Indian Journal of Agricultural Sciences **89** (1): 105–10, January 2019/Article
https://doi.org/10.56093/ijas.v89i1.86187

Dynamics and distribution of weed species in weed associations

PLAMEN MARINOV-SERAFIMOV[1], IRENA GOLUBINOVA[2] and VILINANA VASILEVA[3]

Institute of Forage Crops, General Vladimir Vazov Street, Pleven 5800, Bulgaria

Received: 19 March 2018; Accepted: 2 October 2018

ABSTRACT

Dynamics of weed density with a natural background of weeds in agrophytocenoses of sainfoin (*Onobrychis sativa* L.), birdsfoot trefoil (*Lotus corniculatus* L.) and alfalfa (*Medicago sativa* L.), pure grown (100%) and in mixtures with cocksfoot (*Dactylis glomerata* L.) (50:50%) and sown under a cover of pea (*Pisum sativum* L.) were tested in field trial in the Institute of Forage Crops, Pleven, Bulgaria. It was found that the weed infestance and species composition changed depending on the type of edificator. The species composition in weed associations was the highest in pure grown *Lotus corniculatus* L. In mixtures of *Onobrychis sativa* L. + *Dactylis glomerata* L. the highest weed infestance was recorded, and the lowest in *Onobrychis sativa* L. under cover of *Pisum sativum* L. Weed infestance in mixtures was lower as compared to pure grown swards, except *Medicago sativa* L. + *Dactylis glomerata* L. For the specific environment of study the highest part for annual dicotyledonous weed species (from 0.0 to 49.5%), followed by perennial dicotyledonous (from 3.7 to 58.2%) was obsereved. There was a strong variation in the percentage in agrophytocenoses of *Convolvulus arvensis* L. (from 0.0 to 11.4%), *Sonchus arvensis* L. (from 0.0 to 19.0%) and *Erigeron canadensis* L. (from 0.0 to 47.8%), whereas *Matricaria recutita* L. varied within narrow range (0.0 to 3.7%). The dependance allows to be used for developing more effective weed control systems in the studied forage crops and mixtures.

Key words: Diversity, Forage crops, Richness, Shannon-Wiener index, Weeds species

Studies on the species composition, ratio, distribution and relationship between species in weed association of agrophytocenoses are extremely limited, despite the fact that every year huge money is spent for the control against them (Liebman and Davis 2000, Hiltbrunner *et al.* 2007, Dimitrova 2010a, b, Meiss *et al.* 2010 Carbonero *et al*. 2011 Hijano *et al*. 2013, Pacanoski *et al.* 2017). Sporadic results have been published to clarify changes in weed density dynamics in different crops, but they refer to a particular type of agrophytocenoses under specific agro meteorological conditions, relevant agro technology and intensity of use (Schoofs and Entz 2000, Derksen 2002, Dimitrova 2005, Saatkamp 2011, Hassannejad and Ghafarbi 2014).

The revelation of the main points in the dynamics of weed associations in some legume forage crops and mixtures is a key element of the theoretical basis for the development of integrated weed control systems defined by the specific environment. Mixed crops between legumes and grasses have an essential role in building a system of sustainable and ecologically friendly farming (Luscher *et al*. 2014). They are more effective than pure grown in using environmental resources, better withstand adverse conditions and are more productive (Porqueddu *et al*. 2003).

[1]e mail: plserafimov@abv.bg, [3]e mail: viliana.vasileva@gmail.com.

The purpose of the study was to determine the species composition, density, distribution and aggregation of weed species in a mixed type of infestance in pure and mixed growing of legume and grass forage crops after intensive use.

MATERIALS AND METHODS

The dynamics of weed density with a natural background of weeds in thirteen agrophytocenoses grown under cover of spring forage pea was tested in field trial in the Institute of Forage Crops, Pleven, Bulgaria (2014-2017). Sainfoin (*Onobrychis sativa* L.) (local population), birdsfoot trefoil (*Lotus corniculatus* L.) (cv. Leo) and alfalfa (*Medicago sativa* L.) (cv. Pleven 6) were sown as a pure swards (100%) and in mixtures with cocksfoot (*Dactylis glomerata* L.) (cv. Dabrava) in ratio 50:50. Long plots method with plot size of 10 m^2 was used and variants were four times replicated (Table 1). Spring forage pea (*Pisum sativum* L.) (cv. Pleven 4) was used as a cover of the swards (both, pure and mixtures). Sowing of the cover crop was done perpendicular to main crops and mixtures by 75% of the recommended sowing rate in first year and harvested for forage. Swards were used 4 years obtaining 7 cuts for forage and 8 cuts from alfalfa swards.

The species composition, weed infestance and density of the edificator (plants/m^2) in the agrophytocenoses studied were determined by the BBCH 65-67 scale in constant plots for every replication in the fourth year of usage (Harker

Table 1 Variants of the experiment

Variants	Species, mixtures	Cover crop
V_1	*Onobrychis sativa* (100%)	Without cover crop
V_2	*Onobrychis sativa* (100%)	With cover crop
V_3	*Onobrychis sativa* + *Dactylis glomerata* (50:50%)	Without cover crop
V_4	*Onobrychis sativa* + *Dactylis glomerata* (50:50%)	With cover crop
V_5	*Dactylis glomerata* (100%)	Without cover crop
V_6	*Dactylis glomerata* (100%)	With cover crop
V_7	*Lotus corniculatus* (100%)	Without cover crop
V_8	*Lotus corniculatus* (100%)	With cover crop
V_9	*Lotus corniculatus* + *Dactylis glomerata* (50:50%)	Without cover crop
V_{10}	*Lotus corniculatus* + *Dactylis glomerata* (50:50%)	With cover crop
V_{11}	*Medicago sativa*	Without cover crop
V_{12}	*Medicago sativa* + *Dactylis glomerata* (50:50%)	Without cover crop
V_{13}	*Medicago sativa* + *Dactylis glomerata* (50:50%)	With cover crop

et al. 2001).

The species diversity in agrophytocenoses depending on the edificator was determined according to Shannon and Weaver by Begon *et al.* (1996).

Species composition (*S*): $S = \sum x_1 + x_2 + ... + x_n$ (1)

where x_1 ... x_n - the number of plant species forming agrophytocenoses;

Shannon diversity index (*H*) $H = \left[\left(\frac{n_i}{N}\right), \log_2\left(\frac{n_i}{N}\right)\right].100$ (2)

where n_i - the number of species of each *i* species, and N - the number of all species (total number) in the particular agrophytocenose;

Shannon-Wiener evenness index (J): $J = \frac{H}{H_{\max}} = \frac{\sum p_i \ln p_i}{\ln N}$ (3)

where p_i – quantitative ratio of the species (weeds and edificator) to the total number of agrophytocenoses, N - total number of species in agrophytocenoses.

Index of interpopulation distribution of species (D) $D = \frac{S-1}{\ln N}$ (4),

where s – species composition, N – total number of species in the agrophytocenoses;

Equality Index (*e*): $e = \frac{H}{\log_2 N}$ (5),

where H - index for individual species diversity, N – total number of species in the agrophytocenoses;

Degree of similarity according to the species composition of weed associations in agrophytocenoses by equation (6):

$$S_i = \left(\frac{2c}{A}\right) \cdot \left(\frac{2c}{B}\right) \quad (6),$$

where A - total number of species in weed association and in agrophytocenoses (weed species + edificator) - first sample compared, B - number of species in weed association and in agrophytocenoses (weed species + edificator), accepted for a second sample compared, c - number of species in weed association and in agrophytocenoses compared.

RESULTS AND DISCUSSION

The species composition, dynamics and distribution of plant species are the result of complex interactions between the components of agrophytocenoses (Lososova *et al.* 2008, Jaskulski and Jaskulska 2012, Jastrzebska *et al.* 2013). The weed infestance and species composition were changed depending on the type of edificator. The species composition (S) in weed communities in agrophytocenoses studied varied in relatively narrow ranges of 2 to 4 weed species, mainly represented by the group of annual dicotyledonous weed species *Capsella bursa-pastoris* Medik, *Erigeron canadensis* L. and *Matricaria recutita* L.; and perennial dicotyledonous *Convolvulus arvensis* L., *Mentha arvensis* L., *Plantago lanceolata* L., *Sonchus arvensis* L. and *Taraxacum officinale* L. An exception was found for pure grown *Lotus corniculatus* L. (var V_7), where species composition (*S*) in weed communities was the highest – numbered 8.0. This dependence can be explained on the one hand with the relatively weaker competitive ability of *Lotus corniculatus* L., and on the other, with the dilution after the intensive use of swards (Dimitrova 2010b).

The weed infestance depends on the type of the edificator and varied widely from 8.0 to 150.0 plants/m^2 (Table 2). The lowest weed infestance (8.0 plants/m^2) was recorded in mixtures of *Onobrychis sativa* + *Dactylis glomerata* and the highest (150.0 plants/m^2) in the variant *Onobrychis sativa* + *Pisum sativum.* The weed infestance of the swards can be ranked in the following ascending order $V_3>V_5>V_{10}>V_9>V_6>V_1>V_{12}>V_{11}>V_8>V_4>V_7>V_{13}>V_2$. Differences in the weed infestance could be explained by the biological and morphological differences in the tested forage crops and mixtures, as well as by the integral impact of biotic and abiotic environmental factors.

The Shannon diversity index (H) of agrophytocenoses varied in relatively narrow ranges from -1.00 to -1.91 and did not change significantly under the influence of the edificator except for the pure growing of *Lotus corniculatus* (variant V_7) H = 2.12 (Table 2). The results obtained with regard to the Shannon-Wiener evenness index (J) were found similar. In agrophytocenoses of *Onobrychis sativa* L. or *Lotus corniculatus* L. Shannon-Wiener evenness index (J) changed in the range from 59.6 to 76.9 and from 58.8 to 79.4, respectively in pure and in mixed swards of *Dactylis glomerata* or *Medicago sativa*.

The Shannon-Wiener evenness index (J) varied in a broad range of 66.1 to 101.6 which also determines the different weed control capability of the edificator for the specific conditions of the study. The index of inter-population distribution of species (D) in agrophytocenoses varied relatively narrowly from 0.356 to 0.493 and did not depend

Table 2 Species composition and weed infestance in agrophytocenoses depending on the edificator, plants/m^2

Weed species	Variants												
	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}
Edificator	70	40	0+50	0+20	84	44	128	64	84+92	12+60	148	28+50	16+52
Annual monocotyledonous		30											
Echinochloa crus-galli		30											
Annual dicotyledonous	40	74		26	3	44	49	50	2	32	50	28	90
Capsella bursa-pastoris	40						12						
Erigeron canadensis		74		26		44	36	50		28	46	28	86
Matricaria recutita					3		1		2	4	4		4
Perennial monocotyledonous		32											
Cynodon dactylon		32											
Perennial dicotyledonous	12	14	8	64	18	4	50	30	38	4	12	30	24
Convolvulus arvensis	12		2	6	12	4	6		14	2		10	
Mentha arvensis							16						
Plantago lanceolata							6		6				
Sonchus arvensis	0	14	6	6			10	10		2	6	10	12
Taraxacum officinale				52	6		12	20	18		6	10	12
Total for weed	52	150	8	90	21	48	99	80	40	36	62	58	114
Total for agrophytocenoses	122	190	58	110	105	92	227	144	216	108	210	136	182
$S_{\text{Total for weed}}$	2	4	2	4	3	2	8	3	4	4	4	4	4
$S_{\text{Total for agrophytocenoses}}$	3	5	3	5	4	3	9	4	6	6	5	6	6
H	-1.14	-2.13	-1.69	-1.91	-1.10	-1.22	-2.12	-1.71	-1.00	-1.28	-1.24	-1.76	-1.68
J	76.9	59.6	101.6	69.9	84.1	83.3	55.8	68.8	72.8	79.4	70.1	68.9	66.1
D	0.416	0.381	0.493	0.425	0.430	0.442	0.356	0.402	0.372	0.427	0.374	0.407	0.384

S – species composition, H - Shannon diversity index, J - Shannon-Wiener evenness index, D - Index of intrapopulation distribution of species in weed associations and agrophytocenoses.

on the type of the edificator.

The values recorded for the Shannon diversity index (H) in weed agrophytocenoses depending on their biological background varied widely from 0.07 to 0.53 for annual and perennial dicotyledonous weed species, whereas the values were relatively constant from -0.50 to -0.51 for annual and perennial monocotyledonous. The low species diversity (H) found in weed communities (from -0.53 to +0.33) also determines low equality index (e) between species (from -0.05 to 0.10) (Table 3).

This can be explained by the increased fragmentation and the resulting distribution of weed species. In natural conditions it was difficult to expect equalized quantitative parameters due to the complementary impact of biotic and abiotic factors, including anthropogenic ones (intensive mowing, applying of fertilizers, etc.) that influence the composition and structure of agrophytocenoses. The results obtained in the experimental works of Storkey and Westbury (2007), Petit *et al.* (2011) and Jastrzębska *et al.* (2013) were analogous.

The increase in total infestance in pure swards compared to mixtures of *Onobrychis sativa* was due to an increase in the density of weeds of *Echinochloa crus-galli* (L.) Beauv., *Erigeron canadensis*, *Cynodon dactylon* (L.) Pers. and *Taraxacum officinale*. In the agrophytocenteses of *Dactylis glomerata* and *Lotus corniculatus*. it was due to the increased density of *Erigeron canadensis* L., and relatively less of *Mentha arvensis* and *Plantago lanceolata*. An exception of the described dependence was found in the swards of *Medicago sativa* L., where the total weed infestance was higher in the mixtures of *Medicago sativa* + *Dactylis glomerata* (114 plants/m^2) as compared to the pure *Medicago sativa* (62 plants/m^2) of weed species. A decrease of the total density of *Medicago sativa* was found, whereas the portion of the *Dactylis glomerata* L. in the agrophytocenoses studied was relatively unchanged (Table 2). This dependence can be explained by the competitive and/or allelopathic effect of mixed growing of *Medicago sativa* and *Dactylis glomerata*. Similar results have been reported by San Emeterio *et al.* (2004), Djurdjević *et al.*

Table 3 Species diversity (H) and equality index (e) in weed community depending on their biological affiliation in agrophytocenoses

		Weed species														
Variants	Coefficients	Edificators	Annual monocotyledonous	*Ehc.crus-galli*	Annual dicotyledonous	*C.bursa-pastoris*	*E. canadensis*	*M. recutita*	Perennial monocotyledonous	*C. dactylon*	Perennial dicotyledonous	*C. arvensis*	*M. arvensis*	*P. lanceolata*	*S. arvensis*	*T. officinale*
V_1	*H*	-0.46			-0.53	-0.53					0.33	0.33				
	e	-0.07			-0.08	-0.08					0.05	0.05				
V_2	*H*	-0.53	-0.50	-0.50	-0.44		-0.44		-0.51	-0.51	-0.36				-0.36	
	e	-0.07			-0.08	-0.08					-0.05	-0.05				
V_3	*H*	-0.53									-0.26	-0.10			-0.21	
	e	-0.09									-0.04	-0.01			-0.03	
V_4	*H*	-0.43			-0.48		-0.48				-0.49	-0.21			-0.21	-0.52
	e	-0.06			-0.07		-0.07				-0.07	-0.03			-0.03	-0.08
V_5	*H*	-0.37			-0.13			-0.13			-0.41	-0.33				-0.21
	e	-0.06			-0.02			-0.02			-0.06	-0.05				-0.03
V_6	*H*	-0.53			-0.53		-0.53				-0.16	-0.16				
	e	-0.08			-0.08		-0.08				-0.02	-0.02				
V_7	*H*	0.07			-0.53		-0.52	-0.06			-0.53	-0.21	-0.38	-0.21	-0.3	
	e	0.01			-0.08		-0.07	-0.01			-0.08	-0.03	-0.06	-0.03	-0.04	-0.05
V_8	*H*	-0.49			-0.53		-0.53				-0.50				-0.3	-0.43
	e	-0.07			-0.08		-0.08				-0.07				-0.04	-0.06
V_9	*H*	0.76			-0.10			-0.10			-0.52	-0.36		-0.21		-0.41
	e	0.1			-0.01			-0.01			-0.08	-0.05		-0.03		-0.06
V_{10}	*H*	-0.45			-0.51		-0.49	-0.16			-0.16	-0.10			-0.10	
	e	-0.07			-0.07		-0.07	-0.02			-0.02	-0.01			-0.01	
V_{11}	*H*	0.34			-0.53		-0.53	-0.16			-0.33				-0.21	-0.21
	e	0.04			-0.08		-0.08	-0.02			-0.05				-0.03	-0.03
V_{12}	*H*	-0.41			-0.49		-0.49				-0.50	-0.30			-0.30	-0.30
	e	-0.06			-0.07		-0.07				-0.07	-0.04			-0.04	-0.04
V_{13}	*H*	-0.47			-0.32		-0.36	-0.16			-0.46				-0.33	-0.33
	e	-0.06			-0.05		-0.05	-0.02			-0.07				-0.05	-0.05

H - Species diversity index, e – equality index

(2006) and Dong *et al.* (2009).

There were no significant differences in the quantity of weed species in agrophytocenoses depending on the type of edificator (Table 4). For the specific environment of study the highest percentage of participation in agrophytocenoses was found for annual dicotyledonous weed species (from 0.0 to 49.5%), followed by perennial dicotyledonous (from 3.7 to 58.2%). The variation in the percentage was found strong in agrophytocenoses of *Convolvulus arvensis* – from 0.0 to 11.4%, *Sonchus arvensis* L. – from 0.0 to 19.0% and *Erigeron canadensis*– from 0.0 to 47.8%, whereas *Matricaria recutita* L. varied within the range 0.0 to 3.7%.

A positive correlation ($r = 0.793$) between the percentage of annual and perennial dicotyledonous weeds and negligible negative correlation dependence between the percentage of edificator and weeds of agrophytocenoses (r ranges from -0.060 to -0.480) was found. Analogous were the results obtained by Hartzler (2000) and Korolova *et al.* (2006).

For the specific conditions the degree of similarity (Si) in the studied agrophytocenteses was relatively close to both, the type of the edificator (from 8.021 to 9.158) (Table 5) and the species composition of the weed associations (from 8.013 to 9.760) (Table 6). An exception to the described dependence was found in weed associations formed on *Onobrychis sativa*, where Si values were relatively higher and ranged from 10.463 to 17.308. Probably the reason for this was the relatively smaller number of weed species (S) forming the weed community in agrophytocenoses.

The analysis of the obtained results showed that the species composition (S), the Shannon diversity index

Table 4 Percentage of the total quantity of the species in agrophytocenoses depending on the edificator

Weed species	Variants												
	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}
Edificator	57.4	21.1	86.2	18.2	80.0	47.9	56.4	44.5	81.5	66.7	70.5	57.3	37.3
Annual monocotyledonous		15.8											
Echinochloa crus-galli		15.8											
Annual dicotyledonous	32.8	38.9		23.6	2.9	47.8	21.6	34.7	0.9	29.6	23.8	20.6	49.5
Capsella bursa-pastoris	32.8						5.3						
Erigeron canadensis		38.9		23.6	0.0	47.8	15.9	34.7		25.9	21.9	20.6	47.3
Matricaria recutita					2.9		0.4		0.9	3.7	1.9		2.2
Perennial monocotyledonous		16.8											
Cynodon dactylon		16.8											
Perennial dicotyledonous	9.8	7.4	13.8	58.2	17.1	4.3	22	20.8	17.6	3.7	5.7	22.1	13.2
Convolvulus arvensis	9.8		3.4	5.5	11.4	4.3	2.6	0.0	6.5	1.9	0.0	7.4	
Mentha arvensis													
Plantago lanceolata													
Sonchus arvensis		7.4	10.3	5.5			4.4	6.9		1.9	2.9	7.4	6.6
Taraxacum officinale				47.3	5.7		5.3	13.9	8.3	0.0	2.9	7.4	6.6

Table 5 Degree of similarity (S_i) in agrophytocenoses depending on the edificator

Variants	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}
V_1	-												
V_2	8.399												
V_3	9.158	9.158											
V_4	8.021	8.021	8.021										
V_5	8.045	8.045	8.045	8.045									
V_6	8.160	8.160	8.160	8.160	8.160								
V_7	8.796	8.796	8.796	8.796	8.796	8.796							
V_8	8.055	8.055	8.055	8.055	8.055	8.055	8.055						
V_9	8.671	8.671	8.671	8.671	8.671	8.671	8.671	8.671					
V_{10}	8.030	8.030	8.030	8.030	8.030	8.030	8.030	8.030	8.030				
V_{11}	8.605	8.605	8.605	8.605	8.605	8.605	8.605	8.605	8.605	8.605			
V_{12}	8.024	8.024	8.024	8.024	8.024	8.024	8.024	8.024	8.024	8.024	8.024		
V_{13}	8.324	8.324	8.324	8.324	8.324	8.324	8.324	8.324	8.324	8.324	8.324	8.324	-

Table 6 Degree of similarity (S_i) in agrophytocenoses depending on the weed infestance

Variants	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}
V_1	-												
V_2	10.463												
V_3	17.308	17.308											
V_4	8.617	8.617	8.617										
V_5	9.760	9.760	9.760	9.760									
V_6	8.013	8.013	8.013	8.013	8.013								
V_7	8.858	8.858	8.858	8.858	8.858	8.858							
V_8	8.377	8.377	8.377	8.377	8.377	8.377	8.377						

(*Contd.*)

Table 6 (*Concluded*)

Variants	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}
V_9	8.138	8.138	8.138	8.138	8.138	8.138	8.138	8.138					
V_{10}	8.274	8.274	8.274	8.274	8.274	8.274	8.274	8.274	8.274				
V_{11}	8.062	8.062	8.062	8.062	8.062	8.062	8.062	8.062	8.062	8.062			
V_{12}	8.024	8.024	8.024	8.024	8.024	8.024	8.024	8.024	8.024	8.024	8.024		
V_{13}	9.297	9.297	9.297	9.297	9.297	9.297	9.297	9.297	9.297	9.297	9.297	9.297	-

(H), the Shannon-Wiener evenness index (J) and species diversity (e) in the weed communities of the different agrophytocenoses varied according to the edificator. This allows these indicators to be determined experimentally in a shorter term and to be used to develop more effective weed control systems in the crop species studied, both pure and in mixtures and mixtures studied.

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