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THE USE OF MICROWAVE IRRADIATION FOR STIMULATING SOME QUANTITATIVE TRAITS IN FLAX

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Abstract. *In order to emphasize the influence of microwave irradiation for stimulating some quantitative traits in flax (Linum usitatissimum* L.*) seven varieties were took into consideration. Three cultivars are used for oil, two have mixed use, and one for fiber. The cultures were developed within the Didactical and Experimental Station Jucu, of UASVM Cluj-Napoca. A bifactorial experiment (F1 – variety, with seven graduations represented by the flax (Linum usitatissimum* L.*) cultivars; F2 – irradiation, with two graduations, irradiated and non-irradiated seed) was developed, according to randomized blocks methodology. A microwave enclosure was used to create the electromagnetic field in the laboratory, in order to irradiate the seeds, which will be used in culture. An electromagnetic field was applied, informally modulated with a frequency of 2450 MHz and 750 W with a power level of 48 %. The influence of the microwave field on some growth and productive traits in linen culture is quantified using the following indices: the emergence percentage, plant height, seed yield, and oil production. The seed irradiation has different effects on analyzed indices, function of cultivar. Majority of best performances are identified for irradiated experimental variants. The results of our study may contribute to the scientific and practical substantiation of the use in culture of an unconventional method of stimulating physiological processes in flax (Linum usitatissimum* L.*) cultivation, which, correlated with the productive capacity of some cultivars lead to quantitative and qualitative increase of production.*

Keywords*: cultivar, emerging percent, Linum usitatissimum* L.*, oil, plant height, seed.*

INTRODUCTION

Flax plant (*Linum usitatissimum* L.) is an annual herb belonging to the *Linaceae* family, cultivated for oil seds, known as linseed as well for fiber namely flaxseed (AMIT, ET AL., 2010). Flax plant for oil is used for every part, for its seeds, which provide a siccative oil with many industrial uses like the oil-based paints and varnishes, linoleum, tarpaulins and special inks manufacture (ROMAN ET AL., 2012). Flax cakes resulting from the extraction of oil are among the most valuable (34-37% protein, 30% carbohydrates, 8% lipids) being recommended especially in cows and foals feeding (LEDUC et al., 2017). The plant stems left after threshing are baled and can be used as raw material for the pulp and paper manufacture. goyal et al. (2014), wrote that besides the use in animal nutrition, research also focused on disease research due to the linseeds potential health benefts associated with some biologically active components. Same, linseeds are rich in lipids, proteins, carbohydrates (PRIYANKA ET AL., 2015), especially in the form of dietary fiber represented by insoluble fibers - 19% (cellulose and lignin) and soluble fibers – 9% (mucilaginous substances) (YOUNG, ET AL., 2014, HAJIAHMADI ET AL, 2021). Flax plants for fiber are cultivated for its very valuable fibers, with a high resistance to breakage and rot, good heat conductivity, making them underwear and bedding fabrics, tablecloths, clothes, fabrics, fine lace and more. In recent years, many products are obtained from the mixture of flax fibers with synthetic fibers that remove many of the shortcomings of synthetic fabrics (RAMESH, 2019).

Due to the growing population and its food needs, agriculture is coming as a reliable solution for this century. Flax cultivation is very old, the first species being a biennial. The rustic annual species of Asian origin are currently being cultivated. Ourdays, according to the last FAO statistics, in Europe, the linseed area harvested was of 1.089.209 ha with a yield of 8.818 kg/ha. For flax fiber, the area harvested was of 265.075 ha with a yield of 35.415 kg/ha. The global world linseed area harvested was of 3.540.139 ha with 9.512 kg/ha yield, while for flax fiber 285.418 ha area harvested is reported, with 34.199 kg/ha yield (https://www.fao.org/faostat/en/#data/QCL).

In order to ensure the food needs of the population, agriculture has to adopt various innovative techniques to increase crop yield (ALADJADJIYAN, 2007). International Food Policy Research Institute (2002) informed that it took only 40 years during the 20th century to increase yields from 2 to 6 tonnes per hectare. These astonishing improvements in yield are made with the development of inorganic fertilisers, the development of chemical pesticides and herbicides, large scale irrigation schemes, and the mechanisation of farming systems. There is great potential for using microwave technologies to solve problems associated with agricultural production (HAN, 2010). Studies have been undertaken to use microwave energy to: improve crop handling, storage and preservation, provide pest and weed control for agricultural production (BRODIE, ET AL., 2012) , food preservation and quarantine purposes (EPAMINONDAS ET. AL., 2011), land survey, automatic data acquisition and communication, and preconditioning of products for better quality and more efficiency of using energy for processing (GRAHAM ET. AL, 2015; BAKHSHABADI ET. AL., 2017; POPESCU, 2007; METAXAS, 2000).

The purpose of the study was to investigate the influence of the microwave field on some growth and productive traits in flax culture by quantifiing the following indices: the emergence percentage, plant height, seed production, and oil production. The climatic parameters, represented by environmental temperature and air humidity were monitored. STATISTICA v.8.0 for Windows was used for statistical processing of the data.

MATERIAL AND METHODS

The experiment was made on two stages: first in a controlled environment in the Laboratory of the Environmental Engineering and Protection Department, with specific equipment. The second one, in open space established on Didactical and Experimental Station Jucu, of UASVM Cluj-Napoca., in Transylvanian pedoclimatic conditions, characterized by argic faeozion soil. The climatic indices during the growing season reach monthly means within the interval: 15,64ºC – 25.11ºC for temperature, 3,3 mm (with sum of 99 mm) – 5,8 mm (with sum of 165 mm), 69% - 77% for relative humidity, and 5,42 m/s – 7,20 m/s for wind velocity (Table 1). The experimental period was from April to August 2021. The biological material consists in flaxseeds (*Linum usitatissimum* L.).

The varieties of flaxseeds and linseeds used in this study included EOLE – a French variety for oil; STAR FD – a Romanian variety, considered for oil, behaves like a mixed variety; TAURUS – a French variety for oil; ELAN FD – a Romanian variety, considered for oil, behaves like a mixed variety; LIRINA – a Romanian variety for oil; VASILELIN – a Romanian fiber variety; CRISTINA – a Romanian variety for oil, supplied by Center for Plant Variety Testing (VTC) from Sibiu.

The firs stage of the experiment consists in exposure of the seeds to an electromagnetic field generated by a 2450 MHz domestic microwave oven with a nominal power of 750 W with a power level of 48 %. Seeds of each seven selected flax cultivars were divided into 4 variants, each variant containing 100 seeds (four replicas of 25 seeds each).

Table 1

The indicators of the climatic conditions from the experimental field located in Didactical and Experimental Station Jucu of UASVM Cluj-Napoca, during the growing season

Month	No. of days	Parameter	Mean	Minimum	Maximum
April	30	Temperature (ºC	15.64	7	23
		Precipitations (mm)	3.3 99	5	20
		Relative humidity (%)	69	50	82
		Wind velocity (m/s)	7.20	5.2	19.9
May	31	Temperature (ºC	20	12	27
		Precipitations (mm)	4.8 150	8	40
		Relative humidity (%)	75	60	85
		Wind velocity (m/s)	7.23	1.3	18.7
June	30	Temperature (ºC	23	15	29
		Precipitations (mm)	5.5 165	8	42
		Relative humidity (%)	72	53	76
		Wind velocity (m/s)	6.21	1.6	19.7
July	31	Temperature (ºC	25	16	32
		Precipitations (mm)	3.9 120	3	36
		Relative humidity (%)	77	60	81
		Wind velocity (m/s)	6.02	1.5	19.2
August	31	Temperature (ºC	26	15	31
		Precipitations (mm)	4.2 131	1	42
		Relative humidity (%)	72	59	83
		Wind velocity (m/s)	5.42	1.2	9.17

The first group represent the untreated variant, remaining the variants, which were irradiated with microwave for 5, 10 and 15 seconds, respectively. In order to determine the influence of the electromagnetic field, the seeds germination was determined. Germination percent of control (untreated) and treated flax cultivars were recorded after 3, 5 and 7 days. Based on the obtained results (the percentage of germinated seeds, maximum number of germinated seeds) was chosen 10 seconds of microwave pre-treatment time for the next step of the experiment.

In the experimental field, located in Didactical and Experimental Station Jucu, the observations were focused on physiological development of plants, in order to determine the influence of microwave irradiation made in the first part of the experiment. A bifactorial experiment, in 5 repetitions, was developed according to randomized blocks methodology: F1 – variety, with seven graduations and F2 – irradiation, with two graduations, irradiated and non-irradiated seeds. The plot size was 1 m^2 and the plot consisted of 10 rows with a row width of 12 cm. The seeding rate was 800 germinating seeds /m^2 with a distance between grains by 2.5 cm. The seeds did not receive chemical treatment before drilling.

During the growing season, daily lower temperature increase from 0°C to 14°C, while the higher temperature values increase from 20°C in April to 35°C in August. The highest monthly amount of precipitation, of 85 mm, is reported on the last period of the experiment.

RESULTS AND DISCUSSIONS

The experiment conducted in the open field in the specific climatic conditions of 2021, from April to August, led to results highlighting specific features.

The emergence percentage for all seven varieties, with irradiated and non-irradiated seeds recorded different results. The higher flaxseed emerging means are reported for Vasilelin variety, both irradiated (93,33%), and non-irradiated seeds (90%), Taurus irradiated seeds (90%), followed by Eole variey both irradiated and non-irradiated seeds and Taurus variety non-irradiated seeds (86,67%).

Figure 1. The stages of experimental field

Weak and very weak results are reported in Star FD and Elan FD varieties, both irradiated and non-irradiated (Table 2). According to variability, one may find that flaxseed emerging is satisfactory for majority of varieties, exception been reported in Star FD, and Elan FD irradiated variety. In all varieties, irradiation led to a higher emerging percent, compared with lack of irradiation. In Star FD, Taurus, Elan FD, and Lirina differences are statistically significand at different significance thresholds. This shows that both irradiated and non-irradiated Star FD, and Elan FD flax varieties has low adaptability to growing conditions in experimental field and are not recommended.

Table 2

Basic statistics for flax emerging (%)

Flax variety	**Experimental variant**	**n**	**X**	**s**	**CV**
1	1	5	86.67a	5.77	6.66
	2	5	86.67a	5.77	6.66
2	1	5	5.00*d	4.36	87.18
	2	5	18.00*d	13.11	72.86
3	1	5	86.67b	11.55	13.32
	2	5	90.00b	0.00	0.00
4	1	5	2.00d	0.00	0.00
	2	5	13.33*d	11.55	86.60
5	1	5	70.00c	0.00	0.00
	2	5	80.00c	10.00	12.50
6	1	5	90.00a	0.00	0.00
	2	5	93.33a	5.77	6.19
7	1	5	66.67a	5.77	8.66
	2	5	70.00a	17.32	24.74

1- Eole; 2- Star FD; 3- Taurus; 4- Elan FD; 5- Lirina; 6- Vasilelin; 7- Cristina;
1st Variant – not irradiated; 2nd Variant – irradiated;
* - median; a – $p > 0.05$; b – $p < 0.05$; c – $p < 0,01$; d – $p < 0,001$.

Table 3

Basic statistics for plant length at 7.07.2021 (cm)

Flax variety	**Experimental variant**	**n**	**X**	**s**	**CV**
1	1	5	50.17a	4.19	8.36
	2	5	47.67a	2.52	5.28
2	1	5	57.33a	8.08	14.10
	2	5	61.00a	2.00	3.28
3	1	5	52.17a	3.75	7.19
	2	5	50.50a	0.87	1.71
4	1	5	63.00b	3.00	4.76
	2	5	56.00b	3.46	6.19
5	1	5	50.17a	1.61	3.20
	2	5	52.83a	5.92	11.21
6	1	5	73.00b	2.65	3.62
	2	5	67.83b	1.44	2.13
7	1	5	48.67b	4.31	8.86
	2	5	54.67b	7.29	13.33

1- Eole; 2- Star FD; 3- Taurus; 4- Elan FD; 5- Lirina; 6- Vasilelin; 7- Cristina;
1st Variant – not irradiated; 2nd Variant – irradiated;
* - median; a – $p > 0.05$; b – $p < 0.05$; c – $p < 0,01$; d – $p < 0,001$.

The plants length means are higher in irradiated variants (Table 3), in three of variants: Star FD, Lirina, and Cristina. Differences between irradiated and non irradiated variants within the same variety are not significant in majority of cases, except Elan FD, Vasilelin, and Cristina varieties. The means of the biggest length are reported in Vasilelin variety irradiated (73 cm), and non-irradiated (67 cm), and the smallest in Star FD non-irradiated variety (47.67 cm), and Cristina non-irradiated variety (48.67 cm).

Table 4

Basic statistics for flax seed yield (g/m^2)

Flax variety	**Experimental variant**	**n**	**X**	**s**	**CV**
1	1	5	122.50*d	49.30	40.24
	2	5	186.41d	39.37	21.12
2	1	5	53.08*d	23.80	44.83
	2	5	84.80*d	61.07	72.01
3	1	5	134.80*d	55.51	41.18
	2	5	164.19d	32.16	19.59
4	1	5	39.86d	15.64	39.24
	2	5	28.91*d	29.74	102.85
5	1	5	103.90*d	33.94	32.66
	2	5	119.38d	32.68	27.37
6	1	5	118.90d	21.08	17.73
	2	5	140.51d	7.14	5.08
7	1	5	199.30d	23.09	11.58
	2	5	231.02d	49.91	21.60

1- Eole; 2- Star FD; 3- Taurus; 4- Elan FD; 5- Lirina; 6- Vasilelin; 7- Cristina;
1st Variant – not irradiated; 2nd Variant – irradiated;
* - median; d – $p < 0,001$.

Except Elan FD variety, the flaxseed yields are higher in irradiated variant, differences between variants being statistically very significant in all cases (Table 4). Best results are reported in irradiated and non-irradiated varieties Eole (122.5 g/m^2 and 186.4 g/m^2, respectively), and Cristina (199.3 g/m^2 and 231.02 g/m^2, respectively).

The highest flaskseed oil content are reported in Lirina (54%), Elan FD (46%), and Star FD (44%) irradiated varieties (Figure 2). In majority of varieties irradiation led to higher oil content. Exception is reported in Vasilelin and Cristina varieties, where identical oil content are emphasized in both non-irradiated and irradiated variants.

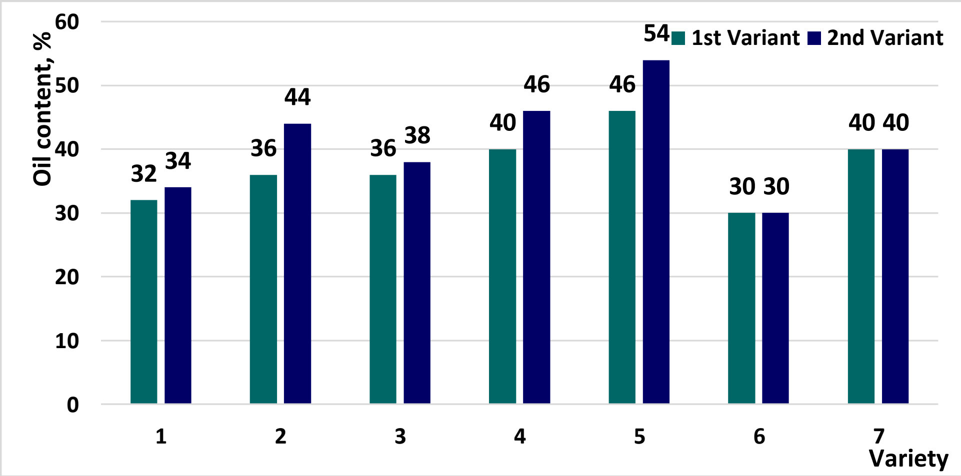
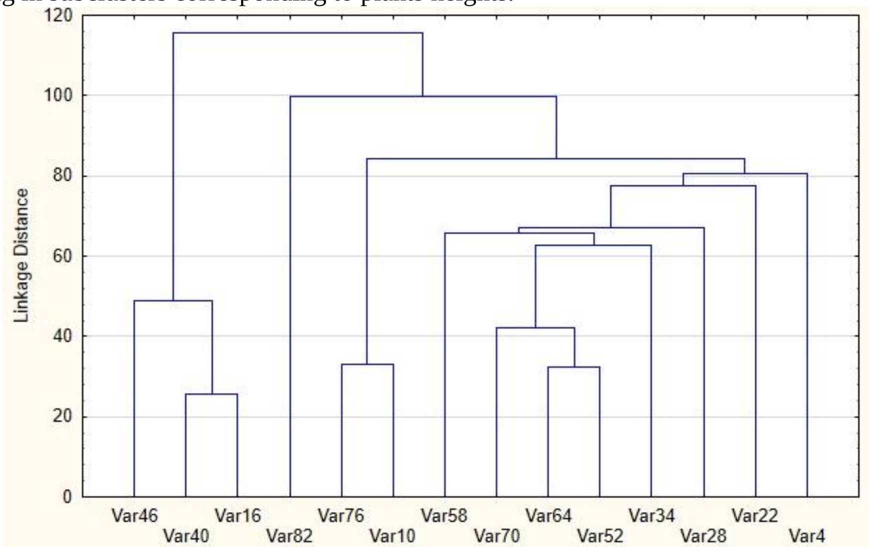


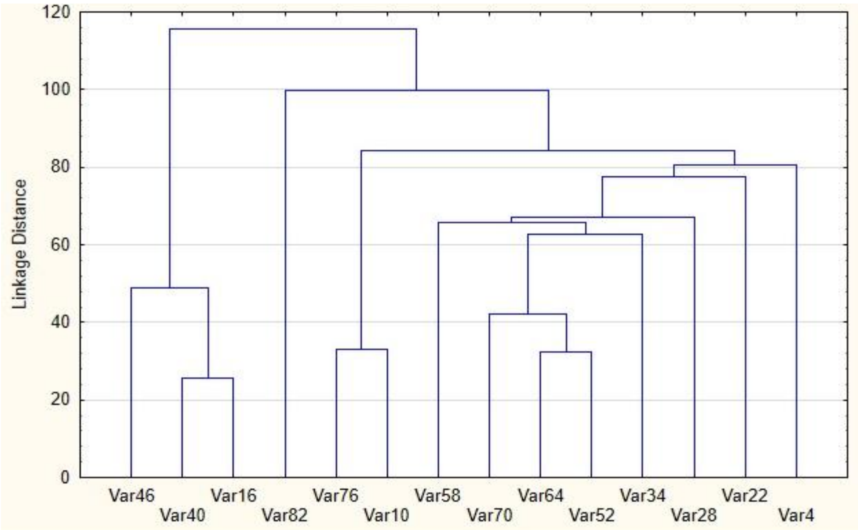
Figure 2. The mean flaskseed oil content by experimental varieties and variants

The cluster analysis applied for plant length shows two groups (Figure 3). One with a single branch corresponding to Star FD variety (Var 15), and other with lots of ramifications yielding in subclusters corresponding to plants heights.



Var 3 – Eole V1; Var 9 – Eole V2; Var 15 - Star FD V1; Var 21 - Star FD V2; Var 27 - Taurus V1; Var 33 - Taurus V2; Var 39 - Elan FD V1; Var 45 - Elan FD V2; Var 51 - Lirina V1; Var 57 - Lirina V2; Var 63 - Vasilelin V1; Var 69 - Vasilelin V2; Var 75 - Cristina V1; Var 81- Cristina V2; V1 – 1st Variant, not irradiated; V2 – 2nd Variant, irradiated

Figure 3. The cluster analysis for plant length at 7.07.2021 (cm)



Var 4 – Eole V1; Var 10 – Eole V2; Var 16 - Star FD V1; Var 22 - Star FD V2; Var 28 - Taurus V1; Var 34 - Taurus V2; Var 40 - Elan FD V1; Var 46 - Elan FD V2; Var 52 - Lirina V1; Var 58 - Lirina V2; Var 64 - Vasilelin V1; Var 70 - Vasilelin V2; Var 76 - Cristina V1; Var 82- Cristina V2; V1 – 1st Variant, not irradiated; V2 – 2nd Variant, irradiated

Figure 4. The cluster analysis for flask seed yield (g/m^2)

Close linkage distances are seen in varieties with similar mean length. At close linkage distance are located clusters coresponding to the highest plants, Vasilelin variety irradiated, and non-irradiated – Variants 63 and 69.

Concerning the seed yeld, the cluster analysis groups varieties with lowest performances (Star FD – Var 16, and Elan Var 40, Var 46) in one branch with two subclusters, at considerable linkage distance from the varieties with lowest performances, Eole – Var 4, Var 10 and Cristina – Var 82, Var 76, respectively (Figure 4).

CONCLUSIONS

Microwave had both positive and negative effects on germination and plants growth. Our study shows that in both experimental conditions (laboratory and open field) the action of the microwaves stimulates the germination at 10 seconds of exposure with 48% of power. The stems growth show differences between irradiated and non irradiated variants, but not significant in majority of cases. Best results for seeds yield are reported in irradiated and non-irradiated Eole and Cristina varieties. The highest oil content are reported in Lirina, Elan, and Star FD irradiated varieties.

The results of the present study led to the accumulation of new knowledge in domain that would contribute to the scientific and practical use of an unconventional method of stimulating physiological processes in flax cultivation, which, correlated with the productive capacity of some varieties, lead to the quantitative and qualitative increase of the production, in environmentally friendly conditions.

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