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ASSESSING THE ALLELOPATHIC POTENTIAL OF VARIOUS SPECIES FOR WEED CONTROL IN ORGANIC FARMING ON A CLIMBING BEAN CROP

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Abstract

The aim of the research was to assess the allelopathic potential of certain species for weed control in climbing bean crop. Field trials were carried out to examine the allelopathic impacts of the following allelopathic species: white clover (Trifolium repens), red clover (Trifolium pratense), sainfoin (Onobrychis viciifolia), oil radish (Raphanus sativus var. oleiformis), yellow mustard (Sinapis alba), oats (Avena sativa), barley (Hordeum vulgare), two-rowed barley (Hordeum distichon) and Japanese grass (Lolium perene, Festuca rubra and Poa pratensis). These species were sown with "Auria Bacăului" climbing bean (Phaseolus vulgaris) on intercropping system. It has been observed that main weed species identified in climbing bean crop were: red-root amaranth (Amaranthus retroflexus), cockspur (Echinochloa crus-galli), Canada thistle (Cirsium arvense), perennial sow thistle (Sonchus arvensis), pale knotweed (Persicaria lapathifolia), groundsel (Senecio vulgaris), bindweed (Convolvulus arvensis), guasca (Galinsoga parviflora), flower-of-an-hour (Hibiscus trionum) and petty spurge (Euphorbia peplus). In conclusion, intercropping beans with allelopathic species such as red clover, yellow mustard, and oil radish, along with red clover, oats, sainfoin, two-rowed barley and barley, resulted in a substantial diminishment in weed infestation.

Key words*: ecological agriculture, biological phenomenon, weed infestation, intercropping system.*

INTRODUCTION

The impacts of regional and global climate shifts are becoming evident across different aspects of life on our planet. However, the repercussions on agriculture and food supply stand out as potentially among the most significant threats to sustaining life (Malhi et al., 2021). Assessment of the effects of global climate change factors on agriculture and farming practices is important to anticipate and adapt practices that maximize agricultural production in future climate scenarios. To attain sustainable crop production in unpredictable environments, a comprehensive strategy is essential. This strategy should not only aim to boost crop productivity but also to prioritize the effective management of agricultural pests like weeds (Varanasi et al., 2016). Weeds, given their intricate nature, exert significant adverse effects on agriculture, forestry, rangelands, public health, and various human activities. In contrast to sporadic and irregular outbreaks of pests and diseases, weeds present a constant challenge, causing severe issues in crop production (Kostov and Pacanoski, 2007). Despite widespread herbicide usage, crop production continues to suffer losses due to weed-related issues.

Abiotic factors such as atmospheric CO2 levels, temperature variations and the availability of water or nutrients play a crucial role in influencing the physiology and growth of weeds. Weeds exhibit rapid responses to changes in resources and possess a higher capacity for adaptation and proliferation in diverse habitats, primarily due to their extensive genetic diversity and physiological adaptability compared to crops. As climate change introduces new constraints on resources vital for plant growth, the dynamics of interactions between crops and weeds, as well

as crop losses attributed to weeds, are likely to be influenced accordingly (Valerio et al., 2013).
Effectively tackling both cost and ecological considerations involves implementing diverse weed management strategies. One notable innovative approach to weed control involves utilizing the allelopathic phenomenon, as highlighted by studies such as Jabran and Farooq (2012) and Zeng (2014). In specific cropping systems, such as organic farming, allelopathic weed control may serve as a standalone strategy. Additionally, it can be integrated with other methods to establish a comprehensive approach known as integrated weed management, as discussed by Jabran et al. (2015).
Therefore, the combination of allelopathy and competition emerges as a promising environmentally friendly tool, particularly for weed management. However, a comprehensive understanding of this phenomenon is essential for its successful application, given the currently limited available knowledge. The judicious utilization of allelopathic crops in agriculture holds the potential to diminish pesticide usage, consequently reducing environmental and food pollution. This approach also has the potential to lower costs in agriculture, enhance food security in impoverished regions, improve soil productivity and contribute to increased biodiversity and sustainability within the agro-ecosystem (Farooq et al., 2020).
Controlling weeds in organic agriculture stands out as one of the most challenging aspects of this farming approach (Archer et al., 2007; Cavigelli et al., 2008; Munteanu and Stoleru, 2012). It primarily relies on preventive methods, encompassing practices such as utilizing cover crops, employing mulches, incorporating green manure, and implementing intercropping, with allelopathy potentially playing a significant role in these strategies (Kalinova, 2010; Tesio and Ferrero, 2010; Liebman and Davis, 2015).
The objective of this study was to assess the impact of some allelopathic species on weed control, including white clover (*Trifolium repens*), red clover (*Trifolium pratense*), oats (*Avena sativa*), sainfoin (*Onobrychis viciifolia*), oil radish (*Raphanus sativus* var. *oleiformis)*, yellow mustard (*Sinapis alba*), barley (*Hordeum vulgare*), two-rowed barley (*Hordeum distichon*) and Japanese grass (42% *Festuca rubra* 'Trac Maxima 1', 10% *Festuca rubra* 'Gz Greenmile', 20% *Lolium perene* 'Fabian', 25% *Lolium perene* 'Greenway', 3% *Poa pratensis)*.

MATERIALS AND METHODS

Site description

The research was carried out at the Vegetable Research and Development Station, located in the North-Eastern region of Bacau, during 2023 vegetation season, as part of a series of experiences on climbing bean crop, under ecological farming conditions.
Plant material
The biological material utilized in the study consisted of the "Auria Bacăului" climbing bean cultivar, a variety patented by the Vegetable Research and Development Station Bacau. The bean seeds were sown at a spacing of 40 cm. The species with allelopathic potential utilized in the experiment were: white clover (12 kg/ha), red clover (20 kg/ha), yellow mustard (25 kg/ha), sainfoin (90 kg/ha), oil radish (30 kg/ha), two-rowed barley (200 kg/ha), barley (180 kg/ha), oats (120 kg/ha) and Japanese grass (200 kg/ha).

Experimental design

The study was conducted in randomized block design, with three replicates. The experimental factor was represented by climbing bean in an intercropping system with allelopathic species. A number of six experimental variants were investigated (including Control) as is shown in Table 1.

Table 1. Variants used in the study

Variants	Species with allelopathic properties
V1	- red clover;
V2	- white clover, red clover, sainfoin;
V3	- red clover, Japanese grass;
V4	- red clover, oil radish, yellow mustard;
V5	- red clover, oats, sainfoin, two-rowed barley, barley;
VM	- soil tillage (the control).

The allelopathic species were sown on 20th March, while the climbing bean on 3rd of May. Mowing was performed twice, with a garden strimmer. The control was tillaged two times manually and once mechanically.

The research methods used

Weed presence was evaluated utilizing a metric frame. The fresh matter and number of weeds per m^2 were assessed. The identification of weed species was conducted using a weed descriptor (Gurău, 2007). The assessment of weed infestation occurred at two intervals: A- before the first tillage/mowing, B- before the second tillage/mowing. The calculations for the proportions of competitive and allelopathic effects in the experiments were determined using the formula established by Sturm et al. (2018):

Overall weed biomass reduction (%) = 1 - (Weed biomass with allelophatic species)/ (Weed biomass without allelopathic species)*100.

The level of chlorophyll and anthocyanins was measured using OPTI-SCIENCES Chlorophyll Content Meter and OPTI-SCIENCES Anthocyanin Content Meter. Leaves for all measurements were randomly sampled from three plants in each replicate. The concentration of total soluble solids was measured using a highly precise handheld portable refractometer. The analysis utilized homogenized juice obtained by pressing fresh pods, and the findings are reported in °Brix, following the 932.12 methodology (AOAC, 2005; Brezeanu et al., 2022). Fresh pods were randomly sampled from three plants for each replicate.

During harvest, the total seed yield (kg/ha) and seed yield per plant (g) were recorded. Towards the end of the harvest, stem diameter (mm), root length (mm) and root weight (g) were analyzed.

Statistical analysis

The statistical ANOVA was used to process the experimental data. In IMB SPSS Statistics 20, means were separated using a Tukey's HSD test at $P < 0.05$.

RESULTS AND DISCUSSIONS

A number of 10 weed species were identified in the climbing bean crop, belonging to both dicotyledonous and monocotyledonous classes (Table 1). The weeds observed in the experiment belong to the following botanical families: *Asteraceae*, *Amaranthaceae*, *Convolvulaceae*, *Poaceae*, *Malvaceae*, *Euphorbiaceae* and *Polygonaceae*.

Table 2. The weed species identified within the bean crop

Classification	Species
Annual dicotyledons	red-root amaranth (*Amaranthus retroflexus*)
	petty spurge (*Euphorbia peplus*)
	gallant soldier (*Galinsoga parviflora*)
	lower-of-an-hour (*Hibiscus trionum*)
	curlytop knotweed (*Persicaria lapatifolia*)
	groundsel (*Senecio vulgaris*)
Perennial dicotyledons	creeping thistle (*Cirsium arvense*)
	field bindweed (*Convolvulus arvensis*)
	perennial sow thistle (*Sonchus arvensis*)
Annual monocotyledons	cockspur (*Echinochloa crus-galli*)

The results of the ANOVA highlighted the existence of a significant difference between the variants ($p < 0.001$) regarding the number of weeds/m^2 in both observations (Figure 1). Tukey's post-hoc analysis revealed that the control variant exhibited a significantly higher number of weeds/m^2 compared to the other variants, prior to the first mowing/tillage. The control variant exhibited the highest number of weeds/m^2, whereas variants V2, V3, V4 and V5 were positioned at the opposite end, displaying the lowest level of weed infestation, in the observation conducted before the second mowing/tillage.

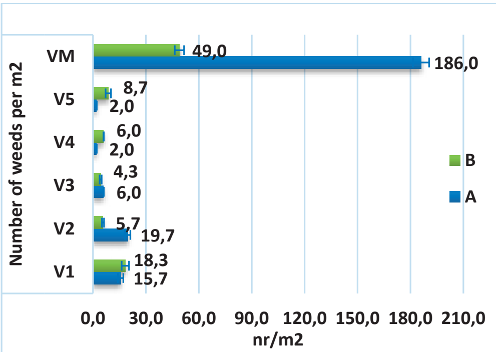

Figure 1. Number of weeds per m^2: A - before the first tillage/mowing; B - before the second tillage/mowing

The ANOVA results highlighted a significant difference between the variants ($p < 0.001$) in terms of weed biomass g/m^2 in both observations (Figure 2). According to Tukey's post-hoc analysis, the weed biomass g/m^2, in the control variant and V1 significantly differed from all other variants before the first mowing/tillage. Conversely, variants V3, V4 and V5 exhibited reduced weed biomass. The control variant showed the highest weed infestation level, while variants V2, V3, V4 and V5 displayed the lowest levels of weed infestation in the observation conducted before the second mowing/tillage.

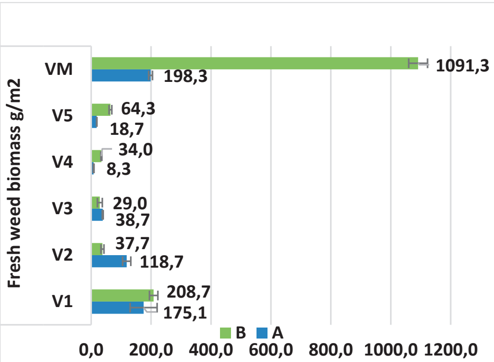

Figure 2. Fresh weed biomass g/m^2: A - before the first tillage/mowing; B - before the second tillage/mowing

It was observed that the weed biomass was reduced for all variants. The average value for the percentage reduction of weed biomass ranged from 11.20% to 97.34%, with the highest value recorded for variant V3, before the second mowing/tillage (Figure 3).

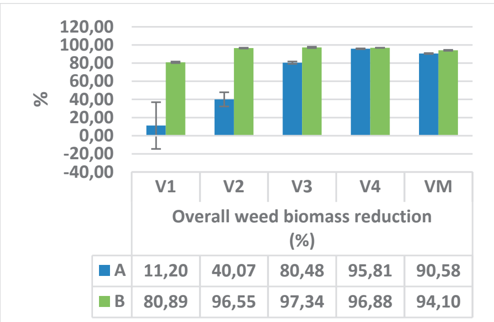

Figure 3. Overall weed biomass reduction (%):
A - before the first tillage/mowing; B - before the second tillage/mowing

The results of the ANOVA indicated a significant difference between the variants ($p < 0.003$) regarding the total seed production. According to Tukey's post-hoc analysis, variant V5 exhibited a significant higher total seed production, compared to the control variant and V3 (Figure 4).

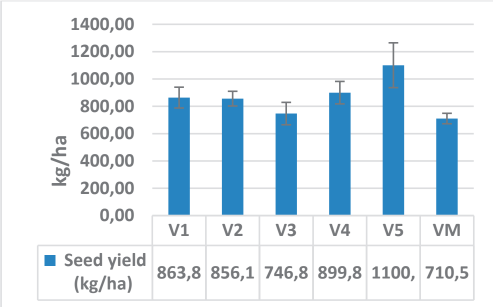

Figure 4. Seed yield (kg/ha) at climbing bean "Auria Bacăului" cultivar

The ANOVA results highlighted a significant difference between the variants ($p < 0.046$), in terms of seed yield per plant. Variant V5 exhibited a significant higher total seed production per plant, compared to the control variant (Figure 5).

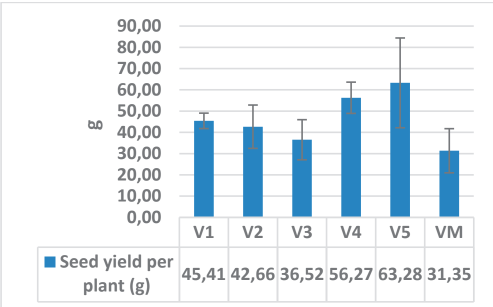

Figure 5. Seed yield per plant (g) at climbing bean "Auria Bacăului" cultivar

It was observed that there were no statistical significant differences between the variants, in terms of leaf chlorophyll content ($p < 0.068$) and soluble solid content in green pods ($p < 0.463$), according to the ANOVA test. However, a significant difference was noted in the anthocyanin content ($p < 0.346$) of the leaves (Figure 6). According to Tukey's post-hoc analysis, variant V1 had a significant lower anthocyanin content, compared to the control.

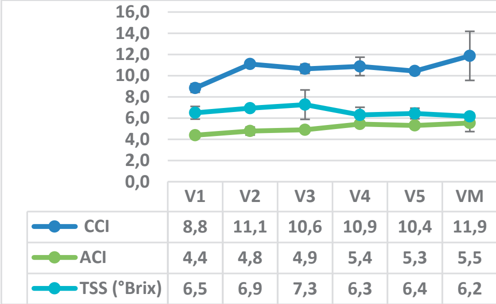

Figure 6. Chlorophyll content index (CCI), Anthocyanin content index (ACI) and Total soluble solids (TSS) at climbing bean "Auria Bacăului" cultivar

Roots play a crucial role in plants' absorption of water and nutrients (Polania *et al.*, 2017). Phenotypic assessments of root traits in common beans under drought stress have highlighted the significance of various rooting patterns, such as deep rooting, enabling access to water from deeper soil layers (Burridge et al., 2016). Fine roots and root hairs possess the capacity to traverse a substantial soil volume, requiring minimal carbon and energy for their functioning (Rao et al., 2016). It was observed that there were no statistically significant differences between the variants in terms of stem diameter (mm) and root weight (g). Concerning root length, subtle differences were observed among the variants (Table 3).

Table 3. Results of the biometric measurements within the bean crop

Variant	Stem diameter (mm)	Root length (mm)	Root weight (g)
V1	9.08±0.4	86.77±1.5bc	3.53±0.5
V2	9.44±0.6	80.99±6.9c	4.6±0.6
V3	9.28±0.3	89.71±4.6ab	4.15±0.1
V4	8.84±1.0	98.22±1.5a	3.50±0.8
V5	9.4±0.6	94.86±1.3ab	4.75±0.7
VM	9.3±0.3	83.52±5.0bc	3.63±0.4
	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.

The observed differences in weed biomass, seed production, and anthocyanin content underscore the potential of integrating allelopathic species into organic cultivation strategies. It is important to note that allelopathic species did not have a negative impact on the bean crop. However, long-term studies are necessary to fully understand their effects on production, soil, and weed species. From observations in the previous years, it has been noted that the timing of sowing allelopathic species plays a crucial role. Optimal results are achieved when these species are sown simultaneously with the bean seeds.

CONCLUSIONS

The degree of weed infestation was significantly reduced by the intercropping of bean, red clover, oil radish, yellow mustard variant and bean, red clover, barley, two-rowed barley, oats and sainfoin.

This research additionally revealed that plant species possessing allelopathic properties did not adversely affect the seed yield of the climbing bean crop.

It was found that there was no significant difference in the level of chlorophyll content, soluble solid content, stem diameter and root weight for the bean crop.

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