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Morphological and Agronomic Response of Grafted Bitter Gourd (*Momordica Charantia*) to Different Cucurbitaceae Root Stocks

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Abstract

The study was conducted to evaluate the morphological, agronomic and economic performance of grafted bitter gourd. Specifically to determine the effects of different rootstocks on growth, physiological responses, yield and returns of bitter gourd. The experiment was laid out using Randomized Complete Block Design (RCBD) with three treatments replicated three times. The Treatments were: T_1 – non-grafted bitter gourd, T_2 – bitter gourd grafted onto ridge gourd *(Luffa acutangula),* and T_3 – bitter gourd grafted onto squash (*Cucurbita maxima).* Results showed that Grafting on ridge gourd rootstock gave higher number of secondary and tertiary branches, the biggest stem diameter and longest root. Significant effects were also observed in some reproductive and yield characters. Grafted plants on ridge gourd rootstock resulted to the highest number of female flowers, marketable fruits, total fruits per plot, fruits per plant, weight of fruit, length of fruit, yield per plant, yield per plot and yield per hectare. The highest yield of 15.61 t ha-1 was obtained from plants grafted on ridge gourd rootstock. The fruit diameter; vine length; and number of non-marketable fruits were not affected by the treatments. Cost and return analysis revealed that the grafted ampalaya using ridge gourd rootstock secured the highest net income and ROI of 186.97% which indicates higher profitability than the rest of the treatments. From the study conducted, it was found out that the most suitable rootstock for grafted ampalaya for better growth, yield, stress tolerance, and profitability under field condition is the ridge gourd *(Luffa acutangula).*

Keywords: Agronomic Performance, Bitter Gourd, Cucurbitaceae Rootstocks, Grafting, Profitability, Yield Performance

Introduction

Bitter gourd (*Momordica charantia L.),* locally known as ampalaya, is one of the most widely consumed vegetables in the Philippines because of its nutritional, medicinal, and economic value. Despite its importance, production in Cagayan Valley remains lower than in leading regions, indicating the need for improved cultivation strategies (PSA, 2023). One promising approach is grafting, a horticultural technique that combines desirable rootstock and scion traits to improve plant growth, stress tolerance, yield, and disease resistance (Lee, 2010). Although grafting has been widely studied in other cucurbit crops, research on grafted bitter gourd remains limited, particularly regarding suitable Cucurbitaceae rootstocks, morphological responses, yield performance, and profitability. This study therefore evaluates the growth, yield, and profitability of grafted bitter gourd using different Cucurbitaceae rootstocks under local growing conditions.

1.1 Background of the Study on Grafted Bitter Gourd Using Cucurbitaceae Rootstocks

Bitter gourd (*Momordica charantia L.*) is among the top vegetable crops consumed in the Philippines and other tropical countries because of its nutritional and medicinal properties. In 2022, the Philippines produced approximately 88,675 metric tons of bitter gourd, with Cagayan Valley contributing around 5,113 metric tons (PSA, 2023). Despite this contribution, the region ranked only fifth nationally in production, highlighting opportunities to improve productivity and farming practices. Bitter gourd is valued for its rich content of vitamins A, B, and C, iron, calcium, and phosphorus (Department of Agriculture, Regional Field Office in Region 2, 2015). Studies also report its anti-diabetic, antioxidant, and lipid-regulating properties, including improved glycemic control and enhanced insulin sensitivity (Kumar et. al.,, 2024; Sitepu and Tobing, 2024; Akeerele et. al, 2023). In the Philippines, bitter gourd is widely integrated into traditional cuisine and herbal medicine because of its therapeutic value (Gayathry & John, 2022).

Grafting is an important horticultural practice that combines two genetically distinct plants to enhance crop performance. This technique improves stress tolerance, nutrient uptake, flowering, fruiting, and overall yield (Lee, 2010). In cucurbit crops, grafting has been associated with improved vegetative growth, higher fruit yield, and increased tolerance to environmental stresses (Davis, 2008). Despite these advantages, studies specifically focused on grafted bitter gourd remain limited. Existing research lacks standardized grafting protocols and comprehensive evaluation of compatible Cucurbitaceae rootstocks for bitter gourd production. Furthermore, there is insufficient information regarding the morphological, physiological, and agronomic responses of grafted bitter gourd under drought and environmental stress conditions.

1.2 Themes and Insights from Related Literature on Grafted Bitter Gourd Production

Several studies emphasize the role of grafting in improving crop productivity, disease resistance, and stress tolerance in cucurbit crops. Grafting has historically been used to reduce losses caused by soil-borne diseases and environmental stresses while improving yield and crop quality (Peil, 2003; Tsaballa et. al.,, 2021; Lee et. al.,, 2010). Research on rootstock selection demonstrates that Cucurbitaceae rootstocks significantly improve plant vigor and yield. Grafting cucumbers onto Cucurbita maxima × C. moschata rootstocks improved fruit number and fruit weight under nematode-infested conditions (El-Tawashy, 2024; Kamel & Taher, 2021). Similar benefits were observed in watermelon, melon, and squash through enhanced disease resistance and productivity (Johnson & Kao, 2006; Stapleton et. al.,, 2023). Studies involving sponge gourd and pumpkin rootstocks revealed high graft compatibility with bitter gourd, with graft success rates ranging from 81.3–89% (Tamilselvi & Pugalendhi 2017). Sudaria et. al., (2023) further reported that grafted bitter gourd plants exhibited earlier female flowering, lower disease incidence, improved shelf life, and higher chlorophyll and carotenoid content compared to non-grafted plants. Rootstock selection also affects drought tolerance and stress adaptation. Bottle gourd rootstocks possess longer root systems and improved antioxidant activity under drought conditions (Gisbert-Mullor et. al., 2023; Kumar et. al., 2017). Pumpkin and luffa rootstocks improved heat and low-temperature tolerance in bitter gourd by enhancing membrane stability and physiological regulation (Frontiers in Plant Science, 2022; Peng et. al., 2024). Comparative studies showed that grafted bitter gourd demonstrated improved vegetative vigor, higher fruit yield, and enhanced nutrient uptake efficiency compared with non-grafted plants (Tamilselvi and Pugalendhi, 2017; Şavşatlı and Karataş, 2021). However, some studies also reported variable effects of grafting on fruit quality depending on rootstock–scion combinations and environmental conditions (Rouphael et. al., 2010; Turhan et. al., 2011; Al-Harbi et. al., 2016).

1.3 Local, National, and Global Context of Grafted Bitter Gourd Production

Globally, vegetable grafting has become an important agricultural practice for enhancing crop resilience, improving yield, and reducing losses caused by diseases and environmental stress (Lee et. al., 2010). Countries such as Japan and Korea pioneered grafted vegetable production to address soil-borne diseases aggravated by continuous cropping systems. In the Philippines, bitter gourd production remains economically important for small-scale farmers because of high market demand and profitability (A. B., & Neerugatti, M. P. 2023). However, production efficiency remains constrained by pests, diseases, and climate-related stresses. Root-knot nematodes and cucurbit leaf curl disease are among the major biotic stresses reducing bitter gourd productivity (Singh et. al., 2019; Bhati et. al., 2019; Neoh et. al., 2023). Environmental factors such as drought, high temperature, and declining soil health also negatively affect crop growth and yield ("Impact of Climate Change on Perennial Vegetables Production and Mitigation Strategies", 2023; Choudhary et. al., 2022; Solankey et. al., 2021). Optimal cultivation conditions for bitter gourd include well-drained sandy loam to silty loam soils with a pH range of 6.0 to 7.5 (Valyaie et. al., 2021; Jat et. al., 2024). Studies also show that organic amendments such as vermicompost and poultry manure improve nutrient use efficiency, plant growth, and fruit yield (Ghimire et. al., 2023).

1.4 Theoretical or Conceptual Basis of Rootstock–Scion Interaction in Grafted Bitter Gourd

The study is anchored on the principle that grafting enhances crop performance through beneficial rootstock–scion interactions. Rootstocks influence nutrient uptake, water absorption, stress tolerance, disease resistance, and physiological responses, thereby affecting plant growth and productivity (Lee et. al., 2010). Studies on cucurbits demonstrate that compatible rootstocks improve vegetative vigor, fruit yield, and stress adaptability by enhancing antioxidant activity, biomass accumulation, and water-use efficiency (Davis, 2008; Liu et. al., 2016; Rouphael et. al., 2008). Rootstocks also affect fruit quality, mineral uptake, and biochemical composition through physiological and metabolic interactions between the rootstock and scion (Rouphael et. al., 2010). The concept of drought-adaptive and constitutive responses further explains the performance of grafted plants under water stress. Drought-adaptive traits improve tolerance under severe stress, while constitutive traits improve productivity under both normal and stress conditions (Boopathi, 2012; Tuberosa, 2012).

1.5 Research Gaps and Rationale for Grafted Bitter Gourd Production

Although grafting technology is widely used in cucurbit crops, research focusing specifically on bitter gourd remains limited. Existing studies lack standardized grafting protocols for *Momordica charantia L.* and provide limited information regarding compatible rootstock–scion combinations. There is also insufficient understanding of the morphological and physiological responses of grafted bitter gourd under drought and environmental stress conditions. While previous studies demonstrated improved growth, disease resistance, and fruit quality in grafted cucurbits, limited data exist on the profitability and agronomic performance of grafted bitter gourd under Philippine conditions. These gaps justify the conduct of this study to evaluate selected Cucurbitaceae rootstocks for improving the growth, yield, and profitability of bitter gourd production.

1.6 Alignment with Relevant Sustainable Development Goals (SDGs)

This study aligns with SDG 2 – Zero Hunger by promoting improved bitter gourd productivity and food availability through enhanced grafting technologies. It also supports SDG 8 – Decent Work and Economic Growth by improving farm profitability and reducing production risks for vegetable farmers. The study further contributes to SDG 12 – Responsible

Consumption and Production through efficient water use, reduced disease losses, and sustainable crop management practices. In addition, it supports SDG 13 – Climate Action by exploring grafting strategies that improve drought tolerance and climate resilience in vegetable production systems.

1.7 Importance of the Study to Multidisciplinary Sustainability

The study contributes to socio-economic sustainability by improving the productivity and profitability of bitter gourd farming for small-scale producers. Enhanced drought tolerance and disease resistance may reduce production losses and increase income stability for farmers. The research also contributes to environmental and agricultural sustainability by promoting efficient water use and reducing dependence on chemical inputs through improved rootstock resistance. Increased bitter gourd production may also improve access to nutrient-rich vegetables that contribute to food and nutritional sustainability. Furthermore, the study supports climate resilience and institutional sustainability by providing information that can guide agricultural extension programs, crop management strategies, and future research on grafted vegetable production systems.

Material and methods

2.1 Research Design

A Randomized Complete Block Design (RCBD) was used in this study to minimize variability among the experimental units. The total land area was 400 m2 including spaces between blocks and plots. The area was divided into three (3) equal blocks to represent three (3) replications. Each block was further subdivided into three (3) equal plots (6 x 6 m) representing the four (3) treatments. The treatments evaluated were: T_1- Non-grafted Bitter gourd T_2-Ridge Gourd (Luffa acutangula) + Bitter gourd , T_3- Squash (Cucurbita maxima) + Bitter gourd

2.2 Locale of the Study

The study was conducted at the research area of Cagayan State University Lal-lo Campus, located in Sta. Maria, Lal-lo, Cagayan, from January to April 2026. The site was selected due to its suitability for the conduct of the study and the availability of the necessary resources and environmental conditions required for the research.

2.3 Grafting and Healing Process

For the grafting process, side grafting was employed. This involves making a precise 35-45-degree angled cut into the side of the rootstock. The scion was placed against the exposed cambium layer of the rootstock. To ensure the rootstock has sufficient carbohydrates, one cotyledon was intact at the time of grafting. A grafting clip was applied to secure the graft union, and a bamboo stick was provided for additional support. After grafting, the plants were placed inside a healing chamber maintained at a temperature of 25–30°C and 85–95% relative humidity (RH) to promote successful graft union healing. Temperature and relative humidity inside the chamber were regularly monitored using a digital thermo-hygrometer to ensure favorable environmental conditions. This controlled environment minimized plant stress and enhanced the integration between the scion and rootstock.

When the relative humidity exceeded the optimum level, the chamber covering was partially opened and gradually removed in stages to slowly reduce moisture content and prevent sudden environmental shock to the grafted seedlings. Daily monitoring and adjustment of environmental conditions were conducted to ensure proper recovery and maintain graft stability.

2.4 Data Gathering Procedures

The study evaluated the morphological, flowering, and agronomic responses of grafted bittergourd using several parameters. Morphological parameters included the number of secondary branches, which were counted manually during the peak vegetative growth stage; the length of secondary branches, measured from the point of attachment on the primary stem up to the terminal tip using a measuring tape; the number of tertiary branches, which were counted from the secondary branches considering only healthy and fully developed branches; and the length of tertiary branches, measured from the point of emergence to the terminal end. Vine length was measured from the soil surface up to the apical tip of the main vine, while stem diameter was determined using a digital vernier caliper approximately 2 cm below the grafting union. Root length was measured at the termination of the experiment after carefully washing the roots and determining the distance from the base of the stem to the tip of the longest root. Flowering behavior included the number of days to male and female flowering, counted from transplanting until the appearance of the first fully opened flowers. The total number of male and female flowers produced per plant was also recorded throughout the flowering period. Agronomic parameters included the total fruits per plot, fruits per plant, fruit weight, marketable and non-marketable fruits per plot, fruit length, and fruit diameter. Yield per plant and yield per plot were determined by weighing the harvested fruits using a digital weighing scale, while yield per hectare was computed and expressed in tons per hectare. Return on Investment (ROI) was also computed to determine the profitability of each treatment, wherein net income was obtained by subtracting the total production cost from the gross income, and gross income was computed by multiplying the total yield by the selling price.

2.9 Statistical Analysis

The collected data were subjected to Analysis of Variance (ANOVA) to determine significant differences among treatments in terms of morphological, agronomic, and economic parameters. The analysis was performed using the Statistical Tool for Agricultural Research (STAR) software. Whenever significant differences among treatment means were observed, the Least Significant Difference (LSD) test was used to compare the means. All statistical analyses were conducted at the 5% level of significance ($p \leq 0.05$).

Results and Discussion

3.1 Morphological and Growth Performance of Grafted Bitter Gourd

3.1.1 Mortality Rate and Grafting Success

The non-grafted bitter gourd recorded 100% survival at 14 days after transplanting, indicating successful establishment under field conditions. Among the grafted treatments, ridge gourd + bitter gourd showed a low mortality rate of 4.17%, while squash + bitter gourd recorded 6.25% mortality. In contrast, bottle gourd + bitter gourd exhibited a very high mortality rate of 93.75%, indicating poor survival and graft incompatibility. In terms of grafting success, ridge gourd + bitter gourd achieved the highest survival rate at 7 and 14 days after grafting, followed closely by squash and bottle gourd rootstocks. The results indicate that compatibility between rootstock and scion greatly influenced plant survival and graft establishment. The low mortality rates observed in ridge gourd and squash rootstocks suggest efficient graft union formation and successful physiological integration. In contrast, the poor performance of bottle gourd indicates incompatibility and severe transplant stress. These findings emphasize the importance of selecting compatible rootstocks to ensure successful grafting and field establishment of bitter gourd.

3.1.2 Crop Stand, Plant Vigor, and Pest Occurrence

Ridge gourd-grafted bitter gourd plants exhibited more vigorous growth, healthier foliage, better branching, and improved crop stand compared with non-grafted plants. These plants maintained greener leaves and adapted well under field conditions throughout the growing period. In contrast, bottle gourd-grafted plants showed weak growth, poor establishment, stunted development, and high mortality. Pest and disease incidence remained minimal during the experiment, although aphids, beetles, and fruit flies were occasionally observed in the field. The improved vigor observed in ridge gourd-grafted plants may be attributed to enhanced nutrient and water uptake provided by the vigorous rootstock. Better vegetative growth and healthy foliage indicate improved physiological efficiency and adaptability under field conditions. The low incidence of pests and diseases further suggests that proper crop management practices, including field sanitation and monitoring, contributed to maintaining healthy plant growth during the experiment.

3.2 Morphological Characteristics of Grafted Bitter Gourd

3.2.1 Secondary and Tertiary Branch Development

Ridge gourd-grafted bitter gourd produced the highest number of secondary and tertiary branches compared with the non-grafted and squash-grafted treatments. Significant differences were observed in the number of secondary and tertiary branches, while the lengths of secondary and tertiary branches were not significantly affected by grafting treatments. The increased branching observed in ridge gourd-grafted plants suggests improved nutrient absorption and stronger vegetative growth. Greater branching may enhance canopy formation and photosynthetic activity, which can contribute to improved productivity. The non-significant effect on branch length indicates that branch elongation may have been more influenced by the genetic characteristics of the scion rather than by the rootstock. These findings conform with the reports of Davis et. al., Kumar et. al., Lee et. al., Oda (2007), and Colla et. al., who emphasized the role of vigorous rootstocks in improving vegetative growth and canopy development in cucurbit crops.

3.2.2 Vine Length, Stem Diameter, and Root Length

Vine length was not significantly affected by grafting treatments, although squash-grafted bitter gourd numerically produced the longest vines. In contrast, significant differences were observed in stem diameter and root length. Ridge gourd-grafted bitter gourd produced the thickest stems and the longest roots compared with non-grafted and squash-grafted plants. The thicker stems and longer roots observed in ridge gourd-grafted plants indicate improved compatibility and enhanced nutrient transport between the rootstock and scion. Stronger root systems improve water and nutrient uptake efficiency, leading to better vegetative growth and plant stability. The non-significant effect on vine length suggests that vine elongation was less responsive to rootstock influence and may have been largely controlled by the scion genotype. These findings agree with the reports of Colla et. al., Davis et. al., Lee et. al., and Oda, who reported improved root development, stem growth, and stress tolerance in grafted cucurbit crops.

3.3 Flowering Behavior of Grafted Bitter Gourd

3.3.1 Days to Flower Appearance

Significant differences were observed in days to female flower appearance, while days to male flower appearance were not significantly affected by grafting treatments. Ridge gourd-grafted and squash-grafted bitter gourd produced female flowers earlier than non-grafted plants. Male flower appearance was statistically similar among treatments. Earlier female flowering in grafted plants indicates enhanced reproductive development due to improved nutrient uptake and plant vigor. Early flowering is advantageous because it may lead to earlier fruit set and harvesting. The non-significant effect on male flower appearance suggests that male flower initiation was more influenced by the scion genotype and environmental conditions than by the rootstock. These findings support the reports of Oda. M., (2007), Lee et. al., Kumar et. al., and Colla et. al., who stated that vigorous rootstocks improve reproductive performance and flowering behavior in cucurbit crops.

3.3.2 Number of Male and Female Flowers

The number of male flowers was not significantly affected by grafting treatments. However, ridge gourd-grafted bitter gourd produced the highest number of female flowers compared with non-grafted and squash-grafted plants. The increased production of female flowers in ridge gourd-grafted plants indicates improved reproductive efficiency and assimilate allocation toward fruit-bearing flowers. Female flowers are directly associated with fruit production; therefore, increased female flowering may contribute to higher yield potential. The non-significant effect on male flower production suggests that grafting exerted greater influence on female reproductive development. These findings corroborate the reports of Colla et. al., Davis et. al., Lee et. al., and Oda, who emphasized that vigorous rootstocks enhance flowering behavior and reproductive growth in grafted cucurbits.

3.4 Fruit Characteristics of Grafted Bitter Gourd

Table 3. *Fruit Characteristics of Grafted Bitter gourd (*Momordica charantia*) as Affected by Different Cucurbitaceae Rootstocks.*

Treatments	Marketable Fruits per Plot	Non-marketable Fruits per Plot	Fruit Length (cm)	Fruit Diameter (cm)
T_1 – Non-grafted Bitter gourd	171.67 ab	21.67	28.92 b	4.36
T_2 – Ridge Gourd + Bitter Gourd *(Luffa acutangula)*	196.67 a	24.67	31.63 a	4.47
T_3 – Squash + Bitter gourd (*Cucurbita maxima*)	155.67 b	19.00	30.39 ab	4.41
ANOVA Result	*	NS	*	*
C.V. %	6.81	21.18	2.49	2.25
LSD	26.97	-	1.71	

Note: Means with the same letters are not significantly different at 5% level using LSD.
***NS** – Not Significant*
** - Significant*

3.4.1 Marketable and Non-Marketable Fruits

Significant differences were observed in the number of marketable fruits per plot, while non-marketable fruits were not significantly affected by grafting treatments. Ridge gourd-grafted bitter gourd produced the highest number of marketable fruits, whereas squash-grafted plants produced the lowest. The higher number of marketable fruits obtained from ridge gourd-grafted plants indicates improved fruit quality and reproductive performance. Enhanced nutrient and water uptake likely contributed to better flower retention and fruit development. The non-significant differences in non-marketable fruits suggest that environmental conditions and crop management practices may have exerted greater influence on fruit defects than rootstock effects. These findings support the reports of Colla et. al., Davis et. al., Lee et. al., and Oda regarding the positive effects of vigorous rootstocks on fruit quality and productivity.

3.4.2 Fruit Length and Fruit Diameter

Fruit length was significantly affected by grafting treatments, with ridge gourd-grafted bitter gourd producing the longest fruits. Fruit diameter, however, was not significantly influenced by the different rootstocks. The longer fruits observed in ridge gourd-grafted plants suggest improved nutrient translocation and assimilate accumulation that promoted fruit expansion and development. Longer fruits are desirable because they contribute to improved marketability and economic value. The non-significant effect on fruit diameter indicates that fruit thickness may have been primarily controlled by the genetic characteristics of the scion. These findings are consistent with the reports of Colla et. al., Davis et. al., Lee et. al., and Kumar et. al., who reported that grafting improved fruit size while some fruit parameters remained less responsive to rootstock effects.

3.5 Fruit Production of Grafted Bitter Gourd

Table 4. *Fruit Production of Grafted Bitter gourd (*Momordica charantia*) as affected by different Cucurbitaceae Rootstocks.*

Treatments	Total Fruits per Plot	Fruits per Plant	Fruit Weight (g)
T_1 – Non-grafted Bitter gourd	193.33 ab	9.67 b	209.74 b
T_2 – Ridge Gourd + Bitter Gourd *(Luffa acutangula)*	221.33 a	14.00 a	260.67 a
T_3 – Squash + Bitter gourd (*Cucurbita maxima*)	174.67 b	9.33 b	230.89 b

ANOVA Result	*	*	*
C.V. %	6.30	13.38	5.96
LSD	28.05	3.34	25

Note: Means with the same letters are not significantly different at 5% level using LSD.
***NS** – Not Significant*
** - Significant*

3.5.1 Total Fruits per Plot and Fruits per Plant

Significant differences were observed in total fruits per plot and fruits per plant. Ridge gourd-grafted bitter gourd produced the highest number of fruits per plot and per plant compared with the non-grafted and squash-grafted treatments. The superior fruit production observed in ridge gourd-grafted plants indicates enhanced reproductive efficiency and improved assimilate distribution. Vigorous root systems likely improved nutrient and water uptake, leading to better flower retention and fruit set. Increased fruit production also suggests effective rootstock–scion compatibility and improved physiological performance. These findings agree with the reports of Colla et. al., Davis et. al., Oda, and Lee et. al., who reported increased fruit production in grafted cucurbit crops due to enhanced plant vigor and nutrient uptake efficiency.

3.5.2 Fruit Weight

Fruit weight was significantly affected by grafting treatments. Ridge gourd-grafted bitter gourd produced the heaviest fruits, followed by squash-grafted plants, while non-grafted bitter gourd produced the lightest fruits. The heavier fruits observed in ridge gourd-grafted plants indicate improved assimilate accumulation and enhanced fruit development resulting from vigorous root activity. Improved nutrient uptake and translocation likely promoted better cell enlargement and fruit growth. Increased fruit weight contributes directly to higher yield and improved market value. These findings corroborate the reports of Colla et. al., and Davis et. al., who emphasized the beneficial effects of vigorous rootstocks on fruit size and marketable quality in cucurbit crops.

3.6 Agronomic Performance of Grafted Bitter Gourd

Table 5.*Agronomic Performance of Grafted Bitter gourd (*Momordica charantia*) as Affected by Different Cucurbitaceae Rootstocks.*

Treatments	Yield per Plant (kg)	Yield per Plot (kg)	Yield (t ha⁻¹)
T_1 – Non-grafted Bitter gourd	2.03 b	36.14 b	9.02 b
T_2 – Ridge Gourd + Bitter Gourd *(Luffa acutangula)*	3.51 a	49.67 a	15.61 a
T_3 – Squash + Bitter gourd (*Cucurbita maxima*)	2.17 b	40.29 b	9.65 b
ANOVA Result	*	*	*
C.V. %	17.92	8.25	2.49
LSD	26.97	-	1.71

Note: Means with the same letters are not significantly different at 5% level using LSD.
***NS** – Not Significant*
** - Significant*

3.6.1 Yield per Plant and Yield per Plot

Yield per plant and yield per plot were significantly affected by grafting treatments. Ridge gourd-grafted bitter gourd produced the highest yield per plant and per plot compared with non-grafted and squash-grafted treatments. The increased yield observed in ridge gourd-grafted plants may be attributed to improved vegetative growth, greater female flower production, enhanced fruit set, and better nutrient absorption efficiency. Strong root systems likely improved physiological efficiency and assimilate production necessary for fruit development. These findings support the reports of Colla et. al., Davis et. al., and Oda, who reported that vigorous rootstocks significantly improve yield performance and productivity in grafted vegetable crops.

3.6.2 Yield per Hectare

Significant differences were observed in yield per hectare. Ridge gourd-grafted bitter gourd produced the highest yield, while non-grafted and squash-grafted plants produced lower yields. The superior yield performance of ridge gourd-grafted bitter gourd demonstrates the beneficial effect of vigorous rootstocks on productivity and stress tolerance. Improved root development enhanced water and nutrient acquisition, resulting in better vegetative and reproductive growth. The lower yield observed in the other treatments suggests reduced efficiency in supporting fruit production compared with ridge gourd rootstock. These findings are consistent with the reports of Oda and Colla et. al., who stated that grafting improves yield and stress tolerance in cucurbit crops through enhanced root activity and nutrient uptake.

3.7 Cost and Return Analysis

Cost and Return Analysis. Although T_2 incurred a relatively higher production cost amounting to Php 272,033.00 due to additional expenses associated with grafting materials and labor, the substantial increase in yield compensated for the added cost of production.

Table 6. *Cost and Return Analysis of of grafted Bitter gourd (*Momordica charantia*) as affected by different Cucurbitaceae rootstocks.*

Treatment	Yield in Kg	Cost of production	Gross Income	Net Income	ROI %
T_1- Non-grafted control	9023.33	254,456	451166.5	196,710	77.31
T_2- ridge gourd + bitter gourd	15,613	272,033	780650	508,618	186.97
T_3- smooth gourd + bitter gourd	9646.67	275,433	482333.5	206,901	75.12

The non-grafted plants (T_1) produced a yield of 9,023.33 kg ha^{-1} with a gross income of Php 451,166.50 and net income of Php 196,710.00. It recorded **an** ROI of 77.31%, indicating moderate profitability. Similarly, grafted plants using smooth gourd rootstock (T_3) yielded 9,646.67 kg ha^{-1} with a gross income of Php 482,333.50 and net income of Php 206,901.00. Despite having slightly higher yield than the control, T_3 recorded a lower ROI of 75.12% due to its relatively higher production cost amounting to Php 275,433.00.The results suggest that grafting Bitter gourd onto ridge gourd rootstock significantly improved not only yield performance but also economic returns. The higher profitability obtained from T_2 demonstrates that the additional investment required for grafting technology can be justified by the substantial increase in productivity and income.

4. Conclusion and Recommendations

The study revealed that grafting significantly improved the morpho-physiological characteristics, flowering behavior, yield, stress tolerance, and profitability of Bitter gourd production under field conditions. Among the Cucurbitaceae rootstocks evaluated, ridge gourd (*Luffa acutangula)* was identified as the most compatible and effective rootstock, producing superior vegetative growth, earlier female flowering, higher fruit yield, greater yield components, and improved economic return compared to non-grafted plants and squash-grafted plants. The use of ridge gourd rootstock also enhanced plant vigor and productivity, making grafting a promising technology for improving Bitter gourd production.

Farmers and growers are encouraged to use ridge gourd (*Luffa acutangula*) as rootstock for grafted Bitter gourd production to improve plant growth, yield, stress tolerance, and profitability. Further studies should be conducted using other Cucurbitaceae rootstocks to identify additional compatible rootstocks for Bitter gourd production. Future researchers may also evaluate grafted Bitter gourd under different environmental conditions, seasons, and soil types, including studies focusing on disease resistance, water-use efficiency, and postharvest quality.

The study was limited to the evaluation of three treatments under field conditions using selected Cucurbitaceae rootstocks and was conducted within a specific location and growing season. The investigation focused mainly on morphological characteristics, flowering behavior, yield, and profitability, while other factors such as long-term disease resistance, water-use efficiency, postharvest quality, and performance under varying environmental conditions were not extensively evaluated.

Compliance with ethical standards

The authors declare no conflict of interest. This study received no external funding and was conducted with the permission and cooperation of the concerned institution and participants involved in the research.

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