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PRECISION APICULTURE IN BANGLADESH: OPPORTUNITIES AND CHALLENGES

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ABSTRACT

Apiculture has shown considerable development in honey bee rearing, and honey and other byproducts manufacturing that lead to an increase in pollination and conservation of the ecosystem. Precision apiculture (PA) is an apiary management strategy based on the monitoring of individual bee colony using a set of instrumentation to minimize resource consumption and maximize the productivity of apiculture. Bangladesh follows artisanal beekeeping methods for apiculture. The general rearing techniques are fixed and migratory rearing. Currently, hives and breeding programs are used as equipment for colonization and multiplication of the bees. Various information and communication technologies (ICTs) can be used in the beekeeping to partly support the beekeepers by implementation of automatic or semi-automatic solutions for the monitoring of bee colony. In addition, an Internet of Things (IoT) and wireless sensor network-based technology could be experimented for the promotion of a low-cost precision apiculture (PA). However, PA systems should be optimized by searching for appropriate combinations of different sensors, and corresponding decision support systems that provide convenient, reliable and cost-efficient solutions. The development and specifications of a PA system should consider business interest, distance to the apiary, possible risk and other peculiarities. The aim of this report is to discuss the opportunities and challenges of the introduction of PA system for enhancing productivity in apiculture in a profitable and sustainable manners in Bangladesh.

Keywords: ICT, IoT, honey production, beekeeping, sustainable apiculture

Introduction

The People's Republic of Bangladesh has 160 million inhabitants and is the most densely populated among countries with populations exceeding 10 million, standing in eighth position as the most densely populated country among the 182 countries in the world (Syeed *et al.* 2020). The economy of Bangladesh depends primarily on agriculture contributing 14.2% of the country's GDP (BER 2019). Approximately, more than 85% of the people in Bangladesh live in the rural areas and are directly or indirectly engaged in a wide range of agricultural activities. Apiculture, or rearing of bees, a promising branch of agriculture, can play an important role in conserving environment and developing economy. Honey bees being great pollinators and responsible for producing products like honey, beeswax, bee venom, and polishing agents (propolis) have a great national and international demand.

A sector of apiculture, precision apiculture (PA) is a subsection of precision agriculture, relies on a set of instrumentation used to monitor the health and productivity of beehive colonies. It can open a new window for existing and new business related to the products of apiculture. Beekeeping is an agricultural sector with rural development functions for honey and hive's goods production and the maintenance of ecological balance. It is an important part of agriculture, with distributed locations, needing the monitoring of the honey bees and surrounding environment in a 24/7 mode. The honey production cycle takes place inside beehives placed in an open field in the presence of plants in bloom. The success in this traditional apiculture not only depends on the strength of the honey bee colonies but also on many other factors, some of which are environmental factors, such as temperature, relative humidity, and wind (Zacepins and Stalidzans 2013). Application of advanced intelligent ambiance technologies can benefit the apiculture in multiple ways. Wireless in-hive sensor networks show promise in apiary management and research (Henry *et al*. 2019). To improve production and marketing of apiculture products, program protocols should be drawn up comprising technical assistance, swarm control, control of varroosis, management of hive restocking in the community and cooperation on research programs between partners (Ferrari *et al.* 2008). Application of PA system will enable beekeepers of Bangladesh to add a new dimension to honey and other hive products production. It facilitates rearing and multiplication of bees, strategically supervises individual hive integrating IoT and wireless technologies. Therefore, PA may reduce manual labor and promote sustainable apiculture. This report reviews current update of PA, and discusses the opportunities and challenges for introduction of PA in Bangladesh for promoting sustainable apiculture and food security.

Current status of apiculture in Bangladesh

Apiculture is a branch of agriculture in which bees are reared on a commercial scale for the purpose of producing honey and using them as pollinators for enhancing crop production. Bangladesh is rich in natural resources that is favorable for producing year-round various cross-pollinated crops. Thus, honey bees play a vital role for cross pollination and improvement in crop yield. Government and many non-government organizations (NGOs) such as Bangladesh Institute of Apiculture, Bangladesh Small and Cottage Industries Corporation, Proshikkhan Shikkha Karmo, and Mouchas Unnayan Sangstha have various schemes to provide technological support for sustainable beekeeping to increase the production of honey and honey products in the country. The PROSHIKA has innovated and introduced a number of new technologies to modernize apiculture practice in Bangladesh. Beekeeping needs low capital and little time, and promises a high return (Moniruzzaman and Rahman 2009).

Among various species of honey bees, *Apis cerana* and *Apis indica* are indigenous species that have been commonly used for the traditional beekeeping. The *A. cerana* is a great plant pollinator. *A. mellifera*, native to Europe, is used for modern beekeeping. Regions in Rajshahi and exclusively Modhupur, Bhuapur and Gopalpur in Tangail regions have shown promising development in apiculture. Despite being a cottage industry mostly, it has been reported that 46% of the total beekeeper has their own land, ranging from 0.51-1.50 acres. About 37% of the beekeepers are young aspiring entrepreneurs ranging between 15-30 years of age. The average benefit-cost ratio in apiculture in Bangladesh stands at 1.59, which indicates that it is a profitable venture (Amin 2020).

Honey bee is a great pollinator and thus directly involves in crop production. They are responsible for 70%-80% of the crop production (Meikle and Holst 2014). They contribute to pollinate for the higher yield and good quality of the crop products. Honey, the main product produced by the honey bee, has a greater use as it has medicinal value that can cure various diseases. It can be used as a remedy for malnutrition and also as a food condiment. Other hive products such as beeswax and propolis are polishing agents which have great national and international demand in cosmetic and pharmaceutical industry. The bee venom can be a flourishing scope for exportation in the world market. The honey bees help to keep the balance in the ecosystem by reducing the use of chemical resources, reduce emission of greenhouse gases and limit soil erosion. They are also highly important in horticultural aspects.

The apiculture has a cultural importance in Bangladesh. The "mowalis" (honey collectors) in the world's largest mangrove forest, the Sundarbans play a major part in collecting honey in the natural way. Apiculture has opened opportunities for livelihood in rural areas and spiked interest in the youth for entrepreneurship. By using

Table 1. Increased production of honey using cultivated bees in various crops (Amin *et al.* 2019)

Honey Production (Metric ton)			
crops	2015-16	2016-17	Increased honey production
Mustard	522.6	770.3	247.6
Black cumin	125.5	164.6	49.0
Coriander	267.1	117.2	50.1
Litchi	106.4	171.7	65.3
Sesame	85.0	90.5	5.5
Jujube	4.1	4.5	0.4

cultivated bees for apiculture, there was a significant increase in honey production from June 2015 to June 2017 (Figure 1). Cultivated bees are used on various crops such as mustard, black cumin, coriander, litchi, sesame and jujube. It was evident that the amount of production was increased after using cultivated bees, for instance in 2015 there was 522.6 mt honey produced from mustard, in 2017 it increased up with 247.6 mt making a total production of 770.3 mt (Table 1) (DAE 2018).

Though beekeeping is a profitable business, the popularity is still less because of lower marketing of honey and other byproducts in Bangladesh and all over the world (Islam *et al.* 2016). The apiary industry has an economic impact via direct effects (the gross value of production), indirect effects (demand stimulated in linked sectors) and crop pollination effects (Islam *et al.* 2016). In recent times, the effects have been comprehended on a greater scale. The marketing policy has spiked and the honey has reached more to the consumers in Bangladesh, which can be demonstrated by depicting the annual productions in the span of time. The variability in total production can be found in table 2 and figure 1.

Over the course of time honey production in Bangladesh fluctuated at a great scale from 2008-2009 to 2016-2017, then had a slow and steady increase till present time. This trend line shows the variability of honey production. Factors that mainly affected honey production were availability and utilization of resources, government interference, policy reinforcement, consumers' interest, and efficient marketing.

Table 2. Annual total production of honey in Bangladesh from 2008-09 to 2019-2020 (BBS 2008- 2020)

Year	Total Production (kg)
2008-09	3075.6
2009-10	2763.2
2010-11	25097.0
2011-12	165731.0
2012-13	51866.1
2013-14	51866.1
2014-15	2822.9
2015-16	1924.0
2016-17	82224.1
2017-18	79831.0
2018-19	302968.3
2019-2020	445200.0

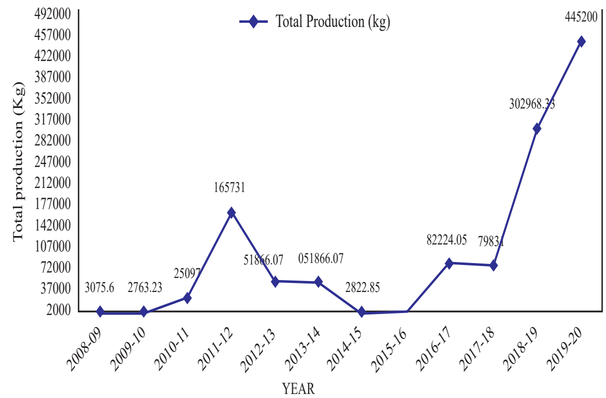

Figure 1. Variability in production of honey in Bangladesh from 2008-2009 to 2019-2020.

It is revealed that the price of *Apis mellifera* colony is so high for the marginal farmers. So that, a comparatively high initial cost is required for *A. mellifera*, but in terms of long-time business it could provide efficient gain by higher yearly return. *A. cerana* exhibit lower benefit than *A. mellifera*, but the initial investment costs are lower and comparatively easy to obtain a bee colony. The high cost of labor and other resources of beekeeping practice largely affect the benefit from traditional apiculture. Although a majority of the beekeepers received basic training in beekeeping, it's required to provide more technical training to reduce labor cost and increase their profitability (Islam *et al.* 2016).

Apiculture has huge impacts in Bangladesh notably like agricultural, ecological and socio economical aspects. From Bangladesh's perspective, it is a huge venture because apiculture doesn't require huge capital to start and only needs a minimal training. Honey bees being a great pollinator for cross pollinated crops, play a significant role in increased production resulting in soil conservation and lesser use of inputs and greater output. Rearing of honey bees in the horticultural field has a great prospect. The bees collect nectar and honey from the litchi, mango, mustard, sesame fields etc. and also increase the amount of fodder crops by pollination which are used as feeds for livestock animals. Bangladesh has a great variability in flora. Appropriate climate of the country makes it easier to practice year-round apiculture as a flourishing enterprise. The exportation scope of the good quality apicultural products are drawing entrepreneurs for start-up and giving small scale farmers an opportunity to utilize their land for a profitable business in a sustainable way of living. In this way, apiculture is also paving the way of employment and

Table 3. Estimation of return, cost and benefit cost ratio in accordance with various size of hive in Bangladesh (Moniruzzaman and Rahman 2009)

Size of hive	Gross return (Tk.)	Cost (Tk.)	Net return (Tk.)	Benefit cost ratio
Small	8892.81	6017.48	2875.33	1.48
Medium	13428.16	9209.18	4218.98	1.46
Large	19678.77	12054.10	7624.67	1.63
All Farms	15382.74	9699.82	5682.93	1.59

Table 4. Current status and potential for apiculture in Bangladesh

Activities	Existing	Potentiality	Remarks
Honey production	1,600 Mt	25,000 Mt	Including the Sundarban honey and honey hunter throughout the country
No. of wild colonies	4,55,000	9,50,000	
No. of domesticated colonies	35,000	9,00,000	
No. of beekeeper	25,000	4,00,000	
No. of honey hunter	45,000		Existing bee hunter may be converted to bee keeper
Employment generation	70,000	4,30,000	Existing employment generation includes the bee hunter
Enhanced crop yield per year	Tk. 1200 million	Tk. 80,000 million	

Mt, Metric ton.

livelihood for rural people helping them to retain their cultural heritage, boosting up the economy of the country (Moniruzzaman and Rahman 2009). The present status and economic potential of apiculture in Bangladesh is summarized in table 3 and table 4.

The concept of precision apiculture

Precision apiculture (PA) is a subdivision of precision agriculture which is a process of monitoring the bee colony individually to limit the input resources and increase productivity and efficiency with the help of developed technologies (Henry *et al.* 2019). It can be referred to as an apiary management strategy with the purpose of rearing the bees to the optimal condition for the best output.

The precision apiculture (PA) relies on a set of instrumentation used to monitor the health and productivity of beehive colonies. In-hive monitoring system produces information on food consumption, recognize pre-swarming conditions and colony losses due to various environmental and health parameters, such as temperature, acoustics, hive weight, and humidity (Zacepins *et al*. 2015). In a commercial grade apiculture venture, it is nearly impossible to monitor every single bee colony and meet their needs, and also to inspect every colony activity and ensure the optimization of resources. By using wireless technology, radio frequency electromagnetic radiation (RF-EMR), remote hive monitors and developed algorithms, bee keepers can assess the condition of their hives without inspecting physically (Zacepins and Stalidzans 2013). The idea of precision apiculture system (PAS) is basically developed around the thought of saving time for the beekeepers. Physical inspection is highly time consuming for the beekeepers, hindered natural activity and increased number of deaths per colony are documented during the process. The PAS doesn't replace the beekeepers; it helps them to achieve higher efficiency (Henry *et al*. 2019). It saves time that is lost due to physical inspection and reduces the cost and consumption of resources, ensures sustainable productivity and improves the health of bees by enabling way of monitoring their activities without harming them or killing them in the process. This technique is necessary for the commercial apiaries for enhancing their bee rearing ability and production of the products.

Precision apiculture is considered as a three-phase cycle (Figure 2) (Imadeddin 2016); firstly, data are acquired using sensor equipment and networks. The next step is data analysis where the data are compared with the parameters and automated algorithms about conditions in the beehive, colony behavior, development of disease and bee activities. In the third stage, necessary management steps are taken using the acquired data to get desired results. Therefore, grossly it can be said that there are at least three essential elements in the PAS: information, technology and management (Zacepins and Stalidzans 2013).

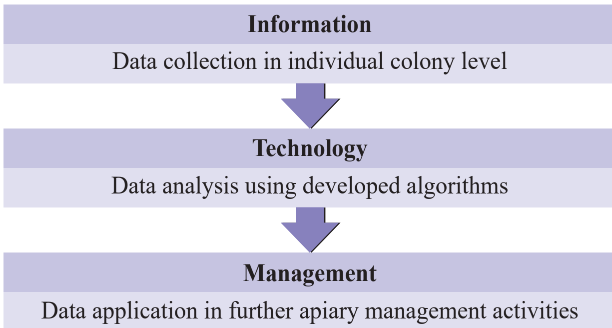

Figure 2. Basic concept of three phase cycle in precision apiculture system (PAS).

Acquiring information: data collection phase

Data collection from different colonies in PAS system cumulatively helps beekeepers to understand internal conditions of the hive and how the fluctuations of the factors such as temperature, humidity, sound, moisture affect bee activity. Automatic tools mostly wireless sensor network-based technology are used to obtain data for better implementation and management in three classified groups in data collection phase described below.

Apiary level monitor: Apiary level management is the least complicated as it includes obtaining meteorological data such as light, wind, precipitation and video monitoring for the better understanding in bee behavior in colony level monitoring (Henry *et al*. 2019). This data can be obtained remotely or from meteorological station, or by video monitoring which captures human movement that interrupts bees in the apiary. Video monitoring can produce enormous amount of raw data so this should be processed only when requested and in special cases of observation such as frequency of heavy wind, heavy rain, uncontrolled human interventions etc. (Henry *et al*. 2019).

Colony level monitor: Colony level monitoring includes observing imperative factors such as temperature, humidity, weight, sound that affect honey quality and production. Use of temperature monitoring device allows beekeepers to observe hive temperature, swarming and pre-swarming, food accumulation and consumption, bee death etc. This device also allows to observe the trend and analyze data between different colonies (Karasha 2013). Weight monitoring using automatic and manual scales detects nectar flow during foraging period, food consumption during non-foraging period, number of foragers, daily nectar flow and amount of accumulation. Automatic scales are used in commercial level despite being costly and at same accuracy level it is hard to operate with manual scales in industrial level (Human *et al*. 2013). Sound monitoring can be done by continuous recording of sound emission such as flight noise, fanning noise and hive activity by honey bee colonies. The output of sound, with respect to both amplitude and duration can be labeled and used to predict swarming period and recognize patterns of behavior (Henry *et al*. 2019). Also, accelerometers are used to measure vibrations and the output can be used to indicate specific physiological processes in honey bees, and applied to better understanding of swarming and health issues (Henry *et al*. 2019).

Individual bee related parameter: Individual bee related monitoring is solely based on the purpose of counting the number of bees in the entrance of the hive, counting total number of bees, numbers of incoming and outgoing number of bees in a single colony using video camera devices and bee counters (Henry *et al*. 2019). Video camera setup helps to detect disease infestation in the hive by monitoring unusual movement in the hive. Camera setup for automatically counting honey bees makes it possible to recognize the population dynamic. Also, bee counters are used to count number of incoming and outgoing bees, peak flight time, and impact of weather on flight, change in flight pattern, swarms and return rates back to the hive.

Applying technology: data analysis phase

Data analysis mainly correlates obtained data from various devices with hive condition and developing standard parameters using automated algorithms. These measurements have to be accurate to formulate proper management strategies which can be executed in the hive, colony or in the apiary.

Data analysis can be used to detect annual state of bee hives. At the developing cycles of bees, the beekeepers can synchronize their activities for individual colonies. Video, audio and sound monitoring help to detect swarming and pre-swarming activities. Weight and temperature scales are used to determine nectar flow, and increasing hive weight that indicate nectar accumulation and food consumption in non-foraging period (Karasha 2013). Death and disease infestation cause weight and temperature variation in the hives, so using all the parameters we can easily detect loss of number in bees and decreasing physiological activities. Declining temperature accurately indicates broodless state and then beekeepers can conjoin multiple colonies or add queen to repair the colony (Karasha 2013).

All of these parameters are often unnoticed during manual inspection by beekeepers. Thus data analysis using precision apiculture system facilitates better management of the apiaries.

Apiary management: data application phase

Using developed algorithm and specific software, every aspect of each colony is supervised by the beekeepers. Smaller, cheaper, and more accurate sensors, along with easier connections to computers and the internet, have made it possible for bee researchers and beekeepers to monitor many physical aspects of bee colonies continuously, remotely, and with little manpower. Once sensors have been installed, hives can be monitored without disturbance, including during the periods when invasive hive inspections are contraindicated, such as during winter or times of colony stress (Meikle and Holst 2015)

Measuring weight continuously with automated scales helps to determine food accumulation, nectar flow and health conditions of the bee. Importantly data interpretation of weight is easier to define. But there are some certain aspects of weather that influences reading, i.e higher moisture content increases the weight of wooden boxes (Zacepins *et al*. 2015). Increase of temperature during swarming and brooding due to movement of bees, also maintaining constant optimum temperature using heating apparatus during wintering help to create a microclimate for each colony.

Thermometers and sensors are used to detect the warmest parts of the hive during brooding and occurrence of bee clusters. Variability in temperature indicates inconsistency in number of bees, the beekeepers can use automated feeder during non-foraging season or use bee counters to monitor movement of bees (Henry *et al*. 2019).

Parameters, monitors and equipment used in various PAS

The Macdonald Campus of McGill University in Quebec, Canada experimented and developed sensors during the summer and fall of 2015 (Table 5). The hives were created with 2015 queens and 4 frames of brood from pre-existing hives from the McGill Apicultural Association that possess hybridized Italian and Russian genetics (Henry *et al*. 2019). The hive monitoring equipment used are briefly discussed in the following sections.

Each in-hive data acquisition system that served as a node for the wireless sensor network was based on a Raspberry Pi 2B V1.1 (Raspberry Pi Foundation LLC, Cambridge, UK) microcomputer. This 85 × 56 × 17 mm microcomputer contains a Broadcom BCM2836 ARM Cortex-A7 (ARM Holdings PLC, Cambridge, UK) based quad-core processor, which runs at 900 MHz and holds 1 GB of RAM memory. The Raspberry Pi 2B V1.1 receives 5 V, 2 A power from a micro USB socket, provides 4 USB

Table 5. Equipment used in PAS in the experimentation of McGill University (Henry *et al*. 2019)

Parameters	Equipment position	Location	Equipment
Temperature	In and out of hive	Field	AM2303 Sensor
Humidity	In and out of hive	Field	AM2303 Sensor
Sound	In hive	Field	PLMC15 omnidirectional microphone

Table 6. Equipment used in PAS in the experimentation of The University of Palermo (Cecchi *et al*. 2020)

Parameters	Equipment position	Location	Equipment
Temperature	In and out of hive	Field	AM2302 sensor
Relative Humidity	In and out of hive	Field	AM2302 sensor
Weight	Out of hive	Field	PSD-S1 metal load cell
Air Speed	Out of hive	Field	3-armed cup rotor anemometer

ports, a micro SD reader, and an Ethernet port. An 8 GB micro SD acted as the storage device and ran Raspbian, a Raspberry Pi specific Linux operating system. The specially developed hive-sensor software was installed on the Raspbian operating systems to facilitate data acquisition (Henry *et al*. 2019).

The Department of Agricultural, Food and Forest Sciences of the University of Palermo developed a PAS, which consists of an Arduino board with an Atmel microcontroller (ATmega2560) with 8 bits used as the data acquisition system (Table 6) (Catania and Vallone 2020).

The Arduino board consisted of external 12 V DC power supply connector; load cell connector (and bridge power supply outputs and two bridge unbalance measurement inputs); HX711 load cell amplifier; real time clock DS1307; Hitachi 16 × 2 display; 12 V output for anemometer/vane power supply and two measurement inputs; HC05 Bluetooth module; level translator for SD card level converter 3.3 V/5 V (Cecchi *et al*. 2020).

The card has the following characteristics: operating voltage: 5 V, recommended input voltages: 7–12 V; maximum input voltage: 6–20 V: number of digital inputs/outputs: 54 (14 of which can be used as PWM outputs); number of analogue inputs: 16; current supported for input and output pins: 40 mA; current supported for 3.3 V pin: 50 mA; Flash memory: 256 KB (8 KB used for the bootloader); SRAM: 8 KB; EEPROM: 4 KB; clock frequency: 16 MHz (Human *et al*. 2013). PAS is a platform capable of continuously recording and monitoring the following parameters: temperature (°C) and relative humidity (%) inside and outside the hive, quantity of honey produced (kg), and wind (m s^{-1}). The Arduino card has a Bluetooth module which facilitates regular data download and acquisition to devices such as a smartphone of laptop which has Bluetooth application.

The basic idea of the Internet of Things (IoT) is that almost every physical thing in our world can also become a computer or a data generating device that is connected to the Internet. The IoT idea and concept are not new. However, it only recently became relevant to the practical implementations mainly because of the huge progress made in hardware development. The decline of size, cost and energy consumption, hardware dimensions that are closely linked to each other, now allows the manufacturing of extremely small and inexpensive low-end devices and microcomputers.

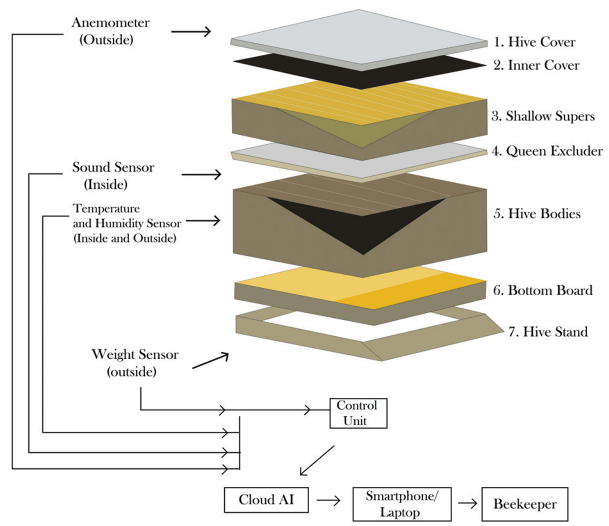

Figure 3. A common beehive integrated with necessary equipment suitable for Precision Apiculture System.

In the model illustrated in Fig. 3, 3 layers of IoT are integrated, first layer is IoT device which comprises of data collection, data gathering, data observation using wireless devices and sensors with nodes. Physical variables including weight, temperature, humidity, air gases, vibrating, sound, and forager traffic, are continuously monitored and data are constantly uploaded,

Table 7. Estimates and availability of equipment used in PAS with price range in Bangladesh

Equipment	Function	Price Range (in Tk.)
AM 2303 sensor	Temperature and umidity Sensor	350-500
PLMC 15 Omnidirectional Microphone	Sound Sensor	150-200
AM 2302 Sensor	Temperature And Humidity Sensor	850-900
PSD- SI Metal Load Cell	Weight Sensor	1695-4663
3-Armed Cup Rotator Anemometer	Air Speed Sensor	1100- 5700
Available Source: E-Commerce Services such as Techshop BD, Telecomspares BD, Daraz, AliExpress		

this part includes the second layer which is IoT gateway. This second layer entails connectivity, the protocol, data aggregation, filtering and processing, data security, data management (Meikle *et al*. 2015). In this layer, the sensors are connected to a wireless sensor network and Wi-Fi protocols were used in the system. The Arduino board as microcontroller is connected with temperature sensor, humidity sensor and the weight scales which are linked to the Wi-Fi module. This board uploads data to the cloud service to the mobile application of computer software by which researchers and hive managers can accumulate the data and prioritize tasks for optimum management of the apiary.

The third layer is the IoT platform which comprises of the cloud computing services in the system that helps end point users to assess the condition of beehive from the processed data. The algorithm or the software developed will include definite set of parameters according to proven literature that will guide the apiary management to upscale and get desired result and increase efficiency. The sensor network will provide a rich dataset suitable for academic and apiary management applications.

The placement of the equipment depends on the ease of management of beekeepers to ensure proper monitoring of inhive activities without disruption. A gross estimation and availability of equipment is shown in Table 7.

Application of PAS in Bangladesh: opportunities

The PAS can play a vital role in commercial production of honey in Bangladesh. The PAS will significantly reduce resource consumption by enabling to monitor individual colonies separately (Cecchi *et al*. 2020). Main target of PAS is to facilitate the time-consuming process of physical inspection of hives which results in queen and worker bee death, interruption in natural activities of bees like nectar flow, food consumption, swarming of bees, increasing susceptibility to pest and diseases. By using wireless devices in PAS many online data storage and real-time analysis systems have been recently developed in order to evaluate the hive internal parameters as temperature and relative humidity and the environmental condition such as temperature, relative humidity, rainfall, wind, and cloud cover (Imadeddin 2016). Continuous monitoring systems have the ability to benefit research and apiary management through generating colony data throughout the season, such as developmental stages of colonies, annual brood rearing phases, and swarming events.

Utilizing existing horticultural fields, small scales lands and commercial grade projects, conventional apiculture integrating PAS will result in quality control of honey and amplified production, exporting scope to neighboring countries such as Japan and India, increase in employment source, significant rural development and also woman empowerment. The economy of Bangladesh depends primarily on agriculture, approximately 77% of the total population and more than 85% of the people in Bangladesh live in the rural areas and are directly or indirectly engaged in a wide range of agricultural activities, precision apiculture can be the dawn of a new era. The PAS will make it possible to identify any critical points in the honey production process, namely: certain date of production start; daily production according to climate, certain date of production end; identification of the exact time to add/remove honeycombs, and warning of swarming (Imadeddin 2016).

Application of PAS can overcome vital constraints currently existing in Bangladesh. Precision beekeeping is the future of sustainable apiculture that ensures higher productivity and better rearing and management of bees in commercial grade apiaries. That will result in the survival of great pollinators in nature, increase in commercial grade honey production, enhanced productivity in the small-scale farmers ventures, scope of better establishment of entrepreneurs by investing in technology-based apiculture and overall, making apiculture a more successful and effective venture.

The PAS should be optimized by searching appropriate combinations of different sensors, and corresponding decision support systems must provide convenient, reliable and cost-efficient solutions. The development and specification of PB systems should consider business interests, distance to the apiary, expected risks and other peculiarities (Zacepins *et al*. 2015). mplementation cost of PAS in an apiary can be included with the fixed costs along with wooden box, honey extractor, bee veil, hand gloves etc. which is influential in the cost benefit ratio determinaton. The initial investment and proper management can successfully establish PAS in Bangladesh (Islam *et al*. 2016).

Challenges of PAS in Bangladesh

As apiculture is mainly based on marginal farmers as a cottage industry, the adoption of PA technology seems challenging considering the cost of setting the technology in Bangladesh's perspective. The lack of technological know-how of the farmers and young entrepreneurs is a big obstacle. High maintenance cost of equipment and set ups increase the initial cost and acquainting with the instruments will require significant amount of time. The development of algorithm to observe parameters in accordance with the hives for appropriate evaluation needs research and adequate knowledge. Furthermore, proper supervision of the PAS is obligatory. Development of the control unit with proper sensors and networking with IoT and artificial intelligence (AI) technology is a new concept in this practice for the existing market in Bangladesh. There is a great risk that the outcome of trial and error at the experimental stage can supersede the necessity of PAS establishment as it is a bit of time consuming and laborious process. This may result in skepticism in the integrity of the process.. Lack of government supervision on the commercial market of the produce from this sector and insufficient funding for research may hinder this venture to achieve maximum potentiality.

On the other hand, young entrepreneurs who have shown promising interest in apiculture and have ample amount of technological comprehension and familiarity can be utilized for inspection and experimentation in field level to determine key factors of success in the application of PAS in commercial level. The result can be used in advertising and introducing PAS as a viable and profitable venture. However, without adequate capital and complicacy in obtaining loans for business enterprises can compromise with the objective of the whole process.

But on the bright side, young entrepreneurs who are generally tech savvy can comprehend the impact of PAS. With the help of agricultural extension officers, technicians and trainers, farmers can be acknowledged about PAS system and with proper training with simplified equipment. As the government of Bangladesh is technology-friendly, the Department of Agriculture Extension or relevant authority may take an initiative to introduce PAS for sustainable and profitable honey production in Bangladesh. In this aspect, the government may initiate a project of promoting PAS for sustainable production of honey and other commercial products that ultimately help to ensure food and nutritional security of the country and also creation of new jobs for the rural youths.

Conclusions

Apiculture is a profitable venture with its ecological, socio-economical and cultural impacts. There are high opportunities to make apiculture as a commercial grade successful agricultural endeavor in Bangladesh. Due to geographical location and abundance of flowers all over the year and availability of manpower, the apiculture has a bright prospect in this country. Not only focusing on the honey production, the apiculture should be fully exploited for the pollination benefits by honey bee for maximizing crop production in a sustainable manner and ensure land conservation and retaining ecological balance. All of these can successfully and efficiently be achieved if precision apiculture is introduced with proper training, incentives and vision. Greater application of the precision apiculture with supports from government and non-governmental organization (NGO) will not only promote entrepreneurship in rural areas but also increase crop productivity for ensuring food and nutritional security of the ever-increasing population of the country.

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