WEED INFESTATION DYNAMICS INFLUENCED BY SOME ALLELOPATHIC SPECIES IN CLIMBING BEAN (*PHASEOLUS VULGARIS*) CROP

DINAMICA ÎMBURUIENĂRII SUB INFLUENȚA UNOR SPECII ALELOPATICE ÎN CULTURA DE FASOLE URCĂTOARE (*PHASEOLUS VULGARIS*)

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Abstract.
The aim of this study was to evaluate the effect of eight allelopathic plant species on weed infestation in "Auria Bacăului" climbing bean (Phaseolus vulgaris) crop. The biological material included plant species with allelopathic potential: yellow mustard (Sinapis alba), sainfoin (Onobrychis viciifolia), oil radish (Raphanus sativus var. oleiformis), barley (Hordeum vulgare), two-row barley (Hordeum distichon), oats (Avena sativa), red clover (Trifolium pratense) and white clover (Trifolium repens). The experimental design involved a single factor represented by mixtures of these allelopathic species, which were sown simultaneously with climbing bean in an intercropping system. The weed species identified in the field included red-root amaranth (Amaranthus retroflexus), guasca (Galinsoga parviflora), flower-of-an-hour (Hibiscus trionum), pale knotweed (Persicaria lapatifolia), groundsel (Senecio vulgaris), purslane (Portulaca oleracea), field bindweed (Convolvulus arvensis), Canada thistle (Cirsium arvense), hairy crabgrass (Digitaria sanguinalis), and cockspur (Echinochloa crus-galli). The results showed that weed infestation was significantly reduced by intercropping of climbing bean with allelopathic species, highlighting the potential of this practice in sustainable weed management.

Key words: intercropping system, weed management, secondary metabolites

Rezumat.
Scopul acestui studiu a fost de a evalua efectul a opt specii de plante cu potențial alelopatic asupra nivelului de îmburuienare în cultura de fasole *urcătoare „Auria Bacăului" (Phaseolus vulgaris). Materialul biologic a inclus specii de plante cu potențial alelopatic: muștar alb (Sinapis alba),*

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sparceta (Onobrychis viciifolia), ridiche furajeră (Raphanus sativus var. oleiformis), orz (Hordeum vulgare), orzoaică (Hordeum distichon), ovăz (Avena sativa), trifoi roșu (Trifolium pratense) și trifoi alb (Trifolium repens). A fost studiat un singur factor experimental. Acesta a fost reprezentat de mixurile de specii cu propietății alelopatice semănate simultan, în sistem intercropping, cu fasolea urcătoare. Speciile de buruieni identificate în cultura de fasole au fost: știrul (Amaranthus retroflexus), busuiocul dracului (Galinsoga parviflora), zămoșița (Hibiscus trionum), iarba roşie (Persicaria lapatifolia), cruciulița (Senecio vulgaris), iarba grasă (Portulaca oleracea), volbura (Convolvulus arvensis), pălămida (Cirsium arvense), meișorul roșu (Digitaria sanguinalis) și mohorul lat (Echinochloa crus-galli). Rezultatele au arătat că nivelul de îmburuienare a fost redus semnificativ de intercropping-ul dintre fasolea urcătoare și speciile alelopatice, subliniind potențialul acestei practici în controlul buruienilor.

Cuvinte cheie: culturi intercalate, controlul buruienilor, metaboliți secundari

INTRODUCTION

The term "allelopathy," introduced by Molisch in 1937, refers to the direct and indirect effects of biochemical substances released by one plant that impact another. Molisch's concept of "reciprocal perception" suggests plants interact both positively and negatively. In 1996, the International Allelopathy Society expanded the definition to include secondary metabolites from plants, viruses, microorganisms, and fungi that influence growth and development in biological and agricultural systems [Cheng and Cheng, 2015]. Allelochemicals, non-nutritive compounds produced by plants or microbial decomposition, usually act in mixtures under field conditions [Scavo and Mauromicale, 2021].

Reigosa et al. [1999] noted that environmental fluctuations, especially under abiotic and biotic stress, significantly impact plants' allelopathic potential. Stressors like drought, light intensity, temperature, nutrients, salinity, weeds, plant density, and pathogens can increase allelochemical production [Xuan et al., 2016; Scavo and Mauromicale, 2021]. Allelopathic crops are increasingly used for weed management in practices like intercropping, crop rotation, cover crops, green manure, and allelopathic extracts [Silva et al., 2014; Haider et al., 2015; Jabran et al., 2015]. These methods can be used alone or integrated into a broader weed management strategy [Scavo and Mauromicale, 2020].

The utilization of allelopathy for weed management is highly adaptable, differing from location to location, based on the unique attributes of each context, such as weed species present, soil and climate conditions, economic limitations, agricultural practices employed, and the goals of the farmer (Scavo and Mauromicale, 2020). Numerous allelopathic crops have been utilized in agricultural production [Calara *et al*., 2021]; however, their use has largely been restricted to small-scale and localized regions [Cheng and Cheng, 2015].

For many years, in agroecosystems, weed management has relied almost exclusively on mechanical methods and chemical herbicides. However, modern agriculture is now encountering several adverse effects stemming from the excessive use of tillage and synthetic herbicides, including accelerated soil erosion, degradation of soil structure, shifts in weed species composition, the proliferation of herbicide-resistant weeds, and herbicide residues persisting in crops [Scavo and Mauromicale, 2021]. Many of these issues can be mitigated by diversifying weed control strategies through the incorporation of allelopathic approaches. Employing a combination of multiple weed management techniques has been shown to effectively reduce the likelihood of weeds, developing resistance to herbicides [Cheng and Cheng, 2015].

Sustainable weed management is essential to securing food availability for future generations [Farooq *et al*., 2020]. Among the low-input, eco-friendly approaches available for weed control, the strategic use of allelopathic mechanisms is particularly significant [Scavo and Mauromicale, 2021]. Allelopathy can be utilized across various cropping systems, but it is especially advantageous in organic farming and in conservation, minimum, and no-tillage agricultural practices, where managing weeds frequently presents challenges [Munteanu and Stoleru, 2012; Scavo and Mauromicale, 2021].

The aim of this study was to evaluate the effects of various allelopathic species on weed management in climbing bean cultivation under organic farming conditions: yellow mustard (*Sinapis alba*), sainfoin (*Onobrychis viciifolia*), oil radish (*Raphanus sativus* var. *oleiformis*), barley (*Hordeum vulgare*), two-row barley (*Hordeum distichon*) oats (*Avena sativa*), red clover (*Trifolium pratense*) and white clover (*Trifolium repens).*

MATERIAL AND METHOD

The study took place at the Vegetable Research and Development Station Bacău in Moldavia during the 2024 growing season, focusing on climbing bean (Phaseolus vulgaris) cultivation under organic farming conditions. The "Auria Bacăului" climbing bean cultivar was used, and seeds were sown alongside allelopathic species at a 30 cm spacing. Allelopathic species included yellow mustard, sainfoin, oil radish, oats, two-rowed barley, barley, white clover, and red clover. A randomized block design with three replications was used, with five experimental variants, including a Control.

Table 1

Variants used in the study

Variants	Species with allelopathic properties
V1	- red clover*;*
V2	- white clover, red clover, sainfoin;
V3	- red clover, oil radish, yellow mustard;
V4	- red clover, oats, sainfoin, two-rowed barley, barley;
VM	- soil tillage (the control).

Mowing was carried out twice using a garden strimmer. The control variant was tillaged once mechanically and two times manually.

Weed presence was assessed using a metric frame to measure fresh biomass and density per square meter, with species identified based on a weed descriptor [Gurău, 2007]. Infestation was evaluated at two points: A - before the first tillage/mowing, B - before the second. Competitive and allelopathic effects were quantified using the formula: Overall weed biomass reduction (%) = 1 - (Weed biomass with allelopathic species / Weed biomass without allelopathic species) * 100. The constancy (K%) of each species was calculated as the percentage of repetitions/variants in which the species was present. [Magurran, 2004].

K = (pi / P) * 100

Where:pi = the number of repetitions/variants in which the species was present,

P = the total number of repetitions/variants

Chlorophyll and anthocyanin levels were measured using the OPTI-SCIENCES Chlorophyll and Anthocyanin Content Meters. Leaf samples were randomly collected from three plants per replicate. Total soluble solids concentration was measured with a handheld refractometer on juice from fresh pods, with results expressed in °Brix, following the 932.12 methodology [AOAC, 2005; Brezeanu *et al*., 2022].

At harvest, the total seed yield (kg/ha) and seed yield per plant (g), root length (mm), and root weight (g) and stem diameter (mm) were measured.

Statistical analysis were conducted using ANOVA. Mean comparisons were performed using Tukey's HSD test at a significance level of P < 0.05, utilizing IBM SPSS Statistics 20.

RESULTS AND DISCUSSIONS

The weeds encountered in the experiment belong to the following botanical families: *Asteraceae, Amaranthaceae, Convolvulaceae, Poaceae, Malvaceae, Portulacaceae,* and *Polygonaceae* (Table 2).

Table 2

Constancy of weed appearance (%): A- before the first tillage/mowing, B- before the second tillage/mowing

Classification	**Species**	**Constancy of weed appearance (%)**	
		A	**B**
Annual dicotyledons	red-root amaranth (*Amaranthus retroflexus*)	80	80
	gallant soldier (*Galinsoga parviflora*)	0	80
	flower-of-an-hour (*Hibiscus trionum*)	0	20
	pale knotweed (*Persicaria lapatifolia*)	40	0

	groundsel (*Senecio vulgaris*)	100	0
	purslane (*Portulaca oleracea*),	0	20
Perennial dicotyledons	creeping thistle (*Cirsium arvense*)	80	0
	field bindweed (*Convolvulus arvensis*)	60	40
Annual monocotyledons	cockspur (*Echinochloa crus – galli*)	100	100
	hairy crabgrass (*Digitaria sanguinalis*),	0	100

Observations showed cockspur and red-root amaranth had the highest constancy, while purslane and lower-of-an-hour had the lowest. Table 3 presents the weed species density in climbing bean crops, with cockspur, hairy crabgrass, red-root amaranth, and gallant soldier having the highest plant counts. The control variant had more weeds, like cockspur with 223.3 weeds per m², indicating higher infestation without allelopathic species.

Table 3

Number of weeds per m^2: A- before the first tillage/mowing, B- before the second tillage/mowing

Species	**Number of weeds per m^2**									
	V1		**V2**		**V3**		**V4**		**VM**	
	A	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Red-root amaranth	16.7 ± 15.1	4.3 ± 0.5	3 ± 1	1.7 ± 0.6			1 ± 0	1 ± 0	4 ± 1	1.3 ± 0.6
Creeping thistle	1 ± 0		1.3 ± 0.6		1 ± 0				3 ± 1	
Field bindweed			2 ± 1.7			1 ± 0	1.3 ± 0.6		4.3 ± 1.5	1.7± 0.6
Hairy crabgrass		7.3 ± 2.3		5.7 ± 1.5		1.3 ± 0.6		11.7 ± 5.5		5.7 ± 1.5
Cockspur	54 ± 9.6	13 ± 3	22 ± 12.1	14.7 ± 1.5	3.3 ± 1.5	2 ± 1	5.7 ± 1.2	4 ± 1	223.3 ± 20.8	9 ± 1
Gallant soldier		3.33 ± 2.1		5.7 ± 1.5				4.3 ± 3.1		2 ± 1
Flower-of-an-hour										1 ± 0
Pale knotweed	10.3 ± 13.7		1.7 ± 0.6							
Purslane										2.3 ± 0.6

Groundsel	5 ± 3.6		1.7 ± 0.6		1 ± 0		1.7 ± 0.6		1±0	

Red-root amaranth initially shows high numbers with allelopathic species but decreases over time, eventually being better controlled than the control. Hairy crabgrass and field bindweed are less affected, with their numbers remaining the same or increasing. This indicates that intercropping with allelopathic species is effective for controlling some weeds, like cockspur and red-root amaranth, but varies by species.

Table 4 presents the statistical interpretation of weed biomass within the bean crop. The species with the highest biomass are also represented by: cockspur, hairy crabgrass, red-root amaranth and gallant soldier.

Table 4

Fresh weed biomass g/m^2: A- before the first tillage/mowing, B- before the second tillage/mowing

Species	**Fresh weed biomass g/m^2**									
	V1		**V2**		**V3**		**V4**		**VM**	
	A	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Red-root amaranth	16.3 ± 12.1	83.3 ± 15.3	6 ± 1	32.7 ± 11.0			2.0 ± 0.0	23.3 ± 5.8	6.7 ± 2.1	52.7 ± 14.2
Creeping thistle	3 ± 1.7		4 ± 1.7		3.3 ± 2.3				8.0 ± 2.0	
Field bindweed			4.3 ± 3.2			25.0 ± 0.0	3.0 ± 1.7		25.0 ± 5.0	80.0 ± 36.1
Hairy crabgrass		69.7 ± 21.2		37.3 ± 11.2		26.7 ± 2.9		257.0 ± 262.5		180.3 ± 17.9
Cockspur	50 ± 13.2	923.3 ± 92.9	11 ± 3.6	900.3 ± 44.5	6.3 ± 0.6	9.0 ± 3.6	7.3 ± 2.3	95.0 ± 18.0	103.3 ± 15.3	1263.3 ± 25.2
Gallant soldier		31 ± 18.5		71.7 ± 10.4				33.3 ± 25.7		23.3 ± 12.6
Flower-of-an-hour										5.3 ± 0.6
Pale knotweed	4 ± 2.6		2.3 ± 0.6							
Purslane										72.3 ± 19.7
Groundsel	4.3± 2.1		3 ± 1		1.7 ± 0.6		4.3 ± 2.5		2.0 ± 0.0	

Table 5 presents the statistical interpretation of the height of weeds in the climbing bean crop. In this case as well, cockspur is the species that recorded the highest values. Red-root amaranth and cockspur show noticeable reductions in height in the variants with allelopathic species compared to the control, suggesting effective growth suppression. Field bindweed also shows a significant reduction in height, almost half the size in variants with allelopathic species, compared to the control.

Table 5

Height of weeds (cm): A- before the first tillage/mowing, B- before the second tillage/mowing

Species	Height of weeds (cm)									
	V1		V2		V3		V4		VM	
	A	B	A	B	A	B	A	B	A	B
Red-root amaranth	6.0 ± 0.0	42.3± 4.0	5.7 ± 0.6	31.0 ± 1.7			5.0± 0.0	25.0 ± 5.0	7.3 ± 0.6	50.0 ± 0.0
Creeping thistle	5.3 ± 1.2		6.7 ± 2.9		5.3± 2.3				6.0± 0.0	
Field bindweed			9.3 ± 1.2			32.7 ± 4.6	5.3± 0.6		17.7 ± 2.5	51.7 ± 7.6
Hairy crabgrass		33.7± 4.0		41.7 ± 2.9		36.3 ± 15.5		43.7 ± 3.2		55.0 ± 5.0
Cockspur	11.3 ± 1.2	55.0± 5.0	11.7 ± 1.5	57.3 ± 2.5	7.3± 0.6	26.7 ± 2.9	7.3± 0.6	44.7 ±13.6	15.3 ± 0.6	66.7 ± 2.9
Gallant soldier		25.7± 1.2		33.7 ± 1.5				31.0 ±1.7		41.7 ± 2.9
Flower-of-an-hour										21.7 ± 2.9
Pale knotweed	4.3 ± 0.6		4.7± 0.6							
Purslane										25.0 ± 0.0
Groundsel	5.0 ±0.0		4.3 ±0.6		4.3± 0.6		6.3± 3.2		4.3 ± 0.6	

For hairy crabgrass and creeping thistle, the allelopathic species has little to no effect on reducing height, as their measurements remain similar between the variants and control. Gallant soldier experiences a moderate reduction in height in the variant with allelopathic species.

In Table 6, the phenophases of weeds in climbing bean crop are presented. The encountered weeds exhibited various developmental stages, ranging from plants with only a leaf rosette to those bearing fruits or seeds. Gallant soldier experiences a moderate reduction in height with the allelopathic treatment.

Table 6

The phenophases of weeds in climbing bean crop

Species	Phenophases									
	V1		V2		V3		V4		VM	
	A	B	A	B	A	B	A	B	A	B
Red-root amaranth	1	4	1	4			1	4	1	4
Creeping thistle	1		1		1				1	
Field bindweed			1			1	1		1	1
Hairy crabgrass		4		4		4		4		4
Cockspur	1	4	1	4	1	3	1	4	1	4
Gallant soldier		3		3				3		3
Flower-of-an-hour										3
Pale knotweed	1		1							
Purslane										1
Groundsel	1		1		1		1		1	

Phenophases: 1 – plants with only a leaf rosette or those that exhibit stems and leaves; 2 – plants with floral buds or grasses in the booting stage; 3 – flowering plants; 4 – plants with fruits; 5 – plants that have undergone seed dispersal.

It was observed that the weed biomass was reduced across all treatments. The average value for the percentage reduction in weed biomass fluctuated between 33.9% and 96.4%, with the highest value recorded for treatment V3, prior to the second tillage/mowing (Figue 1)

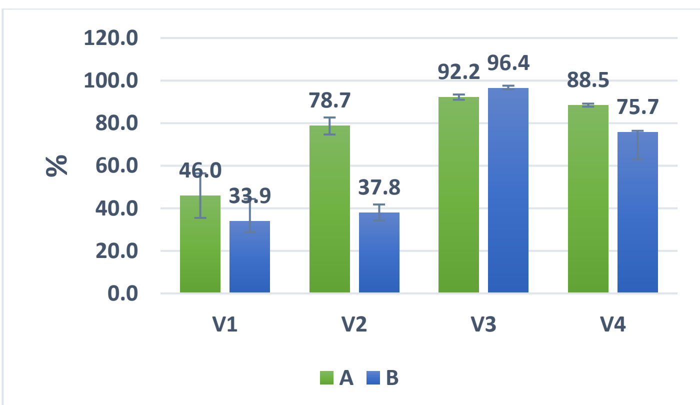

Fig. 1. Overall weed biomass reduction (%): A- before the first tillage/mowing, B- before the second tillage/mowing

Variant 3 demonstrated the most prolonged weed suppression, maintaining the field free of weeds for an extended duration, compared to the other variants.

The results of the ANOVA did not reveal any significant differences between the experimental variants concerning total seed production (Figure 2). The seed yields across the different variants ranged between 592.8 kg/ha and 664.8 kg/ha, with the lowest value recorded in the control variant. Despite these numerical variations, the differences were not statistically significant.

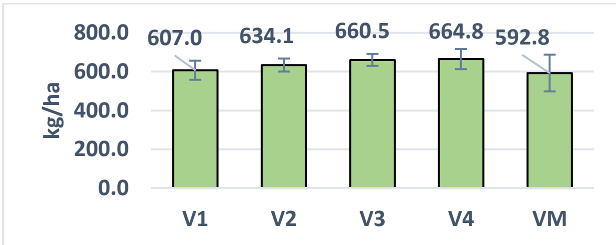

Fig. 2. Seed yield (kg/ha) at climbing bean

It is important to note that the observed seed production was considerably lower than the average yield of the cultivar, a result likely attributed to the specific climatic conditions experienced during the growing season.

Similar to the results observed for seed production (Figure 3), no significant differences were found between the experimental variants regarding the number of pods per hill. The number of pods per hill ranged from 16.8 in the control variant to 18.6 in the V3 variant.

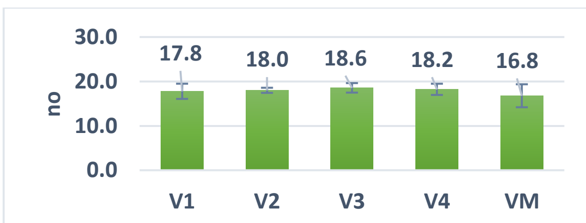

Fig. 3. Number of pods per hill

No significant differences were observed between the treatments in terms of the Chlorophyll Content Index (CCI), Anthocyanin Content Index (ACI), Total Soluble Solids (TSS), or root weight (g) in the bean crop. However, significant differences were observed in stem diameter (mm) and root length (mm).

Table 6

Results of Biometric Measurements and Quality Indicators within the bean crop

Variant	Chlorophyll content index (CCI)	Anthocyanin content index (ACI)	Total soluble solids (TSS) (Brix)	Stem diameter (mm)	Root length (mm)	Root weight (g)
V1	13.3 ± 1.1	5.7 ± 0.7	6.3 ± 0.7	8.9 ± 1.1 bc	143.7 ± 22.3 a	8.1 ± 1.4

V2	11.7 ± 1.7	5.6 ± 0.3	6.8 ± 0.3	11.6 ± 1.5 ab	102.1 ± 6.5 ab	12.9 ± 6.2
V3	14.2 ± 1.8	5.3 ± 0.3	6.2 ± 0.8	8.6 ± 2.0 bc	104.2 ± 4.3 ab	7.7 ± 1.8
V4	14.5 ± 1.3	5.8 ± 0.6	6.5 ± 0.6	13.7 ± 2.1 a	95.6 ± 15.5 b	14.6 ± 2.4
VM	13.6 ± 0.5	5.4 ± 0.3	6.3 ± 0.2	6.4 ± 0.9 c	81.8 ± 30.6 b	6.2 ± 2.9
	ns	ns	ns	*	*	ns

The results are presented as means ± SD. Distinct letters indicate significant differences between the groups, as determined by the Tukey post-hoc test ($P < 0.05$): a–the highest value for the test performed, *–significant differences; ns- non-significant.

Specifically, the treatments with allelopathic species resulted in significantly increased stem diameter and root length compared to the control.

The lack of significant differences in biochemical markers like CCI, ACI, and TSS suggests that the allelopathic species did not cause any measurable stress or alterations in the metabolic functions associated with these quality indicators. This could imply that the allelopathic species did not interfere with the beans' photosynthetic activity, but instead acted primarily on the physical aspects of growth, such as root and stem development.

CONCLUSIONS

The level of weed infestation was significantly reduced by intercropping climbing beans with yellow mustard, oil radish, red clover, and climbing beans with barley, oat, two-row barley and red clover. It was noted that the weed biomass was reduced in all variants.

These findings suggest that the allelopathic species may have had a positive influence on the overall growth environment of the beans, particularly by improving root architecture.

The present study did not observe significant differences in the total climbing bean seed production between the variants.

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