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Good Agricultural Practices: A Pathway to Safe, Sustainable and Profitable Farming

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Abstract: -

Good Agricultural Practices (GAP) are a set of principles, regulations and technical recommendations applied to on-farm production and post-production processes to deliver safe, healthy and quality food and non-food products while sustaining the natural resource base and the livelihoods of farmers and workers. As consumers, retailers and importing countries demand traceable, residue-free produce, and as climate change, soil degradation and water scarcity tighten the limits of production, GAP has moved from a voluntary quality label to an essential framework for competitive and responsible agriculture. This article reviews the concept and evolution of GAP, its core components from site selection to post-harvest handling, its status in India, its benefits and constraints, and future prospects including digital traceability, climate-smart integration and group certification for smallholders.

Keywords: *good agricultural practices, food safety, sustainable intensification, INDGAP, traceability, integrated pest management, smallholders etc.*

1. Introduction:

Agriculture is expected to feed a global population approaching 9.7 billion by 2050, and this must be achieved with less land per person, less water, fewer chemical inputs and a more variable climate. At the same time, the food system faces a quality challenge that is as important as the quantity challenge. The World Health Organization has estimated that unsafe food causes about 600 million cases of foodborne illness and some 420,000 deaths every year worldwide (WHO, 2015), and the FAO estimates that around 14% of food

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produced is lost between harvest and retail (FAO, 2019). A large share of these problems originates not in the kitchen or the market but on the farm, through contaminated water, improper manure use, misuse of pesticides, unhygienic harvesting and poor storage.

Good Agricultural Practices address these risks at their source. The FAO describes GAP as practices that address environmental, economic and social sustainability for on-farm processes and result in safe and quality food and non-food agricultural products (FAO, 2003). In essence, GAP translates the principles of sustainable agriculture into practical, verifiable actions that a farmer can adopt on a given field and crop. This article presents an overview of GAP with emphasis on the Indian context, where small and marginal holdings, which account for more than 85% of operational holdings, make the adoption of such systems both essential and challenging.

2. Concept and Evolution of GAP

The modern GAP movement began in the late 1990s, when a group of European retailers developed a common protocol known as EUREPGAP (1997) to harmonise food-safety and production standards among their suppliers. It was renamed GLOBALG.A.P. in 2007 as it expanded beyond Europe. In parallel, FAO introduced a policy-level framework for GAP in 2003, emphasising that standards should be inclusive of developing-country farmers rather than becoming a trade barrier. National schemes, such as ChileGAP, ThaiGAP, MalaysiaGAP and India's INDGAP, have since been developed and, in many cases, benchmarked against GLOBALG.A.P. for international recognition.

GAP is built on four pillars:

Table 1. Major GAP-related standards and schemes

Scheme	Origin / owner	Main focus
GLOBALG.A.P.	Private, international (1997)	Food safety, environment, worker welfare, traceability; widely used for export of fruits and vegetables
FAO GAP framework	FAO (2003)	Policy framework to guide national and regional GAP codes, inclusive of smallholders
INDGAP	Quality Council of India, India	National certification for crops, with scope for group certification of small farmers
Codex Alimentarius codes	FAO/WHO	Hygienic practice for fresh produce, pesticide residue limits (MRLs)
Participatory Guarantee System	Ministry of Agriculture, India	Peer-based assurance, mainly for organic produce sold on domestic markets

Note: Scheme details should be verified against the latest official documents before use in a formal manuscript.

(i) economically viable and efficient food production; (ii) sustainable management of natural resources; (iii) social sustainability, including worker health, safety and welfare; and (iv) the production of safe and nutritious food that meets market and regulatory requirements. Unlike organic farming, which prohibits specific inputs, GAP is not input-prohibitive. It encourages the *right* input, at the *right* dose, at the *right* time and with proper records, which makes it particularly suitable as an entry-level system for conventional farmers.

3. Core Components of Good Agricultural Practices

3.1 Site selection and soil management

GAP begins before sowing. The site history must be assessed for risks such as previous industrial use, heavy-metal contamination, flooding, or proximity to livestock operations and waste dumps. Soil testing should guide crop choice and nutrient planning. Practices such as crop rotation with legumes, addition of organic matter, conservation tillage, residue retention and contour or bund-based erosion control protect the soil as a long-term asset. Soil fertility records, including test results and amendments applied, form the first pages of the farm logbook.

3.2 Seed and planting material

Quality seed accounts for a major share of yield potential. GAP requires the use of certified, disease-free seed or planting material of adapted varieties, with records of source, variety, lot number and any seed treatment. Seed treatment with fungicides or biological agents, and *Rhizobium* culture in the case of pulses such as greengram (*Vigna radiata*), lowers early disease pressure and nitrogen cost. Where genetically modified material is used, it must be legally approved and traceable.

3.3 Water management

Agriculture withdraws roughly 70% of global freshwater, and irrigation water is also a major route for microbial and chemical contamination of fresh produce. GAP therefore requires periodic testing of irrigation water for microbial and chemical quality, protection of water sources from sewage and animal waste, and use of efficient methods such as drip, sprinkler and alternate wetting and drying in rice. Irrigation scheduling based on crop stage and soil moisture, rather than on habit, saves water, energy and nutrient losses, and is an important element of climate adaptation.

3.4 Nutrient management

Over- and mis-application of fertilizers is both uneconomical and polluting. Nitrogen use efficiency in many Indian cereal systems is reported to be below 40%, with the remainder lost to the environment as nitrate, ammonia or

nitrous oxide. GAP advocates balanced and site-specific nutrient management based on soil tests, the 4R principle (right source, right rate, right time, right place), integration of organic manures and biofertilizers, and calibration of application equipment. Raw or inadequately composted manure should not be applied close to harvest of produce eaten fresh, because of pathogen risk from *E. coli* and *Salmonella*.

3.5 Crop protection and integrated pest and weed management

Crop protection is the area in which GAP has the largest effect on consumer safety. Integrated pest management (IPM) combines resistant varieties, cultural practices, monitoring, biological control and need-based use of chemicals. Integrated weed management follows the same logic, combining crop rotation, competitive cultivars, stale seedbed, mulching, timely mechanical or manual weeding and judicious herbicide use with rotation of modes of action to delay resistance. In short-duration crops such as greengram, the critical period of weed competition generally lies within the first three to four weeks after sowing, so timing of weed control is more important than the number of operations.

Where pesticides are necessary, GAP requires that only products registered for the crop be used, at the label dose, with calibrated sprayers, and with strict observance of the pre-harvest interval (PHI), so that residues at harvest remain below the maximum residue limits (MRLs) set by the Food Safety and Standards Authority of India (FSSAI) and by importing countries. Spray records, safe storage and triple rinsing and disposal of containers are mandatory components. The health stakes are considerable: a global review estimated about 385 million cases of unintentional acute pesticide poisoning among farmworkers each year (Boedeker et al., 2020).

3.6 Harvest and post-harvest handling

Harvesting at the right maturity, with clean tools and containers, avoids both quality loss and contamination. Produce should not touch the soil, should be shaded and cooled quickly, and should be graded and packed in a clean area. Post-harvest losses in fruits and vegetables in India have been estimated in the range of 5-16% in different studies, and cold chain gaps, poor packaging and rough handling are principal causes. For grains and pulses, drying to safe moisture, hermetic storage and pest management prevent insect damage and mycotoxin contamination such as aflatoxin.

3.7 Worker health, safety and welfare

GAP treats farm workers as stakeholders rather than inputs. It requires training in hygiene and in the safe handling of agrochemicals, access to clean drinking water

and sanitation, protective equipment, first-aid facilities, written procedures for accidents, and compliance with child-labour and minimum-wage laws. Women, who contribute a large share of agricultural labour in India, often handle sowing, weeding and harvesting, and should be specifically included in training and in protective measures.

3.8 Records, traceability and farm management

A GAP-certified farm can answer the question: *what was applied, where, when, by whom and why?* Field-wise records of seed, inputs, irrigation, pest incidence, harvest dates and sales allow any quality problem to be traced back to the plot and corrected. Internal audits, a documented complaint procedure and periodic review of risks complete the management system. In the experience of many farmers, record keeping is the most difficult habit to establish and, simultaneously, the one that produces the greatest long-term benefit in cost control.

4. GAP in the Indian Context

India is the world's largest producer of pulses, milk and spices and the second largest producer of rice, wheat, fruits and vegetables, yet its share in high-value global trade remains small compared with its production potential. A frequently cited reason is non-compliance with quality and safety standards, particularly pesticide residues, microbial contamination and traceability, which has led to rejection or alerts for consignments in major import markets. GAP is therefore a direct tool for improving export competitiveness and for

Table 2. Summary of GAP components, key actions and risks addressed

Component	Key actions	Risk addressed
Site and soil	Site history, soil testing, rotation, organic matter, erosion control	Contamination, fertility decline
Seed	Certified seed, treatment, lot records	Seed-borne disease, poor stand
Water	Water testing, efficient irrigation, source protection	Pathogens, scarcity
Nutrients	Soil-test-based, 4R, composted manure, calibration	Nutrient loss, pathogens
Crop protection	IPM, registered products, label dose, PHI, spray records	Residues, resistance, poisoning
Harvest and storage	Right maturity, clean handling, cooling, safe moisture	Spoilage, mycotoxins, losses
Workers	Training, protective equipment, sanitation, welfare	Injury, poisoning, exploitation
Records	Field logbook, traceability, internal audit	Unaccountability, recalls

protecting domestic consumers.

The Quality Council of India developed INDGAP as a national certification scheme with provisions for individual and group certification, and APEDA has promoted traceability systems for export crops such as grapes, pomegranate and vegetables. Related initiatives that support GAP objectives include the Soil Health Card scheme, the Paramparagat Krishi Vikas Yojana, the National Mission on Sustainable Agriculture, micro-irrigation support under PMKSY, the Insecticides Act, 1968, and FSSAI regulations on contaminants and residues. Agricultural universities, Krishi Vigyan Kendras and farmer producer organisations (FPOs) are the natural delivery channels for training. The framework exists; what is needed is convergence of these programmes at the farm level.

5. Implementing GAP on a Farm: A Stepwise Approach

Adoption is easiest when it is treated as a progressive process and not as a one-time audit. A practical sequence that has worked in extension programmes is described below.

- **Baseline assessment:** map the farm, identify hazards (water source, manure storage, chemical store, nearby contamination) and record current practices.
- **Training:** train the farmer and workers in hygiene, safe pesticide use, IPM and record keeping, preferably through demonstrations in the local language.

Table 3. Indicative GAP calendar for summer greengram

Stage	Good practice	Record to keep
Pre-sowing	Soil test; residue management after wheat; selection of a certified, disease-tolerant variety	Soil report, seed source and lot number
Sowing	Seed treatment with fungicide and Rhizobium culture; recommended seed rate and spacing; line sowing	Date, seed rate, treatment details
Early growth (0-30 DAS)	First irrigation at the right stage; weed control within the critical period	Weeding dates, method, herbicide dose if used
Vegetative to flowering	Need-based irrigation; scouting for yellow mosaic vector (whitefly) and other pests; IPM first	Scouting results, any spray product and PHI
Pod filling to harvest	Harvest at physiological maturity in two or three pickings; avoid late irrigation	Harvest dates, yield, moisture
Post-harvest	Sun-dry to safe moisture; clean bags; hermetic storage; grading	Storage conditions, treatment, buyer details

- **Corrective action:** fix priority gaps first, such as a lockable chemical store, a clean handwashing point, calibrated sprayers and a protected water source.
- **Documentation:** start a simple field logbook for inputs, operations, irrigation, harvest and sales from the first day of the season.
- **Internal review and verification:** check the records against the standard, correct deviations, and then approach a certification body for individual or group audit.

5.1 Illustration: GAP calendar for summer greengram

Crop-specific protocols make GAP easier to follow. Table 3 illustrates how the general components translate into a field calendar for greengram, a short-duration legume of particular value for soil fertility and farm income in the rice-wheat belt. The recommendations are indicative and must be adapted to the variety, soil and region.

6. Benefits of Adopting GAP

The benefits of GAP can be grouped into four categories.

- Economic: reduced input cost through efficient use of seed, fertilizer, water and pesticides; improved yield stability; access to premium and export markets; fewer rejections and lower post-harvest losses.
- Environmental: conservation of soil and water, reduced greenhouse gas emissions per unit of output, protection of pollinators and natural enemies, and lower contamination of ground and surface water.
- Social: safer workplaces, better health for farm families, greater inclusion of women and youth through training and group certification.
- Food safety and consumer trust: lower residues and microbial hazards, traceability, and a stronger relationship between producer and buyer.

Studies from different countries report that farmers who adopt GAP generally achieve higher net returns and lower pesticide expenditure, although the magnitude varies by crop, region and the cost of certification. The most consistent finding is that the benefits are greatest when GAP is linked to a market that pays for compliance, which underlines the need for supportive procurement and branding.

7. Constraints and Challenges

Despite its advantages, adoption in India remains limited. The principal constraints are summarised below along with possible strategies.

8. Future Prospects

8.1 Digital traceability and precision tools

Mobile applications, QR codes, blockchain-based records, remote sensing and

Table 4. Major constraints to GAP adoption and possible strategies		
Constraint	**Description**	**Strategy**
Small, fragmented holdings	Individual certification is costly relative to farm size	Group certification through FPOs and cooperatives
Low awareness and skills	Limited knowledge of residues, hygiene and records	KVK and university training; demonstrations in local language
Certification cost	Audit and testing fees; infrastructure upgrades	Subsidy support, shared testing labs, public-private partnerships
Market linkage	No price premium in domestic mandis	Contract farming, branding, institutional procurement
Input quality	Spurious pesticides and uncertified seed	Stricter enforcement and farmer-friendly verification apps
Record keeping	Low literacy, time burden	Mobile-based, voice-enabled farm logbooks

low-cost sensors can reduce the burden of record keeping and make verification cheaper and more transparent. Satellite imagery and drone-based monitoring can support site-specific nutrient and pest management, and decision-support tools can deliver advisories in local languages. A consumer who can scan a code on a pack and see the farm, dates and practices is the strongest incentive a farmer can have for compliance.

8.2 Integration with climate-smart and regenerative agriculture

GAP is being increasingly aligned with climate-smart agriculture, soil carbon enhancement and regenerative practices. Conservation agriculture, legume-based diversification, efficient irrigation and residue management lower emissions and increase resilience, while keeping the system verifiable. In the future, GAP records may support carbon credit and payment-for-ecosystem-services schemes, which would convert good practice into an additional income stream.

8.3 Protected cultivation and controlled-environment agriculture

Polyhouses, net houses and hydroponic and vertical systems offer tight control of water, nutrients and pests and are naturally compatible with GAP, since they permit hygienic production and precise records. Artificial intelligence and automation will further improve climate control and early detection of pests and diseases. Such systems complement open-field GAP, particularly for high-value vegetables, flowers and nursery plants.

8.4 Group certification, FPOs and inclusive standards

The future of GAP in India depends on whether smallholders can participate. Group certification with an internal control system, supported by FPOs, can spread costs and responsibilities. Simplified, modular standards, in which farmers progress step by step from basic hygiene and record keeping to full certification, can bring more farmers into the system without lowering safety standards.

8.5 Research and policy priorities

Priority research areas include region- and crop-specific GAP protocols; low-cost residue and pathogen testing; biopesticides and biological control; socio-economic studies of adoption and returns; and the development of open national databases for traceability. Policy support should include extension reform, subsidised first-time certification for smallholders, strict regulation of input quality, and public procurement that rewards certified produce.

9. Conclusion

Good Agricultural Practices offer a practical and scalable route to reconcile productivity, safety, profitability and sustainability. By addressing hazards at the farm level, from soil and water to harvest, storage and worker welfare, GAP protects the consumer, the farmer and the environment at the same time. India has the policy instruments, institutional network and scientific capacity to make GAP mainstream, but success will depend on reaching the small farmer through training, group certification, affordable technology and markets that reward quality. For agricultural scientists and extension workers, the task is clear: to make good practice the easiest, most profitable and most natural choice for every farmer.

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