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INFLUENCE OF DIFFERENT FOREST SPECIES AND SPACING ON THE WEIGHT OF BUNCHESFROM CULTIVAR 'PLÁTANO D' ANGOLA'

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ABSTRACT

In the present study, banana plants were cultivated in integrated agroforestry systems (IAFSs) established in the Amazon-Cerrado transition region, and the effects of different forest species and crop plant spacings on the weight of the bunches producedwereassessed. The experiment followed a randomized block design in a split-plot arrangement with four treatments in the plots, three treatments in the subplots and three repetitions. The four treatments (plots) corresponded to the forest component of the IAFSs, which included both leguminous (acacia and taxi-branco)and non-leguminous (eucalyptus and casuarina) species. The three treatments (subplots) corresponded to the spacing of the crop component, namely banana cultivar 'PlátanoD'Angola', planted at 1.0, 1.5 or 2.0m apart. Banana bunches with the highest weights were obtained when the leguminous trees acacia and taxi-branco were employed as the forest component, with mean productivities of 9 and 11 t ha^{-1}, respectively. A spacing of 1.0 m between banana plants appeared to be suitable for IAFSs involving the slow-growing forest species taxi-branco and casuarina, whereas spacingsof 1.5 and 2.0m were more adequate for the fast-growing species acacia and eucalyptus. Based on the results obtained in this study, recommendations can be made for the establishment of more productive.

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INTRODUCTION

Although bananas and plantains (*Musa* spp.) are native to Asia, they are cultivated throughout the world andmost especially in Brazil wherethey are of considerable economic importance (BORGES, 2004; BORGES *et al*., 2006). Indeed, Brazil is the fifthlargest producer of bananas in the world, with a production of some 7.07 million tons in 2022 (IBGE, 2023), while production and consumption of the fruit occupies the second position in the country with the Northeastern region being the largest producer at 2.5 million tons in 2022. Although banana cultivation in the Midwestern state of Mato Grossois important to satisfy internal consumption and to supportexportationto other regions, the production of bananas in the state was only 76 thousand tons in 2022 (IBGE, 2023). Such a low figure can be explained by inefficient cultural management and the incidence of fungal diseases, most notablyblack sigatoka (*Mycosphaerellafijiensis*), which decimated the plantations in Cáceres in 1999 resulting inserious economic losses (SOUZA; FEGURI, 2004). While black sigatoka is the main phytosanitary problem affecting banana crops all over the world, other fungal diseases impede the expansion of banana plantations in Brazil, including Panama disease (*Fusariumoxysporum*f. sp. *cubense*) and yellow sigatoka (*Mycosphaerellamusicola*) amongst others (CORDEIRO *et al*., 2004; CORDEIRO; MATOS, 2012). The production systems employed by Brazilian farmers for the cultivation of bananas may be classified as conventional, organic and integrated. Conventional production systems are characterized by intensive soil management and the use of fertilizers and pesticides, although not always in the most appropriate manner. In contrast, organic production systemsattempt to avoid the use of synthetic agents in order toobtain healthy and contaminant-free products of high nutritional value whilst minimizing risks to the lives of farmers and consumers and preserving the environment and biodiversity. In a similar vein, integrated fruit production systemsare based on sustainable practices, the application of natural resources,the regulation of mechanisms for replacing polluting inputs, and the use of appropriate tools for monitoring all procedures for completeproduct traceability (CORDEIRO; MOREIRA, 2006). The concept of sustainable practices is particularly apposite because it is concerned with the needs of both the present and future generations (SANTANA; BAHIA FILHO, 1998). In this context, integrated agroforestry systems (IAFSs) comply with the concept of sustainability because they combine, within a single area, forest species and agricultural crops with the intention of supplying goods and services while maintaining a balanced interaction between economic expansion, environmental protection and social benefits (SILVA, 2013). The success of an IAFS depends on compatible interactions between the various components of the system. According to Fernandes (2001), agroforestry models that associate species of commercial value with thosethatgrow rapidly and have the ability to fixnitrogen from the air or to establish symbiosis with beneficial fungi (mycorrhiza) seem to afford the most suitable combinations. Silva *et al*. (2007) stated that leguminous trees can be employed as green manure and function as "facilitators" ofnitrogen fixation in IAFSs since they can provide an input of more than 200 kg ha^{-1} $year^{-1}$ of nitrogen. According to these authors, the use ofleguminous trees in IAFSs is doubly interesting because they are not only beneficialfrom the agricultural point of view by improving soil fertility but are also commerciallyvaluable asa source of timber. One of the most important management techniques for asuccessfulIAFSis the spacing between plantssince, in the case of banana culture, crop productivity depends onthe growth habit of the plants andthe cutting of the aerial parts, pseudostems and leaves at the time of harvesting the bunches.It is, therefore,of interestto investigate the effects of different spacing betweenbanana plantson crop production and economic efficiency. Moreover, correct plant spacing alongwith the rational use of inputs and pesticides will reduce the risk ofpests and diseases, allow a better balance between the components of the production system and, consequently, improve nutrient absorption. Furthermore, the development of specific schedulesfor the application of fertilizers and other agricultural inputs will allow migration from conventional production systems to less intensive and more sustainable agricultural practices. Considering that the members of the family Musaceaerequire large amounts of nitrogen to maintain good vegetative/reproductive growth and high bunch productivity, IAFSs that combine banana plants with leguminous trees would appear very attractive. Although the arrangement and management of an IAFS must satisfy the ecological requirements of the crop component, selection ofthe leguminous tree must take into accountthe capacity of the species to adapt to the edaphoclimatic conditions of the region.Thus, the present study aimed to evaluate the effects of different forest species (both leguminous and non-leguminous) and spacingsbetween plants of the bananacultivar 'PlátanoD'Angola' on the weight of bunches obtained from IAFSs established in the Amazon-Cerrado transition region.

MATERIALS AND METHODS

The experiment was carried out in property belonging to the company Bianchi Bananas ME located in Sinop, Mato Grosso (11º42'12" S,55º27'36" W;380 m altitude). The hot and humid climate of the region is of type Aw according to the Köppen classification,with a mean annual temperature of 30ºC and a mean annual precipitation of 2000 mm. The biome is typical of the Amazon/Cerrado transition zone with well-defined rainy and dry seasons. The soil in the experimental area presented the following physicochemical characteristics in the 0 to 20 cm layer: 550 g kg^{-1}sand, 91 g kg^{-1} silt, 359 g kg^{-1} clay, pH 4.9 ($CaCl_2$), 74 mg dm^{-3} P (Mehlich-1), 0.05 $cmol_c dm^{-3}$ K, 3.01 $cmol_c dm^{-3}$ Ca, 0.77 $cmol_c dm^{-3}$ Mg, 0 $cmol_c dm^{-3}$ Al^{+3}, 4.66 $cmol_c dm^{-3}$ H + Al, 29.63 g dm^{-1} organic C and 45% base saturation. The micronutrients B, Cu, Fe, Mn and Zn were present at levels of 0.93, 3.40, 71.00, 18.97 and 39.98 mg dm^{-3}, respectively. The experiment was conductedbetween December 2014 and April 2016 and followed a randomized block design ina split-plot arrangement with four treatments in the plots, three treatments in the subplots and three repetitions. The four treatments in the plots corresponded to the forest componentof the IAFSs as follows: IAFS1 - acacia (*Acacia mangium* Willd.; Fabaceae), IAFS2 - taxi-branco (*Sclerolobium paniculatum* Vogel; Fabaceae), IAFS3 - eucalyptus clone Urocam VM 01 (*Eucalyptus urophylla* S.T.Blake*x Eucalyptus camaldulensis* Dehnh.; Myrtaceae), and IAFS4 - casuarina (*Casuarinaequisetifolia* L.; Casuarinaceae). The three treatments in the subplotscorresponded tothe spacing of the crop component, namely banana cultivar 'PlátanoD'Angola', planted at 1.0, 1.5 or 2.0 m apart.

The forest species were installedin December 2014 with 4.0 m between the rows and 2.0 m between the trees, totalizing 1250 trees ha^{-1}. Banana plants were planted in January 2015 at different spacings in alternate alleys between the rows of forest trees such that the distance between rows of banana plants was 8.0 m. Forty five days prior to banana planting, a calculated dose of dolomitic limestone (1,800 kg ha^{-1}) was applied to the soil in order to increase the saturation of bases to 70%, and simple superphosphate (500 kg ha^{-1}) was applied to the planting area by broadcast and incorporated into the soil with a harrow. Banana seedlings were produced via micropropagation and subsequently transplanted to 700 cm^3 polyethylene bags filled with soil-based substrate. The acclimatization period was 50 days and seedlingswere transferred to their definitive positions in the experimental plots when theyhad attained 40 cm in height. At the time of planting, furrows were opened and simple superphosphate (300 kg ha^{-1}) was applied together with a 300 kg ha^{-1} dose of Nutri Solo® (16% Ca, 2% Mg, 8% S, 0.30% B, 0.09% Cu and 0.30% Zn). In addition, composted pig manure was applied to the planting area at a rate of 5 L per linear meter, and reapplied at a dose of 40 m^3 ha^{-1}every 20 days together with 100 kg ha^{-1} of NPK (16-06-16). Management of the IAFSs was performed by pruning the trees and de-tilleringthe bananaplants when the lateral sprouting buds (tillers) emergedcoupled with theremovalof old leaves. In contrast to banana plants, thetreesreceived a top dressing of B and Zn onlyimmediately after planting. Irrigation of the rows of trees and banana plantswas performed with the aid of micro sprinklers. Banana bunch weights (kg) were determinedusing a digital hanging scale by sampling six random plants per subplotharvested 80 days after the flowering of the first bunch. Measurements were carried out at the processing unit of Bianchi Bananas ME. Data were submitted to analysis of variance and *F* test to determine simple and interaction effects. Mean values were compared using Tukey test at 5% probability.

RESULTS AND DISCUSSION

The forest species present in the IAFSsaffected the weight of banana bunches significantly, whereas spacing between the banana plants had little influence overall (Table 1). The absence of response with respect to spacing between banana plants has been describedpreviously for the cultivar 'PlátanoD'Angola' grown in a monoculture system (ARRAIS, 2016).According to Marcilio (2020), this cultivar attained an average bunch weight of 13 kg $plant^{-1}$ and a productivity of 35 t ha^{-1} when cultivated under a dense plantingregime (4 m between rows x 1 m between plants)in Cáceres, Mato Grosso, Brazil. In the present study, whenthe effect of the forest component alone is taken into account, the banana bunches weighed on average 7.15 kg $plant^{-1}$across all tree components, but attained mean weightsof 8.0 kg $plant^{-1}$ in the presence of acacia(IAFS1) and taxi-branco (IAFS2).These values correspond to mean productivities of 9 t ha^{-1} considering all tree components and 11 t $ha^{-1}$for the IAFS1 and IAFS2 systems,but increase to 18 and 22 t ha^{-1}, respectively, when a 4.0 x 1.0 m configurationis taken into account. The banana cultivar 'PlátanoD'Angola'develops in the form of a large herb and is generally cultivated as an annual crop, since productivity declines significantly in the second cycle. Considering that theorchards need to be renovated immediately after the first cycle, a dense planting strategy is appropriate for this cultivar because it increases efficiency regarding the use of labor and inputs. Moreover, dense planting reduces therisk of plants toppling duringhigh winds, diminishes the occurrence of attack by root nematodes and increases control of invasive plants. Marcilio (2020) reported that for 'PlátanoD'Angola',a planting density of 2667 plants ha^{-1} was optimal for annual cultivation since it afforded increased productivity whilst maintaining fruit qualityof the standard expected by a demanding market. Although the distance between banana plants exerted only minor effects on bunch weights within the IAFS3 (eucalyptus) and IAFS4 (casuarina) systems, the average bunch weight inthe former wassignificantly lowerthanin the latter (Table 1). Eucalyptus is a fast-growing species that competes with banana plants for environmental resources (nutrients, water and sunlight).

Table 1. The effects of forest components and crop plant spacings on the weights of banana bunches produced by 'PlátanoD'Angola' cultivated in different integrated agroforestry systems (IAFSs)

Forest component (plots)	Weight of banana bunches (kg plant^{-1}) Plant spacing of the crop component (sub-plots)			
	1.0 m	1.5 m	2.0 m	Mean
IAFS1 - Acacia (leguminous; fast growth)	7.07 ab B	8.49 a A	8.66 a A	8.07 a
IAFS2 - Taxi-branco (leguminous; slow growth)	8.31 a AB	6.98 b B	8.91 a A	8.06 a
IAFS3 - Eucalyptus (non-leguminous; fast growth)	6.11 b A	5.55 c A	6.18 b A	5.94 c
IAFS4 - Casuarina (non-leguminous; slow growth)	7.11 ab A	7.52 ab A	6.74 b A	7.12 b
Mean	7.15 A	7.13 A	7.62 A	
CV in the plots[1]	4.52 %			
CV in the subplots[1]	10.58 %			

On the other hand, casuarinais slow growing with a canopy that is permeable to solar radiation and, therefore, is not very competitive in the first years of growth when compared with eucalyptus. Although casuarina is not a leguminous species, it is capable of establishing symbiotic associations with diazotrophic bacteria. However, the characteristics of the canopy (small leaf area, thin branches and leaves with low nitrogen content) may have contributed very little to the nitrogen nutrition of the banana plants. Intercropping banana with leguminous trees (i.e. acacia and taxi-branco)produced the heaviest bunches of all tree/crop combinations tested, andmeanbunch weights both withinand betweenIAFS1 and IAFS2 systems were not significantly different at 1.0 and 2.0 m spacing.Nevertheless, at 1.5 m spacingthebunchesproducedinthe presence of acacia were significantly heavier thanthose observed in the taxi-branco system (Table 1).Acacia is able to incorporate large amounts of nitrogen-rich biomass into the soil in a short time because its atmospheric nitrogen fixation rate is high, and such ability may have improved nutrient balancein thebananaplants. However, the rapid growth and the dense canopy of acacia may have blocked solar radiation, which possibly explains the lower yieldrecorded when banana plantswere 1.0 m apart (Table 1).

Taxi-branco is a species native toAmazon and Cerradobiomesand, despite having received little scientific attention, has timber potentialand can be used as green manure because of its nitrogen-rich leaves. Moreover, taxi-brancois a slow-growing species with athincanopy that does not interceptmuchsunlight, thus providing adequate levels of radiation for bananaplants even at the closest spacings. At 1.0 m spacing, theIAFS1 (acacia) and IAFS4 (casuarina) systems produced banana bunches with weights that were similar to each other but higher than the bunch weights in IAFS3 (eucalyptus). Under these spacing conditions, IAFS2 (taxi-branco) produced the heaviest bunches, likely because it is a native tree exhibiting slower growth and a thinner canopy resultingin greater sun light availability in a dense orchard setting (Table 1).With 1.5 m spacing, the heaviest banana bunches were produced in the IAFS1 (acacia) system, probably because of the capacity of the leguminous component to improve the nitrogen content of the soil (Table 1). The bunch weights in the IAFS2 (taxi-branco) and IAFS4 (casuarina)systems were similar but markedly higher than that recorded in IAFS3 (eucalyptus).At 2.0m spacing, the heaviest bunches were produced in theIAFS1 (acacia) and IAFS2 (taxi-branco) systems, likely reflecting the capacities of the forest components to improve availability of nitrogen and sunlight.

CONCLUSION

The results presented herein demonstrated that the cultivar 'PlatanoD'Angola' produced banana bunchespresenting the highest weights when the leguminous trees acacia and taxi-branco were employed as the forest component, with correspondingproductivities of 9 and 11 t ha^{-1}, respectively.A spacing of 1.0 m between banana plants appeared to be suitable for IAFSs involving slow-growing forest species such as taxi-branco and casuarina, whereas spacings of 1.5 and 2.0 m were more adequate for fast-growing forest species such as acacia and eucalyptus. However, the denser planting regimes (1.0 and 1.5 mspacings) would provide more efficient management of 'PlatanoD'Angola' orchards. Based on the results obtained in this study, recommendationscan be made for the establishment ofmore productive and profitable commercial orchards in the northern areaof the state of Mato Grosso. The adoption of IAFSs that combine valuable forest species with an important fruit crop such as banana will enable producers to increase their income by reducing costs while increasing productivity. Furthermore, the decreased use of inputs will lead to a reduction in environmental contamination and the production of better qualityfruit.

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