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ORIGINAL RESEARCH ARTICLE

Phytosociological study of weeds associated with carrot crops in two municipalities of Boyacá

Luís David Córdoba-Patiño[1*], Elberth Hernando Pinzon-Sandoval[2]

[*1] *Ingeniero Agrónomo, Universidad Pedagógica and Tecnológica de Colombia, Colombia. E-mail: luis.cordoba01@uptc.edu.co*

[2] *Fisiología Vegetal, Universidad Pedagógica and Tecnológica de Colombia, Colombia.*

ABSTRACT

With the purpose of knowing the phytosocilogy of weeds associated to a carrot crop (*Daucus carota* L.) under conditions of the municipalities of Ventaquemada and Jenesano-Boyacá, one lot per municipality destined to carrot cultivation was selected and a W-shaped layout was made covering an area of 500 m^2. Relative density, relative frequency, relative dominance and the importance value index (IVI) were calculated, as well as the Alpha and Beta diversity indices for the sampled areas. A total of 6 families and 11 species were counted, of which 63.64% were represented by annual plants and 36.36% by perennial plants. The class Liliopsida (Monocotyledon) was represented by the Poaceae family. The Magnoliopsida class (Dicotyledon) was represented by the following families: Asteraceae, Brassicaceae, Boraginaceae, Leguminosaceae, Polygonaceae, the last one being the one with the highest number of species. The species *R. crispus* and *P. nepalense* were the ones with the highest values of Importance Value Index (IVI) with 0.953 and 0.959, respectively. According to the Shannon-Wiener diversity and Simpson's dominance indices, the evaluated areas presented a low species diversity and a high probability of dominant species. The results obtained can serve as a basis and tool for carrot growers in the evaluated areas to define management plans for the associated weeds and thus optimize yields in this crop.

Keywords: Competition; Diversity; Dominance*; Daucus carota*; *Polygonum nepalense*; *Rumex crispu*

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1. Introduction

Carrot (*Daucus carota* L.), is the most widely cultivated member of the Apiaceae family[1], as well as the main vegetable of the tuberous root group[2,3]. it is a species native to temperate zones, but is cultivated in tropical and subtropical regions[4], it is among the ten most economically important vegetable crops in the world in terms of area and market value[5]. In Colombia, carrot cultivation reached a planted area of 10,933 hectares by 2019, with Boyacá being the second department with the highest production and with a contribution of 29.1% to the total national production, surpassed only by the department of Cundinamarca[6].

In the carrot production system, the appropriate management of interspecific competition is a determining factor in the yield and commercial success of the crop[7]. In horticultural crops, weed control is one of the most difficult and costly tasks[8]. It is indicated that the competitive capacity of the carrot plant is low because emergence and early growth are relatively slow[9].

According to Coelho *et al.*[10], failure to rapidly control weeds in

this crop can cause a yield loss of up to 94%. This is a consequence of the interference caused by weeds[11]. The degree of weed interference in agricultural crops can be defined as the percentage reduction in crop yield caused by coexistence with the weed community[12]. This degree of interference depends on factors related to the crop itself (species or variety, sowing spacing and density), the weed community (specific composition, density and distribution) and the timing and duration of the coexistence period[13].

Knowledge of the structure of a weed community is very important. In order to generate an adequate management program, it is necessary to establish an order of priorities among the species present[12]. This is because there are dominant species, which cause most of the interference, secondary species, present in lower density and coverage, and companion species, whose presence is occasional and which hardly generate economic problems for crops[12].

In an agroecosystem, weeds cause interference to different degrees, depending on their individual characteristics; the different soil and climate conditions in the different agroecological regions influence the floristic composition and the predominance of one weed species over another; additionally, to program practices that lead to adequate weed management in the various crops, it is essential to identify whether the composition of weed communities and their qualitative and quantitative characteristics differ from one agroecological region to another[14].

Carvalho and Guzzo[15] emphasize the importance of knowing the composition of the weed community as a fundamental factor in determining the degree of interference, because the populations that make up the community have a strong relationship with each other, which can be studied using phytosociological indices; among these, the one that best expresses this relationship is the relative importance index[15].

One of the most widely used methods or tools to analyze weed communities present in a crop is the phytosociological study, which allows the analysis of weed communities based on their composition and structure, thus providing a global vision of the composition, structure and distribution of plant species in a given community[16,17]. For this, it is necessary to identify the different species in the community, obtain data on abundance, density, frequency of occurrence, among other quantitative characteristics, through floristic inventories, from which indices are estimated to characterize the vegetation[18].

The objective of this research is to evaluate the weed populations associated with the carrot crop in two municipalities of the department of Boya-Ca, in order to generate technical tools for decision making regarding the weed management scheme for the carrot production system under the study conditions.

2. Materials and methods

2.1 Location

Two plots dedicated to carrot (*Daucus carota* L.) production were selected with an approximate extension of one hectare each, belonging to the municipalities of Ventaquemada located at 2,630 masl, average temperature of 16 °C and coordinates N 5°21'25.0" W 73°32'14.1" and the municipality of Jenesano located at 2,076 masl, average temperature of 18°C and coordinates N 5°24'11.5290" W 73°25'8.0100".

2.2 Methodology

To characterize the associated weed species, samples were taken in each lot selected by municipality, a W-shaped layout was made covering an area of 500 m^2 following the methodology described by Cardenal *et al.*[4]. A pvc frame of 0.25 cm × 0.25 cm was used according to Prates *et al.*[19], in order to take 9 samples per lot with a profundity of 30 cm, once the samples were homogenized they were arranged in 9 aluminum trays of 31 cm long by 25 cm wide and 5 cm deep. They were kept under adequate conditions of water, light and humidity.

The identification of the species began 20 days after the disposition of the samples, once the species began to emerge, the respective identification at the seedling level was carried out. For the recognition and identification of the species, the plant

recognition manuals for cold climate zones were used[20,21]. The experiment had a duration of 100 days, with five weed counts every 20 days, until no more seedling germination was evidenced in the trays.

2.3 Data analysis

The following formula was used to determine the importance value index[22]:

$$IVI = Fr + Dr + dr$$

Being:

$$\text{Relative Frequency (Fr)} = \frac{\text{Absolute frequency by species}}{\text{Total frequency of all species}}$$

$$\text{Relative density (Dr)} = \frac{\text{Absolute density per species}}{\text{Total density of all species}}$$

$$\text{Relative dominance (Dr)} = \frac{\text{Dominance by species}}{\text{full dominance}}$$

Alpha (α) diversity indices were determined:

Index	Equation	Parameters
Simpson Dominance Index (D)	$D = \Sigma\left(\frac{ni}{N}\right)2$	ni = number of individuals of the species *N* = total number of individuals of all species pi = proportional abundance of a given species
Shannon-Wiener Index (H')	$H' = -\Sigma[pi\ (\ln pi)]$	

Beta (β) diversity indices were determined:

Index	Equation	Parameters
Jaccard Index (S_j)	$S_j = j/(a+b+j)$	j = number of species found in the two communities a = number of species found only in a single community b = number of species found only in a single community
Sorensen Index (S_S Index)	$S_S = 2j/(a+b+2j)$	

Calculations of the above indexes and parameters were performed using Microsoft® Office Excel 2013 and Past software version 3.17.

Table 1. Classification of the species associated with the carrot crop in producing lots in the municipalities of Ventaquemada and Jenesano

Class	Family	Species	Common name	Cycle	Ventaquemada	Jenesano
Liliopsida (Monocotyledons)	Poaceae	*Bromus catarthicus* Vahl.	Cebadilla	P	x	x
		Lolium temulentum L.	Tares, Ray grass	A		x
Magnoliopsida (Dicotyledons)	Polygonaceae	*Rumex acetosella* L.	Envy	P	x	
		Rumex crispus L.	Cow tongue	P	x	x
		Polygonum nepalense Meisn.	Wounded heart	A	x	x
	Brassicaceae	*Lepidium bipinnatifidum* Desv.	Mastuerzo	A	x	x
		Raphanus raphanistrum L.	Fodder turnip	A	x	x
	Leguminosaceae	*Trifolium repens* L.	Clover	P	x	x
	Asteraceae	*Senecio vulgaris* L.	Yuyito, Senecio	A	x	x
		Sonchus oleoraceus L.	Sagebrush, Milkweed	A	x	x
	Boraginaceae	*Boreqo officinalis* L.	Borage	A		x

Cycle A: Annual, P: Perennial.

3. Results and discussion

A total of 11 species belonging to 6 families were determined, of which, with respect to their life cycle, 63.64% were represented by annual plants and 36.36.79% by perennial plants (**Table 1**). Gámez *et al.*[22] indicate that the predominance of annual plants over perennials may be the response to the excessive use of chemical control.

The monocotyledon class (Liliopsida) was represented by the Poaceae family, with two species. The dicotyledonous class (Magnoliopsida) was represented by the following families: Asteraceae,

Brassicaceae, Boraginaceae, Leguminosaceae, Polygonaceae, the last one being the one with the highest number of species (**Table 1**).

In the study, the presence of the Poaceae family was found, which is mentioned in different studies [4,17], which corroborates what has been described for this botanical family considered as one of the most numerous, since it is estimated that it occupies 20% of the world's plant surface[22]. According to Bastidas and López[23],report *Polygonum segetum*, *Polygonum nepalense*, *Rumex acetosella*, *Pennisetum clandestinum* as the most frequent species in vegetable production systems. Banda *et al.*[24] indicate that families such as Poaceae, Fumariaceae, Chenopodiaceae, Polygonaceae, Amaranthaceae Malvaceae, group some of the most limiting weed species. In vegetable production systems such as carrots and potatoes in the department of Boyacá, the most frequent weed species belong to the Asteraceae, Polygonaceae and Poaceae families[25].

The population parameters of the 8 weed species associated with carrot cultivation in the municipality of Ventaquemada are presented in **Table 2**. The species *R. crispus* had the highest IVI with 0.953, followed by *P. nepalense* with 0.489 and *R. acetocella* with 0.049%. In terms of frequency of occurrence, the species *R. crispus* obtained 45.3%, followed by *P. nepalense* with 25.7%, the other species presented frequencies of less than 6%.

For the municipality of Jenesano, of the 12 weed species associated with the carrot crop, the species *P. nepalense* had the highest IVI with 0.959, followed by *B. catarthicus* with 0.342 and *L. bipinnatifidum* with 0.175. In terms of frequency of occurrence, the species *P. nepalense* obtained 44.9%; followed by *B. catarthicus* with 18.3% and *L. bipinnatifidum* with 9.8%, the other species presented frequencies lower than 6% (**Table 3**).

Table 2. Population parameters of the weed species found in a lot dedicated to carrot production in the municipality of Ventaquemada.

Species	ni	fr	Dr	dr	IVI
Rumex crispus L.	295	0.453	0.295	0.2053	0.953
Polygonum nepalense Meisn.	167	0.257	0.167	0.0658	0.489
Raphanus raphanistrum L.	19	0.029	0.019	0.0009	0.049
Rumex acetosella L	38	0.058	0.038	0.0034	0.100
Bromus catarthicus Vahl.	23	0.035	0.023	0.0012	0.060
Trifolium repens L.	37	0.057	0.037	0.0032	0.097
Senecio vulgaris L.	37	0.057	0.037	0.0032	0.097
Sonchus oleoraceus L.	35	0.054	0.035	0.0029	0.092
Total number of individuals (N)	651				
Total number of species (S)	8				

Note: ni: Absolute frequency; fr: Relative frequency; Dr: Relative density; dr: Relative dominance; IVI: Importance value index (IVI).

Table 3. Population parameters of the weed species found in a lot destined to carrot production in the municipality of Jenesano.

Species	ni	fr	Dr	dr	IVI
Polygonum nepalense Meisn.	307	0.449	0.202	0.307	0.959
Bromus catarthicus Vahl.	125	0.183	0.033	0.125	0.342
Lolium thermulentum L.	32	0.047	0.002	0.032	0.081
Raphanus raphanistrum L.	28	0.041	0.002	0.028	0.071
Trifolium repens L.	23	0.034	0.001	0.023	0.058
Lepidium bipinnatifidum Donn. Sm.	67	0.098	0.010	0.067	0.175
Senecio vulgaris L.	29	0.042	0.002	0.029	0.073
Sonchus oleoraceus	35	0.051	0.003	0.035	0.089
Rumex acetosella L.	21	0.031	0.001	0.021	0.053
Boreqo officinalis L.	16	0.023	0.001	0.016	0.040
Total number of individuals (N)	683				
Total number of species (S)	10				

Note: ni: Absolute frequency; fr: Relative frequency; Dr: Relative density; dr: Relative dominance; IVI: Importance value index (IVI).

A general analysis of the dynamics of weed species associated with the carrot crop in the area under study shows that, according to the IVI, the most important species are *P. nepalense*, *R. crispus*, *B. catarthicus* and *L. bipinnatifidum*, because these stand out widely against the other species. Thus, the species with the lowest IVI were: *R. raphanistrum* and *B. officinalis.*

According to Plaza and Pedraza[25], the high frequency and population increase of the species *P. nepalense* and *R. crispus*, belonging to the Polygonaceae family, are due to their adaptation to the favorable conditions of the productive systems (continuously disturbed environments and high quantity of available water) favoring the development and production of propagules (generalized distribution).

The floristic composition found is similar to those reported in previous research[4,7], which indicates that the species found are part of the typical composition of weeds associated with soils intended for carrot production; it can be inferred that these weed communities persist and are composed of the same species. According to Poggio[26], indicates that the floristic composition of the weed community is a function of climate, availability of water nutrients, soil type, solar radiation and anthropogenic factors. Cardenal *et al.*[4] indicate that the cultural management that the producer employs in his crops may be the cause of the selection of companion species.

Alpha diversity indices (α) in studies on weed populations measure the amount of diversity within a defined community in an area; within these, the Shannon-Wiener index is based on the proportional abundance of each species and Simpson's index is based on the probability that two individuals in a sample are of the same species[18]. These are frequently used in studies related to weed ecology[27].

It was observed that the areas evaluated in this study differed in their diversity. According to the Shannon-Wiener index, the evaluated areas presented low species diversity with values of 1.44 in Ventaquemada and 1.77 for Jenesano (**Table 4**). According to Moreno[28], values lower than 2 represent a poor diversity in the evaluated community. On the other hand, Simpson's dominance indexes presented values greater than 0.7, which indicates that the evaluated areas have a high probability of having dominant species (**Table 4**).

Table 4. Shannon Wiener diversity index and Simpson dominance index of the weed community associated with the carrot crop in two plots dedicated to carrot production in the municipalities of Ventaquemada and Jenesano, Boyacá

Municipality	Shannon-Wiener Diversity Index	Simpson Dominance Index
Ventaquemada	1.57	0.714
Jenesano	1.77	0.743

In general terms, Simpson's dominance coefficient and the uniformity coefficient indicated that the communities were dominated by few species. These results are possibly related to the weed control practices carried out in this production system, since when a weed community is diverse, it tends to require control treatments that differentially affect the sensitivity of the different species[12].

The Jaccard and Sorensen beta diversity indices facilitate the comparison of areas in terms of weed community composition[29]. According to Booth *et al.*[18] the values should be interpreted on a scale of 0 to 1, where 0 indicates total dissimilarity and 1 indicates absolute similarity. The Jaccard and Sorensen similarity indices showed values of 0.63 and 0.66, respectively. This indicates similarity between the weed communities in the municipalities evaluated (**Table 5**), possibly due to the similarity of cultivation practices between the zones, such as low crop rotation and intensification of sowing. Concenço *et al.*[30] indicate that areas where a crop is grown continuously or without rotation for a long period of time, there will be no disconnection or dissimilarity in the weed communities. Ramírez *et al.*[27] indicate that the Jaccard index varies according to climatic conditions and agronomic management.

Table 5. Jaccard and Sorensen diversity index in the carrot crop in two lots dedicated to carrot production in the municipalities of Ventaquemada and Jenesano, Boyacá

Index	Ventaquemada-Jenesano
Jaccard	0.63
Sorensen	0.66

The results of the present study agree with the results found by Cardenal *et al.*[4], who, when stud-

ying the composition of the weed bank in the carrot production system in the municipality of Villapinzon, found Jaccard indices higher than 0.6, due to the fact that the areas studied share the same production system, the type of vocation and the type of conventional tillage, being similar to those found in the municipalities analyzed in this study.

4. Conclusions

Through the research it was possible to characterize that the community of weeds in plots destined to the production of carrot crops in the municipalities of Ventaquemada and Jenesano is composed of 6 families, the most important being the Polygonaceae family, since the species *P. nepalense* and *R. crispus* were present in the two evaluated zones with the highest IVI values. The diversity indices indicate that the zones may show similarity in relation to climatic conditions and crop management. The results found can serve as a basis and tool for carrot growers in the evaluated zones to define management plans for the associated weeds and thus optimize yields in this crop.

Conflict of interest

The authors declared no conflict of interest.

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