

SCIENTIFIC ARTICLE

Morphological and postharvest treatments in *Alpinia* cultivars

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Abstract

The characterization and morphological evaluation of plants are essential steps towards the germplasm classification and use in breeding. The objective of this study was to improve the morphological characterization of four *Alpinia purpurata* cultivars by means of qualitative evaluations to identify genotypes with promising traits for the ornamental plant market. Four cultivars of *A. purpurata* ('Jungle King', 'Kimi', 'Red Ginger' and 'Pink Ginger') were assessed in a partially shaded cultivation system. Quantitative morphological descriptors such as stem length and diameter, number of leaves on floral stem, leaf width and length, inflorescence width and length, fresh weight of floral stem and the number of produced and marketable stems were evaluated. The qualitative descriptors were evaluated on inflorescence, floral stem, petiole, leaf and bracts. Postharvest longevity was tested in a cold chamber (at 16 and 19°C) and at ambient temperature (26°C). The most outstanding quantitative traits of the cultivars 'Jungle King', 'Kimi' and 'Pink Ginger' were stem length and diameter, fresh weight, floral stem durability, inflorescence length and width and productivity. Cultivar 'Red Ginger' was less outstanding in the quantitative traits mentioned for the other cultivars. Variation among the cultivars was observed for inflorescence shape and color. The cultivars 'Kimi' and 'Pink Ginger' produced a stem yield of 6,654.32 and 7,580.24 ha⁻¹ year⁻¹, respectively, and cultivars 'Red Ginger' and 'Jungle King' 6,012.34 and 4,037.03 ha⁻¹ year⁻¹, respectively. The postharvest durability of the four cultivars evaluated under refrigeration exceeded 15 days and that of the control was less than 8 days. The qualitative and quantitative traits of the cultivars 'Jungle King', 'Kimi' and 'Pink Ginger' were promising for the tropical ornamental plant market.

Keywords: Postharvest durability, ornamental potential, productivity, tropical ornamental plants

Resumo

Morfologia e tratamentos pós-colheita em cultivares de *Alpinia*

A caracterização e avaliação morfológica de plantas são etapas imprescindíveis à classificação e a utilização do germoplasma para fins de melhoramento genético. Este estudo teve por objetivo ampliar os conhecimentos sobre a caracterização morfológica de quatro cultivares de *Alpinia purpurata* por meio de avaliações quali-quantitativas a fim de identificar genótipos com características promissoras para o mercado de plantas ornamentais. Quatro cultivares de *A. purpurata* ('Jungle King', 'Kimi', 'Red Ginger' e 'Pink Ginger') foram avaliados em um sistema de cultivo a meia sombra. Descritores morfológicos quantitativos como comprimento, diâmetro e número de folhas na haste floral, largura e comprimento da folha, largura e comprimento da inflorescência, massa fresca da haste floral, número de hastes produzidas e comercializáveis foram avaliados. Os descritores qualitativos foram avaliados na inflorescência, haste floral, pecíolo, folha e brácteas. A longevidade pós-colheita em câmara fria a 16 °C e 19 °C e temperatura ambiente a 26 °C foram testadas. As características quantitativas das cultivares 'Jungle King', 'Kimi' e 'Pink Ginger' que se destacaram foram: comprimento, diâmetro, massa fresca, durabilidade da haste floral, comprimento; largura da inflorescência e produtividade. A cultivar 'Red Ginger' não obteve destaque nas características quantitativas mencionadas para as demais cultivares. As características qualitativas que apresentaram variação entre as cultivares foram o formato e coloração da inflorescência. As cultivares 'Kimi' e 'Pink Ginger' apresentaram produtividade de 6654,32 e 7580,24 hastes ha⁻¹ ano⁻¹, respectivamente e as cultivares 'Red Ginger' e 'Jungle King' 6012,34 e 4037,03 hastes ha⁻¹ ano⁻¹, respectivamente. A durabilidade pós-colheita das quatro cultivares avaliadas em ambiente refrigerado foi superior a quinze dias e no controle foi inferior a oito dias. As cultivares 'Jungle King', 'Kimi' e 'Pink Ginger' apresentaram características qualitativas e quantitativas promissoras para a utilização no mercado de plantas ornamentais tropicais.

Palavras-chave: Durabilidade pós-colheita, potencial ornamental, produtividade, plantas ornamentais tropicais.

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Introduction

Plants of the family Zingiberaceae have been widely used as food (*Curcuma longa* L.) and for medicinal (*Zingiber officinale* Roscoe) and ornamental purposes (*Hedychium coronarium* J. Koenig) (Althaus-Ottmann et al., 2011). In Brazil, the occurrence of two species of the genus *Alpinia*, namely *Alpinia purpurata* and *Alpinia zerumbet*, has been recorded in all Brazilian regions (Maas and Maas, 2017).

Alpinia purpurata (Zingiberaceae) is a perennial, herbaceous and upright perennial monocot that can reach a height of 4 m, with clumps with a diameter of 1.5 m. The stem is underground, rhizomatous, with horizontal growth. The pseudostem consists of long, tightly overlapping leaf sheaths. The leaves are broad, lanceolate and dark green (Bezerra and Loges, 2005).

The potential of *A. purpurata* as cut flower is known worldwide for the exuberant inflorescences, along with uninterrupted flowering and high durability as cut flower (Lamas, 2000). In Brazil, the *A. purpurata* cultivars (cv) with red bracts ('Red Ginger' and 'Jungle King') and those with pink bracts ('Pink Ginger' and 'Jungle Queen') are the most commonly cultivated (Bezerra et al., 2008) and the seedlings and cut flowers are extensively commercialized on the ornamental market (Victório, 2011).

The morphological plant characterization and qualitative evaluation are fundamental steps for germplasm classification and use, to identify promising genotypes that can be integrated into breeding programs or recommended for cultivation (Silva et al., 1999). For *Alpinia purpurata* production, desirable traits of the inflorescence are a length of 15 - 20 cm, floral stem diameter of 1 cm and postharvest durability of ≥ 15 d (Teixeira and Loges, 2008).

The initial and postharvest development of *Alpinia* sp. was studied in Lavras, Minas Gerais (Dias-Tagliacozzo et al., 2003); cultivation and commercialization of *Alpinia* in the state of Pernambuco (Teixeira and Loges, 2008); seedling production of *Alpinia purpurata* (Vieill.), cultivar "Red Ginger", with different substrates and a rooting stimulator in Aracaju, Sergipe (Moreira et al., 2011); and the pollen viability of *Alpinia zerumbet* by colorimetric tests in the state of Mato Grosso (Macedo et al., 2016).

The objective was to increase the knowledge about the morphological and postharvest traits of four *A. purpurata* cultivars based on qualitative evaluations, to identify genotypes with promising traits for the ornamental plant market.

Material and Methods

The Active Germplasm Bank (BAG) of the State University of Mato Grosso (14°39' S, 57°25' W; 321 m asl), established in 2015, contains numerous tropical ornamental plant species. The regional climate of Tangará da Serra, Mato Grosso is tropical, with a dry season from May to September, a rainy one from October to April and an

average annual rainfall of 1830 mm (Dallacort et al., 2011). The soil is classified as a Latossolo Vermelho Distroférico with a clayey texture and flat to slightly undulating relief (Embrapa, 2018).

The four *A. purpurata* cultivars 'Jungle King', 'Kimi', 'Red Ginger' and 'Pink Ginger' were evaluated under 30% shading. The experiment was arranged in a randomized complete block design, with nine replications. The plants and rows were spaced 3.0 m apart, and one rhizome per planting hole was planted. The experiment was carried out as proposed by Costa et al. (2007). Irrigation was performed by micro (drip) irrigation. Base fertilization consisted of 50 g monoamonic phosphate (MAP) per planting hole and was repeated monthly, applying MAP, urea and potassium chloride. Weeding of the BAG area, pruning, insecticide and fungicide applications and other cultural treatments were carried out when necessary.

The qualitative morphological traits were evaluated according to the availability of flowers in the field, from April 2016 to March 2017, analyzing 10 floral stems per clump (plot).

The evaluation of the four *Alpinia* cultivars was based on 16 morphological descriptors, of which 11 were quantitative. The following traits were measured with a measuring tape, pachymeter and digital scale: floral stem length (pseudostem base to apex), floral stem diameter (measured with a digital caliper 20 cm below the inflorescence base, on the leaf blade), inflorescence length (inflorescence base to apex), inflorescence width (maximum distance between lateral bracts), number of leaves on floral stem, leaf width, leaf length, floral stem weight without leaves, number of stems produced, number of marketable stems, postharvest durability.

The six qualitative descriptors were evaluated: on the inflorescence (type, shape and color), floral stem (hairiness and waxiness), bracts (firmness), petiole and leaf (hairiness and waxiness), as described by Teixeira and Loges (2012). The Munsell color book (Munsell Plant Tissue Color Book, 2012) was used to define the inflorescence colors. The postharvest durability of 10 stems per clump (plot) was determined. From April 2016 to March 2017, the four above cultivars and three temperatures (16 °C and 19 °C at 80% humidity in a cold chamber and ambient temperature, at around 26 °C and 50% humidity, as control) were evaluated in a 4x3 factorial design. To this end, 10 freshly cut flower stems were placed in buckets with 5 L water and, every two days, the water was exchanged. This evaluation was based on a 1 - 4 grade scale, adapted from Dias-Tagliacozzo et al. (2003). The evaluation was always carried out by the same evaluator, who assigned: grade 4 to inflorescences with an excellent general appearance, bright turgid bracts and green leaves; grade 3 to good general appearance, beginning gloss loss of bracts, onset of leaf yellowing; grade 2 for poor overall appearance, with yellow and dry leaves, gloss loss of the bracts and inclining of the inflorescence; grade 1 for disposal (Figure 1).



Figure 1. Senescence process of floral stems of *Alpinia purpurata*.
A: grade 4; B: grade 3; C: grade 2 and D: grade 1 (Disposal).

The production was evaluated during the flowering period, from April 2016 to March 2018, with two cuts per week. The flower stems were cut at a distance of 20 cm above the soil, when 2/3 of the bracts had opened. After harvesting, the flower stems were divided into two groups: marketable and non-marketable stems. The market standards of Loges et al. (2008) were taken as basis, which define an inflorescence size between 15 and 17 cm as small; 18 to 20 cm as medium and > 20 cm as large. The overall quality was classified as: Type A - good structure, 1/3 of the lower bracts closed, turgid tissues, pseudostem diameter > 1 cm and no cauterization or mechanical damage on the inflorescences; Type B - slightly deformed stem, full bract expansion, pseudostem diameter of < 1 cm and slight mechanical damage. Floral stems with severe mechanical damage, lesions, and pest and insect attack symptoms were considered non-marketable.

The exploitation rate of marketable stems of the *Alpinia purpurata* cultivars was calculated by the equation: $SER = NMS \cdot 100 / TSN$, where: SER - stem exploitation rate; NMS - number of marketable stems; and TSN - total number of stems. Evaluations were carried out from April 2016 to March 2018.

Statistical analyses were performed with software Sisvar® (Ferreira, 2000), the quantitative descriptors subjected to analysis of variance and the means compared by Tukey's test at 5% probability.

Results

After the growth of the first bracts, all cultivars continued production uninterruptedly. In April 2016, eight months after planting, first floral stems of cultivar 'Red Ginger' were observed. Cultivar Jungle King and Kimi grew flower stems in May and June 2016, respectively, about nine months after planting, while 'Pink Ginger' flowered 11 months after planting.

The flowering peak of 'Red Ginger' occurred in July and August 2017 and that of 'Jungle King' in January 2018, of 'Kimi' in March 2017 and of 'Pink Ginger' in May and November 2017 (Figure 2). The production of all four cultivars decreased in March 2018 (Figure 2).

The floral stems length of the evaluated cultivars varied from 61.57 cm to 111.98 cm. The floral stem length of cv. Jungle King was about 50 cm longer and statistically different from that of cv. Red Ginger, which was the shortest (Table 1).

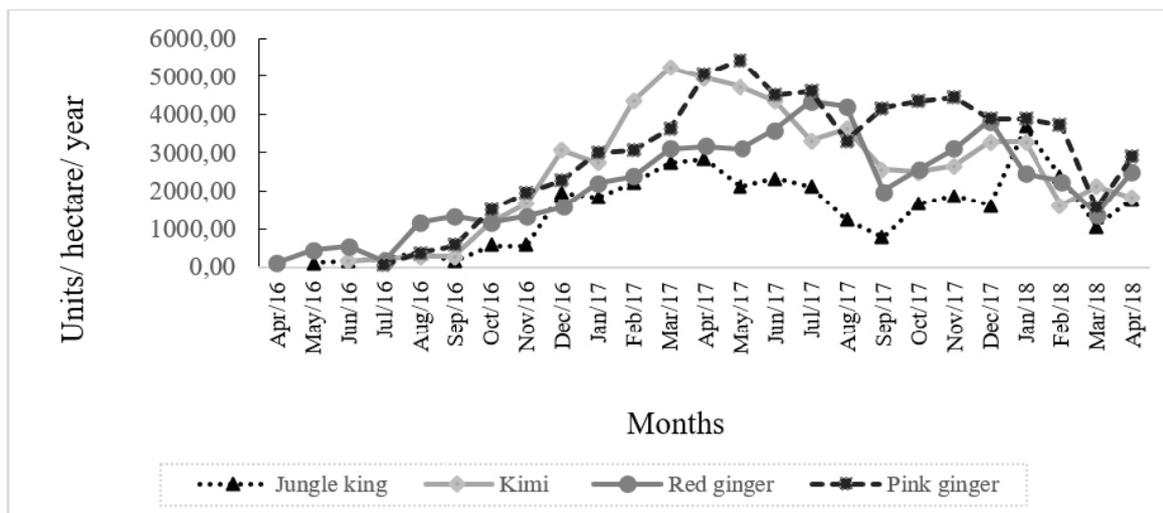


Figure 2. Monthly yield per units ha⁻¹ year⁻¹ of *Alpinia purpurata* cultivars, between April 2016 and April 2018.

Table 1. Means of floral stem length (CHF), floral stem diameter (FSD), inflorescence width (LW), inflorescence length (CI), number of leaves per stem (NFH), leaf width (LW), leaf length (LL), fresh floral stem weight (FFSW), total stem number (TSN), marketable stem number (NMS) of *Alpinia purpurata* cultivars of the active germplasm bank of the State University of Mato Grosso.

<i>Alpinia purpurata</i> Cultivars	Traits									
	CHF (cm)	FSD (cm)	LI (cm)	CI (cm)	NFH (un)	LW (cm)	LL (cm)	FFSW (g)	TSN (ha ⁻¹ year ⁻¹)	NMS (ha ⁻¹ year ⁻¹)
'Jungle King'	111.9a	1.02a	5.96a	12.2ab	13.2a	10.7a	36.0a	94.7a	4037.03b	2938.27b
'Kimi'	87.38b	1.01a	5.65a	10.9c	11.0b	9.2b	28.4b	77.2a	6654.32a	4783.95a
'Red Ginger'	61.57c	0.63b	4.29b	11.3bc	8.5c	6.9c	19.3c	29.2c	6012.34ab	4117.28ab
'Pink Ginger'	82.76b	0.74b	4.72b	13.0a	10.1b	9.2b	25.2b	52.3b	7580.24a	5456.79a

^{1/} Means followed by the same letter in a column do not differ from each other, by Tukey's test at 1% and 5% probability.

The cultivars Jungle King and Kimi had the highest floral stem diameter and inflorescence width and 'Red Ginger' and 'Pink Ginger' the lowest means for these two traits (Table 1). The inflorescence length of 'Pink Ginger' was 16% longer and statistically different from that of 'Kimi' (Table 1).

The leaf number, width and length of the cultivars were similar (Table 1). The leaves of the cultivars with a lower leaf numbers were also narrower and shorter (Table 1). The fresh stem weight of 'Jungle King' was 69% higher and statistically different from that of 'Red Ginger', which was the lowest (Table 1).

The mean productivity of the cultivars Kimi, Pink Ginger and Red Ginger was high, ranging from 6012.34 to

7580.24 ha⁻¹ floral stems year⁻¹ (Table 1). The productivity of floral stems of cultivar Kimi was 60% higher and significantly different from that of 'Jungle King', with the lowest mean (Table 1).

The mean number of marketable stems varied from 2938.27 to 5456.79 units ha⁻¹ year⁻¹. 'Pink Ginger' and 'Kimi' had the highest and 'Red Ginger' and 'Jungle King' the lowest means for this trait. 'Pink Ginger' produced a 53.84% higher marketable stem yield than 'Jungle King' (Table 1).

Although the stem yield of cultivar Jungle King was the lowest (Figure 3), the exploitation rate was 72.87%. Cultivar Red Ginger produced more floral stems ha⁻¹ year⁻¹ than Jungle King (Figure 3), and had a 68.48% lower exploitation rate than the other cultivars (Figure 3).

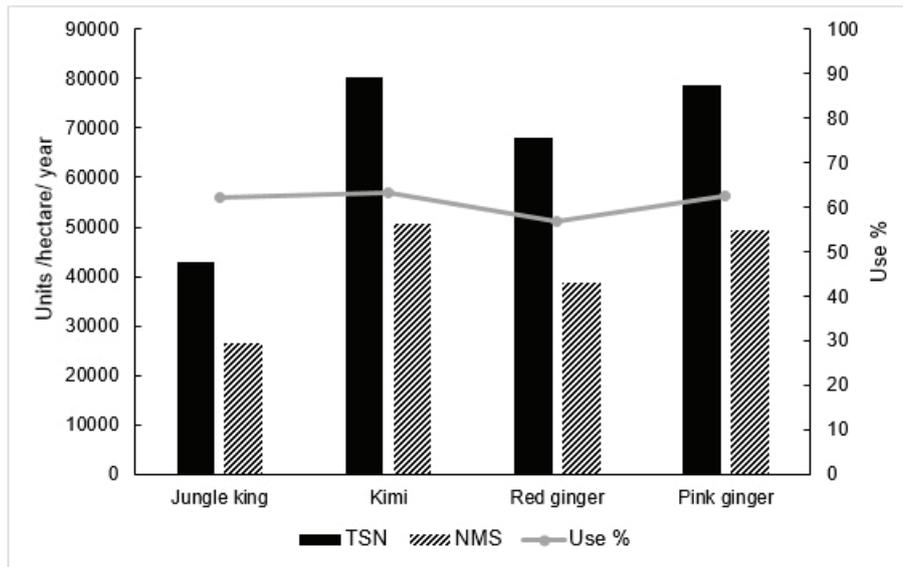


Figure 3. Total number of stems (TSN), number of marketable stems (NMS) and exploitation rate of flower stems of *Alpinia purpurata* cultivars evaluated from April 2016 to April 2018.

The inflorescence shape of the cultivars Jungle King and Kimi is rounded. The cultivars Red Ginger and Pink Ginger have elongated inflorescences (Figure 4). The inflorescence color varied between shades of red ('Jungle King' 25R/6, 'Red Ginger' 10R7/8)

and pink ('Kimi' 2.5R4/8, 'Pink Ginger' 2.5R7/6). A number of traits were similar for the four evaluated cultivars: inflorescence shape; floral stem hairiness and waxiness; bract firmness; petiole and leaf hairiness and waxiness.



Figure 4. *Alpinia purpurata* cultivars of the active germplasm bank of the Mato Grosso State University, Tangará da Serra, MT: A) 'Jungle King', B) 'Kimi', C) 'Red Ginger' and D) 'Pink Ginger'.

In the postharvest evaluation, the inflorescence durability of the *A. purpurata* cultivars was longer under refrigerated conditions than in the control treatment. At 16°C, the inflorescence durability of all four cultivars lasted

between 15.61 and 19.13 days. The temperature of 19 °C extended inflorescence durability by 13.63 to 16.44 days over that of the control (Table 2).

Table 2. Mean post-harvest durability (in days) of *Alpinia purpurata* cultivars under refrigerated conditions (16 and 19 °C) and ambient temperature (control, 26 °C).

Cultivar	Temperature		
	16 °C	19 °C	26 °C
‘Jungle King’	17.48 Aab	16.44 Aa	8.84 Ba
‘Kimi’	19.13 Aa	14.76 Bab	6.72 Cb
‘Red Ginger’	18.16 Aa	14.72 Bab	8.32 Cab
‘Pink Ginger’	15.61 Ab	13.63 Bb	7.76 Cab

¹Means followed by the same capital letter in a line between temperatures and lowercase letter in a column between cultivars do not differ from each other by the Tukey test at 5% probability.

The postharvest durability of cultivar Jungle King was significantly higher (~ 97.74%) under refrigerated conditions (16 °C) than that of the control. In other words, a temperature decrease of 10 °C and a 30% increase in relative air humidity, in relation to the control, resulted in a doubled inflorescence vase life for this cultivar (Table 2).

‘Kimi’ inflorescences had a longer vase life at 16 °C than at 19 °C, which exceeded that of the control by 12 days (Table 2).

The mean postharvest durability of the cultivars Red Ginger and Pink Ginger lasted between 8 and 18 days under refrigerated conditions, at 16 °C and 19 °C. For these cultivars, the inflorescence durability was about 4 to 5 days longer than that of the control (Table 2). The postharvest durability at 16 °C was about 8-10 days longer than at the control temperature (Table 2).

The postharvest durability of the inflorescences of the cultivars Jungle King, Kimi and Red Ginger at 16 and 19 °C was similar (Table 2).

At ambient temperature (26 °C), the postharvest durability of all evaluated cultivars was statistically lower (6-8 days) (Table 2).

Discussion

During the experimental period, the temperature in the state of Mato Grosso varied from 23 °C to 30 °C (INMET, 2017). According to Medeiros et al. (2009), in studies with *A. purpurata* in the state of Pernambuco, where the climate is tropical, with an average annual temperatures of 25 °C, this species develops well under 50% (mainly the pink species) or 20% - 45% shading.

The great ornamental value of *A. purpurata* and its use as cut flower and in landscape projects is mainly due to the year-round flowering (Alonso and Sousa-Silva, 2010). The variations in the production peaks of the cultivars evaluated under the cultivation conditions of Pernambuco (Loges et al., 2009) differed from those recorded in this study, which may be due to the differences between the regional climates.

The variation in floral stem length between four *A. purpurata* cultivars (‘Vermelha’, ‘Jungle Queen’ and

‘Jungle King’) in Recife, Pernambuco (Loges et al. 2008) in which the floral stem of cultivar Jungle King was longer (21 cm) and the diameter larger (1.8 cm). Variations in stem length of four cultivars and three hybrids of *Heliconia psittacorum* were also recorded (Costa et al., 2007).

According to the standards of Loges et al. (2005), the inflorescence size of *Alpinia* was classified as small in this study. However, further evaluations of this nature will be needed to ensure the establishment of an inflorescence size pattern for the study area. Inflorescences that do not meet the market standards can also be offered on national or regional markets, in the form of mini arrangements and in short-lived decorations.

Floral stems with a higher number of leaves and larger diameter of the floral stem may be the result of a greater accumulation of reserves in these organs. Light stems weighing up to 100 grams (Castro et al., 2007) are desirable in the cut flower market, although the stem weight is directly related to durability, since floral stems with a higher weight contain higher quantities of carbohydrates and consequently have a longer postharvest durability (Nowak and Rudnicki, 1990).

Among the quantitative descriptors, the floral stem length and diameter and inflorescences height, diameter and fresh weight are considered relevant for cut flowers, with a view to the development of lighter plants, resulting in lower transport and packaging costs for producers (Gonçalves et al., 2014).

The traits bract color variations and firmness are desirable in evaluation studies of the ornamental potential of tropical species. Similarly, traits such as absence of leaf and inflorescence waxiness are desirable, since the visual appearance can be affected at handling when they are present (Loges et al., 2005).

The stem yield of *A. purpurata*, recorded in this study was higher than the results (2.028 stems ha⁻¹ year⁻¹) for the same species in a study in the coastal region of the state of Ceará (Bezerra et al., 2008). Refrigerated environments (15 °C) were indicated for the storage of flower stems for *A. florurata* species in the state of Pernambuco (Teixeira and Loges, 2008) and of *Strelitzia reginae* in São Paulo (Vieira

et al., 2014), confirming the results of this study for the state of Mato Grosso.

Temperatures below 20 °C and relative humidity above 70% seem to be the most adequate conditions for postharvest conservation of *A. purpurata* inflorescences. In addition to the maintenance of floral stems, full sun cultivation (personal observation) the harvest, at temperatures above 26 °C, are not recommended for *A. purpurata* cultivation in the state of Mato Grosso, where high temperatures favor the appearance of lesions (cauterization) on inflorescences and leaves.

Temperatures of <20 °C and relative humidity >70% seem to define the most adequate conditions for postharvest conservation of *A. purpurata* inflorescences. Full-sun cultivation (personal observation) is not recommended for *A. purpurata* in the state of Mato Grosso, since the high temperatures (> 26 °C) would favor the appearance of lesions (cauterization) on inflorescences and leaves.

Conclusion

Flowering of *Alpinia purpurata* began about nine months after planting.

The inflorescences of *A. purpurata* varied in stem and inflorescence length, fresh stem weight and stem yield and quality for commercialization.

The cultivars Jungle King and Kimi have relevant traits required for commercialization, e.g.: higher floral stem length and diameter, inflorescence width and fresh weight of the floral stem. Cultivars 'Red Ginger' and 'Pink Ginger' on the other hand produced more floral stems. Crosses between the promising cultivars 'Jungle King', 'Kimi' and 'Pink Ginger' are suggested for the breeding of superior cultivars.

For postharvest conservation of *A. purpurata* inflorescences, a cooling temperature of 16 °C is recommended.

Author Contribution

R.P.A.F.⁰⁰⁰⁰⁻⁰⁰⁰¹⁻⁸⁵⁰⁴⁻²⁹²⁸: field analysis, data collection and analysis, manuscript preparation and revision; **A.F.B.**⁰⁰⁰⁰⁻⁰⁰⁰³⁻⁴⁰⁶⁰⁻⁷⁹⁴²: data collection and analysis; **H.M.A.**⁰⁰⁰⁰⁻⁰⁰⁰³⁻³⁹⁵⁰⁻¹⁴⁹⁷: data collection and analysis; **W.K.**⁰⁰⁰⁰⁻⁰⁰⁰²⁻⁵³⁰⁸⁻⁷⁷¹⁵: data analysis and interpretation, text revision; **C.A.S.**⁰⁰⁰⁰⁻⁰⁰⁰¹⁻⁷⁸⁹⁸⁻⁷⁹³¹: data analysis and interpretation, manuscript preparation and revision.

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