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WEED PHYTOSOCIOLOGY AND DISTRIBUTION IN VINEYARDS IN THE SÃO FRANCISCO RIVER VALLEY[1]

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ABSTRACT - Information on the different species that compose a weed community is essential for plant protection managements in production systems, which should include not only flora identification and diversity assessments, but morphological and ecophysiological aspects that can to show the potential effect of the agrosystem and guide the conduction of weed control strategies. Therefore, the objective of this work was to conduct a floristic and phytosociological surveying to identify the grouping patterns of weed populations in vineyards in the Petrolina-Juazeiro irrigated perimeter, in the Sub-Mid São Francisco River Valley, Brazil. The absolute and relative values of weed frequency, density, abundance, importance value index, population distribution level, and similarity between areas were evaluated in five properties. A high diversity of species of the families Poaceae, Malvaceae, and Asteraceae were found. The most important species found were *Commelina benghalensis*, *Euphorbia hirta*, and *Cyperus aggregatus*. The distribution of populations was mainly in aggregate and highly aggregate forms.

Keywords: Weed community. *Commelina bengualensis*. Irrigated fruit production. Grape. Semiarid.

FITOSSOCIOLOGIA E DISTRIBUIÇÃO DE PLANTAS DANINHAS EM ÁREAS DE VITICULTURA NO VALE DO RIO SÃO FRANCISCO

RESUMO - O conhecimento sobre as diferentes espécies que compõem uma comunidade infestante torna-se fundamental no manejo fitossanitário dos sistemas de produção vegetal, não somente pela identificação da flora e diagnóstico da diversidade, mas também pelos aspectos morfológicos e ecofisiológicos, o que pode revelar o potencial de interferência ao agrossistema e nortear a condução das estratégias de controle. Neste sentido, o objetivo deste trabalho foi realizar o levantamento florístico e estudo fitossociológico, assim como conhecer o padrão de agrupamento das populações infestantes em áreas de videira no perímetro irrigado do polo Petrolina-PE/Juazeiro-BA, submédio do Vale do Rio São Francisco. As avaliações ocorreram em cinco propriedades, sendo analisados os parâmetros de: frequência, densidade, abundância e índice de valor de importância absolutos e relativos, assim como o grau de distribuição das populações e a similaridade entre as propriedades. As famílias Poaceae, Malvaceae e Asteraceae apresentaram maior diversidade de espécies. E as espécies com maiores níveis de importância foram *Commelina benghalensis, Euphorbia hirta e Cyperus aggregatus*. De maneira majoritária, a distribuição das populações apresentou-se de forma agregada ou altamente agregada.

Palavras-chave: Comunidade infestante. *Commelina bengualensis*. Fruticultura irrigada. Uva. Semiárido.

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INTRODUCTION

The Sub-Mid São Francisco River Valley (SMSFRV) encompasses a center of irrigated agriculture in the Semiarid region in the Northeast of Brazil. Vine crops in the SMSFRV became the second most important in terms of area, with approximately 12.000 hectares planted. The region of the municipalities of Petrolina in the state of Pernambucco (PE) and Juazeiro in the state of Bahia (BA) is one of the most important fruit production centers in the SMSFRV; in addition, 98.7% of all exported grapes from the region in 2009 to 2015 was produced in the São Francisco River Valley (SÁ; SILVA; BANDEIRA, 2015; CODEVASF, 2018). Vineyard fields require care to maintain the health quality of plants, since the environment of production areas are prone to intense weed infestations due to the wide spacing between plants and abundant resources for their growth.

The presence of weeds in agricultural areas cause production losses in agricultural crops of up to 40% in tropical environments (LORENZI, 2008), mainly due to allelospoly (competition for resources), allelopathy (chemical interaction between plants), allele-mediation (host of pests and diseases), and interference with cultural practices. Weeds are described as any superior plant that interfere with human interests or with the environment (PITELLI, 2015).

Weeds present characteristics that make them highly persistent and have fast growth, high seed production, dormancy mechanisms, easy dispersion, high phenotypic plasticity, and tolerance to environmental adversities (CARVALHO, 2013). Therefore, preventive or remedial weed control practices are essential to reduce the effect of weeds on agricultural production areas. However, the use of such practices requires information on the species and morphophysiological characteristics of weed communities and on the potential effect of each population.

Studies on weed infestations also consider the distribution of populations in the area, which can be generally or locally (spots) distributed. This information assists in the planning of sustainable managements using specific measures that bring benefits such as higher economic return and lower environmental impact (ROCHA et al., 2015). Several studies present economy of up to 25% for the application of pesticides when using the precision agriculture technique termed variable-rate application, i.e., when the input is applied based on the spatial arrangement of the target (GUNDY; DILLE; ASEBEDO, 2017; KEMPENAAR et al., 2017; BHAKTA; PHADIKAR; MAJUNDER, 2019).

Information on floristic characteristics and population distribution of weeds in agricultural areas are important tools to analyze the occupation and establishment of weed communities, mainly in irrigated areas and areas with wide spacing between plants. Therefore, the objective of this work was to conduct a floristic and phytosociological surveying to identify the grouping patterns of weed populations in vineyards in the Petrolina-Juazeiro irrigated perimeter, in the Sub-Mid São Francisco River Valley, Brazil.

MATERIAL AND METHODS

The study was conducted from August 2016 to January 2018 in five agricultural properties with vineyards: three in Petrolina (PE) and two in Juazeiro (BA), Brazil. The properties were termed as PROP-A, PROP-B, PROP-C, PROP-D, and PROP-E; they presented planted areas of 370, 220, 45, 130, and 150 ha, respectively. The geographical reference of the properties is shown in Figure 1.

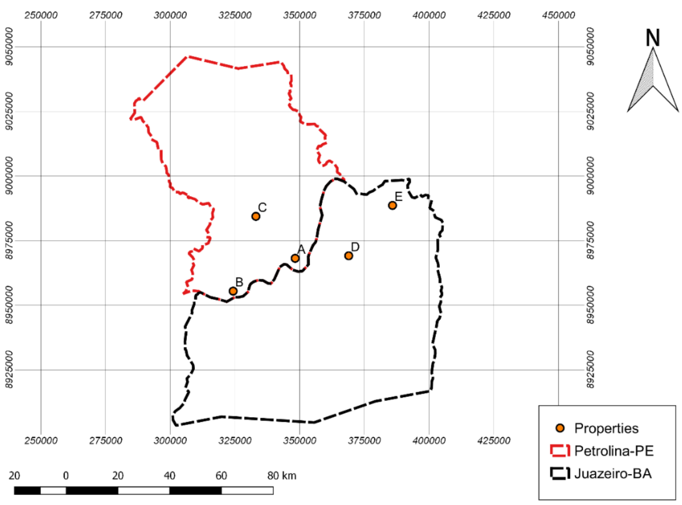

Figure 1. Geographical location of the agricultural properties used for the phytosociological survey of weeds. Source: Software Qgis 2.18, Coordinate Reference System WGS 84 / UTM zone 24S.

The climate of the region is classified as BSh, semiarid of low altitude and latitude, according to the Köppen classification (ALVARES et al., 2013). The region presents mean annual rainfall depth of 571.5 mm and mean annual temperature of 26.4 °C, with mean minimum of 20.6 °C and mean maximum 31.7 °C.

The areas of each property were sampled using a PVC square frame (0.5 x 0.5 m), according to the method proposed by Braun-Blanquet (1979). A square frame was randomly launched in each parcel of the area, following a zigzag path, to determine the sample plot and assess the weeds within it; the last launching was performed when no more new species were found. A total of 367 sample plots were determined for the properties—90 for PROP-A, 18 for PROP-B, 35 for PROP-C, 144 for PROP-D, and 80 for PROP-E.

The plants in each sample plot were counted and separated by species. An individual of each species was collected, pressed, and sent to the Laboratory of Seeds and Flora Management (LASMAF) of the Federal University of the São Francisco Valley to record, confirm their identification, and add to the exsiccate collection. The plants were identified through consultations to the Valley of São Francisco Herbarium (HVASF) and the manual of weed identification, as done by Lorenzi (2008) and Moreira and Bragança (2011). The scientific names were checked by using the online platform of the Reflora program (FLORA DO BRASIL, 2020).

The plants in the sample plots were collected by cutting their shoots, separated by species, placed in kraft paper bags, and dried in an oven at 70 °C for 72 hours to determine their dry biomass (CABRERA et al., 2019).

The data collected were subjected to weed community analysis using phytosociological parameters, which show the absolute and relative values of weed frequency, density, abundance, and importance value index, through the formulas proposed by Mueller-Dombois and Ellemberg (1974) and described by Cabrera et al. (2019). In addition, the coefficient of Sorensen (1972) was used to determine the similarity between the areas evaluated (properties). The results were considered when the importance value index of the weed plant was equal to or higher than 1%.

The weed population grouping was studied through three methods: 1) variance to mean ratio; 2) coefficient of Green; and 3) exponent k of the negative binomial distribution. These analyses included the variance (s2) and sample mean by species, considering the total sampled plants (n) for each property, separately (GREEN, 1966; ELLIOTT, 1979; MONQUERO; HIRATA; PITELLI, 2014).

RESULTS AND DISCUSSION

Vineyard areas in Petrolina, PE (PROP-A, PROP-B, and PROP-C)

The infested areas in PROP-A had 38 weed species distributed into 15 families, most from the Poaceae (13), Malvaceae (4), Fabaceae (3), Amaranthaceae (3), Asteraceae (2), Euphorbiaceae (2), Phyllanthaceae (2), and Rubiaceae (2). Only one species was found for the following families: Aizeaceae (*Trianthema portulacastrum* L.), Commelinaceae (*Commelina benghalensis* L.), Cucurbitaceae (*Momordica charantia* L.), Cyperaceae (*Cyperus aggregatus* (Wild.) Endl.), Molluginaceae (*Mollugo verticillata* L.), Portulacaceae (*Portulaca oleraceae* L.), and Talinaceae (*Talinum fruticosum* (L.) Juss.).

C. benghalensis and *T. fruticosum* (L.) Juss. had the highest importance value indexes, representing 58.2% of the weed community importance value (Table 1), followed by *Euphorbia hirta* L. and *Phyllanthus niruri* L. These four species together represented 70% of the entire weed community in PROP-A.

C. benghalensis presented the highest IVI (39.5%), denoting its predominance. This is a naturalized species of annual or perennial cycle and C3 photosynthetic metabolism; it reproduces by seeds and vegetatively through stems (LORENZI, 2014; GHOSH et al., 2019a). Another important characteristic that makes it highly persistent is its seed production in the root regions that are buried, which hinders the control of the species (BLANCO, 2014).

In addition to inherent factors to species and biotypes, climate, physiographic, and anthropogenic (management agricultural) factors determine the occurrence and permanence of weed plants in the field (BOOTH; MURPHY; SWANTON, 2003). Thus, the high infestation of *C. benghalensis* in PROP-A can be also explained by the management practices that are, in general, adopted by producers, such as the use of broad-spectrum herbicides usually combined with hoeing. *C. benghalensis* biotypes present variable levels pf tolerance to the herbicide glyphosate (BRITO et al., 2017), the most used molecule for control of weeds (GONÇALVES et al., 2016), which does not justify its use to control this species. The vegetative propagation capacity of this species makes hoeing practices to increase the infesting potential, since each stem nodal region can originate a new plant.

The type of propagation also partially explains the infesting potential of *T. fruticosum* in this site. *T. fruticosum* also presents characteristics that make it efficient in spatial distribution. This native plant has propagation by seeds, but it has high potential of forming new plants through asexual propagation (MOREIRA; BRAGANÇA, 2011). *T. fruticosum* has a CAM photosynthetic metabolism (Crassulacean acid metabolism) under water stress conditions, which is reversible when the stress stops (BRILHAUS et al., 2016). This may favor the persistence of the species under different environmental conditions, such as renewed or abandoned areas and natural environments near vineyards, which is an advantageous evolutionary strategy for growing in semiarid environments. In addition, this species has a thick cuticular wax layer that hinders the permeability of herbicides, especially those with more hydrophilic formulations.

Table 1. Relative phytosociological parameters and population distribution level of weeds in areas of viticulture in Petrolina, PE, Brazil (PROP-A).

Species	F	D	A	Do	IVI	Distribution		
	---------------------- %				--------------------	I	Cx	K
Commelina benghalensis L.	22.4	52.9	11.9	43.3	39.5	A	A	HA
Talinum fruticosum (L.) Juss.	10.5	16.1	7.7	29.3	18.7	A	A	HA
Euphorbia hirta L.	9.4	7.0	3.7	2.3	6.2	A	A	HA
Phyllanthus niruri L.	10.5	5.4	2.6	1.4	5.7	A	A	HA
Digitaria sanguinales (L.) Scop.	5.7	1.4	1.2	3.1	3.4	A	A	MA
Eleusine indica (L.) Gaertn.	5.1	1.6	1.6	2.9	3.2	A	A	HA
Amaranthus deflexus L.	4.8	1.9	1.9	1.0	2.6	A	A	HA
Setaria vulpseta (Lam.) Roem & Schult	3.2	1.6	2.5	1.2	2.0	A	A	HA
Digitaria insularis (L.) Fedde	2.1	1.6	3.7	1.2	1.6	A	A	HA
Richardia grandiflora (Cham. & Schltdl.) Steud.	0.5	1.6	150	2.2	1.4	A	A	HA
Tridax procumbens L.	1.6	1.1	3.5	1.4	1.4	A	A	HA
Malvastrum coromandelianum Garcke	2.9	0.6	1.0	0.3	1.3	A	A	MA
Cyperus aggregatus (Wild.) Endl.	1.0	0.9	4.5	1.2	1.1	A	A	MA
Digitaria horizontalis Willd.	1.6	0.7	2.3	0.7	1.0	A	A	HA

Relative values of frequency (F), density (D), abundance (A), dominance (Do), and importance value index (IVI); I = variance to mean ratio; Cx = Green coefficient; K = negative binomial distribution; A = aggregated; HA = highly aggregated; MA = moderately aggregated.

E. hirta is another weed species that presented broad distribution. It presents C3 metabolism, seminiferous propagation, and specific leaf morphology. Its leaves present a thick cuticle with presence of trichomes on both surfaces (PINTO et al., 2014), which hinders the penetration and, consequently, the efficiency of herbicides.

E. hirta presents broad phytochemical diversity, with production of secondary metabolites such as flavonoids, alkaloids, resins, tannins, and triterpenoids (PINTO et al., 2014; GHOSH et al., 2019b). This characteristic increases the infestation potential and persistence of the species, since it can release such compounds in the environment and affect the growth and development of nearby plants, which is a phenomenon known as allelopathy; these metabolites have been reported as causal agents of allelopathic interactions (CARVALHO, 2013).

Production of secondary metabolites is also found for *P. niruri*, which is the fourth most important species in the survey in PROP-A. This species is native to Brazil and presents more than 50 components in its metabolism, including flavonoids, alkaloids, and triterpenes (BOIM; HEILBERG; SCHOR, 2010; ROSARIO; ALMEIDA, 2016). The intense production of these substances denotes that the species also has allelopathic effects, depending on the nearby plants.

The predominant plants in PROP-A could interfere with the vines through allelospoly (competition) and allelopathy, and provide a favorable environment for phytopathogenic agents, characterizing the risk of emergence of a third phenomenon: allele-mediation. *C. benghalensis* and *E. hirta* are knowingly alternative hosts for nematode species, especially *Meloidogyne incognita* (BLANCO, 2014; LORENZI, 2008). This pathogen is one of the most important causes of damages to vines and induces the formation of root knots, causing loss of absorption of water and nutrients and making the plants susceptible to attack by other pathogens (SOMAVILLA; GOMES; QUECINE, 2012).

The floristic diversity in PROP-B showed 22 species distributed into 13 families, most from the Poaceae (6), followed by the Asteraceae (3). Species from the families Cyperaceae Commelinaceae, Euphorbiaceae, Molluginaceae, Nyctaginaceae, Portulacaceae, Phyllanthaceae, Solanaceae, Talinaceae, Cucurbitaceae, and Nyctaginaceae were also found in this property.

C. benghalensis was the most important species in PROP-B, with an IVI of 31% (Table 2), similar value to that found for PROP-A, followed by *Bidens pilosa* L. and *Eleusine indica* (L.) Gaertn. These species together presented importance of 56.3%, i.e., more than half of the weed community were formed by these three species (Table 2). These species are important representants of their botanical families. *B. pilosa* and *E. indica* are naturalized, annual plants with similar propagation dynamics and size propagules. They are seminiferous species that produce many small-size seeds per cycle, which favors their infestation due to a high spatial distribution and easy formation of soil seed banks.

Table 2. Relative phytosociological parameters and population distribution level of weeds in areas of viticulture in Petrolina, PE, Brazil (PROP-B).

Species	F	D	A	Do	IVI	Distribution		
	-----------------------	%			---------------------	I	Cx	K
Commelina benghalensis L.	17.3	31.1	9.2	44.9	31.1	A	A	MA
Bidens pilosa L.	8.6	20.9	12.3	13.0	14.2	A	A	HA
Eleusine indica (L.) Gaertn.	8.6	9.8	5.8	14.5	11.0	A	A	HA
Cynodon dactylon (L.) Pers.	3.8	9.5	12.6	7.9	7.1	A	A	HA
Solanum americanum Mill.	4.8	6.8	7.2	8.3	6.6	A	A	HA
Euphorbia hirta L.	9.6	4.6	2.5	2.2	5.5	A	A	HA
Digitaria horizontalis Willd.	7.7	2.8	1.8	2.5	4.3	A	A	HA
Amaranthus deflexus L.	8.6	1.1	0.7	0.7	3.5	A	A	MA
Phyllanthus niruri L.	6.7	2.0	1.5	0.5	3.1	A	A	MA
Echinochloa colona (L.) Link	0.9	5.2	2.9	1.5	2.6	U	U	U
Cyperus sp.	1.9	2.5	6.7	1.5	2.0	A	A	HA
Digitaria insularis (L.) Fedde	1.9	2.0	5.3	1.1	1.7	A	A	R
Talinum fruticosum (L.) Juss.	2.9	0.1	0.2	0.3	1.1	U	U	U

Relative values of frequency (F), density (D), abundance (A), dominance (Do), and importance value index (IVI); I = variance to mean ratio; Cx = Green coefficient; K = negative binomial distribution; A = aggregated; HA = highly aggregated; MA = moderately aggregated; U = Uniform; R = Random.

B. pilosa is the main weed species of the family Asteraceae; a single plant can produce 3 to 6 thousand seeds, which are easily dispersed by wind, animals, and humans. This plant is also known for its allelopathic potential and host of nematodes of the *Meloidogyne* genus (BLANCO, 2014; GUSMAN; YAMAGUSHI; VESTENA, 2011). Thus, it causes losses in vineyards not only because of allelospoly and its higher frequency and importance value, but also by allelopathy and allele-mediation.

PROP-C was the agricultural area of Petrolina with the lowest floristic diversity; 14 species were identified, distributed into 11 families. Poaceae was the family that presented the largest number of species (4). The other families with species found in this area were: Euphorbiaceae, Amaranthaceae, Phyllantaceae, Cyperaceae, Commelinaceae, Portulacaceae, Asteraceae, Molluginaceae, Heliotropiaceae, and Onagraceae. *E. hirta* showed the highest representativeness in the area (Table 3).

Different from the two first areas, PROP-C presented high infestation of *Digitaria sanguinalis* and *Amaranthus deflexus*. These species, together with *E. hirta*, were the predominant weed plants. These three species represented an importance of 60% of the entire weed community, and *E. hirta* presented importance of approximately 30% (Table 3).

Table 3. Relative phytosociological parameters and population distribution level of weeds in areas of viticulture in Petrolina, PE, Brazil (PROP-C).

Species	F	D	A	Do	IVI	Distribution		
	------------------------- % -------------------------					I	Cx	K
Euphorbia hirta L.	26.8	40.7	16.7	21.6	29.7	A	A	HA
Digitaria sanguinalis (L.) Scop.	11.8	15.2	14.1	20.9	16.0	A	A	HA
Amaranthus deflexus L.	18.1	11.9	7.2	13.0	14.3	A	A	HA
Phyllanthus niruri L.	10.2	13.1	14.0	3.6	9.0	A	A	HA
Eleusine indica (L.) Gaertn.	8.7	7.8	9.9	7.7	8.1	A	A	HA
Chloris barbata Sw.	4.7	4.4	10.3	14.2	7.8	A	A	MA
Cyperus sp.	3.1	3.4	11.8	10.4	5.6	A	A	HA
Commelina benghalensis L.	3.9	0.5	1.4	6.8	3.7	A	A	MA
Portulaca oleraceae L.	2.4	1.3	6.2	0.7	1.4	A	A	MA
Emilia sonchifolia (L.) DC.	3.9	0.2	0.6	0.1	1.4	U	U	U
Mollugo verticillata L.	2.4	1.0	4.9	0.0	1.1	A	A	HA

Relative values of frequency (F), density (D), abundance (A), dominance (Do), and importance value index (IVI); I = variance to mean ratio; Cx = Green coefficient; K = negative binomial distribution; A = aggregated; HA = highly aggregated; MA = moderately aggregated; U = Uniform.

D. sanguinalis and *A. deflexus* are herbaceous weeds of annual cycle and C4 photosynthetic metabolism, which are biochemical advantages considering the high photosynthetic efficiency of the two species under high-temperature (> 30 °C) environments. These species have a highly competitive potential and can release allelopathic compounds, which was already proved by their effect on the development of vegetable species, such as lettuce, onion, and carrot. *D. sanguinalis* and *A. deflexus* are important species in grape production systems; species of the genus *Amaranthus* are alternatives hosts for *Xanthomonas campestris* pv. viticola bacterium, which causes the vine bacterial canker; and *D. sanguinalis* hosts the sucking insect *Eurhizococcus brasiliensis*, which is a pest that attacks vines (MOREIRA; BRAGANÇA, 2011; BRIGHENTI; OLIVEIRA, 2015).

The level of species population distribution (IVI ≥ 0.01) showed aggregate or highly aggregate infestation patterns for the properties in Petrolina, with few exceptions (Tables 1, 2, and 3), showing that populations of these species occur in spots, i.e., in specific sites or parcels, which is common for weed communities, according to Monquero, Hirata and Pitelli (2014).

Considering the predominant species in all production areas in Petrolina, a more specific control, considering the botanical characteristics and spatial distribution of populations, may be adequate for weed managements in vineyards in the São Francisco River Valley. The aggregate pattern of the weed populations can be explored in precision agriculture, mainly for the use of herbicides, with applications at variable rates based on maps, according to the needs of each parcel, to avoid excesses applications and to control inefficiency (MONQUERO; HIRATA; PITELLI, 2014; GUNDY; DILLE; ASEBEDO, 2017).

Vineyards in Juazeiro, BA, BRASIL (PROP-D and PROP-E)

PROP-D had 38 weed species distributed into 18 botanical families, most from the families Poaceae (8), Cyperaceae (5), Asteraceae (3), Fabaceae (3), Malvaceae (3), Amaranthaceae (2), Convolvulaceae (2), and Phyllantaceae (2). Only one species was found for the following families: Apocynaceae (*Calotropis procera* (Aiton) W.T. Aiton), Commelinaceae (*C. benghalensis*), Cucurbitaceae (*M. charantia*), Euphorbiaceae (*E. hirta*), Lamiaceae (*Rhaphiodon echinus* Schaer), Molluginaceae (*M. verticillate*), Polygonaceae (*Polygonum convolvulus* L.), Portulacaceae (*Portulaca oleracea* L.), Verbenaceae (*Priva bahiensis* A. DC.), and Zygophyllaceae (*Kallstroemia tribuloides* (Mart.) Steud).

PROP-E had 31 weed species distributed into 12 botanical families, most from the family Poaceae (9), followed by Fabaceae (4) Malvaceae (4), Convolvulaceae (3), Amaranthaceae (2), Asteraceae (2), Cyperaceae (2), Commelinaceae (1), Cucurbitaceae (1), Euphorbiaceae (1), Loganiaceae (1), and Portulacaceae (1). *Spigelia anthelmia* L. (Loganiaceae) was the only species that had not been found in the other properties.

The predominant species in both areas in Juazeiro was *C. benghalensis*, which had the higher IVI. The same species was also predominant in PROP-A and PROP-B in Petrolina, denoting the high infestation potential of the species.

Contrastingly, PROP-D had intense infestation of *C. aggregatus*. Weed species of the *Cyperus* genus were not found in the other properties with such high significance (Table 4).

Table 4. Relative phytosociological parameters and population distribution level of weeds in areas of viticulture in Juazeiro, BA, Brazil (PROP-D).

Species	F	D	A	Do	IVI	Distribution		
	-------------	-------------	%	-------------	-------------	I	Cx	K
Commelina benghalensis L.	20.8	35.5	14.3	48.9	35.1	A	A	HA
Cyperus aggregatus L.	15.0	37.5	20.9	14.2	22.2	A	A	HA
Euphorbia hirta L.	20.8	16.5	6.6	13.8	17.0	A	A	HA
Phyllanthus niruri L.	7.8	2.5	2.7	2.6	4.3	A	A	HA
Chloris barbata (L.) Sw.	5.3	1.9	3.0	5.1	4.1	A	A	HA
Amaranthus deflexus L.	6.2	1.1	1.5	2.2	3.2	A	A	HA
Digitaria sanguinalis (L.) Scop.	4.0	1.2	2.4	1.6	2.3	A	A	HA
Herissantia crispa (L.) Brizicky	2.9	0.2	0.7	1.7	1.6	A	A	HA
Portulaca oleracea L.	2.7	0.6	1.9	1.5	1.6	A	A	HA
Cyperus meyenianus Kunth.	1.3	0.7	4.5	1.1	1.0	A	A	HA

Relative values of frequency (F), density (D), abundance (A), dominance (Do), and importance value index (IVI); I = variance to mean ratio; Cx = Green coefficient; K = negative binomial distribution; A = aggregated; HA = highly aggregated.

Weeds species of the *Cyperus* genus cause losses in several crops due to their high infestation potential. *C. aggregatus* is native to Brazil; it is a perennial plant, with wide adaptability to agricultural and non-agricultural environments and is often found in irrigated fruit production areas (RIBEIRO et al., 2015).

The infestation potential of *C. aggregatus* and other weeds from the *Cyperus* genus is due to their capacity to reproduce sexually and asexually. According to Silveira et al. (2010), tubers of perennial *Cyperus* species are the main dispersion propagules over time; they remain dormant in the soil for long periods, which contributes to the persistence of such propagules. This characteristic hinders the control of the species, especially through mechanical methods, and favors the dissemination of propagules on the area, as found for *C. benghalensis*.

Despite the high quantity of *C. aggregatus* plants, the highest IVI was found for *C. benghalensis* plants. This is due to the high biomass contribution, denoted by the dominance parameter. *C. benghalensis*, *C. aggregatus*, and *E. hirta* represented an importance of almost 75% of total weed community in PROP-D.

PROP-E, besides *C. benghalensis*, had the *Malvastrum coromandelianum* Garcke (Malvaceae) and *A. deflexus* (Amaranthaceae) species as the most importance species (Table 5), representing 52% of the total weed community. Moreover, PROP-E had more intense infestation of *M. coromandelianum* (second most important species), which is a plant native to Brazil, not endemic, that infests annual and perennials crops and had low or no importance in the other properties evaluated.

Regarding the distribution pattern of the weed populations, all the species (IVI ≥ 0.01) surveyed in the properties in Juazeiro presented aggregate or highly aggregate patterns (Table 4 and 5). Therefore, the same weed managements and potentials of precision agriculture described for PROP-A, PROP-B, and PROP-C are valid for PROP-D and PROP-E. Thus, weed management in irrigated vineyards can be done locally, using maps of weed infestations, and with control practices considering the status of each parcel.

Table 5. Relative phytosociological parameters and population distribution level of weeds in areas of viticulture in Juazeiro, BA, Brazil (PROP-E).

Species	D	F	A	Do	IVI	Distribution		
	------------------------ % ----------------------					I	Cx	K
Commelina benghalensis L.	35.2	14.5	10.5	21.8	23.8	A	A	HA
Malvastrum coromandelianum Garcke	13.8	13.3	4.5	17.1	14.7	A	A	HA
Amaranthus deflexus L.	9.0	14.9	2.6	16.9	13.6	A	A	HA
Digitaria sanguinalis (L.) Scop.	8.6	8.3	4.5	5.3	7.4	A	A	HA
Chloris barbata Sw.	5.0	5.8	3.7	6.4	5.7	A	A	HA
Euphorbia hirta L.	2.3	7.5	1.3	3.9	4.6	A	A	HA
Cyperus luzulae (L.) Retz.	5.3	2.5	9.2	2.7	3.5	A	A	HA
Aeschynomene spp.	1.5	5.4	1.2	2.0	3.0	A	A	HA
Indigofera suffruticosa Mill.	2.8	2.9	4.2	2.8	2.9	A	A	HA
Cyperus distans L.	5.1	1.7	13.3	1.1	2.6	A	A	HA
Sida santaremensis Mont.	0.7	1.7	1.8	4.2	2.2	A	A	HA
Herissantia crispa (L.) Brizicky.	0.8	1.7	2.1	3.6	2.0	A	A	HA
Dactyloctenium aegyptium (L.) Willd.	0.7	3.3	0.9	1.7	1.9	A	A	HA
Portulaca oleracea L.	1.5	1.2	5.2	1.2	1.3	A	A	HA
Distimake aegyptius (L.) A.R. Simões & Staples	1.6	1.2	5.7	0.8	1.2	A	A	HA
Conyza bonariensis (L.) Cronquist	1.8	0.8	9.2	0.4	1.0	A	A	HA
Echinochloa colona (L.) Link	0.4	1.7	1.1	0.9	1.0	A	A	HA
Digitaria horizontalis Willd.	0.6	1.2	2.0	1.1	1.0	A	A	HA

Relative values of frequency (F), density (D), abundance (A), dominance (Do), and importance value index (IVI); I = variance to mean ratio; Cx = Green coefficient; K = negative binomial distribution; A = aggregated; HA = highly aggregated.

Joint analysis (Petrolina and Juazeiro areas)

The grouping of the data of the two municipalities in a single phytosociological study totaled a collection of 23,013 plants of 74 species from 26 botanical families (Figure 2): 70% dicotyledons and 30% monocotyledons. The families with larger number of species were: Poaceae (15), Malvaceae (8), Cyperaceae (7), Asteraceae (6), and Fabaceae (5) (Figure 2).

Poaceae is among the most important families for weed sciences due to the large number of species with high dissemination, establishment, and persistence capacities. This is mainly because of their C4 metabolism, which enables high photosynthetic rates (TAIZ et al., 2017).

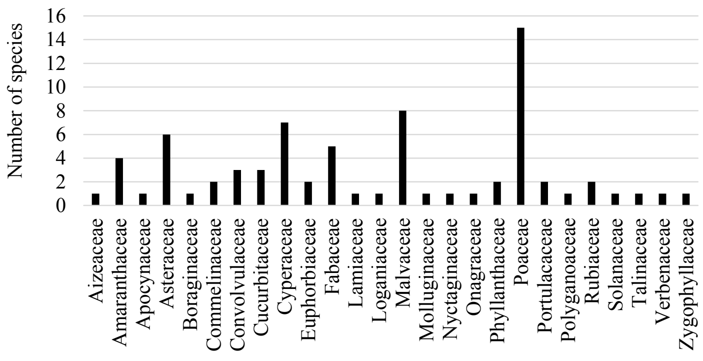

Figure 2. Botanical families and number of weeds species found in vineyards in the municipalities of Petrolina, PE, and Juazeiro, BA, in the Mid-Lower São Francisco River Valley, Brazil.

The floristic diversity was studied based on the Sorensen coefficient, which showed similarities between properties from 21% to 45% (Table 6). Based on Carvalho and Pitelli (1992), these similarities are mainly related to the distance between the areas evaluated, soil characteristics, and the management practices used. It was confirmed that the distance between properties significantly affected the floristic similarity (Table 6 and Figure 3), since the Sorensen coefficient was higher for properties with shorter distances between them (up to 27 km).

This denotes the importance of monitoring and identifying the weed community to adopt more adequate control practices, i.e., based on the biology of the predominant species. Therefore, it should be taken into consideration for weed managements in irrigated orchards in the São Francisco River Valley.

Table 6. Floristic similarity of weed communities in five properties with vineyards in the municipalities of Petrolina, PE, and Juazeiro, BA, in the Mid-Lower São Francisco River Valley, Brazil.

Properties	A	B	C	D	E
A	-	0.45*	0.32	0.44	0.40
B	-	-	0.36	0.28	0.21
C	-	-	-	0.38	0.30
D	-	-	-	-	0.39
E	-	-	-	-	-

*Sorensen coefficient.

Figure 3. Aerial view illustrating the distances between the properties studied in the municipalities of Petrolina, PE, and Juazeiro, BA, in the Mid-Lower São Francisco River Valley, Brazil. Altitude of the viewpoint: 71.41 km. Source: Google Earth, 2019.

The overall analyses of properties showed that *C. benghalensis* was the most important weed species, with higher IVI in four of the five properties evaluated, and IVI of 32.2% in the overall analysis (Table 7). The second and third most important species had IVI of 12.1% (*E. hirta*) and 10.2% (*C. aggregatus*). *T. fruticosum*, *A. deflexus*, and *P. niruri* had secondary importance (Table 7).

Three of the seven species considered in the group with IVI of at least 3% present different dissemination forms, including vegetative, as is the case of *C. benghalensis*, *C. aggregatus*, and *T. fruticosum*.

Table 7. Phytosociological parameters for weeds species in five properties with vineyards in the municipalities of Petrolina, PE, and Juazeiro, BA, in the Mid-Lower São Francisco River Valley, Brazil.

Species	Families	D	F	A	Do	IVI
		------------------- % -------------------				
Commelina benghalensis L.	Commelinaceae	18.33	36.62	5.14	41.75	32.24
Euphorbia hirta L.	Euphorbiaceae	15.17	13.70	2.32	7.52	12.13
Cyperus aggregatus (Wild.) Endl.	Cyperaceae	6.18	18.64	7.76	6.04	10.29
Talinum fruticosum (L.) Juss.	Talinaceae	3.02	4.05	3.45	11.51	6.19
Amaranthus deflexus L.	Amaranthaceae	8.63	2.72	0.81	3.92	5.09
Phyllanthus niruri L.	Phyllantaceae	7.33	3.85	1.35	1.69	4.29
Digitaria sanguinalis (L.) Scopz	Poaceae	5.61	2.71	1.24	3.10	3.80
Chloris barbata Sw.	Poaceae	3.67	1.63	1.14	3.29	2.86
Eleusine indica (L.) Gaertn.	Poaceae	2.88	2.20	1.97	2.13	2.40
Malvastrum coromandelianum Garcke	Malvaceae	3.09	1.10	0.92	2.45	2.21
Bidens pilosa L.	Asteraceae	0.72	2.42	8.67	0.73	1.29
Herissantia crispa (L.) Brizicky	Malvaceae	1.80	0.25	0.36	1.22	1.09
Portulaca oleraceae L.	Portulacaceae	1.73	0.56	0.83	0.96	1.08
Digitaria insularis (L.) Fedde	Poaceae	1.51	0.74	1.27	0.96	1.07

Relative values of frequency (F), density (D), abundance (A), dominance (Do), and importance value index (IVI).

The species that propagate exclusively by seeds (*E. hirta*, *A. deflexus*, *P. niruri*, and *D. sanguinalis*) presented high production capacity of small and easily dispersible (mainly by wind) seeds. *D. sanguinalis*, for example, can produce up to 150 thousand seeds per clump. A large size plant of the *Amaranthus* genus can produce more than 200 thousand seeds per cycle, which can remain viable for up to ten years in the soil (CARVALHO, 2015). Therefore, they form seed banks in agricultural soils. Species with this characteristic usually present phytochrome photoreversibility, an important photomorphogenic phenomenon for these species—the wavelengths in the red-distant range inactivates the phytochrome and inhibits the germinative process. Thus, strategies that promote shading of the soil surface (with high quantity of red-distant wavelengths or absence of light), such as soil cover with plant residues and little soil turning, contribute to maintain the phytochrome inactive form (TAIZ et al., 2017; DAS et al., 2020). Thus, the cultural and physical controls are promising methods.

The sustainability of an agrosystem and the efficiency of weed control practices depend on information, careful monitoring and biological description of species that compose the weed community. Moreover, the weed infestation process is dynamic and dependent on edaphoclimatic, anthropogenic, biological factors intrinsic to each species. The present diagnosis denotes the situation within a time and space; thus, new floristic and phytosociological studies are needed for other microregions to better understand the grape production agrosystems and their relations with weed communities.

CONCLUSIONS

The most important weed species found in vineyards in the São Francisco River Valley were *Commelina benghalensis*, *Euphorbia hirta*, and *Cyperus aggregatus*; this denotes the fragility of the weed managements used in the properties and their effect on the propagation and dissemination of weed species. The predominant aggregate distribution pattern of the weed populations enables localized control practices, which may provide more responsible and balanced use of plant protection products. However, logistic factors and additional costs should be weighted.

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