Agribots In Smart Farming of Phytomedicinals and Phytonutrients: Opportunities and Challenges

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***Abstract*—These studies were aimed to form a novel approach using agriculture robots or agribots for its opportunities and challenges in the smart farming of phytomedicinals and phytonutrients. Agribots help serve as important tools in smart farming or precision agriculture because they can quickly collect valuable data to help farmers fine-tune their methods of planting, irrigation, pest control, harvesting and more. Observations from the study revealed that smart farming aided by the use of agribots, is an idea that is compelling. Conventionally, the agriculture of phytomedicinals and phytonutrients has been a manual activity over the years, and getting used to agricultural robots would be a cultural and emotional change. With robotics engineers and scientists who study phytochemistry, plant genetics and biology, these plantations which apply smart farming techniques could prove to be an ideal breeding ground for robotic agricultural technology.**

***Index Terms*—Agribots, Phytomedicine, Phytonutrients, Precision Agriculture**

I.INTRODUCTION

The vast range of medicinal plants distributed around the world is highly remarkable. According to reports, around 70,000 plant species from the lower level of lichens to higher level of trees are have been proven to have the potential for treating various illnesses.[1] Based on WHO, 21,000 medicinal plants are in use for various medical applications. The traditional herbal practitioners are even today known to follows the herbal medicine system in rural areas, using approximately 2500 plants for treating basic illness which has been considered as one of the best methods in Indian medical practices.[2] More than 100 genera of plants which are being used in the indigenous medicinal practices in different part of the world belong to India. India provides the best quality and quantity of medicinal plants and stands second in ranking in terms of export. It is considered as one of the 12 mega biodiversity hotspots of the world with 16 agro-climatic zones and has wide range of about 45,000 plants out of which 7000 plant species are recognized as medicinal plants.[3] AYUSH, the department established by the Government of India for the promotion of Ayurveda, Yoga, Unani, Siddha and Unani medicine has proved very much instrumental in the global recognition of our traditional medicine and thereby influenced our famers indulge seriously in the agriculture of phytomedicinals and phytonutrients.

Plants can protect themselves from pathogenic microorganisms, harmful insects and adverse environmental changes by producing certain chemicals or secondary metabolites which are non-nutritive [4] but useful in defence mechanism. These are known as phytochemicals, and somewhat essential oils. It can not only protect plants, but also humans and animals against certain diseases which are either caused by microorganisms or toxins produced by the microorganism. This is due to its antimicrobial property [5] In future, phytochemicals can be used as chemo-preventive agents [6]. Till date, a number of phytochemicals have been discovered based on difference in chemical structure and have been classified as major groups [7]. The major groups of phytochemicals are phytosterols, flavonoids, terpenoids, saponins, alkaloids, carotenoids, aromatic acid, organic acid, essential oils and protease inhibitors[8].Due to certain properties like antimicrobial, anti-inflammatory, anthelmintic, anticarcinogenic, antigenotoxic, antiproliferative, antimutagenic and antioxidative, the metabolites can provide direct or indirect defensive mechanism against pathogens or harmful ailments.[9]

Phytonutrients contain antioxidant and anti-inflammatory properties that help in providing support to a healthy human body. There are thousands of phytonutrients found in plants and other related foods. Some of the most common phytonutrients are glucosinolates, resveratrol, flavonoids, phytoestrogens, ellagic acid and carotenoids. Phytonutrients such as glucosinolates and flavonoids contain detoxification properties and should be included in the diet.

Dark green leafy vegetables such as broccoli, spinach, kale, book choy, and romaine lettuce are good sources of phytonutrients. Red, orange, and yellow vegetables and fruits such as tomatoes, peppers, carrots, mangos, peaches, citrus fruits, and berries also contain phytonutrients. Some of the other sources include nuts and seeds, legumes, tea, coffee and dark chocolate. When we combine phytonutrients with other nutrition sources it can literally become a nutrition powerhouse for a human body to promote good health. Based on the latest evidence, a working definition for phytonutrient could be a compound present in and/or derived from plants that confer a health benefit, including metabolites after consumption. A nutraceutical can be defined as a compound or a mixture of compounds present in food or food supplements intended to exert a therapeutic effect; the source could be plant or animal [10].

Precision agriculture (PA) is a smart farming management strategy based on observing, measuring and responding to temporal and spatial variability to improve agricultural production sustainability. [11] It is used in both crop and livestock production. Precision agriculture often employs technologies to automate agricultural operations, improving their diagnosis, decision-making or performing.[12,13] Precision farming goes hand in hand with smart farming solutions like drones, satellite imagery, and IoT devices like agricultural sensors. Farming sensors installed in fields are capable of recording climatic data and information on soil water requirements. With data at hand, farmers could improve their decisions about irrigation, fertiliser application, crop protector application, and sowing and harvesting.

The most important person in the adoption of precision agriculture is the farmer. Arguably, those that could benefit most from this agricultural revolution are small family-run farms. Many agricultural scientists and companies are collaborating together to develop robots which can take care of plants as humans.

Previously there was a misperception that smart farming is too costly and complicated, but technology has evolved rapidly, making it more affordable and easy to use.

Not having precision data can nearly cost the entire yield to a farmer. Sensors could aid farmers to fine-tune the irrigation more precisely and measure exactly what is going on, especially in the most important related depth of soil layer and, allow the farmer to determine when irrigation was sufficient and when it wasn't required. Agribots aid by offering farmers more insight into weather, scouting data, soil temperature, and satellite images in showing water stress. Agribots have the capability to provide data every moment of the day. Thus a farmer would be able to save water, fertiliser, and other valuable resources, including his own time, and thereby significantly improve his yield from the prior years.

II.STUDY METHODOLOGY

A. Opportunities for Agribots in Phytomedicinal and Phytonutrient Plantations

Farmer Perspective

The opportunities for agribots in phytomedicinal and phytonutrient plantations were studied for various factors like labour, profits, resources, attraction of young talent and productivity from the perspective of the farmers.

These studies reflected the following opportunities for agribots in phytomedicinal and phytonutrient plantations -

Decreased labour – Most major farming activities could be easily performed by agricultural robots, thereby eliminating human efforts. Resultantly, farmers become more self-reliant as they were not necessitated to depend on manual labour.

Increased profits – agribots are generally one-time investments, but costly. However, low operational costs and enhanced productivity ensure this investment as profitable in the long run.

Saving Precious Resources – With accurate monitoring, agribots ensure optimum utilization of resources like water, chemicals, etc. Moreover, they help reduce the wastage of resources and preserve them for future generations.

Attracts Young Talent – Modern technology and Artificial Intelligence have been fascinating young minds for quite some years now. These advancements influence a growing number of young farmers to consider agriculture as a source of livelihood. This inclination may also encourage the urban population to become a part of the agriculture industry someday.

Maximum productivity – agribots aid farmers in almost every aspect and help in saving their time and energy. Moreover, the accuracy in soil reports help farmers to understand the suitability of crops and optimize production along with maintaining quality.

B. Research and Development Perspective

The opportunities for agribots in phytomedicinal and phytonutrient plantations were studied for various factors like labour, profits, eesources, attraction of young talent and productivity from the Research and Development perspective.

Studies on the opportunities for agribots in phytomedicinal and phytonutrient plantations from the Research and Development perspective revealed the following observations -

Designing of agricultural robots needs to be done, keeping the following aspects in mind:

Structure of mechanical components, dimensional factors, and frame work of the robots

Capability of being agile, maneuvering ability and flexibility of the system

Robust and completely tested electronic control units and power supplies

Strong communication and remotely controlled systems

Limiting of human intervention by maximizing automation of system

The situation was found to be perfectly conducive for the entry of agriculture robots to lead the community into the world of digital farming.

In the research and design of future agribots, the architects and designers need to take into consideration the emerging technologies along with the aspects mentioned above, such as:

Internet of Things (IoT): A technologically advanced large farm may have thousands of devices that are in connection with the internet. The IoT ecosystem will aid connect the robots to its ecosystem through various connectors, actuators, and sensors.

Cloud Computing & 5G: Petabytes of data would be generated by IoT devices that need to be processed and transferred at lightning speed to aid robots in cognitive decision making.

Artificial Intelligence-Machine Learning (AI-ML): An integral part already and the base of robotics, AI-ML must be duly considered as a guiding principle for agribots.

C. Challenges for Agribots in Phytomedicinal and Phytonutrient Plantations

Farmer perspective

Studies on the challenges for agribots in phytomedicinal and phytonutrient plantations from the perspective of the farmer revealed the following observations –

In spite of the different benefits they offer, certain draw backs of agricultural robots hinder their use considerably with the problems as listed under -

High costs – agribots are machines that require significant investment, which make them a costly affair for small and marginal agriculturists.

Complexity of Operations – agribots are possessed with the latest technological advancements, making complex applications more complex.

Requirement of Technical Expertise – agricultural robots require farmers to be skilled and proficient in handling advanced technology, which hampers their ability to care properly their farmlands.

Power Cuts – India faces regular power cuts, especially with regard to rural areas. Resultantly agricultural robots are rendered useless since they cannot work in the absence of electricity, and hence a cause for unnecessary time loss.

Research and development perspective

Studies on the challenges for agribots in phytomedicinal and phytonutrient plantations from the Research and Development perspective revealed the following observations –

Tools have been used by farmers since millennia and the utilization of complex, heavy machinery for a century or more. Further, by adapting to genetically modified foods, farmers have displayed that they are not adverse completely to advances in technology.

Some of the factors that have influenced the adoption of robots in the farming sector include: the availability of cheap labour in agriculture, the processes so much complicated involved in farming (which make duplication by robots a real challenge for technology), shortage of research funds, low prices of seed, and the nearly complicated relationship with risk that exists amongst the agricultural community.

Farmers are huge takers of risk. The risk always pertains to the weather: the amount of sunshine, quantity of rain, the number of unprecedented and untimely storms in a year, etc. It could be understood, farmers fear the unknown effects of new devices.

If companies that manufacture robots prove that their equipment can provide extra reliability amongst agriculture’s inherent uncertainty, then the fear of new technology by farmers could be overcome.

Agricultural robotics is an idea that is compelling. Research and Development of agribots require to address deeply focused operations round-the-clock, that provides a much detailed approach to farming when compared to the workforce that humans can offer.

In addition, it provides the possibility of scaling up operations spread over tens or hundreds of hectares and millions of plants potentially. Automation in addition enables the collection of huge amount of data that could connect operations across the farm, rendering the whole operation smarter, more efficient and with less loss of water, energy, fertilizers and chemicals.

D. Scope for Application of Agribots in the Conventional Methods of Phytomedicinal and Phytonutrients Agriculture

In analysis of soil factors

Soil sampling is currently a growing trend among farm tasks that are performed by robots and automated equipment. Soil Analysis robots take the variability derived by sampling and produce a better result at the end to apply the right amount of fertilizer. Soil sampling naturally fits robots and provides a good business opportunity. Labour is the highest cost of soil sampling.[14, 15]

Rogo's GPS-guided agriculture robots (Fig.1) sample soil of the same locations at the same depth over several acres to produce an accurate picture of fertilizer requirements. Fields are sampled by agricultural robots every three to five years, considering the cation exchange capacity, crop rotation and yield goals.

Fig. 1 Rogo Soil Sampling Robot

Companies, such as Falcon Technologies and Soil Hawk, offer automated soil-sampling machines for hire or sale. Both possess self-contained, trailer-mounted systems that are towed by a pickup or UTV (utility terrain vehicle).

Soil Hawk (Fig. 2) operators, for example, employ GPS to drive the soil sampler to locations which are predetermined. On arrival, the operator with a press of a button on Soil Hawk clears the surface of debris and takes a soil sample using a self-cleaning probe at a predetermined depth and empties the soil in a bag. A core thus can be pulled every 20 seconds. The machine consists of 30 bags on a conveyor belt. Hence sampling 2.5-acre grids, implies that 75 acres can be covered before when bags need to be replenished.

Fig. 2 Soil Hawk Soil Sampling Robot

In preparation of land

The land that is to be prepared for phytomedicinal and phytonutrient cultivation requires to be cleared of all vegetation. A light burn following the trees being felled and drying facilitates the planting operations and aids in slowing down regeneration of weeds. Nevertheless, cleaning and burning in excess, chances to cause destruction of the soil and also expose the soil to erosion.

Ground mobile robots, equipped with latest technologies for positioning and orientation, navigation, planning, and sensing, have demonstrated their advantages already in outdoor applications like farming and forestry.[16]

Tractobot (Fig. 3) is an autonomous tractor. Kyler Laird developed these autonomous tractors. All these tractors are intended for use to the farmers to aid them with tasks like working and planting large areas of land intended for farming. In the first phase, Kyler developed an algorithm for the direction of the tractor the inclusion of the ROS framework was another important step in the development of the project.

Fig. 3 Tractobot Land Preparation Robot

In addition to ROS, Kyler utilized hardware components that were handy to any technology enthusiast along with Raspberry Pi, Arduino, or GPS modules. All of these components do not exceed $2000, which is a modest sum for a normal tractor converted into an autonomous one. Any of these robot tractors are capable of moving straight, turning, and for controlling tools to work the land.

In digging pits for planting

Pits for planting are usually dug to the required size and are filled up with soil and compost. Planting may be done in a rectangular or square or quincunx system during required spacing and seasons.

The Mole-bot (Fig. 4) is anticipated to be used very many digging activities to the extent that which require highly advanced drilling technologies in complex environments. A miniature version of the molebot would prove ideal for application in phytomedicinal and phytonutrients agriculture.

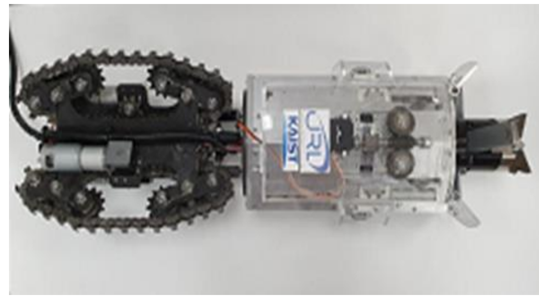

Fig. 4 (a) Mole-bot (Digging Robot), (b) Mole-bot.

Mole-bot (Fig. 4a) includes a stout scapula, a waist which inclines all sides, and forelimbs that are powerful. However, the most significant feature of it is the powerful torque from the expandable drilling bit which mimics the chiselling ability of that of a mole's front teeth, which highlights as the best feature of this drilling robot.

The crushing power of the teeth of the African mole-rat is so powerful that they can dig a hole with 48 times more power than their own body weight. This characteristic was applied for building the main excavation tool. And its expandable drill is designed such that it does not collide with its forelimb.

This robot that is 250mm wide and 840mm long is capable to excavate three times faster with a directional accuracy that is six times higher than the conventional models.

The robot after digging removes the excavated soil and debris employing its forelimbs. This embedded muscle feature was designed on being inspired by the European mole's scapula and converts linear motion into a force powerful rotational. For directional drilling, the elongated waist of the robot changes its direction 360 degrees m7micking living mammals.

For exploring underground environments, latest sensor systems and algorithms to identify the position and orientation of the robot employing graph-based 3D simultaneous localisation and mapping (SLAM) technology that matches with the magnetic field sequence of the Earth, which in turn enables navigation underground in 3D autonomous fashion were developed and applied by the R&D team.

The Mole-bot is anticipated as a giant leap forward for underground drilling and exploration technologies with high efficiency. Unlike conventional drilling processes which employ environmentally unfriendly mud compounds for cleaning debris, Mole-bot has the capability to mitigate environmental destruction. The researchers are certain that the system saves on cost and labour and would not require additional pipelines or ancillary equipment.

In spraying of fertilizers

Nursery, immature and mature are three stages of growth that could be identified in the life of these phytomedicinal and phytonutrient plants. The manuring varies with respect to the stages of growth. An ideal manuring schedule with dosage is adopted.

One area where robots are perfectly suited to be used in agriculture operations is the spraying of fertilizer and pesticides.[17,18,19]

Manual application of fertilizer and pesticides by workers with knapsack sprayers have turned out as methods of the past which are not only highly inefficient but also time consuming, but also result in the requirement of high labour and costs to cover large agriculture fields.[20]

Sitia Trektor Robot (Fig. 5) helps farmers transition toward an increasingly autonomous future. As agriculture robotics and other advancing technologies continued to enter the marketplace, Sitia focussed on a hybrid robot. Operations could be executed with precision, minimizing usage of seeds, fertilizers and pesticides so as not damage our natural resources any further while also optimizing yields on-site.

The ROS Software platform developed by SITIA is fully open, as part of the TREKTOR LAB, so any idea created has an opportunity not only to be tested but also integrated into future developments

Able to make long run, this Sitia TREKTOR hybrid machine is capable of mounting machine between or behind the wheels.

Fig. 5 Sitia Trektor Fertilizer Spraying Robot

Resizing of the machine is possible in different dimensions, therefore is likely to be able to fit a field customized.

Fertilizer and pesticide spraying robots like the Sitia Trektor robot are capable of carrying large storage reservoirs, be operated safely and autonomously too and be deployed at a much lesser cost compared to the traditional methods. In fact, it is projected that fertilizer and pesticide spraying by agricultural robots would reduce labour requirements to a good extent.

In removal of weeds

When weedicides are applied in phytomedicinal and phytonutrient plantations, care needs to be taken such that the other crops do not get affected.

Agricultural robots possess great potential to deliver weed control technologies that are much more adaptable down even to the plant scale. They potentially could aid direct chemical or cultivation tools to directly target weed plants. Agricultural robots need to have these characteristics since they bring recent advances in artificial intelligence (AI) to bear on the control of weeds in crop fields. However, applying AI and robotics technology to weed control would have several challenges that may limit robotic weed control robustness, with the current state of technology.

Weed control requires techniques that are general and robust enough to be efficacious to control the weeds. Obvious challenges for the success of this prototype include informing the robot which plants need to be controlled and in determining the distinguishing features of the weed plants. To control weed plants, their growth requires to be retarded or stopped, without injuring the nearby crop plants. Implementing the control turns difficult when the weeds are found to be in close proximity to the crop plants.

Selective herbicide application systems display tremendous potential in reduction of the volume of chemicals applied (e.g. Lee et al., 1999), and also they by themselves should not be considered to be robotic. Instead they are to be considered as automated control systems which respond to perceived weeds in the field. They generally do not include much machine behavior layer technology to deal with situations that are not certain. However, more recently, selective spraying technology has been coupled with smaller, automatically guided vehicle technology with hardware and control technology to apply herbicide more precisely.

ecoRobotix (Fig. 6) is a spraying robot which is autonomously guided through crop rows using GPS and machine vision sensors. This robot detects weed plants, and later uses two spray nozzles on delta robot arms to position the two nozzles over weed plants and thereby selectively apply herbicide directly to detected weed plants

The ecoRobotix is designed as a four-wheeled robot that is propelled by two electric drive motors, with wheels designed such as to ride over off-road surfaces, such that it should run through any farmland with good ease. It posseses solar panels on top (380W) in order to generate a continuous source of power for the onboard battery, permitting it to run as long as there is even a silver of daylight (as per estimates it can work for 12 hours a day in most places), so there isn't a need to dock and recharge it at the end of the day. It weighs about 286 pounds, which enables it to be lighter than traditional tractors and farm vehicles, such as to minimize soil compaction even when exploring the fields on a regular basis.

An onboard camera, a GPS RTK, along with an array of sensors enable it to identify crops and chart its own course of travel, as well as detect the presence of weeds found among the crops. Once the presence of weed is recognized by it, two hands under the contraption lower themselves and apply a micro-dose of herbicide to their exact location, systematically targeting the detected weed without wastage of chemicals. According to the outfit, micro-dosing with herbicides instead of applying them indiscriminately will enable farms to use just a fraction of what they otherwise would, and thus making it 30 percent less expensive than standard treatments.

The ecoRobotix is estimated to cover about three hectares of surface area per day, although the exact coverage would depend on the concentration of weeds in the cropland, since it would move slower in areas where there's a high concentration of unwanted plants. Accordingly, the outfit recommends using the machine after a standard treatment (normally, you'll still do the usual treatment at least once), relying on the robot to destroy any wild plant that crops up after the initial weeding to avoid taking much long to traverse through a large farmland. If used in this way, it is estimated that a single robot can handle up to 12 hectares of land on its own, traversing by every inch of it at least once a week.

It could hold about 30 liters of herbicide on the integrated tank, which could be enough for a day of weeding, requiring to fill it up again only for the next day's rounds. The other features include, a maximum speed of 1.3 feet per second, a maximum crop height of 9.8 feet, and a companion app that one could use to control the robot remotely (iOS and Android).

Fig. 6 ecoRobotix Weeding Robot

The Australian Centre for Field Robotics' Ladybird robot is similar to the ecoRobotix robot, but used a six-axis robot arm (model UR5, Universal Robots, Odense, Denmark) for moving a spray nozzle end effector to the weed plants.

Ladybird robot (Fig. 7) by University of Sydney's Australian Centre for Field Robotics features a novel design covered with solar panels (left) and a selective spraying system in which the spray nozzle is moved close to weed plants by a six-axis robotic arm (right).

Fig. 7 Ladybird Weeding Robot

III.STUDY FINDINGS

Agricultural robots have already entered the farming sector and their varied applications with rapid technological advancements are bound to motivate farmers in the cultivation of phytomedicinal and phytonutrient plants.

Remote controlled drones moving in agricultural plantations would be a common sight soon. Agribots would help in the reduction of usage of pesticides which in turn would help, the environment from getting polluted due to harmful chemicals.

Agribots have proved to be handy in the agricultural sector as they speed up operations and save human labour. Hence, they have tremendous scope in the cultivation of these plants with maximum human activity. Robots in phytomedicinal and phytonutrient farming can reduce the dependency on human labor to a significant extent. The overall efficiency levels are bound to be improved considerably with approaches of holistic farming by leveraging emerging technologies like Artificial Intelligence (AI) and Machine Language (ML).

The agribots need a great deal of research and development to be continuously improved and updated. It involves R&D investments massively and also is not easily accessible for the small and marginal farmers. On the other hand, conventionally, phytomedicinal and phytonutrient farming has been a manual activity over the years, and getting used to agricultural robots will be a cultural and emotional change.

IV.CONCLUSION

Every new technological advancement in agriculture, be it from tractors to tillage techniques, has enabled farmers to plant and harvest much in less time. Today's era of agricultural innovation is smart farming using precision agriculture techniques that optimizes crop performance in farmers' fields based on their individual characteristics. To combat the range of challenges in phytomedicinal and phytonutrient farming, such as improving crop yields and plant resiliency, increasing pest resistance, addressing nutrient insufficiency, and more, scientific insights into the crop are needed resulting in the demand for continued R&D in smart farming.

Agribots serve as important tools in the cultivation of phytomedicinal and phytonutrient plants because they can quickly collect valuable data to help farmers fine-tune their methods of planting, irrigation, pest control, harvesting and more. Similarly, for scientific discovery that underlies crop improvement, robots make it possible to gather a wide range of information on very large numbers of planktons – tens to hundreds of acres – in order to break new ground in plant science. With robotics engineers and scientists who study plant genetics and biology, phytomedicinal and phytonutrient plantations can prove to be an ideal breeding ground for robotic agricultural technology.

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