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Evaluating the Growth, Yield, and Resilience of F1, F2, and Open-Pollinated Squash Varieties: A Comparative Study

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Abstract

In our country, malnutrition poses a severe challenge due to the limited production of nutritious food. Developing disease and pest-resistant varieties such as squash is crucial to tackle this issue. A recent study conducted in Can-ayan, Malaybalay City, Bukidnon, from July to October 2019, explored the growth and yield performance of different squash varieties (OP, F1, F2). The research aimed to understand the variations in yield, horticultural and reproductive characteristics, inbreeding depression, and profitability of growing diverse squash genotypes. The results, obtained through a Randomized Complete Block Design with five treatments, highlighted significant differences in traits among the genotypes. Notably, inbreeding depression was observed in marketable fruit production and yield. The analysis revealed varying traits across genotypes, with Gracia hybrid emerging as the most profitable choice, showing positive returns on investment. This study sheds light on the importance of developing resilient crop varieties like squash to address malnutrition challenges effectively.

Keywords: Squash Varieties, Growth performance, Yield variations, Inbreeding depression, Resilient crop variety

INTRODUCTION

In the Philippines, a third-world country, a significant portion of the population suffers from malnutrition due to low agricultural yields and inefficient plant nutrient absorption, resulting in inadequate nutrition for the people. Various crops have the potential to address this issue, such as squash, which is rich in vital nutrients including Vitamins A, B, C, Calcium, Phosphorus, and Iron. This nutritious crop could play a key role in combating malnutrition in the country. Squash is a staple vegetable in the Philippines, and its raw materials are used to create a variety of products such as noodles, soup, baby food, snacks, and bread (Cruz, 2009). However, challenges in production have limited the supply of squash.

Squash is a highly valued crop in the province of Bukidnon, where a limited selection of hybrid squash seeds is available in the local market. The Suprema hybrid is the preferred variety among farmers due to its excellent adaptability to Bukidnon's growing conditions and its popularity in the market. These hybrid squash seeds are favored by farmers because they are resistant to insect pests and diseases (East-West et al., 2009). However, the cost of these planting materials can be prohibitive for many farmers. Consequently, some farmers encounter challenges due to the high input costs and may be forced to switch to other crops. As a result, small-scale gardeners primarily use F2 seeds for personal consumption. In contrast, large-scale producers prefer hybrid varieties due to their impressive yield performance, relying on specialized seed companies for these hybrids. F2 seeds could be a feasible alternative for squash if they are not susceptible to inbreeding depression, a common issue in cross-pollinated crops. While inbreeding depression is a concern in many cross-pollinated species, it has been notably absent in cucumber, with varying levels observed in other species (Cramer & Wehner, 1999).

Researchers analyzed various commercially available squash varieties to collect pertinent data to assess the effects of inbreeding on squash reproductive traits and yield. The results of this study were valuable for farmers, particularly those with limited resources who are unable to invest in hybrid seeds. This research helped them determine the most suitable squash genotype for their farm. The study was carried out in Can-Ayan, Malaybalay City, Bukidnon, from July 2019 to October 2019.

The study was designed to examine the yield performance and phenotypic variation among the OP variety, F1, and F2 squash (*Cucurbita maxima*) genotypes. To achieve this, the research set out specific objectives to delve deeper into the characteristics of these squash varieties. Firstly, it aimed to meticulously analyze the horticultural traits displayed by the OP variety, F1, and F2 squash genotypes, providing valuable insights into their growth patterns and physical attributes. Additionally, the study sought to investigate the reproductive characteristics of these genotypes, shedding light on their breeding behaviors and potential for seed production. Furthermore, the research aimed to explore the presence of inbreeding depression, specifically within the F2 squash genotypes, to understand the genetic implications of such occurrences. Lastly, the study evaluated the economic aspects by determining the profitability of cultivating different squash genotypes, providing valuable information for farmers and agricultural practitioners. The research aimed to contribute to the academic understanding of squash genotypes through these focused objectives, offering insights into their horticultural, reproductive, genetic, and economic dimensions in agricultural science.

METHODOLOGY

Experimental Design and Treatment. The experiment used a randomized complete block design (Appendix Figure 1). Five treatments were employed, and each treatment was replicated three times. The treatments included three squash F1 hybrid varieties (Suprema, Engrande, and Gracia), the open-pollinated Rizalina, and the Suprema F2 variety.

Materials and Equipment. The experiment used the following materials: fertilizer, bamboo sticks for labeling, marker pens, a knife for pollination, bolo and digging tools, a record book for recording data needed for evaluation, a meter stick, a tape measure, and a weighing scale.

Planting Materials. The study utilized three (3) commercial F1 hybrid squash varieties, an open-pollinated (OP) variety, and F2 seeds of Suprema hybrid as planting materials. The hybrid and OPV seeds were procured from a local agricultural store in Malaybalay City. In contrast, the Suprema F2 seeds were collected from the farmers' field by selecting an extensive fruit and extracting and sun-drying the seeds.

Cultural Management and Practices

Soil Sampling and Analysis. A composite sample was gathered in a zigzag pattern at the trial site. A one (1) kilogram soil sample was sent to the Soil and Plant Analysis Laboratory (SPAL) in the Department of Soil Science for analysis. The recommended rate for inorganic fertilizer was (40-10-45 kg/ha NPK) as indicated in Appendix Table 21.

Land Preparation. The land was plowed twice to aerate the soil and thoroughly mix all plant residues to aid decomposition. A week after plowing, harrowing was carried out further to break down large soil clods into finer particles. Before planting, furrows were prepared and spaced three (3) meters apart.

Planting. The seeds were planted directly into a hole 8 cm deep and 5 cm wide along the furrows at a rate of 2 seeds per hill. The planting distance between rows was 3 m, and between hills was 1 m. Thinning was carried out after two weeks, leaving one seedling per plant.

Crop Establishment. The vines were trained to crawl within the plot and evenly distribute over the area. They were also adequately trained to help prevent the growth of weeds in the plot.

Care and Maintenance. Weeding was consistently carried out throughout the experiment to minimize competition between plants and weeds for essential nutrients, moisture, and other resources crucial for plant growth. No manual irrigation was necessary since the plants were planted during the wet season.

Fertilizer Application. Before planting, one tablespoon of complete fertilizer (14-14-14) was applied as a basal application. Fourteen days after planting, one tablespoon of Urea (46-0-0) was side dressed about 10cm from the seedling. During flowering, a mixture of one-part Urea and one-part Muriate of Potash (0-0-60) was applied per hill at three-week intervals until the final harvest.

Supplemental pollination. Supplemental pollination was conducted in the early morning within two months of the first female flower opening. This involved handpicking male flowers, removing the petals to expose the pollen-bearing structure, and transferring the pollen to the center of the female flower.

Harvesting. The harvest took place 85 to 100 days after planting when the fruit shell began to harden, displaying a yellow or orange tinge with a dull exterior color. The fruits were harvested weekly with a portion of the peduncle attached to extend their storage life.

Data gathered

A. Vegetative and Reproductive Traits

1. Length (cm) of the main vines fifty (50) days after planting—This was taken from the four (4) data plants in each treatment plot.
2. Number of days to open the first female flower—The number of days to the flowering of the female flower was counted from the date of planting until the emergence of the first female flower from the four (4) data plants in each treatment.
3. Number of days to opening of first male flower- This was counted from the planting date until the emergence of the first male flower from the four (4) data plants in each treatment.
4. Number of female flowers per plant– This was counted from the emergence of the first female flower in two (2) months from the four (4) data plants in each treatment.
5. Number of male flowers per plant- This was counted from the emergence of the first male flower in two (2) months of flowering from the four (4) data plants in each treatment.
6. Percent fruit set- The percent fruit set was determined by counting the number of fruits developed with hand pollination within two (2) months of flowering in four (4) plant samples. This was calculated using the formula below.

$$\%\text{Fruit Set} = \frac{Number\ of\ developed\ fruits}{\substack{Number\ of\ female\ flower \\ developed\ in\ 2\ month\ period\ per\ plant}} \times 100$$

7. Days to first harvest- This was determined by counting the days from planting to the first harvest.
8. Days to last harvest- This was determined by counting the number of days from planting to the last harvest.

B. Yield and Yield Components

1. Average fruit weight (kg)—The weight per plant fruit was determined by weighing the five (5) fruits per treatment in each replication.
2. Length and diameter (cm) of fruit—This was measured by measuring the length and width of the five fruits randomly selected from the data hills. The fruit was cut longitudinally using a ruler, and the length and width were measured. The width was taken at the most comprehensive portion of the fruit.
3. Number of marketable fruits- This was determined by counting the number of fruits harvested from four (4) data plants per treatment in each replication.
4. Number of non-marketable fruits- This was determined by counting the number of non-marketable fruits harvested from the four (4) data plants per treatment in each replication. Non-marketable fruits were described as distorted, small in size, with discolored scars caused by the beetle, the presence of irregular holes,

and dark leathery lesions sunken into the fruit (https://www.plantvillage.org/en/topics/squash/infos/diseases_and_pests_description_uses_propagation, as of December 2015).

5. Marketable yield per plant (kg)—This was calculated by weighing the marketable fruits from the four (4) data plants per treatment in each replication.
6. Non-marketable yield per plant (kg) - This was taken by weighing the non-marketable fruits from the four (4) data plants per treatment in each replication m^2.
7. Marketable yield (tons/ha) - The yield per hectare was computed using the formula below.

$$\text{Marketable Yield (tons/ha)} = \frac{\frac{plot\ yield\ (kg)}{plot\ area} x10{,}000m2}{1000kg/tons}$$

C. Horticultural Characteristics

The description and figures used in gathering the horticultural data were based on the Test Guidelines for the Conduct of the DUS Test on Squash PVPD (n.d.).

a. Fruit shape- This was described accordingly, as shown in Figure 1.

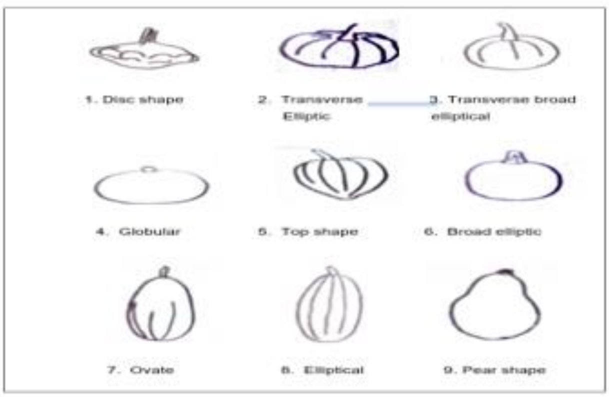

Figure 1
Fruit shape of squash

b. Fruit flesh color- This was rated using the rating scale below.

Rating	Description
One	yellow
Two	yellowish-orange
Three	orange

c. Fruit skin color- This was rated using the rating scale below.

Rating	Description
One	green
Two	cream
Three	yellow
Four	orange brown

D. Reaction to Pests and Diseases

1. Reaction to Insect Pests and Diseases

This was determined using the rating scale for insect pests and disease resistance described by NSIC, as shown in the table. The genotypes were rated at flowering and fruit formation (http://nseedcouncilbpinsicpvpo.com.ph as of March 2016).

$$\%\ \text{fruit damage} = \frac{\#\ of\ damage\ fruit}{Total\ \#\ of\ \ fruits/plot} x100$$

Table 1
Rating Scale for Insect Pests and Diseases Resistance (NSIC, n.d.)

Rating scale		Description
1	Highly resistant	(none of the total plant population was infected /infested)
2	Moderately resistant	(1-25% of the plant population was infected /infested).
3	Intermediate	(26-50% of the plant population was infected /infested).
4	Susceptible	(51-75% of the plant population was infected /infested).
5	Very susceptible	(76-100% of the plant population was infected /infested).

E. Methods of Determining Inbreeding Depression

This was determined using yield parameters like the number and weight of marketable fruit per plant on a hectare basis using the formula below (Kohn & Biardi, 1994).

$$F_{2ID} = \frac{YHF1 - YHF2}{YHF1} \text{x}100$$

Where;

F_{2ID}= Inbreeding Depression in F_2

YHF_1= Yield per Hectare of F_1

YHF_2= Yield per Hectare of F_2

F. Economic Data Analysis

The return on investment using different squash genotypes was computed using the formula below.

1. Return on Investment (ROI)

$$ROI = \frac{Net\ Income}{Cost\ of\ Production}$$

Where:

Net Income= Gross Income–Cost of production

Statistical Analysis. The data was analyzed using Analysis of Variance (ANOVA) based on a randomized complete block design to test the effects of the factors and their interactions. Tukey's Honest Significant Difference was used to compare the means.

RESULTS AND DISCUSSION

Vegetative and Reproductive Traits

Length (cm) of the main vines at 50 DAP. According to the statistical analysis presented in Table 1, there was a notable difference in the length of the main vines at 50 DAP. The longest vine, with a mean length of 401.75 cm, was observed in Engrande. This length did not significantly differ from the mean lengths of 393.59 cm and 346.50 cm observed in Suprema F2 and Suprema F1, respectively. Gracia had the shortest vine, with a mean length of 320.33 cm, which was insignificantly different from Rizalina's mean length of 333 cm. These findings indicate that among the genotypes (Suprema et al.), there was significant variation in the length of the main vines of F2 commercial hybrids, with Engrande exhibiting the most significant length.

Number of days to the opening of the first female flower. The data in Table 2 shows the number of days to open the first female flower for different squash genotypes and the F2 of a commercial hybrid. Among the genotypes, Gracia opened its female flower the earliest, with a mean of 53.75 days after planting (DAP). However, this was not significantly different from Rizalina, Suprema, and Suprema F2, which had respective means of 56.75 DAP, 58.08 DAP, and 59.25 DAP. On the other hand, Engrade took the longest time to open its female flower, with a mean value of 60.58 DAP. According to Davis (n.d.), squash hybrids tend to open their female flowers before the male flowers, suggesting that earlier opening of the female flowers may lead to earlier harvests.

Table 2

Length (cm) of the main vines, number of days to the opening of the first female and male flower of F1, F2, and OPV squash varieties.

TREATMENTS	LENGTH (cm) OF THE MAIN VINES AT 50 DAP	OPENING OF THE FIRST FEMALE FLOWER (DAP)	OPENING OF THE FIRST MALE FLOWER (DAP)
Suprema	346.50^{abc}	58.08^{ab}	65.50^{ab}
Engrande	401.75^{a}	60.58^{a}	67.42^{a}
Gracia	320.33 ^{c}	53.75^{b}	56.75^{c}
Rizalina	333.00 ^{bc}	56.75^{ab}	62.92^{b}
Suprema F_2	393.58^{ab}	59.25^{ab}	66.42^{ab}
F-test	**	*	**
% CV	6.24	3.83	2.47

Using the HSD test, the means in a column followed by the same letter are not significantly different at the 5% probability level.
** = Significant at 1% level of probability

Number of days to the opening of the first male flower. The timing of the opening of the first male flowers varied significantly among the different squash genotypes and the F2 of a commercial hybrid, as illustrated in Table 1. Among the genotypes, Gracia displayed the earliest male flower opening, with a mean value of 56.75 days after planting (DAP), significantly different from Rizalina, which had a mean of 62.92 DAP. However, the male flowers of the genotype that opened last, at 67.42 DAP, did not significantly differ from those of Suprema F2 (66.42 DAP) and Suprema F1 (65.50 DAP).

Number of Female Flowers per Plant. Table 3 presents the count of female flowers per plant for different squash genotypes and F2 of a commercial hybrid. After analyzing the variance, it was found that Gracia had the highest number of female flowers, with a mean value of 10.33, which was not significantly different from England, which had a mean value of 7.17. The lowest number of female flowers per plant was observed in Suprema F2, followed by Suprema F1 and Rizalina, with mean values of 4.50, 5.83, and 6.08, respectively. However, there were no statistical differences between these values.

According to Silvertown (1987), as cited in Campbell (2012), the production of female flowers can incur a higher cost than male flowers when the number of male flowers is not significantly higher. Campbell (2012) also mentioned that under stressful conditions, a reduction in the investment in female function can be expected. Experimental manipulation of water availability showed a decrease in the relative investment in female flowers compared to male flowers in hybrid cultivars but not in open-pollinated varieties (OPVs).

Table 3

Number of female and male flowers per plant and percent fruit set of F1, F2, and OPV squash varieties.

TREATMENTS	NUMBER OF FEMALE FLOWER/PLANT	NUMBER OF MALE FLOWER/PLANT	PERCENT FRUIT SET
Suprema F_1	5.83^{ab}	6.50^{a}	35.77
Engrande	7.17^{ab}	2.58^{b}	26.20
Gracia	10.33^{a}	2.25^{b}	26.31
Rizalina	6.08^{ab}	3.50^{ab}	29.09
Suprema F_2	4.50^{b}	4.67^{ab}	34.29
F-test	*	**	Ns
% CV	27.30	28.72	24.64

Means in a column followed by the same letter are not significantly different at a 5% probability level using the HSD test.
** = Significant at 1% level of probability
ns = not significant

Number of Male Flowers per Plant. Likewise, Table 3 shows that the number of male flowers per plant varied significantly across different squash genotypes and F2 of commercial hybrid. The highest number of male flowers was observed in Suprema F1 and Suprema F2, with mean values of 6.50 and 4.67, respectively, although the difference was not statistically significant. The lowest number of male flowers was recorded in Gracia, with 2.25 male flowers, which did not show a significant difference compared to Engrande and Rizalina, with mean values of 2.58 and 3.50, respectively.

Percent fruit set. Statistical analysis revealed no significant differences in the percent fruit set of the different squash genotypes and F_2 of commercial hybrids. However, among the different squash genotypes, Suprema F_1 had the highest percent fruit set with a mean value of 35.77%, followed by Suprema F_2 with 34.29%. On the other hand, the lowest percent fruit set was recorded in Engrande with a mean value of 26.20%.

The likelihood of female flowers setting fruit increased with the number of male flowers within a population, and the rate of increase was higher in some hybrid varieties. Climate change is predicted to reduce investment in female function in some monoecious crops like squash (Campbell, 2012). Thus, the sex ratio and the fruit set are essential traits in realizing high yield. Elevating sex ratio alone may not be substantially associated with an increased yield and earliness unless the fruit set is high (Mohamed et al., 2003). Moreover, the wet season causes the pollen to become sticky, which would lessen its ability to produce good pollen for the female flower to develop as a fruit (Davis, n.d.).

Days to first and last harvest. Table 4 demonstrates the number of days until the first harvest for different squash genotypes and F2 of a commercial hybrid. The results indicate significant differences among the treatments. Gracia had the earliest maturity, with a mean of 86.83 days after planting (DAP), which was not significantly different from Rizalina, which had a mean of 90.33 DAP. On the other hand, Suprema F2 took the longest time to reach maturity, with a mean of 93.00 DAP, but this was not significantly different from Suprema F1 and Engrande, which both had a mean of 92.67 DAP. In the final harvest of different squash genotypes and the F2 of the commercial hybrid, also presented in the same table, Gracia was still the earliest to harvest, with a mean of 93.33 DAP. At the same time, Suprema F1 and Engrande took the longest time to reach maturity. Additionally, it was observed that earlier flowering led to earlier fruit maturity. East-West Seed Co. (2011) states that Gracia is an early maturing variety (70 DAT).

Table 4

Days to first harvest and days to last harvest of F1, F2, and OPV squash varieties

TREATMENTS	DAYS TO FIRST HARVEST	DAYS TO LAST HARVEST
Suprema F_1	92.67[a]	100.33[a]
Engrande	92.67[a]	100.33[a]
Gracia	86.33[c]	93.33[c]
Rizalina	90.33[b]	97.33[b]
Suprema F_2	93.00[a]	100.00[a]
F-test	**	**
% CV	0.4705	0.5727

Using the HSD test, the means in a column followed by the same letter are not significantly different at the 5% level of probability.
** = Significant at 1% level of probability

Yield and Yield Components

Average fruit weight. The analysis of variance revealed no significant differences among the various squash genotypes and F2 of commercial hybrid. However, it was noted that Suprema F1 exhibited the highest average fruit weight of 2.63 kg, followed by Gracia, Engrande, Suprema F2, and Rizalina with mean values of 2.56 kg, 2.39 kg, 1.98 kg, and 1.85 kg, respectively. The lighter fruit weight was attributed to the infestation of the Leaf Curl Virus, causing damage to the leaves and resulting in smaller and lighter fruits. It is worth mentioning that Gracia is considered a medium-sized fruit, according to the East-West Seed Company.

Length of the fruit. The fruit length in centimeters varied among different squash genotypes and F2 commercial hybrids. Statistical analysis confirmed significant differences among the treatment means (see Table 4). It was noted that Suprema F2 produced the most extended fruit, measuring 14.19 cm, significantly different from Suprema F1 and Engarande, with respective lengths of 11.88 cm and 11.41 cm. Rizalina showed the shortest length, with a mean of 9.39 cm, which was not significantly different from Gracia, with a mean length of 10.78 cm. This suggests an increase in the length of the Suprema F2 fruit compared to the parent. However, as Cardoso (2004) noted, inbreeding of F1 hybrids can lead to a reduction in fruit length.

The diameter (cm) of the fruit. The results in Table 5 illustrate the fruit diameter (cm) of various squash genotypes and F2 of a commercial hybrid. Among the genotypes, Gracia exhibited the most significant fruit (21.87 cm), which was not significantly different from Suprema F1 and Engrande, with mean values of 20.80 cm and 20.89 cm, respectively. The smallest fruit was observed in Suprema F2, with a mean value of 18.35 cm, which did not significantly differ from Rizalina, with a diameter of 19.23 cm. These findings suggest inbreeding depression between T1 Suprema F1 and Suprema F2 regarding fruit diameter (cm).

A study by Cardoso (2004) has indicated that inbreeding of F1 hybrids reduces mean weight, fruit length, and seed production (both in terms of number and weight) per fruit. Large fruits tend to yield higher profits for farmers due to increased yield. Conversely, smaller fruits are more convenient to harvest and demand more in the culinary and industrial markets (Korzeniewska et al., 2004).

Table 5

Average fruit weight (kg), length, and diameter (cm) of the fruit of F_1, F_2, and OPV squash varieties

TREATMENTS	AVERAGE FRUIT WEIGHT (kg)	LENGTH OF THE FRUIT (cm)	DIAMETER OF THE FRUIT (cm)
Suprema F_1	2.63	11.88[b]	20.80[ab]
Engrande	2.39	11.41[b]	20.29[abc]
Gracia	2.56	10.78[bc]	21.87[a]
Rizalina	1.85	9.39[c]	19.23[bc]
Suprema	1.98	14.09[a]	18.35[c]
F-test	Ns	**	**
% CV	14.98	4.81	4.29

Means in a column followed by the same letter are not significantly different at a 5% probability level using the HSD test.
** = Significant at 1% level of probability
ns = not significant

Number of marketable fruits. The number of marketable fruits varied significantly among different squash genotypes and F2 of commercial hybrid, as shown in Table 5. The Gracia genotype produced the highest number of marketable fruits, with a mean value of 2.25. This was not significantly different from the mean values of 1.58 for Suprema F1 and 1.50 for Engrande, respectively. On the other hand, the lowest number of marketable fruits was observed in Suprema F2, with a mean value of 1.17 fruits per plant, which was not significantly different from the mean value of 1.33 for Resalina. These results suggest Gracia was prolific in fruit production and showed disease resistance. However, it also had fewer male flowers and would benefit from planting alongside other squash varieties for pollination.

Number of non-marketable fruit. The number of non-marketable fruits among different squash genotypes and F2 of a commercial hybrid, as shown in Table 6, did not vary significantly. However, the range for non-marketable fruit was from 0.4167 in Engrande, Gracia, and Rizalina to 2.67 in Suprema F2. The non-marketable yield was attributed to deformed fruits, discolored scars caused by beetles, irregular holes, and infestation of watermelon mosaic virus (WMV). The F2 of commercial hybrids had the highest incidence of diseases, resulting in low yield, although the results did not vary significantly. According to Hess et al. (1997), as cited in Niewczas et al. (2014), higher moisture levels contribute to increased incidence of leaf and fruit diseases. Additionally, leaf damage hinders photosynthetic activities, leading to reduced yields.

Table 6

Number of marketable and non-marketable fruits of F_1, F_2, and OPV squash varieties

TREATMENTS	NUMBER OF MARKETABLE FRUIT	NUMBER OF NON-MARKETABLE FRUIT
Suprema F_1	1.58^{ab}	0.5000
Engrande	1.50^{ab}	0.4167
Gracia	2.25^{a}	0.4167
Rizalina	1.33^{b}	0.4167
Suprema F_2	1.17^{b}	0.6667
F-test	*	Ns
% CV	18.08	60.47

Means in a column followed by the same letter are not significantly different at a 5% probability level using the HSD test.
** = Significant at 1% level of probability
ns = not significant

Marketable and non-marketable yield per plant (kg). Table 7 below displays the marketable yield per plant (kg) of different squash genotypes and F2 of commercial hybrid (Table 6). There were statistically significant differences among the treatment means. The highest yield was observed in Gracia, with a mean of 5.16 kg per plant, which was not significantly different from Suprema F1, with a mean of 3.98 kg per plant. Engrande, Rizalina, and Suprema F2 had comparable mean yields of 3.18, 2.74, and 2.34 kg per plant, respectively. However, there were no significant variations in non-marketable yield among the genotypes, with mean values ranging from 0.17 kg in Gracia to 0.82 kg in Suprema F2. Lower yields were attributed to virus infection affecting squash production and unfavorable climatic conditions during the cropping season. According to Fukai (1999), as cited in Panugaling (2016), excessive moisture stress at anthesis commonly delays plant flowering. Interestingly, the longer the delay, the higher the yield penalty.

Table 7

Marketable yield per plant (kg), non-marketable yield per plant (kg), and Marketable yield (tons/ha) of F_1, F_2, and OPV squash varieties

TREATMENTS	MARKETABLE YIELD PER PLANT (kg)	NON-MARKETABLE YIELD PER PLANT (kg)	MATRKETABLE PLOT YIELD (kg)	MARKETABLE YIELD (tons/ha)
Suprema F_1	3.98^{ab}	0.63	15.93^{ab}	17.70^{ab}
Engrande	3.18^{b}	0.35	12.74^{b}	14.16^{b}
Gracia	5.16^{a}	0.17	20.64^{a}	22.93^{a}
Rizalina	2.74^{b}	0.42	10.97^{b}	12.19^{b}
Suprema F_2	2.34^{b}	0.82	9.35^{b}	10.40^{b}
F-test	**	ns	**	**
% CV	17.87	53.26	17.87	17.87

Means in a column followed by the same letter are not significantly different at a 5% probability level using the HSD test.
** = Significant at 1% level of probability
ns = not significant

Marketable plot yield (kg). The results indicated highly significant variances in the marketable plot yield of F1, F2, and OPV squash varieties, as outlined in Table 6. Gracia demonstrated the highest marketable plot yield, averaging 20.64 kg, but did not show a significant difference compared to Suprema F1, which had a mean of 15.93 kg. Conversely, Suprema F2 had the lowest marketable plot yield at 9.35 kg, a figure on par with Rizalina and Engrande, which had means of 10.97 kg and 12.74 kg, respectively.

Marketable yield (tons/ha). The results revealed significant variations in marketable yields (tons/ha) among the five genotypes, as indicated in Table 6. Gracia recorded the highest marketable yield at 22.93 tons/ha, although not significantly different from Suprema F1, which had a mean value of 17.70 tons/ha. Suprema F2 exhibited the lowest marketable yield at 10.40 tons/ha, which is insignificantly different from Rizalina and Engrande, with mean values of 12.19 tons/ha and 14.16 tons/ha, respectively. The lower squash yield observed was attributed to excessive rain during the wet season and disease infection, leading to a low percent fruit set (refer to Table 2) and a reduced yield. Yeboa (2010) noted the significant impact of season on squash yield and fruit length. A reduction in yield ranging from 2% to 15% was observed during the rainy season.

Qualitative Traits

Fruit shape. Table 8 shows that three hybrid squash genotypes (Suprema et al.) and the open-pollinated variety Rizalina exhibited the same fruit shape, which was transverse elliptic. However, the Supreme F2 hybrid displayed three shapes: transverse elliptic, transverse broad elliptic, and top shape (refer to Figure 2). Notably, the top shape was observed to be the dominant phenotype. The F1 hybrid was derived from two pure lines, but it is important to note that it could have originated from various parents at different stages. If seeds were sown from F1 hybrid plants, it is quite possible to observe not only the "parents" but also the "grandparents" in the resulting plants (Hill, 1987).

Fruit flesh color. Table 8 and Figure 3 compare the fruit flesh color of various squash genotypes and F2 of a commercial hybrid. The analysis revealed that all treatments (Suprema et al.) exhibited an orange color, except for the OPV (Rizalina), which displayed a yellow-orange hue.

Fruit skin color. Table 8 indicates that, for the fruit skin color of different squash genotypes, all treatments except Gracia exhibit similar green fruit skin color. Gracia shows variegated fruit skin color (Figure 4).

Table 8
Qualitative Traits of F1, F2, and OPV squash varieties

TREATMENTS	QUALITATIVE TRAITS		
	Fruit shape	Fruit flesh colors	Fruit skin colors
Suprema F_1	2	3	1
Engrande	2	3	1
Gracia	2	3	1
Rizalina	2	2	1
Suprema F_2	2, 3 and 5	3	1

a. Fruit shape

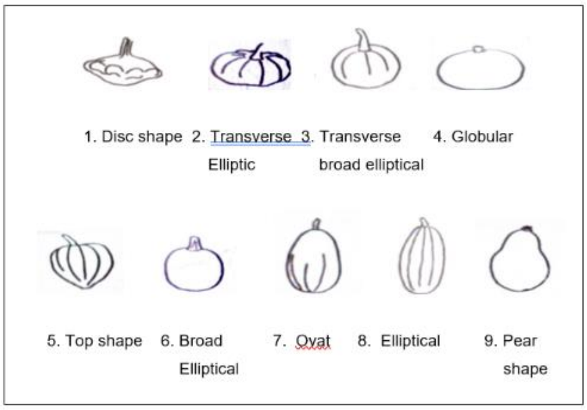

Figure 1
Illustration of the fruit shapes of different varieties of squash.

b. Fruit flesh color
   1. yellow
   2. yellowish orange
   3. orange

c. Fruit skin color
   1. Green
   2. Cream
   3. Yellow
   4. orange brown

Figure 2
Fruit shapes of F1, F2, and OPV squash varieties: a. Suprema (Transverse elliptic), b. Engrande (transverse elliptic), c. Gracia (transverse elliptic), Rizalina (transverse elliptic), and e. Suprema F2, e1 (transverse broad elliptic), e2 (transverse elliptic) and (top shape)

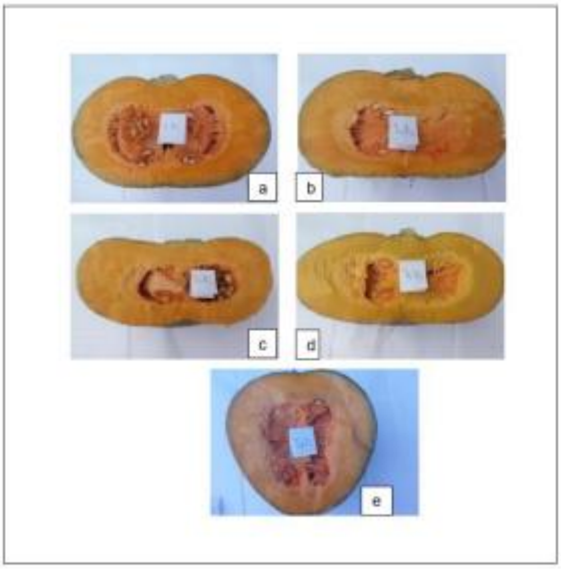

Figure 3
Fruit flesh color of F1, F2, and OPV squash varieties: a. Suprema (orange), b. Engrande (orange), c. Gracia (orange), d. Rizalina (yellowish orange) and Suprema F2 (orange)

Figure 4
Fruit skin color of F1, F2, and OPV squash varieties: a. Suprema (green), b. Engrande (green), c. Gracia (green), d. Rizalina (green) and e. Suprema F2 (green).

Reaction to Squash Leaf Curl Virus Disease. In Table 9, it was observed that there was no significant difference in the response to insect pests and diseases among the various squash genotypes and F2 of the commercial hybrid. Nevertheless, it was evident that Gracia exhibited resistance among the studied squash genotypes, with a mean value of 2.33. Conversely, Suprema F2 displayed the highest susceptibility among the studied population, with a mean value of 4.

The Suprema F2 cultivar suffered severe damage from squash leaf curl virus. Infected plants exhibited stunted growth and had leaves that were mottled, crinkled, or light green in color. Unfortunately, no chemical treatments were available to eliminate the viruses as of February 2017 (http://.clemson.edu/extension/hgic).

Controlling the disease is challenging because infection occurs promptly after insect feeding, and insects easily move among plants.

Table 9
Reaction to insect pests and diseases of different squash genotypes and F2 of commercial hybrid

TREATMENTS	REACTION TO SQUASH LEAF CURL VIRUS[a]
Suprema F_1	3.33
Engrande	2.33
Gracia	2.00
Rizalina	2.67
Suprema F_2	4.00
F-test	Ns
% CV	29.87

Means in a column followed by the same letter are not significantly different at 5% level of probability using HSD test.
** = Significant at 1% level of probability
ns = not significant

a. Reaction to insect pests and diseases

Rating scale		Description
1	Highly resistant	(none of the total plant population was infected /infested)
2	Moderately resistant	(1-25% of the total plant population was infected /infested).
3	Intermediate	(26-50% of the total plant population was infected /infested).
4	Susceptible	(51-75% of the total plant population was infected /infested).
5	Very susceptible	(76-100% of the total plant population was infected /infested).

Inbreeding depression. Table 10 details the impact of inbreeding on yield parameters, such as the quantity and weight of marketable fruits per plant and per hectare. The findings reveal that inbreeding depression is evident in squash, with the highest percentage observed in marketable yield per plant and per hectare at 41.42%. Conversely, the lowest % of inbreeding depression, at 26.22%, is noted in the number of fruits per plant.

Hayes et al. (2005), as cited in Grisales et al. (2014), noted that inbreeding depression in the number of fruits per plant or seeds per fruit was influenced by environmental factors. Falconer & Mackay (1996) estimated a decrease in squash productivity due to inbreeding depression.

However, this finding contradicts the observation of Cardoso (2004), who noted inbreeding depression in squash.

Table 10
Inbreeding depression of Suprema F2 in the yield parameters like number and weight of marketable fruit and hectare bases

Yield parameter	Suprema F_1	Suprema F_2	Inbreeding depression (%)
Number of marketable fruit/plants	6.33	4.67	26.22
Marketable yield per plant (MYP) (kg)	3.98	2.34	41.21
Marketable yield (MY) (tons/ha)	13.28	7.78	41.42

Return on Investment (ROI). Table 11 provides a cost and return analysis for various types of squash. This analysis used the current selling prices of inputs, on-farm labor wages, and the market price of squash fruit.

Gracia achieved the highest gross income, PhP 172,000, followed by Suprema F1, with a gross income of PhP 132,800. Suprema F2 had the lowest gross income, at PhP 77,800 per hectare yield.
Suprema F1 recorded the highest total production cost, PhP 33,979.40, primarily due to the high cost of seeds. Following closely behind was Gracia and Engrande, with costs of PhP 35,423.40 and PhP 32,775.40, respectively. Conversely, Suprema F2 achieved the lowest production cost, totaling PhP 30,714.40.

The highest net income among the various squash genotypes was observed in Gracia, totaling PhP136,576.60. This was followed by Suprema F1, Egrande, and Rizalina with earnings of PhP98,820.60, PhP73,324.60, and PhP60,328.60, respectively. The lowest net income was recorded in Suprema F2 at PhP60,328.60. In terms of return on investment (ROI), the highest ROI was achieved in Gracia at 3.9, followed by Suprema F1 at 2.9. Conversely, the lowest return on investment was found in Suprema F2 at an ROI of 1.5. These results indicate that Gracia was the most profitable treatment, as it had the highest ROI of 3.9. However, the use of Suprema F2 seeds remain profitable, albeit with lower net income compared to using F1 seeds and Rizalina. It is important to note that profitability is contingent upon market prices.

Table 11
Return on investment (ROI) of F1, F2, and OPV squash varieties.

TREATMENT	MARKETABLE YIELD (tons/ha)	TOTAL GROSS INCOME (PHP)	PRODUCTION COST (PHP)	NET INCOME (PHP)	ROI
T1 (SUPREMA)	13, 280	132, 800	33, 979.40	98, 820.60	2.9
T2 (ENGRANDE)	10, 610	106, 100	32, 775.40	73, 324.60	2.2
T3 (GRACIA)	17, 200	172, 000	35, 423.40	136, 576.60	3.9
T4 (REZALINA)	9, 140	91, 400	31, 071.40	60, 328.60	1.9
T5 (SUPREMA F_2)	7, 780	77, 800	30,714.40	47, 085.60	1.5

The prevailing price/kg was Php 10.00 for marketable fruits.

Conclusions and Recommendation. The study revealed notable variations among the F1, F2, and OPV squash variety genotypes in multiple parameters such as vine length at 50 DAP, the timing of first male flower emergence, male flower count, days to initial and final harvest, fruit dimensions, marketable yield per plant, and fruit characteristics. While three traits exhibited significant differences, including the opening of the first female flower, female flower count, and marketable fruit count, six traits, such as percent fruit set and reaction to pests and diseases, showed uniformity across the genotypes. In terms of yield, Suprema F2 displayed similar performance to Suprema F1 but was affected by inbreeding depression, particularly in marketable yield per plant, non-marketable yield per plant, and marketable yield. Despite this, Suprema F2 remained profitable, with the highest net income observed in Gracia and the lowest in Suprema F2. Gracia emerged as the top performer with the highest marketable yield and ROI of 3.9%, recommending its cultivation for enhanced profitability. However, to ensure successful pollination, it is advisable to plant a mix of squash varieties to balance male flower availability. Gracia stands out as a financially rewarding option for farmers, while the option of reusing Suprema F2 seeds when F1 seeds are scarce presents a cost-effective strategy for sustainability in squash cultivation.

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