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Plant catalyst superiorly augment Kamantigi (*Impatiens balsamina*) pod and seed quality parameters: A springboard for ornamental seed production

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Abstract The Philippines faces a pressing challenge in its current seed supply system for ornamental crops, leading to the distribution of low vigor seeds to consumers. The research finding is addressed the critical issue by investigating the optimal fertilizer treatment to achieve superior pod and seed quality for field-grown kamantigi *(Impatiens balsamina)*, an emerging ornamental plant known for its health benefits and landscape use. Results showed that plant catalyst consistently outperformed other treatments in terms of pod morphometry, germination rate, and field emergence. A negative correlation between size and moisture content of seeds and germination rate was also established. Moreover, phosphorus and potassium-based fertilizers supplemented with magnesium and zinc exhibited consistently inferior performance across all parameters, both in germination test and in pots. This study unveiled the promising potential of plant catalyst as a foliar plant growth promoter capable of enhancing seed quality in kamantigi, specifically targeting seed production. Irradiated carrageenan and NP fertilizer suspension with Zn were also found effective in enhancing pods, seeds, and seed quality parameters of kamantigi. These innovative fertilizers showed potential in revolutionizing the Philippines ornamental crop industry by elevating seed quality and ensuring seed viability before reaching the market. Moreover, the findings suggested the wider applicability of these fertilizers to other ornamental crops, thereby enabling the production of high-quality seeds for a sustainable and thriving market.

Keywords: Ornamental crops, Seed supply system, Kamantigi, Foliar fertilizers, Plant growth promoters

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Introduction

The pandemic has elevated the market for ornamental crops most especially those aimed at landscape beautification. Unfortunately, the ornamental crop seed supply systems lack research on quality ornamental germplasm and cultural practices. This was also recognized by Aw-Hassan *et al.* (2003) and Mula (2014), who characterize cereals as having higher relevance than other crop types. There were also low-quality commercially available ornamental crop seeds, as ornamental crop production is not as prominent as other agricultural crops.

Kamantigi *(Impatiens balsamina)*, also known as garden balsam, is one of the ornamental garden crops in the Philippines that is used as an edible flower, a landscape plant and for aesthetic purposes. However, aside from this use, it was also discovered to have potential in the pharmaceutical industry (Thevissen *et al*., 2005), phytochemical constitution (Kim *et al*., 2015) and as food colorant (Pires *et al.,* 2021).

Seed production attributes such as yield, and quality are highly linked with the presence of nutrients (McDonald and Copeland, 2012) in various crop species. For instance, Drostkar *et al.* (2016) found out that foliar application of zinc, iron, nitrogen, phosphorus, and potassium positively affects plant growth and seed yield in chickpea. This was also observed in sunflower where plants treated with foliar applications of fertilizers containing nitrogen, phosphorus, potassium, magnesium, manganese, copper, iron, boron, molybdenum, and zinc gained higher seeds per head, 1000-seed weight, seed yield, and seed weight per head (Akuaku *et al.,* 2020).

The usage of carrageenan in plant growth promotion, enzyme activities, photosynthesis, production of secondary metabolites, and enhancement of physiological activities, was also established throughout the years. This was observed in pechay (Abad *et al*., 2018), peppermint (Ahmad *et al.*, 2019), and wild mint (Naeem *et al.,* 2012). Moreover, Gatan *et al.* (2019) found out that radiation-modified kappa carrageenan can induce flowering, promote plant height, and increase seed yield in mungbean.

To maximize the potential of these advancements, this study investigated the efficacy of various foliar fertilizer products in improving kamantigi seed quality that would lead to the adoption of efficient fertilizer management practices among ornamental seed producers. This would strengthen the ornamental crop industry in the Philippines and provide farmers with more crop options to adopt and establish their businesses upon.

Materials and methods

One hundred flowers of kamantigi plants were tagged in a $2m^2$ area beside the Agronomy Building, Institute of Crop Science, University of the Philippines Los Baños. Developed pods were drenched with foliar fertilizers laid out in a Randomized Complete Block Design replicated thrice. Considering the rapid plant development of kamantigi, foliar application of plant growth promoters and fertilizers was done once a week for 3 applications before pod harvest.

The treatments are displayed in Table 1, following the recommended rate of application on their respective fertilizer packaging.

Table 1. Foliar fertilizer and plant growth promoter treatments utilized throughout the study

Treatment	Treatment Description	Formulation (amount/L)
1	Plant Catalyst	0.018 g
2	Irradiated Carrageenan	1.125 mL
3	NP Fertilizer Suspension with Zn	0.48 mL
4	P&K-based Fertilizer with Mg & Zn	0.75 mL
5	Distilled Water	control

Note: T1 and T2 were classified as plant growth promoters, while T3 and T4 are fertilizers.

Yield attributes

Pod length, width, and seed morphometry were obtained afterwards. The length (mm), width (mm), and thickness (mm) of 20 kamantigi pods (5 pods per block) and 30 seeds were measured using a Mitutoyo CD-6" ASX absolute digimatic caliper (accuracy: ±0.02 mm).

After harvesting kamantigi seeds, the following response variables were collected:

Germination test

Kamantigi seeds were surface sterilized with 5% sodium hypochlorite for 1 minute, then washed with distilled water afterwards. Ten seeds were placed in a petri dish lined with moist filter paper and incubated at room temperature for 72 hours, then replicated three times. Germination rate was determined after 10 days.

Accelerated aging test

The seeds were subjected to accelerated aging at 100% RH and 42°C for 72 hours. Afterwards, a germination test following the above-mentioned protocol was conducted.

Emergence test

Three replicates of 25 seeds for each treatment were sown in the polyethylene bags with garden soil. The percentage emergence after 10 days was determined.

100-seed weight

The weight of 100 seeds was determined using the Mettler Toledo Analytical Balance (AB204).

Moisture content

The moisture content of kamantigi seeds were determined using the Shimadzu MOC63u Moisture Analyzer replicated 3 times with 5 seeds per replicate.

Seed shape indices

Eccentricity, flatness, and circularity indices of kamantigi seeds were calculated using the equations below. Eccentricity index (EI) was computed using the length/width ratio (Eq. 3). Flatness index (FI) was calculated using the three principal axes such as length, width, and thickness (Eq. 4). Values closer than 1 characterize sphere-shaped seeds, while those above 2 are considered spindly seeds. Circularity index (CI) approximates the similarity of the seed to a circle using the area and perimeter of the seed (Rovner and Gyulai, 2007) (Eq. 5), wherein values closer to 1 characterize near-circle seeds.

$$P = 2L + 2W \quad (Eq. 1)$$

$$A = L \, x \, W \quad (Eq. 2)$$

$$EI = \frac{L}{W} \quad (Eq. 3)$$

$$FI = \frac{L + W}{2H} \ (Eq. 4)$$

$$CI = \frac{4\pi \ x \ area}{perimeter^2} \ (Eq. 5)$$

Mold incidence (%)

The number of seeds infested with molds was also documented. The % mold incidence was calculated using the formula below derived from Naik *et al.* (2023).

$$\% \ mold \ incidence = \frac{number \ of \ kamantigi \ seeds \ affected \ with \ molds}{total \ number \ of \ mold \ seeds} \ (Eq. 6)$$

Statistical analysis

The F test was used to perform analysis of variance (ANOVA) on the quantitative seed characterization and germination data. Before ANOVA, the assumptions were validated using Levene's test for normality and the Shapiro-Wilk test for variance homogeneity (Garson, 2012). Following that, the means were compared using Tukey's test with a 5% margin of error (Statistical Tool for Agricultural Research version 2.0.1).

Results

Morphology of the Kamantigi flower, pods and seeds

A visual representation of the developmental stages of kamantigi plant from flower, pods, up to seed is shown in Figure 1.

Plant catalyst enhances Kamantigi pods, seeds response similarly among treatments

Pod morphometry

After harvesting, pod morphometric characterization showed that the plant catalyst obtained significantly the highest pod length and width among all treatments (Table 2). This was followed by irradiated carrageenan and NP fertilizer suspension with zinc which did not vary statistically *($p = 0.05$)*. While

P&K-based fertilizer with Mg & Zn obtained the lowest value followed by the control (distilled water).

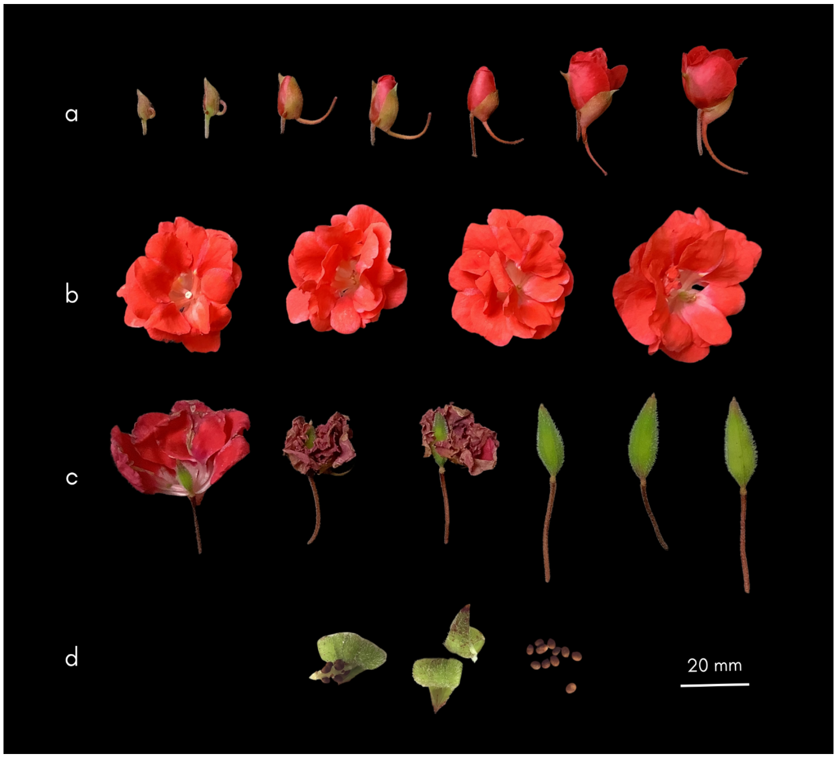

Figure 1. Kamantigi morphology. a) Flower development; b) Anthesis, the stage when flowers were tagged for the experiment; c) Pod development, the stage when foliar plant growth promoters and fertilizers were applied; d) Pod shattering and seed harvest

Table 2. Effects of foliar application of fertilizers and plant growth promoters on the pod morphometry of kamantigi

Treatment	Pod Length (mm)	Pod width (mm)
Plant Catalyst	25.27±0.92 a	7.72±0.26 a
Irradiated Carrageenan	23.77±0.76 ab	7.08±0.30 ab
NP Fertilizer Suspension with Zn	23.73±0.87 ab	7.07±0.46 ab
P&K-based Fertilizer with Mg & Zn	22.17±0.77 b	6.60±0.23 b
Distilled Water	22.62±1.18 b	6.97±0.31 b
CV (%)	9.79	11.35

Mean ± Standard Error (n=20). Means with different letters vary significantly.

Seed morphometry

The application of fertilizers and plant growth promoters was not statistically significant impact on seed length, thickness, eccentricity index, and flatness index. However, the width and circularity index of the kamantigi seeds showed the best and significant effect when P&K-based fertilizer with Mg & Zn was applied.

Table 3. Effects of foliar application of fertilizers and plant growth promoters on the seed size and shape indices of kamantigi

Treatment	Length (mm)	Width (mm)	Thickness (mm)	EI	CI	FI
Plant Catalyst	2.55±0.18	1.68±0.09 b	2.11±0.16	1.52±0.09	1.01±0.08 ab	0.75±0.01
Irradiated Carrageenan	2.59±0.13	1.73±0.08 b	2.18±0.12	1.50±0.10	1.00±0.07 ab	0.75±0.01
NP Fertilizer Suspension with Zn	2.45±0.17	1.65±0.14 b	2.22±0.08	1.51±0.14	0.93±0.06 b	0.75±0.01
P&K-based Fertilizer with Mg & Zn	2.71±0.27	1.90±0.14 a	2.11±0.12	1.43±0.14	1.10±0.09 a	0.76±0.01
Distilled Water	2.33±0.15	1.73±0.08 b	2.10±0.12	1.35±0.08	0.97±0.04 b	0.77±0.01
CV(%)	11.82	10.09	9.25	12.36	2.24	11.15

Mean ± Standard Error (n=10). Means with different letters vary significantly. Abbreviations: EI = eccentricity index;
FI = flatness index; CI = circularity index

Plant catalyst optimizes germination, irradiated carrageenan excels in potted conditions

Although it was not statistically significant, but it was noteworthy that the treatments with significantly lower germination rates had the highest moisture content (Table 4).

Table 4. Effects of foliar application of fertilizers and plant growth promoters on the seed quality parameters of kamantigi

Treatment	MC (%)	SW (g)	GR (%)	PE (%)	AAT (%)
Plant Catalyst	22.40±8.09	0.0320±0.0079	96.67±6.53 a	45.33±27.28	0
Irradiated Carrageenan	21.85±3.25	0.0280±0.0078	83.33±17.29 ab	48.00±7.84	0
NP Fertilizer Suspension with Zn	24.58±6.31	0.0377±0.0035	83.33±17.29 ab	32.00±19.73	0
P&K-based Fertilizer with Mg & Zn	30.91±9.02	0.0293±0.0098	30.00±22.63 c	12.00±4.53	0
Distilled Water	32.39±5.07	0.0343±0.0125	66.67±6.53 b	40.00±11.98	0
CV(%)	23.10	24.13	20.99	41.08	0

Mean ± Standard Error. Means with different letters vary significantly. Abbreviations: MC= moisture content; SW = seed weight of 15 representative seeds (5 seeds per replicate); GR = germination rate; PE = % emergence; AAT = accelerated aging test as expressed in % germination.

The results of the emergence test, seed weight, and moisture content were not significantly different from each other. Regarding the germination rate, the plant catalyst showed the highest performance, followed by both irradiated carrageenan and NP fertilizer suspension with Zn. Surprisingly, even distilled water performed better than one of the fertilizer treatments, specifically the P&K-based fertilizer with Mg & Zn. Another notable observation was using the accelerated aging test showing no signs of germination which observed for all the treatments.

Mold incidence highest in P&K-based fertilizer with Mg & Zn and distilled water

Mold was observed at higher rates in the P&K-based fertilizer with Mg & Zn and distilled water, which were the treatments that had high moisture content.

Table 5. Mold incidence among foliar application of fertilizers and plant growth promoters on kamantigi after the accelerated aging test

Treatment	Mold Incidence (%)
Plant Catalyst	15.00±5.66 b
Irradiated Carrageenan	25.00±5.66 b
NP Fertilizer Suspension with Zn	30.00±14.97 b
P&K-based Fertilizer with Mg & Zn	76.67±11.78 a
Distilled Water	56.57±13.07 a
CV (%)	23.76

Mean ± Standard Error. Means with different letters vary significantly.

Discussion

Among all treatments, plant catalyst performed consistently superior for the pod morphometry and seed quality, specifically germination rate. Plant catalyst is a patented product that makes bold claims of enhancing plant growth. Its composition includes a minor quantity of silica salts and extracts derived from lignite. The solution comprises 0.006% calcium, 0.00114% magnesium, 0.04% nitrogen, 0.005% SiO_2, and 99% water. In hydroponic commercial greenhouses, Plant catalyst has demonstrated significant improvements in the cultivation of mixed variety lettuce (13%), tomatoes (24%), bell peppers (46%), and jalapenos (52%). The primary observed effect appears to be accelerated growth rates and reduced time to reach maturity (Swanson *et al.,* 2015). These results were in line with the findings in the current study as well, as the plant catalyst was able to perform superiorly in germination tests and plant emergence tests.

Another possible reason for the superior effect of plant catalyst is its 0.04% nitrogen composition. It was established by Brar and Singh (2016) that external application of nitrogen improves pod characteristics such as length and width, which was also observed in this study. This phenomenon could also support the good performance of NP fertilizer suspension with zinc in producing big kamantigi pods. Moreover, irradiated carrageenan was also proven to improve growth attributes of plants like Madagascar periwinkle (Naeem *et al.,* 2015), pechay (Abad *et al*., 2016) and rice (Abad *et al*., 2018), which is also parallel to the results in kamantigi.

On the contrary, P&K-based fertilizer with Mg & Zn obtained the lowest value followed by distilled water. Interestingly, seeds from the pods with the smallest size gained the biggest seed morphometric values as revealed by the significantly superior width and flatness index (Table 3). This observation might indicate that the strategy of kamantigi in resource allocation is to invest more on the seed, rather than the pod size. The significantly bigger seed sizes in the treatment with phosphorus and potassium-based fertilizer can also be attributed to the general role of phosphorus in the pod filling mechanism (Carvalho *et al*., 2018) and both phosphorus and potassium in seed-filling (Kakiuchi and Kamiji., 2015). This is supported with the findings of Cheng *et al*. (2002) wherein smallest pods may have normal sized seeds, but are prone to aborted embryos per pod, thus, the detrimental effect on germination capacity. Moreover, excess phosphorus leads to the inability to take up other essential nutrients that are essential for plant growth (Saleem *et al*., 2020).

The treatments with the bigger seed sizes, P&K-based fertilizer with Mg & Zn and distilled water, gained a significantly superior moisture content. With this observation, it might be possible that the harvested seeds from these two treatments are still not at the peak of their physiological maturity, even though all of the seeds were harvested at the same time. Harrington (1972) established that physiological maturity is attained when the dry matter content of seeds is at its maximum. Thus, it is possible that the fertilizer and plant growth promoters foliar treatments that resulted in lower seed moisture content could hasten physiological maturity.

In terms of the pot emergence test, both irradiated carrageenan and plant catalyst displayed a consistent performance as they also produced higher emergence percentage in pot conditions. This result was consistent with Abad *et al.* (2018) on the effect of irradiated carrageenan wherein they discovered improvements in peanut agronomic traits such as faster seed germination and flowering, increased plant height and pod production, and heavier seed weight, which translated into higher total yield. The same findings were established in the utilization of plant catalyst in tomato, lettuce, and bean as its foliar application improved overall plant condition, accelerated seed germination, and increased growth (Swanson *et al.,* 2015).

Vigor test after the accelerated aging test (AAT) was also conducted but germination was not observed in all treatments. This could be attributed to the growth of molds thereby impeding germinability of the kamantigi seeds. Mold incidence could also be attributed to the high moisture content, especially that treatments under P&K-based fertilizer with Mg & Zn and distilled water significantly have higher mold incidence. This was also observed by Wang *et al*. (2020) in wheat seeds and Manu *et al*. (2019) in maize seeds. Both studies observed that with an increase in seed moisture content, there is higher damage tendency i.e., higher production of mycotoxins and aberrations on the internal structure of the seeds i.e. embryo and endosperm.

Plant catalyst was found to have consistent positive performance in pod and seed qualities of kamantigi after foliar fertilization. This was revealed through a series of tests in pod morphometry, seed morphometry, and assessment of seed quality parameters such as germination rate, vigor through the accelerated aging test, seed health, % soil emergence, moisture content, and 100-seed weight. The phosphorus and potassium-based fertilizer with magnesium and zinc performed consistently inferior among all treatments which is an indicator that the abundance of nutrients in this fertilizer might have induced nutrient toxicity for the kamantigi plants. Furthermore, seeds under this treatment together with those under the control did not achieve physiological maturity, indicated by their high moisture content and low germination performance.

The research finding suggested that seed producers aiming to establish Philippines' seed supply system for ornamental crops such as kamantigi could use plant catalyst to produce the best seeds for crop production. Irradiated carrageenan and NP fertilizer suspension with Zn were also found to be effective. As recommendations, this research could be replicated in other flowering plants where seeds are the primary planting material, such as sunflowers and cosmos. This experiment can also be carried out in widely cultivated crops such as rice, corn, and vegetable crops, which require large amounts of fertilizer. Another research gap revealed by this study is the allocation of nutrient resources on pods and seeds, thus nutrient studies could also be done to strengthen this claim. Experiments on the effect of the fertilizers used in this study on crop growth and development at later stages of growth and development are another avenue to pursue in the future. Furthermore, since no germination was observed after the accelerated aging test due to molds, studies on the identity of the molds and pre-treatment through surface sterilization of kamantigi seeds before AAT are also recommended.

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