Appraisal of the age of the trees used as nests by the Hyacinth Macaw in the Pantanal, Mato Grosso.

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SUMMARY

Sterculia apetala, is a key species for Hyacinth Macaw conservation, as 94% of this bird's nests are found in this tree species. Our goals were: (1) to determine the growth rate of *S. apetala*, (2) to estimate the age of the trees that have nest-cavities of Arara Azul[2] Project and (3) provide subsidies to the Hyacinth Macaw conservation plan in Brazilian *Pantanal*. The area studied comprised ridge Semidecidual Forests in farms in the sub-regions of Miranda, Aquidauna and Nhecolândia, Mato Grosso do Sul. The methods used in this study were analyses of annual growth rings, or dendrochronology, in trees that are already used as Hyacinth Macaw for nests. It was observed that the nests are in trees over 60 years of age. Considering the age of the trees that shelter cavities and their frequent loss, there is a trend towards the reduction of availability of natural nests for the Hyacinth Macaw during the next decades, making the bird dependent on the provision of artificial reproductive sites that are made available by conservation projects.-

Key words: Hyacinth Macaw, nest-cavities, conservation, Brazilian Pantanal, *Sterculia apetala.*

INTRODUCTION

Sterculia apetala (Jacq.) Karst, known as *manduvi* in the Pantanal (Pott and Pott, 1994) is a deciduous tree, of fast growth, large size and tropical distribution, composing the dossel or emergent stratum (Janzen, 1972; Cristóbal, 1983). In the Pantanal, *manduvi* grows in natural fragments of non flooded semidecidual forest (Ratter et al., 1988). Johnson et al. (1997) point out that *S. apetala* has been suffering from inadequate environment management, resulting from cattle raising activity, inferred from the different densities of young *manduvi* individuals in areas without cattle, with cattle during six months/year and with cattle during twelve months/year. This study has shown that the density of *S. apetala* seedlings was inversely proportional to the duration of the cattle presence, a fact that can be the result of herbivory or cattle stepping on seedlings, and/or fires, during the drought (Padovani et al., 2004). All these factors could interfere in the structure and dynamics of *S. apetala* populations, in such a way that studies investigating it in isolation should be carried out (Guedes, 1995).

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The plant populations have their structure and dynamics affected by herbivores, pathogenous or by changes to the habitat due to human activities, or by association of these factors (Harris et al., 2005). Various studies have been shown the great impact of herbivorous mammals on plant species (Crisp e Lange, 1976; Gómez et al., 2003).

Sterculia apetala is an important species for a significant portion of the *Pantanal* fauna. During the drought that assails the Pantanal, when there is an apparent lack of food, the seeds from this tree are excessively consumed by various animals, such as macaws, monkeys and rodents, due to the high level of macronutrients they contain (Chaves et al., 2004; Lorenzi, 1998; Pott and Pott, 1994). Approximately 17 species of birds use the cavities in the trunks of *S. apetala* as a reproduction habitat, for example, the Collared Forest Falcon and the Red Macaw (Guedes, 2002). However, the main reason for the development of investigations about the ecolo-gical relations of the *manduvi* is the fact that this tree is a key species for Hyacinth Macaw (*Anodorhynchus hiacinthynus*) conservation. In the Pantanal, 94% of this bird's nests are located in cavities in the trunks of individuals of *S. apetala* (Pinho and Nogueira, 2003; Guedes, 1993) (**FIGURE 1**) .

Figure 1. A Hyacinth Macaw couple (*Anodorhynchus hyiacinthinus*) occupying a nest-cavity in a trunk of *Sterculia apetala*. Caiman Farm, sub-region of Miranda. Photograph: Luciano Candisani (Archive Arara Azul Project / UNIDERP).

The Hyacinth Macaw is the largest representative of the Psittacidae family, reaching a height of over a meter. They are sociable birds, with sedentary populations that can make small daily migrations for feeding and/or reproduction (Guedes, 1993). It is a bird species that is endangered with extinction (Nunes et al., 2006) and the main factors pointed out as causes of its populational decline are the capturing of individuals for illegal trade of wild animals and environment degradation by fires or deforesting (Guedes, 2002).

The relationship between Hyacinth Macaw and *S. apetala* is particularly interesting, as both species are sensitive to human activities, serving as indicators of sustainability for economic enterprises in *Pantanal*. Thus, the characterization of the factors affecting reproduction and recruitment both of the Hyacinth Macaw and *S. apetala* and the interaction between these species, will be the foundations for discussions on how the economical activities should be developed so that the biodiversity at the *Pantanal* region is conserved.

Cavities in trees constitute a limiting resource for birds that use them for nesting. The reduction in their availability, due to the loss of mature trees with natural cavities or with a size that is sufficient for its building, can result in low recruitment rates and gradual reduction of their populations. For instance, the Australian psittacid *Polytelis swainsonii*, a species vulnerable to become extinct, depends on cavities in trunks and branches of *Eucalyptus* spp. trees for its reproduction. However, the areas of remaining forests where they occur are being removed to be replaced by soy plantations (Manning et al., 2004). In Europe, two species of woodpeckers (*Dendrocopos leucotos* in Finland and *Dendrocopos major* in England), who reproduce in cavities of senile or dead trees, have their populations threatened with extinction due to forest management done by man, replacing mature oak (*Quercus* spp.) forests by conifer forests for commercial exploitation (Smith, 1997; Virkkala et al., 1993).

Similarly, the Hyacinth Macaw population could be reduced to critical levels due to the lack of a proper number of sites for nidification (Guedes, 1995). Thus, studies on the minimum age of *S. apetala* adult trees to have nest-cavities for the Hyacinth Macaw are important, as they will provide information on the present and future cavity availability, through forecasts on the dynamics of their populations (Garcia et al., 1999; Hutchings, 1997; Boot and Gullison, 1995).

The existence of environmental factors that annually limit tree growth in the tropics, such as drought (Fahn et al., 1981), periodic flooding (Ishii, 1998; Worbes, 1989) and photoperiod (Cardoso, 1991), induce the formation of annual growth rings (Schweingruber, 1988). Thus, adopting techniques derived from dendrology it should be possible to determine the tree's age. Applying dendochronological techniques in *S. apetala* that shelter nest-cavities of *A. hyacinthinus,* the age structure of its population can be characterized. Based on this information, suggestions for management of the tree population could be proposed to provide a satisfactory offer of nest-cavities for the Hyacinth Macaw.

The goals of this study were: (1) to determine the growth rate of *S. apetala*, (2) to estimate the age of the trees recorded by Arara Azul Project that have nest-cavities and (3) to provide subsidies to the Hyacinth Macaw conservation plan in Pantanal.

MATERIALS AND METHODS

Sampling was made at the following locations: (1) Santa Emília Farm (19º30'24"S – 55º36'00"W), base of studies of the University for the Development of the State and the *Pantanal* Region – UNIDERP, Aquidauana sub-region; (2) Caiman Ranch (19º56'23"S – 56º14'26"W), a cattle and ecotourism farm, field base of Arara Azul Project, Miranda sub-region; 3) Nhumirim Farm (19º00'52"S – 56º38'38"W), research base of EMBRAPA *Pantanal* and neighboring properties, Nhecolândia sub-region (Silva & Abdon, 1998) (**FIGURE 2**). In all areas the sampling was done on ridges with presence of Semidecidual Seasonal Forest; further environment descriptions are found at Ratter et al., 1988; Silva et al., 2000; Salis, 2004.

According to the climactic classification of Köppen, the Pantanal has a tropical sub-humid climate (Aw), with yearly average of around 1,100 mm of rain, with the rainy season from October to March and being relatively dry from April to September. The average annual temperature is 26 ºC, and sporadic frosts may occur (Soriano, 1997; Cadavid García, 1984). Such characteristics of the Pantanal plains climate induce the formation of annual growth rings in tree species, be it due to the excessive flooding (Ishii, 1998), or due to the lack of availability of water (Worbes, 1989).

At each of the working sites, *S. apetala* adult trees have been sampled. The sampling sought trees which had nest-cavities registered by Arara Azul Project and other nearby trees, both smaller and larger in diameter than the nest-trees. In all sampled trees the diameter was measured at chest height (DAP) (1.30 m from the ground) with a diameter tape.

For a macroscopic description of the growth rings, six *S. apetala* trees were sampled, according to the destructive method presented by Worbes (1989), observing the IAWA Commitee (1989) recommendations. Only trees with registered cavities, used by the Hyacinth Macaw and monitored over the

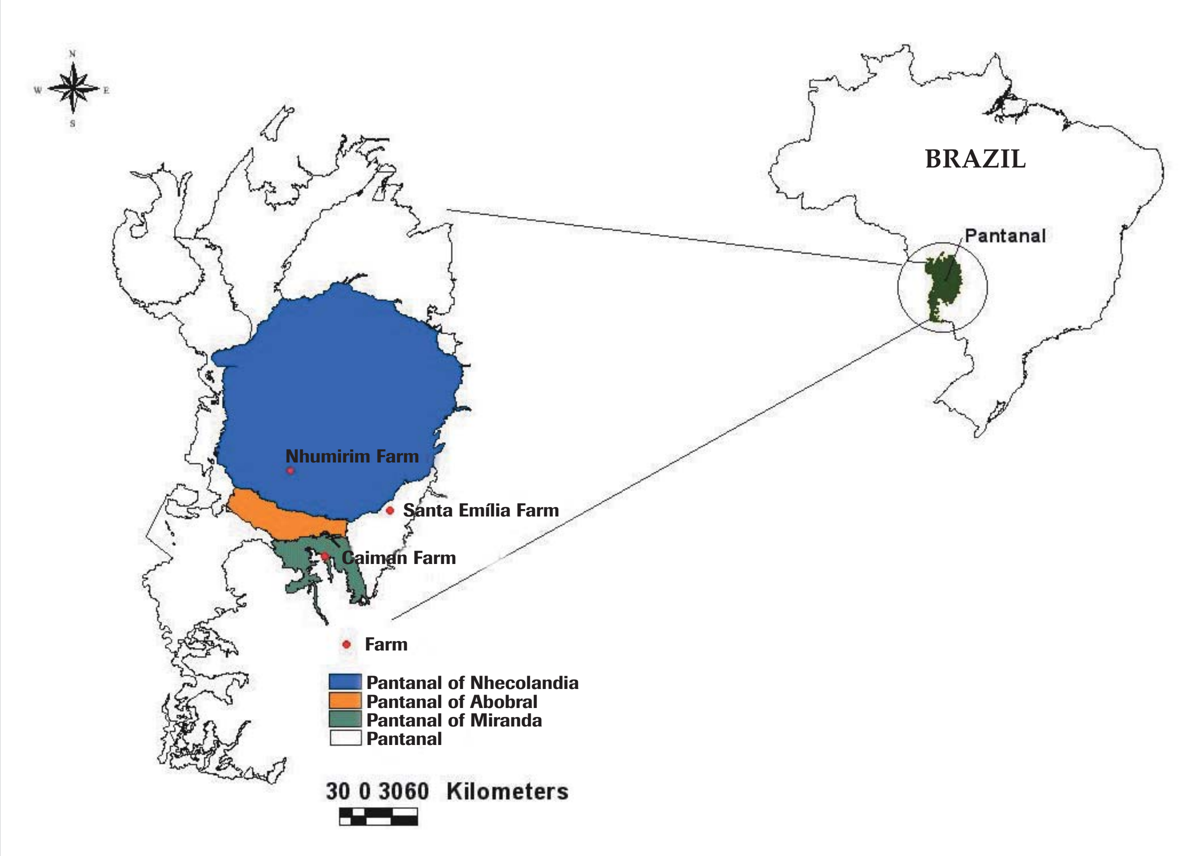

Figure 2. Situation of the sampling sites on Pantanal plains. Adapted from Silva & Abdon 1998. Picture editing by Macieira, A. (Instituto Arara Azul).

past few years, but which broke at the nest height, were sampled using the destructive method. These trees broke at the height of the nest-cavity after storms, gales or deforesting, making their occupation by the Hyacinth Macaw unfeasible (Guedes, 2002). To confirm the existence of annual growth rings, in three of these six trees the cambial lesion method was applied, which consists in the removal of part of the tree's bark, a technique known as Mariaux window (Déttienne, 1989). All the collected samples are in the wood sample collection at the COR/UFMS Herbarium.

Despite being a destructive method, which demands time, it is considered one of the safest in studies, having been successfully used in trees of *Pantanal* floodable riparian forests (Ishii, 1998).

Later, for the growth ring limit definition, another 46 *S. apetala* trees were sampled using the non-destructive method, which employs the Pressler increment borer (Worbes et al. 2003), for the trees average radial growth rate calculation, taking the sample radius divided by the number of tree growth rings (age), as follows.

$$TC = Rm/I$$

RESULTS

Sterculia apetala wood presents brown-reddish heartwood, distinct from the light yellow sapwood. The growth rings are distinct and individualized by marginal terminal parenchyma. The lesions provoked in the cambial tissue clearly show the formation of only one growth ring during the year in the three *S. apetala* sampled trees.

The average annual radial growth rate of *S. apetala* trees in the investigated sub-regions are shown on **TABLE 1**. With this data, it can be noted that *S. apetala* growth is different among the investigated sub-regions (ANOVA; N=52; gl=49,2; F=15.465; P<0,001). The growth differences can be explained either by the variation of the soil quality between (Adámoli 1982) and within the sub-regions (Salis 2004) or by other growth-limiting abiotic factors, which suffer spatial and temporal variations, such as the pluviosity difference between the sub-regions, which affects the flooding pulse regime (Junk and Silva 1999), reflecting the height and period of flooding. The *manduvi*, which is a kind of tree that grows on eutrofic soil spots (Ratter et al. 1988), has its growth strongly influenced by this spatial variation. The age and diameter data relating to the nest-trees registered in each region are shown on **TABLE 2**.

TABLE 1: Average Radial Growth Rate, in milimeters, of 52 *S. apetala* trees in the investigated sub-regions of Pantanal in Mato Grosso do Sul State

SUB-REGION	N	AVERAGE (mm) + SD
Aquidauana	19	3.58±0.61
Miranda	14	3.81±0.48
Nhecolândia	19	2.97±0.35
Total	52	3.44

Where: N: number of trees sampled; SD: standard deviation

TABLE 2 – Age and diameter of *S. apetala* trees registered as reproduction sites by Arara Azul Project in the sub-regions investigated in Pantanal.

SUB-REGION	AGE (YEARS)	DAP (cm)
Miranda	96	105
Miranda	74	77.9
Miranda	71	74
Miranda	89	98
Aquidauana	107	85.5
Aquidauana	72	76
Aquidauana	83	73
Aquidauana	104	106.5
Aquidauana	97	73
Aquidauana	83	73
Aquidauana	69	62.5
Aquidauana	96	90
Nhecolândia	114	91
Nhecolândia	86	78

Where: DAP diameter at chest height, approximately 1.30 m from the floor surface.

Comparing the nest-trees growth response, it is possible to observe that in the Nhecolândia sub-region the trees are older and have a smaller diameter, while the trees in Miranda sub-region, on the other extreme, are younger, presenting a larger diameter. In the Aquidauana sub-region the youngest nest-tree was found, 69 years old. General linear models generated for each sub-region from the sampled trees age, given in number of growth rings, due to the DAP size, have a high predictive power, explaining 97% of the variation in Miranda (**FIGURE 3**), 87% in Aquidauana (**FIGURE 4**) and 68% in Nhecolândia sub-region (**FIGURE 5**).

DISCUSSION

The nests registered by Arara Azul Project are distributed in adult trees, aged 60 and over. Guedes (1995) explains that 5% of *S. apetala* trees which shelter nests used by the

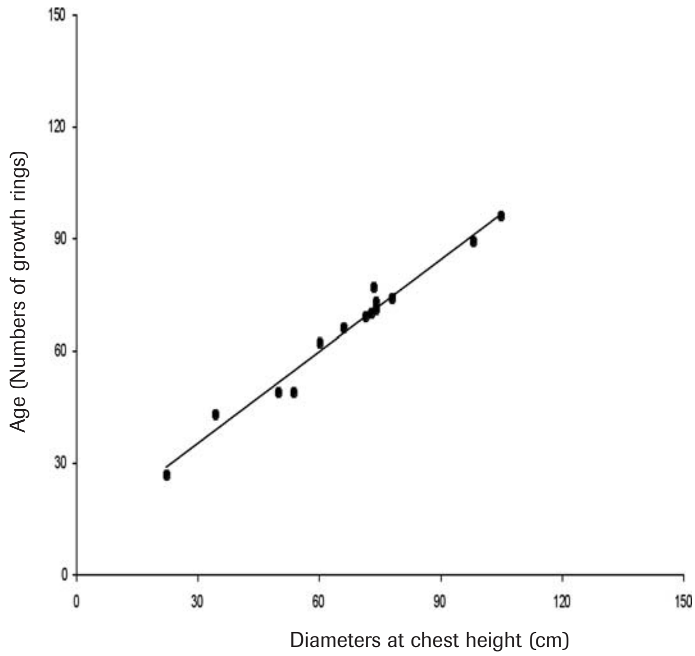

Figure 3. Linear regression model of the age due to the size of the trunk diameter at chest height, at 1.3 m from the soil, for *Sterculia apetala* trees in Miranda sub-region, Pantanal, Mato Grosso do Sul State (GLM; N=14; gl= 13; F=463,845; r^2= 0,975; P=0,0001; y=0,8209x+10,609).

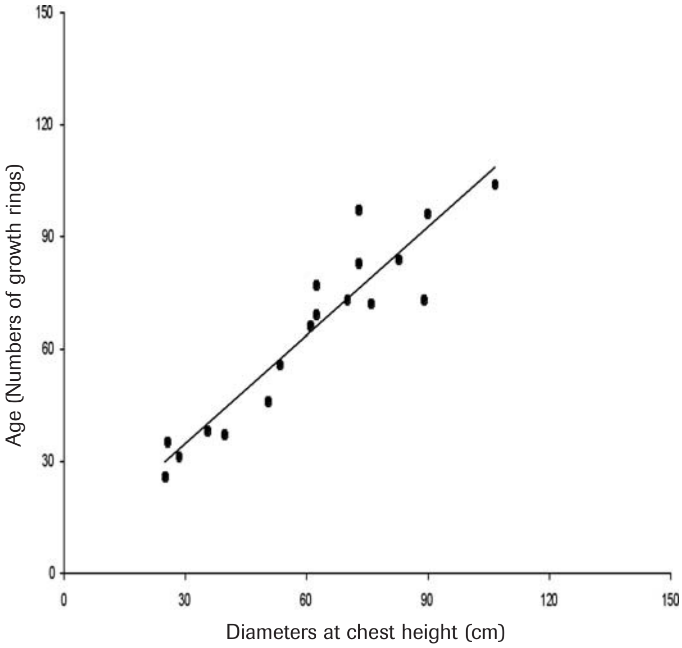

Figure 4. Linear regression model of the age due to the size of the trunk diameter at chest height, at 1.3 m from the soil, for *Sterculia apetala* trees in Aquidauana sub-region, Pantanal, Mato Grosso do Sul State (GLM; N=19; gl= 18; F=122,88; r^2= 0,87; P=0,0001; y=0,9658x+5,7373).

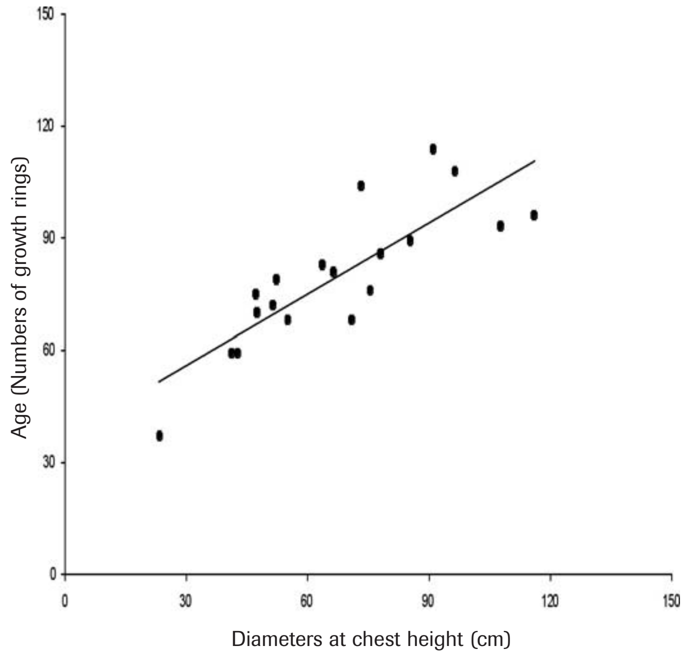

Figure 5. Linear regression model of the age due to the size of the trunk diameter at chest height, at 1.3 m from the soil, for Sterculia apetala trees in Nhecolândia sub-region, Pantanal, Mato Grosso do Sul State (GLM; N=19; gl= 18; F=36,429; r^2= 0,682; P=0,0001; y=0,635x+36,933).

Hyacinth Macaw are lost every year due to fires, deforesting or storms. This phenomenon can have as a serious secondary effect on the Hyacinth Macaw population depression in Pantanal, due to reduced offer of reproduction sites, compromising this bird's population recruitment. Thus, the structure of the various populations of *S. apetala* must be investigated with the goal to confirm their status of conservation, evaluating whether the recruitment of new individuals is occurring, and in case of negative or unsatisfactory recruitment, it becomes urgent the development of a program for management and conservation of the habitats of occurrence of *S. apetala* and, consequently, the reproduction site conservation used by the Hyacinth Macaw in the Pantanal.

Based on the growth of *S. apetala* trees in Pantanal and on the recruitment age of new trees capable of providing nest-cavities, only after approximately 60 years will the trees be able to house nest-cavities for Hyacinth Macaw, if the deforested areas recomposing could be done. In the meantime, management actions such as those made by Arara Azul Project will be important for the Hyacinth macaw population maintenance in *Pantanal*.

Regarding the linear adjustment models, Boninsegna et al. (1989), studying diameter-age relations with tropical trees species, in Misiones, Argentina, obtained for *Cedrela fissilis* a high coefficient of correlation (r=0,87; N=13). Only the coefficient established for a similar relation investigated here to *S. apetala* in Nhecolândia sub-region was less than this value.

Thus, it can be observed that the generated linear models show great ecological applicability. This is because they allow the age range forecast when a certain *S. apetala* tree, in one of the appraised populations, will present conditions to provide nest-cavities for the Hyacinth Macaw, despite an increase in the variation of the data as the trees grow bigger, which could be the effect of the big tabular roots that *S. apetala* develops to support itself with the age increase. These, many times, appear at over two meters of height in the main trunk, affecting the real trunk diameter measurement. To reduce this effect, it is suggested that subsequent studies should describe the size of *S. apetala* trees, adopting more refined techniques, such as Principal Components Analysis (PCA), which extracts from the individuals size measurements the axis for higher explanation. Despite this discussion, the generated models provide subsidies for studies on the ecology and management of *S. apetala* populations, which can compose the conservation plan for the Hyacinth Macaw in *Pantanal*.

Proposals for *S. apetala* populations management, which are also part of a Hyacinth Macaw conservation project, can be suggested: (1) the creation of protected areas to protect *S. apetala* populations in *Pantanal* region; (2) the development of legal protection aiming to preserve the ridges and *S. apetala* trees, such as State Law nº 8.317/2005, which forbids the cutting of *manduvi* in the neighbor state of Mato Grosso, aiming to protect the Hyacinth Macaw reproduction habitat; (3) the offer of nest-cavities in *manduvi* trunks long term monitoring; finally, (4) vegetation recovery in the areas where the lack of reproduction sites for Hyacinth Macaw in Pantanal is detected, due to human activities.

Ultimately, the ridges could be delimited as the properties' legal reserve areas[3], thus becoming legally registered. A simple legal instrument could consider such areas improper for cattle raising, due to the apparent impact on seedling establishment, leading the cattle raisers to fence them.

The proposals for *manduvi*'s habitat management and protection, aimed at Hyacinth Macaw conservation should be immediately considered by the decision makers, as the density of trees that are able to shelter nest-cavities for this bird is low. The density estimate of active Hyacinth Macaw nests in the North of Pantanal, Poconé sub-region, is around one nest in every 2,200 hectares (or 0.045 nest/100 hectares) (Pinho e Nogueira, 2003). For the Nhecolândia sub-region, the estimated density is even lower, where an active Hyacinth Macaw nest is expected to be found at every 4,800 hectares (or 0,021 nest/100 hectares) (Guedes, 1993).

To make this fact even more preoccupying, the deforestation index in Pantanal for the year 2000 has been estimated to be approximately 9% (Padovani et al., 2004).

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