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Precision Farming in Commercial Floriculture: A Review

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ABSTRACT: Precision agriculture encompasses a holistic approach aimed at maximizing production. By incorporating crucial components such as information, technology, and management, precision agriculture offers the potential to enhance production efficiency, elevate product quality, optimize plant chemical utilization, conserve energy, and safeguard the environment. Environmental, technical, labour, economic and marketing related constraints are some of the major obstacles in flourishing the floriculture industry in India. It is important to be prepared for technological innovations to modernize out dated farming methods and establish environment friendly crop production systems. Precision farming should be regarded as a research path rather than a final destination. This is one of the technology-oriented programmes and required great skill. Precision farming in commercial floriculture offers optimized resource management, data- driven decision making, automation and robotics. Despite its numerous benefits, it also comes with several challenges including culture and perception of users, limited access to technology, small operational holdings etc. At present much research is needed to integrate different technologies for precision farming in commercial floriculture in Indian farming situation.

Keywords: Precision Agriculture, Technology, Automation, Challenges, Commercial Floriculture.

INTRODUCTION

Floriculture is rapidly emerging as a significant enterprise on a global scale. It holds significant promise for generating profitable self-employment opportunities for small-scale and vulnerable farmers. Now a days, floriculture is lucrative profession with more returns per unit area than other agricultural or horticultural crops. In India, commercial floriculture has increased its credibility by diversification in agriculture and also evolved as a foreign exchange earner. India is second largest in the world in area under floriculture production next to China. As per the NHB (2018-19) database the area and production of floriculture in India was 303 thousand hectare and 2910 thousand million tons respectively with 2263 thousand million tons of loose flower and 647 thousand million tons of cut flower production. It comes only 0.6 per cent of the global flower production.

Environmental, technical, labour, economic and marketing related constraints are some of the major obstacles in flourishing the floriculture industry in India. It is important to be prepared for technological innovations to modernize outdated farming methods and establish environment friendly crop production systems. Smart farming concepts such as precision farming can be used wisely to achieve this goal (Kalmegh *et al.*, 2016).

Concept of precision farming. Precision farming involves the utilization of contemporary technologies to monitor and address variations within a farm, employing computational analysis of observations to inform farm management decisions (Mandal and Maity 2013). The idea revolves around delivering appropriate input, precisely when it is needed, in the appropriate amount, and in the suitable location. Precision farming automating and streamlining the process of collecting and analyzing information by employing essential components of information, technology, and management. Thereby increase productivity, enhance product quality, minimize reliance on agricultural chemicals, conserve energy and protect environment (Hakkim *et al.*, 2016). The level of management distinguishes precision farming from traditional farming. Instead of treating the entire field as a single unit, the management approach is customized to smaller areas within the field.

"Pierre Robert" is regarded as the father of Precision farming and initially Precision agriculture was also referred to as Site Specific Crop Management (SSCM). The agricultural production system is an integrated output of interaction between soil, water, nutrient, plant and atmosphere; hence all the individual components have to be monitored and the variabilities encountered have to be managed in order to optimize the system (Singh, 2022). The variability in an intensely cultivated field can be categorized as spatial, temporal and predictive variability.

Advantages of precision farming. Enhancing overall crop yield

— Improving operational efficiency

— Lowering production expenses

— Enhancing decision-making in agricultural management

— Minimizing environmental impact

— Accumulating farmers' knowledge for enhanced long-term management

According to Dwivedi *et al.* (2017) the basic steps in precision farming are,

(i) The initial and crucial step in precision farming is to evaluate the extent of variability. This involves measuring and quantifying the diverse factors and processes that influence crop growth and determining the specific combinations of these factors that contribute to spatial and temporal variations in crop yield.

(ii) Once variation is adequately assessed, site specific management recommendations are employed.

(iii) Economic, environmental and technology evaluation—

Tools and techniques

Modern technology enables precise farm management through the utilization of diverse technological tools (Tiwari, 2005) such as:

GPS (Global Positioning System): This system functions as a satellite-based navigation system enabling users to log their precise location, including latitude, longitude, and elevation on Earth. Ground receivers process radio signals emitted by the satellites to establish the geographic position on Earth. Its primary purpose is to assist farmers in accurately identifying field locations, allowing them to apply specific inputs such as seeds, fertilizers, and plant protection chemicals by considering performance criteria and past input applications as a basis.

GIS (Geographic Information System): The system consists of hardware, software, and methodologies developed to facilitate the gathering, storage, analysis and retrieval of data related to feature attributes and location, ultimately resulting in the creation of maps. GIS, a form of computerized mapping, offers multiple layers of information such as topography, soil types, drainage, irrigation, rate of chemical application and crop productivity. By integrating and manipulating these data layers, GIS enables the assessment of current and alternative management scenarios.

VRT (Variable Rate Technology): The utilization of this system enables the precise timing and quantity of delivery for farm inputs. By applying inputs in a site-specific manner, it leads to cost savings in inputs and labour, maximizes productivity, and mitigates the negative effects of excessive application.

Grid Soil Sampling: To intensify soil sampling, the field is divided into smaller grid units. Soil samples are collected from each grid and analyzed in the laboratory to determine the nutrient requirements for each sample. Based on these findings, a fertilizer application map is created for each grid. Utilizing a GPS receiver, the product delivery is controlled, allowing for adjustments in the amount and/or type of fertilizer product applied, in accordance with the application map.

Yield maps: Report card of field that provide information like variability in yield and yield production. Yield is stored on a computer along with the GPS coordinates and variability in yield is expressed using different colours. Each colour on map represents a range in yield.

Remote sensors: Remote sensing is the science of acquiring information and data about an object or area by analyzing measurements made at a distance from the object. It can be used for the estimation of crop area, classification of crops, assessing and monitoring of water resources, estimation of crop yield, measurement of crop canopy, incidence of pest and diseases *etc.*

Proximate sensors: The sensor operates in close proximity to, or in direct contact with, the soil being analyzed, enabling real-time assessment of soil properties at or beneath the soil surface, in specific locations (Rossel and Adamchuck 2013).

Computer hardware and software: In order to analyze the data gathered by other components of precision farming technology and present it in practical formats like graphs, maps, charts, or reports, computer support and dedicated software assistance are vital.

Internet of Things (IoT): IoT enables devices and systems to connect and share data with each other through the internet.

How to improve precision in farming?

Precise land preparation. Land levelling serves as a prerequisite for implementing effective agronomic, soil, and crop management practices. Laser-guided leveling equipment is one of the advanced techniques for precise land levelling. Using a guided laser beam it will level the field within certain degree of desired slope. Laser land leveller consist of a laser transmitter, laser receiver, control box, drag bucket and a hydraulic system. Laser transmitter transmit infrared beam of light and a receiver senses it and convert to an electrical signal. This will activate the hydraulic system for levelling. Laser levelling saves quantity of irrigation water, nutrients and agrochemicals. It also improves quality of environment and yield of crop (Jat *et al.*, 2006).

Precise space utilization. High density planting involves planting a greater number of plants of the same species within a given area by utilizing closer spacing compared to traditional planting methods.

Subiya *et al.* (2017) studied effect of three different planting densities *viz.*, 0.90 m × 0.90 m, 0.60 m × 0.60 m: double row and 0.60 m × 0.60 m triple row on yield and quality of rose. Result of the study showed that a trend of increase in the flower yield as the plant density increased. Bhattacharya *et al.* (2000), reported that high density planting gave superior results in terms of plant height, stem length, flowering, minimum days to first flowering, flowers per unit area and highest yield of flowers per hectare in rose *cv.* Gladiator.

Precise water management. Micro-irrigation is the system of irrigation in which water is applied frequently in and around the root zone of the plant. This system comprises network of pipes along with a suitable emitting device. This system facilitates the attainment of elevated water use efficiency, leading to improved crop yield(Patel, 2017).

Deshmukh (2012) studied the effect of tuberose *cv.* Suvasini underdrip, micro-sprinkler and surface irrigation systems. Micro-sprinkler system found to be the best and gave highest flower yield with better flower quality, than drip or surface method of irrigation. According to Panigrahi *et al.* (2011) irrigation scheduling is regarded as a crucial element to improve water use efficiency under any irrigation system in times of scarcity. Yield and quality of flowers depends on the quantity of irrigation water applied and optimum scheduling of irrigation (Naggar and Byari 2009).

Banik *et al*. (2018) conducted a field experiment on tuberose to examine the impact of three irrigation schedules (IW/CPE = 0.4,0.8, and 1.0) and three varieties (Arka Prajwal, Calcutta Single, and Calcutta Double) on tuberose yield, water usage, and economic outcomes in the Indo-Gangetic plains of West Bengal. The findings revealed that adopting a moderate deficit irrigation schedule of IW/CPE 0.8 for Calcutta Double or Calcutta Single resulted in optimal water utilization, higher yield, and maximum economic returns.

Precise fertilization. Higher yields and high-quality production require the right balance of water and nutrients. The way of fertilizer application has a big impact on how effectively nutrients are used. Through fertigation, crops receive precise and uniform supplies of water and nutrients, timed appropriately to meet their specific nutrient requirements. Fertigation not only enhances fertilizer use efficiency but also minimizes leaching losses (Mmolawa and Or 2000).

The scheduling of fertigation relies on various factors such as type of soil, existing NPK concentration, organic carbon content, soil pH, and soil moisture content at field capacity. To achieve efficient fertigation, it is crucial to implement crop and site-specific nutrient management practices, ensuring frequent nutrient delivery to meet the crop's requirements. Controlled irrigation methods are employed to reduce nutrient leaching, and the injection of nutrients can be tailored based on system design, soil type, and the farmer's preferences.

Methods of fertigation

1. Venturi injector: The system comprises three main components: a converging section, throat, and diverging section. As water flows through the narrow throat section, its velocity increases and pressure decreases, generating a suction effect. This suction effect allows liquid fertilizer from the fertilizer tank to enter the drip system through a tube.

2. Fertilizer tank method: It is also known as By-pass system. This technique involves utilizing a tank where the fertilizer solution is stored. Within this system, a portion of the irrigation water is redirected from the main line to pass through the tank, where the fertilizer in a fluid or soluble solid form is present. This process leads to dilution of the fertilizer and the subsequent flow of the diluted fertilizer into the irrigation stream.

3. Fertilizer injection pump: This approach involves utilizing a pump to extract the fertilizer stock solution from a storage tank and inject it with pressure into the irrigation system.

By implementing the practice of paired row planting on raised beds, along with drip fertigation using Nitrogen (200 Kg/ha) and Potassium(100 Kg/ha) in 10 equal splits at 7-day intervals starting from 30 days after transplanting, gladiolus farmers can achieve optimal yield. This approach offers higher crop yield, increased net profit, and a 24% reduction in water usage compared to conventional irrigation methods (Patel, 2017).

In their study, Divya *et al*. (2018) conducted an experiment to examine the impact of different levels of fertigation on the flowering and shelf life of marigold (*Tagetes erecta* L.) *cv*. PusaNarangiGainda. The treatments included seven levels of fertigation, combining water-soluble and straight fertilizers. The results indicated that fertigation with 75% of the recommended dose of fertilizers (90 N:90 P:75 K Kg/ha) using water-soluble fertilizers yielded the most optimal results in terms of increased flower yield and extended shelf life for marigold flowers cultivated under Telangana conditions.

Surface covered cultivation. Mulching is the practice of covering the soil to make more favourable condition for plant growth, development and efficient crop production. Mulching may reduce the irrigation requirement and also check weed growth and improve fertilizer use efficiency.

Sanas *et al.* (2018) conducted a study to examine the impact of mulch, Nitrogen (N) and Potassium (K) application, as well as their interaction, on the growth characteristics, yield, and yield attributes of annual chrysanthemum (*Chrysanthemum coronarium* L.). The experiment involved three types of mulches, namely crop residue mulch, silver plastic mulch, and black plastic mulch. Among these, black plastic mulch exhibited the highest values in terms of plant height, number of branches per plant, plant spread, number of flowers per plant, number of seeds per flower head, flower diameter, seed yield per plant, and seed yield per plot.

Nutrient monitoring. Precision nutrient management practices like leaf colour chart, chlorophyll meters and optical sensors providing guidance in deciding need-based nutrient applications and thus improvement of nutrient use efficiencies for achievement of high yield levels in various crops. Geo-spatial technologies such as GIS, GPS, RS, VRT etc. can be utilized to ensure need-based nutrient management in crop fields.

Arifin *et al.* (2021) developed a leaf colour sensor for measuring nutritional need of chrysanthemum. The hardware components of the device include a camera sensor box frame, a raspberry pi controller, and a raspberry HDMI LCD for display. The device utilizes image data captured by the Pi camera to analyze leaf colour intensity. Leaf colour levels are assessed by performing histogram processing on the raspberry pi device. The obtained results from image processing are then compared with a standard leaf colour chart to obtain precise readings.

Precise environment. Quality produce with quantity was only made feasible by giving the crop an ideal climate that would allow it to reach its full potential. This requirement leads to the cultivation of plants under protected environmental conditions. Crops such as roses, gerberas, carnations, lilies etc. can be effectively grown through protected cultivation by modifying the microclimate around the plants, either partially or fully, to meet their specific growth needs.

Table 1: Precise cultivation of rose, gerbera and carnation under protected environment (Zambre, 2011; Kaur and Dubey 2019).

Crop	Rose	Gerbera	Carnation
Life cycle (years)	6.5-7	2.5-3	2-2.5
Planting time	Oct-Dec	Oct-Dec	Sept-Oct
Day (°C)	24-28	20-24	16-20
Night (°C)	18.5-20	18-21	10-12
Humidity (%)	65-70	60-65	60-65
Light Intensity (Lux)	60000- 70000	40000- 50000	40000- 50000
CO_2 conc. (ppm)	800-1000	800-1000	800-1000
Water requisite in lit/day/sqm	5-7	4-6	4-6
Fertilizer dose in mmol/L	4:0.15:1.5	4:0.15:1.5	4:0.15:1.5
Varieties	Bordeaux, First Red, Mercedez, Konfetti, Noblesse, Grand Galla, Ravel Vivaldi, Top secret, Gold Strike, Golden Gates	Natasha, Grizzly, Alcatraz, Havana, Julia, Faith, Dakota, Basic	Tanga, Laurella, Sonsara Dakar, Cherrybag, Solar, Fantasia, Master, Picaro, Sintonia, Macarena, Raggio di Sole, Ondelia,
Yield (flowers /sqm per year)	100-150: HT 200 and 250-350: Medium and small flowered varieties	175 - 200	300-400

Jadhav *et al.* (2020) reported that polyhouse cultivation of tuberose has superior quality for all characters for all genotypes compared to open field cultivation. Similar findings were reported by Patil *et al.* (2021) in rose *cv.* Gladiator.

As the population grows, the amount of land required for cultivation decreases. To overcome this requirement the method of hydroponics and aeroponics can be adopted. Ai *et al.* (2021) compared chrysanthemum flowers grown under hydroponics and soil-based system. The result of the study showed that no. of flowers per plant and dry weight of flowers per plant is higher in hydroponic system than soil-based system.

Fascella and Zizzo (2007), compared plants of anthurium *cv.* Tropical under two growing conditions, one is aeroponics and other soil less cultivation using LECA pebbles. Two cultivation systems resulted in comparable numbers of flower stalks for the plants, while aeroponically cultured anthurium produced longest flower stalks, as well as the maximum number of leaves with longest leaf and petiole. Anthuriums grown without soil produced flowers with the broadest spathe.

Precise crop protection. If crop pest and diseases not timely and properly identified it will result into significant yield reduction. In order to achieve efficient, energy-saving, and precise disease management, it is crucial to have early and accurate detection of symptoms on a large scale.

Optical sensors, such as hyperspectral techniques, fluorescence imaging, and thermography have the capability to promptly and accurately detect biotic and abiotic stresses, as well as pathogenic diseases in crops. Traversari *et al.* (2021) employed digital technologies in precision agriculture to achieve sustainable management of fungal diseases in ornamental plants.

Hyper spectral imaging technique measures the changes in reflectance that are experienced upon infection of pest and diseases. By collecting data in three dimensions, this approach enables the acquisition of more precise and comprehensive information regarding plant health. To monitor extensive field areas, sensors are commonly installed on unmanned aerial vehicles (UAVs). Hyperspectral sensors are particularly useful for early detection of pests and diseases, enabling farmers to swiftly and timely protect their crops.

Thermography sensors captures infrared radiation emitted from the plant surface. When a plant is infected with a pathogen, the transpiration reduction leads to an increase in the plant surface temperature. Based on the differences in surface temperature of the plant leaves and canopy, sensor can analyze the presence of pest and disease. High sensitivity of sensor to the change in environmental condition will limits its precise control over pest and disease. Another problem is that type of infection cannot be determined using thermographic sensors.

Precise harvesting. The stage, method, and timing of harvest significantly impact the post-harvest quality of cut flowers. Most cut flowers are best harvested during the early morning or late afternoon. The maturity indices for harvesting vary depending on the specific flower type. For example, roses are typically harvested at the tight bud stage when the color is fully developed and the petals have not yet started to unfold. Standard carnations, intended for long-distance markets, are harvested at the paint brush stage. The optimal picking maturity of flowers for commercial purposes is influenced by factors such as season, environment, distance to the market, and specific consumer requirements.

The introduction of robots in agriculture can contribute to sustainability and consistency in agricultural tasks while also reducing costs. Abarna and Selvakumar (2015) designed a rose flower harvesting robot and aimed to meet the requirements for the automatic harvesting. The mature flower is detected and harvested successfully.

Counting is an important step in yield estimation of flowers so that it should be accurate and precise. Sundar and Bagyamani (2015), an image processing technique have been applied to count the flowers in an image precisely thereby estimate the yield.

Precise post-harvest handling. Standardization of suitable post-harvest technology is important area to maintain the post-harvest life of cut flowers.

Precooling is done immediately after harvest to remove field heat from the produce. It can be done either by room cooling or forced cooling. Temperature for precooling is different for different flowers. Pulsing is a method used to prolong the shelf life of flowers. It involves immersing freshly harvested flowers in a specifically designed solution for a relatively short time, ranging from a few seconds to a few hours. The main ingredient of various pulsing solutions is sucrose, which serve as respiratory substrate. Apart from sugars, pulsing is done with $AgNO_3$, $CaCl_2$, $CaNO_3$, STS *etc.* Important biocides used for treating cut flowers are 8-hydroxy quinoline citrate (200-600 ppm), aluminum sulphate (100-300 ppm), citric acid (50-1000 ppm), slow-release chlorine compounds and ammonium compounds (50-200 ppm).

Elgimabi (2011) conducted a study on enhancement of shelf life of cut roses (*Rosa hybrida*) through the use of silver nitrate and sucrose pulsing. The findings revealed that all treatments involving $AgNO_3$ led to a prolongation of the flower's vase life. The most effective concentration was determined to be 30 ppm, and even better results were obtained when $AgNO_3$ was combined with a 3% sucrose solution. This combination resulted in the longest vase life compared to other treatments.

In general storage can be done in the following methods; Refrigerated storage (wet/dry storage), Controlled atmosphere storage, Modified atmospheric storage and Hypobaric or Low-pressure storage.

Guadalupe and Mayanin (2015) conducted a study on the utilization of modified atmosphere packaging technology (MAP) to enhance the shelf life of cut spikes of gladiolus. The mixture consisting of 70% N2, 15% CO_2, and 15% O_2 resulted in the highest number of open flowers during the vase life of cut gladiolus flowers stored in modified atmosphere packaging (MAP). The cut gladiolus flowers maintained a vase life of 6 days under these conditions.

The choice of packing method is determined by factors such as the crop type, flower variety, mode of transportation, and target market. The primary objective of packing is to ensure the longevity and quality of the flowers by reducing transpiration rates and minimizing cell division during transportation and storage.

Karthikeyan and Jawaharlal (2013) conducted an experiment aimed at establishing standardized wrapping and packaging techniques to improve the post-harvest lifespan of carnation flowers. Wrapping materials used were polyethylene sleeves of 50-gauge thickness, butter paper, newspaper and packed in Corrugated Fiber Board Boxes (CFBB) with different percentage of ventilations (2, 4, 6 %). Result of the study showed that wrapping in polyethylene sleeves of 50-gauge thicknesses and placing in CFB boxes having 4 % ventilation is the best packaging method for transporting carnation flowers to distance market. When compared to the control (newspaper wrapping and CFB boxes with 2% ventilation), this packaging would ensure minimum physical damage, physiological loss in weight and membrane integrity and would extend the vase life to 11.67 days.

Marketing. The floriculture industry is inherently spatial, involving the cultivation of flowers and their subsequent distribution. The implementation of spatial tools can effectively address the various logistical challenges faced by the industry. Therefore, a GIS-based system is highly desirable for efficiently managing the flower supply chain, encompassing producers, distributors, and ultimately florists and consumers.

Precision Farming Development Centres (PFDCs). The Precision Farming Development Centres (PFDCs) in India have the objective of promoting "Precision Farming & Plasticulture Applications for high-tech horticulture". They function as central hubs for advancing plasticulture and precision farming practices within their respective states.

Mandates

— Conduct trials and experiments to evaluate the effectiveness of plasticulture applications.

— Offer technical expertise to state governments in order to demonstrate established plasticulture technologies at farmers' fields.

— Facilitate technology transfer to disseminate proven methods.

— Develop literature, including package of practices and extension materials, on plasticulture applications and precision farming practices.

— Establish a display center to showcase plasticulture technologies.

— Conduct surveys of end users to assess the impact of the technologies and gather feedback.

Challenges. Precision agriculture is progressing slowly compared to the expected pace. There are many challenges to adoption of precision farming in developing countries (Shanwad *et al.*, 2004).

- Users' cultural backgrounds and perceptions.
- Limited land size for small-scale farming.
- Variability in cropping systems and market challenges.
- Constraints related to land ownership, infrastructure, and institutions.
- Lack of adequate technical expertise.

- Knowledge gaps and technical limitations.
- Availability, quality and cost of data.
- Mounting of e-waste
- Increased energy consumption
- Loss of internet connectivity

CONCLUSIONS

Precision farming involves the strategic implementation of appropriate actions in specific locations and at optimal timings. This approach aims to enhance production efficiency, elevate product quality, optimize the utilization of crop chemicals, conserve energy, and safeguard the environment through the utilization of advanced technologies. This is one of the technology-oriented programmes and required great skill. At present much research is needed to integrate different technologies for precision farming in commercial floriculture in Indian farming situation.

FUTURE SCOPE

— Development of precision farming packages specific to commercial flowers
— Precision Agriculture Service Providers/Start Ups plays a crucial role in supporting farmers
— Machine learning applications enables more accurate predictions and decision-making for crop management

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