ideal or not for mulberry growth. Mulberry leaf yield prediction through advance machine learning models (multiple linear regression, ridge regression and random forest regression) based on soil parameters was put forwarded by Srikantaiah and Deeksha (2021). Sheeba *et al*. (2022) analyzed the soil status of districts of Tamil Nadu using machine learning algorithm (extreme learning method) to identify micronutrients level in the soil based on soil samples. The soil was found to be rich in potassium (35%), nitrogen (80%), sulphur (75%) and sufficient or poor in magnesium, boron, copper and zinc.

Application on mulberry cocoon and seed sector: Automatic quality assessment of mulberry cocoons was designed by Prasobhkumar *et al*. (2018), by employing illumination unit, image acquisition, processing unit and camera installation to identify and locate good, defective cocoons on the basis of shape, size and colour. The system was efficient to access 96 cocoons/second in a single frame with 100% accuracy. They further assessed cocoon quality using vibration impact acoustic emission process to classify dried and mute cocoons by analyzing physical state of pupa inside the cocoon which would be a good replacement for manual method (Prasobhkumar *et al*., 2019). Joseph Raj *et al*. (2019) introduced a multi sensor machine to distinguish gender by acquiring weight and images of mulberry silkworm in cocoon stage without human interaction with accuracy and repeatability of 93.54% and 88%, respectively, which might be suitable for industrial purposes. Zhang *et al*. (2010); Yang *et al*. (2010) made automated devices to distinguish between male and female silkworm cocoons using ultraviolet light based on their fluorescent properties. Dai *et al*. (2020) constructed a convolution neural network (CNN) to identify gender and variety of silkworm cocoons from 4^{th} to 13^{th} day with more than 90% accuracy on each day and 100% on 6^{th} day with the help of 1-D near infrared spectroscopy. They also stated that there was no correlation between pupa age, gender and variety detection accuracy of silkworm cocoons. Convolutional neural network (CNN) method of automatic counting of eggs was used by Rangappa and Rajanna (2021) to identify hatched, unhatched eggs and quantify silkworm eggs laid by female mother moth. The method utilized key marker that transformed egg sheet into standard image which can be considered as input to get trained convolution neural network model and predictions. Pavitra and Raghavendra (2022) suggested use of deep learning method to detect and count silkworm eggs which consists of four steps namely, input images, preprocessing followed by segmentation and counting.

Application on muga sector: One of the major constraints of muga silk industry is the occurrence of diseases due to fluctuation of weather factors (temperature, humidity). A mobile based forewarning application for early warning systems on flacherie disease infestation was developed by Goswami *et al*. (2021) to reduce crop loss. The system worked by preparing land use/land cover map and analyzing meteorological factors for ten years of selected muga farms and average of each factor was considered prior to 15 days of brushing till harvest in the sequence of 15, 10 and 5 days. They observed correlation between land surface temperature (LST) and occurrence of flacherie disease (LST of Boko and Nongpoh were more suitable than Lakhimpur, Jogduar and Tura) hence reported that rise in temperature and humidity beyond threshold limit increased flacherie infestation in the rearing field.

Application on eri silkworm rearing: A low cost wireless sensor network-based system to monitor environmental conditions in eri silkworm rearing room was developed by Doloi *et al*. (2019).The parameters like temperature, relative humidity and light intensity were measured by sensors in real time during rearing period and further processed by microcontroller to find out optimum ranges.

Nadaf *et al*. (2021) discussed some potential applications of artificial intelligence in tropical tasar silkworm seed production:

1. Interactive generating adversarial networks (I-GAN) will help in generating images of resultant host plant prior to grafting.
2. Conditional generating adversarial networks (C-GAN) could help in providing expected images of incubated seed cocoons before actually storing in a particular temperature, humidity range.
3. AI through generating adversarial networks-negative samples by using images of yellow fly, uzi fly or pebrinised tasar silkworm helps in controlling generations.
4. Sequence adversarial networks (S-GAN) might help in farming system by recovering fertility status in tasar plantation.

Reshamandi is the first IoT based platform which enables buying, selling of silkworm, cocoons and silk yarn with quality assurance. It helps the rearers and reelers to increase the yield and improve the silk quality by using artificial intelligence, cloud platforms and sensors. It offers scientifically graded cocoons to the reelers by using image processing and deep learning algorithms for renditta grading to increase productivity (Anon., 2022b). These IoT based devices collect data of factors like pH value and moisture content of soil along with temperature, humidity, air quality and light. The gathered information is transferred to a cloud-based server which communicates and alerts the farmers in their respective languages (Anon., 2022c).

CONCLUSION

Modern technology such as artificial intelligence and internet of things could stimulate the development of sericulture and expected to reduce the challenges of the rearers, reelers and those who are involved in the venture. Successful installation of the technologies will surely prevent losses due to fluctuation of environmental factors. Operations related to field activities such as choice of soil for plantation and weather forecasting, diseases, pests will also be made easy. This would require skilled personnel, awareness with high initial installation cost.

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