ISSN 0258-7122 (Print), 2408-8293 (Online)
Bangladesh J. Agril. Res. 50(3): 283-297, September 2025

GOOD AGRICULTURAL PRACTICES FOR BOTTLE GOURD: ADVANCING FOOD SAFETY IN BANGLADESH

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Abstract

Good Agricultural Practices (GAP) is designed to enhance the safety, quality and sustainability of agricultural products by covering areas such as soil management, water use, pest control and post-harvest handling. A GAP validation trial for bottle gourd (*Lagenaria siceraria*) was conducted at the Basna village, Dhamrai, Dhaka during summer season of 2024 with the variety 'BARI Lau-4'. The study aimed to assess the effectiveness of GAP in improving yield and quality. The trial involved meticulous site selection, land preparation, seedling management, and fertilizer application. Recommended practices including balanced fertilization, efficient irrigation, and disease management were implemented. Despite challenges such as drought, gummy stem blight, and high labour costs, the trial achieved a yield of 35 MT per hectare, surpassing the national average of 13.7 MT per hectare, and the benefit-cost ratio (BCR) was calculated as 1.93. Training sessions were conducted to equip farmers with GAP knowledge, resulting in enhanced productivity and higher profitability. The GAP-produced bottle gourd met international quality standards, creating strong export opportunities. Recommendations include adopting drought-resistant practices, improving farmer engagement, and involving the Hortex Foundation and Department of Agricultural Marketing (DAM) for better market access. Future efforts should focus on addressing challenges and leveraging export potential to strengthen both local and international market presence.

Keywords: Bottle gourd, GAP, Food safety, Sustainability and MRL test.

Introduction

Good Agricultural Practices (GAP) represent a comprehensive set of guidelines designed to promote the production of safe, high-quality, and environmentally sustainable agricultural products (FAO, 2003). These practices cover various aspects of farming, including soil management, water use efficiency, pest and disease control, and post-harvest handling (FAO, 2016). By implementing GAP, farmers can enhance productivity, reduce negative environmental impacts, and meet both local and international market standards (FAO, 2003). The adoption of GAP is critical for improving crop yields, ensuring food safety, and supporting sustainable agricultural development (World Bank, 2007).

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Bottle gourd (*Lagenaria siceraria* (Molina) Standl.), also known as white-flowered gourd or calabash, is a diploid species (2n = 2x = 22) belonging to Cucurbitaceae family (Beevy and Kuriachan, 1996; Morimoto *et al.*, 2005). The bottle gourd variety under study, BARI Lau-4, is specifically adapted for summer cultivation in Bangladesh. With its ability to thrive in the summer climatic conditions of Dhamrai, Dhaka, where it has been extensively validated, this variety represents a significant advancement in local vegetable production.

In Bangladesh, bottle gourd is a crucial vegetable crop cultivated across various regions. According to the Bangladesh Bureau of Statistics (BBS, 2023), bottle gourd production totalled 283918 MT from an area of 20710 hectares with a national average yield of 13.7 MT per hectare. Dhamrai, a prominent area in Dhaka Division, is known for its vegetable production, including bottle gourd. This crop contributes significantly to the local economy and food security. The cultivation of bottle gourd in Dhamrai supports many farmers and plays a vital role in the local vegetable market.

Beyond local consumption, bottle gourd has export potential due to its popularity in international markets. With increasing global demand for diverse and nutritious vegetables, bottle gourd offers opportunities for export growth and can contribute to solving problems related to micronutrient malnutrition (Nesamvuni *et al*., 2001; Flyman and Afolayan, 2006; Modi *et al*., 2006; Odhav *et al*., 2007; Schonfeldt and Pretorius, 2011). Properly managed production practices can enhance the quality of the produce, meeting international standards and expanding market access. Exploring export opportunities can provide additional income for farmers and contribute to the agricultural economy.

Although bottle gourd, represents a smaller fraction of the total vegetable production compared to other major crops, its contribution to crop diversity, dietary value, and local economies is substantial. By comparing bottle gourd production with overall vegetable production, it becomes evident that while it may not dominate in volume, its economic and nutritional importance remain significant. Improving production practices through GAP can enhance its competitiveness and contribute to a more balanced and resilient agricultural sector.

The GAP validation trial for bottle gourd conducted in Dhamrai, Dhaka, Bangladesh, was designed to assess and validate the effectiveness of Bangladesh GAP protocols specific to this region. This trial aimed to enhance the productivity, quality and sustainability of bottle gourd production. By evaluating the impact of GAP on local farming practices, the study sought to provide practical recommendations for farmers, improve crop management strategies and contribute to sustainable agricultural practices in the region.

Site selection and justification: The GAP validation trial of bottle gourd was conducted in the village of Basna, Dhamrai Upazila, Dhaka, Bangladesh, with the participation of two local farmers, Babul Hossain and Azmin Akter. This region was selected due to its favourable climatic conditions, which align well with the requirements of the BARI Lau-4 variety. Dhamrai is renowned for its optimal growing conditions for bottle gourd, including temperature, soil type, and water availability, as in AEZ 8 (Young Brahmaputra Jamuna Floodplain).

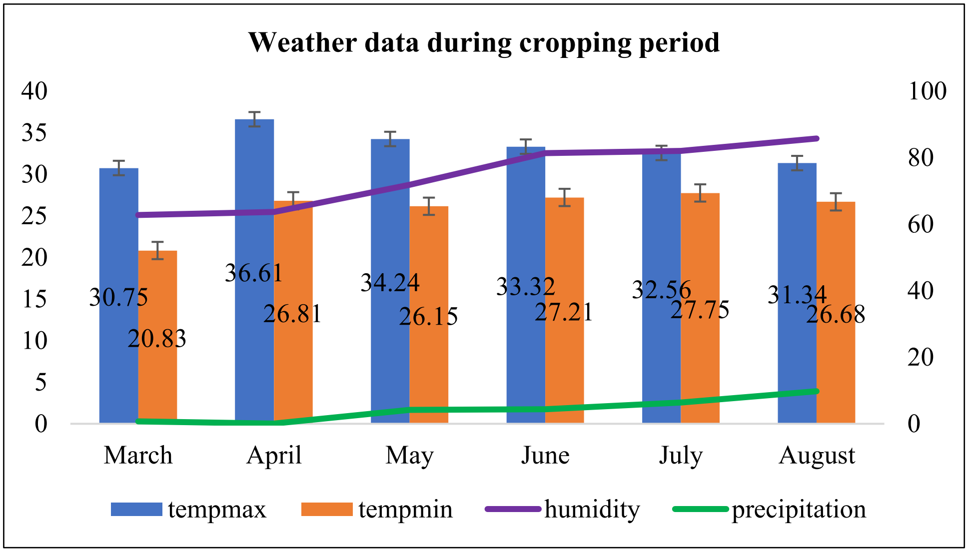

Fig. 1. Weather data during the cropping period at Dhamrai, Dhaka from March to August, 2024.

The precise location of the trial site at 23.9459171^{0}N Latitude and 90.1300177^{0}E Longitude. The region's climate is characterized by summer temperatures ranging from 20.83-36.61°C. Additionally, Dhamrai's soil quality and local farming expertise provide a supportive environment for validating and demonstrating the effectiveness of GAP in enhancing yield and quality.

Plate 1. Site selection at Dhamrai, Dhaka.

Land preparation: The land was cleared of previous crop residues, weeds, and debris. The soil was then ploughed and harrowed four times on 10 March 2024 in Azmin Akter's land and 12 April 2024 in Babul Hossain's land until a fine tilth was achieved, ensuring good seed-to-soil contact and optimal root development.

Plate 2. Field layout for bottle gourd.

Azmin Akter and Babul Hossain cultivated bottle gourd in 40 decimal (0.162 ha) and 50 decimal (0.202 ha) plots, respectively. Soil samples were collected and tested for pH, nutrient levels, and organic matter content. Based on the results, appropriate soil amendments were applied to correct nutrient deficiencies in accordance with *FRG, 2018* guidelines.

Seedling preparation: High-quality seeds of the BARI Lau-4 variety were selected based on their germination potential and health. Seeds were sown on 12 March 2024 for Azmin Akter's land and on 16 April 2024 for Babul Hossain's land in seed trays filled with a well-draining, nutrient-rich growing medium, such as compost and well-decomposed cow dung.

Plate 3. Seedling raising of bottle gourd.

The seeds were treated with Carbendazim (Autostin) fungicide on 12 March and 16 April 2024 and the same day they were sown. The trays were covered by nylon net to protect the young seedlings from extreme temperatures and direct sunlight and attack of red pumpkin beetle. Regular watering was provided to maintain soil moisture. Seedlings were monitored for any signs of disease or pest incidence and necessary treatments such as applying D-limonene 5% (Bioclean) and Carbendazim (Autostin) fungicide to control red pumpkin beetle and fungal infections, respectively.

Fertilizer application: Well-rotten compost or manure @ 5 ton/ha (3kg/pit) and N-P-K-S-Mg-Zn-B at 75-36-60-22-12-2.1-1.4 kg per hectare (45-22-36-13.2-7.2-0.60-0.84 g/pit) were applied for promoting growth and yield (FRG, 2018). In addition, Cadusafos 10% (Ragbi 10G) was used to manage soil-borne pests. This nutrient management strategy ensures the soil is adequately enriched, supporting the healthy growth and development of crops right from the onset of the planting season (Fageria, 2009 and Havlin *et al*., 2014). Full doses of all the manure and P-S-Mg-Zn-B and one-third of K were applied during final land preparation; the entire nitrogenous and two-thirds of the potassium fertilizers were applied in four splits throughout the growing season.


Plate 4. Mixing compost with fertilizers.

This strategy was implemented to ensure that plants receive a continuous supply of essential nutrients, particularly during critical growth stages such as vegetative growth, flowering, and fruit development. By splitting the application, the risk of nutrient leaching was reduced and nutrient use efficiency was enhanced, leading to improved crop performance and yield (Fageria *et al*., 2011; Singh *et al*., 2017).

Transplanting: Seventeen days old seedlings at 3-4 true leaf stage were transplanted in the field on 29 March 2024 in Azmin Akter's plot and on 03 May 2024 in Babul Hossain's plot. This transplanting into well-prepared pits encouraged the plants to establish a strong root system and become robust enough to handle field conditions. Seedlings were carefully removed from the seedling trays and transplanted into pre-prepared pits (50 cm x 50 cm x 45cm) in the field, maintaining 2.5 meters spacing in both directions as per GAP guidelines.

Irrigation: Irrigation was provided eight times in each plot from 05 April 2024 to 20 July 2024 during the growing season, carefully scheduled based on the crop's water requirements and prevailing weather conditions. The watering can irrigation method was preferred to ensure efficient water use, targeting the root zone directly and minimizing water wastage. Additionally, flood irrigation was applied 4 times in each plot at the same time during periods of dry soil conditions to ensure adequate soil moisture levels. This combination of irrigation techniques helped maintain optimal soil moisture, supporting healthy plant growth and maximizing yield potential (Allen *et al*., 1998; Steduto *et al*., 2012).

Fencing or netting around the GAP validation trial: To protect the GAP validation trial, a sturdy fence was constructed around the 90 decimal land area using nylon netting and bamboo sticks. This fencing served as a physical barrier to safeguard the crop from animals and unauthorized access, ensuring the integrity of the trial.

Plate 5. Signboard and fencing placed around the trial.

In addition, two signboards were strategically placed at the entrance of the trial area. These signboards provided essential information about the validation trial, including details such as the crop variety, the objectives of the trial, and the implementation of Good Agricultural Practices (GAP). The signboards also served as a communication tool to inform visitors and passersby about the research being conducted, reinforcing the importance of sustainable farming practices in enhancing crop yield and quality.

Previous crop history

The previous crop in the field was maize (*Zea mays*), which was harvested before starting bottle gourd cultivation process. Maize, being a heavy feeder, significantly depletes soil nutrients, particularly nitrogen, and can influence the soil's physical and biological properties. Consequently, the field required thorough preparation, including soil testing and nutrient replenishment to address any nutrient deficiencies and prepare it adequately for the bottle gourd crop. Additionally, managing any residual pests and diseases from the maize crop was essential to prevent potential impacts on the subsequent bottle gourd cultivation. The transition from maize to bottle gourd involved a comprehensive approach to restoring soil fertility and ensuring optimal growing conditions.

Soil and water analysis results

Plate 6. Collection of soil sample on 12 February, 2024.

After conducting soil and water analysis, it was confirmed that no hazardous materials were present in the trial site. Based on these analyses, adjustments were made following the Fertilizer Recommendation Guide (FRG, 2018), with guidance from a soil scientist. The adjusted fertilizer doses, including nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium

(Mg), zinc (Zn), and boron (B) were applied to the field. Fertilizers were incorporated into the soil prior to planting to ensure nutrient availability and additional applications were made throughout the growing season as needed. Regular monitoring of soil and water quality was conducted to ensure optimal nutrient levels and make any necessary adjustments to maximize plant growth and yield.

Plate 7. Collection of water sample on 12 February, 2024.

Intercultural operations

The successful cultivation of bottle gourd involved a series of intercultural operations aimed at optimizing plant growth and yield. Weeding was performed 12 times (10 April 2024 to 25 July 2024) to keep the field free of competitive weeds, which could otherwise impact plant growth and nutrient uptake. A trellis system was constructed using bamboo and nylon rope to support the climbing nature of the bottle gourd vines, facilitating better air circulation and exposure to sunlight. After each irrigation, the soil was loosened around the plants to enhance aeration and root development. Water suckers were regularly removed from the stem to direct more energy into fruit production. Efficient drainage systems were also implemented to remove excess water following heavy rains, preventing waterlogging and root rot. These intercultural practices were crucial for maintaining the health and productivity of the crop throughout the growing season.

Maintaining register book and documentation

A comprehensive register book was meticulously maintained for the GAP validation trial, documenting all relevant information and activities conducted throughout the project. The register included the names of the two participating farmers and recorded crucial details such as the crop name, variety name, soil and water test results and the precise location of the trial site. The register also tracked the dates of key operations, including irrigation, weeding, pesticide and fungicide applications, and other intercultural activities such as loosening the soil, removing water suckers and hand pollination. Additionally, the number of laborers used for each task was documented to ensure accurate records of resource utilization. This detailed register served as an essential tool for monitoring the trial's progress and ensuring the integrity of the data collected.

Pest management

During the GAP validation trial for bottle gourd, a variety of integrated pest and disease management practices were employed to ensure crop health and optimize yield. Fungicide of carbendazim group (Autostin WDG) was used for seed treatment before sowing. To control the red pumpkin beetle, the insecticide D-limonene 5% (Bioclean) was used at vegetative stage. For fruit fly management, sex pheromone (Cuelure sex pheromone) traps were strategically placed every twelve meters interval to attract and capture the pests, reducing their population and impact. Additionally, yellow sticky traps were deployed at ten meters intervals across the field to target a range of other insect pests, providing an eco-friendly method of pest control. For disease management, copper oxychloride 50% (Cupravit), a copper-based fungicide, was applied throughout the cropping period as a preventive measure against gummy stem blight, a common fungal disease of bottle gourd. To treat any instances of gummy stem blight that occurred, Bordeaux paste bandage was used to effectively cure the affected plants. These targeted interventions were crucial in maintaining the health of the bottle gourd plants, preventing significant yield losses, and ensuring the success of the GAP validation trial.

Table 1. List of pesticides applied to control insect and disease

Sl.	Generic name	Trade name	Application dose	Purpose
1.	Carbendazim	Autostin WDG	2.5 g/kg seed	Seed treatment
2.	Copper oxychloride	Cupravit 35WG	2.0 g/L of water	To control gummy stem blight
3.	Copper sulphate and quicklime	Bordeaux mixture	2.5 g/plant	To control gummy stem blight
4.	D-limonene	Bioclean	1.0 g/L of water	To control red pumpkin beetle

Worker health safety and environmental issues

Worker health safety, and environmental stewardship were prioritized throughout the GAP validation trial for bottle gourd. To ensure the safety and well-being of all workers, they were provided with protective gear including aprons, masks, hand gloves, caps, and shoes. Additionally, a comprehensive farm instrument manual was issued to guide the proper use of tools and machinery. Regular health checks were conducted every six months to monitor worker health, and essential health safety items such as soap were supplied, with washrooms being cleaned regularly using appropriate detergents like lysol.

Plate 8. Spraying with health safety measures.

Pure drinking water was made available to all workers and their working hours were restricted to a maximum of eight hours per day to prevent fatigue. Training sessions were conducted to educate workers on health safety protocols, the correct use of pesticides and the provision of first aid treatment. These measures not only ensured a safe and healthy working environment but also reinforced the importance of environmental responsibility and the ethical treatment of workers within the framework of Good Agricultural Practices (GAP).

Harvesting based on maturity index

Fruits with obscure spine that can be easily indented with fingernail are usually harvested 12-15 days after anthesis, the more harvest the more bearing fruits, harvest must be done with sharp knife during cooler time of the day (early morning or evening).

Plate 9. Suitable harvesting stage of bottle gourd.

Harvested fruits were kept in plastic crates instead of bamboo basket and placed in shaded place. Before marketing, sorting and grading were performed, appropriate packaging material used for transportation, clean handling was ensured.

MRL analysis results

Plate 10. Bottle gourd sample taken for MRL test.

SGS Bangladesh Limited conducted a Maximum Residue Limit (MRL) test for copper oxychloride using a bottle gourd sample collected from Dhamrai, Dhaka, on 09 June, 2024. Following laboratory analysis, the company reported residue levels below 5 mg/kg, which falls within safe thresholds for human consumption, indicating no significant health risks.

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Farmers' Training

The first batch of training on bottle gourd production technology with GAP protocol was conducted in Dhamrai on 20 January 2024, with 30 participants. Following the success of this session, a second batch of training was held in Basna village on 21 March2024, involving five participants. These sessions focused on equipping farmers with the knowledge and skills needed to implement GAP effectively, thereby enhancing the quality and yield of their bottle gourd crops.

Plate 11. Farmers training

Results and Discussion

Yield and yield contributing characters

During the cropping season, there were 27 successful harvests over a 53-day period. The harvesting pattern showed an initial phase with fewer fruits, followed by a mid-period peak, and then a gradual decline in the later stages, consistent with typical cucurbit growth cycles (Patel and Naik, 2021). Peak fruit yield, with individual fruits averaging 2.5 kg, was observed between the 7th and 22nd harvests. This trend aligns with previous research on bottle gourd harvest patterns (Kader *et al*., 2019a). Individual fruit weights generally ranged from 2.1 kg to 2.8 kg throughout the harvesting period, indicating effective crop management and stable phenotypic expression under controlled conditions (Yadav and Kumar, 2022). The heaviest fruits, weighing 2.8 kg, were recorded during the 13th and 15th harvests, with a subsequent decrease in weight in later harvests. This reduction in fruit weight toward the end of the season may be attributed to nutrient depletion in the plants and cumulative photosynthetic stress, a phenomenon noted by Alam *et al*. (2020) and Sharma *et al*. (2018).

The number of marketable fruits steadily increased from 144 fruits at the first harvest, reaching its highest point of 212 fruits between the 11th and 14th harvests. Subsequently, the number of fruits per harvest decreased, dropping to 158 fruits by the 27th harvest. This suggests a peak production period between the 8th and 16th harvests, after which fruit production begins to decline. Similar yield patterns, characterized by an initial growth phase, a peak production period, and a subsequent decline, have been observed in other fruit-bearing crops (Singh *et al*., 2019; Gómez *et al*., 2020).

Overall, the data indicates that peak production occurs approximately 79 to 97 days after planting, followed by a consistent decline. While the weight of individual fruits remained relatively stable, the total number of marketable fruits significantly decreased over time, reflecting resource reallocation in ageing plants (Mondal *et al*., 2023).

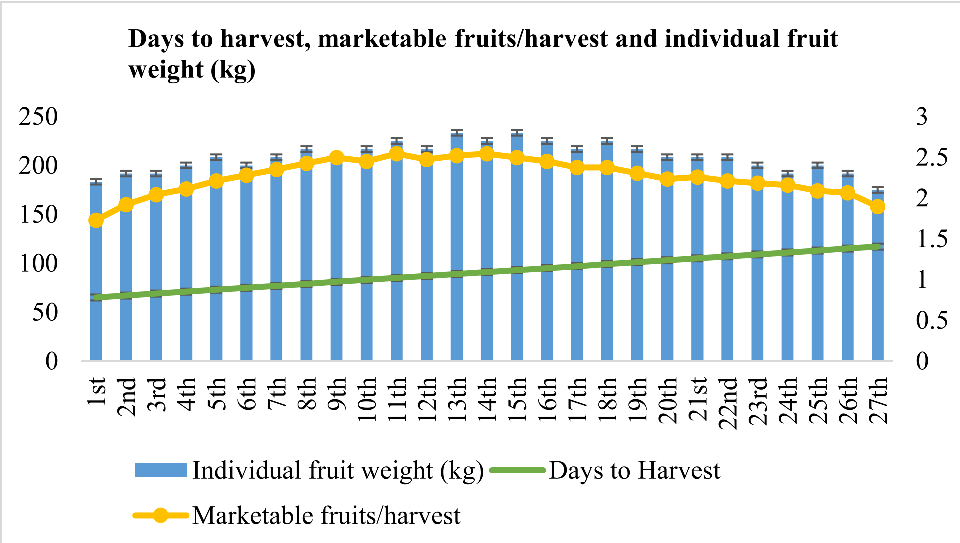

Fig. 2. Days to harvest, marketable fruits/harvest and individual fruit weight (kg) in different harvest stages.

Plate 12: Farmers harvested bottle gourds.

Good Agricultural Practices (GAP) for bottle gourd significantly outperformed the national average and aligned with Bangladesh Agricultural Research Institute (BARI) benchmarks. This superior performance was achieved by maximizing the number of high-quality fruits through optimized nutrient and harvest management (Kader *et al*., 2019b; Alam *et al*., 2020). From a 90-decimal (0.36 ha) plot, 5,098 fruits were harvested, yielding 12.75 MT.

Table 2. Yield of GAP produced bottle gourd compared to national average

Practice	Fruits number	Individual fruit weight (kg)	Yield (t/ 90 decimal land)	Yield (t/ha)
GAP	5098	2.5	12.75	35.0
National average	-	-	5.0	13.7
Research (BARI)	4800-5200	2.5	12-13	33-36

Benefit-cost analysis

The production of bottle gourd on 90 decimals of land adhering to Good Agricultural Practices (GAP) resulted in a total yield of 12.75 MT, with 5,098 gourds produced. The total production cost was Tk. 2,11,500/-, while the average market price per gourd was Tk. 80, generating a total revenue of 4,07,840 Taka. The Benefit-Cost Ratio (BCR) was calculated to be 1.93, indicating that for every 1 Taka invested, there was a return of 1.93 Taka. This demonstrates the economic viability of GAP-based cultivation, highlighting its potential for profitability and sustainability. The yield exceeded the national average, underscoring the effectiveness of improved practices in enhancing productivity and market competitiveness.

Farmer’s Profile and Reaction

Babul Hossain, aged 40 with an eighth-grade education, and Azmin Akter, aged 32 and a Secondary School Certificate (SSC) holder, both residents of Basna village in Dhamrai, Dhaka, achieved successful bottle gourd cultivation by adhering to Good Agricultural Practices (GAP) guidelines.

They expressed satisfaction with the results, noting that the optimum use of compost, fertilizers, insecticides, fungicides and irrigation water significantly improved their yield. Compared to their previous farming methods, adopting GAP led to better crop performance and higher profitability, confirming the advantages of these sustainable farming practices.

Export opportunity

GAP-produced bottle gourd meets international standards for quality and safety, making it highly competitive in global markets. Adherence to GAP enhances the crop's appeal to foreign buyers, offering farmers the chance to access lucrative export opportunities. This not only boosts income but also strengthens Bangladesh’s presence in the international agricultural market.

Marketing

GAP-produced bottle gourd was sold at the local market in Dhamrai, Dhaka. However, there was no noticeable difference in pricing or consumer preference between GAP-produced bottle gourd and those from normal production methods in the local market. There is considerable scope for positioning GAP-produced bottle gourd as a premium, safe and sustainable product. Strategies include targeting health-conscious consumers, supermarkets, emphasizing its compliance with international safety standards and positioning it for export to high demand markets. Leveraging certifications and promoting the benefits of GAP can also attract buyers looking for quality and traceable produce. The involvement of the Hortex Foundation and Department of Agricultural Marketing (DAM) can establish better marketing channels.

Challenges and way forward

During the seedling stage, drought condition caused the death of some plants, which was further compounded by an outbreak of gummy stem blight. Additionally, labour scarcity and high labour costs during April and May posed challenges. Moreover, the Sub-assistant Agriculture Officer (SAAO) requires training on record keeping for the GAP validation trial.

To overcome the challenges faced during the GAP validation trial, several steps can be taken for moving forward. Efficient irrigation methods, such as drip irrigation or mulching, should be introduced to mitigate the effects of drought during the seedling stage. Implementing disease-resistant varieties and enhancing monitoring systems will help manage outbreaks like gummy stem blight more effectively. The issue of labour scarcity and high costs during peak periods, particularly in April and May, can be addressed through mechanization or community labour-sharing initiatives. Additionally, training should be provided to the Sub-assistant Agriculture Officer (SAAO) on record-keeping and data management for GAP trials, ensuring more accurate tracking and reporting. These measures will enhance productivity and sustainability, leading to better outcomes in future GAP practices.

Acknowledgements

Financial support from the PARTNER-APCU-BARC project is greatly appreciated. The initiation of protocol development and provision of GAP training by the BARC authority are gratefully acknowledged. Appreciation is also extended to the BARI authority for the opportunity provided to the scientists to work on GAP. The intensive work carried out in the bottle gourd field by Sub-assistant Agriculture Officer (SAAO) is also acknowledged.

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