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Phytosociology and weed interference in okra under organic cropping system

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A research was carried out to study phytosociology and to determine the periods of weed interference in the okra crop in organic cropping system. The experiment was laid out in a randomized complete block design with 20 treatments and four replications. The treatments were 10 periods of weed coexistence with the crop during 0-7, 0-14, 0-21, 0-28, 0-35, 0-42, 0-49, 0-56, 0-63 and 0-74 days after crop emergence (DAE) and 10 periods weed free during 0-7, 0-14, 0-21, 0-28, 0-35, 0-42, 0-49, 0-56, 0-63 and 0-74 DAE. The weeds were evaluated by the number of individuals and accumulated dry biomass of each population in the treatments. The relative frequency, relative density, relative dominance and importance value index of each species were used to determine the effect the weeds. The most important weeds based on the Importance value index were *Commelina benghalensis* L., *Cynodon dactylon* (L.) Pers., *Eleusine indica* L., *Phyllanthus niruri* L. and *Alternanthera tenella* Colla. The period prior to interference and the total period of interference prevention were respectively of 12 and 36 days after emergence. The weed community caused yield losses of around 51%. In okra organic cropping system, weed control should be done early to boost okra plant growth in order to provide shade on the weeds to reduce the need for long control period.

Key words: *Abelmoschus esculentus* (L.) Moench, competition, weed community.

INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench], is a well adapted species to tropical and subtropical climates. It is widely grown in Brazil, particularly by smallholders (Purquerio et al., 2010) in conventional cropping systems, however it can be grown in organic cropping systems as well, since it generally demands high amount of organic fertilizer which is essential for proper plant nutrition, fruit

quality and yield increase with less or no use of synthetic fertilizers (Sediyama et al., 2009).

Accordingly, Premsekhar and Rajashree (2009) observed that the application of organic fertilizers resulted in various positive effects on okra growth and yield. However, a limiting factor in okra production in organic system is weed interference.

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Ibrahim and Hama (2012) found that treatments with no fertilizer and no weed control resulted in okra growth parameter values significantly lower, due to weed competition for soil nutrients, giving to weeds competitive advantages over the crop. Thus, it becomes necessary to know the weed species occurring in okra crop in order to decrease yield losses and production costs.

Weed community composition studies in conventional okra cropping system were carried out by Bachega et al. (2013). They identified the species *Portulaca oleracea*, *Eleusine indica* and *Nicandra physaloides* among the main weeds. Santos et al. (2010) found that the okra dry matter was affected by *Alternanthera tenella*, *Arachis pintoi*, *Bidens pilosa*, *Commelina benghalensis*, *Cyperus rotundus*, *Ipomoea nil* and, especially, *Eleusine indica* which reduced the number okra leaves. Conversely, Dada and Fayinminnu (2010), studying weed control in okra in Nigeria, reported that *Euphorbia heterophylla*, *Talinum triangulare*, *Eleusine indica*, *Cynodon dactylon*, *Commelina benghalensis*, *Cyperus iria*, *Cyperus difformis*, were the predominant species among the weed community.

Knowledge of the weed species growing in association with okra in organic cropping system is scarce, as well as the determination of the periods in which they interfere with crop yield. According to Pitelli (2014), knowledge of factors affecting the coexistence and interference relationships between crops and weeds is critical to establish cultural practices to direct resources to crop grow at the expense of weeds.

Studies on the determination of weed community interference periods in okra conventional cropping system carried out by Bachega et al. (2013), showed the Period Before Interference (PBI) of 57 days after emergence (DAE) that is, the crop can coexist with the weed community for this period without yield decrease, and the Total Period of Interference Prevention (TPIP) of 14 days, suggesting a short weed control period to ensure crop yield. However, Santos et al. (2010) also studying okra in conventional cropping system, observed lower PBI (25 DAE) and higher TPIP (100 DAE).

Carvalho et al. (2008) emphasized that different critical periods reflect the conditions of crop establishment and management in different times and locations, particularly with respect to soil and climate conditions, the weed community composition and the degree of weed infestation in the study area. Therefore, studies of periods of weed interference in okra should be performed in different cropping systems.

Taking into account that knowledge of the weed species growing in association with okra organic cropping system is of great importance for assessing the degree of interference on crop growth and yield, as well as to subsidize adaptations on weed management, this research aimed to study phytosociology and to determine the periods of weed interference in okra organic cropping system.

MATERIALS AND METHODS

The experiment was conducted between January and April 2014 in a certified organic production area in the municipality of São Luís, state of Maranhão (2°37'39.69" S and 44°11'15.7" W), northeastern Brazil. Local climate is of the Aw' type, according to Köppen classification, equatorial, hot and humid with a rainy season from January to June (average 2,010 mm) and a dry season from July to December (average 180 mm), average annual temperature is 26.1°C and average relative humidity is 88% (Instituto Nacional de Meteorologia, 2009).

The soil is classified as Paleudalf (Embrapa, 2013). Chemical analysis indicated the soil pH (CaCl₂) = 5.4; organic matter = 26 g dm⁻³; P = 111 mg dm⁻³; K = 2.3 mmolc dm⁻³; Ca = 33 mmolc dm⁻³; Mg = 14 mmolc dm⁻³; SB = 49.3 mmolc dm⁻³; H + Al = 26 mmolc dm⁻³; CEC = 75.3 mmolc dm⁻³.

Land preparation consisted of cleaning the area through mowing and opening of holes, with subsequent plot demarcation. Basal fertilization was done as 27.8 t ha⁻¹ of chicken manure, 0.46 t ha⁻¹ of natural phosphate, 0.023 t ha⁻¹ potassium sulfate and 0.20 t ha⁻¹ ash. Okra seeds were previously soaked in water for 24 h in order to break dormancy. Planting was done manually with four seeds per hole.

The experiment was laid out in randomized complete block design, with 20 treatments and four replications. Plots consisted of four rows of 3.20 m length spaced 1.20 m between rows and 0.40 m between plants within rows. The useful plot size for harvesting and non-destructive evaluation was composed of the two central rows, excluding two plants from each end, totaling 20 okra plants.

The treatments were divided into two groups: Weed control periods (weeded) and coexistence periods of the weeds with the crop (unweeded). In the first group, the crop was free from weed interference, by hoeing in the following periods: 0-7, 0-14, 0-21, 0-28, 0-35, 0-42, 0-49, 0-56, 0-63 and 0-74 DAE (harvest). After these periods, the weeds that emerged were left to grow freely, while in the second group, the crop was left in coexistence with weeds from emergence to the periods described above for the first treatment group. After each period of coexistence, the okra plants were kept weed free by hand weeding. The early application of treatments was considered from 80% of the crop emergence.

Okra plant thinning was performed at 10 DAE when the plants were 10-15 cm in height, leaving two plants per hole. The experiment was sprinkler irrigated during January and February in order to meet the crop water demands. Foliar fertilization was performed at 33 DAE with biofertilizers in the amount of 180 L ha⁻¹ at the rate of 0.5 to 20 L of water.

Weed sampling was carried out using a 0.50 m × 0.50 m open metal rectangle which was placed at random three times in the plots. The aerial portions of the weeds were harvested, counted and identified by family, genus and species. Thereafter, the plants were placed in an oven with forced air ventilation at 65-70°C for 72 h until constant weight, and then weighed on a 0.01 g precision scale. The data obtained from each sample was used to perform the weed community phytosociological study, by computing the relative density, absolute and relative frequency and importance value index for each weed species (Mueller-Dombois and Ellenberg, 1974).

Plant height was taken at 32 DAE by measuring 10 okra plants from the soil to the apex from the useful area from each treatment plots. Crop harvest started at 46 DAE. Harvest was done every two days when the fruits showed intense green color, finishing at 74 DAE with a total of 13 harvests. Only fruits that had commercial grade "12" (fruits with a length between 12 and 15 cm) were harvested. Data on plant height and marketable yield were processed by treatment (initial periods of control or coexistence of weeds with the crop) and were subjected to analysis of variance by F test at 5% probability and then applied the Student t test through SAEG 9.1 software (SAEG, 2007). The yield data were studied by

nonlinear regression and adjusted according to the Boltzmann sigmoidal model (Kuva et al., 2000) with the aid of the software ORIGIN 8.0 (OriginLab Corporation, 2002).

RESULTS AND DISCUSSION

The weed flora in the okra organic cropping system was represented by 44 species from 17 families, of which 38.46% were from the monocot group and 61.54% from the dicot group (Table 1).

In the okra conventional cropping system, Bachega et al. (2013) found 19 species arranged in 12 families with 63% of species belonging to the dicot group and 37% to the monocot group. These results show that the weed species diversity in the okra organic cropping system was higher when compared to the conventional cropping system, indicating that no soil disturbance, use of manure and favorable weather conditions contributed to greater weed community diversity.

The highest weed species richness occurred in the period of coexistence, with 41 weed species compared to control, with 30 species. The most important families also occurred during the coexistence periods, these were Poaceae, Amaranthaceae and Cyperaceae with nine, six and five species each, respectively, whereas Poaceae and Cyperaceae with five species each and Amaranthaceae with four species were the most important families in the weed control periods (Table 1). This result suggests that weed control performed since the beginning of the crop growth served as a selection factor for various weed species. Due and Fayinminnu (2010) noted the predominance of Poaceae and Cyperaceae with six and four species each, respectively, in Okra cultivation with fertilizer. However, Smith and Ojo (2007) found that species of these families were rare in okra conventional cropping system.

The population density of the weed community sharply decreased with periods of coexistence in the okra organic cropping system. The highest density occurred at seven DAE with 3,175 plants m^{-2} and the lowest was observed after 74 DAE (crop), with 313 plants m^{-2} (Figure 1a). The initial high weed density can be explained by mowing used in the organic system which favored the spread of some species by their fragmentation influenced by good climate and soil conditions which favored their sprout (Figure 1a). With crop development, interspecific associated to intraspecific competition were intensified which suppressed several species, reducing weed density.

The weed dry matter accumulation increased significantly from seven up to 49 DAE, with values between 51.51 and 1,271.35 g m^{-2} , respectively. Thereafter there was a tendency to stabilize the weed dry matter accumulation to harvest (Figure 1b). This behavior suggests that with the decrease in the weed density, the development potential of some weed species was expressed by greater soil nutrients recruitment, resulting

in higher dry matter accumulation in the weed community. Therefore, in the final period of coexistence, the biomass accumulation prevailed on the weed community density.

In the weed control periods, the weed community density increased up to 21 DAE when it reached 758 plants m^{-2} . Thereafter, there was a rapid decrease until the last evaluation (63 DAE) when it reached the value of 538 plants m^{-2} (Figure 2a). The sharp weed density decrease can be explained by the initial control efficiency that contributed to enhance the intra and interspecific competition resulting in weed death and showed that the crop required an initial period with no weeds to enhance its development. According to Coelho et al. (2009), the evaluation of the weed community in weed control periods does not allow portray the entire crop cycle, since it occurs only at harvest, but it assists in verifying the competitive crop potential.

A sharp decrease in the weed dry biomass in the weed control periods was observed until 35 DAE when they reached 123.13 g m^{-2} . Subsequently, the dry matter accumulation was constantly lower until the last evaluation with 100.47 g m^{-2} (Figure 2b). The weed community dry biomass decrease is associated with the control efficacy of their density which also enhances crop growth and development potential. Ibrahim and Hamma (2012) studying okra cultivation with organic fertilizer found that the supply of manure and the three weeding regime promoted crop development suppressing weeds that were competing mainly for soil nutrients.

The weed species that were common to both periods and had higher relative importance in the okra crop organic cropping system were *A. tenella*, *C. benghalensis* and *C. dactylon*. Other important species were *P. niruri* in periods of coexistence and *E. indica* in the weed control periods (Figure 3a and b). These species are well adapted to growing conditions in organic cropping system and should have special attention on the adequacy of weed management in this system to not reduce crop yield.

The species of greater relative importance in the periods of coexistence was *C. benghalensis* except at 14 and 21 DAE when it was surpassed by *A. tenella*. The larger *C. benghalensis* IVI values were obtained at 35 and 63 DAE with 93.4 and 94.8%, respectively (Figure 3a). This was the result of its high density in the area, coming from the land preparation with mowing that fragmented the plant facilitating its spreading and the use of organic fertilizer which favored its growth resulting in increased dry biomass accumulation. Pitelli (2014) emphasized that soil fertilization influences not only the crop but also weed growth, and some weed species grow faster than crops because they are able to recruit more resources, including those not added by fertilization thereby exerting greater competitive pressure on the crop.

The *A. tenella* population was relevant in the organic

Table 1. Family and weed species identified in different periods of coexistence with the crop and of weed control in okra organic cropping system (São Luís, state of Maranhão, northeastern Brazil, 2014).

Family/species	Okra organic cropping system	
	Coexistence with weeds	Weed control
Amaranthaceae		
<i>Alternanthera tenella</i> Colla	P	P
<i>Amaranthus deflexus</i> L.	P	P
<i>Amaranthus retroflexus</i> L.	P	P
<i>Amaranthus spinosus</i> L.	P	A
<i>Amaranthus viridis</i> L.	P	A
<i>Amaranthus</i> sp.	P	P
Asteraceae		
<i>Eclipta alba</i> (L.) Hassk.	P	A
<i>Emilia sonchifolia</i> (L.) DC	P	A
<i>Synedrella nodiflora</i> (L.) Gaertn.	P	P
Boraginaceae		
<i>Heliotropium indicum</i> L.	P	A
Brassicaceae		
<i>Cleome affinis</i> DC.	P	P
Cyperaceae		
<i>Cyperus</i> sp.	P	P
<i>Cyperus flavus</i> (Vahl) Nees	A	P
<i>Cyperus distans</i> L.f.	P	P
<i>Cyperus brevifolius</i> (Rottb.) Hassk.	P	P
<i>Bulbostylis capillaris</i> (L.) C.B. Clarke.	P	P
<i>Kyllinga odorata</i> Vahl	P	A
Commelinaceae		
<i>Commelina benghalensis</i> L.	P	P
Euphorbiaceae		
<i>Chamaesyce hirta</i> (L.) Millsp	P	P
<i>Euphorbia heterophylla</i> L.	P	A
Linderniaceae		
<i>Lindernia crustacea</i> (L.) F. Muell.	P	P
Loganiaceae		
<i>Spigelia anthelmia</i> L.	P	P
Malvaceae		
<i>Sida</i> sp.	P	A
<i>Gaya pilosa</i> K. Schum.	P	A
<i>Corchorus argutus</i> Kunth	P	P
Molluginaceae		
<i>Mollugo verticillata</i> L.	P	P
Nyctaginaceae		
<i>Boerhavia diffusa</i> L.	P	A
Onagraceae		
<i>Ludwigia octovalvis</i> (Jacq.) PH. Raven	P	P
Poaceae		
<i>Cynodon dactylon</i> (L.) Pers.	P	P
<i>Eleusine indica</i> (L.) Gaertn.	P	P
<i>Digitaria</i> sp.	P	P
<i>Cenchrus echinatus</i> L.	P	P
<i>Paspalum maritimum</i> Trin.	P	P
<i>Panicum maximum</i> Jacq.	P	A
<i>Panicum</i> sp.	P	A

Table 1. Contd.

<i>Brachiaria</i> sp.	P	A
<i>Brachiaria mutica</i> (Forssk.) Stapf	P	A
<i>Eragrostis ciliaries</i> (L.) R. Br.	A	P
Portulacaceae		
<i>Portulaca oleracea</i> L.	P	P
<i>Talinum triangulare</i> (Jacq.) Willd.	P	P
Phyllanthaceae		
<i>Phyllanthus niruri</i> L.	P	P
Rubiaceae		
<i>Hedyotis corymbosa</i> (L.) F. Muell	P	P
<i>Spermacoce latifolia</i> Aubl.	P	A
<i>Spermacoce verticillata</i> L.	A	P

P = Present; A = Absent.

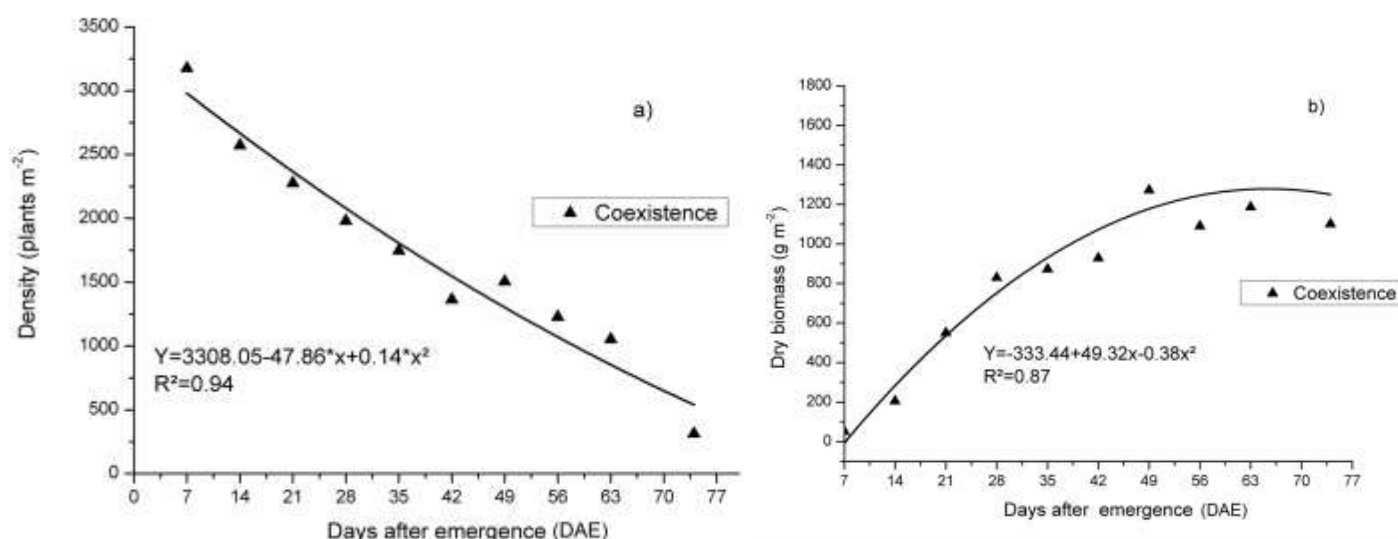


Figure 1. Density (a) and dry biomass (b) of the weed community in different periods of coexistence with weeds in okra organic cropping system in São Luís, state of Maranhão, northeastern Brazil, 2014.

cropping system particularly at the beginning of the coexistence period, at 14 DAE with IVI 85.2% and at 21 DAE with IVI 58.8% (Figure 3a). The practice of mowing in the organic cropping system also spread this species facilitating its regrowth. Santos et al. (2010) reported *C. benghalensis* and *A. tenella* as important species in the okra crop in conventional tillage.

Another important weed species noted in periods of coexistence was *C. dactylon*, particularly at seven and 56 DAE with IVI values above 60% (Figure 3a). This species is difficult to control when well established and it is also a potential host of root-knot nematode (*Meloidogyne* spp.) that causes severe reduction in okra yield, sometimes invalidating its cultivation. Therefore, it should be kept at low density to not harm the okra crop. Law-Ogbomo et al. (2013) noted that *C. dactylon* was one of the most

important weeds found in okra conventional cropping systems.

In the weed control periods, *C. dactylon* population predominated in the weed community throughout the crop cycle except at 21 and 49 DAE, when the main species was *A. tenella* (Figure 3b). The highest incidence of light on the soil as a result of hoeing in the initial weed control periods, the wide spacing used and the okra plants slow growth favored the spread of *C. dactylon*. Ibrahim and Hamma (2012), studying okra cultivation with organic fertilizer also identified this species as one of the most important in the weed community.

It was noted that *C. benghalensis*, *A. tenella* and *E. indica* populations had IVI values below 35% for the whole control period, except at seven and 28 DAE for *E. indica* and at 21 DAE for *A. tenella* (Figure 3b). The initial

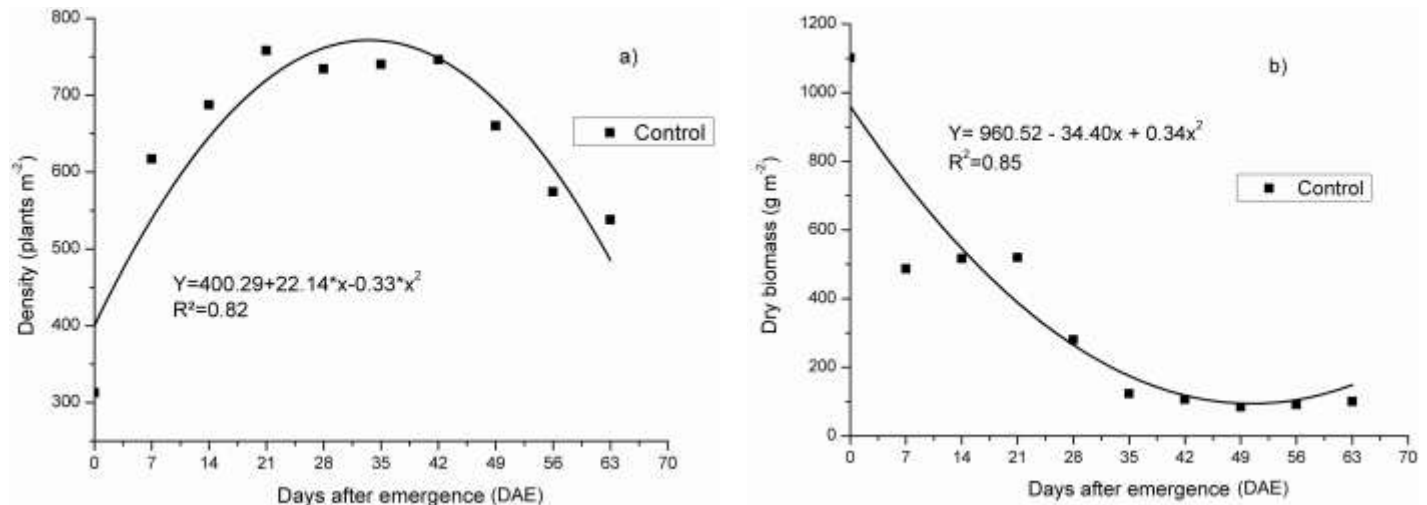


Figure 2. Density (a) and dry biomass (b) of the weed community in different periods of weed control in okra organic cropping system in São Luís, state of Maranhão, northeastern Brazil, 2014.

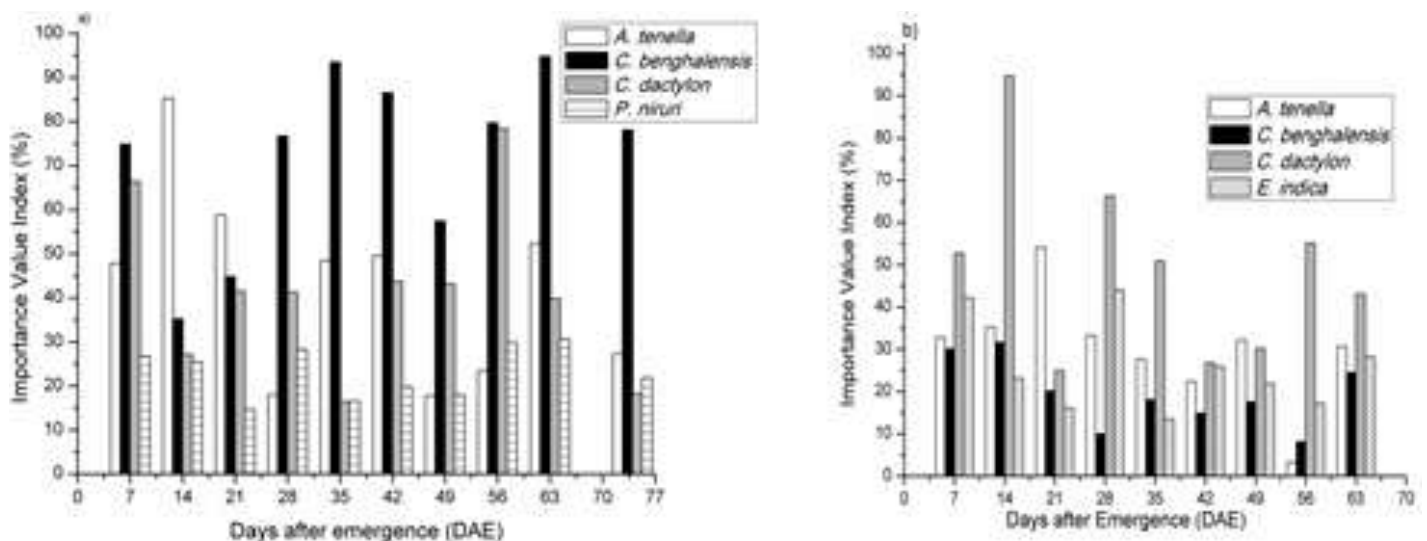


Figure 3. Importance Value Index of the most important weed species identified in different periods of coexistence with the okra crop (a) and of weed control (b) in okra organic cropping system in São Luís, state of Maranhão, northeastern Brazil, 2014.

control was efficient to intensify intra- and interspecific competition, especially the last, because, when the weeds emerged, okra plants were well established and therefore reduced their density.

The greatest okra plant height values were observed from treatments of period of coexistence with the weed community at 28 DAE (Figure 4). Similar results were obtained by Dada and Fayinminnu (2010) with okra grown with organic fertilizer whose plots with weeds had the highest okra plants as a result of competition with weeds for light. Law-Ogbomo et al. (2013) studying okra conventional cropping system observed that after 32

DAS, the okra plants had the lowest heights in treatments of periods of coexistence with weeds. This suggests that competition for light exerted higher effect on okra plant growth and development in an organic cropping system than in the conventional system.

In the weed control periods, the okra plant had the lowest height at 32 DAE compared to the coexistence periods, except in plots with weed control at seven and 14 DAE (Figure 4). Okra crop is slower in its early development, while the weeds are faster in capturing resources to survive and develop; therefore initial weed control enhances the crop growth and development.

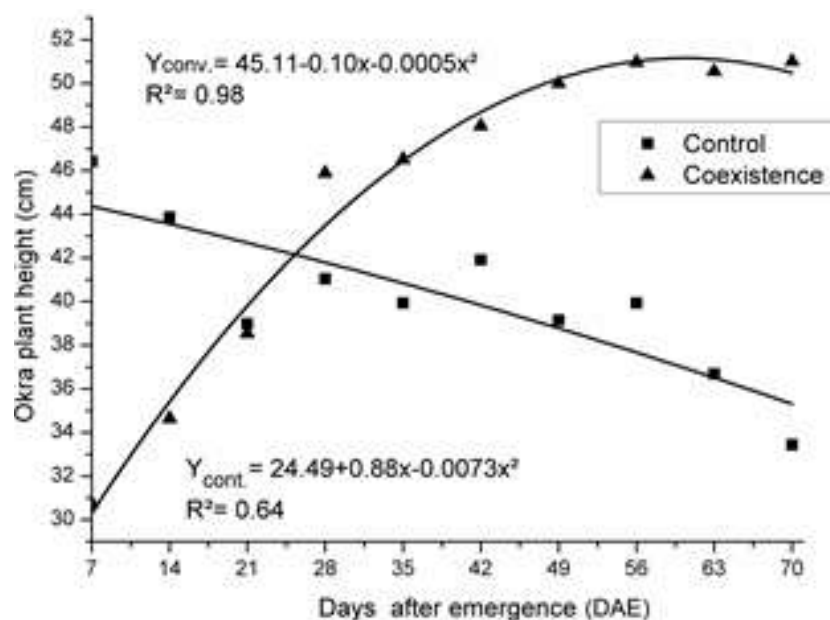


Figure 4. Okra plant height in organic cropping system in different periods of coexistence with the weeds and of weed control in São Luís, state of Maranhão, northeastern Brazil, 2014.

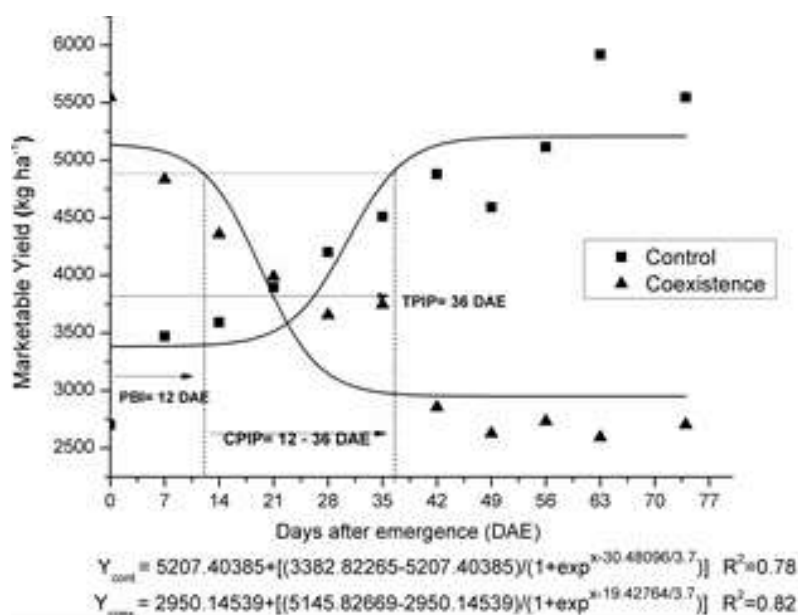


Figure 5. Okra marketable yield and yield data adjustment by the Boltzmann sigmoidal model in function of different periods of coexistence with the weeds and of weed control taking into consideration 5% yield loss. São Luís, state of Maranhão, northeastern Brazil, 2014.

The okra crop grown in organic system was affected by the different periods of coexistence with weeds. The interference was more intense at 12 DAE (Figure 5). The short period of coexistence indicates a crop disadvantage with respect to the weed community when growing in

organic cropping system when compared to the results obtained by Santos et al. (2010) and Bachega et al. (2013) in okra conventional cropping system, whose coexistence periods were 25 and 57 DAE, respectively.

Law-Ogbomo et al. (2013) emphasized that the

frequency and cost of weed removal depends on the weed species, the crop grown, cultural practices, the cropping system and the growing season. Therefore, differences in periods of coexistence between okra organic and conventional cropping systems are related to the weed community management practices in these systems that select different species, the cultivar used and soil and climate conditions.

With regards to weed control it was found that up to 36 DAE, the control was enough since the weeds would not interfere in the crop yield, that is, control beyond this period did not increase the crop yield (Figure 5). This result confirms the good control complementation premise carried out by okra plants, which after this period, formed a canopy that shaded the soil and hindered weed growth and development.

In okra cultivation with organic fertilization, Ibrahim and Hamma (2012) found that weeding for three weeks significantly reduced the weed population that could compete with the crop for soil nutrients. However, in the okra conventional cropping system, Santos et al. (2010) found the need for weed control for 100 DAE. This suggests that in an organic cropping system, the weed control period is lower when compared to the conventional cropping system.

The CPIP was between 12 and 36 DAE covering 24 days of the crop cycle, that is, the period by which the weed control must be concentrated in order to reduce financial costs with unnecessary hoeing and to avoid yield losses. Dada and Fayinminnu (2010) found a CPIP between 21 and 42 days after sowing, covering 21 days of the okra crop cycle when grown with organic fertilizer as the most appropriate for optimal growth, development and fruit production. Bachega et al. (2013) studying okra conventional cropping system noted the non-occurrence of the CPIP since the PBI was more extensive than the TPI. However, Santos et al. (2010) also found in okra conventional cropping system, values between 25 and 100 DAE for the CPIP, covering 79 days of okra crop cycle. These results indicate that in an okra organic cropping system, weed control should be carried out early to boost okra plant growth to provide shading on the weeds, because the time needed for control was not extensive.

Okra yield with in total absence of weed interference was 5,546.87 kg ha⁻¹ and in coexistence with weeds throughout crop cycle was 2,703.12 kg ha⁻¹ with yield losses of 51.3%. Ibrahim and Hamma (2012) reported yield losses around 40% in okra grown with organic fertilizer and three weeks of weeding. In okra grown in conventional cropping system, yield losses due to weed interference ranged from 78.59 to 95% (Bachega et al., 2013; Law-Ogbomo et al., 2013; Santos et al., 2010). This is an indication that organic fertilizer supplied the crop with the required amount of nutrients, and this resulted in a decrease in weed interference compared to the conventional cropping system whose crop yield

losses were higher when in full coexistence with weeds.

Conclusions

The more important weeds in okra crop grown in organic cropping system were *A. tenella*, *C. benghalensis*, *C. dactylon*, *E. indica*, *P. niruri* and *A. tenella*. Weed control in okra crop under organic cropping system must be carried out earlier, between 12 and 36 days after crop emergence to boost growth in order to provide shade to reduce the need for long control period.

Conflicts of Interests

The authors have not declared any conflict of interests.

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