CIRCULAR TÉCNICA 1

Goiânia, GO
December, 2022

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BAMBOO CROPS IN CONSORTIA

Introduction

Bamboo plants have a huge growth that lead to shading soil in association with a vigorous and abundant root system. Thus, competition for water, light and nutrients limit the development of intercrops between bamboo groves. However, it is possible to cultivate other plant species in consortium with bamboo if there are control on the competition factors.

This would allow optimizing the use of natural resources and increasing productivity by area, combining, for example, fruit crops, bamboo shoots, and bamboo sticks. Successive harvests of different products over time would provide increase and diversification in the farmers' income source.

From this perspective, the present work aims to conduct a brief discussion about intercrops in the bamboo production, based on the experiences of researchers and farmers from the Brazilian Cerrado region (Fig. 1).

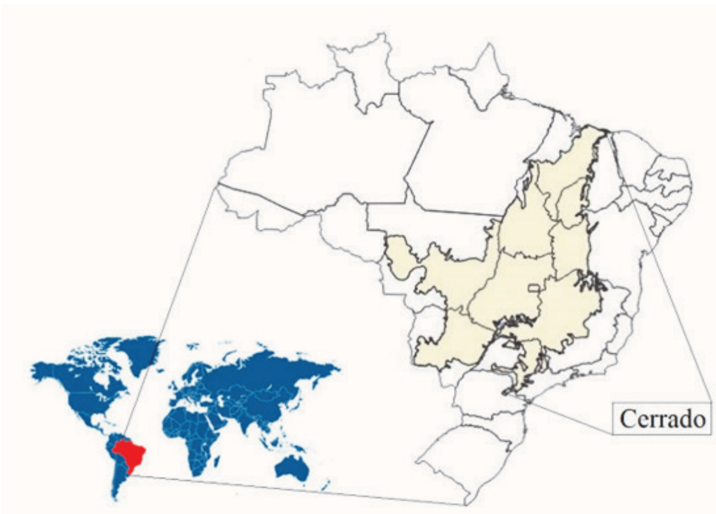

Fig. 1 - Brazil location and area covered by Cerrado Biome

Competition between plants

Competition is the biological interaction that occurs between two or more individuals when resources are limited. The species competitive ability is related to the efficient use of the resources from the environment where is located, where closest individuals are the most vulnerable by competition for resources.

There is competition when individuals overlap their niches, so they are exploring the same resources and competing for them. The effects of competition on plant development and production is variable and the results are dependent on plant stage of development.

Typically, the strongest competitor wins after the weaker competitor takes adjustments to try to survive. However, coexistence can be maintained if the organisms are sufficiently different to provide a refuge for the weaker competitor, or if the competitive ability changes quickly for one competitor to eliminate the other.

The competition between plants depends on several factors, such as the morphology, the ability to extract water and nutrients from the soil, the requirement for light, among others. In Fig. 2, it is possible to verify a range of factors that define the success for agroforestry systems. These included intra and interspecific competition, respectively, between bamboo plants, and bamboo and mango plants. Pests and diseases also can show interaction, increasing or reducing their impacts due to microclimate and environmental condition created by intercropping.

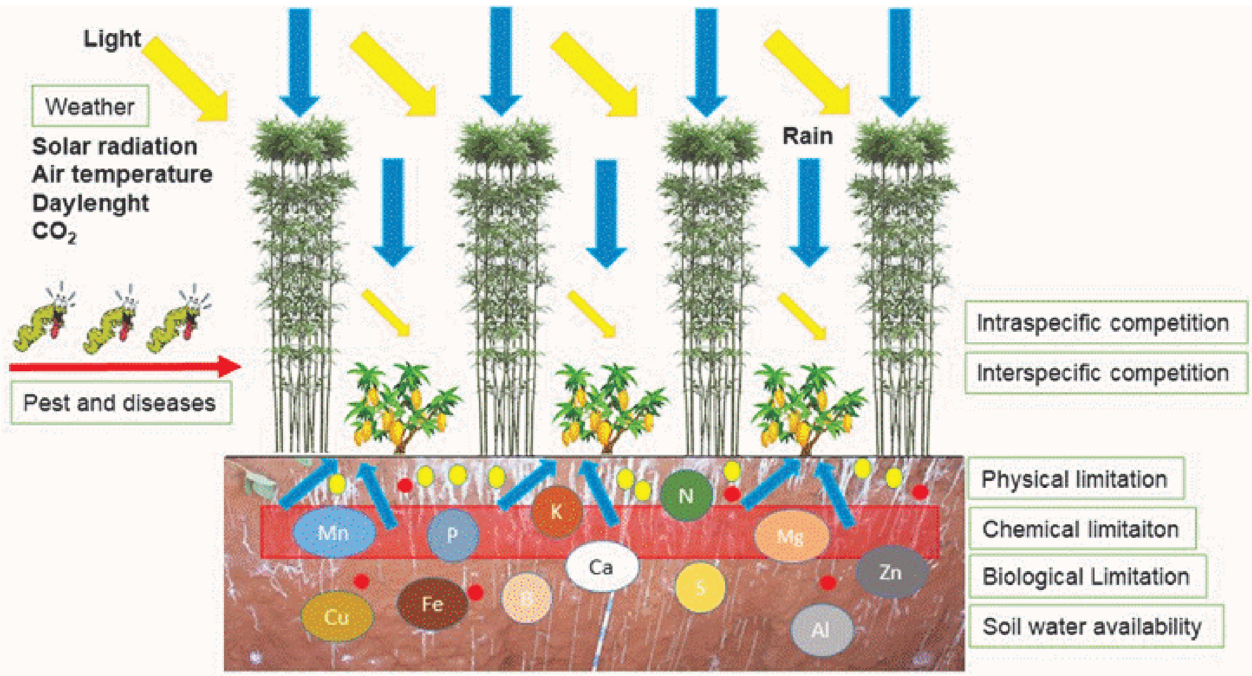

Fig. 2 - Agroforestry systems growing bamboo with mango and factors that define competition and limitation in the system.

In the soil, nutrient availability, and physical, chemical and biological limitations define which species have the capacity to potentialize its growth (Fig. 2). Soil water availability and plants roots growth can define their capacity to water uptake (Battisti and Sentelhas, 2017). The water availability in the soil is an important factor to reduce impacts of limiting macroclimate conditions (Shinohara and Otsuki, 2015; Patra et al., 2022).

The plants also are competing for water and light (Fig. 2) in association with changes in the microclimate conditions (Ichihashi et al., 2015). Black et al. (1969) found that plant's competitiveness by light depends on its ability to assimilate CO_2 and to increase photosynthesis rate and on its leaf area and/or its size.

The solar radiation available below bamboo is defined by four main factors: 1) bamboo species and their structure and size (Rusch et al., 2019); 2) bamboo planting space (Kittur et al., 2016); 3) bamboo harvest and clearance (Ziccardi et al., 2021); and 4) the weather dynamics defining leaf senescence (Andriyana et al., 2020; Mao et al., 2020).

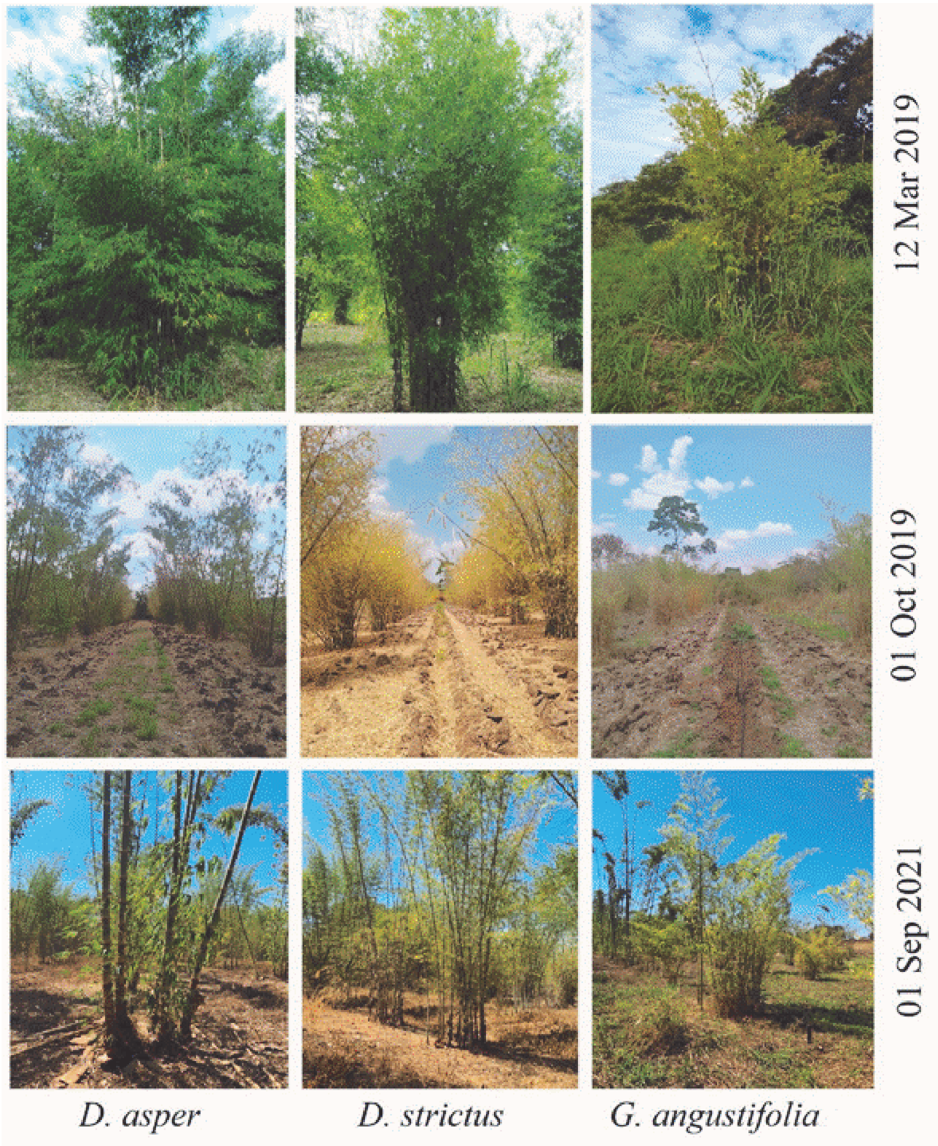

Fig. 3 - Bamboo clump conditions on 12 March 2019, 1 October 2019, and 1 September 2021 for *D. asper*, *D. strictus*, and *G. angustifolia* species.

In the Cerrado biome, the weather dynamics has a huge effect on bamboo agroforestry system. This occurs because the climate type is Aw, a tropical savanna climate with dry winters and rainy summers (Alvares et al., 2013). For example, in Fig. 3 is shown the leaf presence in three bamboo species in the end of wet season (12 March 2019) and in the end of two dry seasons (1 October 2019 and 1 September 2021) in Goiânia, GO, Brazil.

The water available in the soil can range in the Cerrado biome. For example, in Caxias, MA; Peixe, TO; Rio Verde, GO, the dry period begins in June, April and May, respectively, with different levels of water deficit (Fig. 4). Also the rainy season differs in period and level by region. In these scenarios, the water deficit lead to an intense bamboo leaf senescence (Fig. 4), which can potentialize the growth of intercropping with located irrigation.

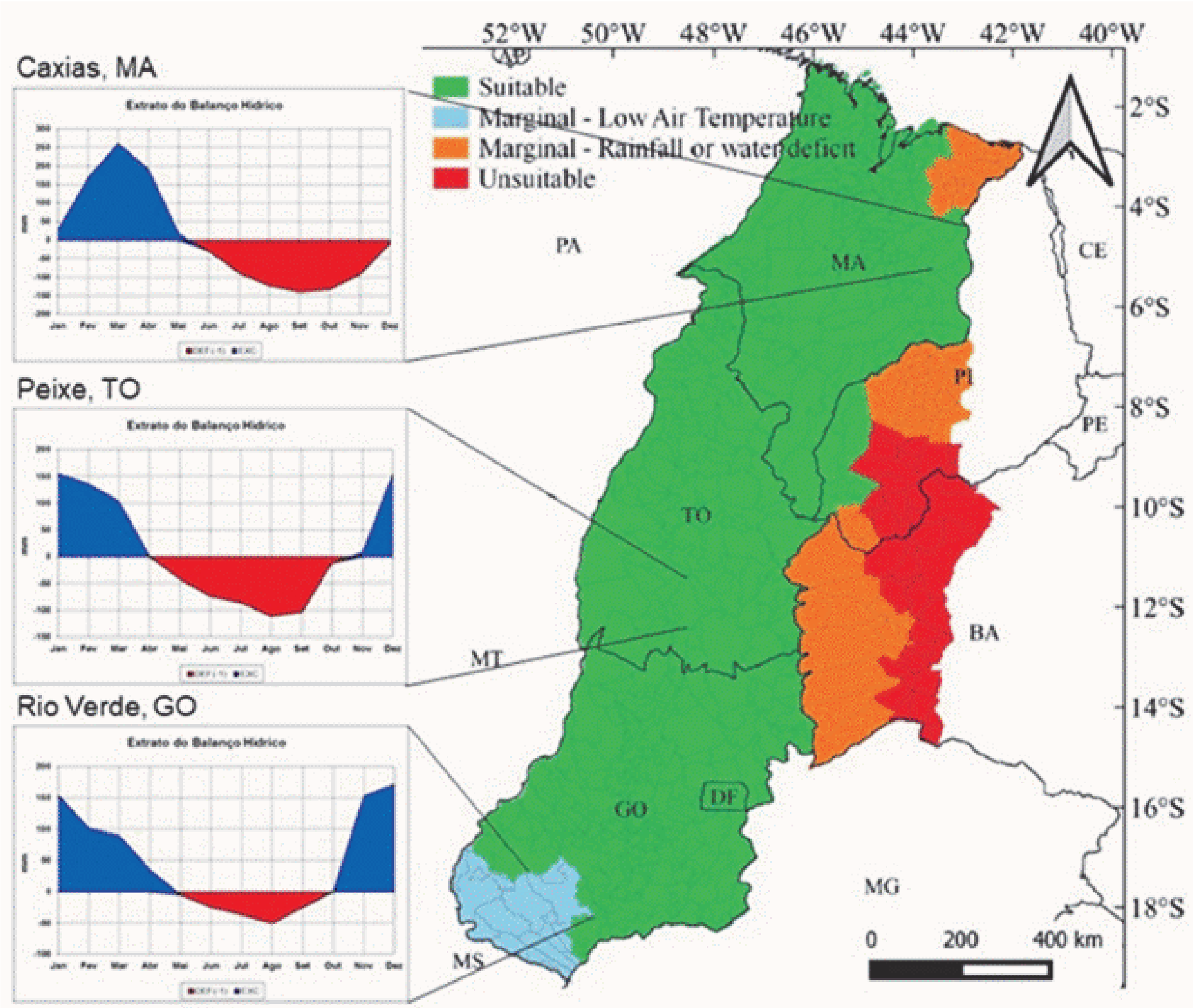

Fig. 4 - Water balance with water deficit (DEF) and water surplus (EXC) for some states in the Cerrado biome with agroclimatic zoning for bamboo. Adapted from Battisti et al. (2019)

Many researchers consider competition for light more important and complex than competition for substrate (Kittur et al., 2016; Dupraz et al., 2018). In competition for light, taller plants have a disproportionate advantage when shading smaller ones. However, some smaller species react to competition for light by activating complex mechanisms and adapting to the new radiation status, which gives them a large adaptive capacity.

The success of a species in nature depends on its ability to continue photosynthesizing even in low light conditions. Plants native to shaded environments, known as umbrophiles, usually have a high photosynthetic rate even at low levels of luminosity, showing extremely low luminous compensation point. This leads plants to grow slowly, but continuously, in their shaded natural habitat, surviving in an environment where species with high luminous compensation points could not photosynthesize, leading plants to death (Berry 1975).

Some plants are strict umbrophiles, others are sun plants, but many are facultative. The facultative C3[1] plants and some C4[2] that develop in full sun are able to adapt to the shading. They undergo changes in their photosynthetic and morphological characteristics that make them similar to shade plants (Salisbury, Ross 1985).

The most important competition between plants occurs underground. In contrast to the aboveground competition, which mainly involves luminosity and reducing of growth rate, in competition within the soil plants decrease the growth and survival of neighbors by reducing the resources available in the soil.

The competitive capacity below ground is correlated with attributes such as root density, surface area and plasticity, either in root growth or in the properties of enzymes involved in nutrient absorption. The underground competition can be diminished by supplying soil resources (Casper, Jackson 1997). Thus, a higher amount of fertilization may decrease competition for nutrients, and irrigation for water.

The root system plays a fundamental role in the competitive process. They perform two distinct functions in the plant: the first, purely mechanical, consists in the provision of support and anchorage; and the second is physiological, where minerals and soil water are supplied to the plant (Radosevich et al. 1997). The internal supply of water and nutrients can suffer negative influences when plants are subjected to the competition process.

Soil resources reach the roots through three processes: interception, mass flow and diffusion of water and nutrients (Salisbury, Ross 1992). Interception is the capture of water and nutrients when the roots grow through the soil. The mass flow, regulated by the transpiration, is a function of the rate of movement of the water to the root and the concentration of nutrients dissolved in the soil solution. The diffusion of nutrients through the roots occurs when their absorption exceeds the supply by mass flow, creating a local concentration gradient.

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[1] C3 plants are defined as the plants that exhibit the C3 pathway. These plants use the Calvin cycle in the dark reaction of photosynthesis. The leaves of C3 plants do not show Kranz anatomy. Here the photosynthesis process takes place only when the stomata are open. Approximately 95% of the shrubs, trees, and plants are C3 plants.

[2] C4 plants have an adaptation that allows better fix of carbon dioxide gas. This process is called C4 photosynthesis, and it enables the plant to convert carbon dioxide gas into organic matter more efficiently than other types of plants, including C3 plants

Diffusion is especially important for nutrients with a large fraction linked to the solid soilmatrix, such as K and P, while mass flow is often more important for N (Marschner 1995).

Plant and soil processes that occur below the soil surface are essential to the productivity and ecosystems stability. The presence of weeds in cultivated areas influences the growth and development of crop roots, interfering in the use of soil resources. Competition will occur between plants, both for water and nutrients, when there is overlap in the depletion zone of the roots from the crop and from the weeds.

The intensity of competition between weed and crop roots, for the resources below the soil surface, depends on the type and availability of resources, plant species, and their ability to develop an extensive root system with reduced diameter and wide surface area. Many bamboo species fit perfectly into this situation, which gives them great root competitive potential.

Planting Bamboo in the middle of a forest already established

The distribution of area where bamboo will grow is governed by the surrounding flora. Some tree species can negatively affect bamboo growth, while other tree species may favor their development compared to monoculture bamboo.

The bamboo consorbed with trees grows straight and with longer distance between the nodes. Longer nodes distance is a result of an effort of the plant in reaching the light on the treetops. On the other hand, bamboos grown in consortium will have less problems with pests and diseases than those grown in monocultures.

Native Brazilian bamboos are originally found amidst natural vegetation (Fig. 5), coexisting for millennia. Herbaceous bamboos, as well as, many species of the genus Guadua, are found in shaded environments. Thus, although the exotic bamboos found in Brazil are mostly cultivated in full sun, it is inferred that they can be cultivated in association with already established forests. The great speed of growth and the large size of these bamboos allow them to reach the luminosity above the treetops.

Fig. 5 - Bamboo native from the central west region of Brazil, coexisting with local vegetation.

In the middle of a forest of *Dendrocalamus asper* at the Experimental Farm of Emater, Goiás state (Araçu, GO), with thirteen years of planting (spacing of 8 x 5 m.), it was observed some trees that already existed in the area when bamboos were planted. Bamboos grow without any prejudice to both trees and bamboos, even those near and in the shade of trees. Meanwhile, a tree of the species Jatobá-da-mata (*Hymenaea courbaril* L.), present in the middle of the bamboo grove, produces fruits every year and its seeds spread over the soil and germinate, producing hundreds of small plants. However, all the new plants die while in the seedling state. Seedlings develop at the expense of the reserves present in the seeds, but after this, they cannot resist the competition imposed by bamboos. Competition for water, light and nutrients imposed by the bamboos extends to other plant species, leading the area to be completely free of other plants (Fig. 6). The trees that already existed on the site continue developing normally, but new plant do not survives under the bamboos.

Fig. 6 - Bamboo forest planted in Araçu GO. The competing power of bamboo eliminates all competitors, leaving the soil surface free of other plants.

A similar situation was observed in a forest of *D. asper*, with seven years of age and spacing of 8 x 5 m, in an area of the Federal University of Goiás (Goiânia, GO). At the time of planting, there was a tree of Angico (Anandenanthera sp.) about five meters high. Bamboo and Angico grew with no competition between them. The existing weeds in the area were disappearing after third year of bamboo planting. The grasses died first, followed by dicotyledons. However, weeds have returned when two years bamboo clumps have been managed with the removal of sticks in order to reduce the shading between rows. This lead to an incidence of at least 50% of the photosynthetically active radiation (PAR) in relation to the area outside the bamboo grove. In this case, it was clear that the decisive competition factor was luminosity.

The bamboo forest of UFG has the species *D. asper*, *D. stricus* and *G. angustifolia*, separately. Bamboos were planted next to a native forest area with large trees and it was observed that the bamboo plants closest to the forest developed better than the others for all species of bamboo, but more expressive for Guadua. In this case, the native forest did not compete with the bamboos, but benefited them in some way.

In the municipality of Goiânia, GO, *G. angustifolia* and *D. asper* were planted in the middle of a planted forest (with medium-sized trees). Parallel streets were opened amid trees and shrubs with a BobCAT. The bamboo seedlings were planted in the middle of the streets. Fertilization was applied in the planting pits, including mulch on the soil surface and using drip irrigation during dry periods. Bamboos developed very well (Fig. 7), without being harmed by the plants already existing in the area.

In the municipality of Nazário, GO, there was a four-year-old African Mahogany (*Khaya senegalense*) forest, consorcised with cattle pasture. The cattle started to eat the bark tree and were removed from the area. The grass was eliminated and two rows of *D. asper* were planted between mahogany (Fig. 8). The bamboo seedlings were drip irrigated during the dry periods. Bamboo grow quickly and after three and a half years, plants were surpassing the mahogany, showing fifteen meters high (Fig. 9).

Bamboo is a plant with great growth when it is supplied by its needs of temperature, water, light and nutrients. In plantations carried out in the Brazilian Cerrado region, it has been observed bamboos submitted to fertilization and irrigation growing twice as fast as those do not irrigated.

Fig. 7 - *Guadua angustifolia* developing perfectly in the middle of a medium-sized forest in Goiânia, GO.

Fig. 8 - *Dendrocalamus asper* planted in double row between African Mahogany rows in Nazário, GO.

Fig. 9 - After three and a half years of planting, D. asper already exceeds the Mahogany in height.

A similar result was observed in bamboos irrigated with sewage (nutrient-rich water) in Senador Canedo, GO. In the first year of cultivation, sprouts had a diameter of six centimeters (Fig. 10). It is important to point out that in crops without irrigation, in the same region, sprouts with this diameter was observed only in the third year of cultivation.

Fig. 10 - *Guadua angustifolia* sprouting in the first year of cultivation, irrigated with sewage.

Another experiment has being conducted in the municipality of Alexânia GO, where seedlings of *D. asper* were planted within the Cerrado vegetation. The seedlings were planted in open pits in the middle of the vegetation and were irrigated in the dry period by dripping. In this case, plants are developing well and apparently without competition with native vegetation (Fig. 11).

Analyzing the presented results, it is viable to cultivate bamboo within forests in the Cerrado region.

In the very shaded areas, with dense vegetation, it is interesting to plant bamboo in the existing open areas or in the open tracks in the middle of the forest. This reduces competition for light while bamboo plants are smaller than existing vegetation.

Fig. 11 - *Dendrocalamus asper* planted in the midlle of cerrado vegetation in Alexânia, GO.

In areas with more light available, bamboo can be planted without the need to open paths within the forest, simply opening the pits for planting the seedlings. Good fertilization in order to minimize competition for nutrients and ensure the good nutrition of bamboo plants. Planting should be carried out at the beginning of the rainy season, ensuring seedling survival, helping rooting growth to access water during dry season.

Seedlings should be healthy and preferably larger. Larger seedlings are more expensive and difficult to transport. So, the farmer can buy smaller seedlings, transplant them to larger recipients (around 20 liters of volume) and grow them during a year before planting definitively in the field. Larger seedlings, between two and three meters high for *D. asper*, for example, have been shown higher resistant to transplanting and can grow faster in search to light.

Bamboo plants need to be kept free of weed competition in association with good fertilizing and, if possible, irrigated in the dry season in the first year of development. The use of mulch around plants helps weed control and maintaining soil moisture due to evaporation reduction.

Among weeds, special attention should be paid to Brachiaria grass (mainly *Urochloa decumbens*, ex *Brachiaria decumbens*). This grass is very aggressive and releases substances by the root, which compromise the development of bamboo plants (allelopathy).

The weeds need be eliminated at least a one meter radius around the plants. This reduce the competition between bamboo and Brachiaria. After around three years, the bamboo will have grown and the shading provided by its canopy will harm the grass. Brachiaria is sensitive to shading, reducing growth and being eliminated naturally from the area.

Forest plants had growth limited by shading when bamboo reaches its higher height. The shading impact is reduced by using larger spacing between bamboo planting lines, and managing the clumps with the removal of shoots and sticks, maintaining an adequate number of rods per clump.

The harvesting need attention, where cutting the sticks will be hampered by the existence of several plants close to bamboos. Cut sticks can fall on neighboring trees causing damage to their branches. The transport of the cut rods out of the area will be difficult, due to the absence of roads and the impossibility of entering in the area with machines and vehicles. The rods will have to be dragged manually or with animal traction.

Consortium of annual crops in the first years of Bamboo cultivation

Bamboo uses large spacing between clumps and in the first years of cultivation, the explored area is very small. As example, in a planting with spacing of 8 x 5 m, each plant has 40 m^2 for its development. If we consider that a seedling occupies an approximate area of one square meter, in the first year only 2.5% of the total area will be explored by the bamboos.

The annual crops planting are carried out at the beginning of the rainy season, where bamboo size will allow weed development that need to be controlled. The consortium of bamboo with annual crops is desirable because weed control are expenses and occurs when there is no financial income from bamboo.

The farmer should plan cultivation system for bamboo and annual crops to allow harvests in the first year of implantation. The annual crops produce financial income, while waiting for the growth and maturation of bamboos. Thus, the products available for commercialization at different times of the year and over time increases income and makes better use of the area and labor.

Soil preparation is done in total area for bamboo and annual crops consortium. If necessary, it is recommended soil tillage, applying and incorporating limestone and eliminating weeds.

The planting of bamboo seedlings will be done in pits, due to the large spacing. However, the opening of a groove in the planting line helps in the opening of the pits for planting and in the water infiltration into the soil.

Annual crops need to be fertilized with amount above the recommendation for single crop growth in order to leave a residual fertility for the bamboo. The cultivation of legumes capable of biological nitrogen fixation is also desirable.

As long as corn, beans, cassava and other crops are grown, the crop treatments will be the normal ones for these crops: fertilization, weeding and harvesting; always remembering to return the harvest residues (corn and bean straws, rams and cassava leaves etc.) to the soil. The farmer should try to keep the soil always covered with straw, protecting it from sun light and the impact of raindrops, reducing water loss by evaporation and soil loss by erosion, improving soil structure and recycling nutrients.

The farmer can grow more than one species between bamboo rows at the same time. The solar radiation available increase from the bamboo line towards to the center area. Thus, there is highest incidence of solar radiation in the middle between lines.

Several annual crops were cultivated in the first three years of a forest of *D. strictus* in Caldas Novas, GO, (Fig. 12). The annual crops provided financial income to the farmer and kept the area weed-free.

Fig. 12 - Cultivation of corn, pumpkin, pepper and banana in the between lines of *Dendrocalamus strictus* in the second year after planting

Annual crops can be grown as long as bamboo plants are not shading the area between rows. This period is usually from bamboo planting until three years old. Smaller bamboos or greater spacing between bamboos rows allow intercropping for a longer period. On the other hand, larger bamboos culms, smaller rows spacing and the use of larger seedlings can reduce this period.

The intercropping time can be potentiated based on bamboos clearance and harvest, which can increase light for intercrops. The climate type also need to be considered (Mesquita et al., 2022). These authors indicated that the longer dry period (May-Oct) in Cerrado Biome lead bamboo to reduce number of green leaf, increasing the senescence, leading to more light in the underwood area. This make possible to include an intercrop with short cycle, however, it is required a localized irrigation to supply water demand of annual crop or its growth will be limited by water deficit.

Bamboo clumps will be handled to keep the bushes always clean, airy, healthy and with good productivity. Usually, the first management of a bamboo crop is in the fourth year, by cleaning and removing the stems that were born in the first year. In the fifth year, the stems born in the second year are removed and so on.

As a rule, it is harvested annually only the mature stems (at least three years old), defective stems and those very closed to each others, which would congest the chard.

It is very important to know the age of the stems for management purpose. The lifetime of a stem in a clump varies according to the species, but rarely reaches twelve years. For example, the average lifetime is seven to eight years for *Guadua angustifolia*. The stems show signs of deterioration and begin to dry out a year early. Young stems are fragile and susceptible to wind and can break with the effect of strong winds, being recommend to keep adult stems to protect the young ones.

Harvest occurs cutting sticks near the ground and above the first node, leaving no room for rainwater accumulation. Young stems should not be cut under the age of two. It is recommend using the "horseshoe" cutting technique by cutting the mature rods in the center of the clump from an opening space. In the annual cutting cycle is recommended not to remove more than half of the stems from a clump. In biannual cycle cut, no more than 65% can be cut, while in the triannual cycle cut, no more than 75%. Mature stalks, old, non-marketable and dry ones should be removed to preserve maximum vigor and productivity of rhizomes.

The management for the shoots production is slightly different from the usual management. The clump should not have more than ten stems for its production, and cutting the bud with 30 to 60 cm (depending on the species). This causes the activation of a new gem present in the rhizome. Thus, it produces a new sprout, which when harvested stimulates a new sprout and so on, for two or three months. It is required a good fertilization to properly nourish the plants, ensuring good shoots.

In shoots production management, the stems are also managed, since the clump has shoots and stems of one, two and three years. In the clump, two to three sprouts are let to grow annually, which will turn into ripe stems and will be the mothers for the shoots of the following year. The three-years-old stems will be harvested for structural use.

Simultaneous planting of Bamboo and tree species in consortium

Bamboos and tree species can be planted at the same time in the area. In this way, both can settle without competing, since there will be abundant light, water and nutrients.

Over time, plants will grow above and below the soil, sharing niches, and exploring the same resources. Those plants that are more efficiently using middle resources and growing faster will take advantage in the competition.

The species consorted with bamboo need to have deep root systems, fast growth and great height, being able to resist the competition and coexist in the area. Smaller species can also be chosen, but requiring adaptation to survival in low light environments. As example, there are coffee cultivars adapted to this condition, producing grains with high drink quality.

On the other hand, bamboo rows can be spaced and clumps can be managed by limiting the number of sticks in order to reduce shading, ensuring the survival and productivity of intercrops.

In the dry season, bamboos dropped leaves to minimize the effects of decreasing soil moisture levels, increasing luminosity in the area. Farmers can fertilize and irrigate intercrops in this period, providing better condition for intercrops to growth to compete in the consortium with bamboo.

In small areas, tree species can be cultivated in all bamboo interrows. However, it is advisable to plant the trees between alternating lines for larger areas, leaving one interrows with trees and another without. The interrows without trees will serve for the transit of vehicles and machines in the operations of sprout harvesting and stick management, and harvesting fruits of the trees.

When cutting sticks of large bamboo species, it is necessary to be careful that the cut sticks do not fall on the other plants, breaking their branches. The free interrows can be used to drive the fall of the rods, avoiding damage for the trees.

Another strategy is the planning and conduction of cutting bamboo shoots for consumption. At the time of shoots harvesting, the cutting need to be done in the shoots that are facing the row of consortium, leaving to turn sticks the shoots that are aligned with the bamboos or facing the street without trees. This strategy also can be used in bamboo clumps that are close to houses and electrical grids, for example. The rods will always grow to the opposite side, reducing the risk of accidents.

A bamboo consortium system was implemented with other plants species planted in the same period in Alexânia, GO. The suppressive effect (competition for water, light and nutrients) of the bamboo forest on the intercropping plants has being evaluated. The plants will be evaluated throught the development of the aerial part, measuring height, which will be compared with single planting.

Two bamboo species (*Dendrocalamus asper* and *D. latiflorus*) were planted in a 10 x 10 meter spacing, consorted with the perennial species of economic interest (Guariroba

- *Syagrus oleracea*, Açaí - Euterpe oleracea, and Pitaya - *Hylocereus undatus*), that were planted between the bamboo rows and also in single cultivation. Bamboo and perennials were planted at same month. A localized irrigation system was installed for all the cultures. The plants are growing and, within two years, it will be possible to evaluate the competition effect of bamboos with these species.

Planting of other species between rows of Bamboo already established

The control on competition factors is one of main factor that define the possibility to cultivate other plants species in consortium with bamboo, providing diversification in the farmers' income source.

In this way, seedlings of five perennial fruit species of economic interest (avocado - *Persea americana*, mango - *Mangifera indica*, jaboticaba - *Plinia cauliflora*, ambarella - *Spondias dulcis* and soursop - *Annona muricata*) were planted between bamboo rows of three species (*Guadua angustifolia*, *Dendrocalamus asper* and *Dendrocalamus strictus*). Bamboo had four years old from planting, being spaced of 8 x 5 meters, and located in Goiânia, GO.

The objective is to evaluate the survival and development of seedlings of perennial fruit species, planted under shading conditions of established bamboo forest.

The soil was prepared up to 30 cm deep with a subsoiler before planting the intercrops seedlings, cutting part of the bamboo roots. The bamboo root system is dense, extensive and superficial. Medina et al. (2010) found that 73% of Bambusa vulgaris Vittata roots were up to 45 cm deep.

The intercropped fruit plants were grown in rows, spaced 5.0 meters between plants, using drop irrigation to ensure water supply in the dry period of the year, which occurs from April to October. Bamboos were not irrigated and naturally lost leaves in the dry season, reducing the shading. A groove was opened in the middle of the bamboo interrows to facilitate the planting of fruit species (Fig. 13).

Fig. 13 - Open groove between two bamboo rows to facilitate the opening of pits and planting of seedlings of fruit species. The effect of the subsolator on the soil surface can be observed in the photo.

During the wet period, the bamboo plants gained new leaves and the clumps had to be managed, removing the culms that were more than two years old, in order to reduce the shading over the fruit species. The reduction of shading leads the weeds to reinfest the area (Fig. 14), requiring a frequent swiddens to keep the weeds under control to not compete with tree and bamboo.

Fig. 14 - Weeds between the bamboo rows due to the reduction of the shading, carried out with a view to the survival of fruit species cultivated in intercropping.

In this system, the avocado did not adapt to the consortium with bamboo. The plants were yellowing and burning of the leaves in the first month after transplanting, and, until the sixth month, 60% of plants died. After one year, all avocado plants died and were replaced by cagaita (*Eugenia dysenterica*) seedlings, a fruit tree native to the Brazilian Cerrado region.

Almost all the ambarella plants died by the second year. There were only two left, which were close to the border and received more luminosity. This suggests that the reduction of shading was not sufficient for the development of the ambarella. Ambarella is a large species, capable of growing taller than giant bamboos. The successfully grow in a consortium with bamboo will required to plant larger seedlings, which could grow faster and access luminosity. Further, it could be adopted a reduced bamboo number of rods per clump during the time necessary for initial ambarella growth. After that, it could go back to the initial bamboo stand.

Jaboticaba species resisted to the shading provided by bamboo plants. However, its growth has been very slow and it will take years to produce fruit, which is not interesting for the farmer. Thus, if it is desired to cultivate it in the consortium, it is important to use well-developed seedlings with short period to start production.

Soursop plants also did not adapt to bamboo competition because of the size of the seedlings. The same happen to the cagaita plants.

The mango adapted well to the system, including producing fruits (Fig. 15). Therefore, the good adaptation of mango in the experiment lead to replaced dead plants by mango seedlings, in order to evaluate if it really adapt to the proposed cultivation system.

At second year, bamboo clumps had culms cut again in order to reduce the shading on the plants of fruit species. Culms were cut in all clumps to reach 50% of photosynthetically active solar radiation in the canopy of fruit species when compared with observed in the free area external to the bamboo.

Fig. 15 - Mango grown in the middle of bamboo, in full bloom.

The solar radiation was taken using an interception bar with ten sensors (Apogee Instruments). The sensor quantifies the total solar radiation available in the wave spectrum from 400 to 700 nm, which is the spectrum of photosynthetically active radiation.

For the Forest of *Dendrocalamus asper*, the desired solar radiation was obtained by removing 46.9% of the sticks in the clumps. On average, each clump had 10.7 sticks. Five sticks were cut (average diameter at breast height of 6.3 cm and average length of 12.6 m). There were 5.7 rods left per clump (average diameter of 8.0 cm).

For the forest of *Dendrocalamus strictus*, the desired solar radiation was obtained by removing 52.8% of the sticks in the clumps. On average, each clump had 35.5 sticks. 18.8 sticks were cut (average diameter at breast height of 3.9 cm and average length of 9.2 m). There were 16.8 rods left per clump (average diameter of 4.6 cm).

It is observed that to achieve 50% of the photosynthetically active radiation observed outside the forest, it was necessary to remove approximately half of the sticks of each clump. This amount is expected to increase in the coming years, since the new rods have larger diameter and height, consequently, providing higher shading.

As long as there is an increase in the diameter of the rods each year, the management will be done by removing the sticks from the previous year. Thus, there will always be one-year-old sticks left, which will never mature, as they will be removed in the following year. This management will only be interesting if there is commercial demand for one-year rods, which does not occur at the moment.

After stabilization of the diameter of the rods, the management can be done by removing 100% of the shoots (which have commercial value), and the rods will mature every year. In the year that the sticks are mature all of them will be cut. Thus, at the beginning of that year (rainy season, in which the sprouting occurs), a number of shoots per clump corresponding to the number of sticks previously present will be preserved. In the middle of the year it will be cut all mature sticks, leaving only the young sticks, newly sprouted, which will now remain maturing in the clump for a few years, until their maturation, being removed all the shoots for several years (as established by the management).

Currently, six *D. asper* sticks and seventeen *D. strictus* sticks per clump were maintained. In the next cut, these numbers should be reduced, because the sticks that remained are larger than those that were removed, resulting in greater shading. Considering that bamboos were planted at a spacing of 8 x 5 m (250 clumps per hectare), the current populations are 1,500 *D. asper* sticks and 4,250 *D. strictus* sticks, per hectare.

If the management is done with the annual cutting of rods, there will be the cutting of half of the population annually (this amount may be lower, if the shoot harvest is also carried out), corresponding to 750 and 2,125 rods per hectare, for *D. asper* and *D. strictus*, respectively.

If the management of mature rods is chosen, every period chosen (e.g. every five years), 1,500 *D. asper* sticks and 4,250 *D. strictus* sticks per hectare will be harvested. In the years of maturing of sticks, quantities similar to these, however, of shoots, will be harvested.

When cutting culms of the species *D. asper* (higher height) one must be very careful that the cut sticks do not fall on the fruit plants, as they will cause damage. If the fruit plants are small, they can be killed.

Leaf-cutting ants is a serious problem for the consortia with fruit species between bamboo rows. Ants focus on fruit trees since these insects almost do not attack bamboo. Ants inhabit forests on neighboring properties and attack at night. Even the use of protective discs in the stems of plants has not been enough to prevent this attack.

Another consortium system that could be interesting is the cultivation of short-cycle plants in the dry winter period, when bamboo loses leaves, allowing light to enter. The soil would be prepared in beds, which would be renewed each year. The soil preparation implement (rotovator) would cut the roots of bamboo, reducing competition with the plants in the beds. The crops would be implanted with the planting of seedlings, in order to reduce the period in the field. Their selection could be made through their demand for photosynthetically active radiation. Drip irrigation will be required for the intercropped plants. The fertilization residue of the interim crops would be used by bamboo in the rainy season.

Final remarks

Bamboo plants has a great potential to be grown with multiply application. In this scenario, the growth of intercrops is an alternative to potentialize the use of land and financial income to the farm, due to long period for bamboo beginning financial return. The intercrops with bamboo in Cerrado Biome is a topic in development, where farmers and researchers are going together to find the best alternative and management that can better promote growth of both crops. In this material, we bring some insights about current research and management observed in the state of Goiás. The intercrops in the bamboo forest can be lead in different ways, considering annual crops in the first growth years, planting bamboo in an existing forest, or implanting annual and trees crops in an existing bamboo forest. Thus, the knowledge about bamboo grown in Cerrado is under building, but the potential of this crop is well known.

Acknowledgement

The authors thank the International Network for Bamboo and Ratan (INBAR) for their support in carrying out some of the research reported in this study.

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Bamboo crops in consortia. Circular Técnica 1 - Agro UFG - Rede Bambu Goiás. Dezembro de 2022
Publicação periódica de difusão científica e tecnológica da Rede de Pesquisa e Desenvolvimento da Cultura do Bambu no estado de Goiás, dirigida a estudantes, profissionais e produtores rurais.

Editoração e Layout
Mariana Marques Almeida

Coordenação
Prof. Dr. Rogério de Araújo Almeida