Scientific Article

Development of everlasting flowers (*Comanthera elegans* (Bong.) L.R. Parra & Giul.) in three cultivation systems[1]

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ABSTRACT

Marketing the inflorescences of *Comanthera elegans* (Bong.) L.R. Parra & Giul. represents a source of income to many families from extractives communities in the portion of the Espinhaço Range located in the state of Minas Gerais, Brazil. Cultivating this species stands out by allying income generation with conservation since the species is currently endangered. This study aimed to assess aspects of the development of *C. elegans* in three cultivation systems: beds, rows, and whole area. Sowing took place in January 2009 and the inflorescences were harvested in May 2010, which characterized the experimental period. Emergence; plant density; rates of flowering, mortality, resprouting, and recruiting of new individuals; and production of inflorescences per plant and per area were assessed. Emergence began approximately 50 days after sowing. Plant density ranged from 130 to 350 plants.m^{-2} among the three cultivation systems. The highest mortality rate (18%) was observed at the peak of the dry season (August) and the overall mortality rate over one reproductive cycle was 49%. Of the plants that lost the aerial part, 36% resprouted. Sprouting and seed germination accounted for 30 and 3% of the recruiting of new individuals, respectively. *C. elegans* had two bloom (April-May 2009 and April-May 2010): 5.4% of the plants bloomed in the first season and 78%, in the second. Each plant produced between three and 178 inflorescences and the highest inflorescence production in terms of weight (232 g.m^{-2}) and number (2,910 inflorescences.m^{-2}) was observed in the cultivation in beds at 1,624 kg.ha^{-1}.

Keywords: *Campos Rupestres*, Eriocaulaceae, production, management, dry cut flowers.

RESUMO

Desenvolvimento da sempre viva (*Comanthera elegans* (Bong.) L.R. Parra & Giul.) em três sistemas de cultivo

A comercialização das inflorescências de *Comanthera elegans* (Bong.) L.R. Parra & Giul. representa fonte de renda para muitas famílias de comunidades extrativistas da porção mineira da Serra do Espinhaço. O cultivo representa uma importante alternativa de geração de renda aliada à conservação, já que a espécie consta em lista de ameaçadas. Objetivou-se com o presente trabalho avaliar os aspectos do desenvolvimento de *C. elegans* em três sistemas de cultivo: em canteiro, faixa e área total. O semeio ocorreu em janeiro de 2009 e a colheita das inflorescências em maio de 2010 caracterizou o final do período experimental. Avaliou-se a emergência, a densidade de plantas, as taxas de floração, de mortalidade, de rebrota e de recrutamento de novos indivíduos e a produção de inflorescências por planta e por área. A emergência iniciou aproximadamente 50 dias após o semeio. A densidade de plantas variou entre 130 e 350 plantas.m^{-2} nos três sistemas de cultivo. A maior taxa de mortalidade (18%) foi observada no pico da estação seca (agosto) e a taxa de mortalidade acumulada durante um ciclo reprodutivo foi de 49%. Das plantas que perderam a parte aérea, 36% rebrotaram. O brotamento e a germinação de sementes contribuíram com 30 e 3% do recrutamento de novos indivíduos. *C. elegans* apresentou duas florações (abril-maio de 2009 e abril-maio de 2010): 5,4% das plantas floresceram na primeira e 78%, na segunda floração. Cada planta produziu entre 3-178 inflorescências, e a maior produção de inflorescências, em peso (232 g.m^{-2}) e número (2910 inflorescências.m^{-2}), foi observada no sistema de cultivo em canteiros, o que corresponde a 1624 Kg.ha^{-1}.

Palavras-chave: Campos Rupestres, Eriocaulaceae, produção, manejo, flores de corte secas.

1. INTRODUCTION

Among the many everlasting species of the families Eriocaulaceae, Xyridaceae, Cyperaceae, and Rapataceae collected in the state of Minas Gerais, Brazil, and marketed in the category of "dry cut flowers," the ones in the genus *Comanthera*, belonging to the family Eriocaulaceae, are the most valued and *Comanthera elegans*, known as everlasting flowers *"pé-de-ouro"*, is the most popular. The family Eriocaulaceae is found in Africa and in the Americas and its main center of diversity is located in the Espinhaço Range in the Brazilian states of Minas Gerais and Bahia (GIULIETTI et al., 1988).

Collecting everlasting flowers is a common activity for traditional communities in the portion of Southern Espinhaço Range located in the state of Minas Gerais and is part of the sociocultural identity and life strategies of part of this rural population (MONTEIRO et al., 2012). The region of Diamantina in that state is considered the largest center of production and distribution of everlasting flowers in Brazil. Collection and commercialization of everlasting flowers of the genus *Comanthera* can be traced

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back to the 1930s (GIULIETTI et al., 1988) or even earlier (MONTEIRO et al., 2012). By the 1950s, this product reached the international market. Ever since, marketing everlasting flowers, at larger or smaller amounts according to market demand, is the main source of income to many families in extractives communities.

The great ornamental value of everlasting flowers, characterized by inflorescences and scapes maintaining their appearances after collection as if they were still alive, is what makes them unique and command high commercial value. These ornamental characteristics exert great pressure on collection, which, in addition to the endemic distribution of some species, has caused many everlasting flowers, among which *C. elegans*, to be included in endangered species lists under the category of critically endangered (BIODIVERSITA, 2007; MARTINELLI and MORAES, 2013).

In face of the intense exportation of everlasting flowers, the first initiatives of sowing for crop production took place. According to reports by collectors and wholesalers in the region and based on photographic records of the time, *C. elegans* cultivation in Diamantina began in the late 1970s and early 1980s. It was properly implemented in 1982/1983, when the Sakurai brothers, Japanese immigrants living in Diamantina, founded the exporting company "Irmãos Sakurai Ltda." By the end of the 1980s, the idea of cultivating everlasting flowers had expanded and, in parallel with the rise of other exporting companies, many collectors began sowing ground inflorescences in areas where the species naturally occurs. However, this initiative was conducted on a small scale in an attempt to increase inflorescence production, which created the so-called "enriched fields" or "cultivated fields."

Everlasting flowers featured as the second largest planted area (57 hectares) (only behind roses) and the third largest exported volume (behind roses and orchids) in the category of cut flowers in the state of Minas Gerais (LANDGRAF and PAIVA, 2009). Although that study reports 57 hectares of planted area, the actual sowed area is much larger, but mostly comprising enriched native fields. The lack of regulation for collection and marketing, justified by scarce knowledge on the species, is thought to highly discourage cultivation since native and grown inflorescences are not differentiated during commercialization. That, in turn, contributes to most of the flowers sold being collected in extractives practices.

Normative Instruction 177/2008 by the Brazilian Institute of the Environment and Renewable Natural Resources (*Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis* - IBAMA) established that the commercialization of plant species featured in endangered species lists is allowed when they are artificially bred (cultivated) or when they come from the management of natural ecosystems. In this context, stimulating the cultivation of endangered everlasting flower species becomes an important perspective for sustainable use as it reduces collection pressure on native areas and has been suggested by some researchers (GIULIETTI et al., 1988; SCATENA et al., 2004). Nonetheless, the literature lacks studies proposing cultivation systems for everlasting flowers.

Knowledge on cultivation techniques along with systematization of information on traditional knowledge are required to generate information that may foster management regulations and guidelines, reduce collection pressure on native fields, and represent an alternative among ornamental species grown in the state of Minas Gerais.

This study aimed to assess aspects of the development of the everlasting flower *C. elegans* in three cultivation systems.

2. MATERIAL AND METHODS

Comanthera elegans (Bong.) L.R. Parra & Giul. cultivation took place in Galheiros (18° 20'S and 43°53'W, 1,291 m), a traditionally extractivist community located 25 km from the city of Diamantina-MG, Brazil. The climate in the region is Cwb, i.e., subtropical highland, featuring dry winters and wet summers and mean temperature of the hottest month below 22 °C (VIEIRA et al., 2010). Physicochemical analysis of the soil in the experimental area was performed for the layers of 0-20 cm and 20-40 cm (Table 1), where the root system of *C. elegans* develops.

After the experimental area was delimited, the treatments were applied. The treatments consisted of sowing in beds (T1), in rows (T2), and in whole area (T3). Beds with 5 m in length, 1 m in width, and 20 cm in height were prepared for T1. For T2, 1 m x 5 m rows were cleared of vegetation and the material removed was placed in the adjacent row onto the native vegetation, creating alternating rows of native vegetation and planted area, which was sowed with *C. elegans*. In T3, a 25 m^2 area was cleared of vegetation. Each set of five 5 m x 1 m beds (totaling 25 m^2) or five 5 m x 1 m rows (totaling 25 m^2) or continuous area of 25 m^2 represented one experimental plot. Three replicates were used for each treatment. Whole area sowing is the practice adopted by collectors-growers of the region. The system employing beds was adopted by Irmãos Sakurai Ltda., but its use is currently limited. The system using rows sought to minimize the management of the land and removal of original vegetation.

Inflorescences ground in 3 mm screens were used for sowing. The material resulting from grinding was sent to the laboratory, where the number of seeds per gram and the germinating rate of the seeds were determined. For the germination test, 30 seed were placed in each Petri dish and kept in a germinator at 25±2 °C. Four replicates were used and the seeds that showed the embryonic axis were considered germinated. The test was conducted until germination had stabilized.

In order to determine the amount of ground material distributed per area (12 $g.m^{-2}$), the number of seeds/g, the germination rate, and the 20% rate of establishment of plants in the field were considered. The rate of establishment was based on a previous evaluation of an enriched area belonging to a producer in Diamantina, which revealed mortality of up to 80% of new plants during the first dry period subsequent to sowing.

Seeds were manually broadcast sowed in January 2009 (wet season) at 12 $g.m^{-2}$ of the plant material resulting from grinding the inflorescences, which contained, on average, 800 seeds per gram. After sowing, the seeds were embedded into the soil 0.5 cm deep. All steps of the experiment attempted to reproduce the procedures normally adopted by growers/sowers of the region.

After emergence (May 2009), five 0.5 m^2 subplots were delimited in each plot (replicate). The three treatments and the three replicates with five further replicates (subplots) totaled 45 subplots or observation units. The treatments were randomly distributed in the land. The Latin square experimental design was adopted. The fact there was a soil moisture gradient in two directions due to the slight slope of the experimental area was the criterion to choose the Latin square design, which allows for better control of environment heterogeneity, thus improving experimental precision (PIMENTEL GOMES, 2009).

Between May 2009 and May 2010, monthly measurements were performed to assess plant density (plants.m^{-2}), number of modules (basal shoots) per plant, and the number of modulated plants, dead plants, flowering plants, and new plants derived from seed germination. From these data, the rates of mortality, flowering, recruiting of new individuals via seeds and via sprouting, and resprouting rate were calculated. The plants lacking the aerial part or with all leaves dry were considered dead. At the time, it was unknown whether those plants would resprout. The mortality rate represents the percentage of dead plants in relation to the live plants at the beginning of the experiment. The flowering (characterized by the anthesis of capitula) rate represents the percentage of flowering plants in relation to the total number of plants present on the day of assessment. The recruiting rate represents the percentage of plants derived from seed germination and sprouting in relation to the total number of plants on the day of assessment. Sprouting took into account the number of modules that spawned on the living plants (plants with green leaves or that maintained at least part of the leaves green during the experimental period). The resprout rate represents the number of plants, among those considered dead, that had new modules in relation to the number of dead plants during the experimental period.

By the end of May 2010, the inflorescences in the plots (25 m^2) and subplots (0.5 m^2) were collected. The inflorescence production data (weight) in the plots were converted into kg.ha^{-1}. The calculation of production per hectare (P) considered 70% of useful area (corresponding to the beds or rows) and 30% of corridors. Hence, P = [(production in the plot * 10,000)/25]*0.7. In the subplots, the number and weight of inflorescences per plant and per area were assessed. Scape length (inflorescence stem) and capitula diameter were assessed in 20 inflorescences. The inflorescences were weighed for three days after collection to simulate the drying process that normally takes place prior to commercialization of everlasting flowers.

Climatologic data (rainfall and mean, maximum, and minimum temperature) were collected at the meteorological station in Diamantina (INMET) between May 2009 and September 2010 (Figure 1).

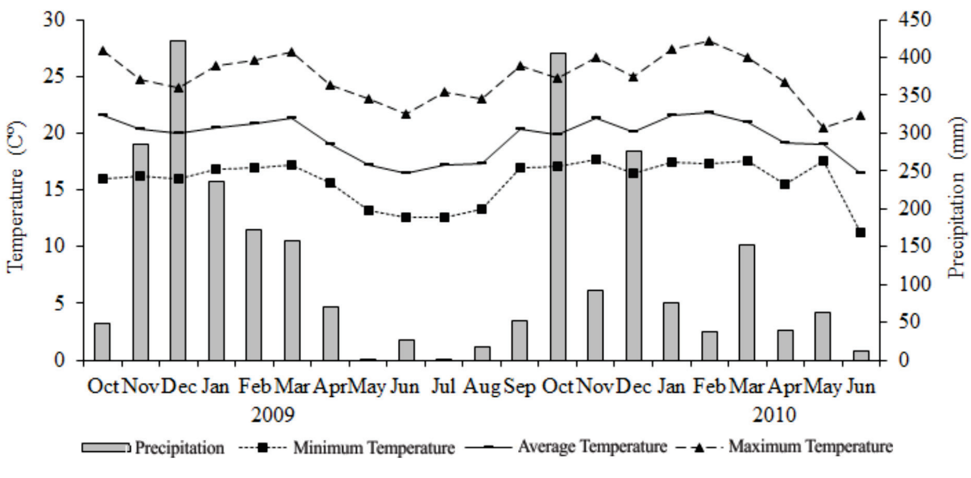

Figure 1. Monthly variation of precipitation and temperature from October 2008 to September 2010. Data collected at the INMET climatological station in Diamantina-MG, located at latitude 18.25ºS, longitude 43.60ºW and altitude of 1296.9m.

Over the same period, soil samples were collected in the plots 10 cm deep to determine moisture content. The variables assessed were compared among the three cultivation systems. The data underwent statistical analysis and the variances were compared by F-test at 5% probability. The multiple comparisons among means were performed using Tukey's test at 5% probability.

3. RESULTS

Cultivation Soil Characterization

The soil in the experimental area had sandy texture and pH 4.4, which places it in the strong acidity range. The 0-20 cm deep layer had higher P and K contents (7.4 and 17 mg/dm^3, respectively) compared to the 20-40 cm deep layer (3 and 7 mg/dm^3, respectively) (Table 1).

Table 1. Chemical and physical attributes of soil samples collected in the crop area of Comanthera elegans (Bong.) L.R. Parra & Giul., Galheiros-MG.

Soil profundity (cm)	0-20	20-40
pH (water)	4,4	4,4
P (mg/dm^3)	7,4	3
K (mg/dm^3)	17	7
Ca (cmol/dm^3)	0,2	0,3
Mg (cmol/dm^3)	0,1	0,1
Al (cmol/dm^3)	1,7	1,5
H+Al(cmol/dm^3)	6,5	4,2
SBS (cmol/dm^3)	0,3	0,4
t (cmol/dm^3)	2,0	1,9
T (cmol/dm^3)	6,8	4,6
m (%)	83	78
V (%)	5	9
M.O (dag/kg)	2	1,2
Sand (dag/kg)	80	80
Silt (dag/kg)	14	14
Argil (dag/kg)	6	6

pH_{water} – Proportion soil-water 1:2,5; P e K – Mehlich-1 Extractor; Ca, Mg e Al – KCl Extractor (1 mol L^{-1}); V – Base Saturation; t- Effective Cation Exchange Capacity; T- Cation Exchange Capacity at pH 7; M.O. = Soil Organic Matter; BS- Base Sum; m-Aluminum saturation.

Field Establishment

The emergence of the first *C. elegans* plantlets was observed by the end of February 2009, approximately 50 days after sowing (in early January 2009), and continued on until June, likely favored by soil moisture due to rainfall, which occurred as late as June in that year (Figure 1).

Plant density differed among the three cultivation systems ($P < 0.05$), ranging from 204 to 350, 165 to 280, and 130 to 246 plants.m^{-2} in the bed, row, and whole area cultivation systems, respectively. The highest density was observed in May 2009 (beginning of the dry season) and started decreasing in July in the bed system and in August in the others, reaching minimum levels in September (end of the dry season), after which it remained stable until the end of the experimental period in May 2010 (Figure 2).

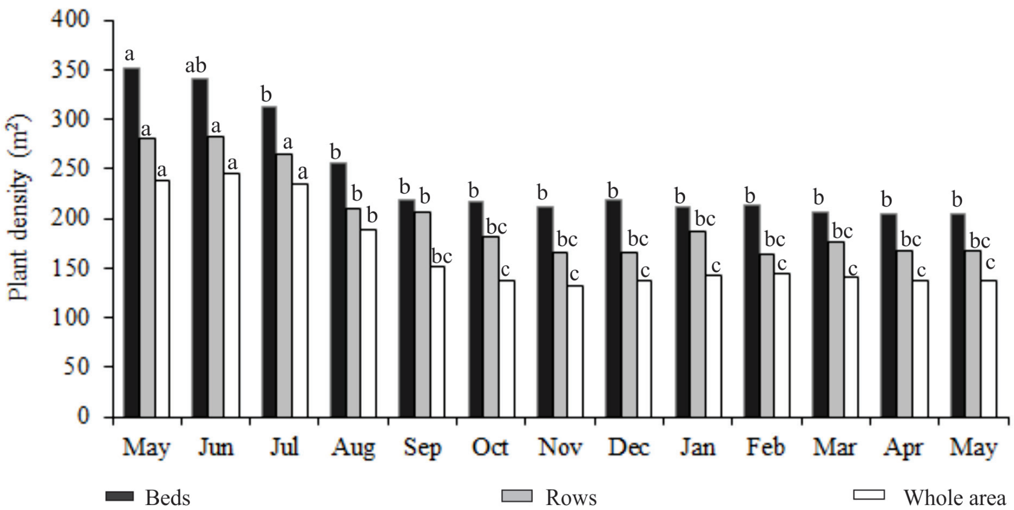

Figure 2. Density of plants per m^2 of *Comanthera elegans* (Bong.) L.R. Parra & Giul. In various seasons (May 2009 to May 2010) in the systems of cultivation of land, range and total area. * Bars of the same color, followed by equal letters, do not differ by the Tukey test at 5% probability.

Vegetative Growth, Mortality, and Plant Recruiting

The plant dead occurred throughout the experimental period, particularly between July and October, with mean accumulated rate of 42% (Figure 3). The highest value (18%) was reached in August, when soil moisture 10 cm deep was 1.3%. A positive correlation was observed between mortality rate and plant density (R^2=0.77).

Recruiting, which means the increase in plant population via sexual or asexual reproduction, occurred between December 2009 and May 2010 and did not significantly differ among the three cultivation systems (P > 0.05). Concomitant mortality and recruiting (Figure 3) allowed the density to remain constant over the period. The recruiting that started in December was due to seed germination. Starting in March, recruiting took place via two processes: seed germination and sprouting (production of vegetative structures, called modules, in plants that remained green over the experimental period). The new plants recruited in June 2009 emerged from seeds remaining from the sowing performed in January of that year (Figure 3).

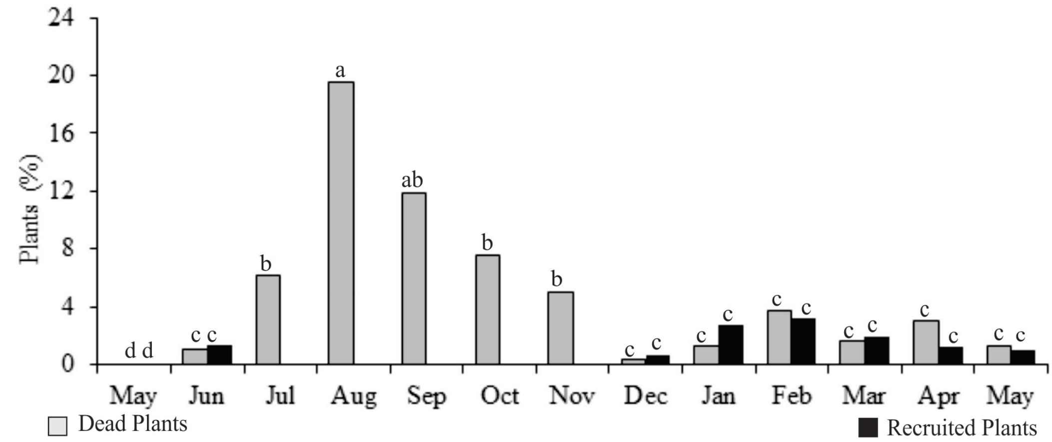

Figure 3. Percentage of dead and recruited plants belonging to *Comanthera elegans* (Bong.) L.R. Parra & Giul. at various times (May 2009 to May 2010). * Bars of the same color, followed by equal letters, do not differ by the Tukey test at 5% probability.

Starting in January 2010, resprouting (the appearance of leaves or modules in the plants that appeared to be dead, lacking the aerial part, of whose leaves were all dry) was observed. The resprouting rate of 36% did not significantly differ among the three cultivation systems (P > 0.05). The resprouted plants produced between four and 12 modules with leaves of a darker shade of green compared to the leaves of the other plants.

Considering the plants that remained green throughout the experimental period, 20% had new sprouts (new modules), which appeared in April during the anthesis phase of the capitula in the second flowering. The percentage of plants with new sprouts did not significantly differ among the three treatments (P > 0.05). Although 10% of those plants had between eight and ten modules (basal shoots) the mean number of basal shoots (1.4/plant) produced by those plants during the experimental period was lower than the mean number of basal shoots produced by plants that resprouted after losing the aerial part (6/plant).

Flowering and Production

In May 2009, approximately five months after sowing, 1.84, 3.31, and 6.16% of the plants in the bed, row, and whole area cultivation systems, respectively, were experiencing anthesis of the capitula, characterizing the first flowering (Figure 4), in which each plant produced between one and five inflorescences. The flowering rate differed among the three cultivation systems and the highest rate was observed in the whole area system (P < 0.05).

The second reproductive phase (second flowering), characterized by the emission of sheaths (spathes) of the inflorescences, began in December 2009 (one year after sowing). In March 2010, when the plants were approximately 15 months old, the maximum number of flowering plants was observed. Of the ones that lost the aerial part and resprouted, 51% showed inflorescences in the second flowering and 12% of those that produced flowers in the first flowering did so in the second flowering too. The anthesis of capitula began in February 2010, peaking (average of 90% inflorescences in anthesis) in April of the same year. Regardless of plant age (first or second reproductive phase), of cultivation system (bed, row, or whole area), or plant origin (seed or resprout), peak flowering (anthesis of most capitula) occurred in April, when the plants were 16 months old.

In the second reproductive phase, flowering rate differed among the three cultivation systems (P < 0.05) at 91% in bed, 67% in row, and 75% in whole area systems (Figure 4), which corresponds to 185, 112, and 102 flowering plants.m^{-2}, respectively. Each plant produced on average 14 inflorescences (1.11 g) with 8 to 16 mm diameter and 20 to 60 cm scape length, while 43% of the scapes presented between 30 and 40 cm long. Production per plant ranged from three to 178 inflorescences, which corresponds to 0.12 to 17.61 g.$plant^{-1}$. The plants that resprouted produced, on average, 18 inflorescences each that were 13 to 22 cm tall. Overall, the inflorescences produced in resprouted plants had spiral-shaped stems.

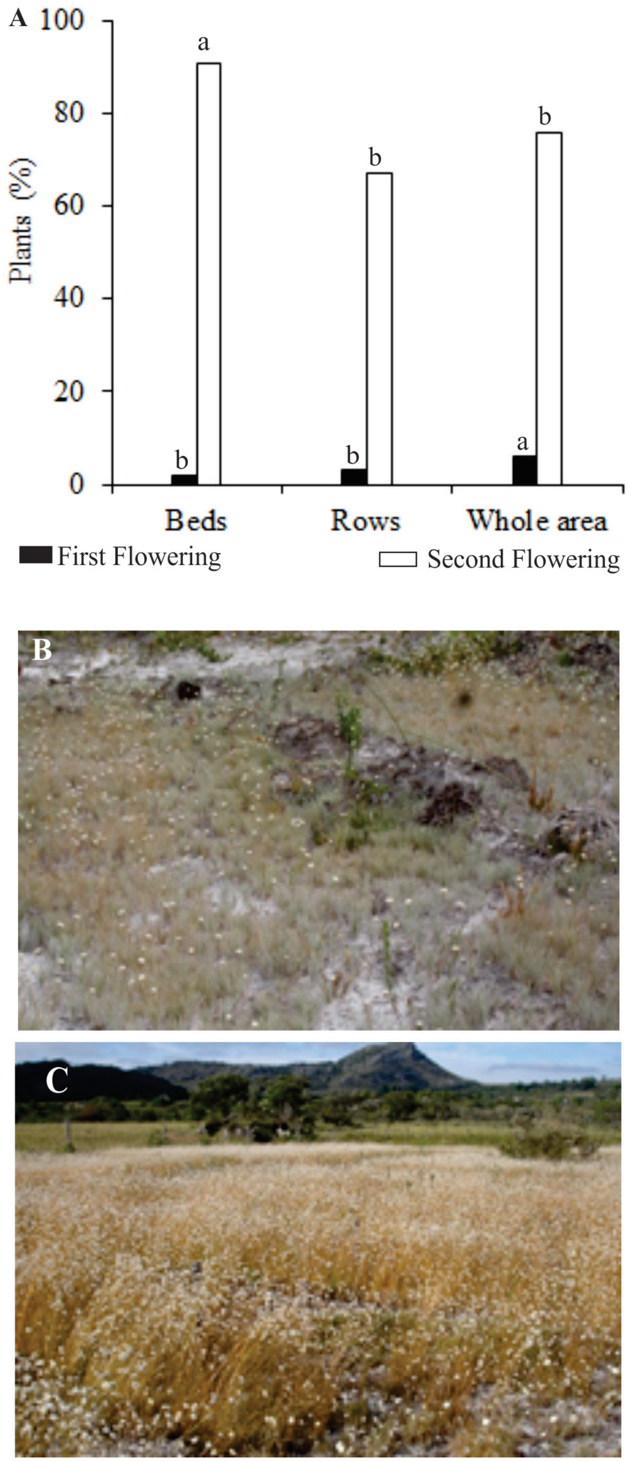

Figure 4. Flowering rate of plants (A) of *Comanthera elegans* (Bong.) L.R. Parra & Giul. In the first (B) and second flowering (C) in the systems of cultivation in beds, bands and total area. * Bars of the same color, followed by equal letters, do not differ by the Tukey test at 5% probability.

Inflorescence production per area (m^2), in weight and number, was the highest in the bed cultivation system ($P < 0.05$) and did not differ between the row and whole area systems. The bed system produced 2,910 inflorescences.m^{-2} with mean weight of 232 g, while the whole area and row systems produced 1,578 and 1,370 inflorescences.m^{-2} with mean weight of 106 and 79 g, respectively (Figures 5 and 6).

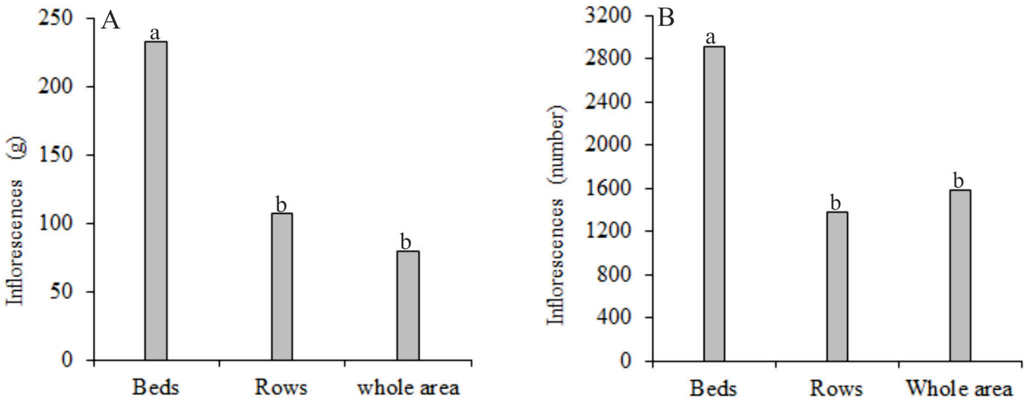

Figure 5. Production of inflorescences by area of *Comanthera elegans* (Bong.) L.R. Parra & Giul. (A) and number (B) in the crop, range and total area systems. Second flowering. Values followed by the same letters do not differ from each other, by the Tukey test at the 5% probability level.

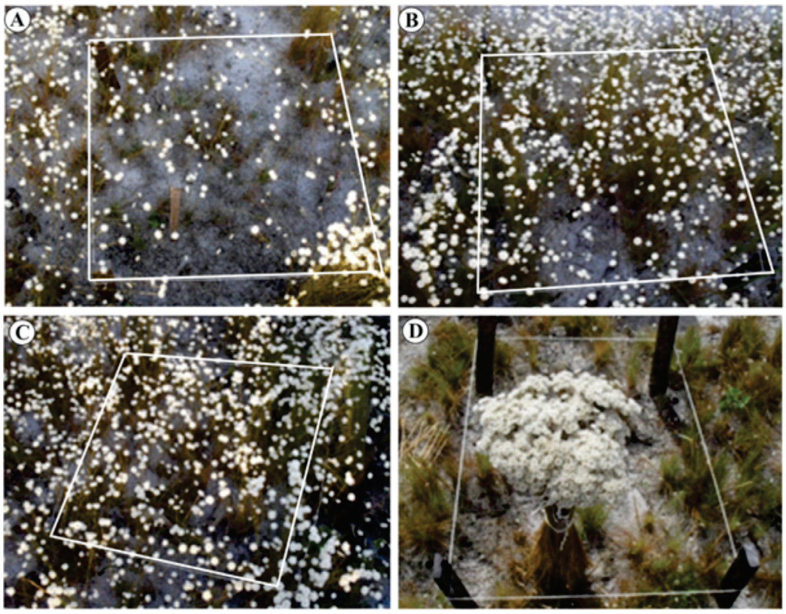

Figure 6. Production of scapes by area of *Comanthera elegans* (Bong.) L.R. Parra & Giul. (A), strips (B) and beds (C and D) in the second flowering.

4. DISCUSSION

Knowing the fertility of the soil in the area where a species naturally occurs and its relation with the fertility in areas where it is planned for introduction represent an important step in the process of establishing a native species in a new environment. The high acidity and low macronutrient availability in the soil of the cultivation area are within the range of other soils where Eriocaulaceae are found (BENEDITES et al., 2003), of *campos rupestres* (NEGREIROS et al., 2008), and of native *cerrado* areas (SILVA and HARIDASAN, 2007). The contents of phosphorus, potassium, organic matter, aluminum, and cation exchange capacity of the soil in the experimental area were above those observed by Borba and Amorim (2007) in an area where *C. mucugensis* and *C. curralensis* naturally occur and by Marra et al. (2012) in an area where *C. elegans* is naturally found. The exception is the phosphorus content observed in the 0-20 cm deep layer (7.4 $mg.dm^{-3}$m soil), which was within the range found in soils cultivated in no-till and conventional systems (1 to 10 $mg.dm^{-3}$ soil) (CONTE et al., 2002).

The time required for the emergence of *C. elegans* was close to that reported by collectors/growers of this species in the region of Diamantina, who reported a period of at least 40 days after sowing the fields, usually done between October and November.

The highest plant density observed in May and June shows that emergence began in February and continued until June, when plant emergence and death occurred concomitantly. A possible explanation is that, despite May and June being normally dry months, 2009 had rainfall in April and June (Figure 1) and soil moisture was satisfactory for emergence. The overlap of the initial plant development phase and the beginning of the dry season compromises survival and results in a high mortality rate (49%) distributed along virtually the entire experimental period and peaking in August (18%). Those results confirm what is observed in native fields of *C. elegans*, where emergence begins in mid wet season (December) and often extends until June, when concomitant emergence and death of plantlets occurs depending on whether the plants develop in a micro habitat of different soil sand contents.

Normally, recently established *C. elegans* plants (germinated in the latest wet season) remain vigorous until mid June, when some begin to show symptoms related to soil water deficit. By the peak of the dry season, they exhibit three distinct morphological patterns: Those whose leaves dry out and remain attached to the plant and the plant remains attached to the soil; the ones whose leaves gradually drop from the plant and leave a golden powdery mass on the soil surface resulting from the accumulation of hair from the base of the plant; and whole plants, with some green leaves or all dry leaves, that detach from the soil due to the action of wind, which exposes the plant's root system by removing the sandy top soil layer. In the first and second cases, many plants (36%) resprout, which represented 15% of the initial population of established plants in the present experiment. Such results may indicate that mortality is not associated only with water scarcity, but represents a phenological pattern of this species.

The high plant densities in the initial development phase may have placed greater competition among specimens, thus favoring mortality, which is shown by the positive correlation between density and mortality rate. Starting in October 2009, when rainfall was 405.2 mm (Figure 1) – an atypical situation since the average rainfall in that month is 116.3 mm (VIEIRA et al., 2010) –, water accumulation, resulting from the temporary flooding stress of plants, may have contributed to mortality in the rainy season for the row and whole area cultivation systems. That may have favored the death of seeds and/or hindered plantlet development, which may justify the lower plant density in those cultivation systems at the beginning of the experimental period. In contrast, the surface of the beds rising above de soil prevented water from accumulating, leading to higher plant densities in this cultivation system.

Recruiting through seeds is commonly observed in Eriocaulaceae species (CASTELANI, 1996; SANO, 1996), including those in the genera *Comanthera* (OLIVEIRA et al., 2014; OLIVEIRA et al., 2015) and *Syngonanthus* (SCHMIDT et al., 2007). For *Syngonanthus nitens* (golden grass), 40% of the plants in a population evaluated by Schmidt et al. (2007) were recruited via seeds. The recruiting of *C. elegans* via seeds observed from December 2009 onwards resulted from the germination of seeds produced in the first flowering (April/May 2009) or from the germination of seeds remaining from sowing (done in January 2009) and contributed with 3% of the individuals recruited. Whether remainders of sowing or produced in the first flowering, the recruiting started in December indicates the seeds remained viable in the soil for 12 and eight months, respectively. Since the mortality rate is higher in younger plants – such as in *C. elegantula*, for which mortality of 40.3% was observed in plants with one rosette and of 6.3% in plants with two or more rosettes (NEVES et al., 2011) – late sowing *C. elegans* (in January) may lead/contribute to the death of more plants. Hence, the stage of development the plants are in by the beginning of the dry season (after sowing, in the case of cultivation, or after dispersion in the case of native fields) may play a key role in the survival rate during this period. Therefore, in the case of cultivation, it would be better to sow in the beginning of the rainy season so as to allow for better development and ensure the establishment of a larger number of plants.

In extreme environments, the difficulty of plantlets establishing favors asexual reproduction (FENNER, 1985). This type of reproduction (resprouting and sprouting) is common among Eriocaulaceae and may be advantageous as it allows resources to be mobilized in different microsites, which may be a strategy of competition for space. It represents a way of increasing the persistence of individuals in the population as the risk of mortality of the genet (clump) is split among ramets (modules) (SANO, 1996). The periodical water deficit and the intense solar radiation to which *C. elegans* is constantly subjected may explain the great contribution of asexual propagation via sprouting, which accounted for 30% of the recruiting of individuals during the experimental period. Sprouting started in April, concomitant with the anthesis of the capitula of the second flowering, when the plants were approximately 15 months old, thus characterizing the beginning of asexual reproduction. Sprouting was also observed after the flowering of *S. nitens* and contributed to the recruiting of 61% of new plants of that species (SCHMIDT et al., 2007). With the lack of photosynthesizing leaves, the resprouting and/or sprouting of *C. elegans* must be associated with reserves stored in the rhizome in the form of starch, which, according to Scatena et al. (1997), provides an adaptation to plants that experience temporary water scarcity in *campos rupestres* and are able to use the reserves during that time (STANCATO et al., 2001).

The sexual reproduction of *C. elegans* began four months after sowing, when approximately 5.4% of the plants flowery and the rosette of most plants was between 3 and 4 cm in diameter, considered small since it may reach over 20 cm in adult plants. A similar behavior was observed in *C. elegantula*, which flowery at approximately six months old (NEVES et al., 2011). Since the inflorescences of the first flowering were produced in small amounts and sizes (mean escape length of 14 cm), they are not collected for marketing. However, the capitula produce viable seeds, which may indicate that investing in reproductive strategies in the early development phases, when the plants are not at an age that favors asexual reproduction yet, may represent an important strategy to make up for the low rate of establishment due to the high mortality rate, which occurs continually and intensifies during months of greater water scarcity, thus reducing mainly the density of younger plants.

In the second flowering (April/May 2010), as well as in the first, the period of maximum anthesis of the capitula (May) of *C. elegans* did not differ from what was observed for the species developed in its natural environments. Regardless of the time of sowing, normally starting in October in the region of Diamantina and continuing until January (as is the case in the present experiment), the period of flowering/anthesis of capitula is the same, which indicates that the species's phenological pattern is maintained.

The rate of the second flowering can be considered high (between 67 and 91%) compared to the rate of *C. elegantula* (NEVES et al., 2011) and of *S. nitens* (SCHMIDT et al., 2007) of 36.8% and 31%, respectively. The maximum density of flowered plants observed until March indicates that the plants bloom until March and that, from April and May onwards, only capitula and scape maturation takes place. In *C. elegans*, as the inflorescence matures, the hairs in the scape sheath turn a golden color, which imparts the common name *pé-de-ouro* (gold plant, in free translation) to the species. Scape size and capitula diameter are within the ranges found for the species developed in native or enriched fields. In the commercialization process, capitula diameter and its whiteness are more valued than scape length since the stems are usually cut down during the preparation of bouquets (organization of inflorescences in bundles for wholesale).

In a hypothetical cultivation of one hectare of *C. elegans* employing the bed cultivation system (70% of the area for beds and 30% for corridors) and considering production of 232 g inflorescences.m^{-2}, the final yield could be 1,624 kg inflorescences.ha^{-1}. Besides the easy harvest, cultivation in beds or rows prevents the heterogeneous plant density normally observed in the whole area sowing system.

5. CONCLUSIONS

The cultivation systems assessed did not impact recruiting and resprouting rates, production of inflorescences per plant, number of modules per plant, scape length, and capitula diameter.

Plant density, blooming rate, mortality rate, and inflorescence production per area evidence the superiority of the bed cultivation system compared to cultivation in rows and whole area.

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AUTHORS CONTRIBUTIONS

FCM: performed the research, collected the information analyzed the data, take the photos, made the figures and wrote the manuscript. **MNSO:** helped in development of the idea of the research as well as critical reading the manuscript. **MKT:** helped in development of the idea of the research, in adapting the methodology and take the photos.

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