



Impact of Plant Growth Regulators on Vegetables: Farmers' Perspectives, Promotional Preferences and Challenges

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Plant growth regulators (PGRs) regulate the physiological processes of crop plants, like, rooting, flowering, growth, sprouting and ripening. The use of PGRs in vegetable production are found to be beneficial for yield and yield contributing characteristics of various vegetable crops. This study examines the impact of PGRs on vegetable growth, yield and quality, identifies farmers' preferred promotional activities and examines the challenges in their usage. Using a multi-stage sampling technique, two talukas in the Junagadh district, namely Junagadh and Vanthali, were purposefully selected. From each taluka, 40 farmers were selected, resulting in a total of 80 farmers. Analyses included basic descriptive statistics (frequency, mean, and standard deviation), Garrett's ranking technique and response priority index (RPI). Results indicated a moderate increase in vegetable growth, yield and quality. On-farm demonstrations were identified as the most preferred promotional activity, followed by farmers' meetings, exhibitions, and social media. Farmers' adoption of plant growth regulators is hindered by lack of awareness, misinformation, counterfeit products, high costs, and inadequate training and support.

(Key words: Garrett's ranking, Plant growth regulators, Promotional activities, Response priority index)

Vegetable farming is a critical sector in agriculture, providing essential nutrients and addressing the increasing dietary needs of a health-conscious population. However, achieving maximum productivity is often challenging for farmers, given the diverse factors that affect yield. Plant Growth Regulators (PGRs) have emerged as a key solution, offering benefits such as enhanced fruit setting, synchronized ripening, and improved overall crop physiology. While the application of these regulators is widely acknowledged for improving crop outcomes, understanding how farmers perceive, utilize, and benefit from them is crucial for tailoring support and extension services (Kumar *et al.*, 2024a).

Farmers' perspectives on PGRs play a pivotal role in the success of these products, as acceptance and correct application are influenced by various factors including cost, accessibility, and perceived effectiveness (Kumar *et al.*, 2024b). Studies exploring farmers' preferences, knowledge gaps, and promotional needs related to PGRs are limited, especially within the context of vegetable farming, where PGRs can

be transformative. This research, therefore, focuses on investigating the viewpoints of vegetable growers regarding PGR use, highlighting the promotional preferences that could foster greater adoption, as well as the barriers farmers face. Through this study, we aim to bridge the gap between available technologies and farmer adoption, ensuring that PGR solutions are effectively aligned with farmers' requirements and challenges in the field (Kumar *et al.*, 2024c).

Vegetables are very important to the human diet. They are the main sources of nutrients such as vitamins, minerals, folic acid, and dietary fiber and are low in fat and sodium. People are now becoming more interested in their health and improving their quality of life, which has led to a rise in vegetable consumption in recent years. Besides this, the application of plant growth regulators has become essential for increasing the productivity of vegetable crops. These chemicals are highly regulated because they are used on plants or their products which will be consumed (Khan *et al.*, 2023). Dieticians recommend eating 300g of vegetables every day. When ingested in sufficient quantities, they increase appetite

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and include a good amount of fiber. Furthermore, they neutralize the acids produced during the digestion of fatty and proteinaceous foods, provide healthy roughage that promotes digestion, and contribute to the prevention of heart disease (Nivethitha *et al.*, 2022).

As vegetables occupy a vital place in a balanced diet, it is equally important that the area and production of vegetable crops be increased. The use of high-yielding varieties and improved technologies can increase production to meet the growing demand for vegetables (Chand *et al.*, 2014). Vegetable crops encompass over 200 plant species utilized as human food. These predominantly herbaceous plants can be consumed raw or cooked, either fresh or preserved, in various forms, including leaves, roots, fruits, seeds, flowers, inflorescences, and stems. In addition to providing calories, vegetables also provide various micronutrients for healthy diets to combat hidden hunger. Thus, vegetables, together with fruits and legumes, are proposed as new-generation staple foods (Duan and Yann-rong, 2024).

Plant growth regulators (PGRs), also called plant hormones or phytohormones, are essential in enhancing vegetable production. The term “phytohormones” refers to naturally occurring compounds produced within plants, while “plant growth regulators” are synthetically derived chemicals with similar effects (Faruk *et al.*, 2023; Kaur *et al.*, 2018). These compounds influence various metabolic and physiological activities governing plant growth and development, with some synthesized in one part of the plant and transported to another for their effects (Prajapati *et al.*, 2015).

The maximum potential yield of vegetables is often not achieved due to factors like poor physiological efficiency, suboptimal plant architecture, inadequate fruit setting, and lack of synchronized maturity (Wakchaure *et al.*, 2020). PGRs address these issues by improving blooming, fruit setting, maturity synchronization, and the physiochemical efficiency of crops (Choudhury *et al.*, 2013). These regulators are classified into five major categories: Auxins, gibberellins, cytokinins, abscisic acid, and ethylene. Auxins, gibberellins, and cytokinins are growth promoters, while abscisic acid and ethylene act as growth inhibitors (Bagale *et al.*, 2022).

Gibberellic acid is particularly notable for its role in enhancing plant growth, yield, and yield-contributing traits (Ali *et al.*, 2022). Synthetic regulators like naphthalene acetic acid (NAA) stimulate growth and root development in various plant species, making them valuable for horticultural crop production (Misu *et al.*, 2023; Netam and Sharma, 2014). Furthermore, salicylic acid, a phenolic compound, positively influences processes like photosynthesis, ion uptake, membrane permeability, enzyme activity, flowering, transpiration, and chlorophyll enhancement, thereby supporting overall plant growth and development (Amanullah *et al.*, 2010; Sahu, 2013; Souri and Tohidloo, 2019).

Despite the extensive focus on physiological and biochemical impacts, studies specifically addressing farmers' perspectives on adopting PGRs are scarce. Limited research examines the promotional strategies preferred by farmers or the challenges they encounter while implementing these technologies, which are critical for ensuring practical utility and widespread acceptance of PGRs in vegetable farming. Although there is ample evidence of the benefits of PGRs in improving vegetable growth and yield, limited studies have explored the perspectives, preferences, and challenges faced by farmers in adopting these technologies. Particularly in the context of vegetable farming, there is a gap in understanding the knowledge gaps, promotional preferences and barriers to PGR adoption among growers. This gap hinders the development of tailored extension services and promotional activities that align with farmers' needs. This study seeks to address critical questions surrounding the adoption and impact of plant growth regulators (PGRs) in vegetable farming. Key research questions include how farmers perceive the effectiveness and usage of PGRs, what promotional activities they prefer to encourage adoption, and the challenges they face in utilizing these regulators effectively. The objectives of this research was to assess the impact of PGRs on vegetable growth, yield, and quality; identify the promotional activities preferred by farmers; and examine the constraints they encounter in using these technologies. By addressing these questions and objectives, the study aimed to bridge the gap between available technologies and farmer adoption, fostering a more effective and sustainable use of PGRs in vegetable farming.

MATERIALS AND METHODS

Sampling design

The current experiment utilized a multistage sampling method to identify the final sample units. In the first stage, the Junagadh district of Gujarat was purposefully selected due to the company's interest in establishing a market presence in the region. This district was selected to assess the impact of plant growth regulators on vegetable growth, yield and quality, identify farmers' preferred promotional activities and examine challenges in their usage. In the second stage, the talukas of Junagadh and Vanthali within the district were also purposefully chosen, in alignment with the company's market development strategy. In the third stage, villages within these talukas were selected, with 8 villages from Junagadh taluka and 8 villages from Vanthali taluka randomly chosen to ensure a representative sample. Finally, in the fourth stage, 5 vegetable growers from each selected village who were users of PGRs were purposively chosen for participation. This resulted in a total of 40 farmers from Junagadh taluka and 40 farmers from Vanthali taluka, making a combined sample of 80 farmers across the district.

Statistical analysis

Basic descriptive statistics

The basic descriptive statistics were used to find out the impact of plant growth regulator on the growth, yield, and quality of vegetables. The study employed a five-point scale, where Highly Increased (HI) is scored as 5, Moderately Increased (MI) as 4, Slightly Increased (SI) as 3, No Change (NC) as 2, and Decreased (D) as 1.

Garrett's ranking technique

Garrett's ranking technique was used to determine the most preferred promotional activities for the plant growth regulator among farmers. The order of the merit given by the respondents was converted into ranks by using the following formula. Accordingly, these ranks were converted to scores by referring to Garrett's table. Garrett's formula for conveying ranks into a percent is given by,

$$\text{Percent position} = \frac{100 (R_{ij} - 0.5)}{N_j} \quad \dots(1)$$

Where,

R_{ij} = Rank given to the i^{th} attribute by the j^{th} individual

N_j = Number of attributes ranked by the j^{th} individual

In Garrett's ranking technique, the per cent positions were converted into scores. Thus, for each factor, the scores of the various respondents were added, and then the mean values were estimated. The attributes with the highest value were considered as the most important one, and the others in their respective order (Dey *et al.*, 2012; Kalvakolanu *et al.*, 2019).

Response priority index

For analyzing the constraints faced by the farmers, the Response Priority Index (RPI) was constructed as a product of the Proportion of Responses (PR) and Priority Estimate (PE) where PR for the i^{th} constraint is the ratio of the number of responses for a particular constraint to the total responses (Archana *et al.*, 2019). The ranking was calculated by the following formula (Navaneetham *et al.*, 2019).

$$\text{GDD} = \frac{\sum_{j=1}^k f_{ij} X_{[(k+1)-j]}}{\sum_{i=1}^l \sum_{j=1}^k f_{ij}} \quad 0 \leq \text{RPI} \leq 5 \quad \dots(2)$$

Where,

RPI_i = Response Priority Index for i^{th} constraint

f_{ij} = Number of responses for the j^{th} priority of the i^{th} constraint ($i=1,2,\dots,l$; $j=1,2,3,\dots,k$)

$\sum_{j=1}^k f_{ij}$ = Total number of responses for the i^{th} constraint

K = Number of priorities (1. Strongly agree; 2. Agree; 3. Moderate; 4. Disagree, and 5. Strongly disagree)

$X_{[(k+1)-j]}$ = Scores for the j^{th} priority

$\sum_{i=1}^l \sum_{j=1}^k f_{ij}$ = Total number of responses to all constraints

The larger the RPI, the higher was the importance of that constraint (Mehta *et al.*, 2022).

RESULTS AND DISCUSSION

Growth, yield and quality of vegetables

The impact of plant growth regulator on the growth, yield and quality of vegetables was calculated

Table 1. Analysis of impact of plant growth regulator on the growth, yield and quality of vegetables

Sr. No.	Parameters	Frequency					Mean	SD	Decision
		No. of respondents = 80							
		HI	MI	SI	NC	D			
A. Growth									
1	Plant height	33	24	18	4	1	4.05	0.97	MI
2	Stem diameter	9	4	16	46	5	2.58	1.07	NC
3	Number of branches plant ⁻¹	38	28	10	4	0	4.25	0.86	HI
4	Internodal length	10	9	20	29	12	2.70	1.22	SI
5	Plant spread	36	17	20	5	2	4.00	1.08	MI
6	Number of nodes plant ⁻¹	6	18	35	15	6	3.04	1.01	SI
7	Number of leaves plant ⁻¹	2	16	15	42	5	2.60	0.96	NC
B. Yield									
1	No of vegetables plant ⁻¹	44	20	14	2	0	4.33	0.85	HI
2	Vegetable yield plant ⁻¹	41	27	9	2	1	4.31	0.86	HI
3	Vegetable yield harvest ⁻¹	38	16	20	5	1	4.06	1.04	MI
4	Vegetable yield hectare ⁻¹	42	22	11	2	3	4.23	1.02	HI
5	Vegetable length	15	35	20	4	6	3.61	1.08	MI
6	Vegetable diameter	31	12	22	14	1	3.73	1.18	MI
7	Vegetable weight	25	35	18	1	1	4.03	0.84	MI
C. Quality									
1	Appearance	32	26	16	5	1	4.04	0.98	MI
2	Texture	20	22	10	20	8	3.33	1.35	SI
3	Freshness	28	20	24	8	0	3.85	1.01	MI
4	Flavour	13	29	18	15	5	3.38	1.14	MI
5	Size and maturity	23	30	24	3	0	3.91	0.85	MI
6	Shelf life	40	26	14	0	0	4.33	0.75	HI
7	Uniformity	35	20	17	8	0	4.03	1.02	MI
Overall							3.73	1.01	MI

Source: Field Survey, 2024

Note: *For growth, yield and quality level category, the fonts are to represent qualitative value, namely Highly Increased (HI) = 4.21-5.00, Moderately Increased (MI) = 3.41-4.20, Slightly Increased (SI) = 2.61-3.40, No Change (NC) = 1.81-2.60, and Decreased (D)= 1.00-1.80 from the value of mean.

by using basic descriptive statistics as mentioned in Table 1 below.

Impact of plant growth regulator on the growth of vegetables

Plant height exhibited a moderately increased (MI) response, indicating that the regulators effectively promoted vertical growth. Stem diameter, however, showed no change (NC), suggesting that the plant growth regulators did not significantly affect stem thickening. The number of branches plant⁻¹ experienced a highly increased (HI) impact, reflecting enhanced branching and overall plant vigor. Internodal length saw a slightly increased (SI) response, implying minor elongation of the segments between nodes. Plant spread demonstrated a moderately increased (MI) response, indicating a noticeable but moderate expansion in horizontal growth. The number of nodes plant⁻¹ showed a slightly increased (SI) effect, highlighting a moderate promotion of node formation. Similarly, the number of leaves plant showed no change (NC), indicating that the regulators did not significantly enhance leaf production.

Impact of plant growth regulator on the yield of vegetables

The number of vegetables plant⁻¹ showed a highly increased (HI) response, indicating a significant boost in vegetable production. Similarly, the vegetable yield plant⁻¹, vegetable yield ha⁻¹, and vegetable weight all exhibited highly increased (HI) responses, reflecting a substantial improvement in yield due to the application of growth regulators. The vegetable yield harvest⁻¹ and vegetable diameter showed a moderately increased (MI) response, suggesting a positive but less pronounced effect on these parameters. The vegetable length also exhibited a moderately increased (MI) response, indicating an improvement in length due to the growth regulators, albeit to a lesser extent compared to overall yield.

Impact of plant growth regulator on the quality of vegetables

Appearance and freshness showed moderately increased (MI) responses, suggesting that the produce

had a more appealing look and maintained its just-harvested quality for a longer period. Texture exhibited a slightly increased (SI) response, indicating a minor improvement in firmness and mouth feel. Flavour showed a moderately increased (MI) response, reflecting an enhancement in taste. The size and maturity of the vegetables demonstrated a moderately increased (MI) response, indicating more uniform and possibly earlier ripening produce. Shelf life exhibited a highly increased (HI) response, showing a significant extension in the duration the vegetables could be stored without significant quality loss. Uniformity also exhibited a moderately increased (MI) response, indicating a more consistent size and shape among the harvested vegetables, beneficial for marketability and consumer preference.

Overall, the application of plant growth regulators had a moderately increased (MI) impact on the growth, yield, and quality of the vegetables studied, demonstrating their potential as valuable tools in agricultural practices to enhance productivity and marketability.

Promotional activities

The most preferred promotional activities of farmers about plant growth regulators among vegetable growers were calculated by using Garrett ranking technique as mentioned in the below Table 2 and Fig.1.

The per cent positions and Garrett values

The Garrett ranks were calculated using the appropriate garrett ranking formula. Based on these ranks, the garrett values were determined (Ao and Jamir, 2020; Radhika *et al.*, 2023). The percentage position of each rank was converted to scores by referring to the Garrett ranking tables given by Garrett and Woodworth (1969) (Rajpoot *et al.*, 2023). Percent position of each rank given by the respondents and Garrett ranking conversion table helps to convert the orders of merits to Garrett Scores and Garrett Scores multiply with each rank and estimate the total score and average score of each rank. The factor having the highest average score is considered as the most important factor (Manikandan and Bhuvaneshwari, 2023).

Table 2. Most preferred promotional activities for plant growth regulator among farmers

Sr. No.	Parameters	Percent position	Garrett value	Total score	Mean Garrett's score	Rank
1	On-farm demonstration	3.85	84	5206	65.08	I
2	Farmers meeting	11.54	73	4759	59.49	II
3	Distribution of literature	19.23	67	3892	48.65	VII
4	Through participation in fairs	26.92	62	3885	48.56	VIII
5	Wall paintings	34.62	58	3206	40.08	XII
6	Banners	42.31	54	3631	45.39	X
7	Posters	50	50	3874	48.43	IX
8	Calendars	57.69	46	2394	29.93	XIII
9	Exhibition	65.38	42	4661	58.26	III
10	Testimonials	73.08	38	4268	53.35	V
11	Local newspapers	80.77	33	4021	50.26	VI
12	Social media	88.46	26	4465	55.81	IV
13	Product catalogue	96.15	16	3298	41.23	XI

Source: Field Survey, 2024

In determining the most preferred promotional activities for plant growth regulators among farmers, it was found that on-farm demonstrations were ranked first with a mean score of 65.08. This high ranking indicated that farmers greatly valued the ability to observe the effects of the plant growth regulators on their crops, first-hand. Such demonstrations allowed farmers to witness improvements in crop health and productivity, thereby creating a strong impression and instilling confidence in the efficacy of the products. Farmers' meetings were ranked second, with a mean score of 59.49. These meetings provided a platform for direct interaction between farmers and representatives from plant growth regulator companies or agricultural experts. This setting facilitated in-depth discussions, allowing farmers to ask questions and gain a deeper understanding of the products, thus enhancing their trust and willingness to adopt these regulators. Exhibitions were ranked third, with a mean score of 58.26. These events showcased various plant growth regulators and allowed farmers to see multiple products in one place, compare them, and discuss their features with experts.

Social media ranked fourth, with a mean score

of 55.81. The use of social media platforms enabled the dissemination of information about plant growth regulators to a broad audience quickly and effectively, providing farmers with easy access to updates, usage tips, and success stories from other farmers. Testimonials, with a mean score of 53.35 and ranked fifth, were also highly valued. Positive testimonials from fellow farmers provided credible and relatable endorsements that influenced other farmers' decisions to use plant growth regulators.

Local newspapers, which had a mean score of 50.26 and were ranked sixth, served as a trusted source of information for many farmers. Articles and advertisements in local newspapers reached a wide audience and provided detailed information about the benefits and usage of plant growth regulators. The distribution of literature, such as brochures and pamphlets, ranked seventh with a mean score of 48.65. These materials offered detailed information that farmers could refer to at their convenience, reinforcing the promotional messages.

Participation in fairs was ranked eighth, with a mean

score of 48.56. Fairs allowed for direct engagement with farmers, similar to exhibitions, but on a potentially smaller and more localized scale. Posters, ranked ninth with a mean score of 48.43, and banners, ranked tenth with a mean score of 45.39, served as visual promotional tools placed in strategic locations to catch farmers' attention and convey key messages about plant growth regulators.

Product catalogues, with a mean score of 41.23 and ranked eleventh, provided comprehensive information about various plant growth regulator products, helping

farmers make informed decisions. Wall paintings, which had a mean score of 40.08 and were ranked twelfth, acted as long-term visual advertisements in rural areas, although they were less preferred compared to other promotional activities.

Finally, calendars, ranked thirteenth with a mean score of 29.93, were the least preferred promotional activity. While they served as a constant reminder of the product, their utility as a promotional tool was limited compared to more interactive or detailed forms of promotion.

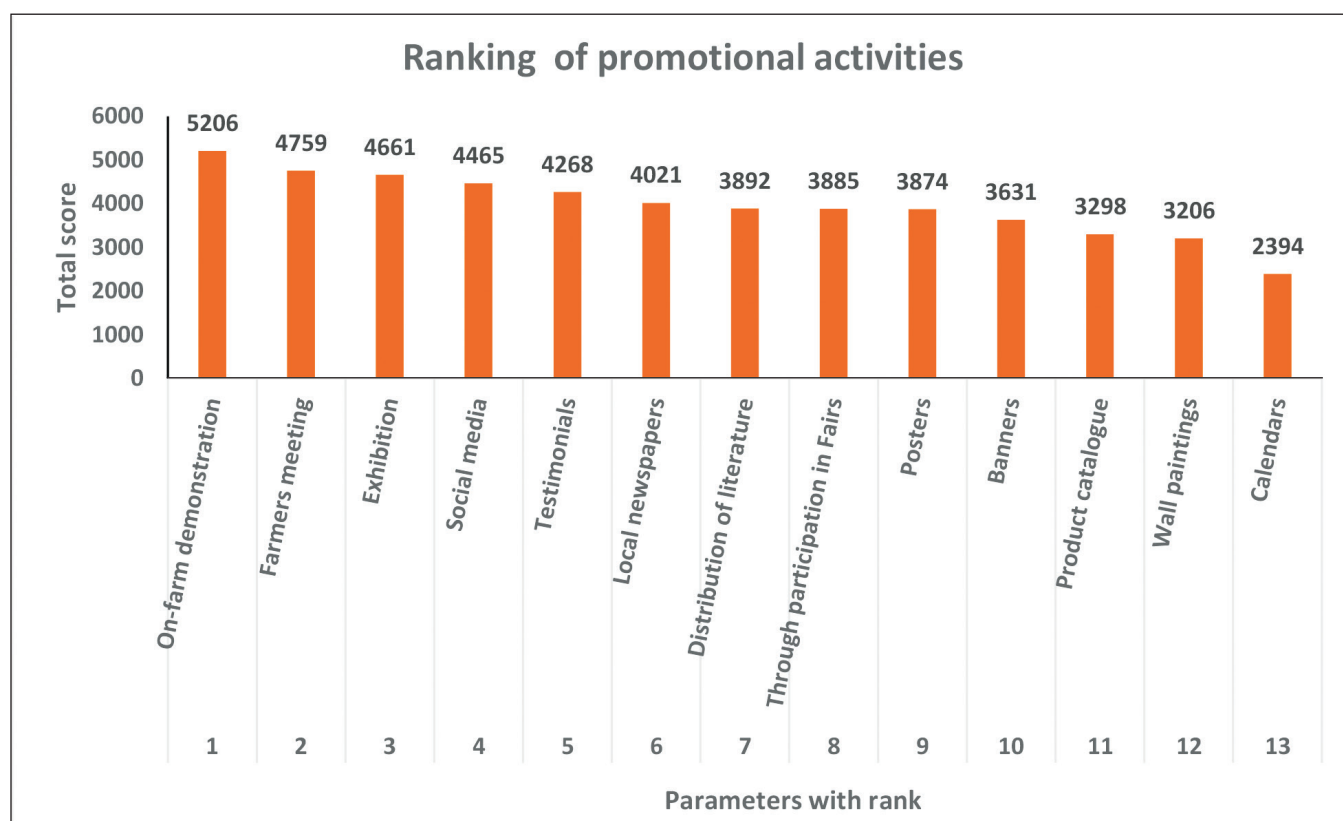


Fig 1. Most preferred promotional activities for plant growth regulator among farmers

Constraints faced by farmers with respect to plant growth regulators

The constraints were ranked based on the Response Priority Index (RPI) score, which was calculated from the farmers' responses on a five-point scale ranging from strongly disagree to strongly agree. The RPI score indicated the severity of the constraint and its priority

for the farmers. The higher the RPI score, the higher the priority of the constraint.

Based on the Response Priority Index (RPI) scores, the analysis of constraints faced by farmers in the adoption of plant growth regulators (PGRs) in vegetable cultivation highlights several key issues. The most critical constraint, ranked first, was the unawareness

Table 3. Constraints faced by farmers with respect to plant growth regulators

Sr. No.	Constraint	Total score	RPI score	Rank
1	Lack of awareness among farmers regarding the benefits and applications of plant growth regulators hinders their adoption	362	0.302	I
2	Uncertainty about the compatibility of PGRs with other agrochemicals discourages their combined use	316	0.263	XII
3	Inconsistent performance of PGR brands creates doubts about their effectiveness in different farming conditions	332	0.277	IX
4	Some PGRs have a short shelf life, limiting their effectiveness over time	248	0.207	XV
5	The relatively high cost of PGRs makes them unaffordable for many small-scale farmers	339	0.283	VI
6	Lack of adequate training programs leaves farmers unaware of the proper application techniques for PGRs	346	0.288	IV
7	Untrained agro-input dealers often misinform farmers, leading to incorrect use of PGRs	356	0.297	II
8	The market is flooded with counterfeit PGR products, creating mistrust among farmers	351	0.293	III
9	Companies provide inadequate extension services, limiting farmers' knowledge about the correct use of PGRs	344	0.287	V
10	The long distance to retail outlets discourages farmers from purchasing PGRs regularly	338	0.282	VII
11	Government regulatory bodies do not consistently enforce proper standards for PGR products	335	0.279	VIII
12	Limited research and development efforts result in a lack of region-specific PGR formulations suited to local crops and conditions	290	0.242	XIV
13	Poor labeling practices on PGR packaging lead to confusion about appropriate dosage and application methods	299	0.249	XIII
14	The absence of field demonstrations prevents farmers from seeing the practical benefits of PGRs	319	0.266	XI
15	Farmers are resistant to adopting new technologies like PGRs due to their reliance on traditional farming methods	324	0.270	X

Source: Field Survey, 2024

among farmers regarding the benefits and applications of PGRs, with an RPI score of 0.302. This lack of awareness significantly hindered their adoption, as many farmers were unfamiliar with the potential advantages PGRs could offer in improving crop yields and quality. Ranked second, with an RPI score of 0.297, was the issue of untrained agro-input dealers misinforming farmers, which often led to incorrect use of PGRs, further discouraging their effective application.

Another major constraint, ranked third (RPI 0.293), was the prevalence of counterfeit PGR products in the market, creating mistrust among farmers. Farmers hesitated to invest in these products, fearing they would be ineffective or harmful. Additionally, inadequate extension services provided by companies, ranked fifth (RPI 0.287), limited farmers' access to accurate information on the proper use of PGRs. The lack of training programs (RPI 0.288, rank 4) compounded this

issue, as farmers were left without the necessary skills and knowledge to apply PGRs correctly.

The relatively high cost of PGRs (RPI 0.283, rank 6) was another significant barrier, especially for small-scale farmers, making these inputs unaffordable. Farmers were also discouraged by the long distance to retail outlets (RPI 0.282, rank 7), which made regular purchasing difficult. Additionally, inconsistent enforcement of proper standards by regulatory bodies (RPI 0.279, rank 8) led to concerns over the quality and safety of PGRs, while the inconsistent performance of PGR brands (RPI 0.277, rank 9) further contributed to doubts about their effectiveness in varying farming conditions.

Farmers' reliance on traditional methods also played a role, with resistance to adopting new technologies like PGRs (RPI 0.270, rank 10). Furthermore, the absence of field demonstrations (RPI 0.266, rank 11) prevented farmers from seeing first hand the practical benefits of using PGRs. Uncertainty about PGR compatibility with other agrochemicals (RPI 0.263, rank 12) and poor labeling practices (RPI 0.249, rank 13) added to the confusion, while limited region-specific research and development (RPI 0.242, rank 14) resulted in a lack of formulations suited to local crops. Lastly, the short shelf life of some PGRs (RPI 0.207, rank 15) limited their long-term effectiveness, further deterring their use.

CONCLUSION

Plant growth regulators are essential compounds that influence the growth, development, and differentiation of plant cells, tissues, and organs. The growth shows moderate increase, the yield shows a significant increase, and the quality shows a moderate increase in cultivation of vegetable crops. The sales promotional activities for plant growth regulators prioritize on-farm demonstrations, followed by farmers' meetings, exhibitions, and social media. For companies looking to enter this market, focusing on effective marketing strategies that include on-farm demonstrations and leveraging strong local networks can enhance adoption rates. Farmers face significant challenges in adopting plant growth regulators (PGRs), with the main issues being a lack of awareness, misinformation from

untrained dealers, and the prevalence of counterfeit products. High costs, inadequate training, and poor extension services further hinder effective use of PGRs.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study, the collection, analysis and interpretation of the data, nor in the writing of this manuscript or in the decision to publish the results.

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