RESEARCHES REGARDING THE USING THE VARIETAL DIVERSITY OF BARLEY IN THE INTERCROPPING SYSTEM WITH WHITE LUPINE (*LUPINUS ALBUS* L.) AND OAT (*AVENA* SPP.)

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Abstract

The aim of this study is to test the varietal mixtures of barley in intercropping system and to select genotypes adapted for the redesign of breeding programs in the management of modern agroecosystems. Descriptors such as yield / genotypes, seeds weight and foliar diseases were evaluated in 36 barley genotypes (10 advanced cultivars, 16 local populations, 10 inbred lines) by testing in mono-cropping and intercropping experiments in two years (2019, 2021), in the climatic conditions of northeastern Romania. Intercropping experiments (barley-oats, barley-white lupine) versus mono-cropping (barley, oats, white lupine) were performed in blocks with 36 genotypes sown in alternating rows (intercropping) and successive (mono-cropping) 2 m long and 12.5 cm between rows, for each variant. The results obtained of the barley evaluation in the two cropping systems by using the descriptors of productivity, disease and equivalent land ratio (LER) showed: high barley yield in mono-cropping and intercropping systems with white lupine, low incidence of powdery and life stripe in white lupine intercropping and spot blotch in oat intercropping, respectively positive interspecific interference regarding the resources in white lupine intercropping especially of local barley populations (LER -1.15). The selection of the varietal mixture (7-advanced cultivars, 13 local populations, 3 inbred lines) in the Ward dendogram can be used in intercropped crops and as genetic sources to obtain forms well adapted to the intercropping system.

Key words: intercropping, mono-cropping, white lupine, barley, varietal diversity

Intercropping - agricultural practice of renewed interest in order to reduce the impact of modern agriculture faces a multitude of challenges in competition with monoculture, requiring complex research in space and time, customized equipment and adapted genotypes.

Simultaneous cultivation of several crops, including a variety of genotypes of a single species (Smithson J.B., Lenné J.M., 1996; Chateil C. *et al*, 2013), can lead to higher yields and increased yield stability, food security (Raseduzzaman M., Jensen E.S., 2017) of critical importance in low-input agricultural systems, often to small-scale. Intercropping demonstrates greater nutrient efficiency and increased biological control, leading to more sustainable agricultural systems (Boudreau M.A., 2013; Li L.*et al*, 2014).

Plant genetic diversity can reduce fungal disease levels (Mundt C.C. et al, 1994), increase yield level (Newton A.C. *et al*, 1997), or produce a higher yield stability over the seasons (Bowden R. *et al*, 2001).

Cereals-legumes intercropping, plays an important role in the production of subsistence food in situations of limited water resources (Tsubo M. *et al*, 2005). Plant growth factors such as light, water and nutrients are more fully utilized and converted to crop biomass by intercropping.

The objective of the present research is to study the effect of different intercropping on barley yield, the incidence of foliar diseases and the selection of genotypes adapted to intercropping as a source of genetic material for the redesign of breeding programs.

MATERIAL AND METHOD

The intercropping experiments barley-oats, barley-white lupine versus oats monoculture respectively white lupine were performed in the experimental field of the Suceava Gene Bank in two years, 2019 and 2021 in the different climatic conditions.

Table 1 shows close values of the average temperatures and a water deficit of the average precipitation in 2021 (186.3 mm) compared to 2019 (400 mm).

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[1] Suceava Genebank, Romania

Table 1

Climatic conditions (temperatures and precipitations) during vegetation period of *Vicia faba* (2019, 2021)

Month	III	IV	V	VI	VII	VIII	Average/vegetation season
Average monthly temperature / ^{0} C							
Year 2019	6.1	9.3	14.3	20.8	19.2	20.4	15.01
Year 2021	2.6	7.1	14.1	19.0	22.5	19.9	14.2
Average monthly precipitation/ mm							Total/vegetation season
Year 2019	18.8	36.6	118.9	149.6	30.1	46.0	400
Year 2021	37.2	23.6	44.3	35.2	11.0	35.0	186.3

The biological material was represented by 36 barley genotypes from different biological categories (10 advanced cultivars, 16 local populations, 10 inbred lines) tested in two experimental varieties: monoculture and intercropping with oats in 2019 and monoculture and intercropping with white lupine in 2021 (Table 2).

Table 2

Biologic material tested (*Hordeum vulgare*) in the two intercropping types

Experimental system	Intercropping system 2019		Intercropping system 2021	
	Barley	Oat	Barley	White lupine
Cultivars	10	7	10	12
Local populations	16	26	16	13
Inbreed lines	10	3	10	11

The intercropping experiments (2019, 2021) were sown in 36 plots of 2 m length, with the distance between rows of 12.5 cm (*figure 1*).

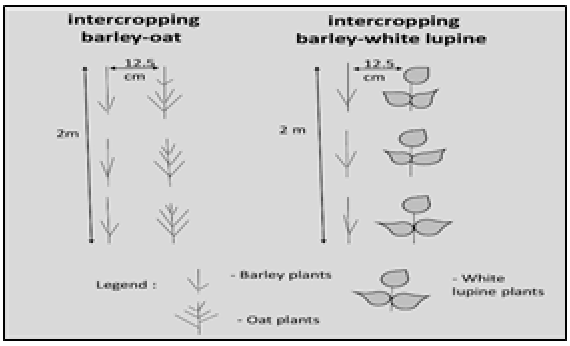

Figure 1 **The experimental design for intercropping system**

Blocks of barley and oats were sown separately in 2019 and lupine in 2021 in monoculture in rows of 2 m and 12.5 cm between rows of the same genotype categories.

In the crop technology, no chemical treatments for foliar diseases were applied in the two types of experiments (intercropping and monoculture). In monoculture, for destroying of the weeds manual weeding was done.

In order to evaluate the barley behavior, in the monoculture and intercropping systems, the morphological descriptors and the equivalent field ratio (LER) were used.

The following morphological descriptors were made: yield / genotype, one thousand seeds weight, attack degree of the foliar diseases: *Erysiphe graminis sp.hordei, Helminthosporium sativum (%), Helminthosporium gramineea* (%).

The equivalent land ratio (LER) was calculated using the formula LER = $\sum$ (Ypi / Ymi), where Yp is the yield of each variety in intercropping system and Ym is the yield of each variety in monoculture.

A partial LER ratio was calculated for each variety (i). The partial LERs were added together to obtain a total LER for the intercropped varieties. This total LER is an equal measure of the yield level, obtained by cultivating two or more crops, varieties in intercropping, in comparison with cultivating the same crops or varieties as a separate crop, in monoculture (Mazaheri D. et al, 2006).

The average values for the mentioned descriptors were calculated and the barley genotypes studied by the Hierarchical Cluster Analysis (IBM SPSS Statistics 26) were classified in the dendogram.

RESULTS AND DISCUSSIONS

Yield level analysis of barley grown in mono-cropping and intercropping systems, with oats and lupine showed a considerable variation in the two years of testing. High average values of barley yield level were found in mono-cropping system in comparison with intercropping system, at advanced cultivars (515.6), local populations (453.4), inbred lines (425.3) (*table 3, figure 2).*

Concerning the intercropping system, a higher barley yield level was observed in association with white lupine compared to the barley-oats association, such yields of: 354.2 gr (advanced cultivars), 367.5 gr (local populations), and 269.5 gr (inbred lines) (*table 3, figure 2*).

Regarding seeds weight, the highest values were observed in barley-oat intercropping system at advanced cultivars (44.0 gr), local populations (42.53 gr), and inbred lines (43.32 gr.) (*table 3, figure 3*). The hydric stress in April of 2021 (23.6 mm) during the emergence period and in June (35.2 mm) during the flowering-heading phenophase determined in the case of barley genotypes from intercropping with white lupine a variable number of seedlings with a large number of inflorescences and kernels with a lower degree of grain roundedness compared to 2019 barley-oat intercropping and mono-cropping systems.

Regarding the barley attack degree to *Erysiphe graminis sp.hordei*, a lower level of infection is observed in mono-cropping versus intercropping system with oats and lupine (*figure 4*). In the intercropping system, there was a reduction in the incidence of the disease in intercropping system with white lupine at local populations (10.38%) and inbred lines (16.8%) compared to barley-oat intercropping system (*table 3, figure 4*). *Helminthosporium sativum* showed a low intensity of infection in the intercropping system of barley with oats (0.40% - advanced cultivars; 4.19% - local populations; 2.10% - inbred lines) (*table 3, figure 5*). *Helminthosporium graminearum* was manifested in white barley-lupine intercropping system with low level of infection (0.50% - advanced cultivars; 0.63% - local populations; 0.10% - inbred lines) compared to mono-cropping and barley-oat intercropping systems (*table 3, figure 6*).

The partial and total land equivalent ratio (LER), for the evaluation of barley in the two cropping systems, was determined. Thus, LER partially had lower values for barley (0.26 – advanced cultivars; 0.39 - local populations; 0.15 – inbred lines) compared to oats (0.59 – advanced cultivars; 0.76 - local populations; 0.66 – inbred lines) that show negative interspecific interferences (barley-oats) regarding barley capacity in intercropping system compared to mono-cropping system. LER-total on 1.15 for local populations shows the existence of advantage of oat populations in intercropping with barley compared to mono-cropping, for this value would need a row length of 15% longer to produce the same yields if they were grown in mono-cropping system (*table 4*). In the barley-white lupine intercropping system (*table 4*), LER partially had higher values in barley (0.68 – advanced cultivars; 0.81 - local populations; 0.63 –inbred lines) compared to white lupine (0.31- advanced cultivars; 0.29-local populations; 0.35 inbred lines), the interspecific interferences (barley - white lupine) of the barley capacity, being positive in intercropping system. LER-total on 1.10 for local populations shows the existence of an advantage of barley populations in intercropping with white lupine compared to mono-cropping system, for this value the rows must be with 10% longer, in order to produce the same yields if it was cultivated as unique crop.

Hordeum vulgare genotypes tested in intercropping experiments in two years (2019 and 2021), were analyzed hierarchically by the Ward variance method based on the dissimilarity of the performance of agronomic productivity traits and the attack degree of some diseases, grouping in three clusters with different number of members (11 in cluster 1, 38 in cluster 2, 23 in cluster 3). Data on the variation amplitude (min-max) and average values of all clusters showed that the maximum values of the following descriptors: yield (g)/genotype (387.58), seeds weight (g)/genotype (41.73), the degree attack of plants with *Erysiphe graminis sp.hordei* (7.78), *Helminthosporium sativum* (3.61) and *Helminthosporium gramineea* (0.35) were observed at members of cluster III, followed by members of cluster II (*table 5*).

The Ward Linkage dendrogram (*figure 7*) built on the Euclidean distance showed the maximum distance in cluster III represented by the following members: 7 advanced cultivars: SVGB - 6614, SVGB-13451, SVGB-6624, SVGB-11055, SVGB-13402, SVGB-13419, SVGB-12715), 13 local populations: SVGB-14214, SVGB-7864, SVGB-17813, SVGB-10251, SVGB-7263, SVGB-19101, SVGB-16509, SVGB-17145, SVGB-17143, SVGB-16617, SVGB-10253, SVGB- 8890, SVGB-19100), 3 inbreed lines: SVGB-13440, SVGB-2673, SVGB-2695. Therefore, these barley genotypes from cluster three were highlighted in the intercropping experiment of white lupine with barley by high heterogeneity of productivity descriptors, the degree of disease attack on plants can be used in the development of mixtures adapted for intercropping system.

Tabel 3

The average values of morpho-physiological descriptors for barley in intercropping and mono-cropping systems

Variety	Advanced cultivars			Local populations			Inbreed lines		
Experimental design	Barley-mono-cropping system	Barley-intercropping system		Barley-Mono-cropping system	Barley-intercropping system		Barley-mono-cropping system	Barley-intercropping system	
		Oat	White Lupine		Oat	White Lupine		Oat	White Lupine
Yield(g)/genotype	515.9	137.9	354.2	453.4	180.1	367.5	425.3	67.7	269.5
Seeds weight (g) / genotype	40.20	44.00	41.29	41.44	42.53	41.81	42.80	43.32	41.06
Erysiphe graminis sp.hordei (%)	8.10	10.10	12.30	8.06	11.44	10.38	14.00	20.80	16.80
Helminthosporium sativum (%)	0.50	0.40	4.60	4.38	4.19	5.25	3.40	2.10	3.00
Helminthosporium gramineea (%)	2.70	1.00	0.50	3.50	3.19	0.63	0.60	0.00	0.10

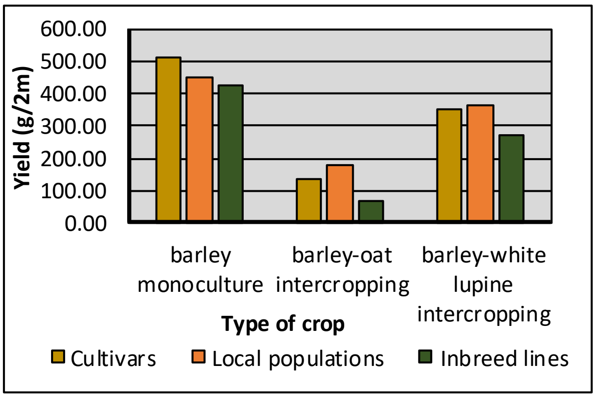

Figure 2. **The influence of intercropping system on barley yield**

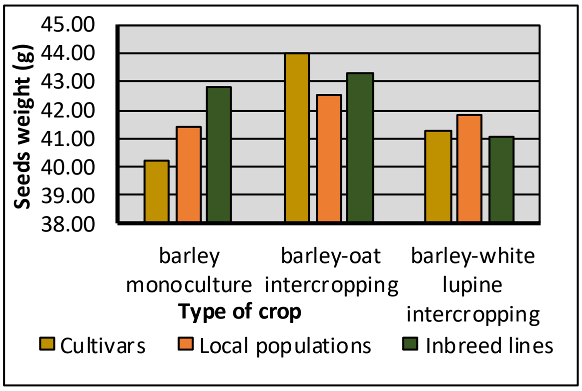

Figure 3. **The influence of intercropping system on barley seeds weight.**

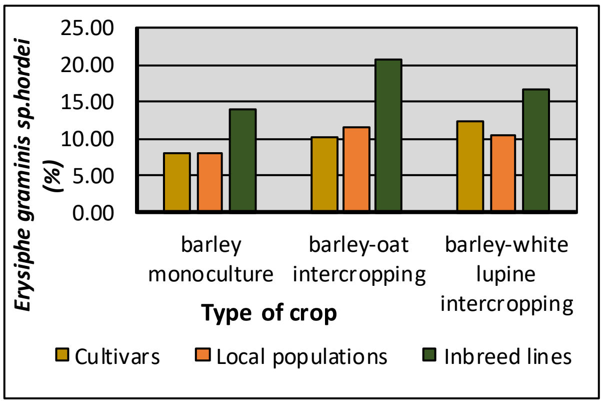

Figure 4. **The influence of intercropping system on the attack degree of barley powdery mildew**

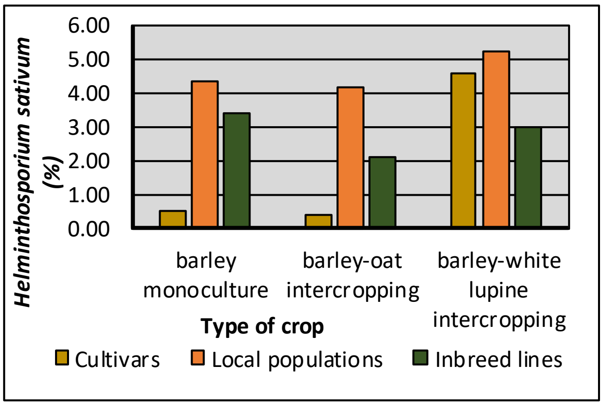

Figure 5. **The influence of intercropping system on the attack degree of barley spot blotch**

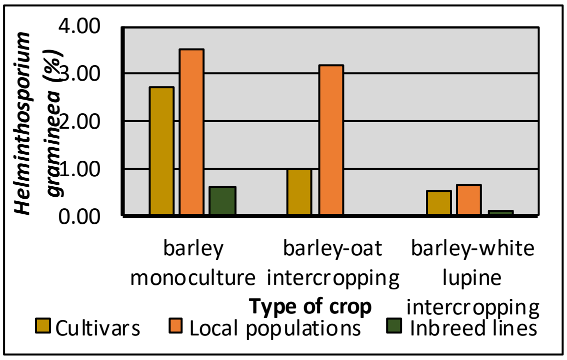

Figure 6. **The influence of intercropping system on the attack degree of barley life stripe**

Table 4

Land equivalent ratio for barley intercropped with oat and white lupine

Yield	Yields in intercropping system (g/ 2 m)			Yields in mono-cropping system (g/ 2 m)			Partial LER		
Variety	Advanced Cultivars	Local Populat	Inbreed lines	Advanced Cultivars	Local Population	Inbreed lines	Advanced Cultivars	Local Popula	Inbreed lines
Barley	137.97	180.10	67.77	515.90	453.40	425.30	0.26	0.39	0.15
Oat	126.61	124.80	136.81	211.81	164.30	206.85	0.59	0.76	0.66
Total LER							0.85	**1.15**	0.81
Barley	265.67	275.69	202.13	515.90	453.40	425.30	0.68	0.81	0.63
White lupine	126.40	122.60	124.60	401.66	414.13	351.42	0.31	0.29	0.35
Total LER							0.99	**1.10**	0.98

Table 5

Range values of various traits in different clusters

Clusters	Cluster 1		Cluster 2		Cluster 3	
Estimators	Min-Max	Average	Min-Max	Average	Min-Max	Average
Yield (g)/genotype	10.3- 53.2	24.18	55.4- 391	206.67	252.0- 596.1	387.58
Seeds weight (g)/genotype	18.2- 51.6	43.05	27.2-51.4	42.44	35.1- 47.3	41.73
Erysiphe graminis sp.hordei (%)	0- 50	16.64	0- 40	15.45	0- 25	7.78
Helminthosporium sativum (%)	0- 10	1.55	0- 40	4.05	0- 20	3.61
Helminthosporium gramineea (%)	0- 10	0.91	0 -50	1.63	0 -5	0.35

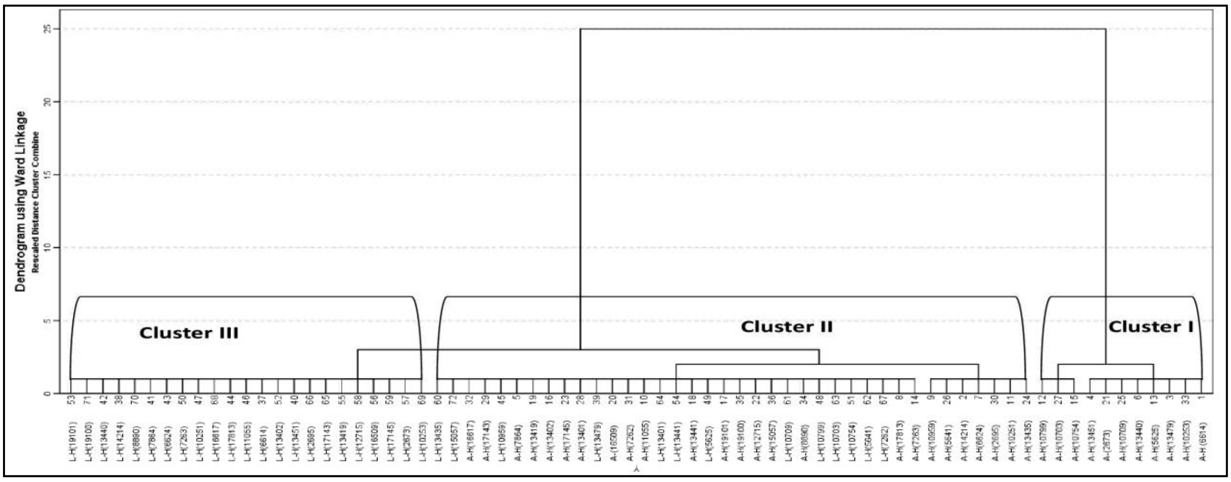

Figure 7. **Dendogram Ward based on Euclidean distance using the data from two experiments and five agro-morphological traits**

CONCLUSIONS

In white lupine mono -cropping system and intercropping with white lupine, the barley plants have developed better than in association with oat. In this sense, high average values of barley yield were highlighted due to the low competition of plants for soil water, nutrients, light in mono-cropping system and fixation of symbiotic nitrogen when is associated with white lupine in intercropping system.

The hydric regime of the two years of testing (2019-wet, 2021-dry) influenced the emergence and grain roundedness of barley, higher values of seeds weight/genotype, obtaining in the year 2029, in the intercropping system barley-oats.

The intercropping system reduced the incidence of barley leaf diseases, for powdery mildew and life stripe in intercropping with white lupine and spot blotch in association with oat.

The values of the partial ground equivalent ratio (LER) of the barley varieties tested in barley-oat intercropping system, were lower compared to those of oats, showing an interspecific negative interference for barley in terms of its capacity to use the food, water and light. In the intercropping system barley-white lupine, interspecific positive interference showed the higher partial LER values compared to values of white lupine. A total LER of 1.15 for local oat populations and 1.10 for local barley populations demonstrated the adaptability of these genotypes and better land use in intercropping system compared to mono-cropping system.

The barley genotypes identified in cluster 3 (7 advanced cultivars; 13 local populations; 3 inbred lines) of the Ward dendogram can be used in the development of varietal mixtures, in breeding programs as gene sources for obtaining forms adapted to the intercropping system.

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